



Sustainability Science

- *The Hague 7 maart 2024*

- TU Delft

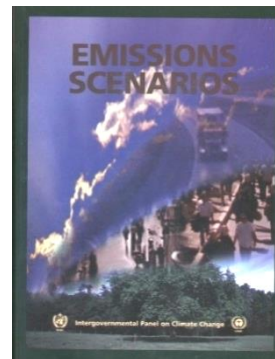
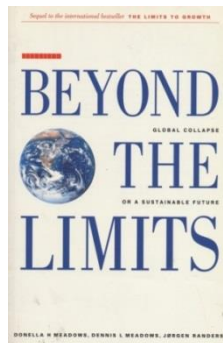
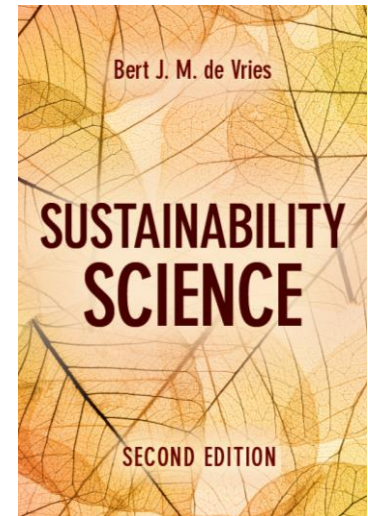
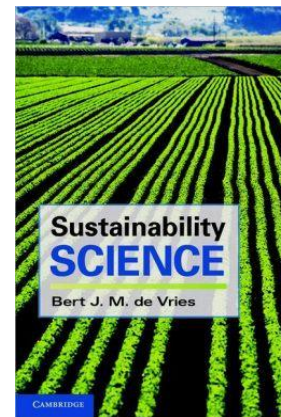
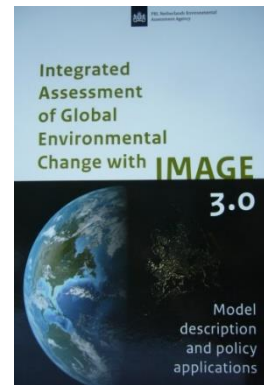
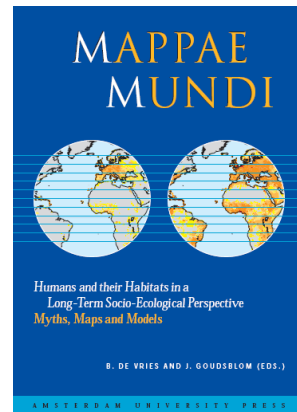
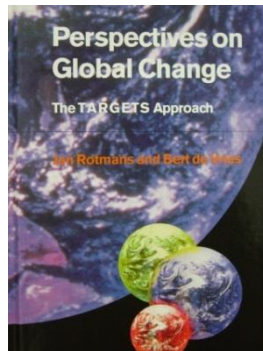
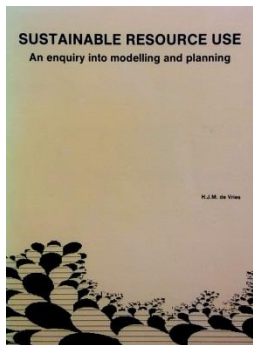
Faculteit Techniek, Bestuur en Management

Models and scenarios
exploring world futures

Prof. em. Dr. Bert J.M. de Vries
Universiteit Utrecht

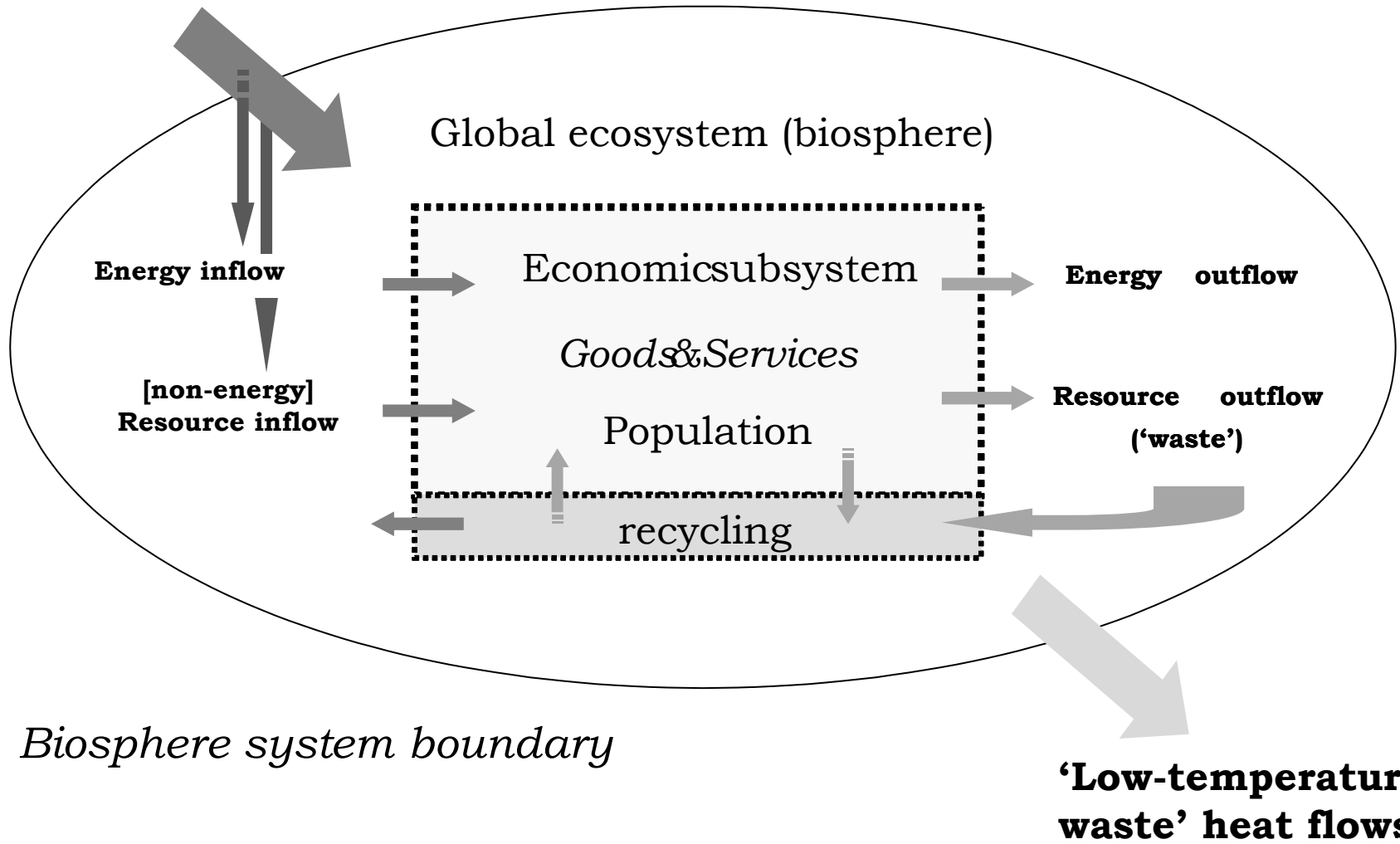
Prof. Dr. Bert J.M. de Vries - Universiteit Utrecht

Background: natural science and philosophy, energy and global change/climate modelling and policy, teaching sustainability science



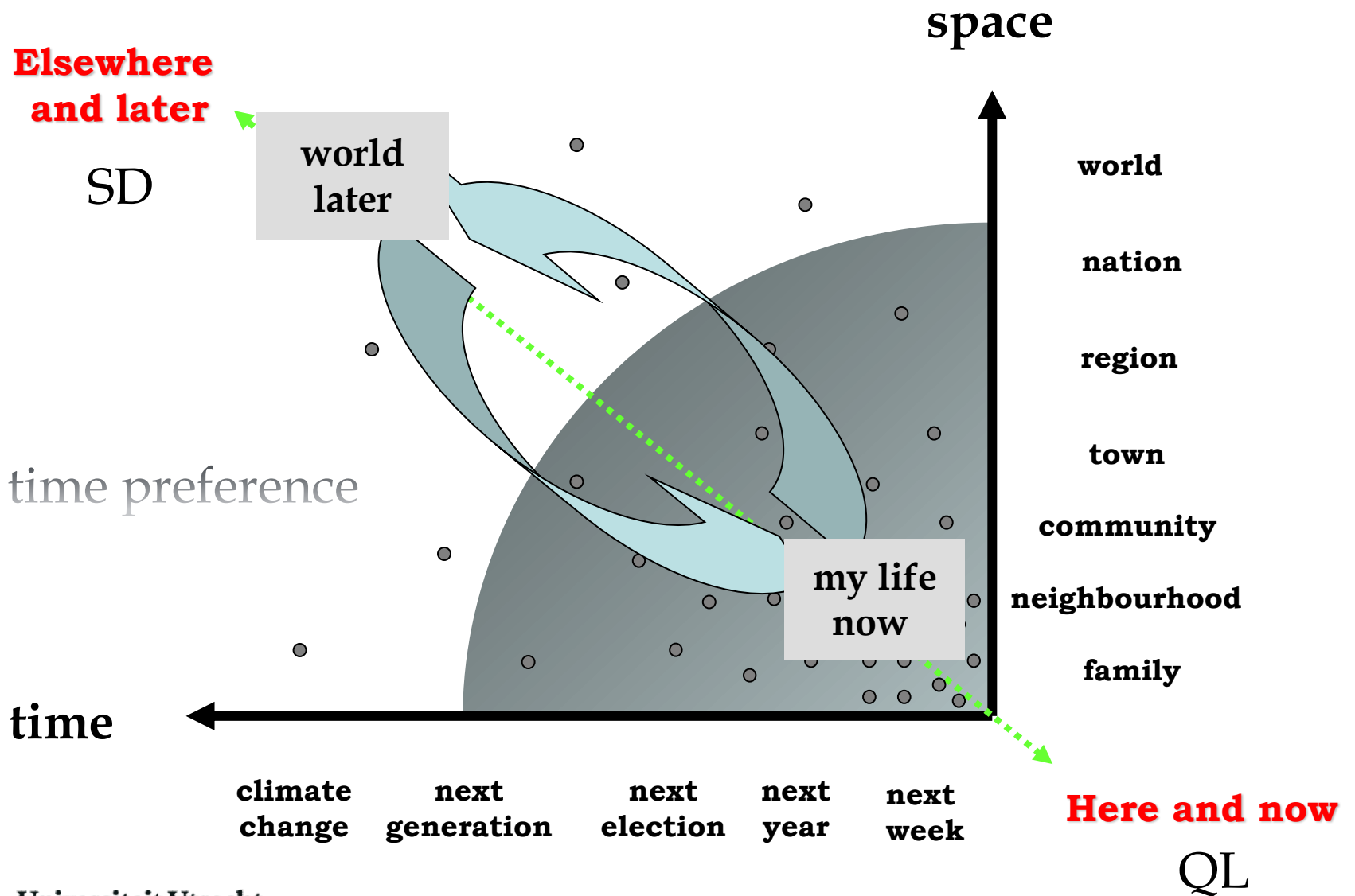
www.sustainabilityscience.eu

Solarenergy flow

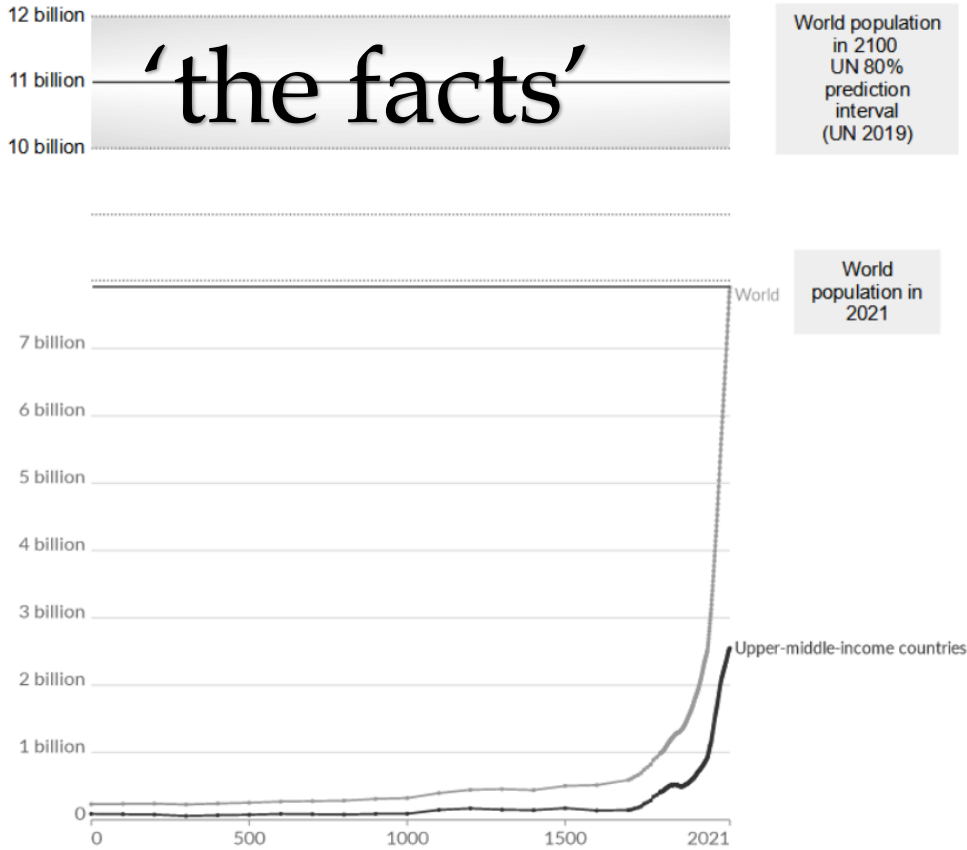


Human populations are living within an open self-organizing system called Earth

Bridging the time-space dimensions in (the ideals of) development and sustainability

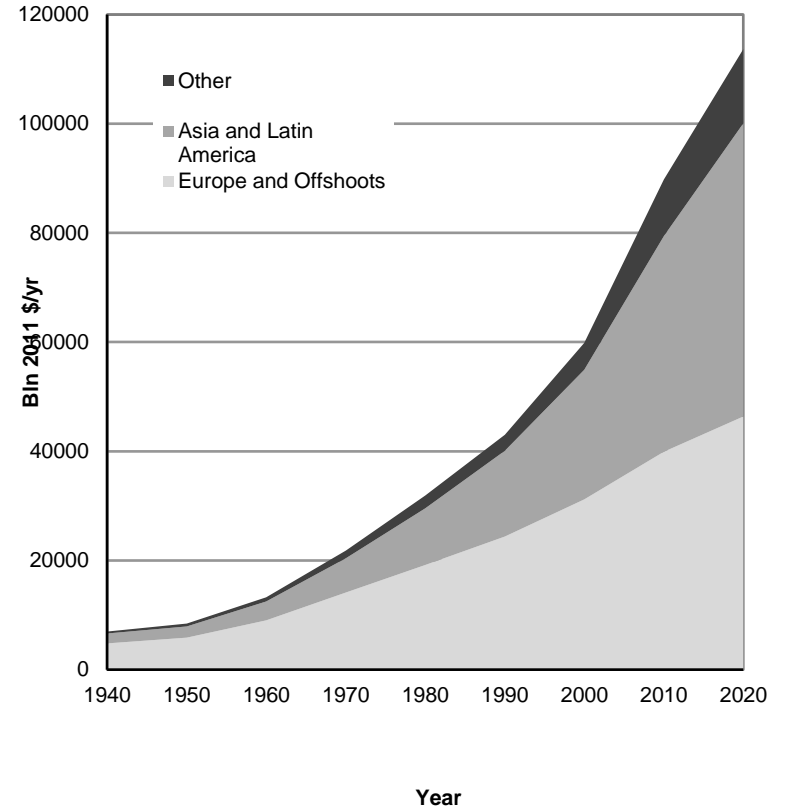


'the facts'



Source: Gapminder (v6); HYDE (v3.2); UN (2022)

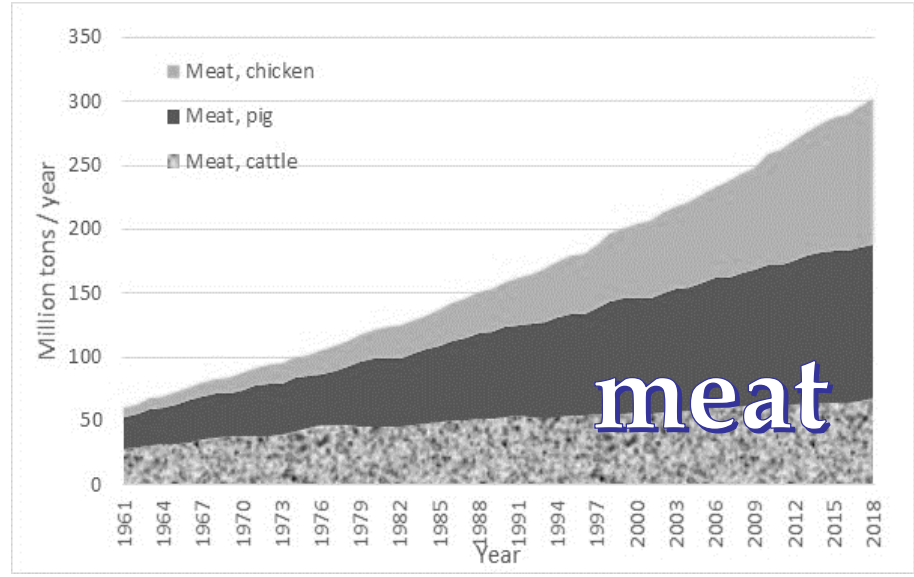
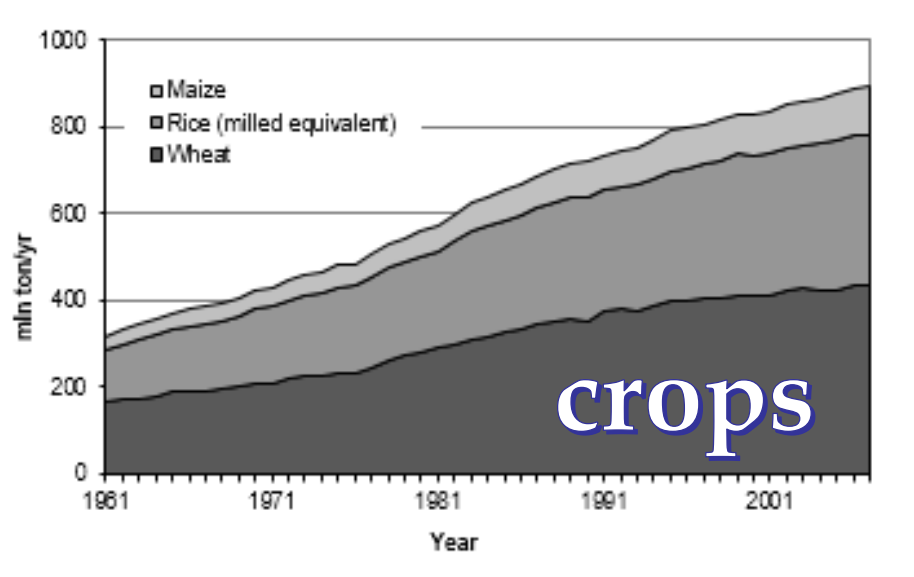
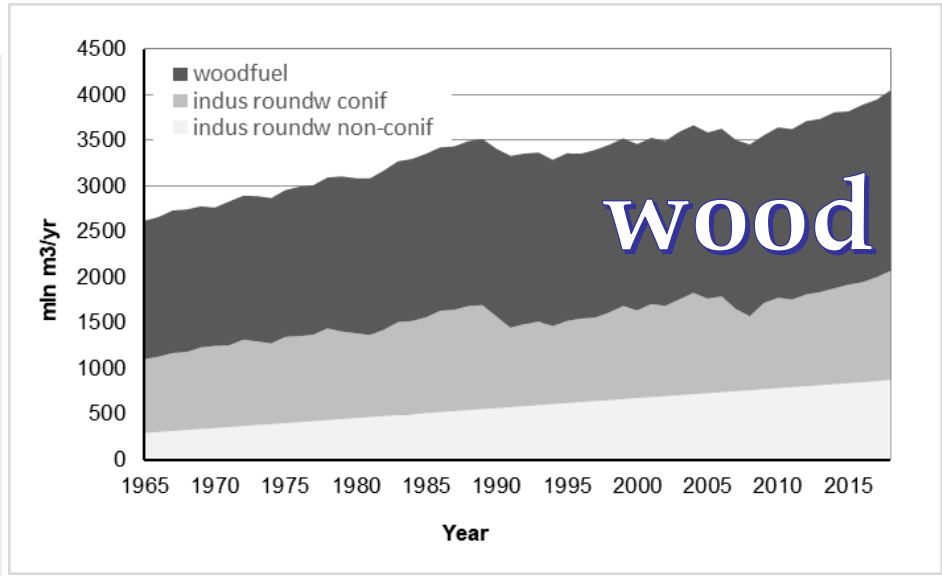
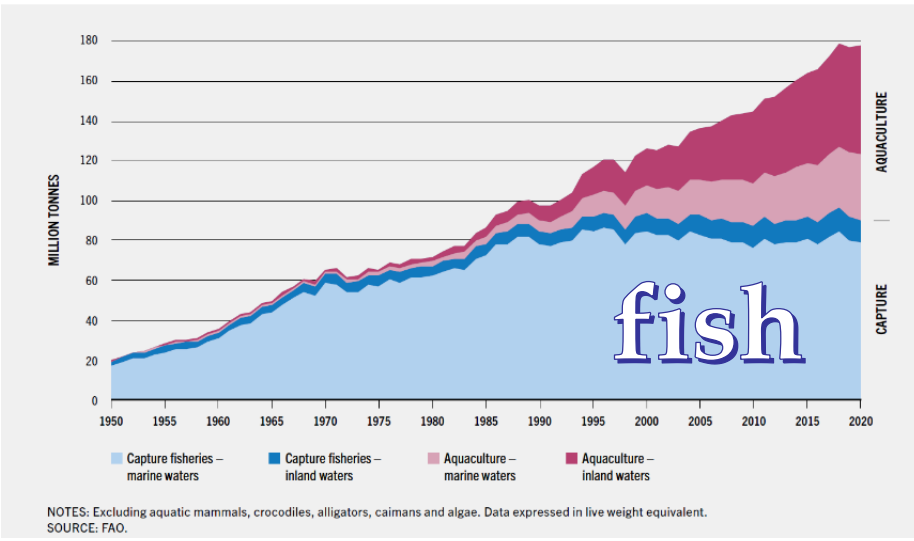
Economic activity (bln US\$/yr)



Population (# of people)

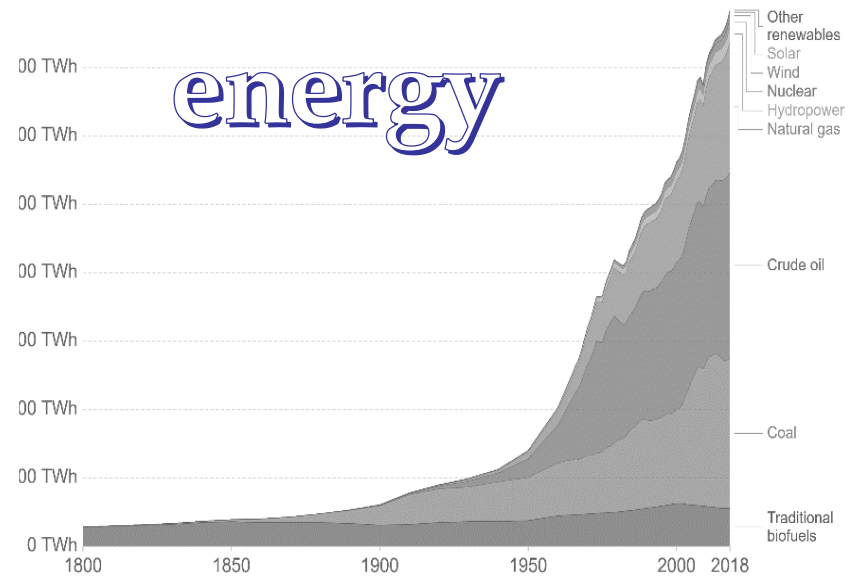
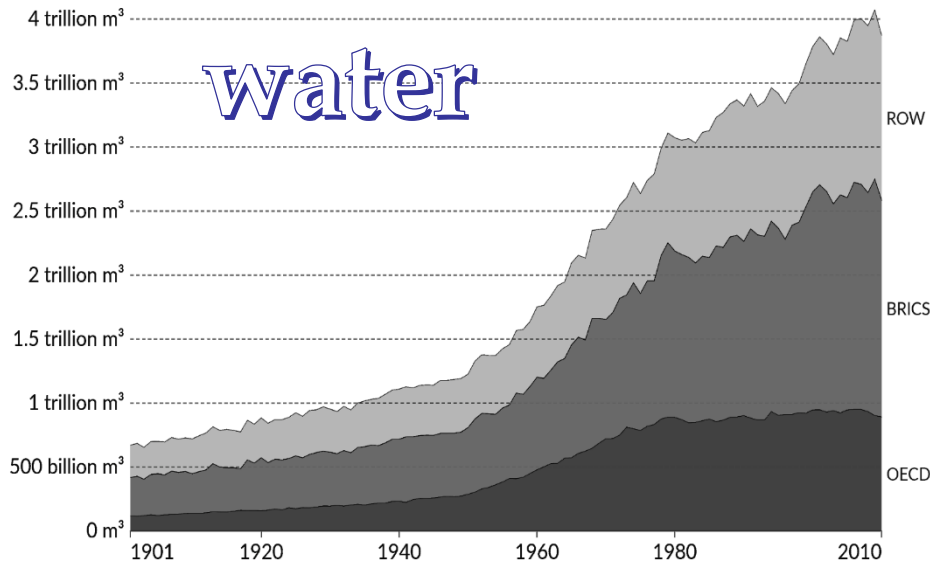
Growth in population and economic activity...



