Sustainability: A way forward for IEQ/IAQ- researchers and practitioners

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Sustainability: A way forward for IEQ/IAQ- researchers and practitioners

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Preview of take-home messages

- The indoor and outdoor environments are interconnected and inter-dependent
- Choices we make
- Values that (quietly) inform our choices
- The science is uncertain and challenging
- There is no alternative, no PLAN B
- The choice is up to us

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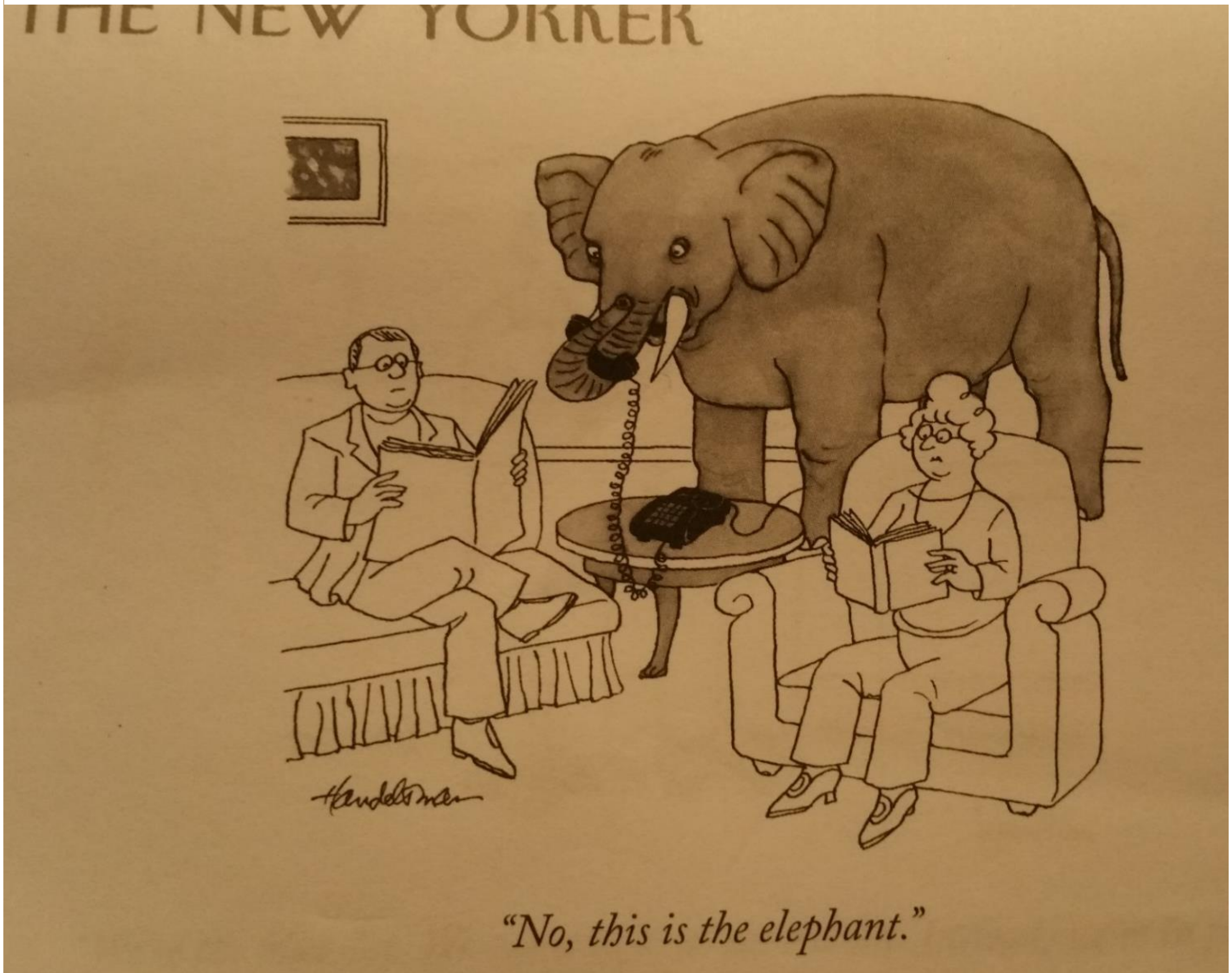
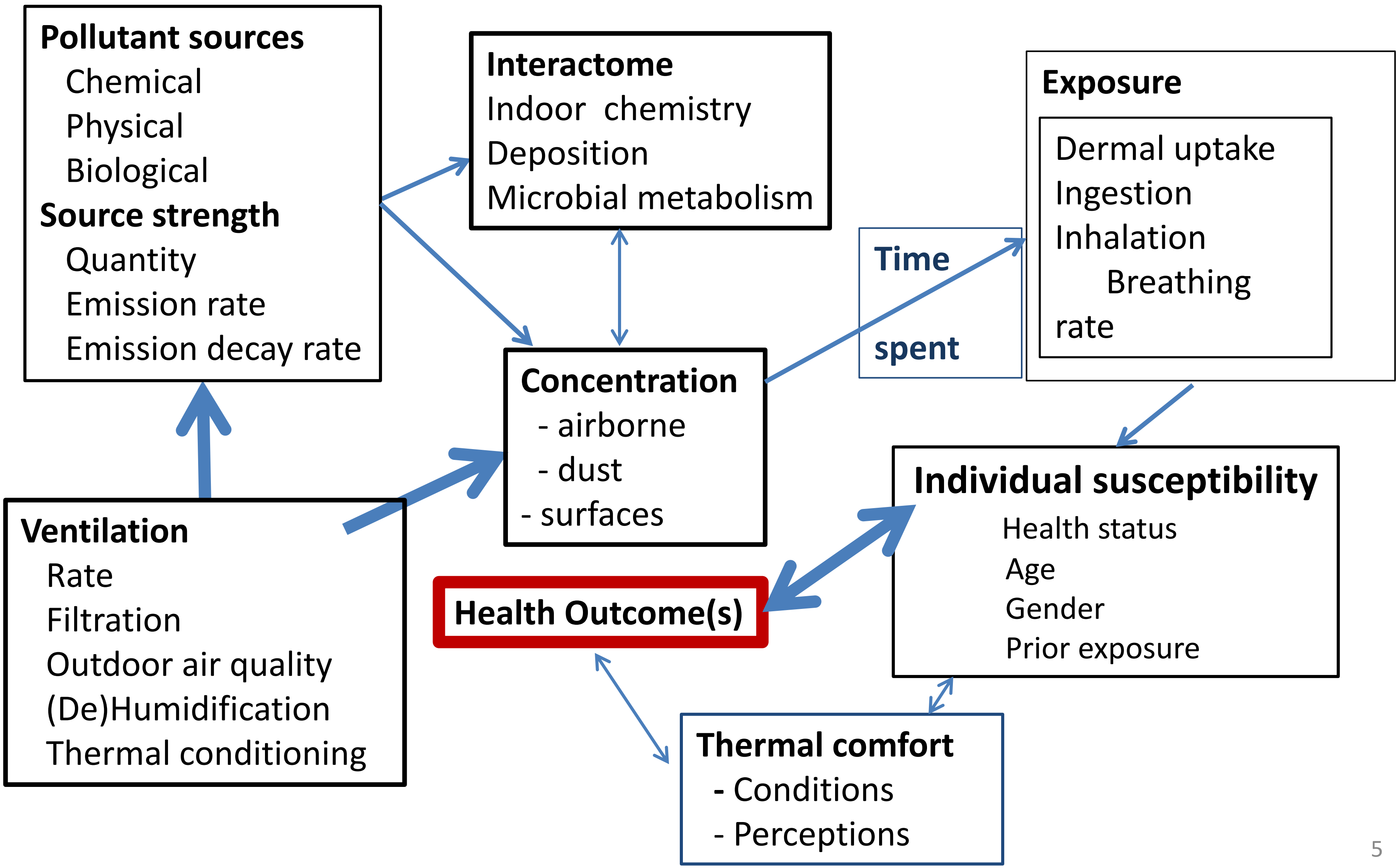
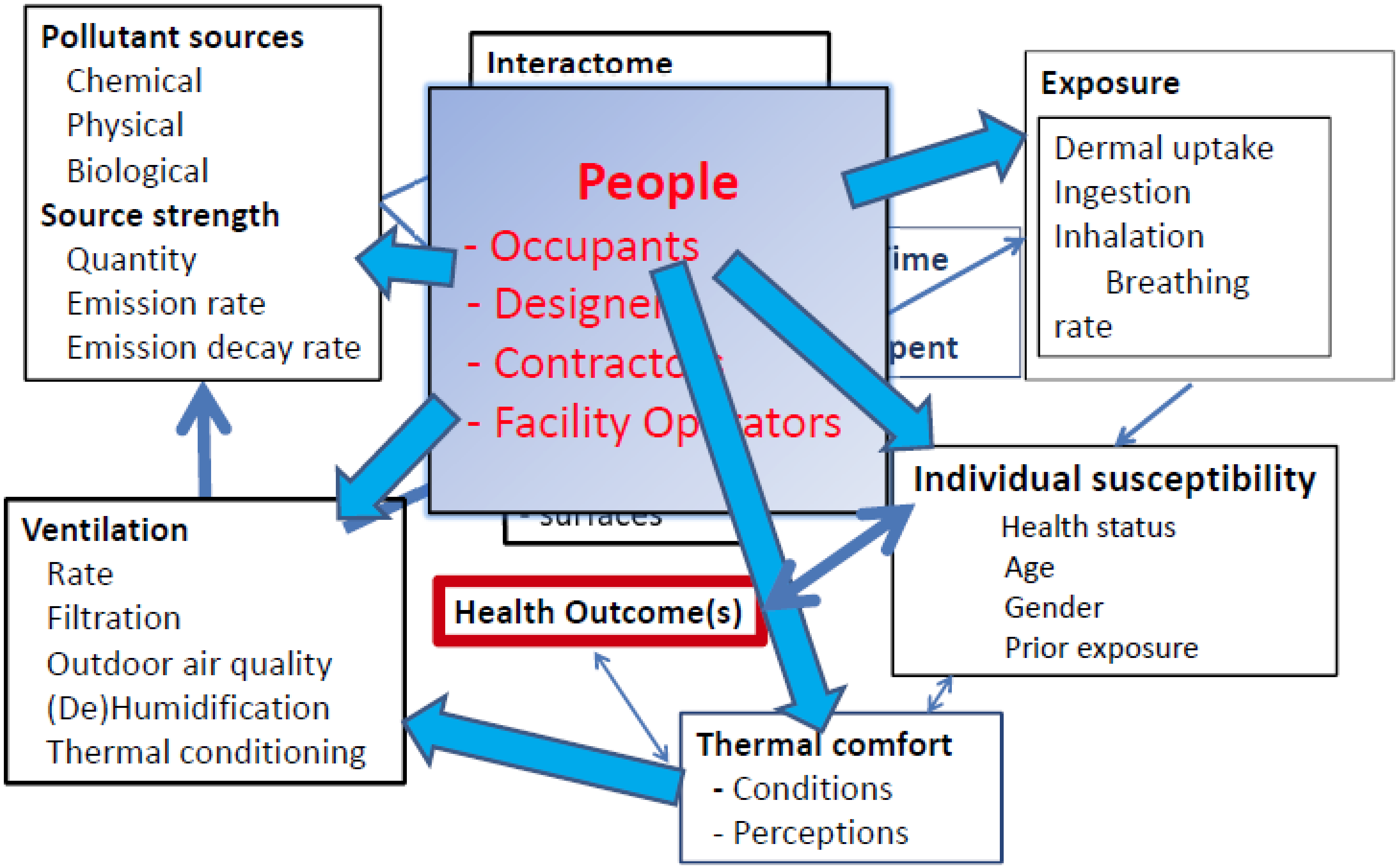
“The Elephant in the Room”



Theory of nearly everything
in the Indoor Environment



Theory of more nearly everything in the Indoor Environment



What is ^all this talk about?

