Environmental *Change* Institute

The role of complex Infrastructure Systems and space in mediating global change

Frontiers of Global Change Science, 17 – 22 August 2014, Aspen, CO

Alex **Otto**

Main Messages

(Infra)Structure links the environmental with the socio-economic system.

We need to take ***Complexity*** far more seriously both when modelling integrated socio-technical-environmental systems and when trying to manage them.

A conceptualisation and method based on ***Information (and Evolution)*** can help to understand possible long-term dynamics of socio-technical-environmental systems.

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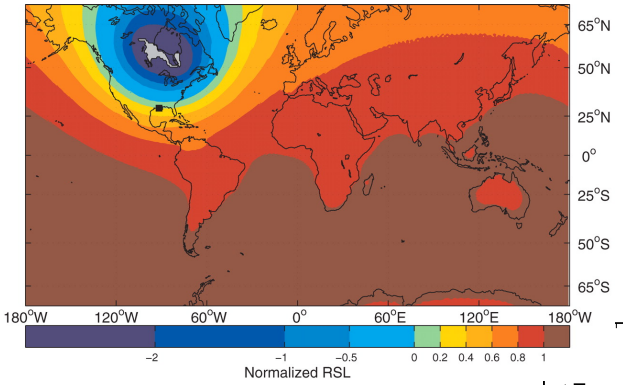
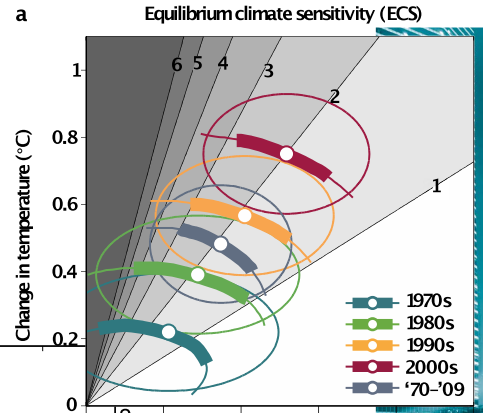
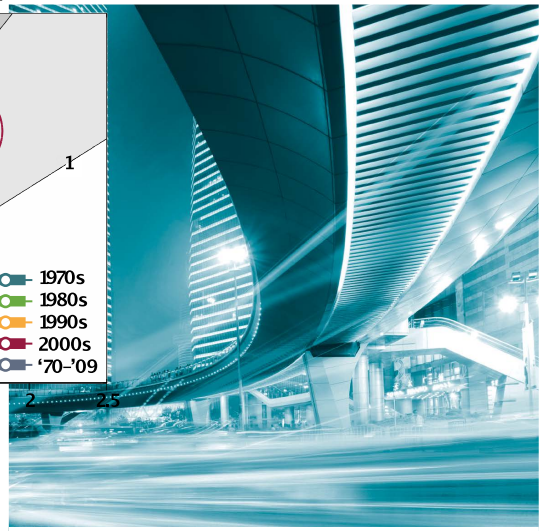
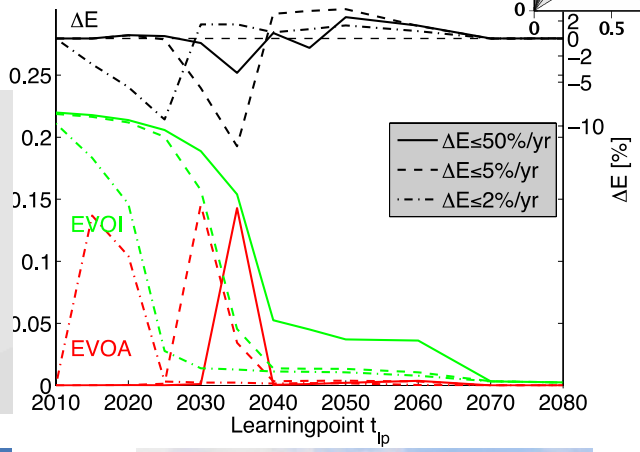
My journey so far





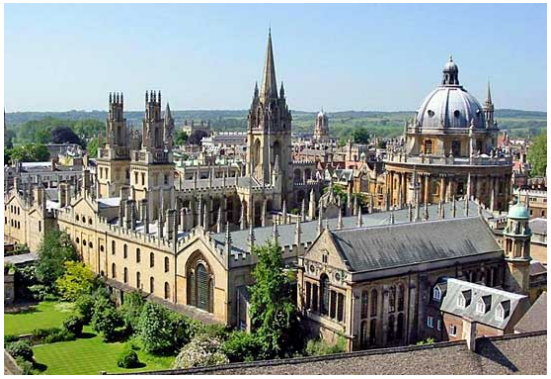


The fun with **Quantum Information** is that you can study the foundations of the enigmatic world of Quantum Mechanics, and, at the same time, you make something useful for practical applications