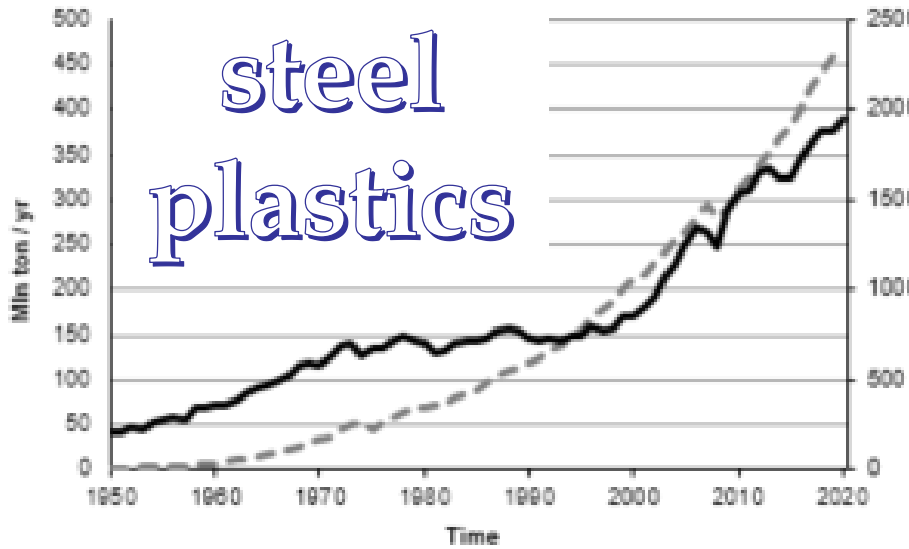


...and exploitation of natural resources

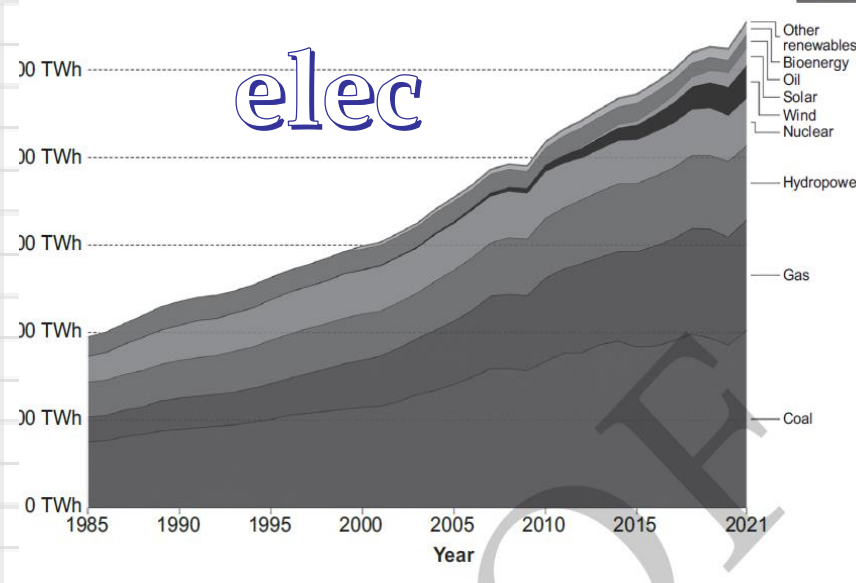




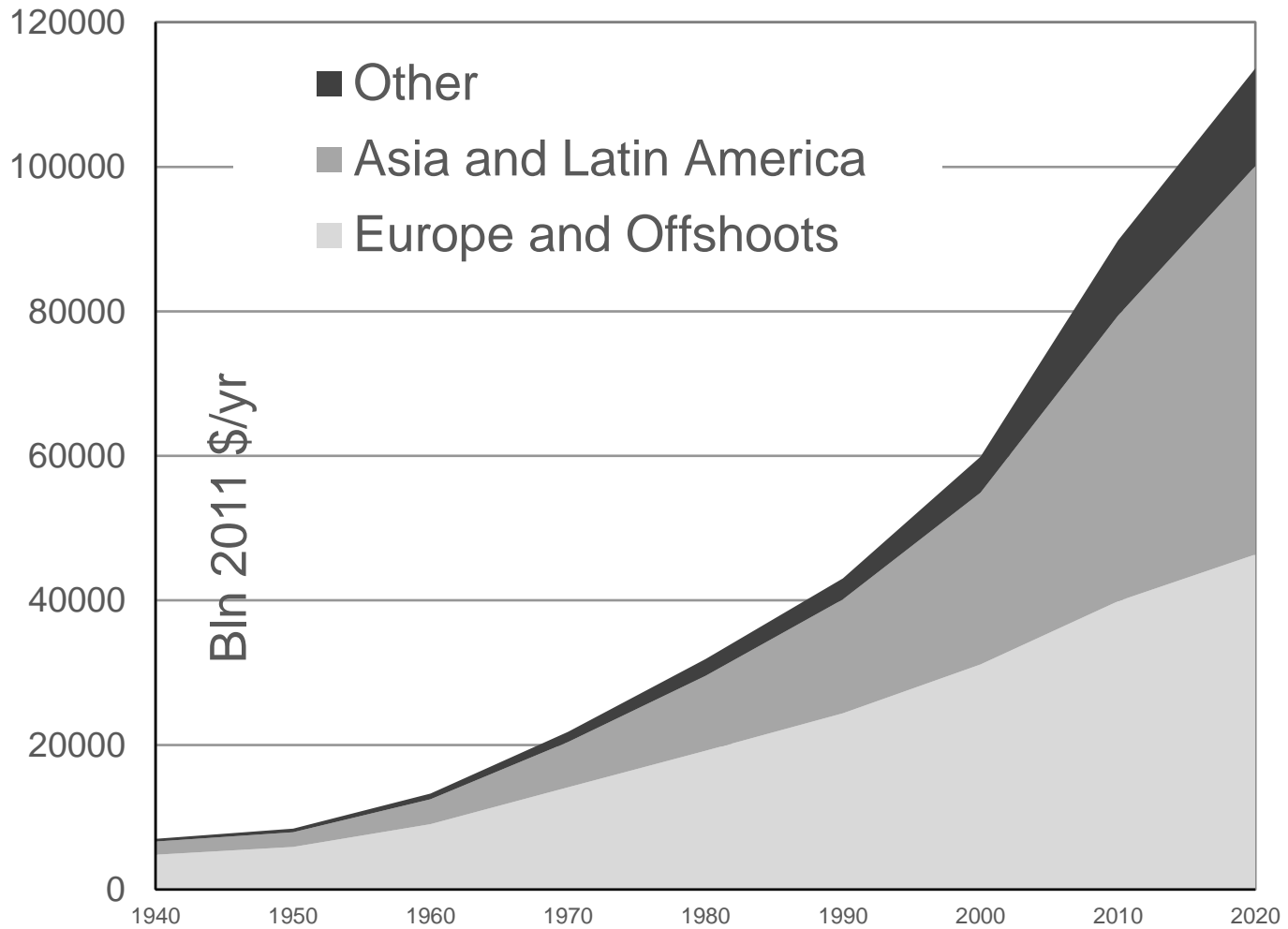
Sc
i)



Vaclav Smil (2017) and BP Statistical Review of World Energy



Economic activity (bln US\$/yr)



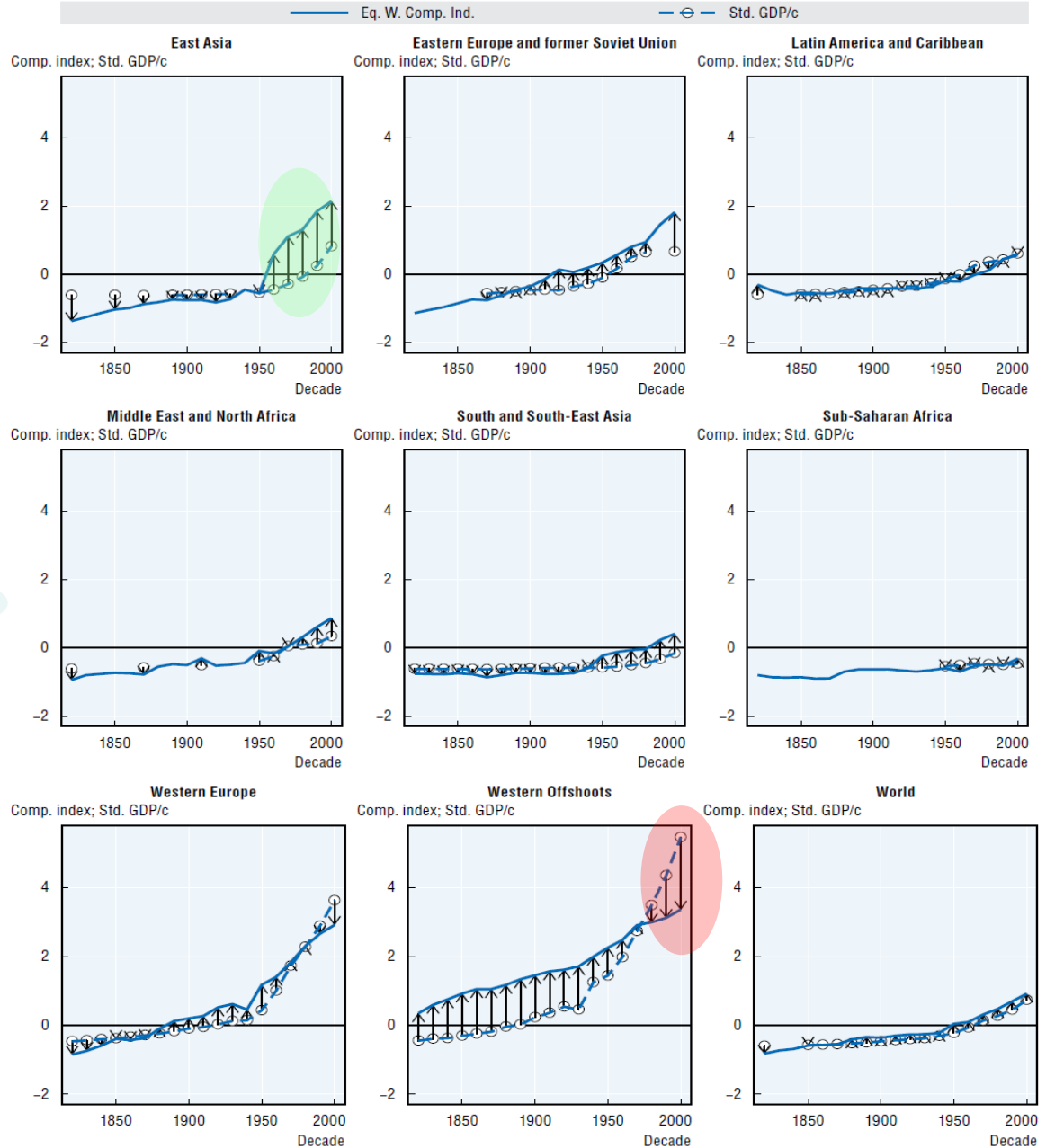
Standardised values (global mean equals zero), population-weighted decadal averages

How Was Life?

GLOBAL WELL-BEING SINCE 1820

Was it progress?
How measured and for whom?

- GDP per capita
- Real wages
- Height
- Life expectancy
- Average years of education
- Income Inequality
- Polity2
- Mean species abundance
- Homicide rate





Universiteit Utrecht



Netherlands Environmental Assessment Agency

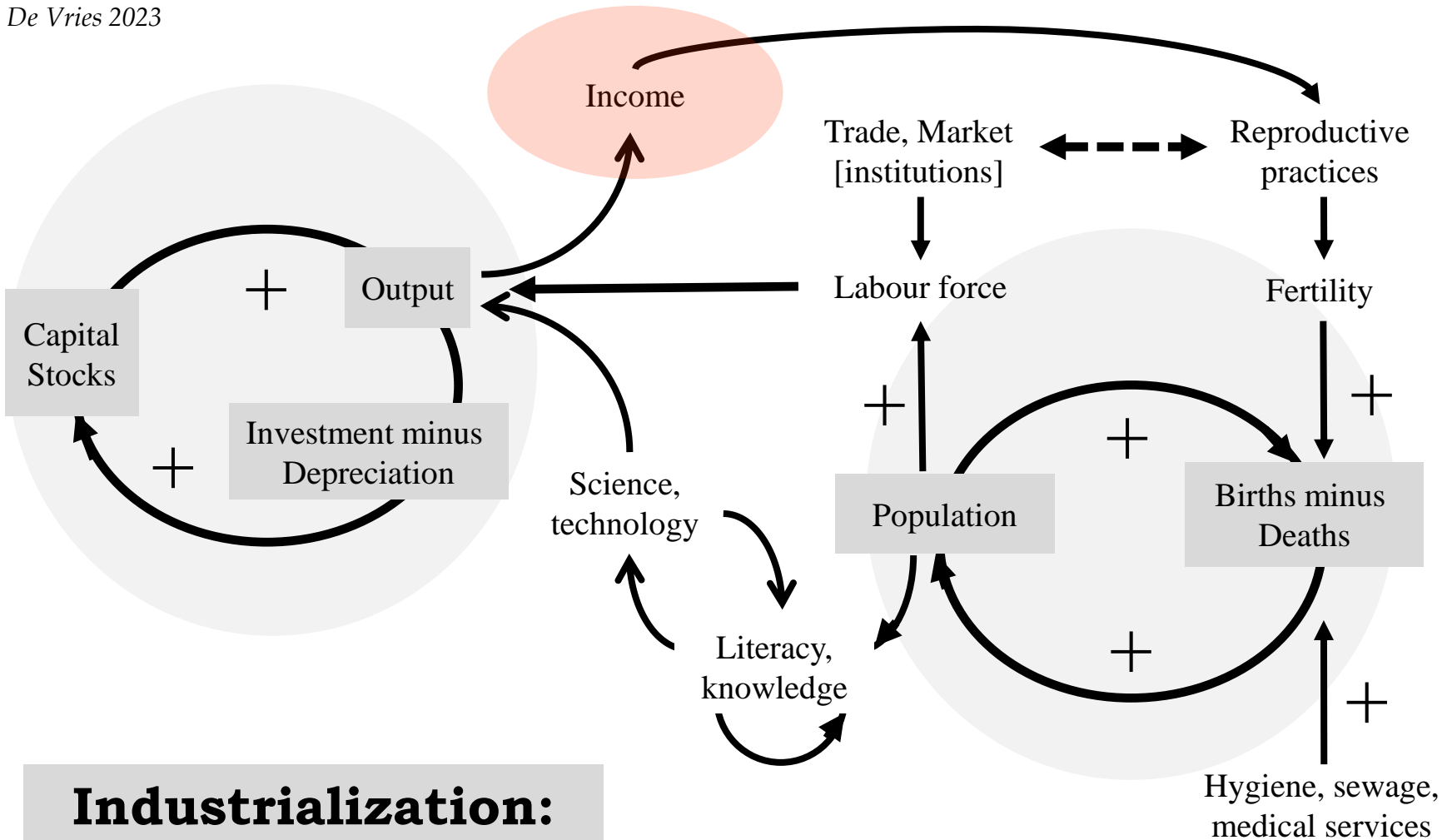
In this lecture I will present some projects on (global and regional) future developments:

- The **World3 model** (Meadows et al. 1971) presented to the Club of Rome in the report Limits to Growth
- The **TARGETS model** (Rotmans and De Vries 1997) using cultural perspectives
- The **IMAGE modelling framework** (RIVM-MNP-PBL) used for IPCC, UNEP(GEO), OECD, MEA...)
- Recent analyses of world scenarios (Earth4All) and of agency in relation to land use (SRC)

The simulation models used in these projects are called **Integrated (Environmental) Assessment Models (IAMs)**



*Prediction is difficult,
especially of the future...*

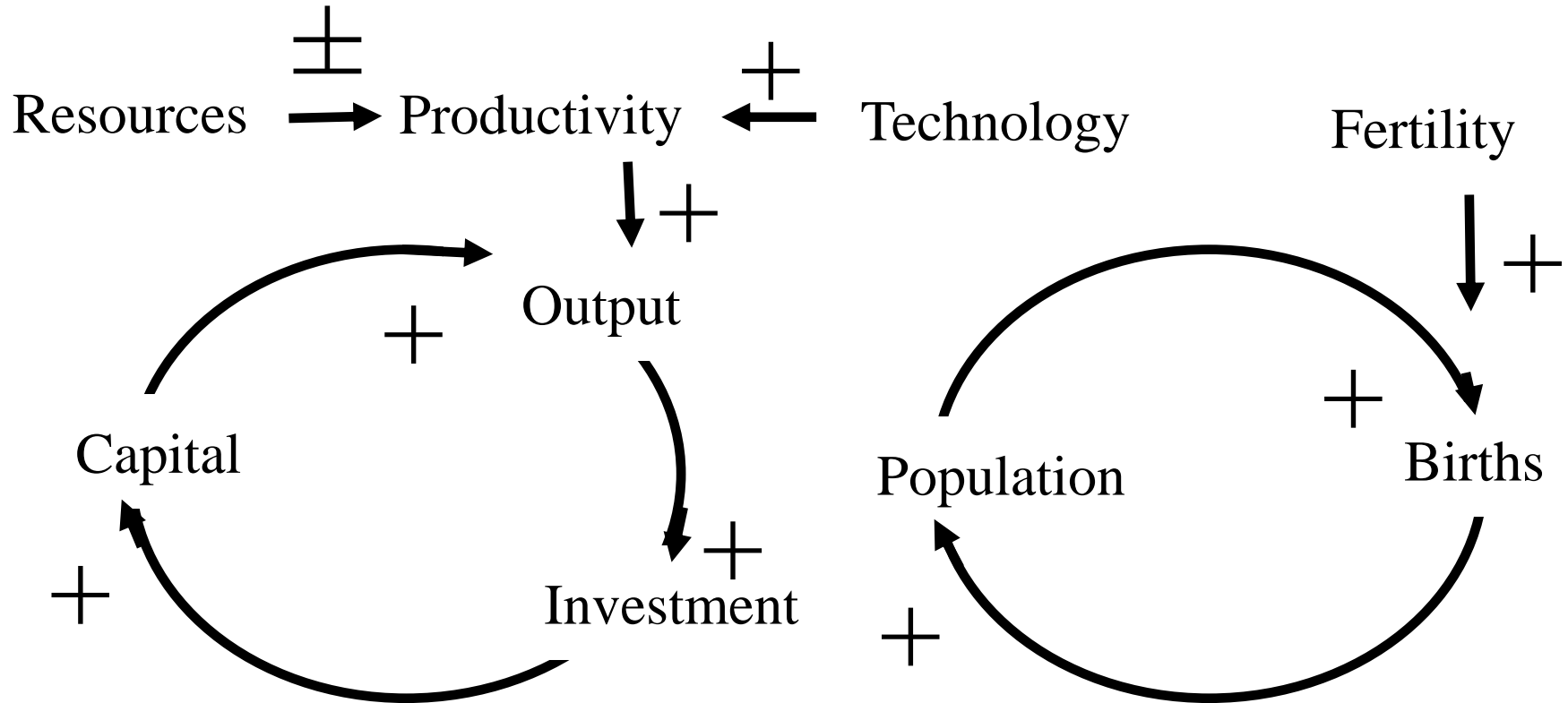


**Industrialization:
growth dynamics**

(with an early and large role for local markets, state, church, monasteries)

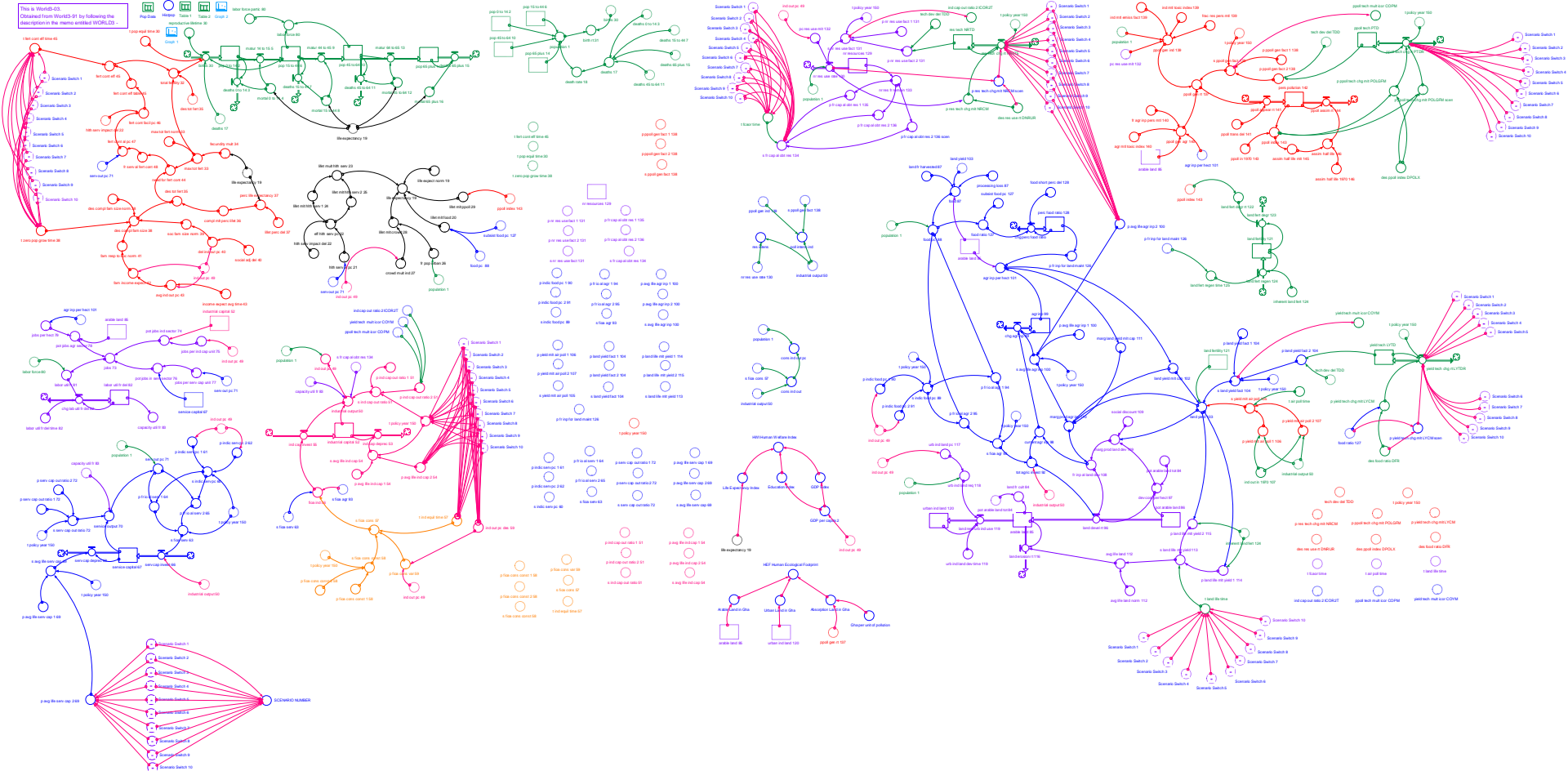
This changes as we enter the new era of the Anthropocene

Key question in the World3-model: how evolve the growth from positive feedback loops – and how to intervene towards sustainability?