- Can we define Sustainability in a way that is useful and meaningful to all of us?
  - Scientists
  - Researchers
  - Design Professionals
  - Policy-makers
  - The public: consumer-citizens
- *I would say "yes we can"*

3x3-step process

1. **Define Sustainability and sustainable building goals**
    1) Define environmental problems/limits/boundaries of concern based on present scientific knowledge
    2) Establish global per capita targets
    3) Allocate resources/pollution emissions (use current ratios?)
2. **Identify building related resource inventories and impacts**
    1) Threshold limit values – “planetary boundaries”
    2) Per capita shares on a global and national scale
    3) Proposed building shares: goals and targets: locally contextualized for developed and developing contexts
3. **Address IEQ issues with allocated resources**
    1) Identify necessary changes in frameworks (consciousness, political, social, economic). Identify ethical issues and way forward for IEQ research and the building community
    2) Identify pollutant sources of concern and available or theoretical control mechanisms. Prioritize by impact criteria and focus on highest priority pollutants.
    3) Researchers: Gather data on resource intensity and improved health impacts of solutions to develop guidelines for building designers, operators, and standards-writers

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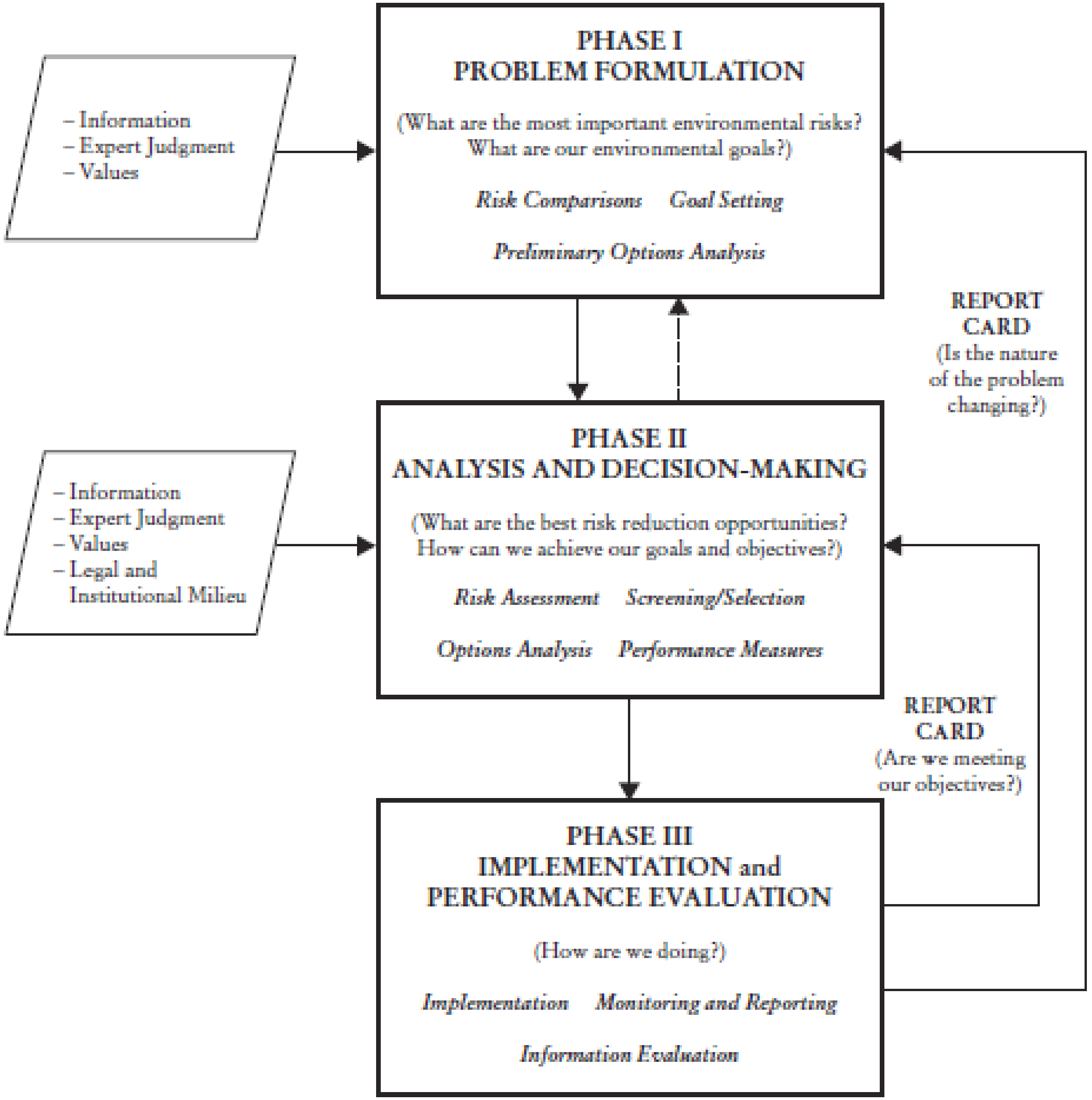
Framework for Integrated Environmental Decision-making

U.S. EPA, Science Advisory Board, August 2000. "Toward Integrated Environmental Decision-making"



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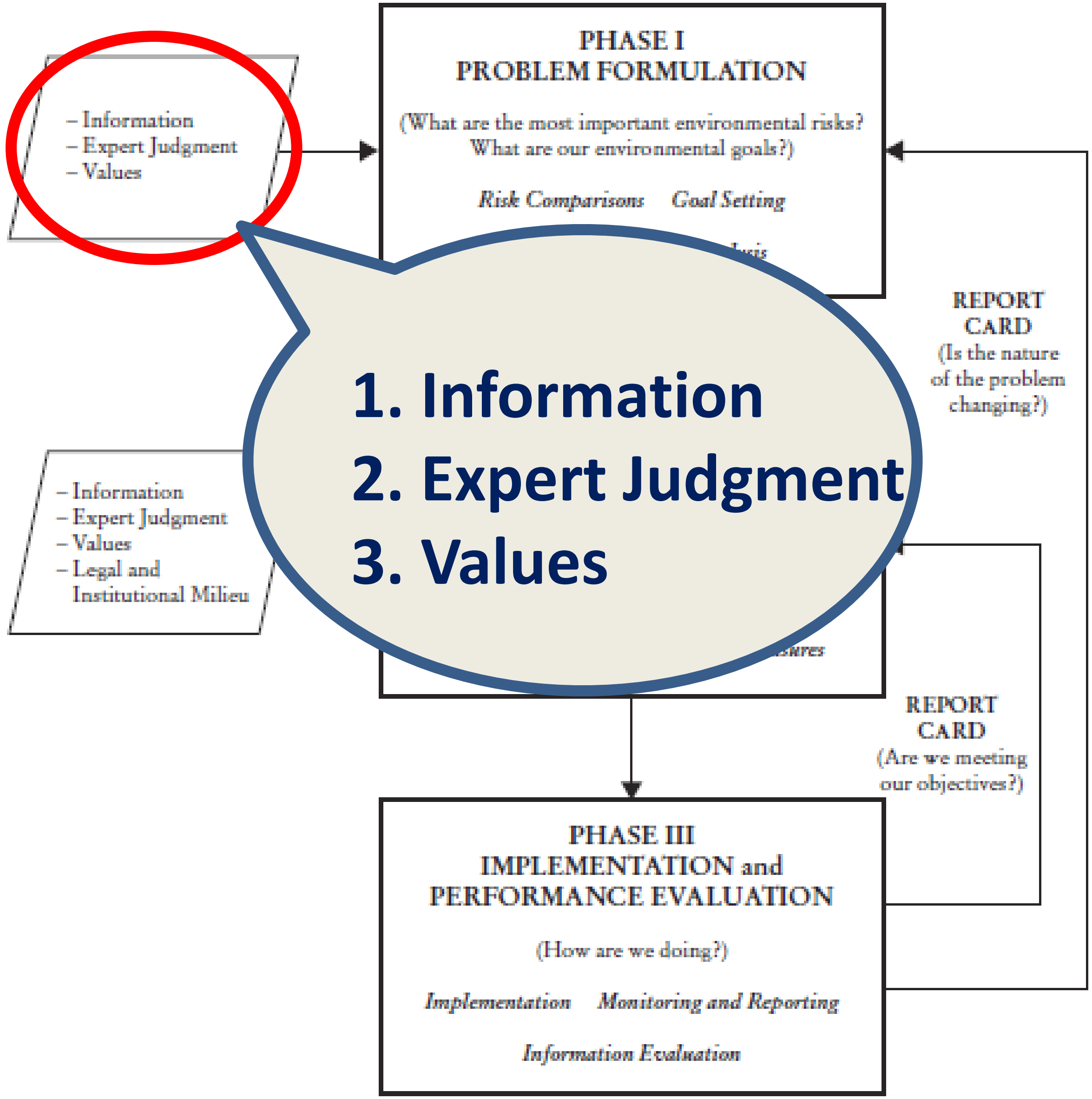


Introduction: Why Sustainability?

- Increasingly apparent (observed) limits of Earth to support human use of the planet's finite resources

Definitions:

- Lack of meaningful definitions: Most definitions are vague and, therefore, not useful

– Sustainability:
  - Historical Roots (1970s) : sustainable fisheries, forestry and agriculture

– Sustainability vs Sustainable development
  - Sustainable Development ≠ sustainable (Redclift, 1987)
  - Conceptions of defining and measuring sustainable development : weak and strong sustainability.
  - weak sustainability: neo-classical economic theory - assumes that manufactured and natural capital are close substitutes. This means that costs of environmental deterioration (e.g., forest damage) can be compensated by benefits from manufactured capital (e.g., income). Thus, environmental damages are valued in monetary units.
  - strong sustainability: denies degree of substitution that weak sustainability assumes, at least for some critical elements of natural capital

“Environmental Sustainabilities: An Analysis and a Typology

Conceptions of environmental sustainability (Dobson, *Env. Politics*, 1996)				
	A	B	C	D
What to sustain?	Total capital (human-made and natural	critical natural capital: e.g., ‘ecological processes’	irreversible natural capital	‘units of significance’
Why?	Human welfare (material)	human welfare (material and aesthetic)	human welfare (material and aesthetic) and obligations to nature	obligations to nature
Objects of concern: Primary Secondary	1,3,2,4	1,2,3,4 5,6	(1,5) (2,6) 3,4	(5,1), (6,2) 3,4
Substitutability between human-made and natural capital	Considerable	not between human-made capital and critical natural capital	not between human-made capital and irreversible natural capital	eschews the substitutability debate

Key to numbers:

1 = present generation human needs
2 = future generation human needs
3 = present generation human wants
4 = future generation human wants
5 = present generation non-human needs
6 = future generation non-human needs

Dobson, 1996. *Environmental Politics*,. 5 (3): 401-428.

Definitions of Sustainability

Dobson, 1996. Environmental Politics 5 (3): 401-428

	Strong	Moderate	Weak
What to Sustain			
Why?			
Objects of concern			
Sustitutability of natural and human-made capital			

Questions of social, generational, and interspecies justice

Early (earliest?) model to calculate targets:

$$I = P\ A\ T$$

(Ehrlich and Holdren, 1974)