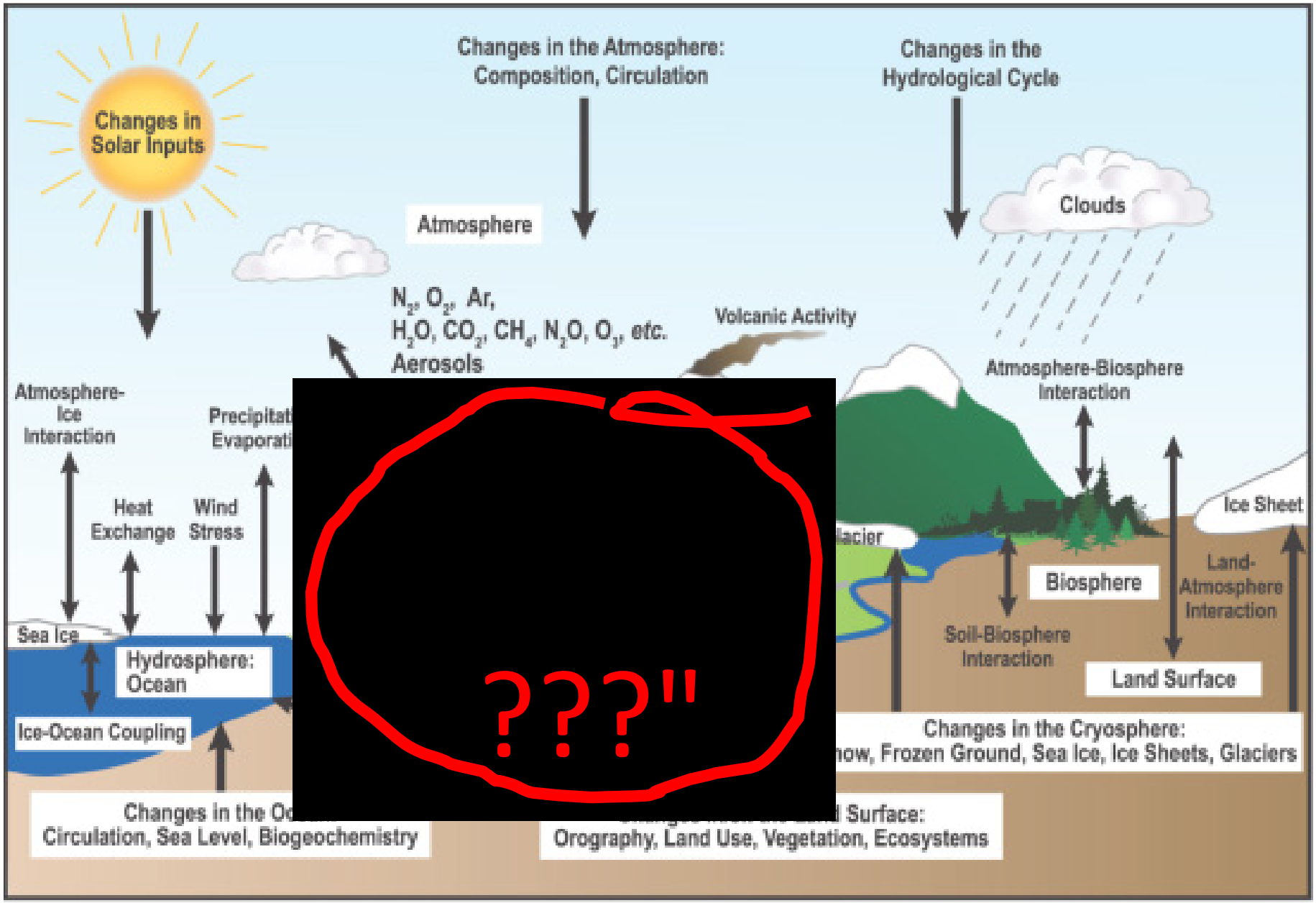
2002 2007

2008 2011

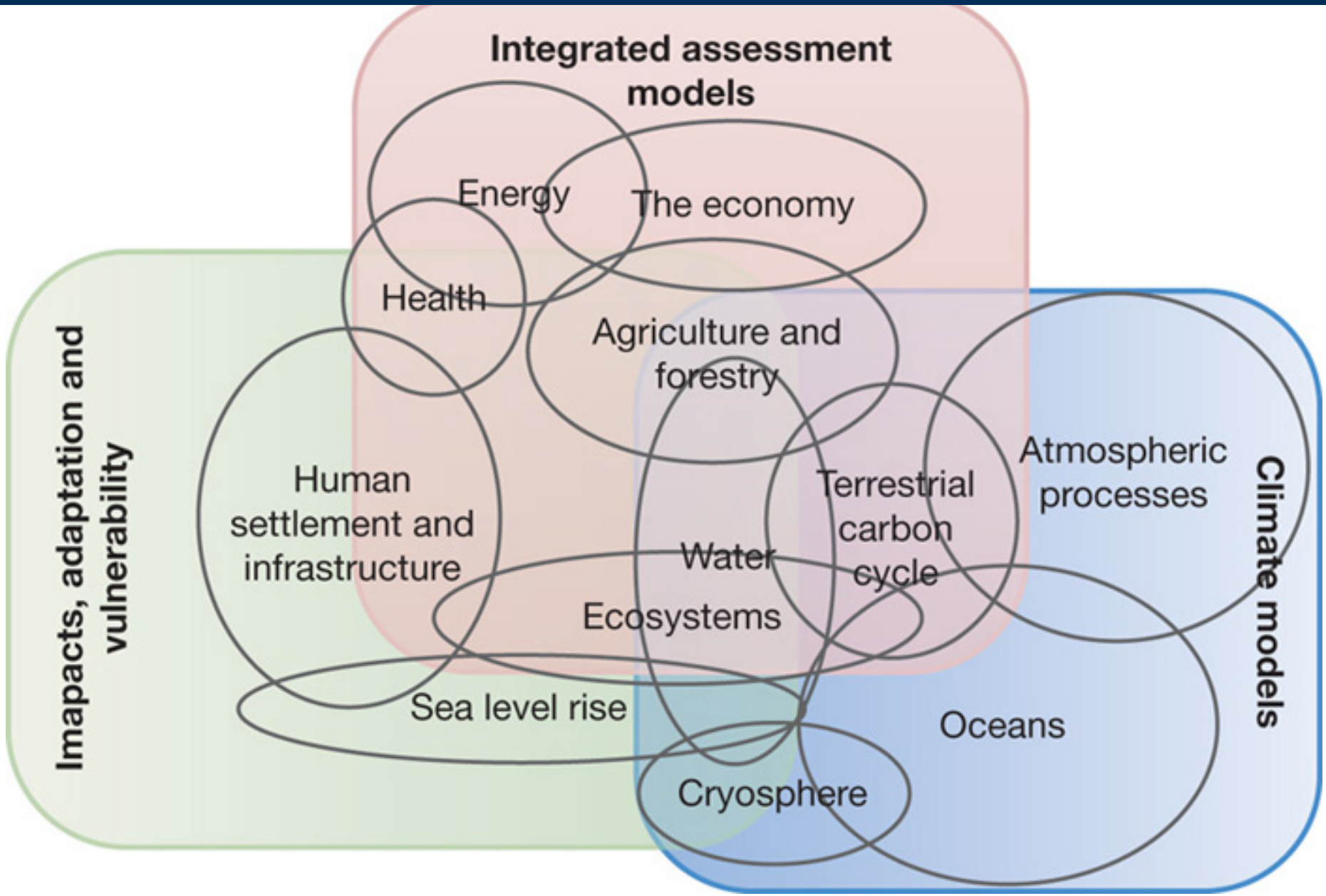


2011 now

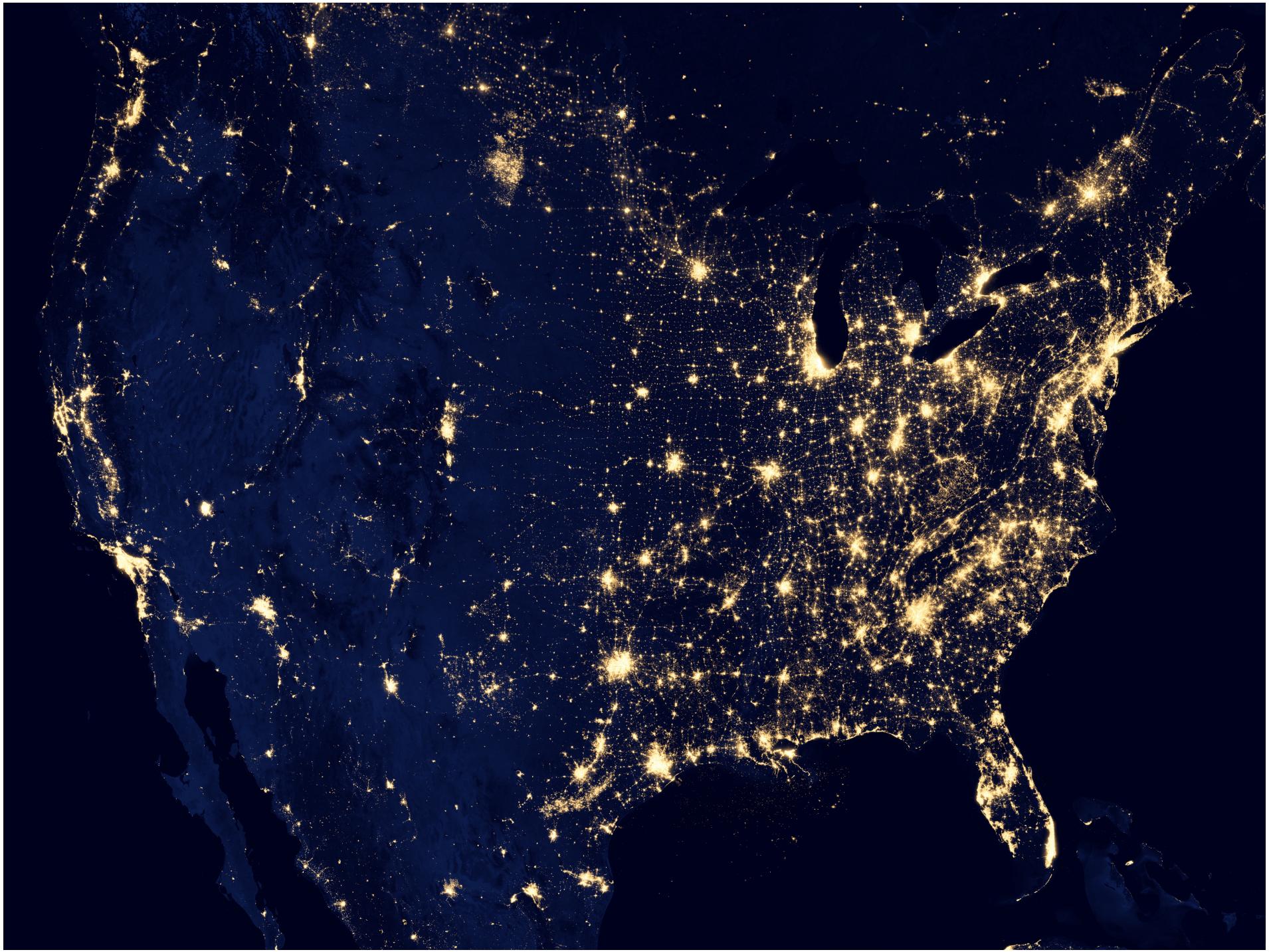
The Frontier for Integrated Assessment



The Frontier for Integrated Assessment



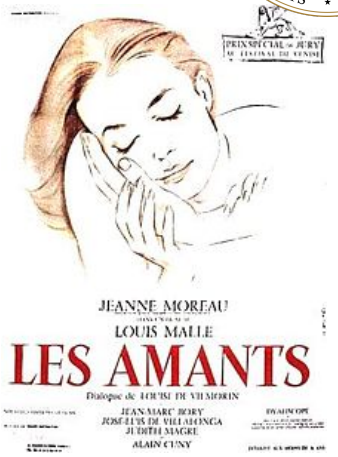
Moss et al., The next generation of scenarios for climate change research and assessment *Nature* **463**, 747-756



What is infrastructure?