Other positive feedback in the World3 model: pollution assimilation, soil erosion, fertility reduction, & growth of related technologies





The World3-model

First version in 1971 in Dynamo, present version in STELLA

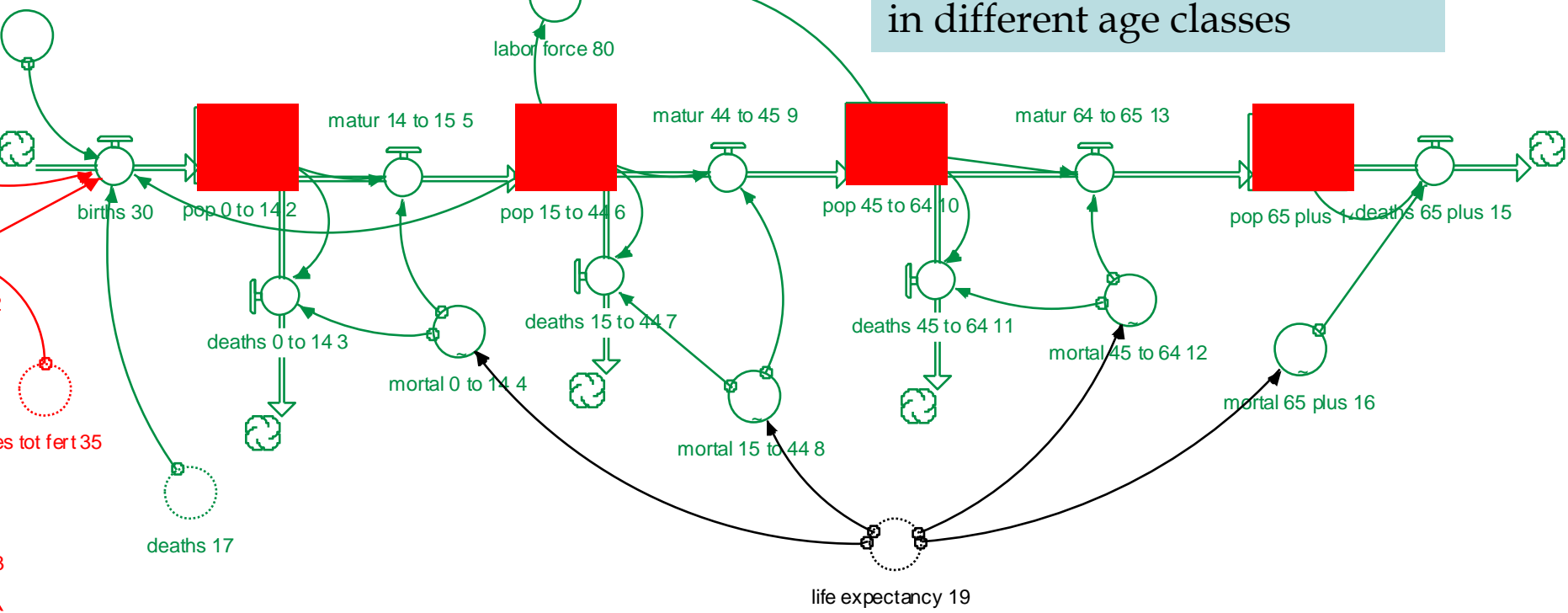


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Stock units: number of people in different age classes

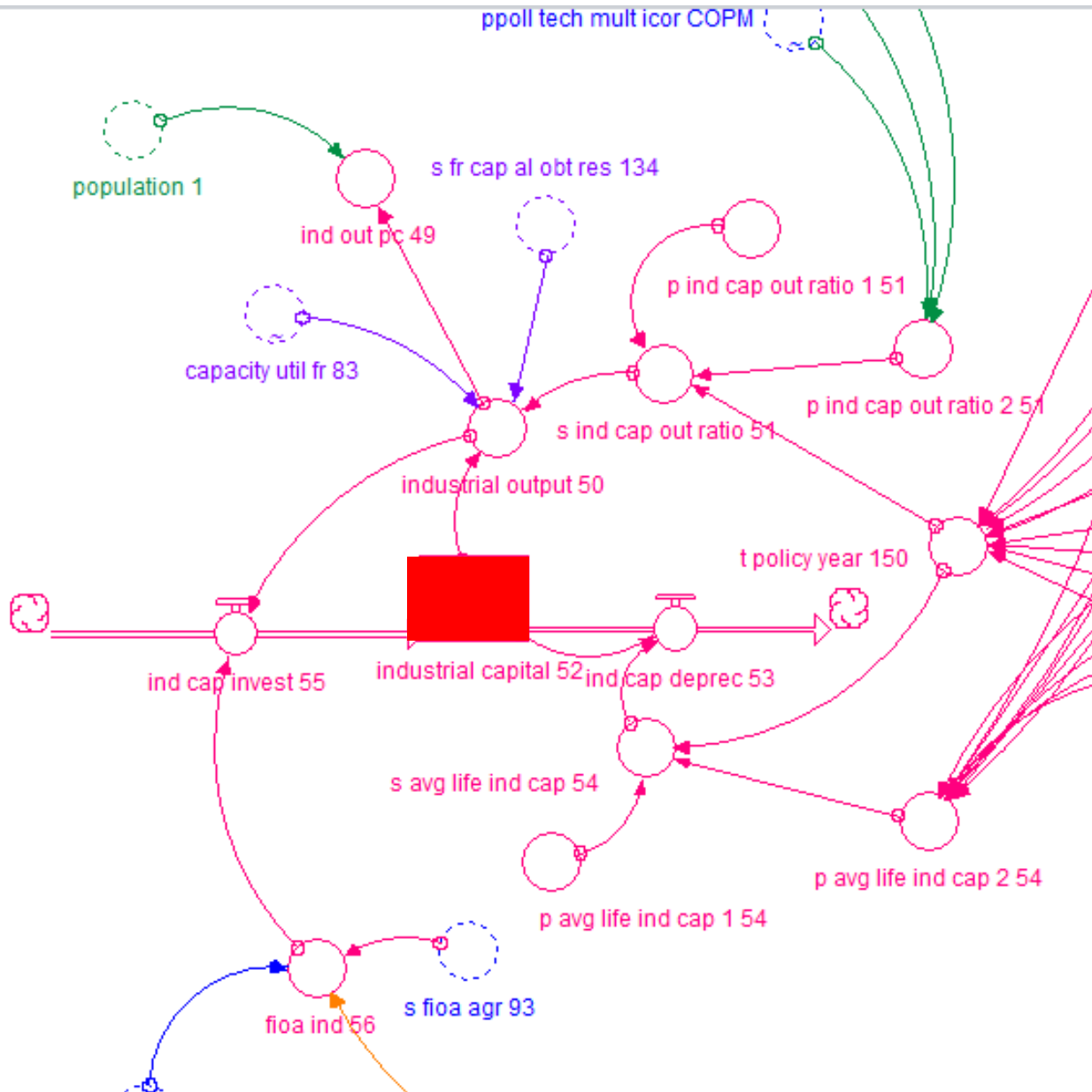


The World3-model: population subsystem

First version in 1971 in Dynamo, present version in STELLA

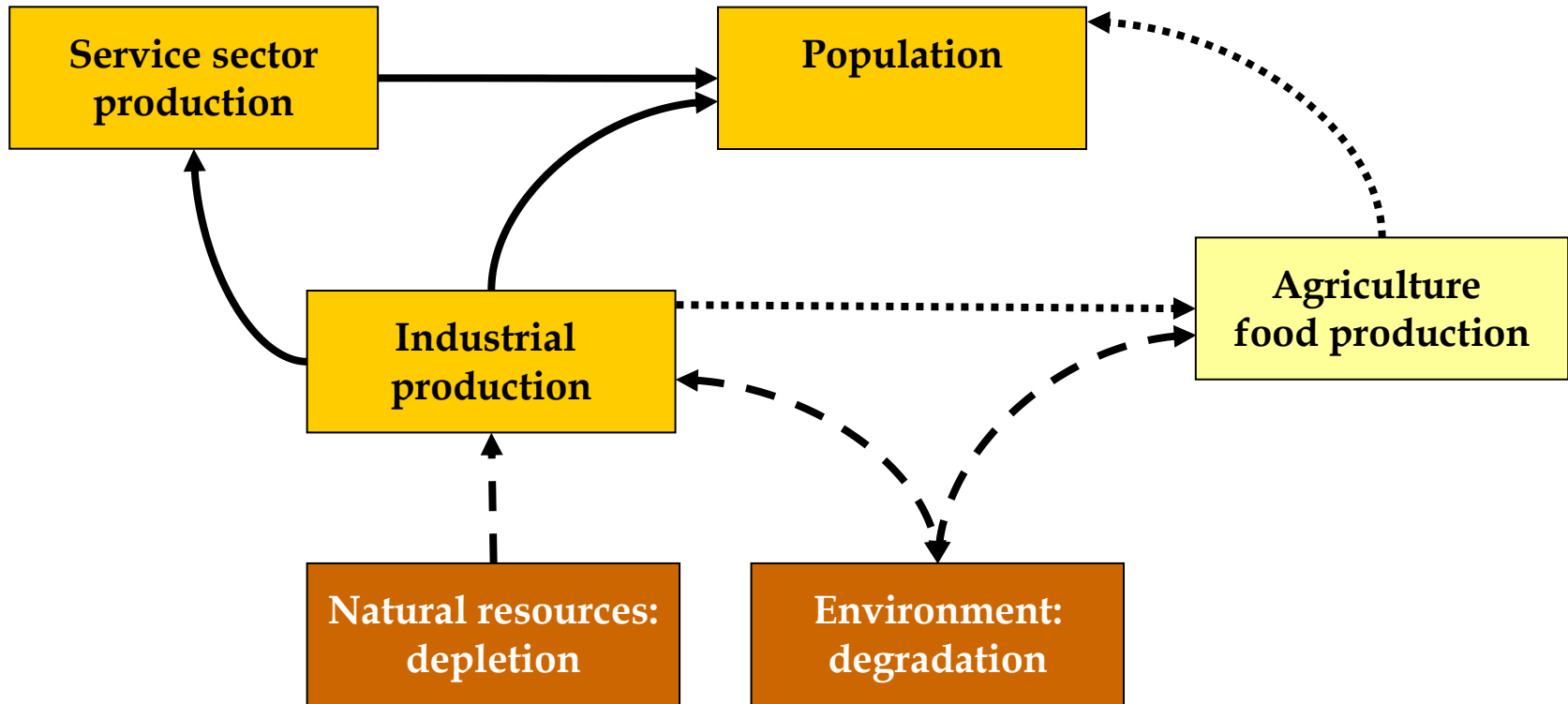


Stock units: capital stock
in financial units



The World3-model: industrial production subsystem
First version in 1971 in Dynamo, present version in STELLA

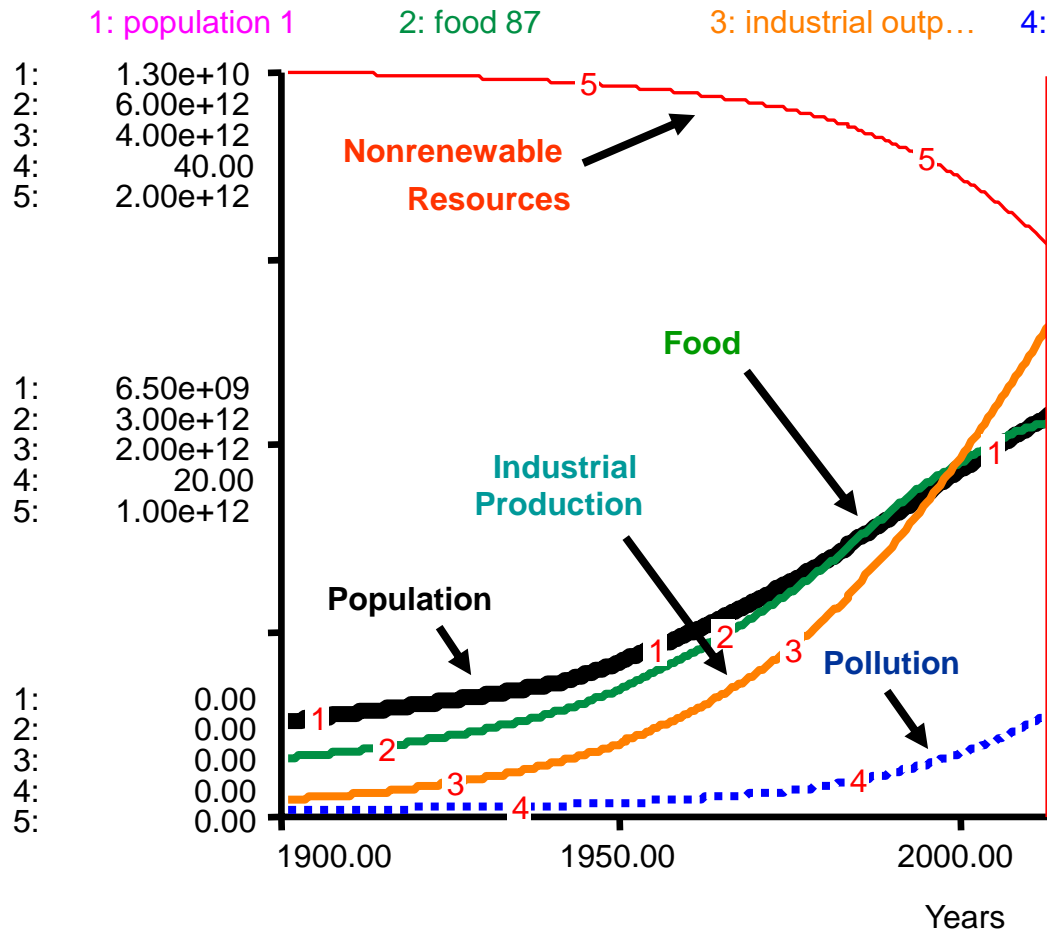
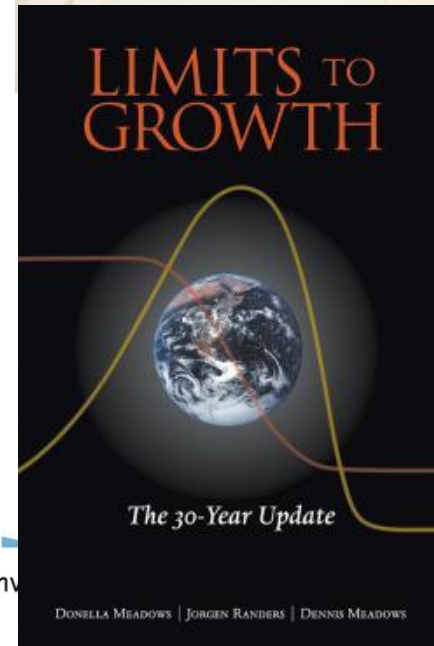
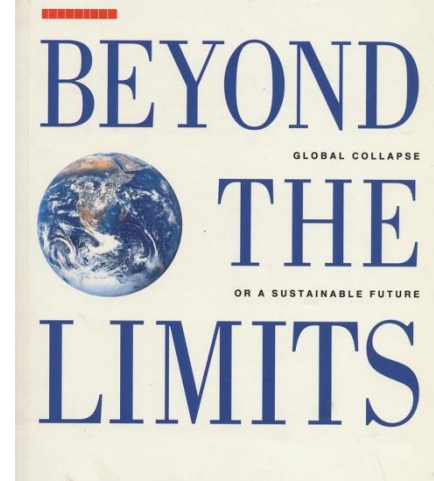
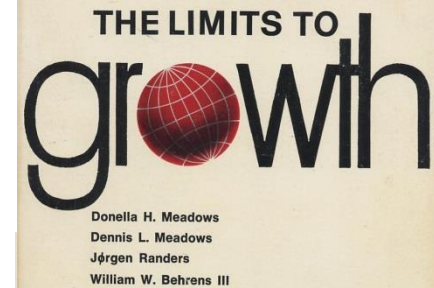
Influence diagram World3: causally linked subsystems



The World3-model: linked subsystems
with limiting resource systems

First version in 1971 in Dynamo, present version in STELLA

World3 Trends until 2020



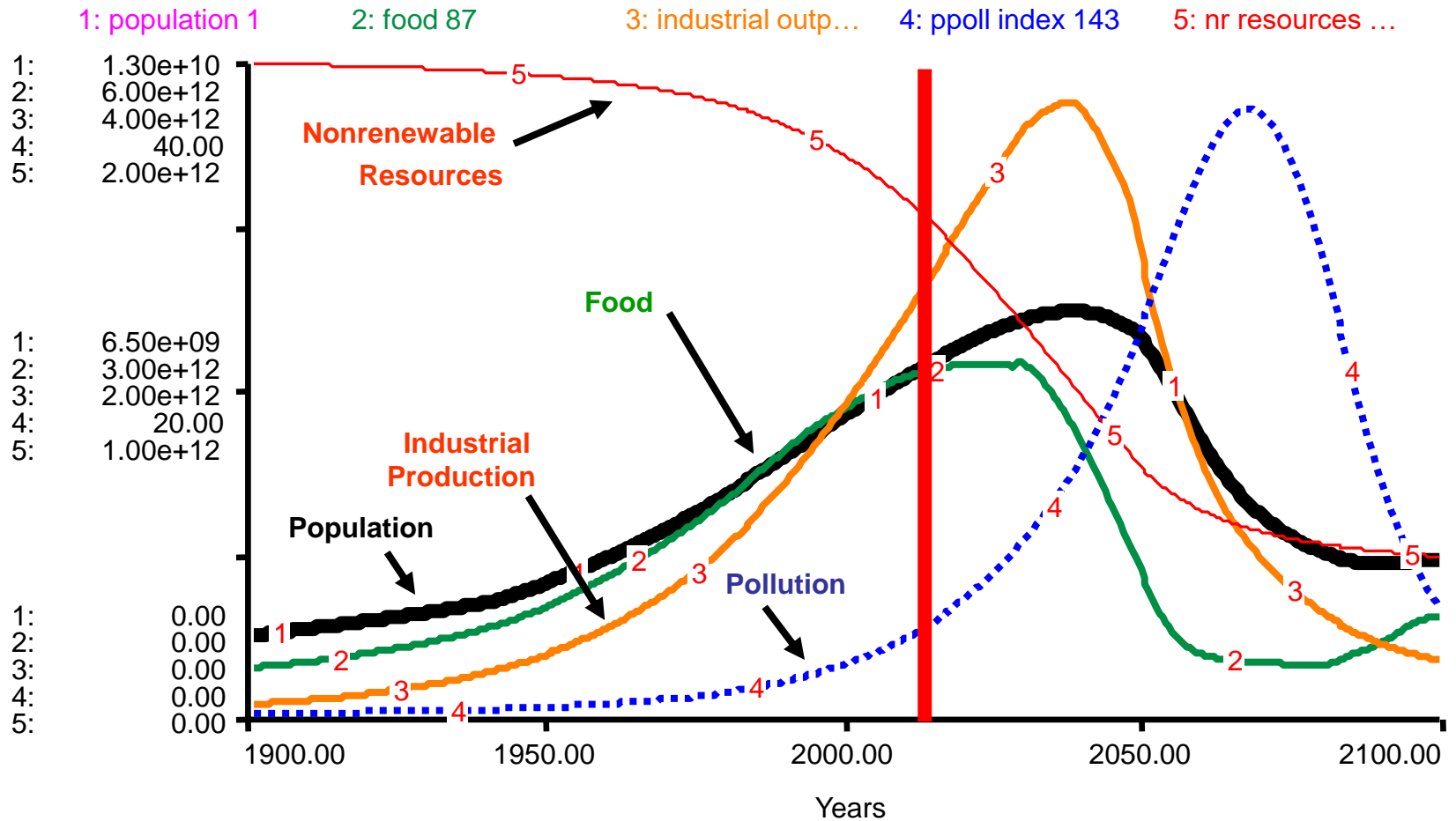
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(Meadows et al. 1972, 1992, 2005)

Netherlands Env

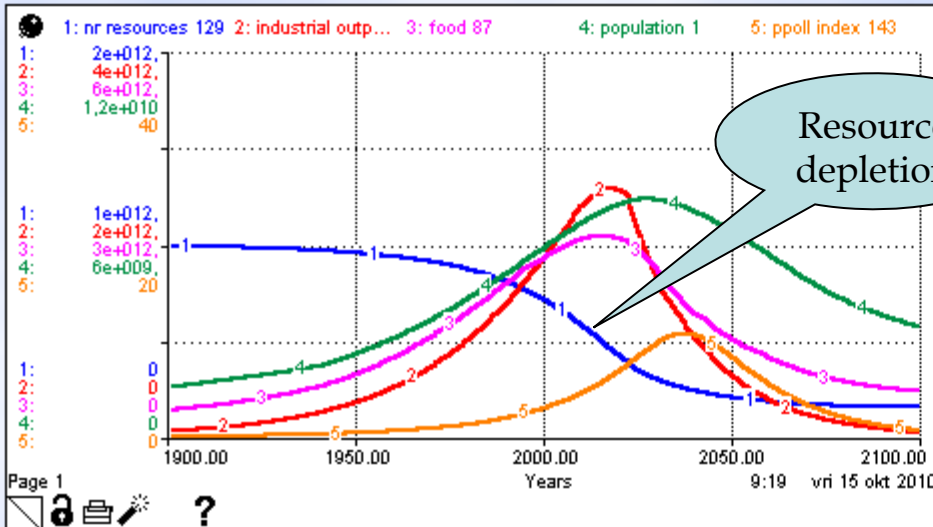
DONELLA MEADOWS | JØRGEN RANDERS | DENNIS MEADOWS

World3 Standard model run (BAU)

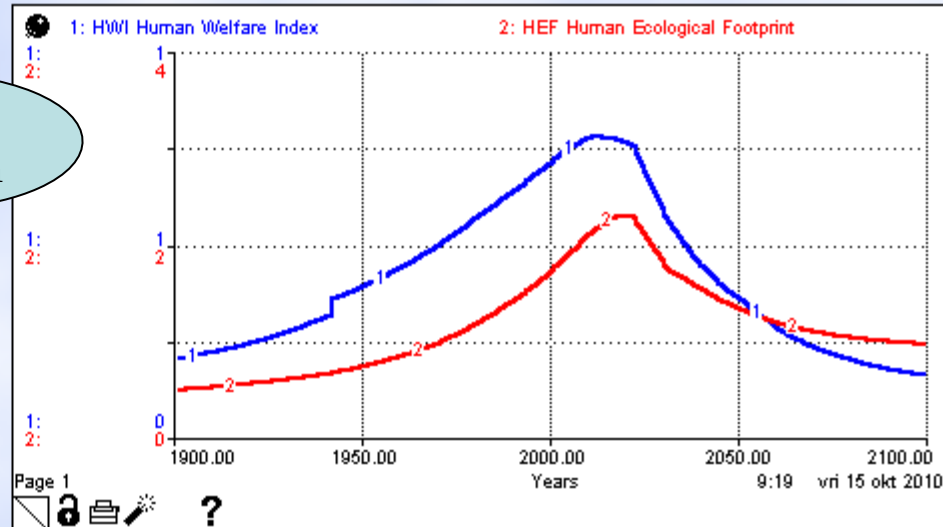


Scenario #1 Business-as-Usual (BAU) – A Reference point

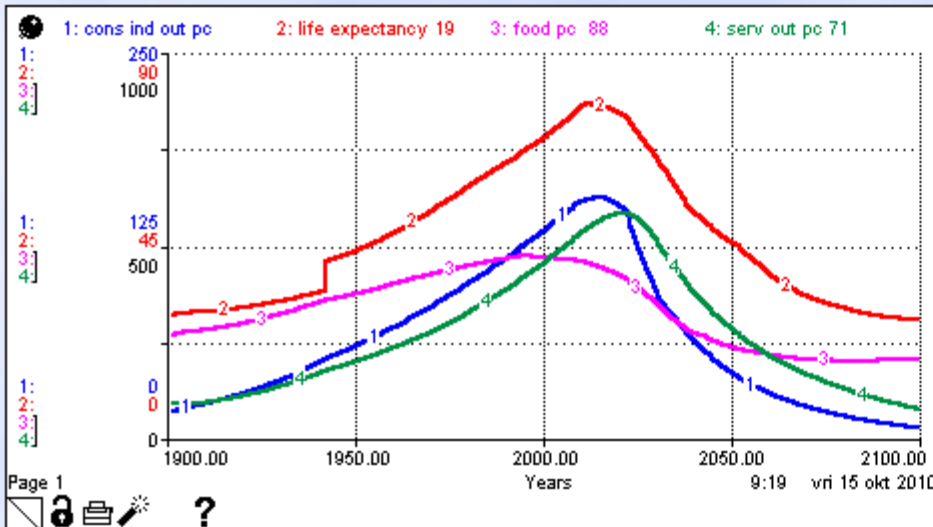
Limits to Growth: Scenario Graphs



State of the World



Human Welfare and Footprint



Material Standard of Living

Scenario 1 Scenario 6

Scenario 2 Scenario 7

Scenario 3 Scenario 8

Scenario 4 Scenario 9

Scenario 5 Scenario 10

Scenario Selection (You must pick only one scenario at a time.)