I = Impact

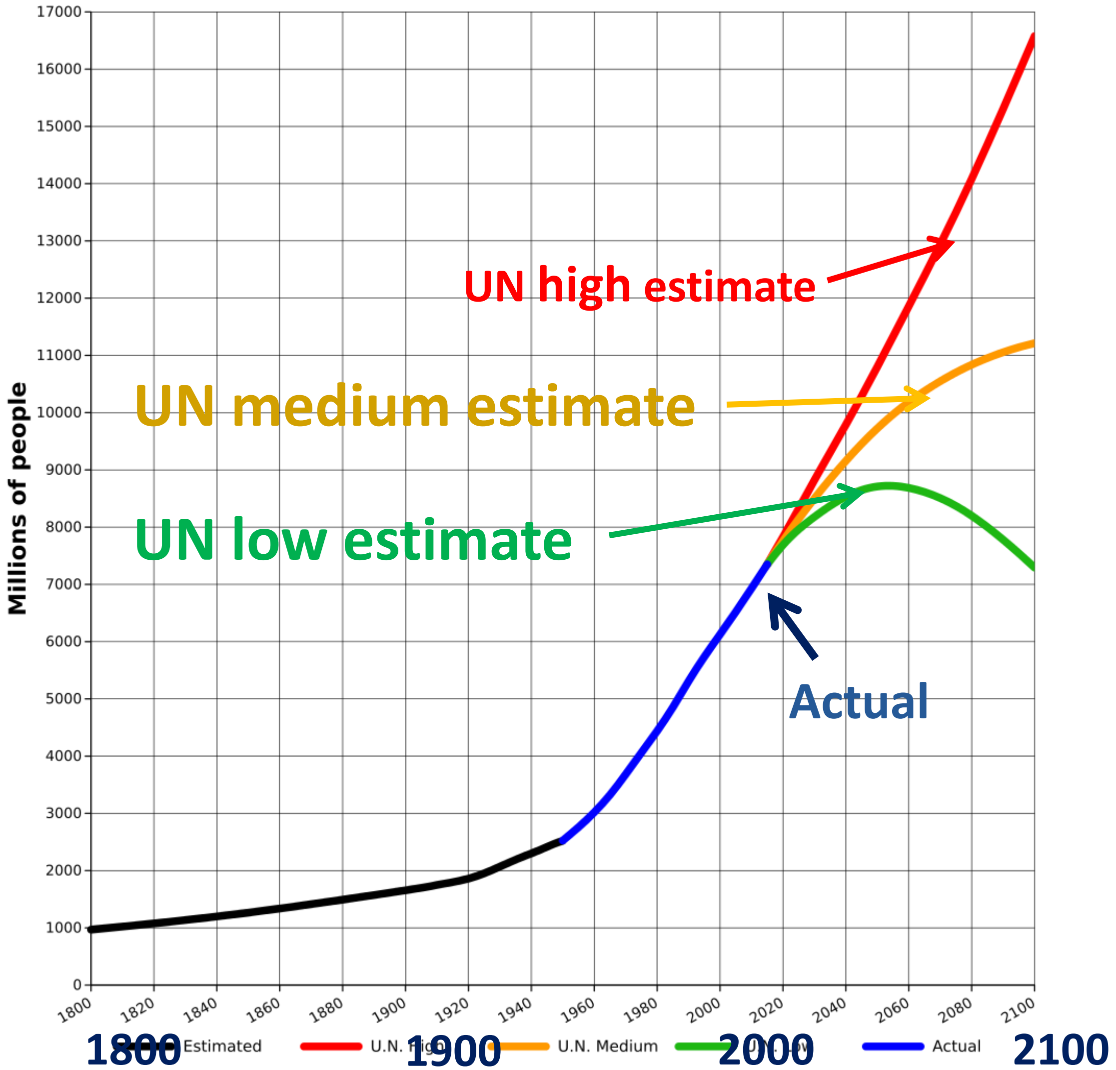
P = population

A= affluence

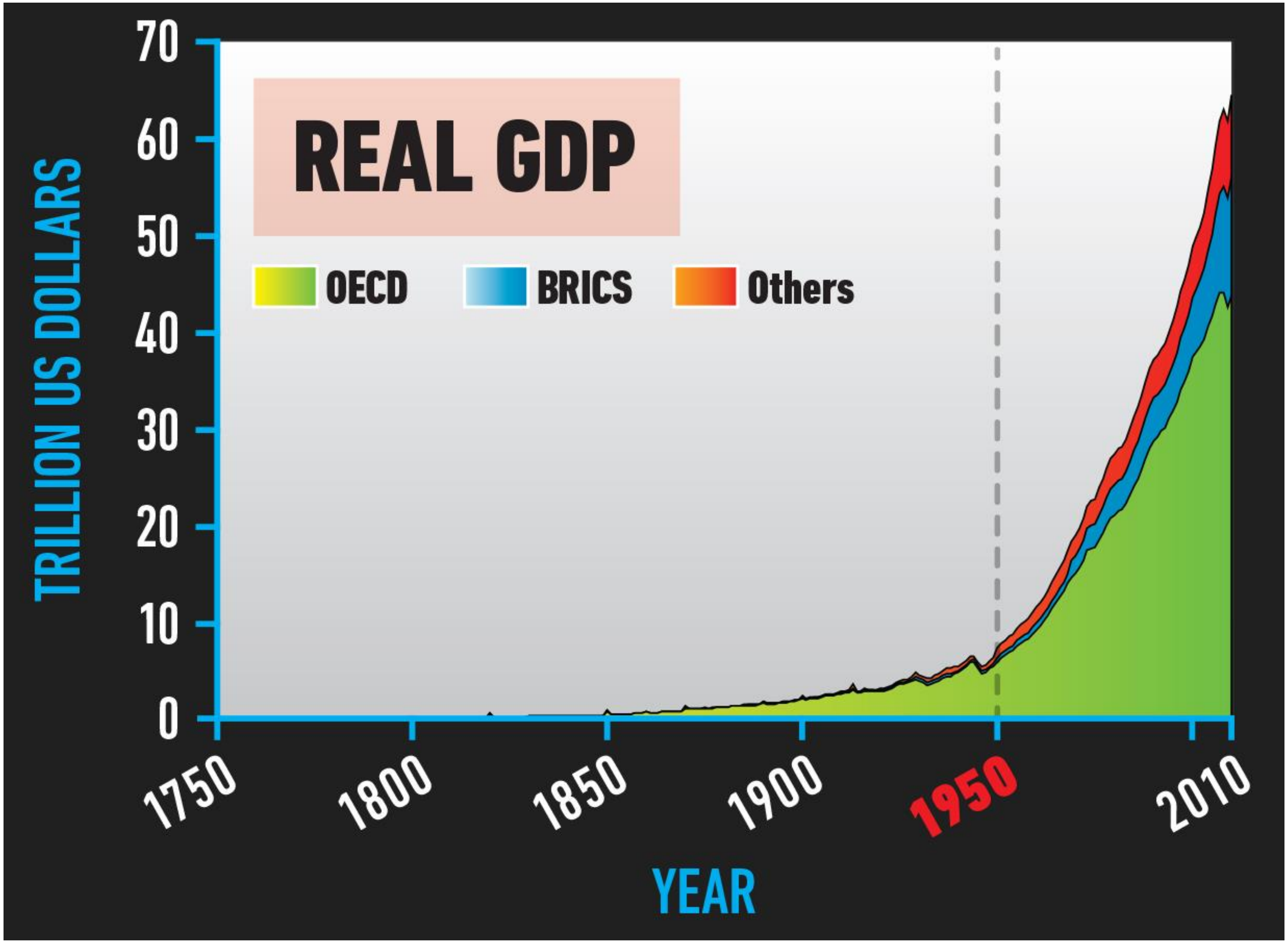
T = impacts per unit of technology

World population estimates: 1800 to 2100,

based on "high", "medium" and "low" United Nations projections in 2010 (colored red, orange and green) and US Census Bureau historical estimates (in black). Actual recorded population figures are colored in blue. According to the highest estimate, the world population may rise to 16 billion by 2100; according to the lowest estimate, it may decline to 6 billion

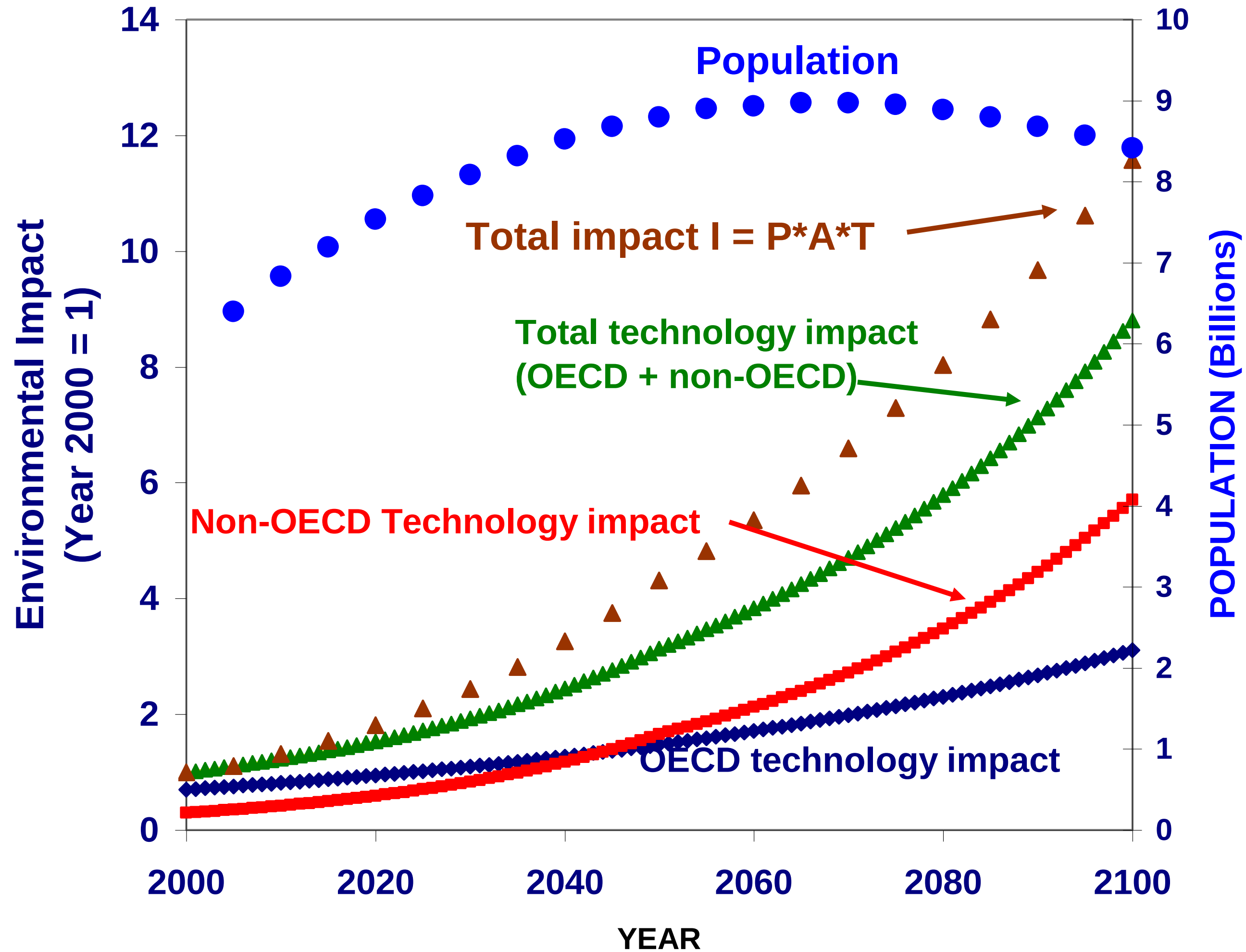


Affluence (economic growth) as GDP



BRICS = Brazil, Russia, India, China and South Africa. ("emerging economies")

Projected anthropogenic environmental impact based on I = PAT model (Ehrlich and Holdren, 1974)



Assumes GDP growth of 3.5%/a (Actual > 10%/a); population in 2100 at 8.25 B

Building related environmental problems

Top priority (global scale)

1. Habitat destruction / deterioration
   (directly resulting in Biodiversity loss)
2. Global warming
3. Stratospheric ozone depletion

High priority (continental or regional scale)

1. Soil erosion
2. Depletion of freshwater resources
3. Acid deposition
4. Urban air pollution / smog
5. Surface water pollution
6. Soil and groundwater pollution
7. Depletion of mineral reserves
   (esp. oil and some metals)

Criteria for Weighting Environmental Problems (e.g., how to decide what's important)

1. **THE SPATIAL SCALE OF THE IMPACT**
   (Global, regional, local - large worse than small)
2. **THE SEVERITY OF THE HAZARD**
   (More toxic, dangerous, damaging being worse)
3. **THE DEGREE OF EXPOSURE**
   (Well-sequestered substances being of less concern than readily mobilized substances)
4. **THE PENALTY FOR BEING WRONG**
   (Longer remediation times of more concern)
5. **THE STATUS OF THE AFFECTED SINKS**
   (An already overburdened sink more critical than a less-burdened one. Sinks = receptors, or environmental compartments)

Sources: 1-4 Daisey et al, EPA/SAB,
5, Norberg-Bohm, 1992, Levin, 1996

Requires information, uncertain projections and strongly depends on values

Methods to determine limits to the Earth's ecocapacity and establish Sustainable targets

Good news: examples in the peer-reviewed literature.

1. **I=PAT** Impact = Population* Affluence*Technology (Ehrlich and Holdren, **1974**)
2. **Ecocapacity as a challenge to Technological Development (**Wetterings and Opschoor**,** RMNO, April **1992**)
3. **Ecological footprint -** [*Rees, W. E. And Wackernagel,* **1992***). "Ecological footprints and appropriated carrying capacity: wha t urban economics leaves out". Environment and Urbanisation* **4** *(2):121.*
4. **Material intensity of products, Services** Schmidt-Bleek, **1994**. Wieviel Umwelt braucht der Mensch? MIPS--Das MaB ftir tikologisches Wirtschaften. Berlin.} [http://www.footprintnetwork.org/en/index.php/GFN/page/calculators**]**
5. **Socio-ecological indicators** (Azar et al, **1996**) [*Ecological Economics* 18: 89-112] ("The Natural Step")
6. **Inidicators Linking Ecology and Economics** Rennings and Wiggering, **1997** [*Ecol Econ* 20: 25-36]
7. **Calculated targets:** [Graedel and Klee, **2002**. "Getting Serious about Sustainability" *Environ. Sci. Technol.*, **2002**, 36(4):523–529]
8. **Planetary Boundaries**: Exploring the Safe Operating Space for Humanity. Rockstrom et al, **2009**. *Ecology and Society*, 14(2):32

Bad news: it may not be simple, easy or quick enough

Limits to calculation of boundaries, target-setting,

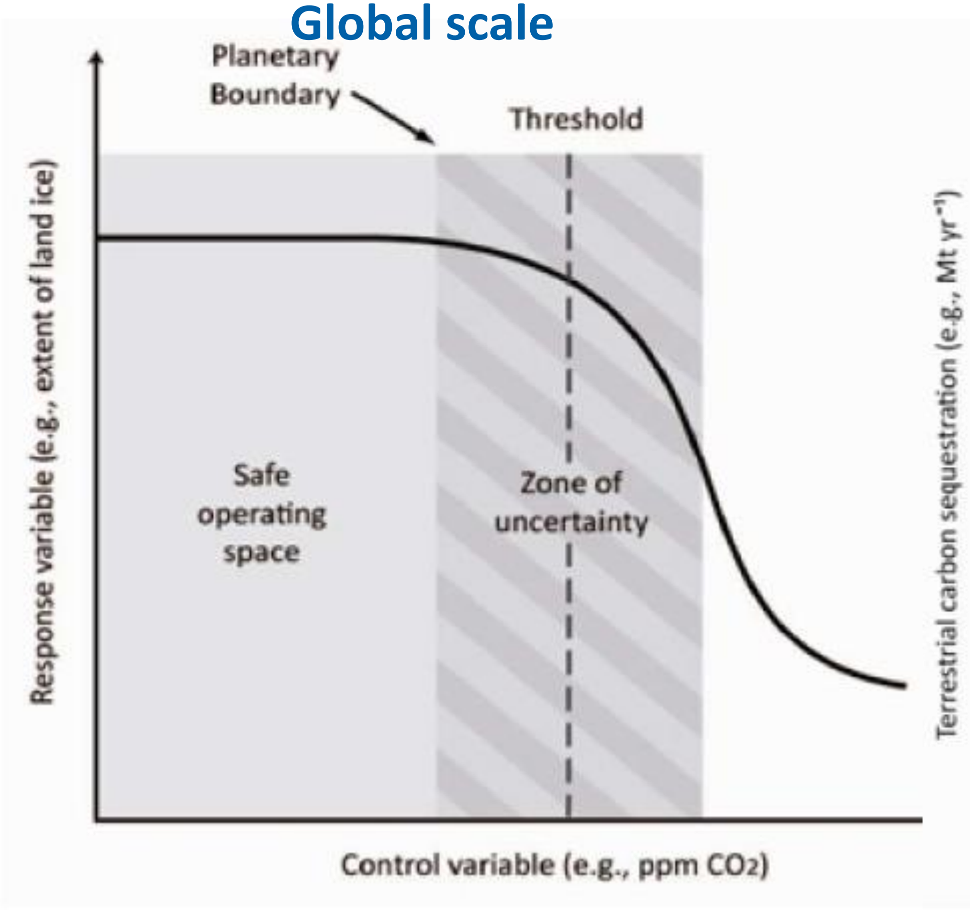
- All these efforts rely on population forecasts (from $7.5*10^9$ to $12.5*10^9$)
- Assume a time frame: mostly 50 years, some 100 years
- Scientific uncertainty – new knowledge on each environmental problem or planetary boundary
- Interdependencies – changes in one system can affect other systems.
- Everything changes: Some progress can be made, e.g., ozone depletion (e.g., Montreal protocol)
- Widely varying accepted Targets/boundaries vary, e.g. for atmospheric CO_2, from 350 ppmv to 550 ppmv (depends on projected impact at various levels and on what is acceptable shift at a regional and global level
- Questions of justice or equity among nations and peoples; Values placed on natural systems –Redwood tree, a threatened species, or clear sky or beautiful view of nature?
- Values placed on human life vs other species
- Values placed on present generation vs future generations