Big lumpy stuff sticking in the ground.

or…

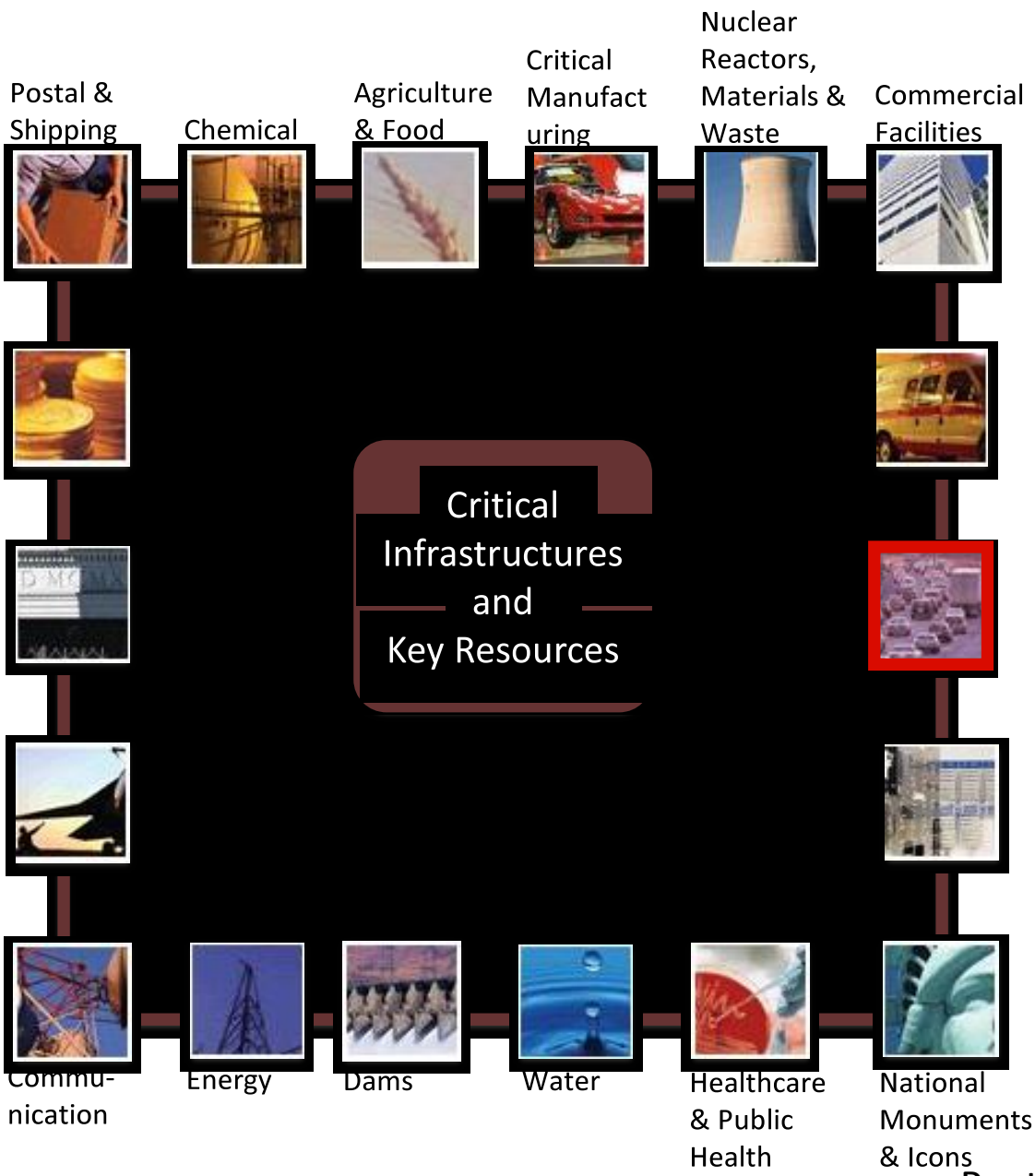


Characteristics of Infrastructures:

- Long gestation periods and lifetime.
- Contractual problems.
- Network effects.
- Foundational services.

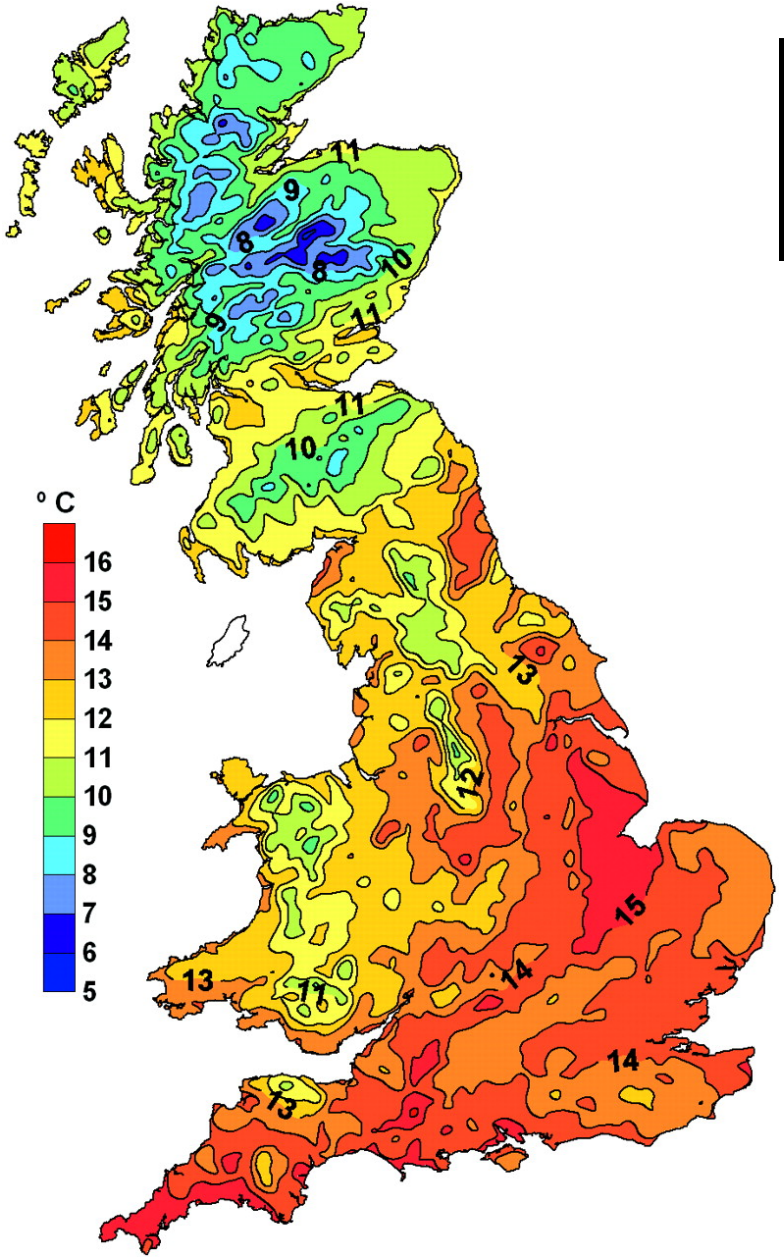
Networks of assets providing foundational services for the functioning of the economy. (e.g. ITRC,…)