World3: a series of 10 scenarios

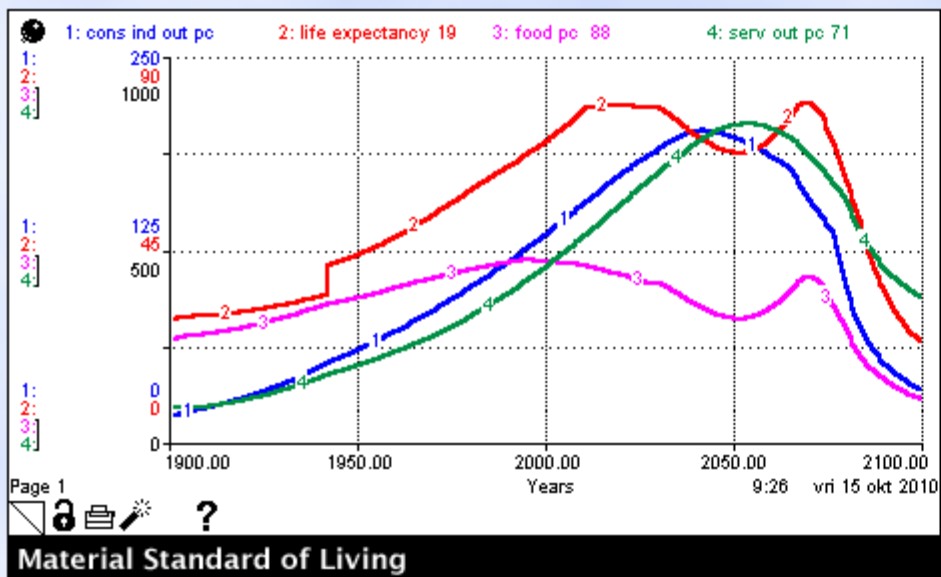
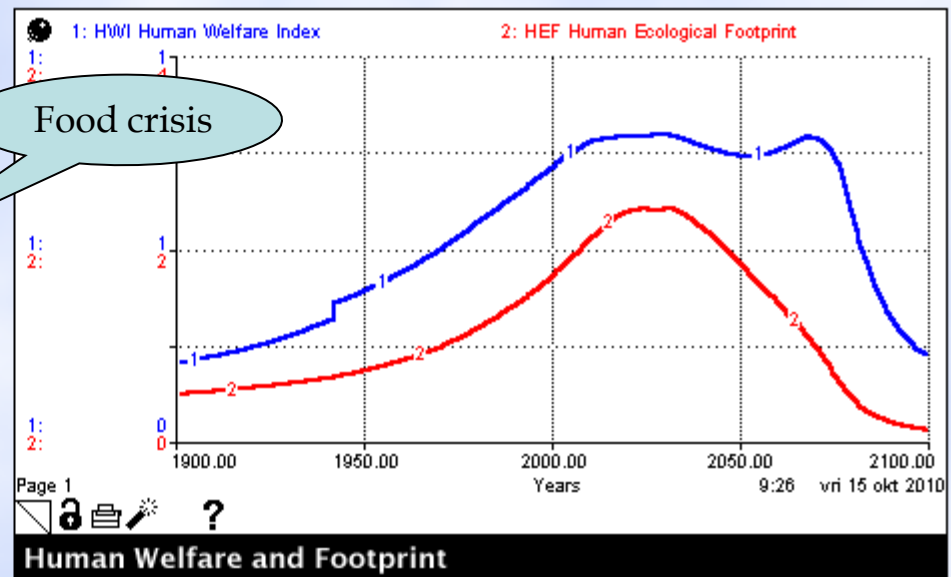
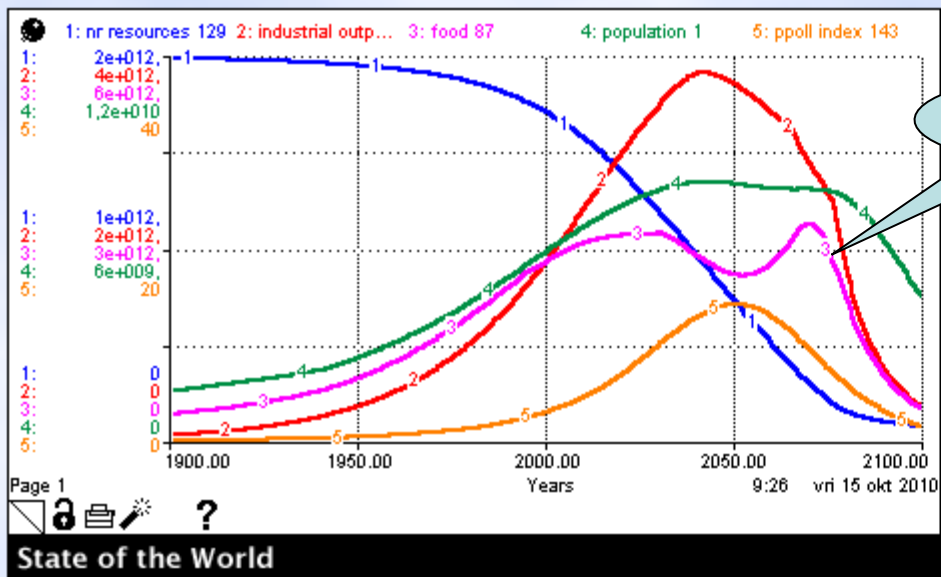
- #1 A Reference Point: Business-As-Usual
- #2 More Abundant Non-Renewable Resources
- #3 More Accessible non-Renewable Resources and Pollution Control Technology
- #4 As #3, with Land Yield Enhancement
- #5 As #4, with Land Erosion Policies
- #6 As #5, with Resource Efficiency Technology
- #7 World Seeks Stable Population from 2002
- #8 As #7, and Stable Industrial Output per Person from 2002
- #9 As #8, with Agricultural, Resource and Pollution Technologies as of 2002
- #10 As #9, but introduced in 1982 instead of in 2002

Published with the book Limits to Growth – the 30-year Update, by Meadows et al. (2005). Courtesy: D. Meadows.



Scenario #4 More Accessible non-Renewable Resources, Pollution Control Technology and Land Yield Enhancement

Limits to Growth: Scenario Graphs

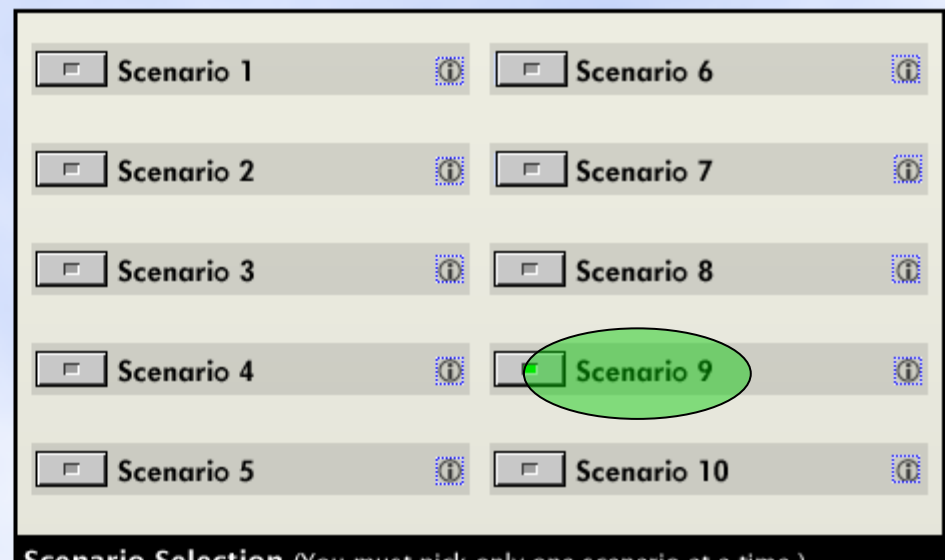
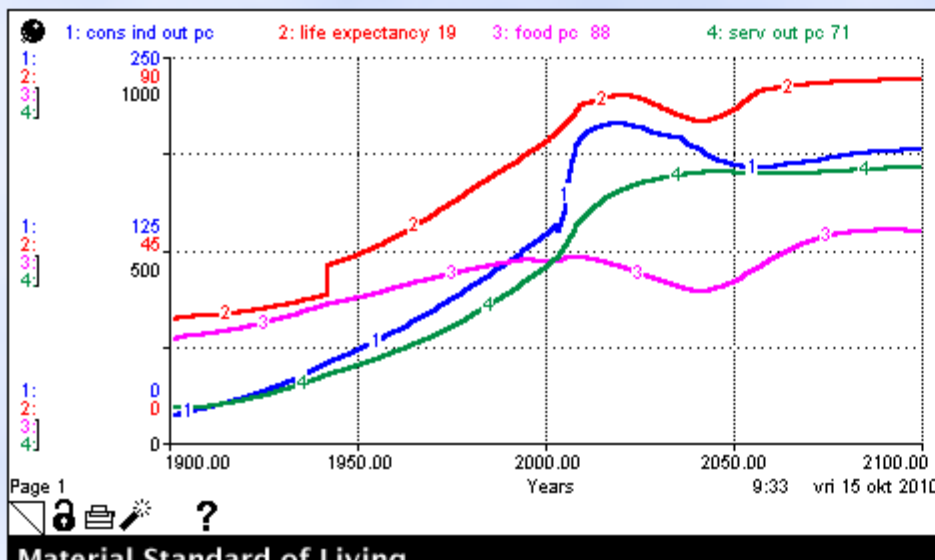
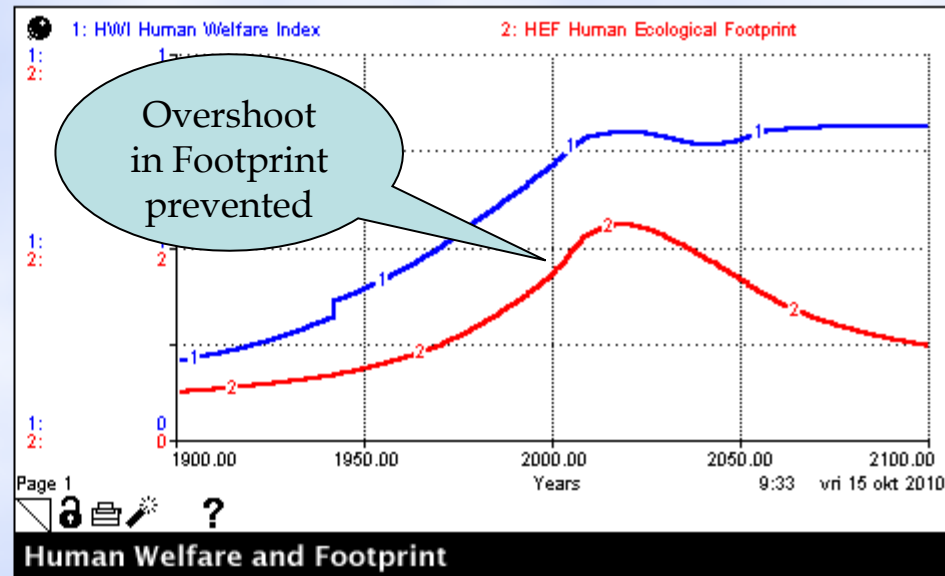
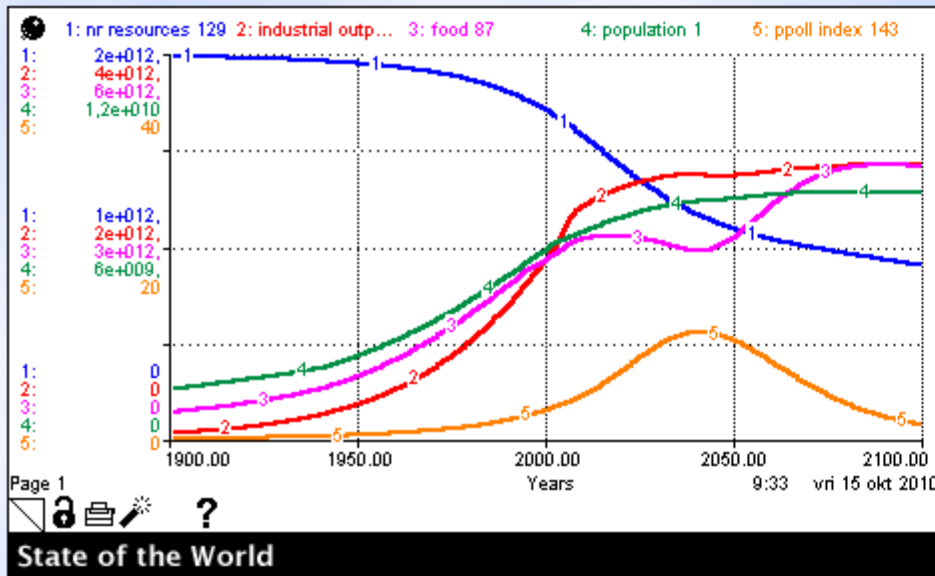


Scenario Selection (You must pick only one scenario at a time.)

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4**
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8
- Scenario 9
- Scenario 10

Scenario #9 World Seeks Stable Population and Stable Industrial Output from 2002 on, in combination with the use of Agricultural, Resource and Pollution Technologies

Limits to Growth: Scenario Graphs



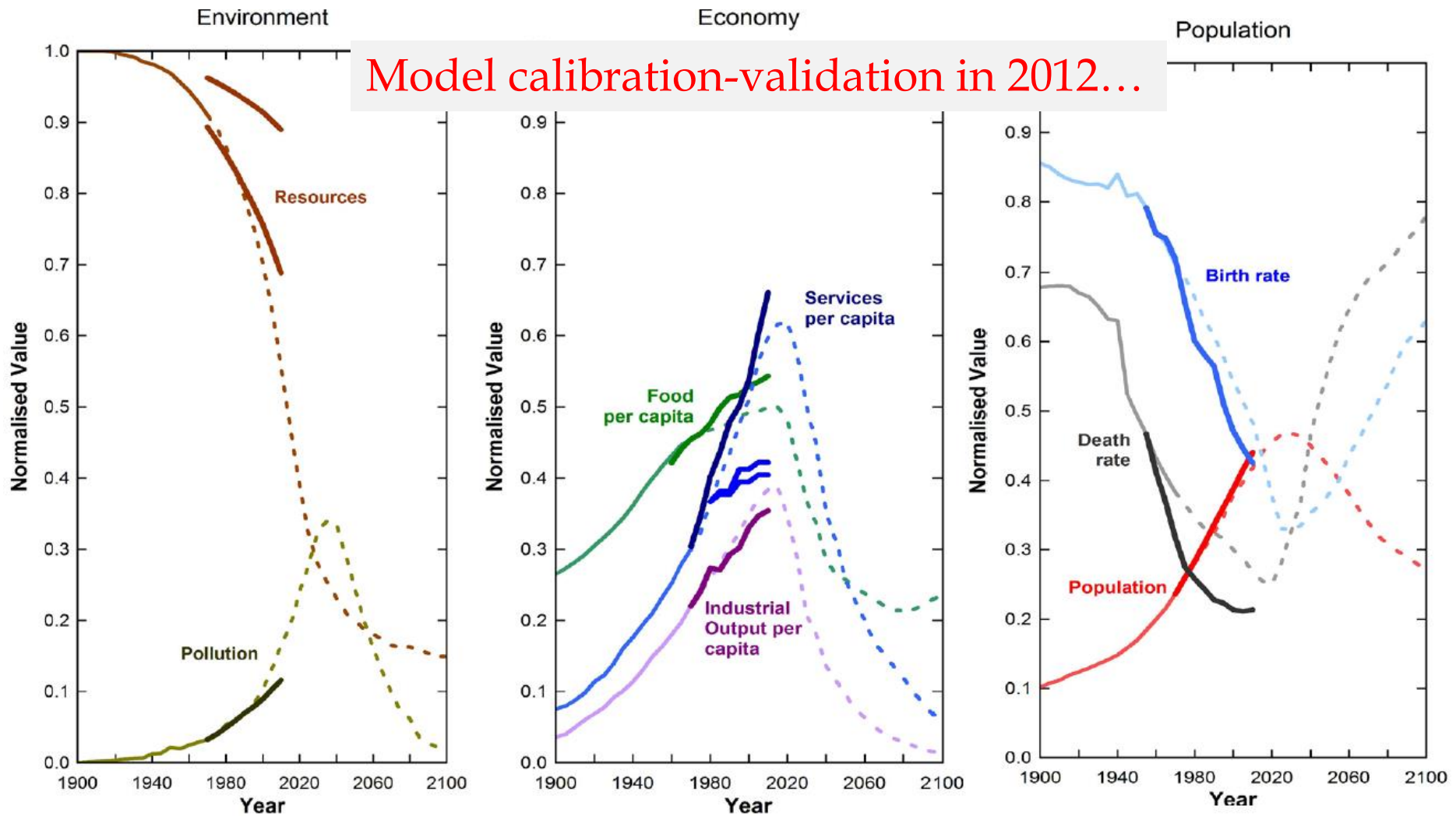
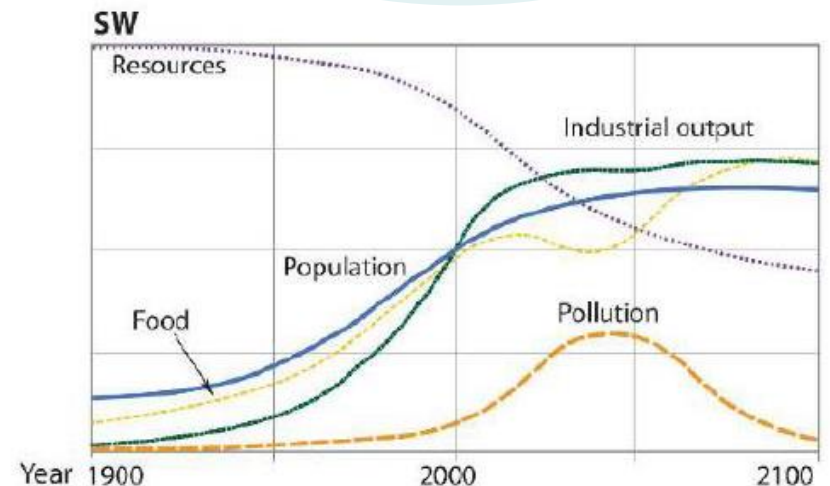
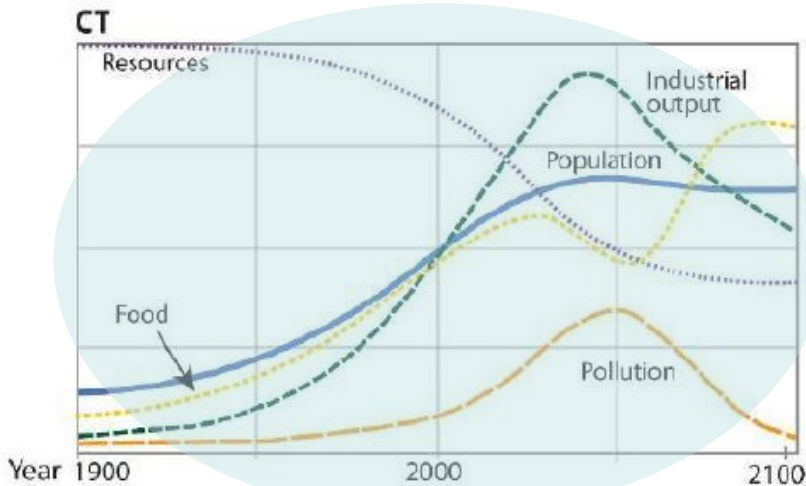
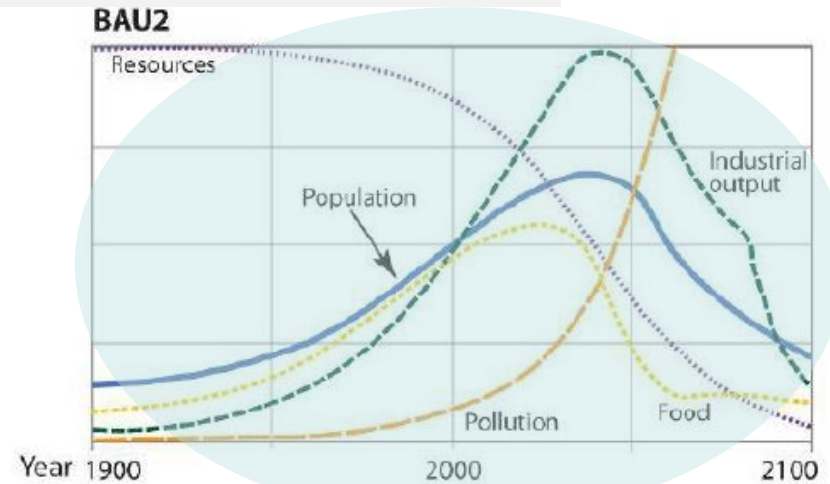
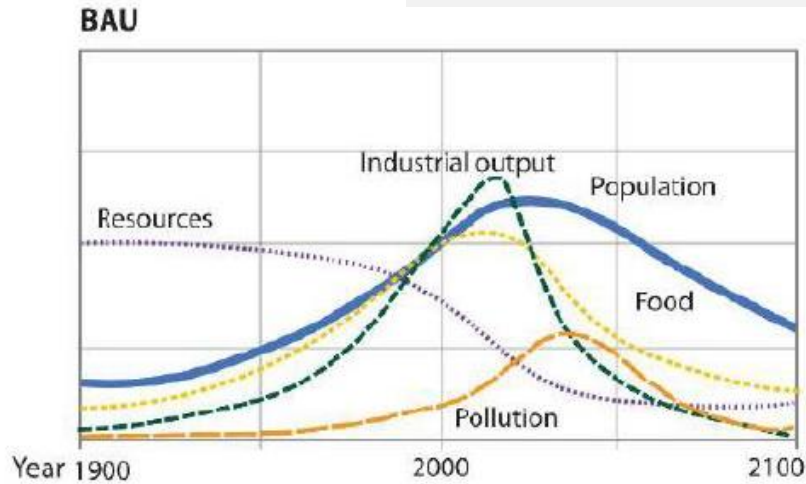


Figure 1. *LTG BAU (Standard Run) scenario (dotted lines) compared with historical data from 1970 to 2010 (solid lines)*—for demographic variables: population, crude birth rate, crude death rate; for economic output variables: industrial output per capita, food per capita, services per capita (upper curve: electricity p.c.; lower curves: literacy rates for adults, and youths [lowest data curve]); for environmental variables: global persistent pollution, fraction of non-renewable resources remaining (upper curve uses an upper limit of 150,000 EJ for ultimate energy resources; lower curve uses a lower limit of 60,000 EJ [http://sustainable.unimelb.edu.au/sites/default/files/docs/MSSI-ResearchPaper-4_Turner_2014.pdf]

Model calibration-validation in 2022...