Economics of environmental externalities

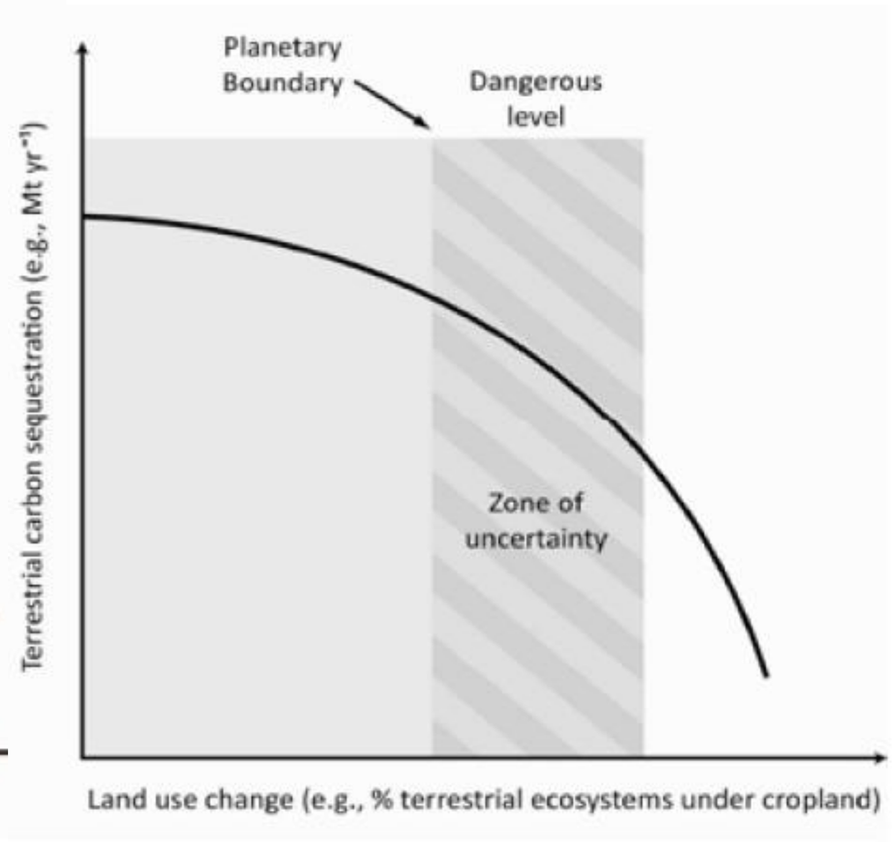
Increasing ventilation ⇧ energy consumption + increased air pollution ⇩ decreased benefit of more ventilation

Conceptual view of the Planetary Boundaries at two different scales: global and local

Global scale



Local scale



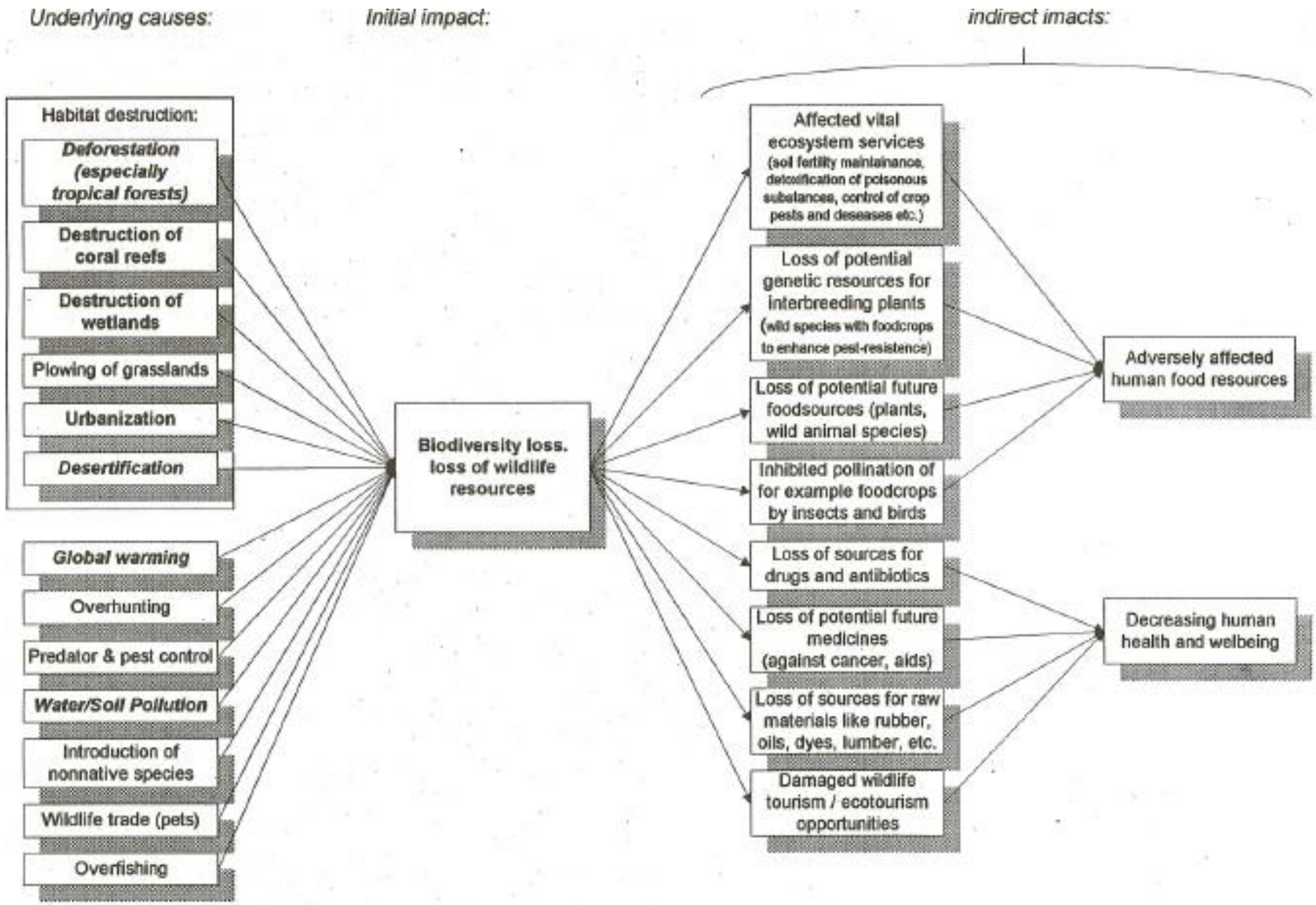
Rockstrom et al, 2009. *Ecology and Society*, 14(2):32

The authors note: Insufficient knowledge and dynamic nature of the boundaries

Network diagram: causes and effects

Biodiversity Loss

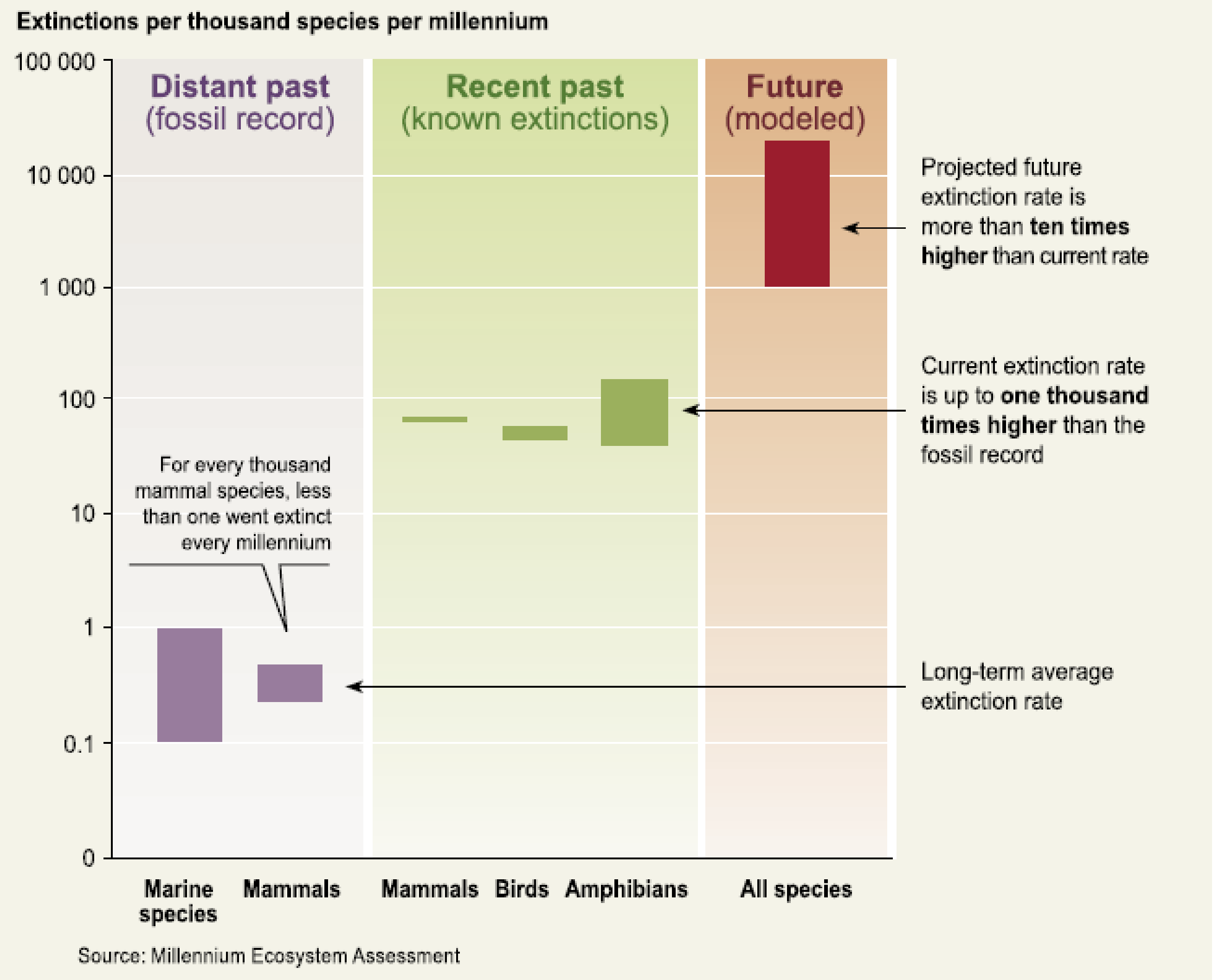
Boerstra, 1996. unpublished



Sources: Lean, Hinrichsen 1994, "Atlas of the Environment", pp. 417-421; Lean "Atlas of th;e environment" pp. 127-132

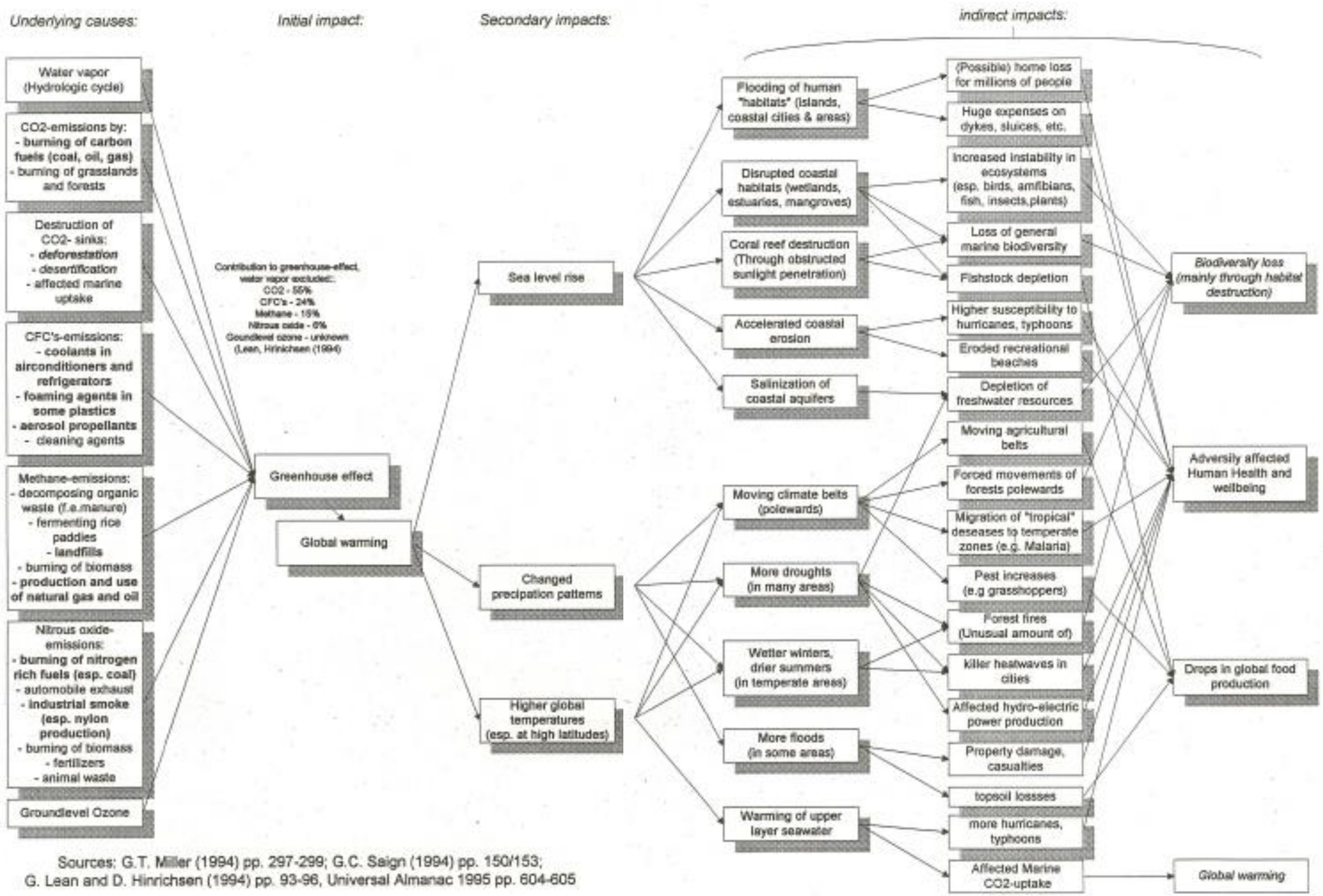
Historic and projected rate of extinctions.