What is infrastructure?



Pant & Barker, 2014)

Fields vs Hierarchical Networks



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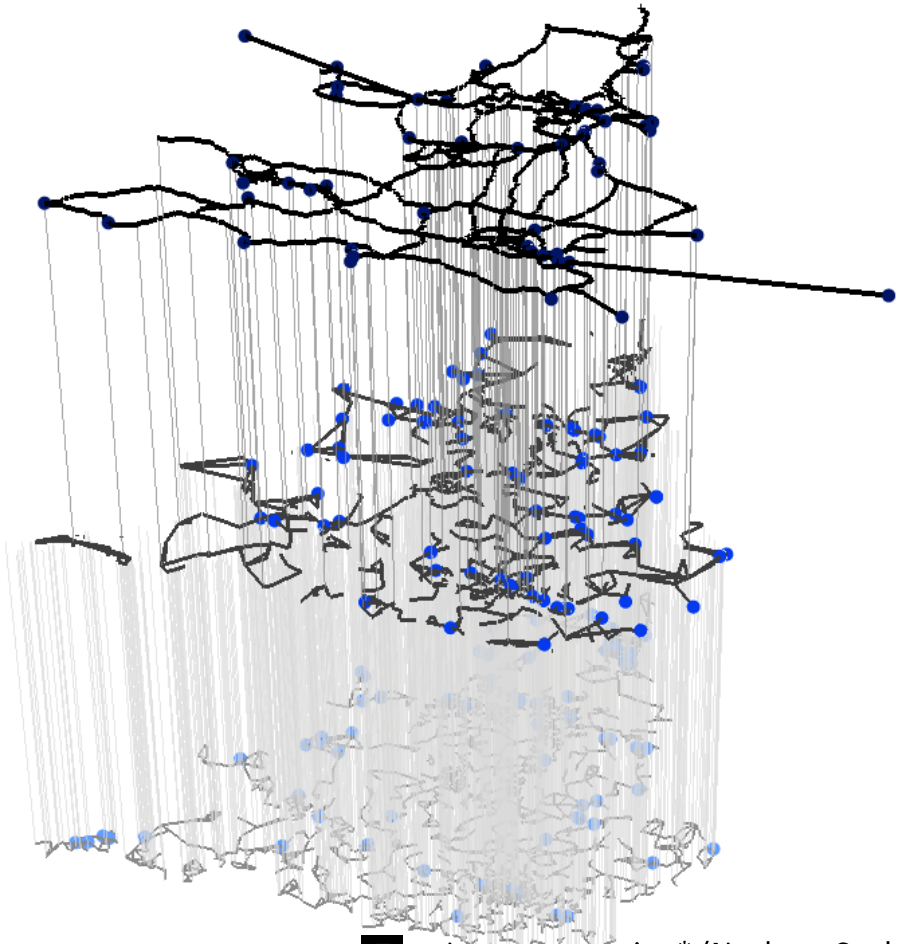
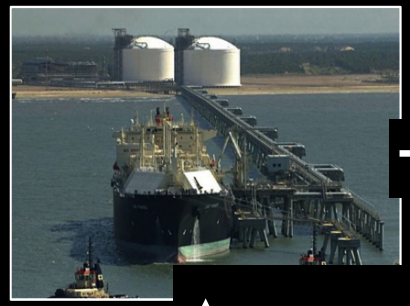
(Integrated(electricity(network((