Four scenarios with the World3 model (Meadows et al. 2004)
BAU Business as Usual BAU2 as BAU with twice as many resources
CT Comprehensive Technologies SW Sustainable World

A recent comparison (Herrington 2021) indicates:

- the business-as-usual (BAU) scenario and the sustainable world scenario (SW – planned stabilization of population and economy) correlate *the least* with historical proxies;
- historical data correlate *rather well* with the two optimistic scenarios with assumptions of twice as many resources (BAU2) or comprehensive technological progress (CT).
- also in these two scenarios, growth of population and economy come to a standstill by the middle of the 21st century, in BAU2 with a greater overshoot-and-collapse than in CT.

These findings echo the two most pressing questions:

- 1) are there abundant energy and other resources but is the constraint on the sink side (climate change, pollution), and
- 2) can the net increase in technological efficiency keep pace with the impacts from continuing growth in population and economic activity?

Model calibration-validation...



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Model calibration-validation 2022...



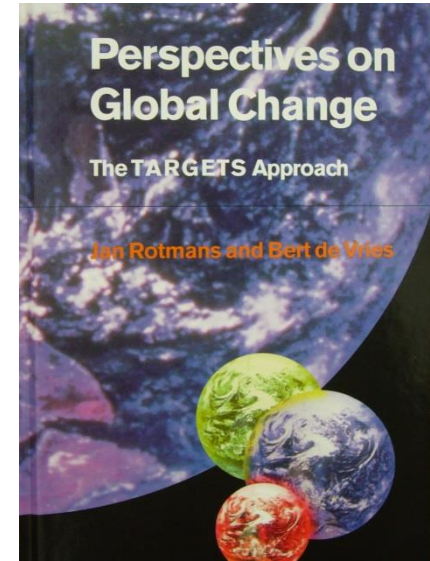
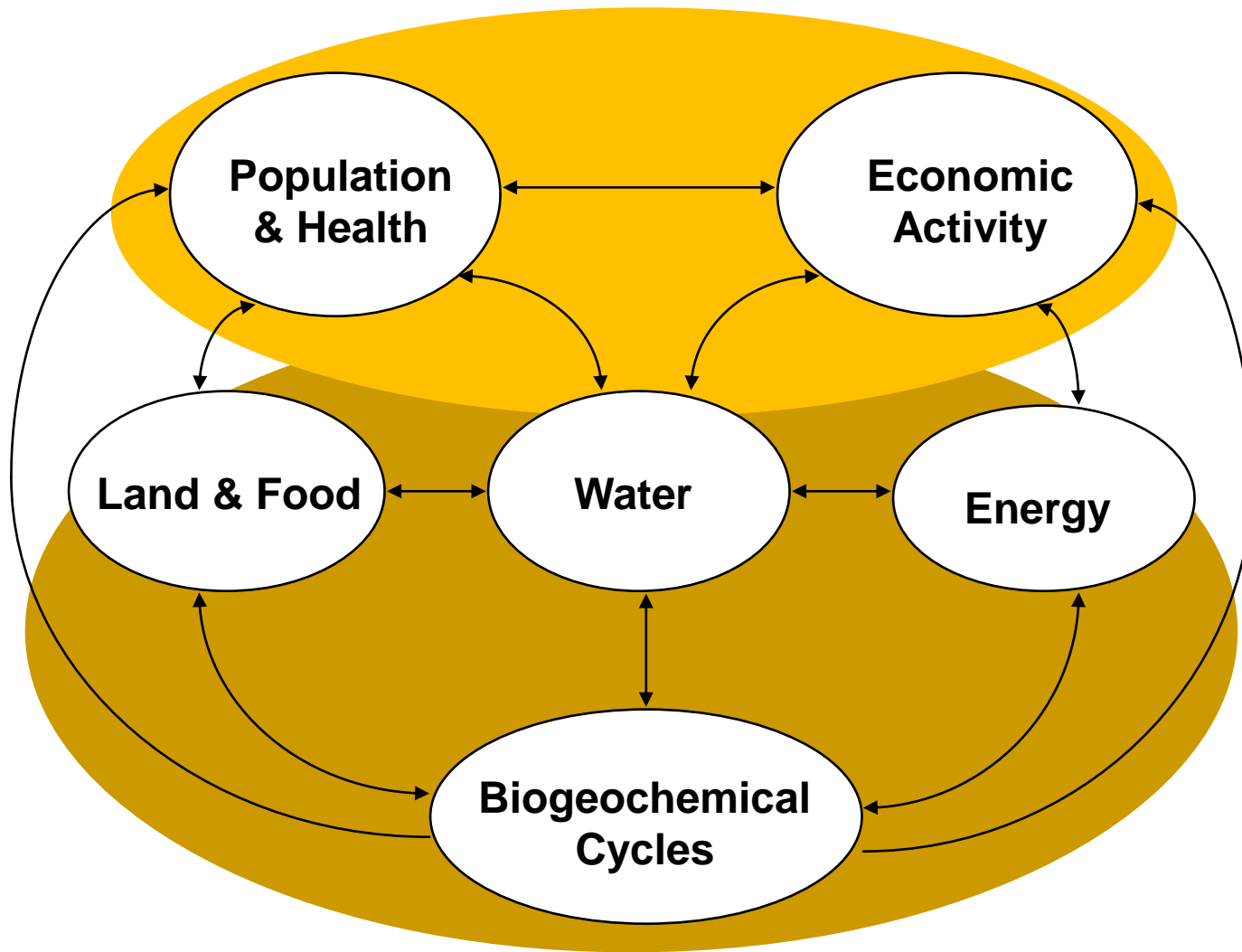


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Netherlands Environmental Assessment Agency

Present, past and future of global change: TARGETS1.0



TARGETS1.0 : Integrated Modelling and Assessment approach



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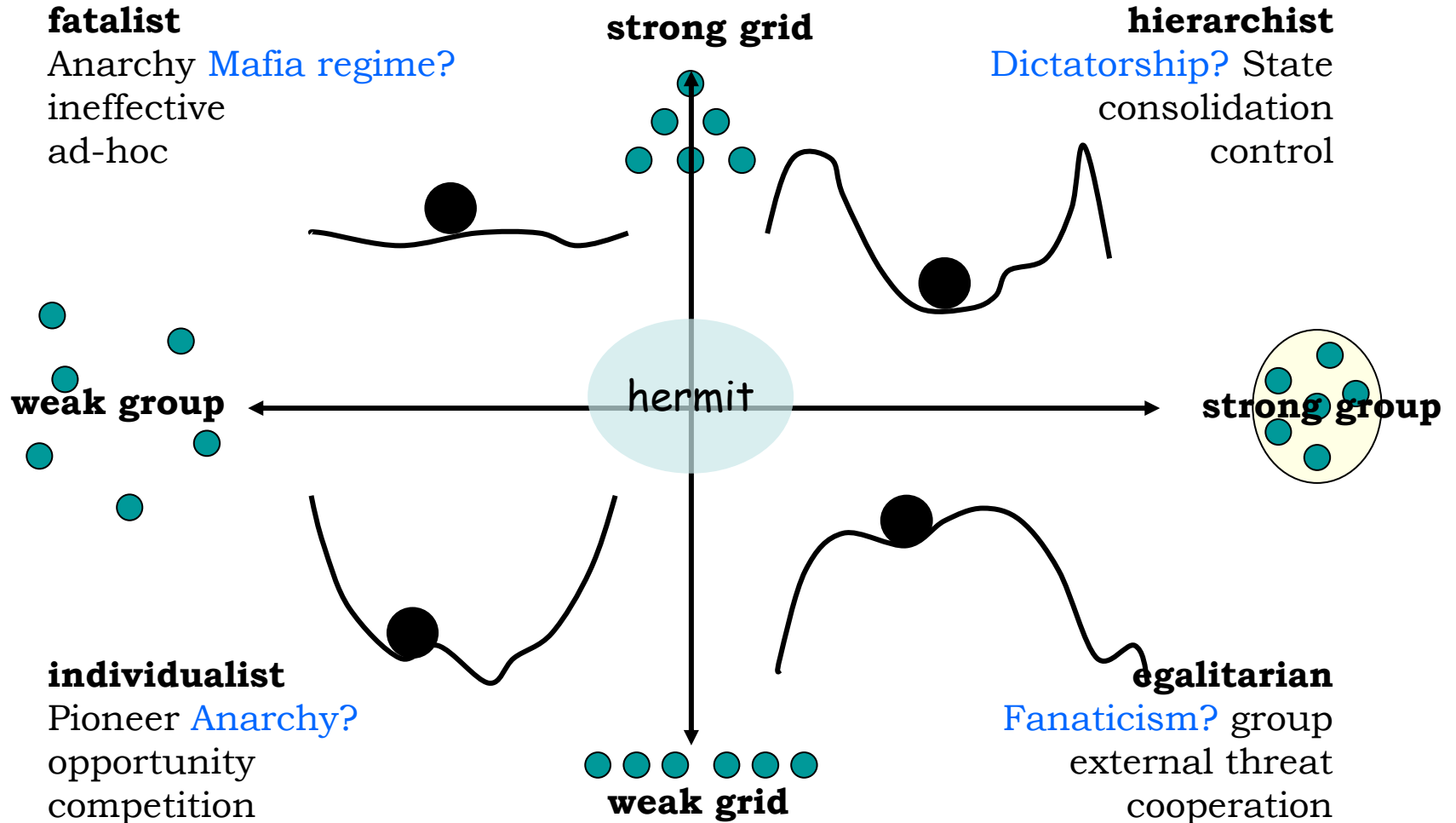
(Rotmans and De Vries 1997)



Netherlands Environmental Assessment Agency

Approach: [Eco]Cultural Theory

merging anthropology and ecology (Douglas, Thompson, Holling)



(de Vries 2023)

Group=degree to which an individual feels [s]he belongs to a group

Grid=degree to which relationships between individuals are formally structured

Worldview: how does the world 'work'?

Individualist **Hierarchist** **Egalitarian**

Management style: according to whose interpretation the world is 'managed'?

Egalitarian **Hierarchist** **Individualist**

Individualist
utopia

UNLEASH THE INDIVIDUALIST IN YOU.
THE CADILLAC SRX CROSSOVER HAS ARRIVED.



KLM cityhopper Business Jets

Binnen vier uur op weg
met een privéjet

Samba en cowboys in Brazilië

Wie Rio de Janeiro als startpunt neemt voor een reis door Brazilië, krijgt een goed beeld van dit land. Immers: Rio's got it all. Zee, stranden, een goed uitgaansleven, rijke cultuur en vriendelijke inwoners. Maar achter Rio ligt nog een andere wereld verscholen, met cowboys en wildlife in de Pantanal. TEKST: WIKKE BINGELING - FOTOGRAFIE: JAN ZWART



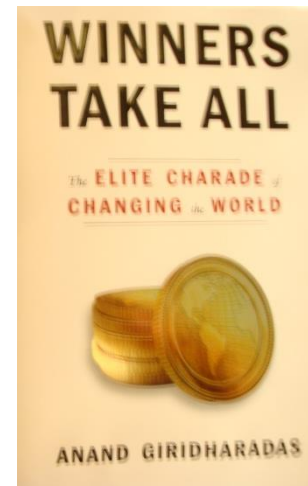
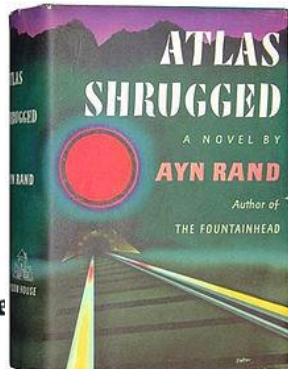
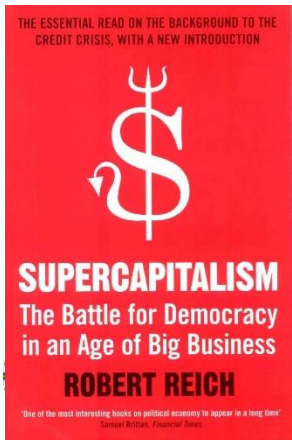
Government "help" to business is just as disastrous as government persecution... the only way a government can be of service to national prosperity is by keeping its hands off.
(Ayn Rand)

"We help companies to grow by helping them to raise capital. Companies that grow create wealth. This, in turn, allows people to have jobs that create more growth and more wealth. We have a social purpose... "We do God's work". (Lloyd Feinstein, CEO Goldman Sachs)



Mercedes-Benz

I'm glad when I enter a restaurant and I am applauded because everyone feels we saved the world
(Bourla, CEO of Pfizer)



An individualist view

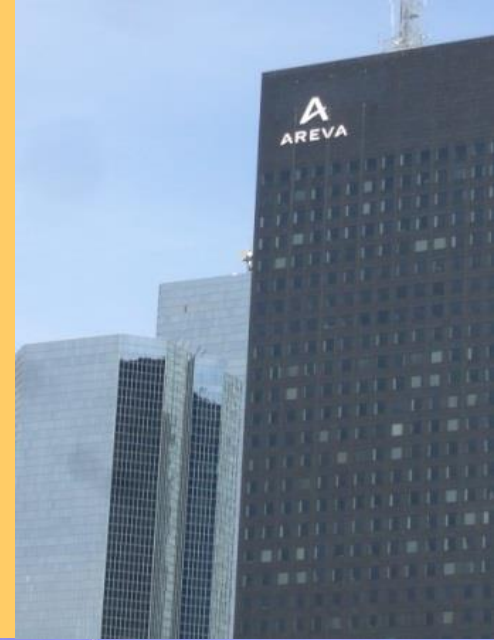
Worldview: how does the world 'work'?

Individualist Hierarchist Egalitarian

Management style: according to whose interpretation the world is 'managed'?

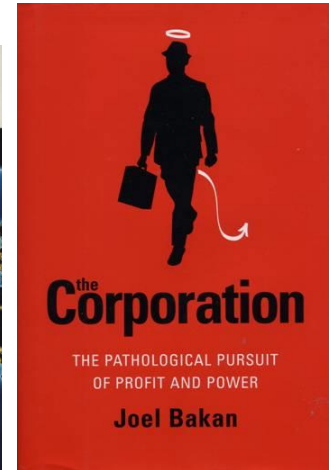
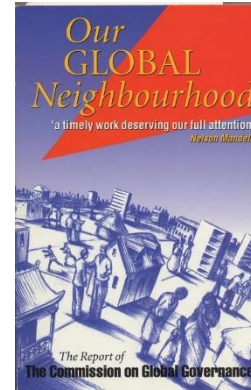
Egalitarian Hierarchist Individualist

Hierarchist
utopia

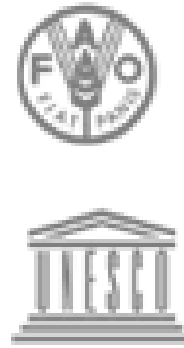


UNEP. The Poverty-Environment Initiative (PEI) of the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) is a global UN-led programme that supports country-led efforts to mainstream poverty-environment linkages into national development planning.

[\(http://www.unpei.org/\)](http://www.unpei.org/)



The one thing every man fears is the unknown. When presented with [U.N. troops restoring order], individual rights will be willingly relinquished for the guarantee of their well being granted to them by their world government. (Henry Kissinger)



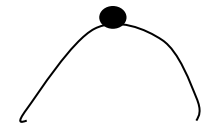
A hierarchist view

Worldview: how does the world 'work'?

Individualist Hierarchist Egalitarian

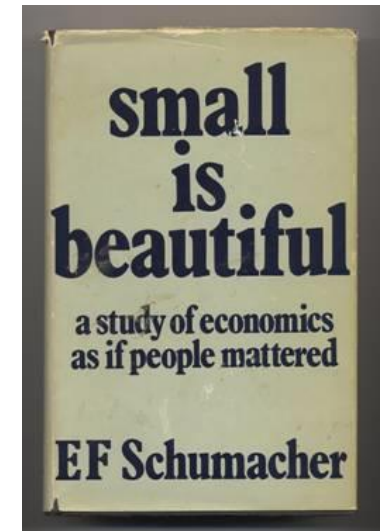
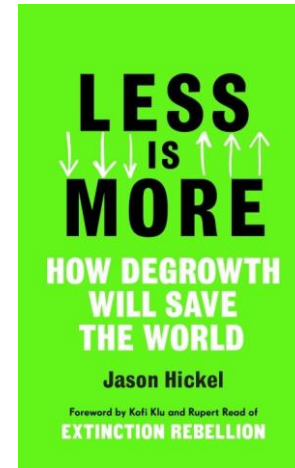
Management style: according to whose interpretation the world is 'managed'?

Egalitarian Hierarchist Individualist



GREENPEACE STATEMENT – Nestlé, maker of Kit Kat, uses palm oil from companies that are trashing Indonesian rainforests, threatening the livelihoods of local people and pushing orang-utans towards extinction... We're asking Nestlé to give rainforests and orang-utans a break and stop buying palm oil from destroyed forests. (<http://greenhouseneutralfoundation.org/>)

"As we see the day approaching there's going to be a cleansing...there's going to be a purging coming forth...and everyone that's living under the immorality cover...will be brought down, and God's new breed will come forth." (Catholic evangelical Bob Jones)



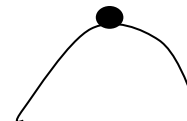
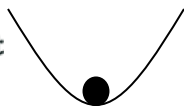
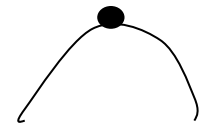
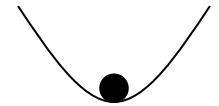
Worldview: how does the world 'work'?

Individualist Hierarchist Egalitarian

Management style: according to whose interpretation the world is 'managed'?

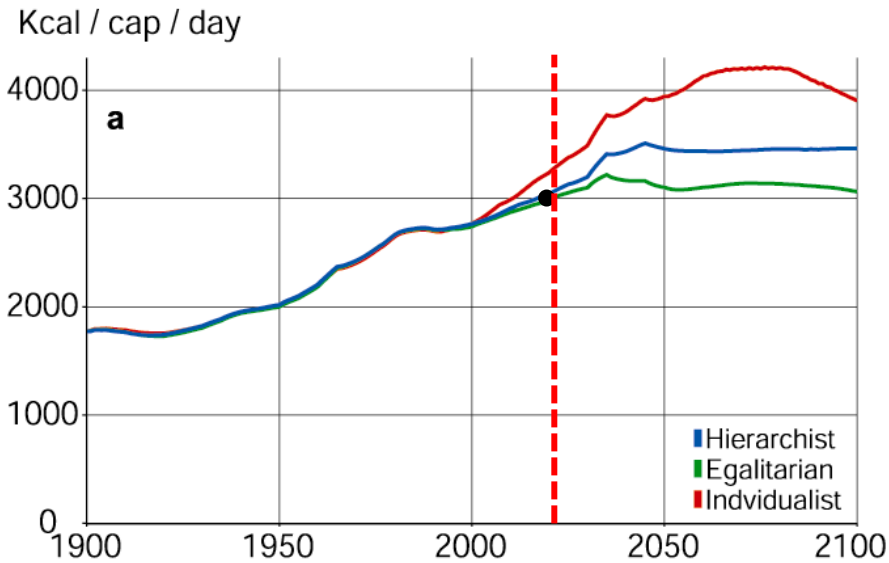
Egalitarian Hierarchist Individualist

Individualist utopia	Hierarchist crisis	Egalitarian nightmare
Too much bureaucracy	Hierarchist utopia	Too little, too late bureaucracy
World of 'missed opportunities'	World of 'anarchist threat'	Egalitarian utopia