(source: Millenium Ecosystem Assessment)



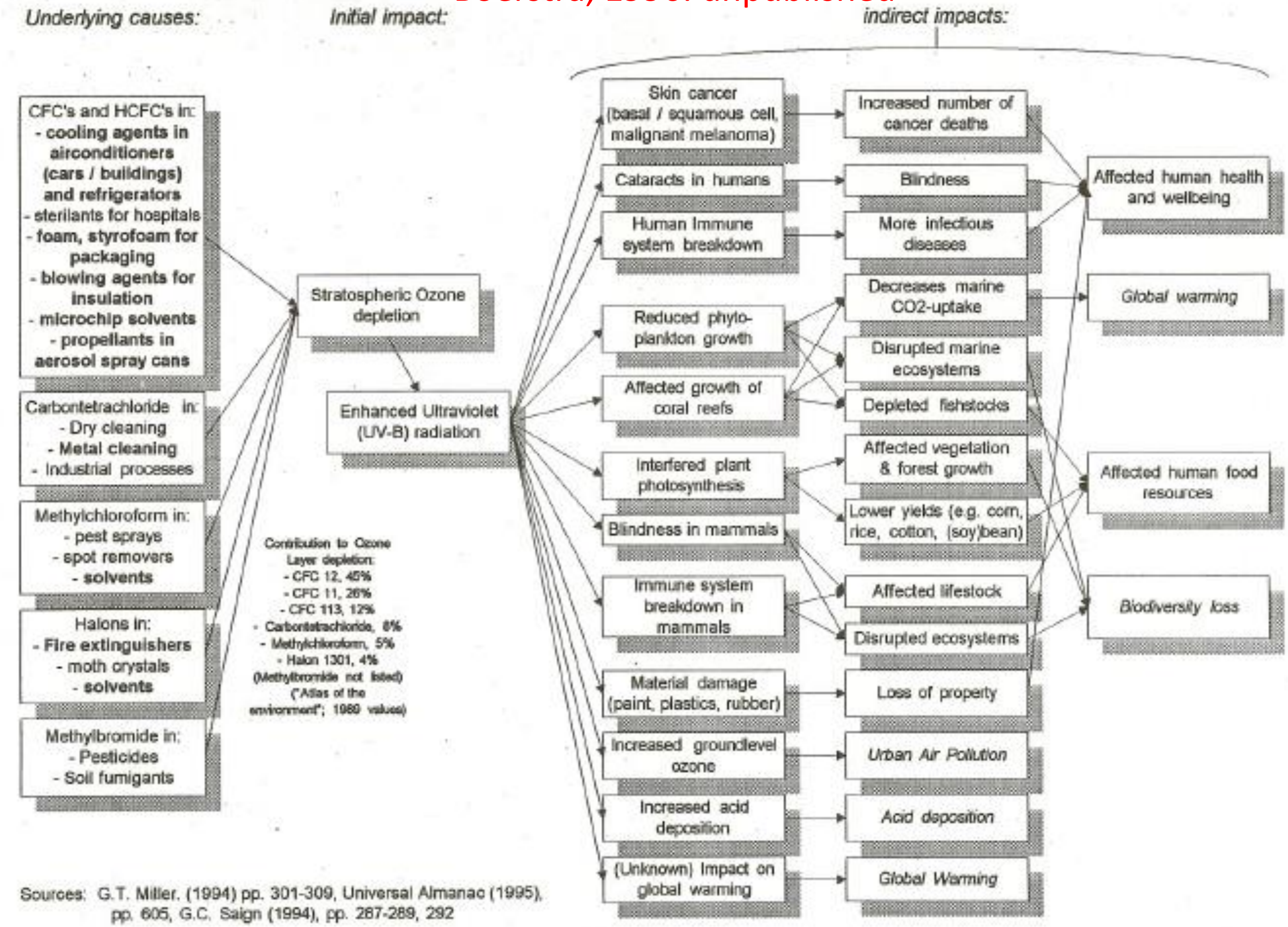
Climate change – global warming

Boerstra, 1996. unpublished

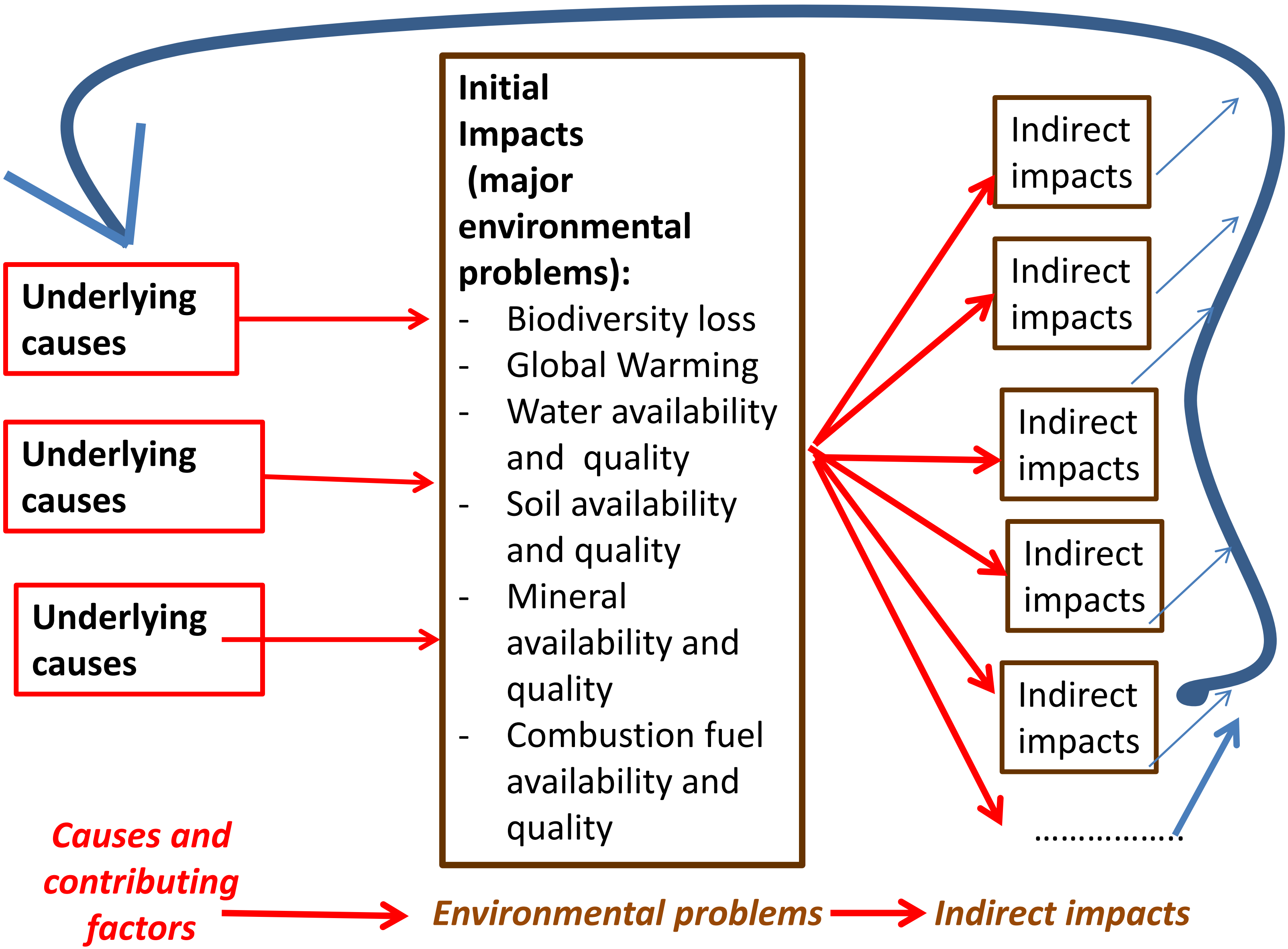


Ozone Depletion

Boerstra, 1996. unpublished



Connections and downstream (indirect) impacts



Getting Serious about Sustainabiliy
(Graedel and Klee, 2002. *ES&T*)

Four step process

- Virgin material supply limit (pollution absorption capacity)
- Allocation of virgin material (supply, sinks)
- Regional re-capturable resource base
- Current consumption vs. sustainable limiting rate

- Examples: zinc consumption, carbon dioxide production (emissions), germanium consumption

Calculation of global carbon limit

from Graedel and Klee, 2002

- Virgin material supply: based on atmospheric limit of CO_2 equivalents of 550 ppm by 2100, global anthropogenic emissions must be limited to ~$7.8*10^{15}$ g (7.8 Pg) of carbon per year.
- Allocation/person: Dividing by $7.5*10^{6}$ global population. Approx. 1 Mg/$CO_{2\ eq}$ per person per year.
- Regional re-capturable resource base: not currently demonstrated technology
- Current consumption rate vs. sustainable limiting rate: U.S.: 6.6 Mt (6.6 Gg/p y) carbon equivalents/person-year. 6,600,000 g C_{eq}/ p yr or 18 kg C_{eq}/p day
- Current consumption in Switzerland ~ 2 Mg C_{eq}/p yr or twice the calculated limit

What's the right" target for global average CO_2 equivalents?

Global atmospheric CO2 target

(James Hansen, 2009. *Storms of my Grandchildren*)

- Rationale for target of 350 ppmv.
- Strongly informed by…
  - Species extinction impacts
  - Sea level rise
  - Tipping points, non-linear dynamics
  - Interdependencies of environmental compartment
  - Uncertainty and values

Planetary Boundaries

(Rockstrom et al 2009 *Ecology and Society*)

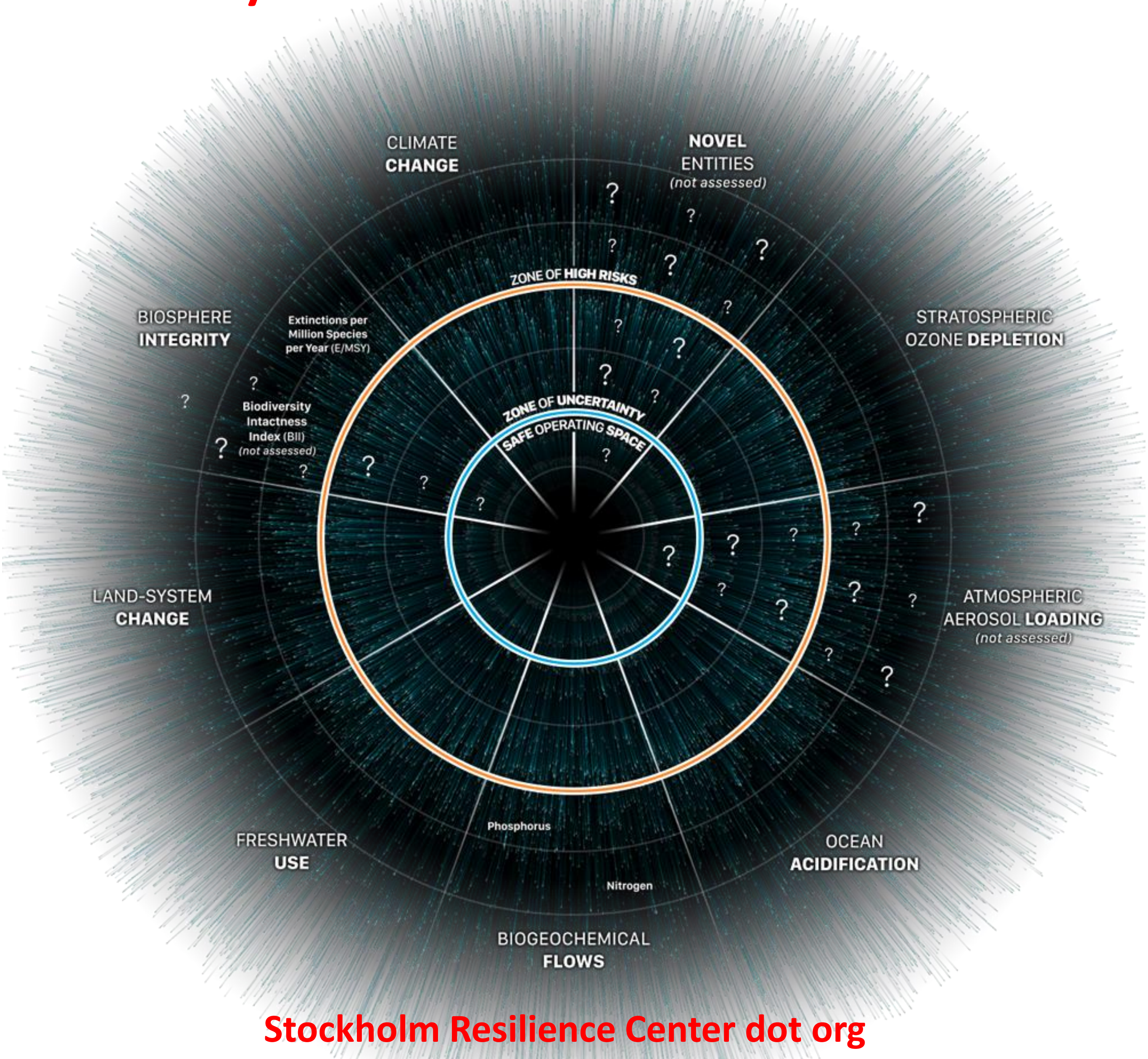
Three step process (Agreement on approach)