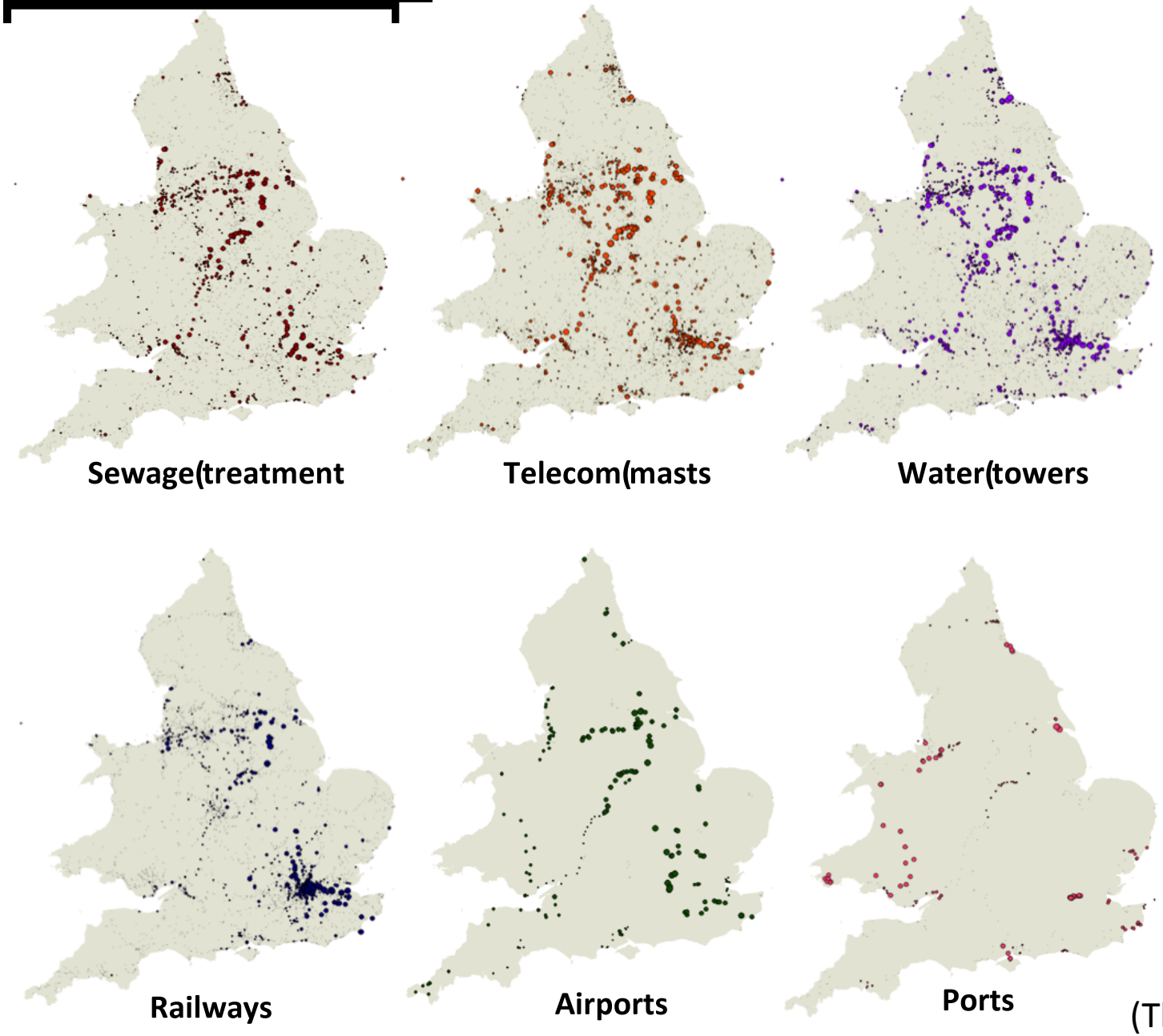
bridging(scales(

(



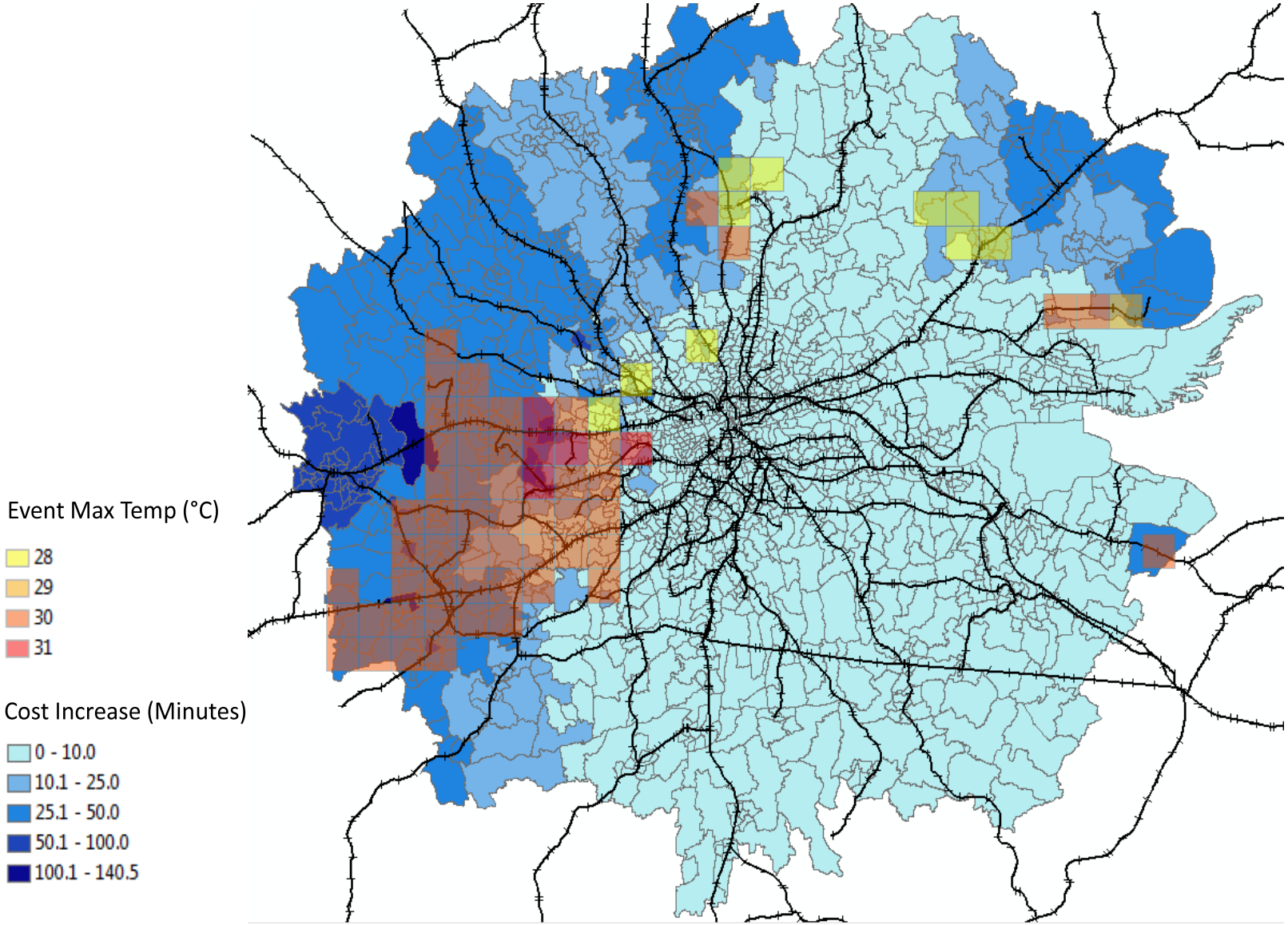