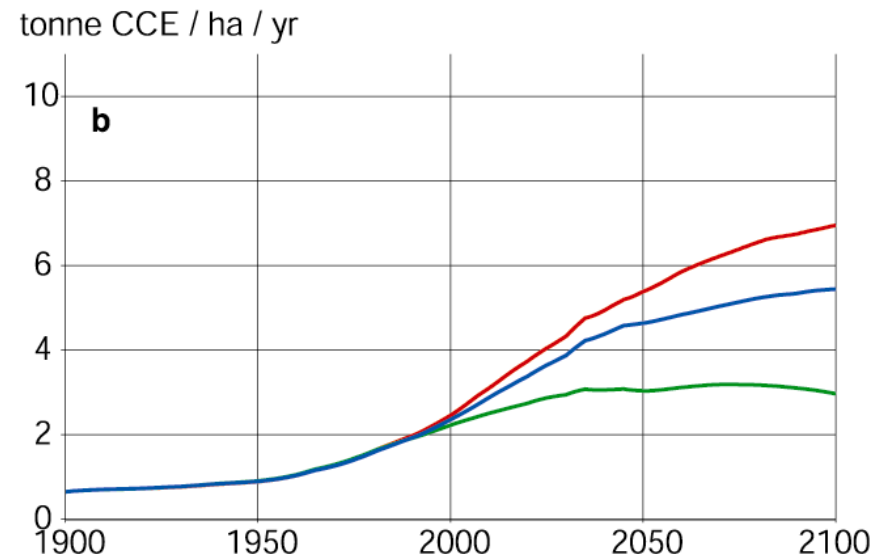


■ Individualist
 ■ Hierarchist
 ■ Egalitarian

Food consumption per capita



Actual yield

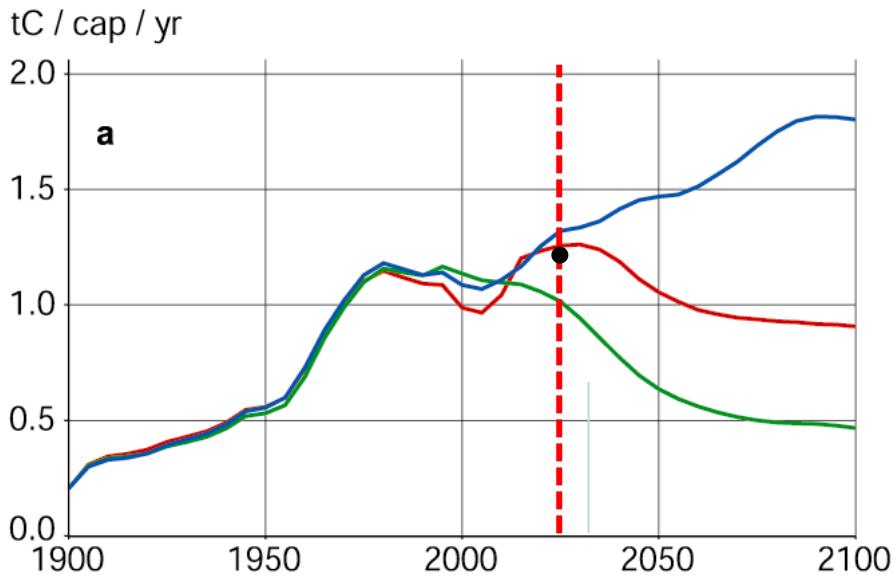


The food transition in three utopian futures

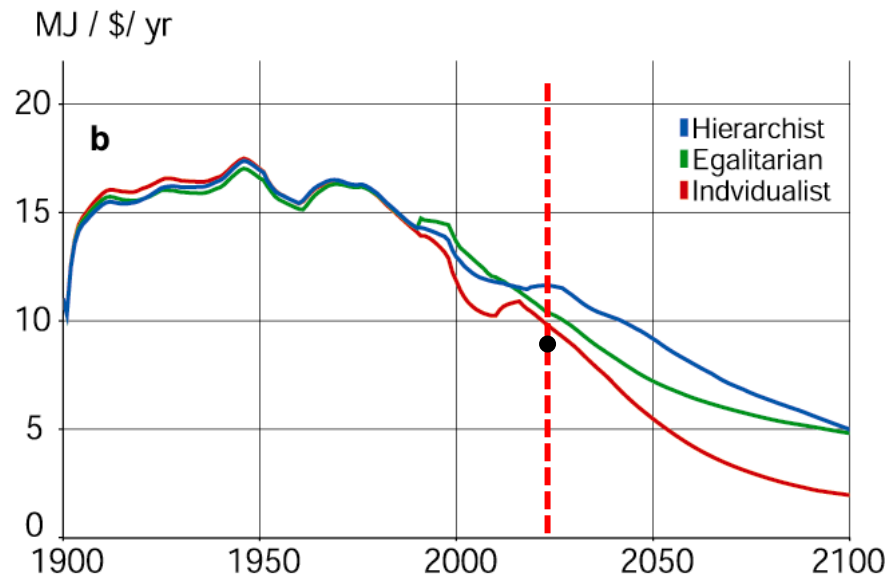


■ Individualist
 ■ Hierarchist
 ■ Egalitarian

CO₂ emission per capita



Energy use per unit of GWP



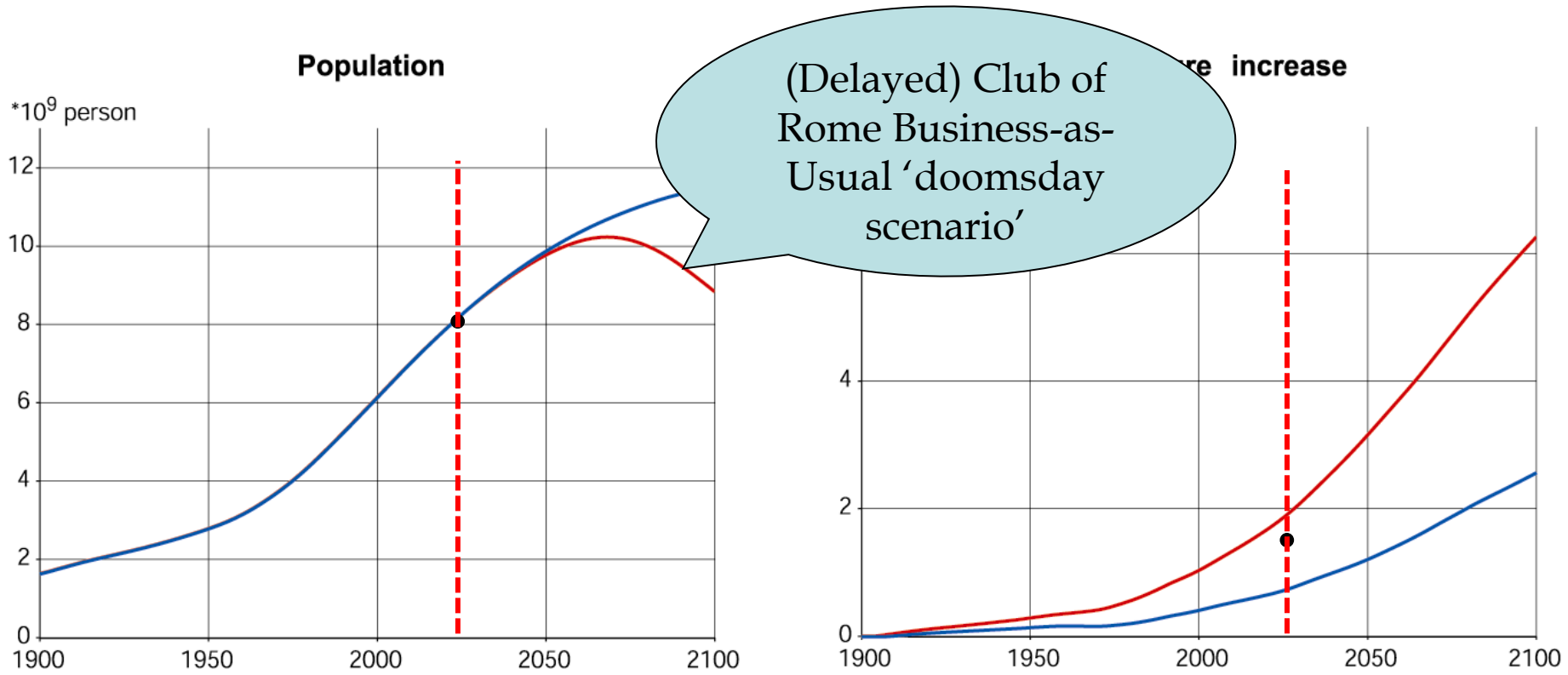
The energy transition in three utopian futures



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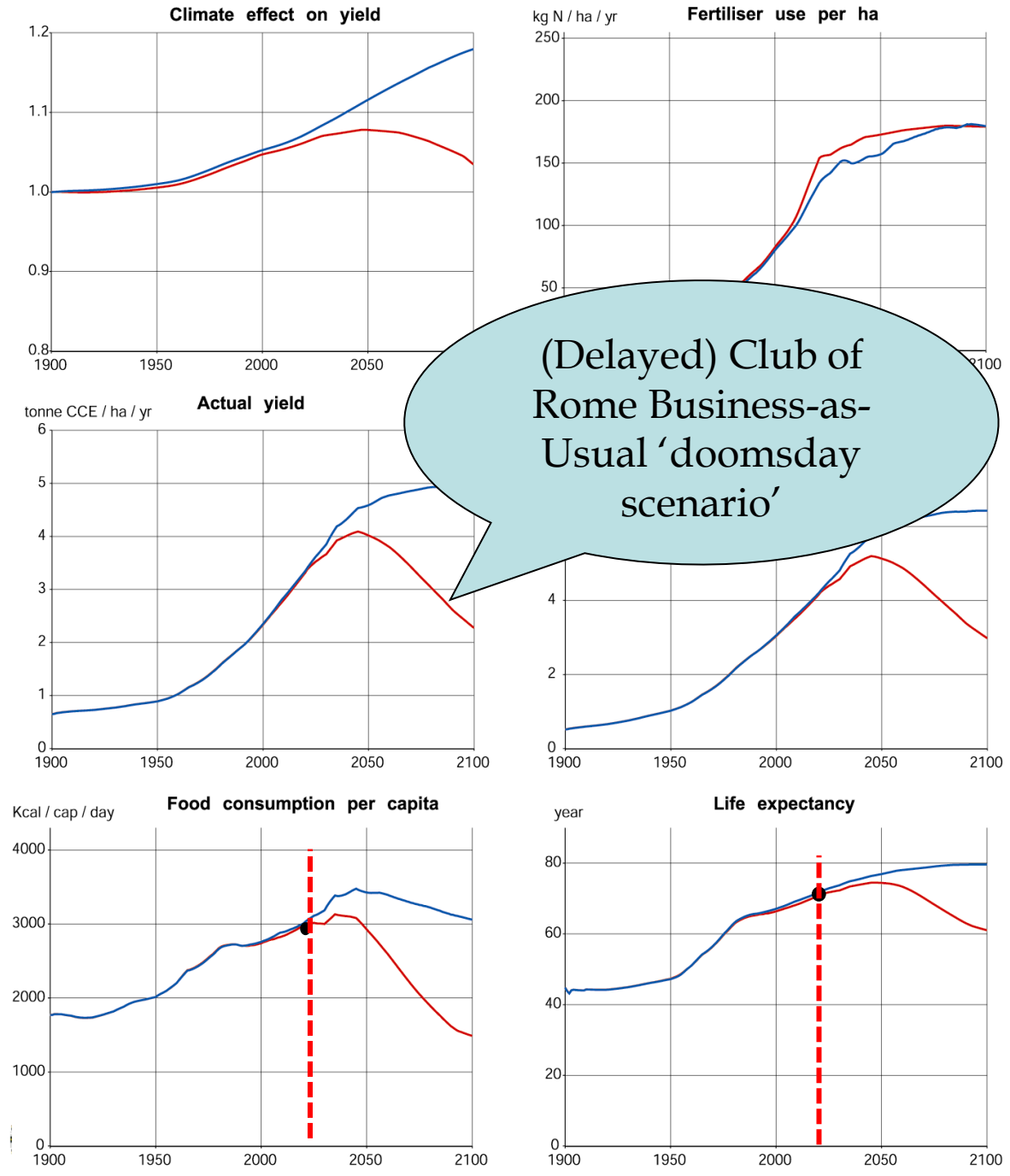
Fig. 17.9 Rotmans and De Vries 1997

■ Individualist
 ■ Hierarchist
 ■ Egalitarian



A dystopian future - the egalitarian nightmare:
 population decline due to the integrated feedback from greenhousegas emissions -> climate change -> declining food availability





- Individualist
- Hierarchist
- Egalitarian

A dystopian future - the egalitarian nightmare:

population decline due to the integrated feedback from greenhouse gas emissions -> climate change -> declining food availability



Universiteit Utrecht



Netherlands Environmental Assessment Agency

IMAGE modelling platform: linked models

PBL Netherlands Environmental Assessment Agency

Integrated Model to Assess the Global Environment

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SEARCH

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[Model Details](#)

[Scenarios](#)

[Projects & Results](#)

[Publications](#)

[Uncertainties](#)

[Background Info](#)

IMAGE model site

Integrated Model to Assess the Global Environment



The IMAGE model is developed by the IMAGE team under the authority of the Netherlands Environmental Assessment Agency (PBL).

KEY PUBLICATIONS

- [Integrated modelling of global environmental change. An overview of IMAGE 2.4](#)

WHAT IS IMAGE

IMAGE is an ecological-environmental framework that simulates the environmental consequences of human activities worldwide. It represents interactions between society, the biosphere and the climate system to assess sustainability issues like climate change, biodiversity and human well-being. The objective of the version of IMAGE described here (version 2.4 released in

RELATED DOSSIERS

- [Climate Change](#)
- [Biodiversity](#)
- [Integral Nitrogen](#)
- [Sustainable Development](#)

RELATED THEMESITES

HYDE



HYDE: Link to this web

FAIR



GISMO



PHOENIX



EDGAR

IMAGE modelling platform: [policy] applications

1994

Alcamo (Ed.) (1994)

Integrated Modeling of Global Climate Change

The Delft Dialogue Process

Rotmans, De Vries (Eds.) (1997) Perspectives on Global Change - the TARGETS approach

1997

**Safe Landing Approach
(Berlin Mandate, EU CC)**

Alcamo, Kreileman, Leemans (Eds.) (1998)
Global Change Scenarios of the 21st Century

2000

**Special Report on Emissions Scenarios
(SRES-IPCC)**

**Climate OptiOns for the
Long term (COOL)**

Contributions to:

- COPs of IPCC
- GHG Emissions Control Strategies (EU, with IEPE a.o.)
- GHG Policy Options for China (China Council)
- IMAGE-team: cd-rom IMAGE2.2 implementation SRES scenarios
- AirClim-project on co-benefits

2003

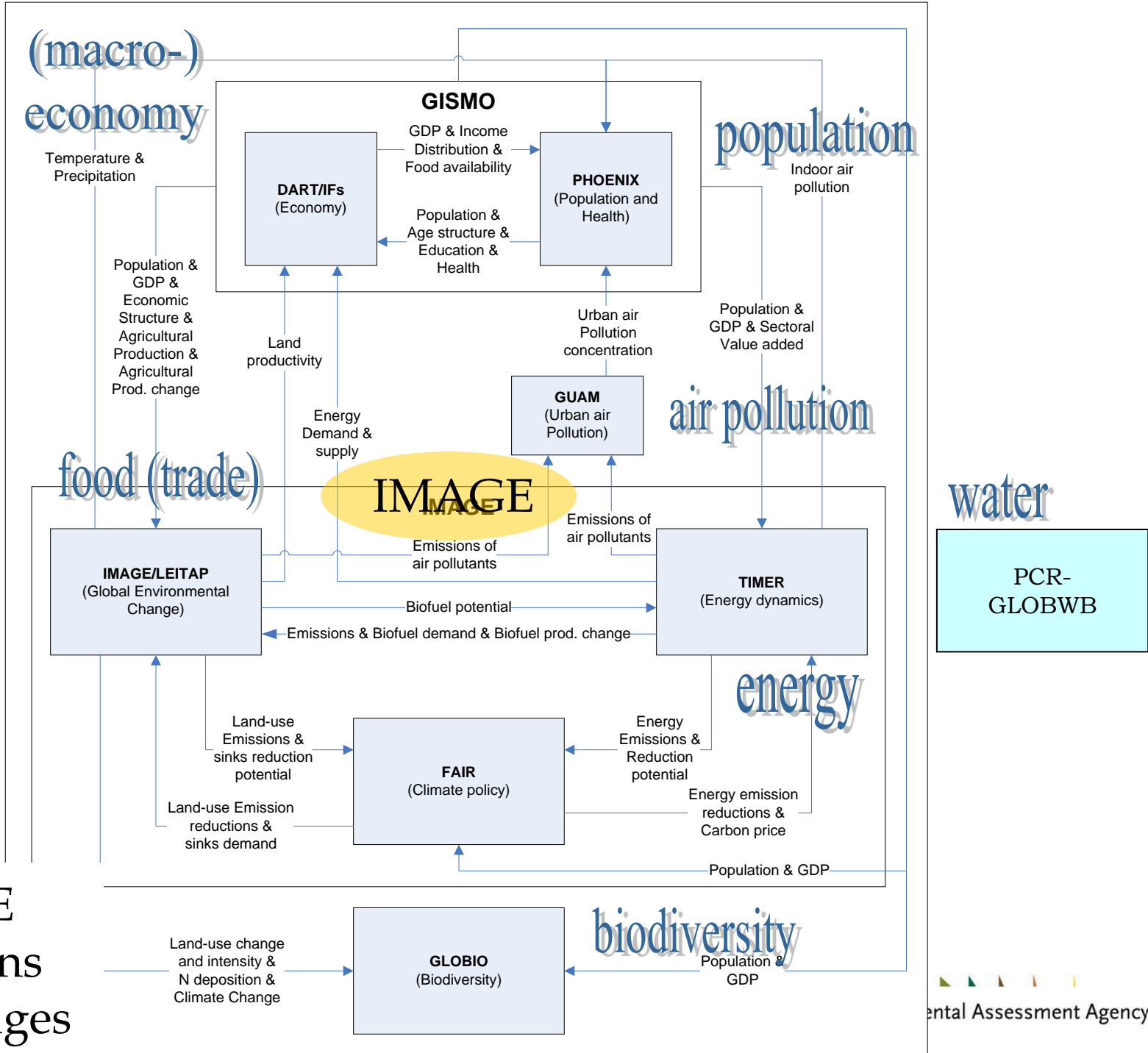
**UNEP Global Environmental
Outlook (GEO-1/2/3)**

van Vuuren, D. P. et al. (2011). A Special issue on the RCPs. *Climatic Change*, 109(1-2), 1-4

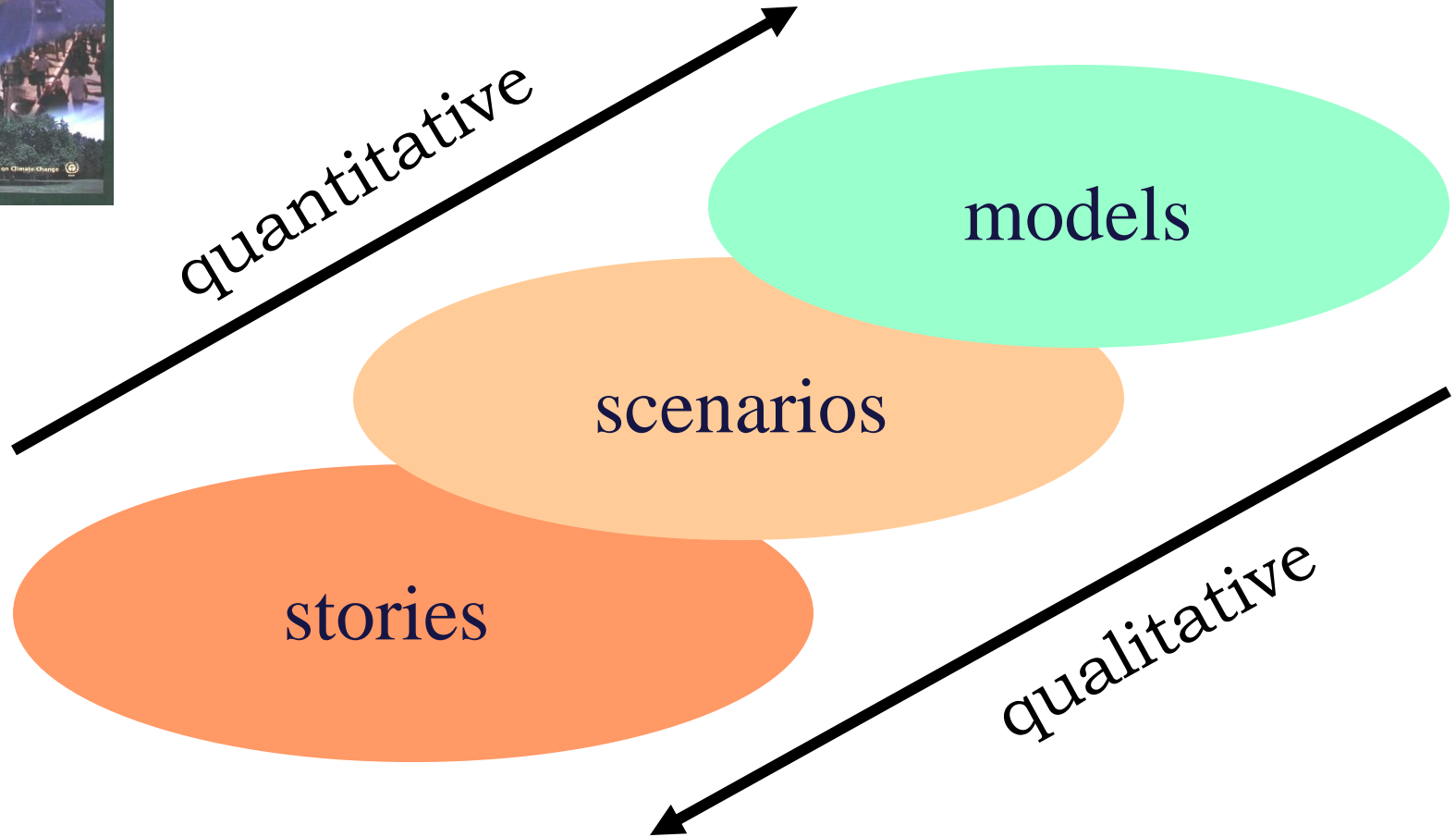
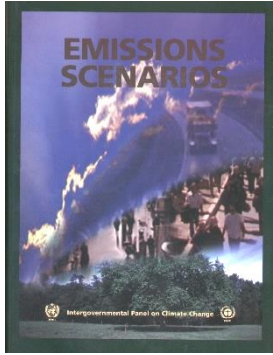
>2014

**Millennium Ecosystem Assessment
IMAGE 3.0 and many others**

IMAGE extensions and linkages



Scenarios: narratives as complements to models



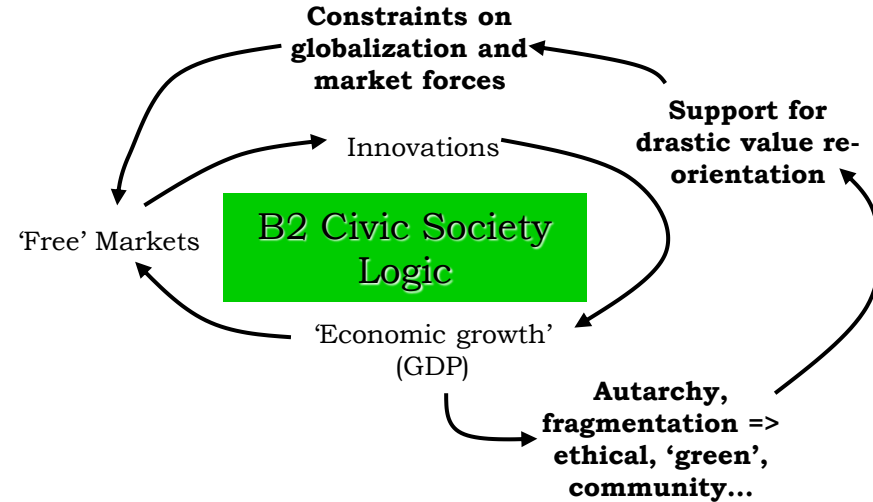
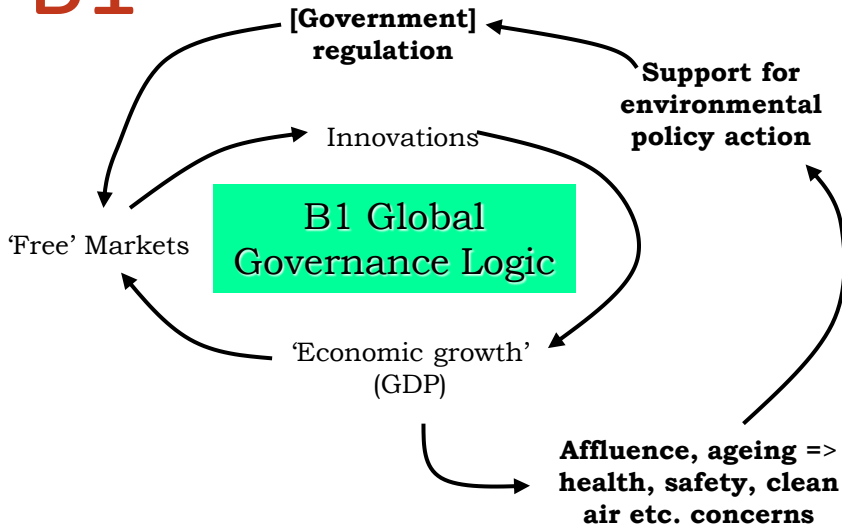
(IPCC 2000)



B1

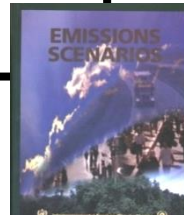
Emphasis on sustainability and equity

B2

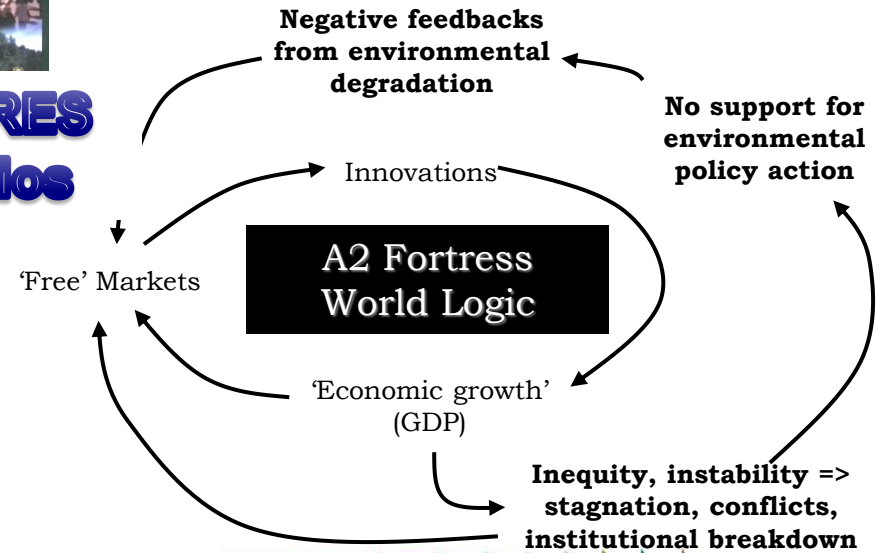
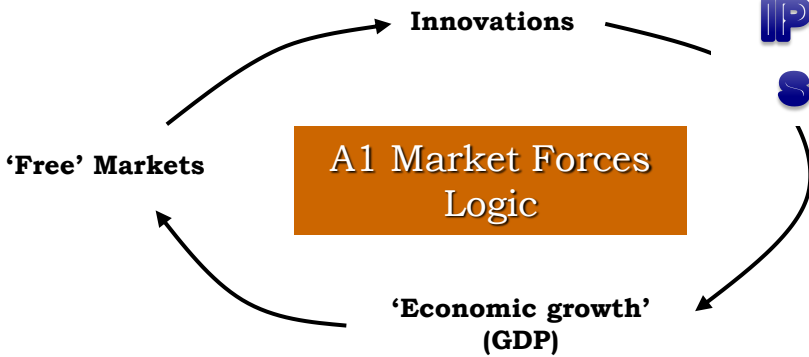


Globalisation

Regionalisation/fragmentation



IPCC SRES scenarios



A1

Emphasis on material wealth

A2

B1

Emphasis on sustainability and equity

B2

[Government] regulation

Free' Markets

Our GLOBAL Neighbourhood
"a timely work deserving our full attention"
Nelson Mandela

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OUR COMMON FUTURE
THE WORLD COMMISSION
ON ENVIRONMENT
AND DEVELOPMENT

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Affluence, ageing => health, safety, clean air etc. concerns

Free' Markets

small is beautiful
a study of economics as if people mattered
EF Schumacher

straints on
ization and

Transition Communities
A Pocket Guide

for
ue-
rion

community...