- Identification of planetary boundaries (or the Earth's "ecocapacity" – ecological carrying capacity)
- Translation of planetary boundaries into targets for human eco-impact
- Comparison of project or program impacts on planet relative to planetary boundaries

Rules

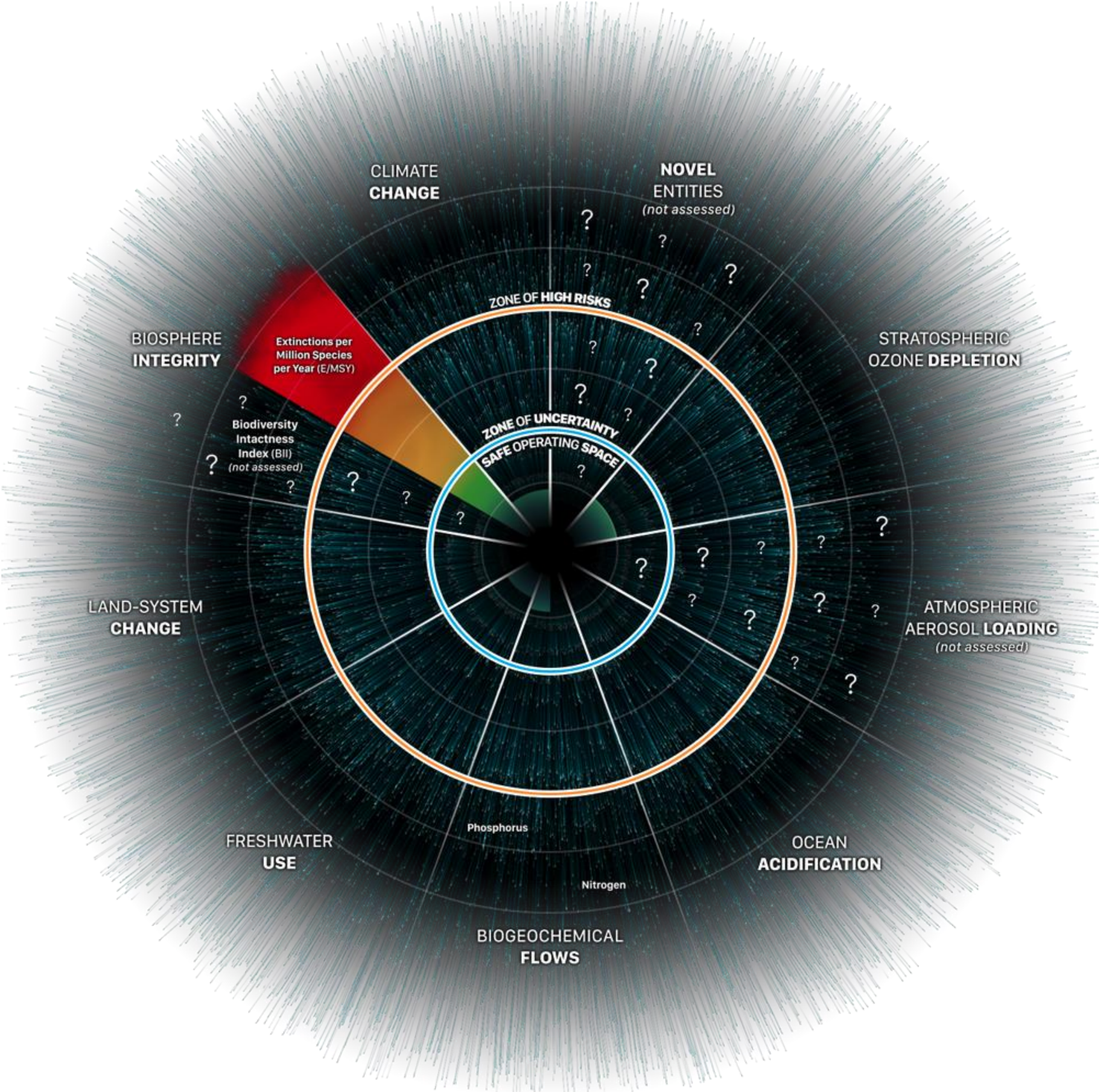
- Transparency:
  - All assumptions identified and declared
  - Uncertainty replaced by credible boundary estimates
  - Propagation of uncertainty in models and Sensitivity analysis to determine key factors