Indirect effects through interconnectedness



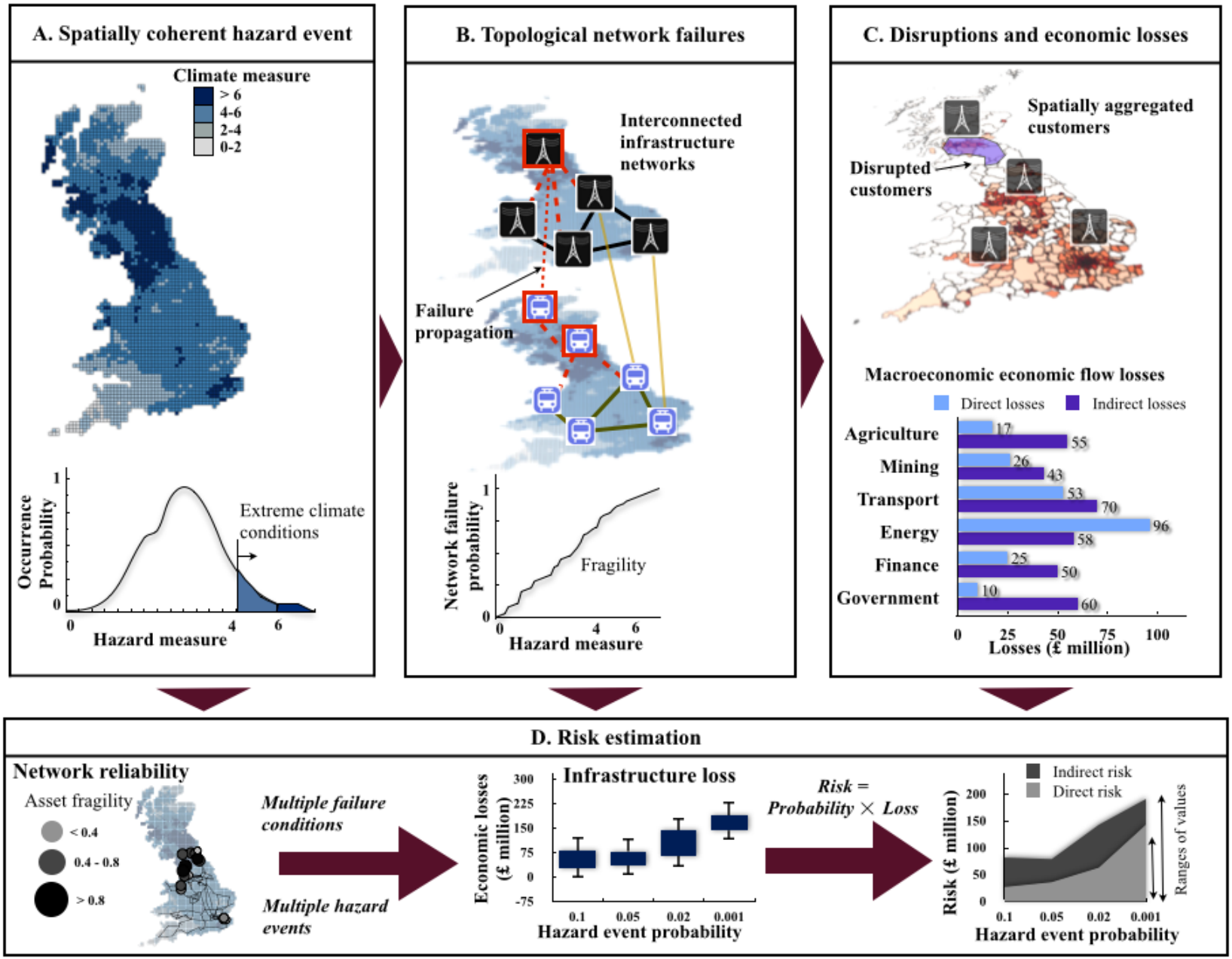
(Thacker, 2014)