Globalisation



Regionalisation/fragmentation

Free' Markets

SCIENTIFIC AMERICAN
SEPTEMBER 2009 \$2.95
SPECIAL ISSUE
MANAGING PLANET EARTH

itions

Francis Fukuyama

THE END OF HISTORY AND THE LAST MAN

IPCC SRES scenarios

ic
(GDP

Free' Markets

Negative feedbacks
Environmental degradation

NATIONAL BESTSELLER
THE CLASH of CIVILIZATIONS
AND THE REMAKING of WORLD ORDER
SAMUEL P. HUNTINGTON

vation

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SUZANNE COLLINS
THE HUNGER GAMES TRILOGY

ic gr
(GDP)

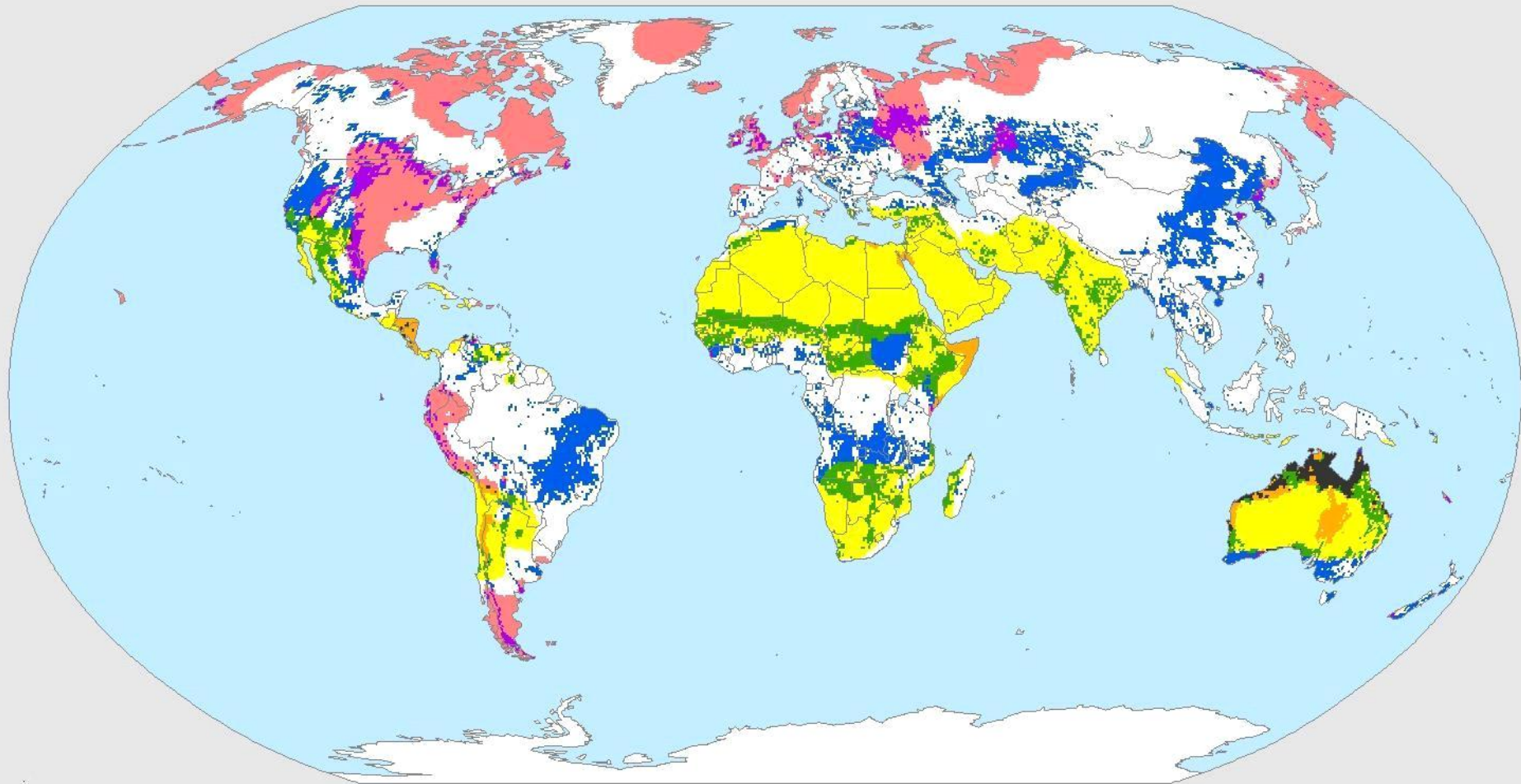
No support for environmental action

ility => conflicts, institutional breakdown

A1

Emphasis on material wealth

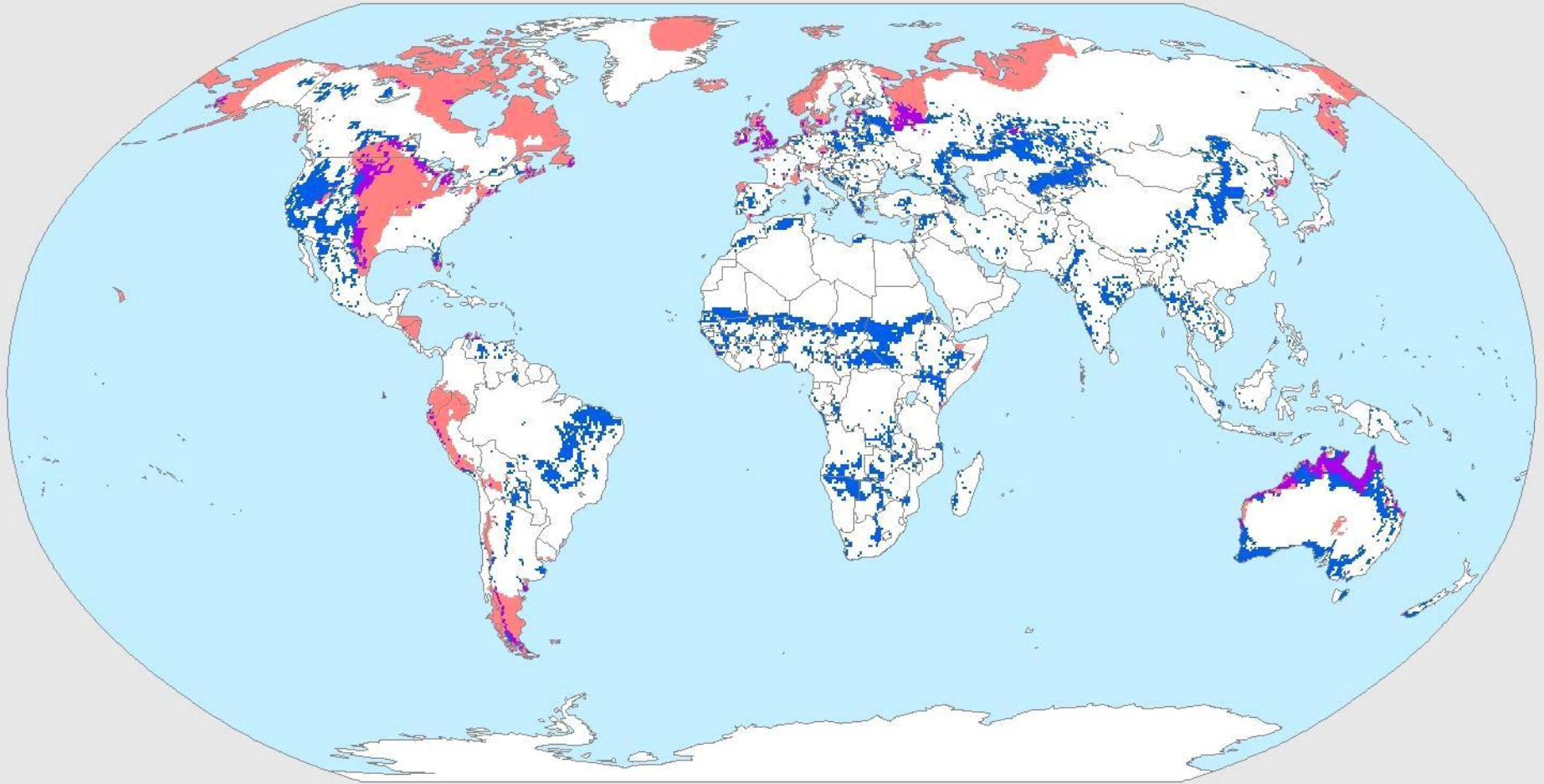
A2



- None
- Wind
- PV
- Biomass
- Wind+PV
- PV+Biomass
- Wind+Biomass
- All

Areas suitable (i.e. generation cost < 0,1 \$/kWh electricity) for Wind Solar-PV Biomass options

WSB (Wind Solar Biomass)options (elec&trp fuel) with interaction, A1 world 2050

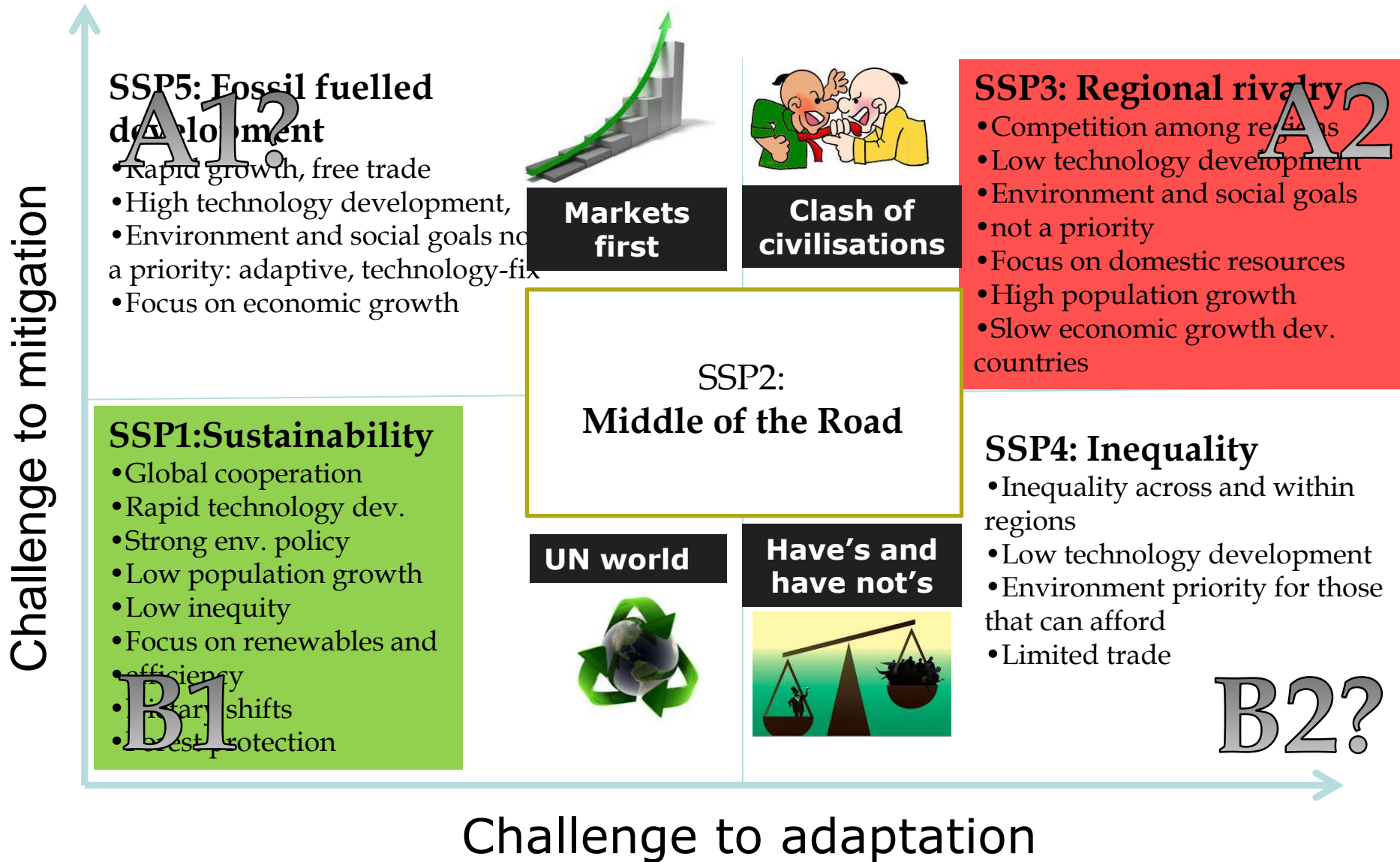


- None
- Wind
- PV
- Biomass
- Wind+PV
- PV+Biomass
- Wind+Biomass
- All

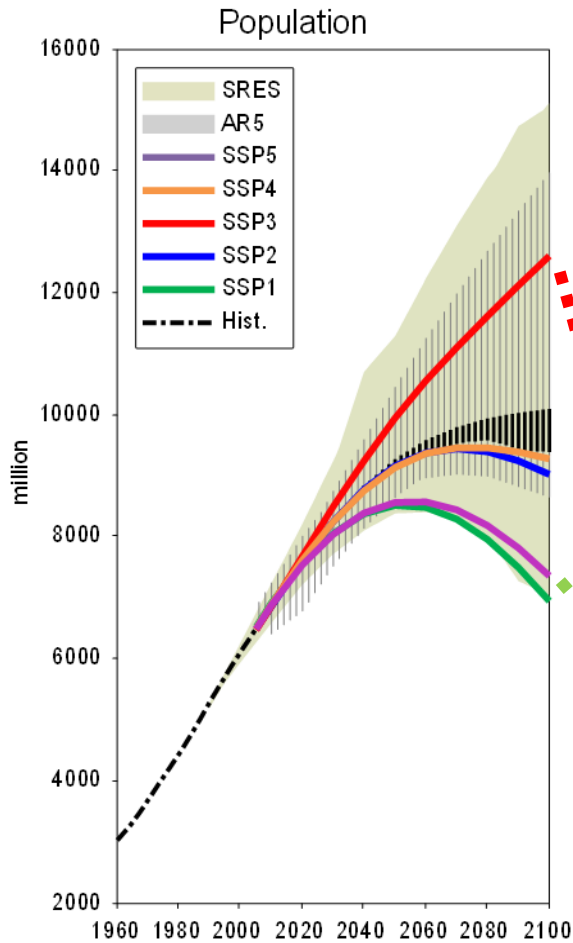
Areas suitable (i.e. generation cost < 0,1 \$/kWh electricity) for Wind Solar-PV Biomass options

WSB (Wind Solar Biomass)options (elec&trp fuel) with interaction, A2 world 2050

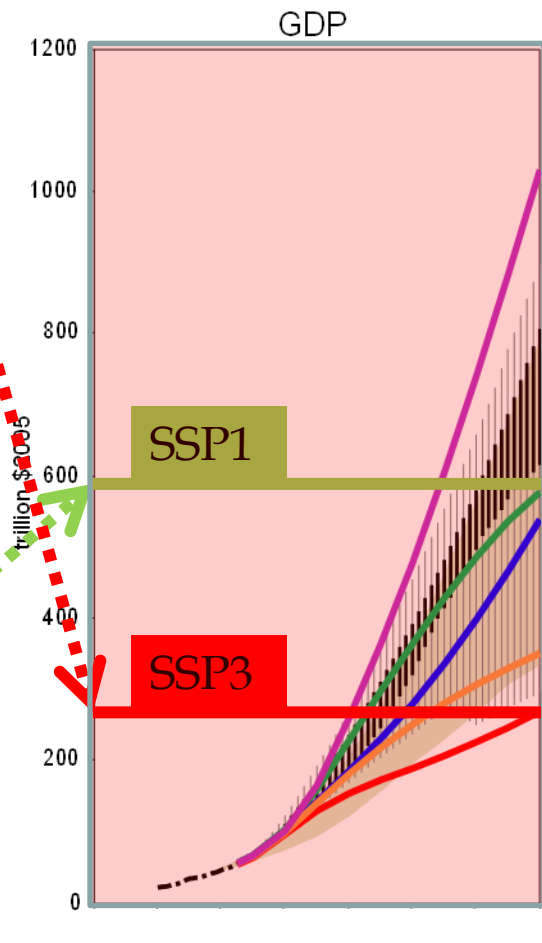
The Shared Socioeconomic Pathways (SSP) Scenario Architecture



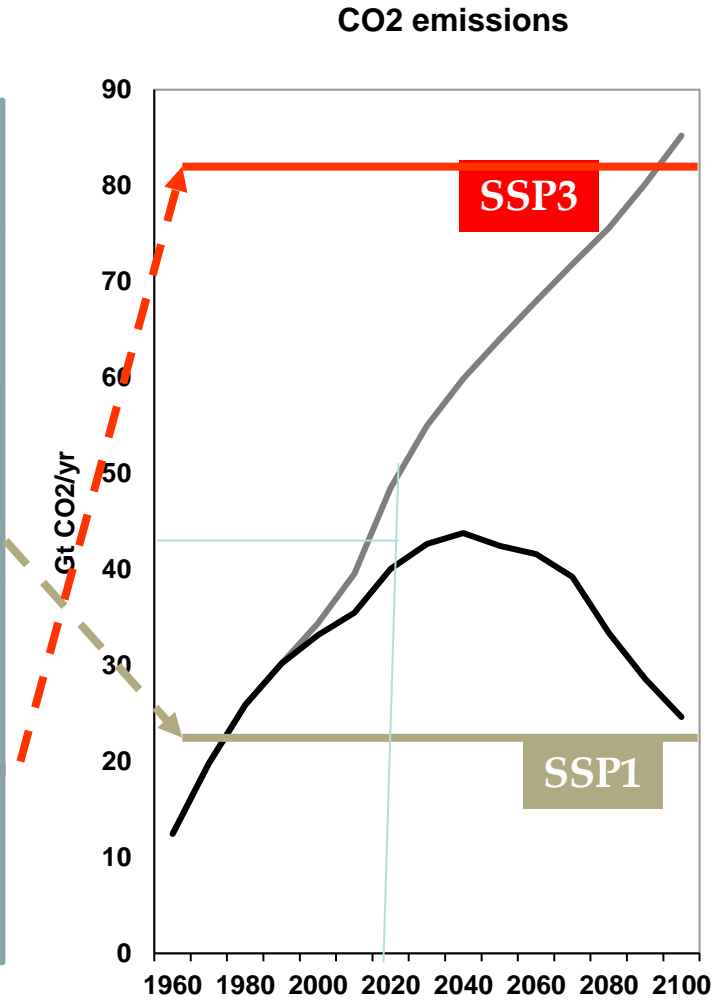
...and what does this mean for welfare (€/cap), its distribution, well-being? Limits to [economic] growth?



KC and Lutz



Dellink et al





Universiteit Utrecht



Netherlands Environmental Assessment Agency

P[lanetary]
B[oundaries] +
S[ustainable]
D[evelopment]
G[Goals] =
doughnut

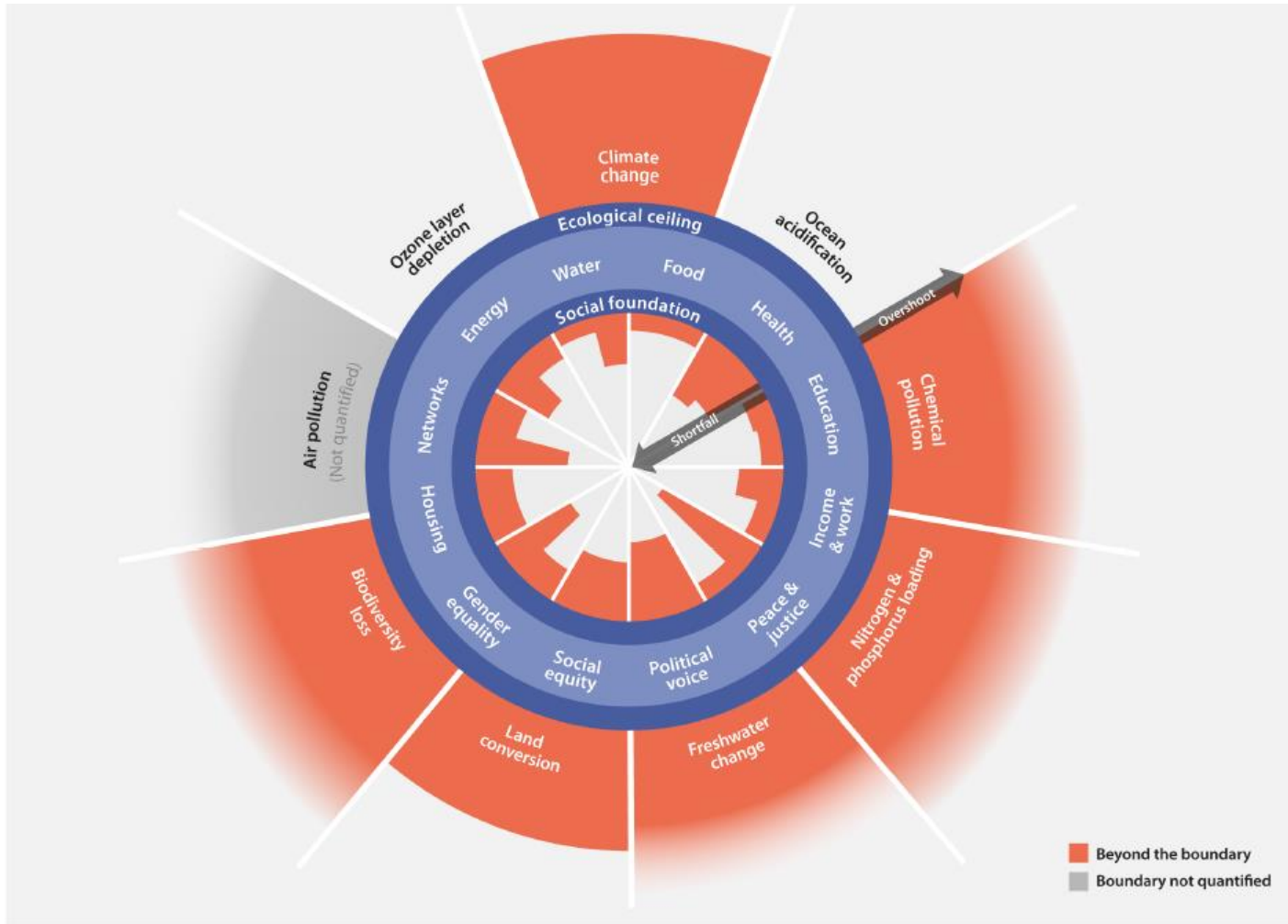


Figure 9 | The “doughnut” of social and planetary boundaries. Based on (Raworth, 2017). The figure has been updated to reflect recent research on the water boundary (Wang-Erlandsson et al., 2022) and chemical pollution (Persson et al., 2022).