Planetary boundaries: Pre-Industrial

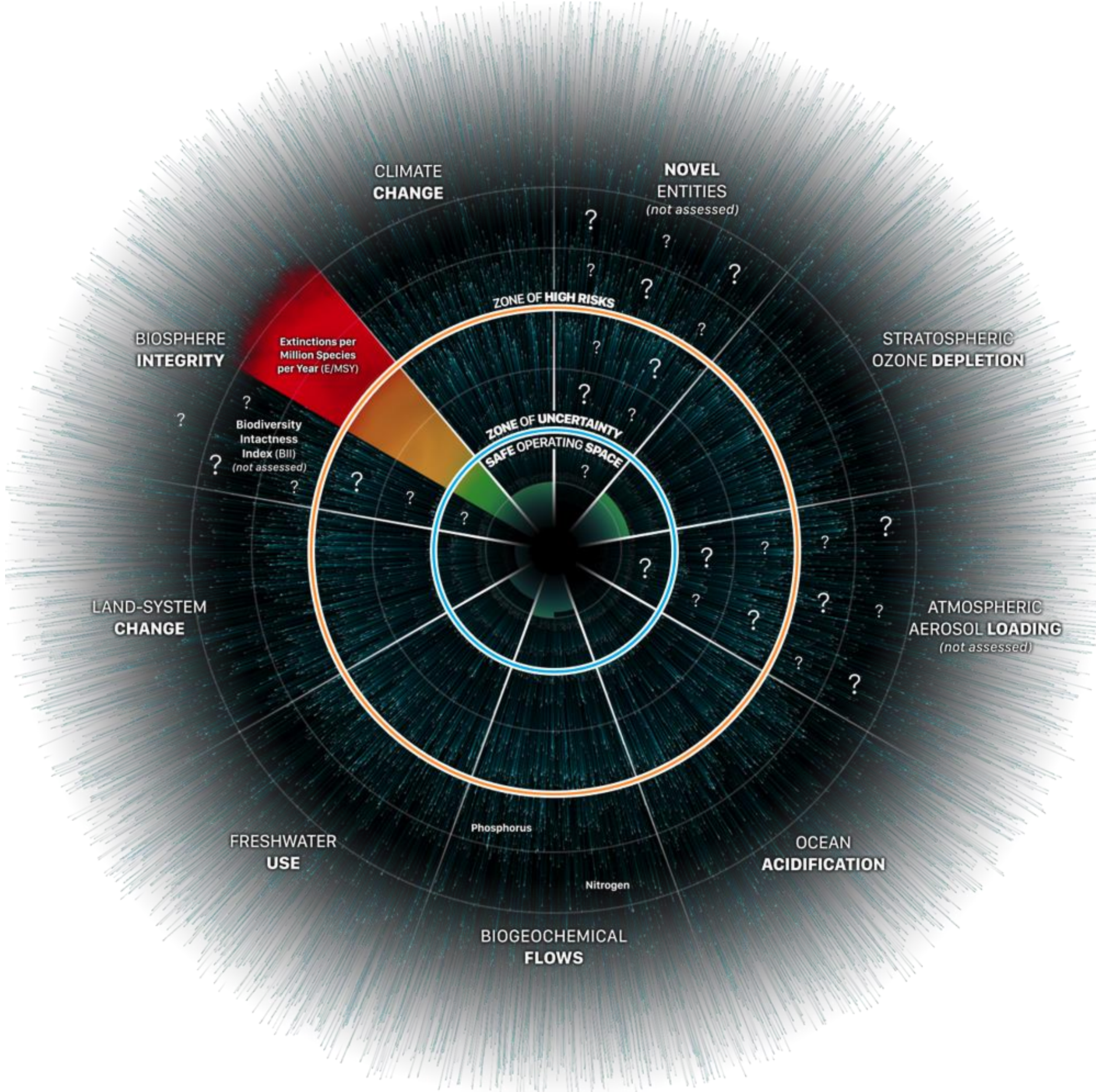


Stockholm Resilience Center dot org

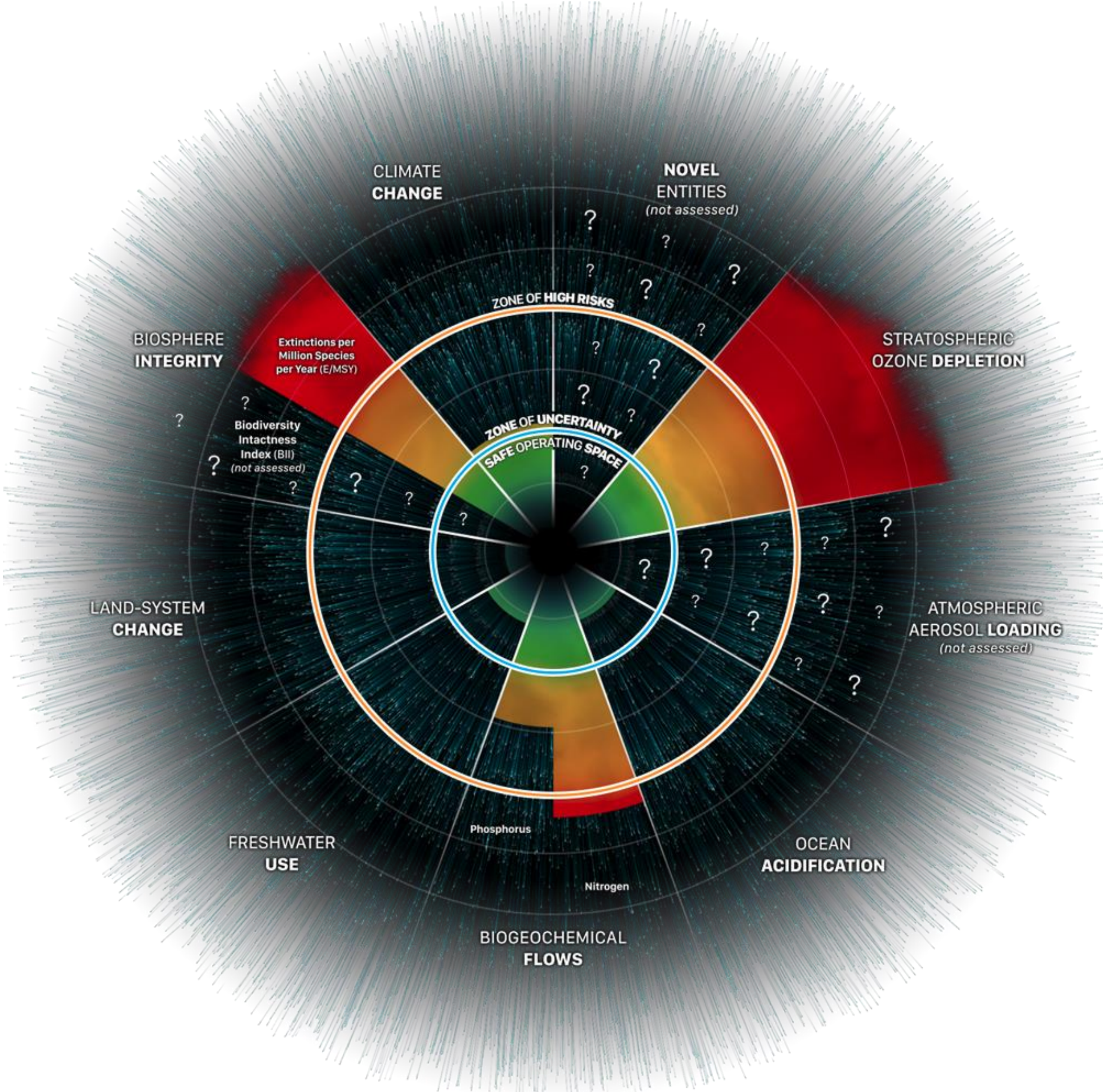
Planetary boundaries
1950



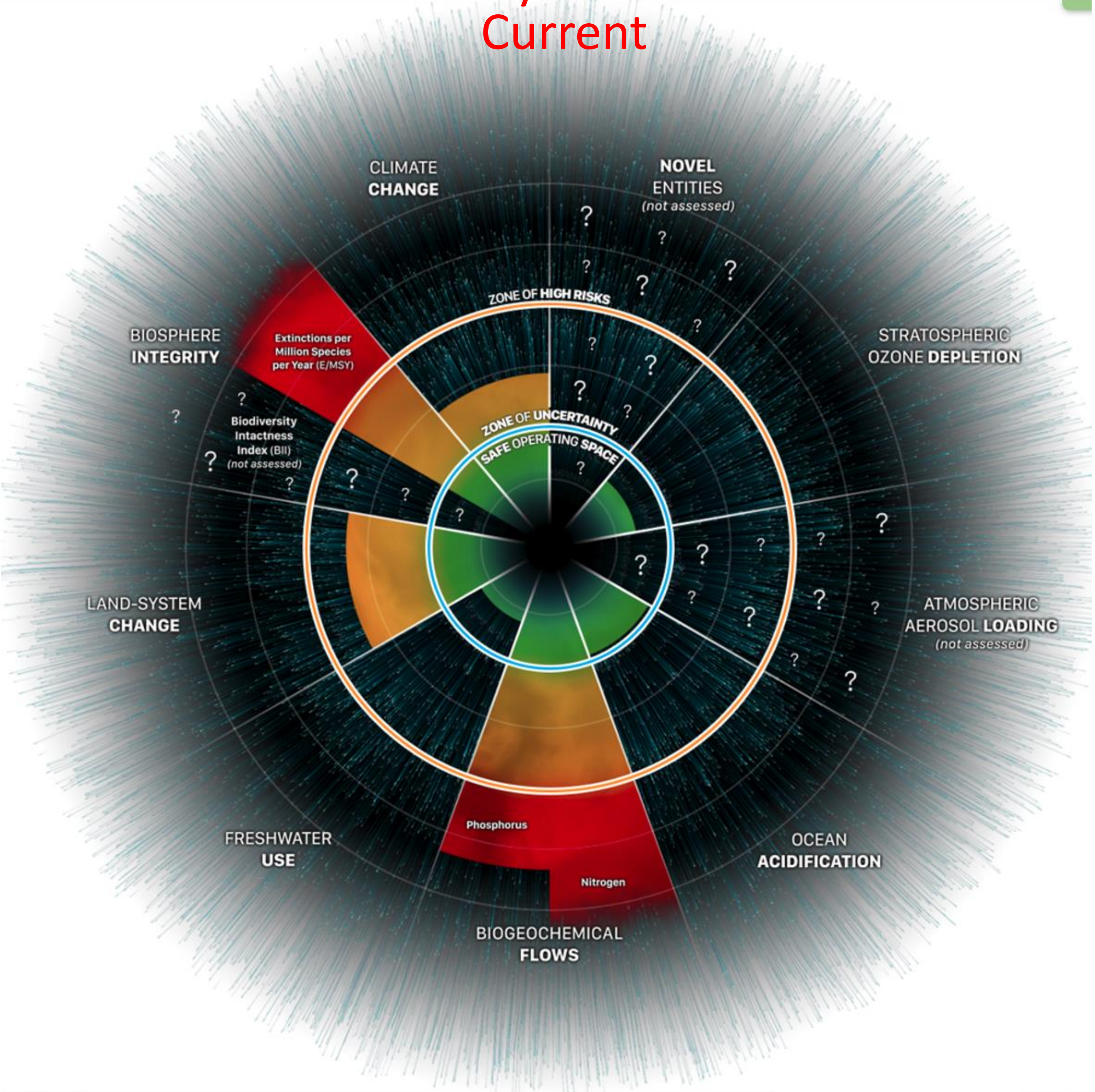
Planetary boundaries
1970



Planetary boundaries 1990



Planetary boundaries
Current



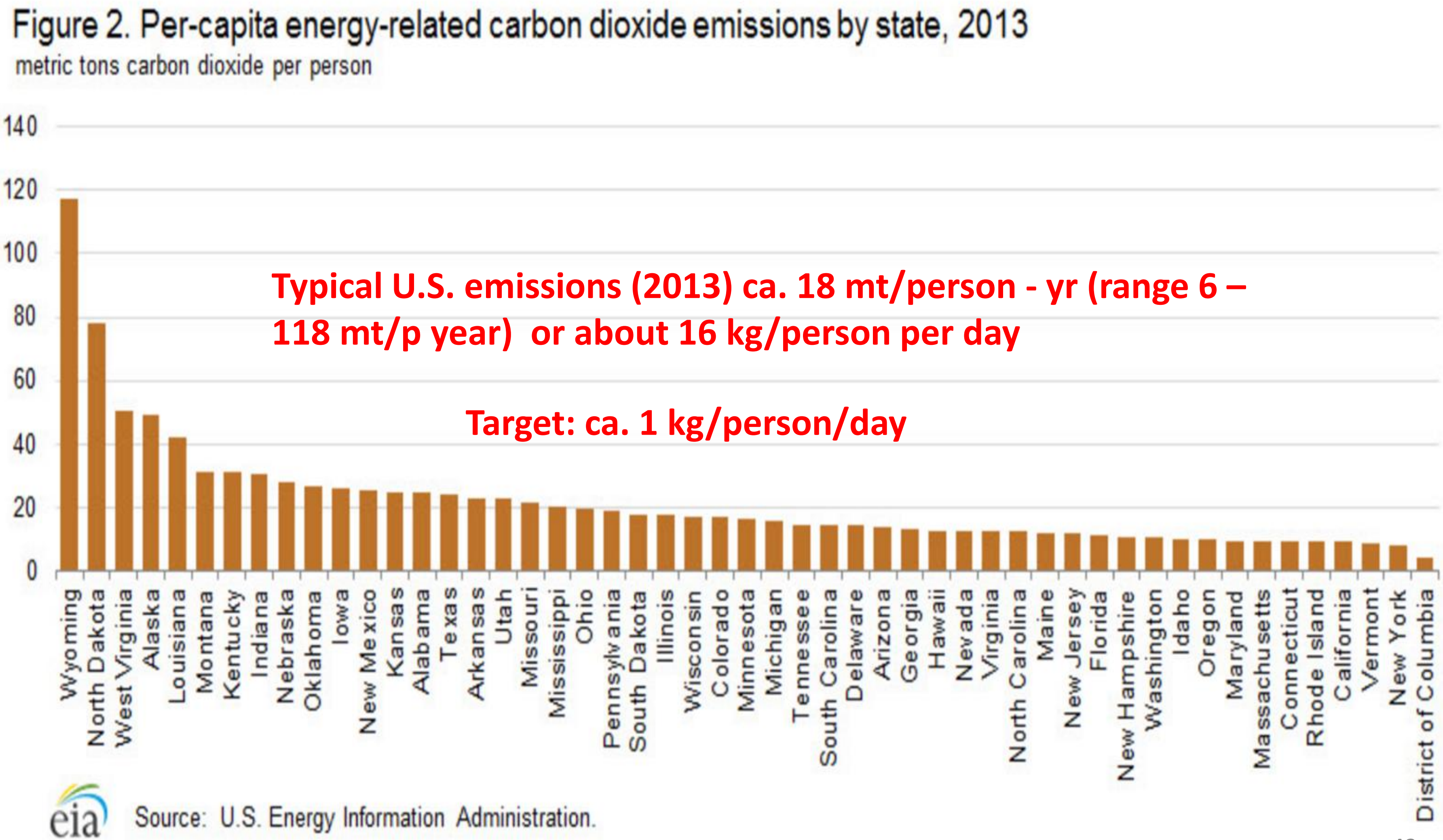
Building Design Targets Can be Based on One or More Comparisons

- Relative to “typical” buildings
- Improvement over past practice
- Reduced resource consumption (e.g., oil, wood)
- Reduced pollutant emission (e.g. GHG emissions)
- Attainment of established goals, limits, e.g.: provide 20 cfm/p (10 l/s-person) ventilation air
- Limit Indoor air pollution (e.g. formaldehyde <27 ppb)
- Limit energy consumption to <70 KBtu/m^2-year

  or

- Limit carbon emissions (e.g. 0.5 kg C_{eq} p^{-1} d^{-1})

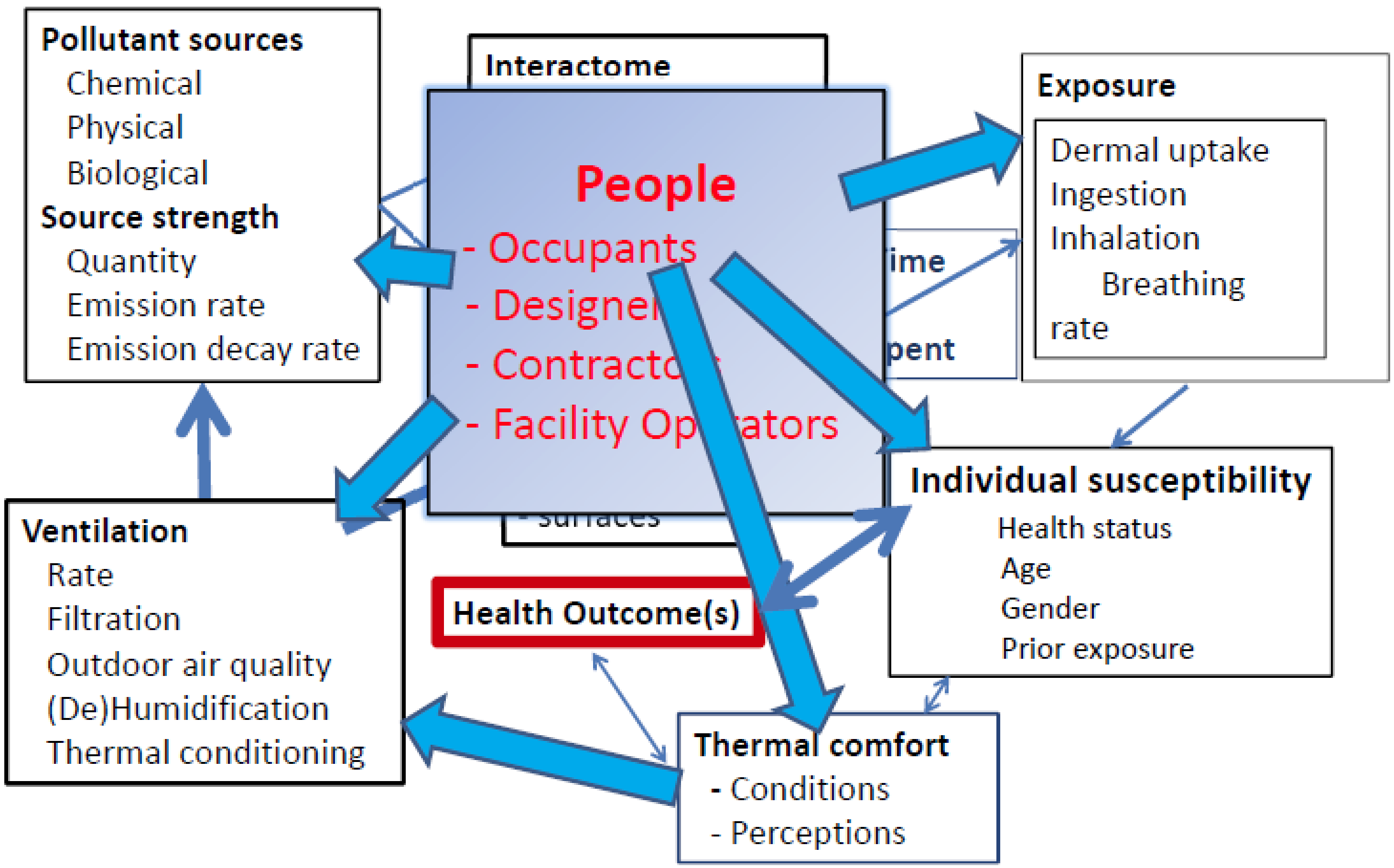
Per capita energy-related carbon dioxide emissions by state, 2013



Typical U.S. emissions (2013) ca. 18 mt/person - yr (range 6 – 118 mt/p year) or about 16 kg/person per day

Target: ca. 1 kg/person/day

Theory of more nearly everything in the Indoor Environment



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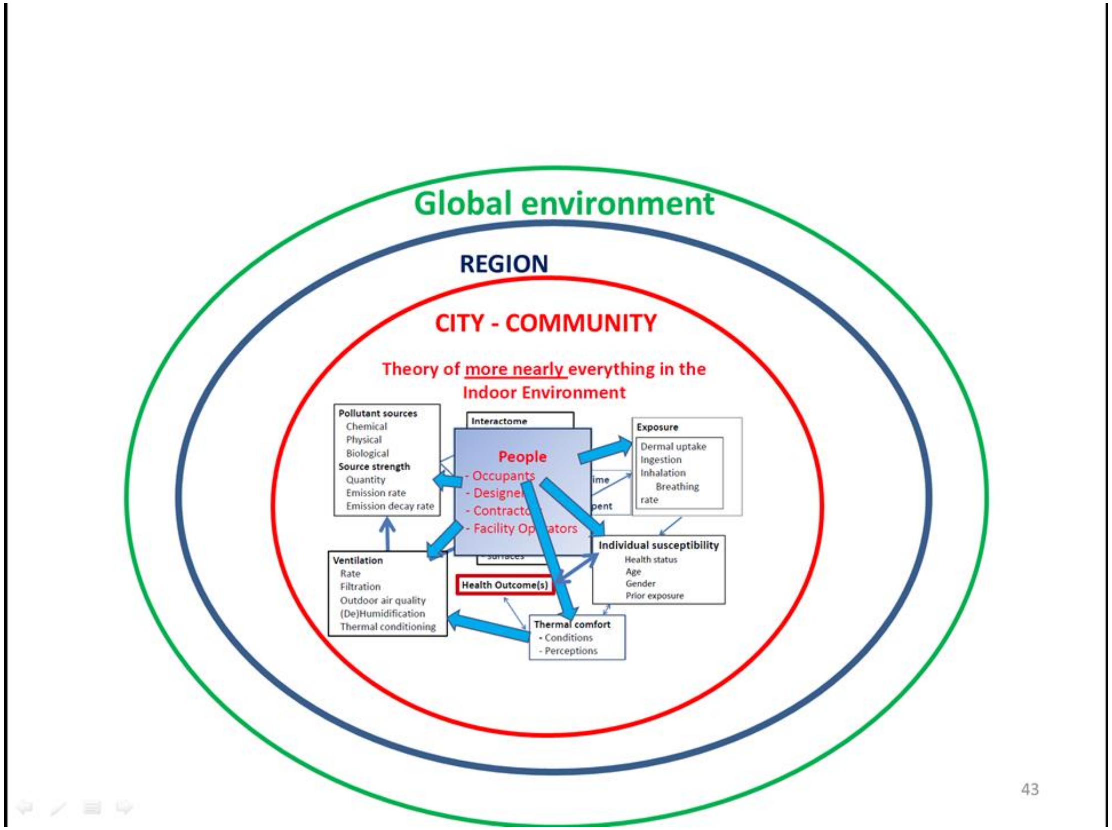
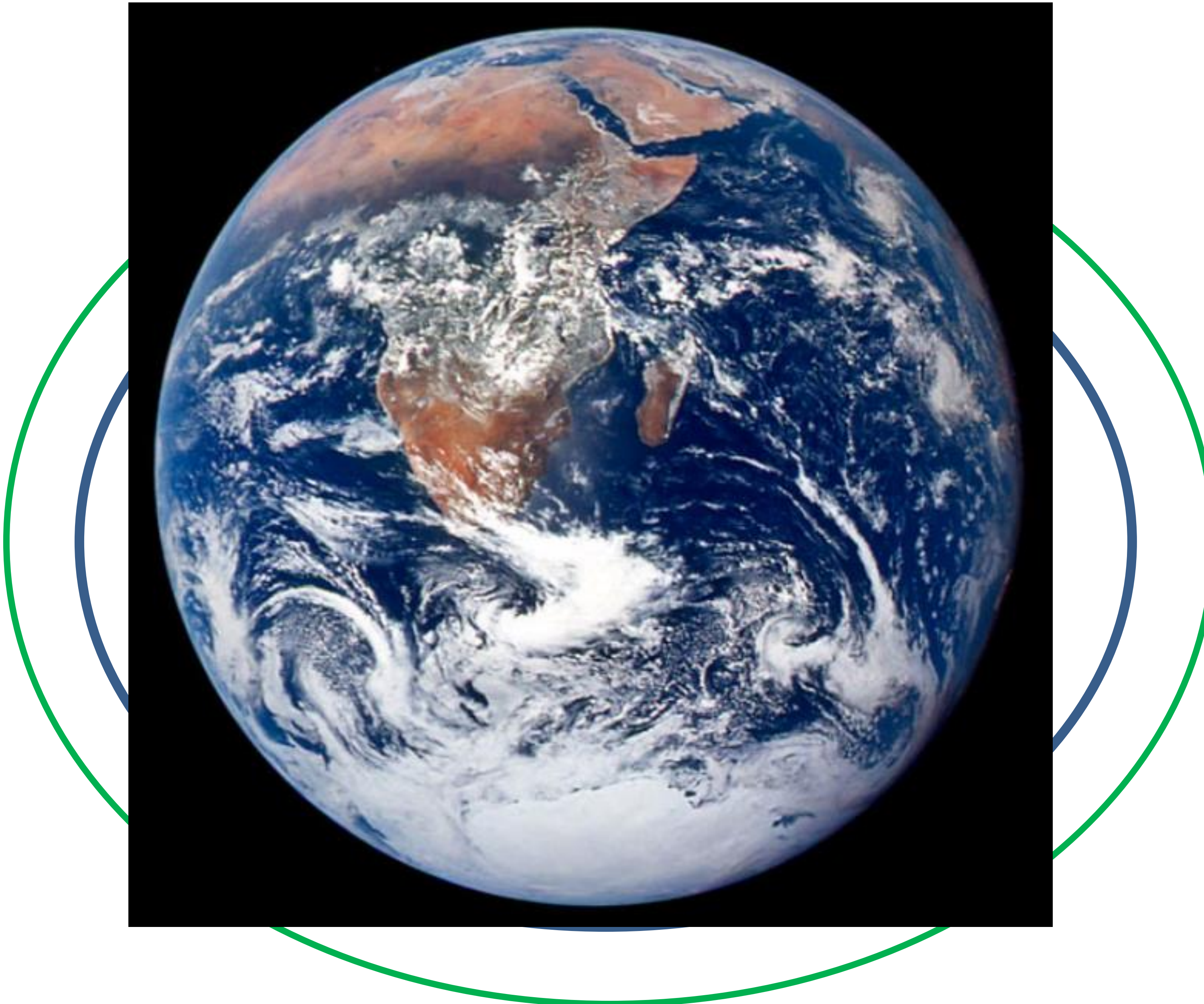


‘No building is an island’



Stephen Hawking says:

13 April 2013 - Humanity Must Colonize Space to Survive.

Earth… "…the fragile planet"

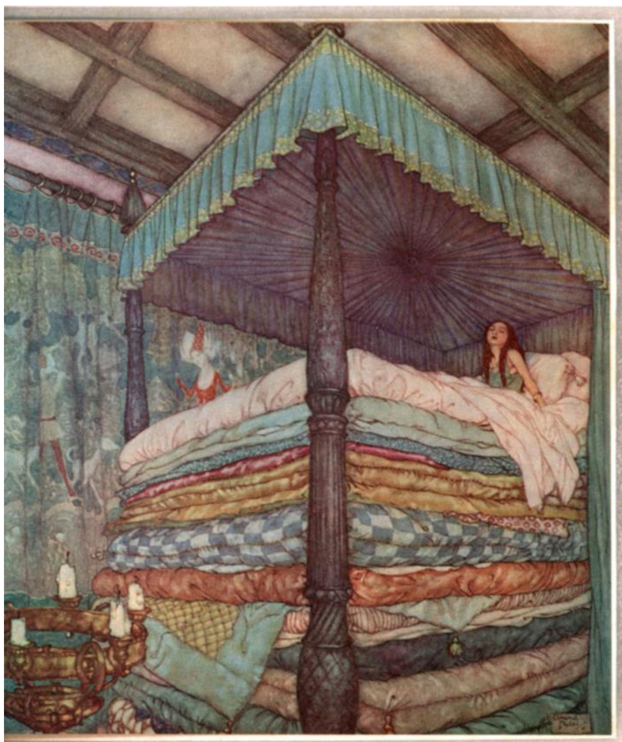
19 Jan. 2016 - Space colonies won't exist for at least 100 years.

The 74-year old Cambridge professor, speaking before giving a lecture on black holes, said that with nowhere else to live humanity needed to treat Earth with great care. Hawking said potential downfalls for humans on Earth include nuclear war, global warming and genetically-engineered viruses, according to the BBC.

The space race – and colonies

Priorities: what's important

Air conditioning for 1.5 Billion of us or decent shelter, health and education for the other 5.5 billion?



Should we do research so we can design a 20^{th} mattress so the princess won't lose sleep due to the pea under her 19 mattress? Or should we try find mattresses for the 5.5 Bn people who sleep on the lfoor or on straw mattresses?

Implications for IEQ

- Sustainable material and energy use
- Human health, comfort and productivity vs other humans, other species, in present and in future generations
- Developed vs. Developing World
- Scope of study that ignores context increases risks of outcomes that are not sustainable
- A shift in human consciousness will be required to approach a sustainable society

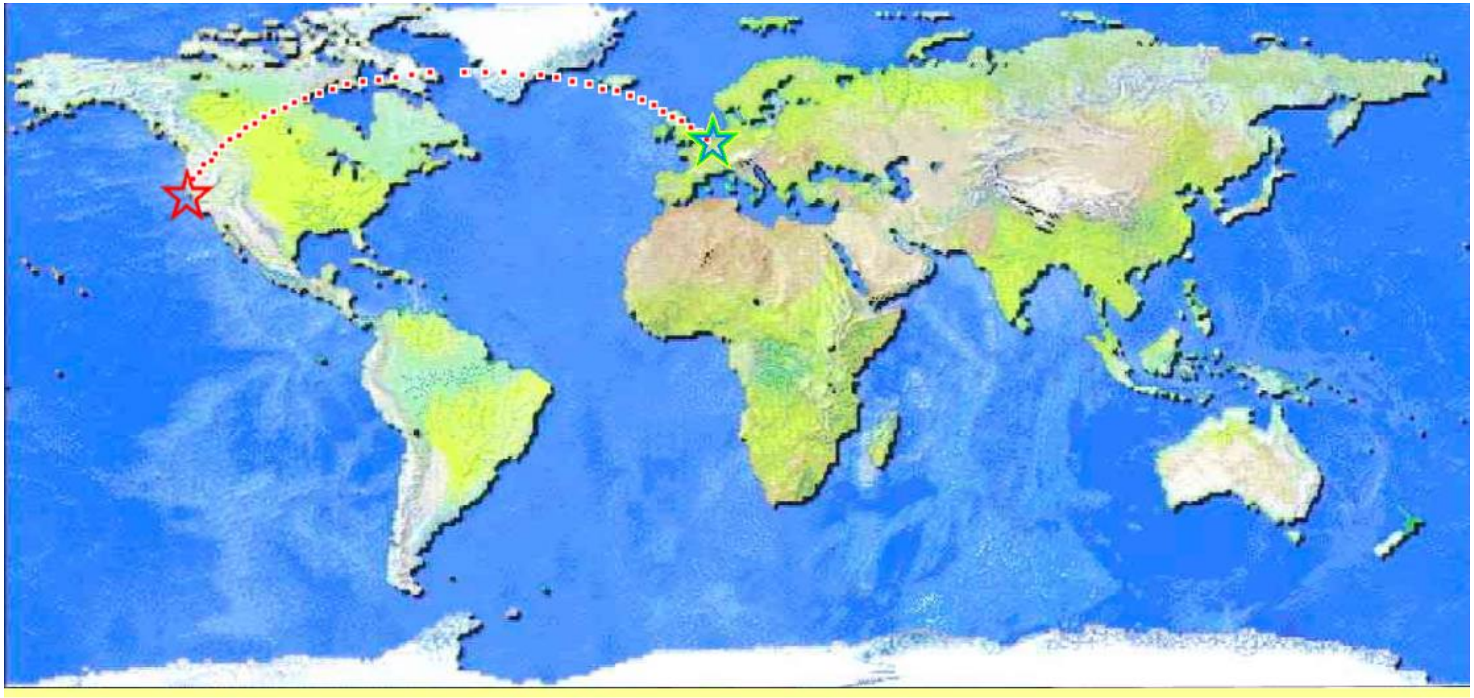
Acknowledgments

- Atze Boerstra (1995-1996) part of Building Ecology Research Group for helping me further my evolving understanding of "sustainability"
- U.S. EPA for funding to develop that understanding.
- Nicholas Kohler for teaching me that sustainability is all about mass flows.
- Mariachiara Tallacchini for helping me understand the limits of scientific knowledge

Thank you for your intentions

References available on request and available on http://buildingecology.com website

Confession:
Flying off (to a warmer climate)
(chooseclimate.org/flying)



In 1995, 6 billion people on the planet emitted 6 bn tons of carbon (C) to the atmosphere (as CO_2*) by burning fossil fuel - i.e. one ton per person on average. The oceans can only absorb about 2 bn tons C annually, and trees absorb less than one ton. So to *stabilise the concentration* of CO_2 now, we need to *cut emissions* by about 60%, to 0.4 ton C per person per year. In comparison, your proposed flight would emit 1.9 tons C (as CO_2) per passenger, i.e. your total sustainable carbon emissions budget for all purposes (including heating, cooking, lighting, local transport, etc.) for 1.33 years. (chooseclimate.org/flying)

Confession:
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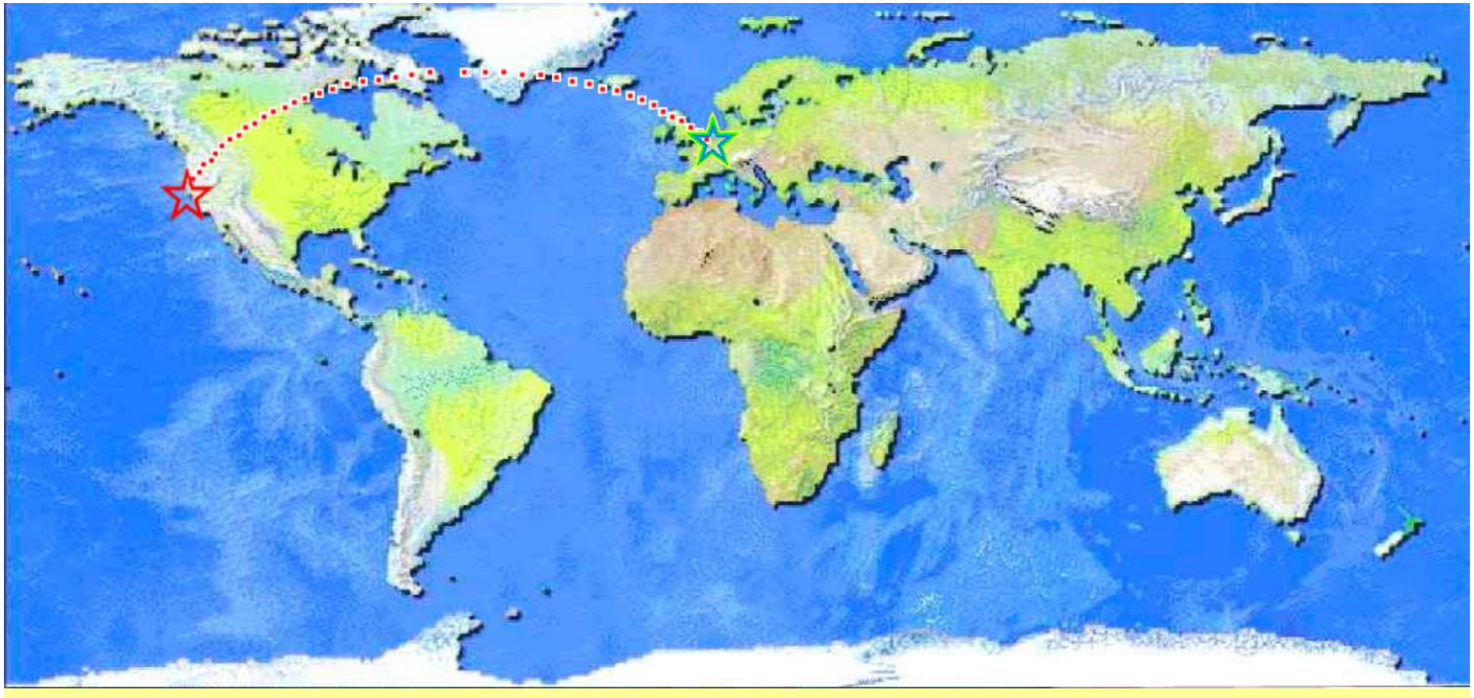

Flight from San Francisco to Brussels (one way)
– about 1.35 years worth of total annual on person emissions budget at target for 350 ppmv global atmospheric concentration