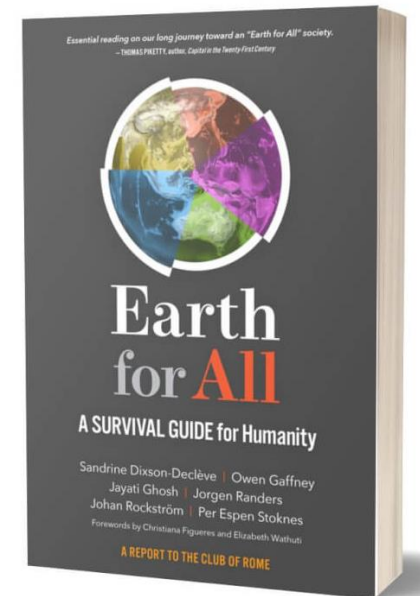
Club of Rome question remains:
prosperity within limits

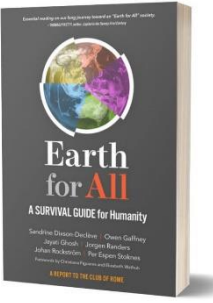
Galaz, V/, and D. Collste (eds.)(2022). Economy and Finance for a Just Futre on a Thriving Planet. Report for Stockholm+50
<https://www.globalresiliencepartnership.org/wp-content/uploads/2022/06/sthlm50reportfinal-1.pdf>

Latest Report to the Club of Rome (Dixson-Declève et al. 2022)

Eart4All

- expanded, regionalized *Limits to Growth* system dynamics model used to construct two scenarios: *Too little Too Late* and *Giant Leap*
- includes economic and finance mechanisms, (in)equ(al)ity, social tensions and environmental stresses
- outcomes are presented in two aggregate indicators: an **Inequality Index** and a **Social Tension Index**. The latter is derived from the **change** in the Average Well-being Index
- deep transformative policies with respect to poverty, education, food, energy, trade and financing can make a significant difference in the quality of life of billions of people in the second half of the 21st century.
- unlike previous reports to the Club of Rome, the report is explicit in its political-economic analysis: the title of the last chapter is *'From 'Winner Take All' Capitalism to Eart4All Economies'*.





1. Main trends

Too Little Too Late scenario

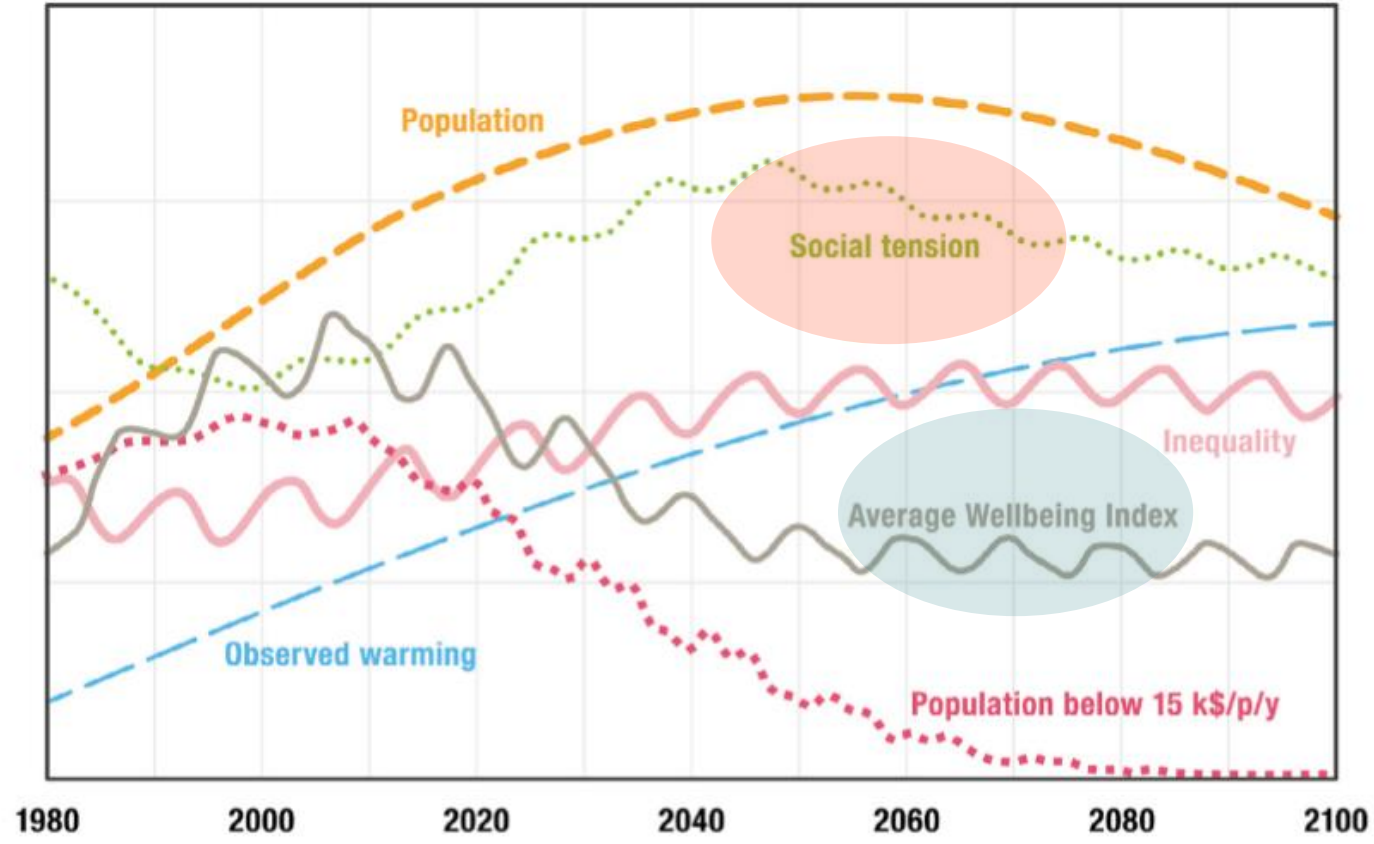
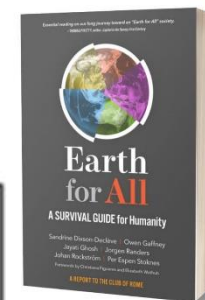
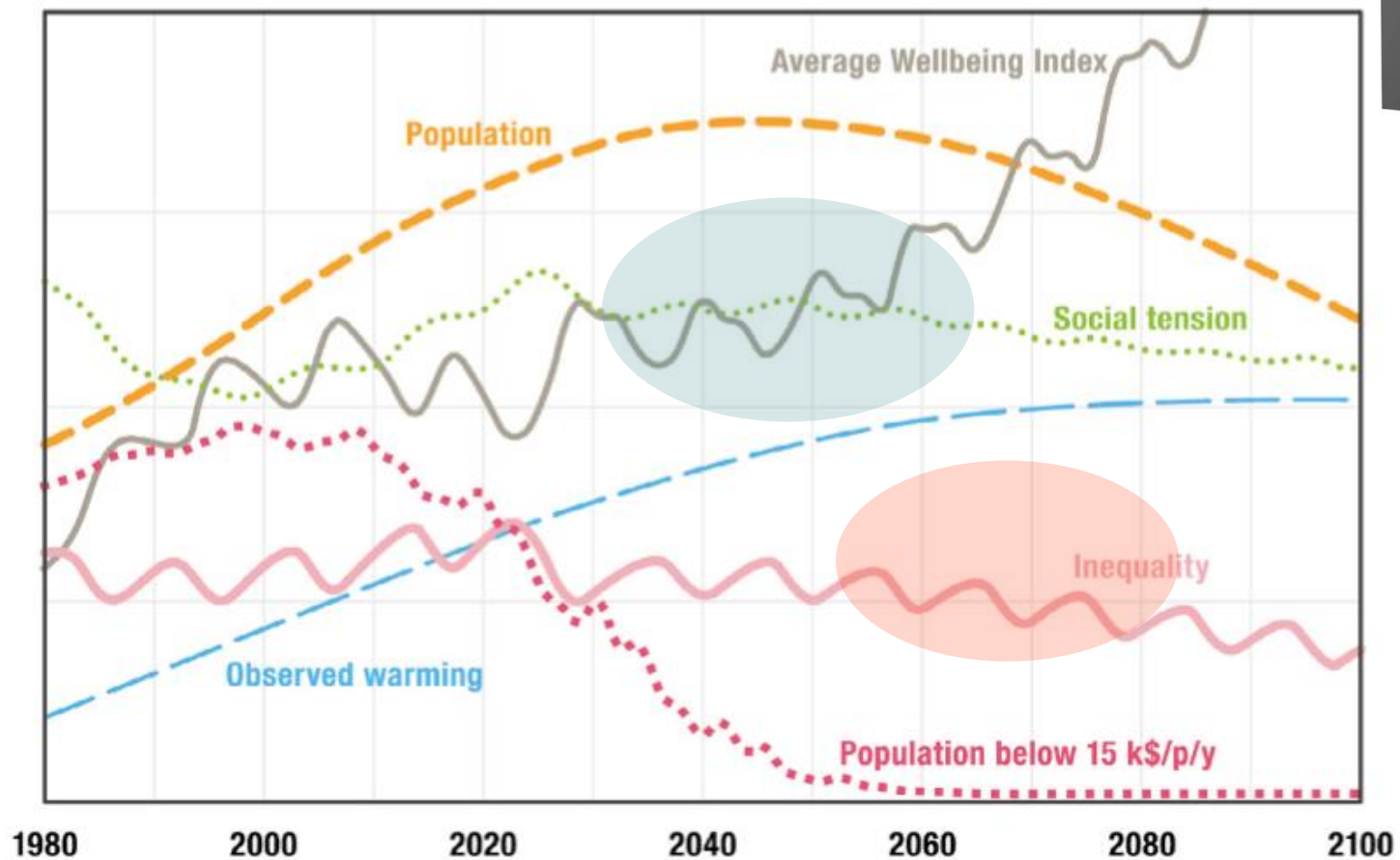


Figure 1. Main trends in the Too Little Too Late Scenario of the Earth4All model – World 1980 to 2100.

Latest Report to the Club of Rome (Dixson-Declève et al. 2022)
Eart4All

Figure 2. Main trends in the Giant Leap Scenario of the Earth4All model – World 1980 to 2100.

1. Main trends Giant Leap scenario

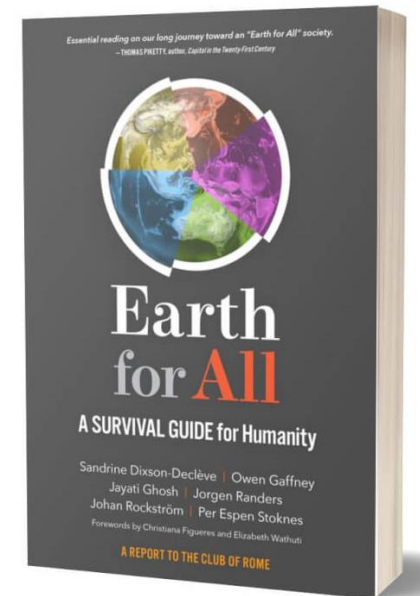


Latest Report to the Club of Rome (Dixson-Declève et al. 2022)
Earth4All

Latest Report to the Club of Rome (Dixson-Declève et al. 2022)

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- expanded, regionalized *Limits to Growth* system dynamics model used to construct two scenarios: *Too little Too Late* and *Giant Leap*
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- unlike previous reports to the Club of Rome, the report is **explicit in its political-economic analysis**: the title of the last chapter is *'From 'Winner Take All' Capitalism to Eart4All Economies'*.



The importance of land use and cover change (LUCC) – and who are deciding

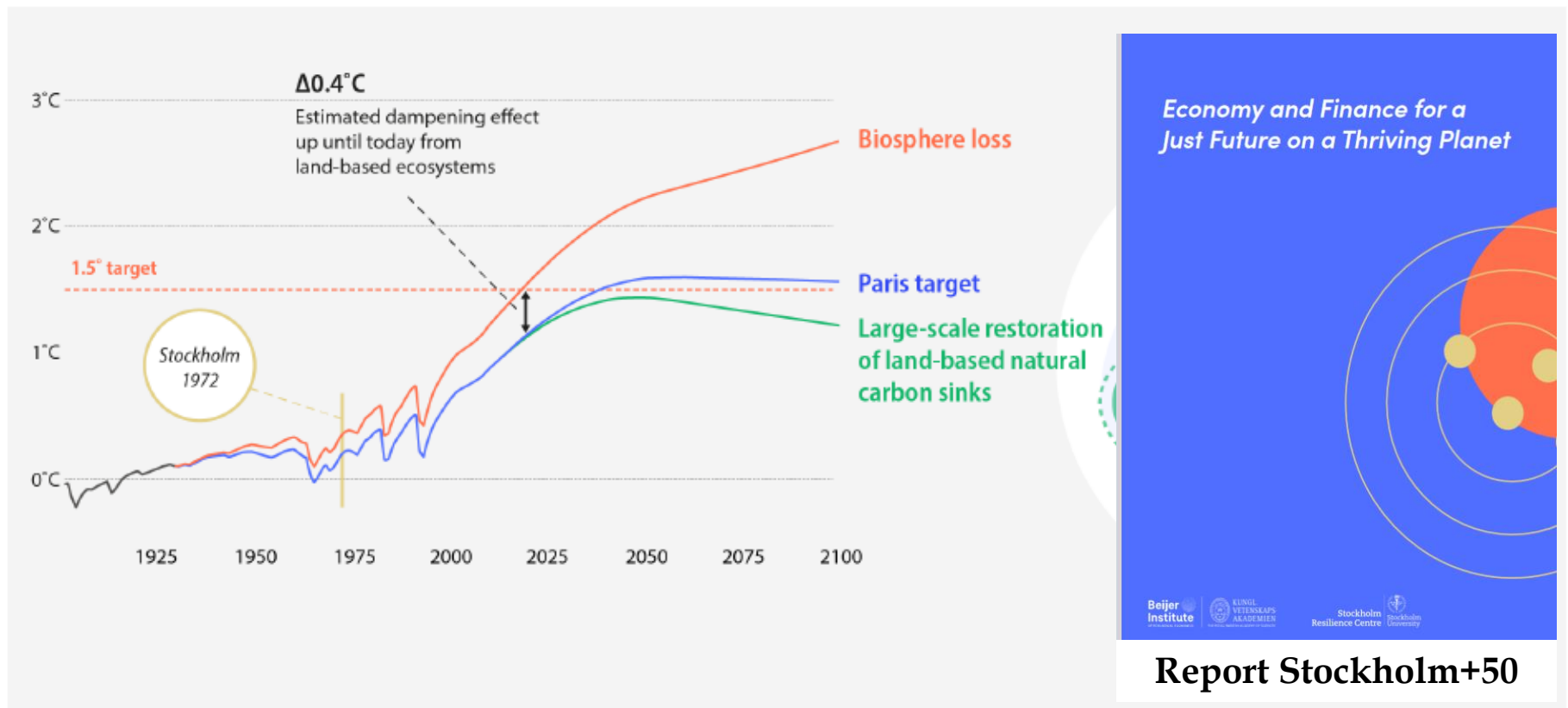
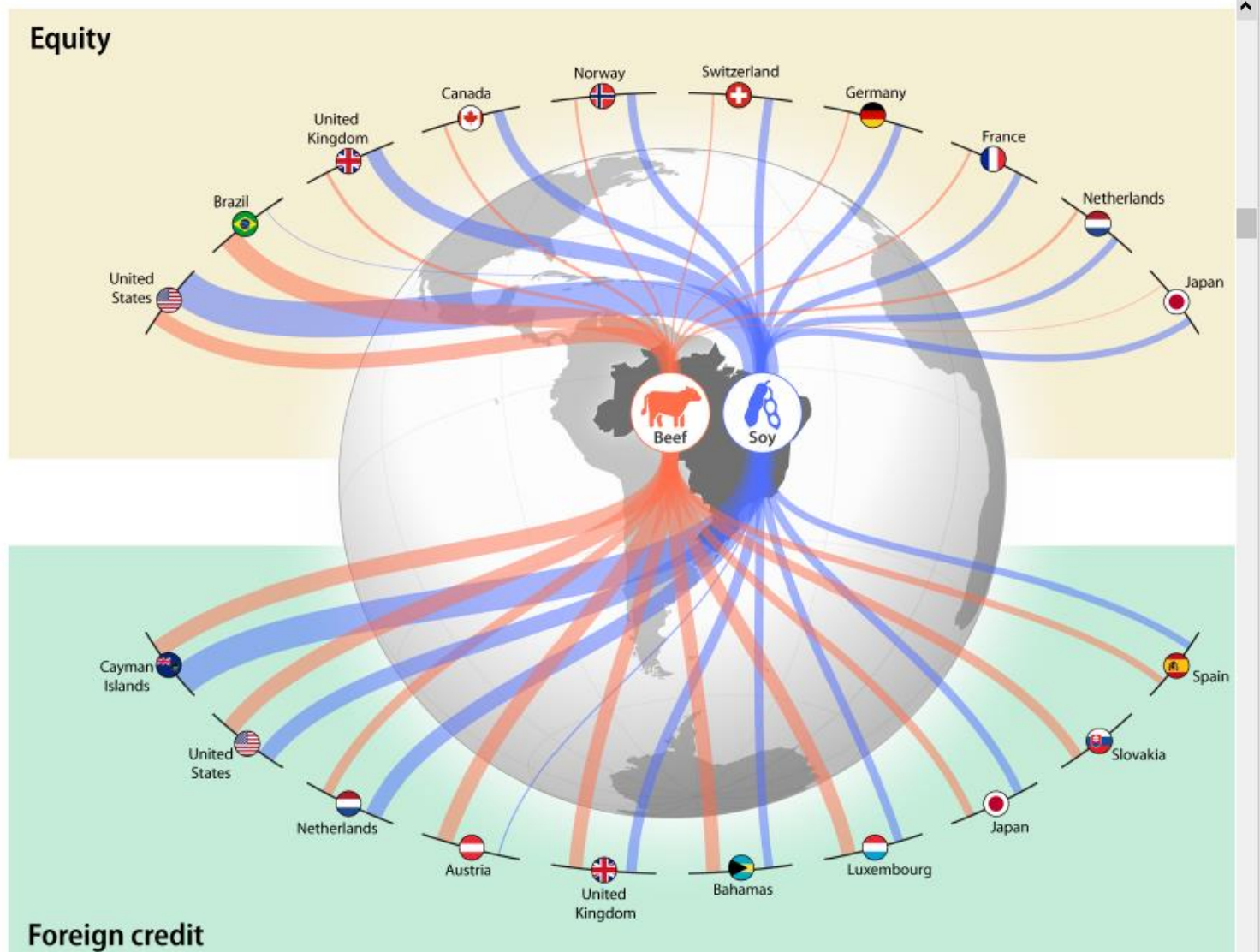
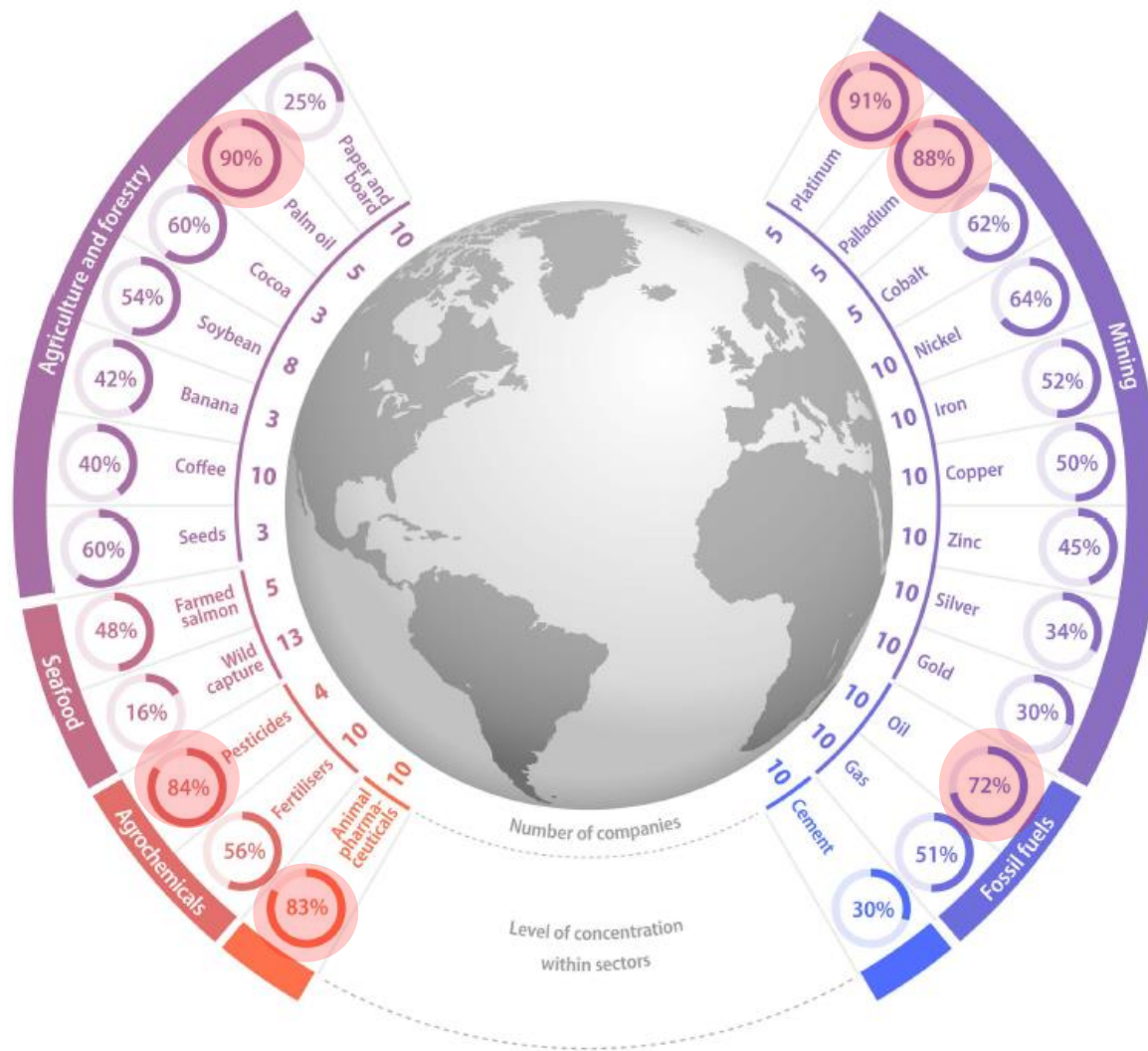


Figure 2 | The importance of the biosphere for the Paris target. The world would already have breached the Paris target without the carbon sinks provided by a resilient biosphere. Source: (Rockström et al., 2021).



Equity and foreign credit to deforestation-risk industries in the Brazilian Amazon





The biosphere in the hands of a few: levels of concentration for industries with a large impact on land- and seascapes



*Dank voor uw aandacht
Merci pour votre attention
Thank you for your attention
Danke für Ihre Aufmerksamkeit*



Universiteit Utrecht



Netherlands Environmental Assessment Agency