Indirect effects through interconnectedness

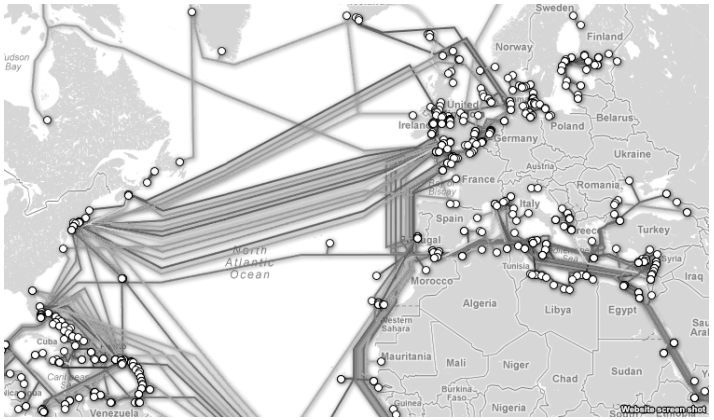


ARCADIA project www.arcc-network.org.uk/project-summaries/arcadia/

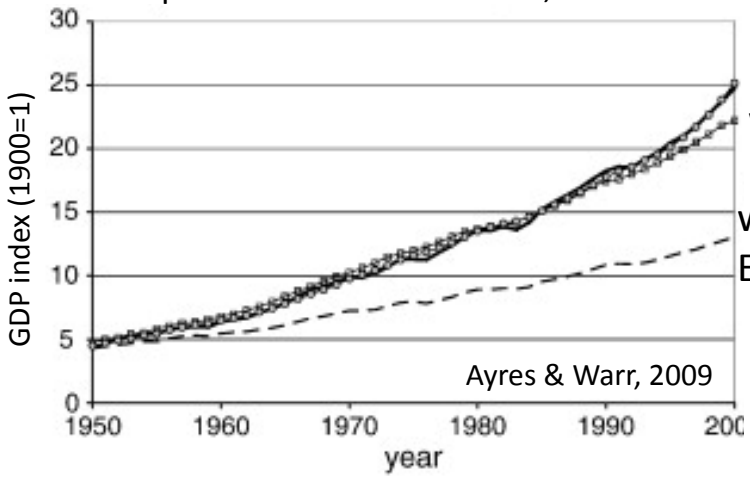
Vulnerability & Resilience analysis of current Infrastructure systems



What about the future?

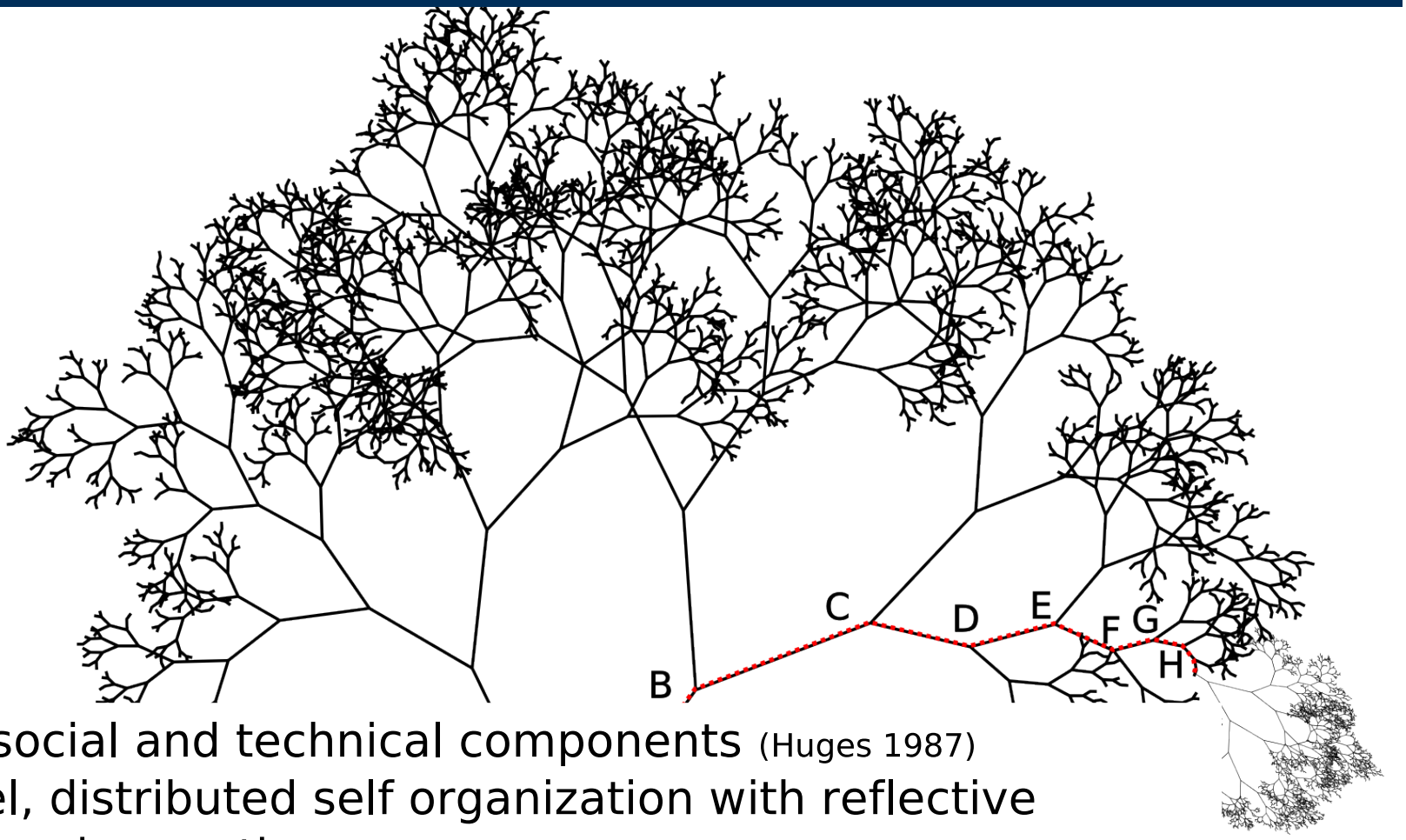


Empirical and estimated GDP, US 1950-2000



Grady et al. Nature Communications, 2012

Bone and Bane of Complexity

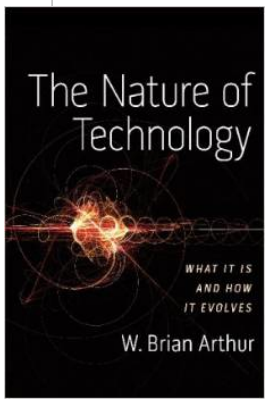


- Many social and technical components (Huges 1987)
- Parallel, distributed self organization with reflective downward causation (Holland 1996, Kroes 2009)
- Evolve over time (Dennet 1996, Dawkins)
- Require multiple formalisms to understand fully (Mikulecky 2001)
- Are value and emotion loaded. (Roesser 2012, van der Hoeve, 2012)

Bone and Bane of Complexity

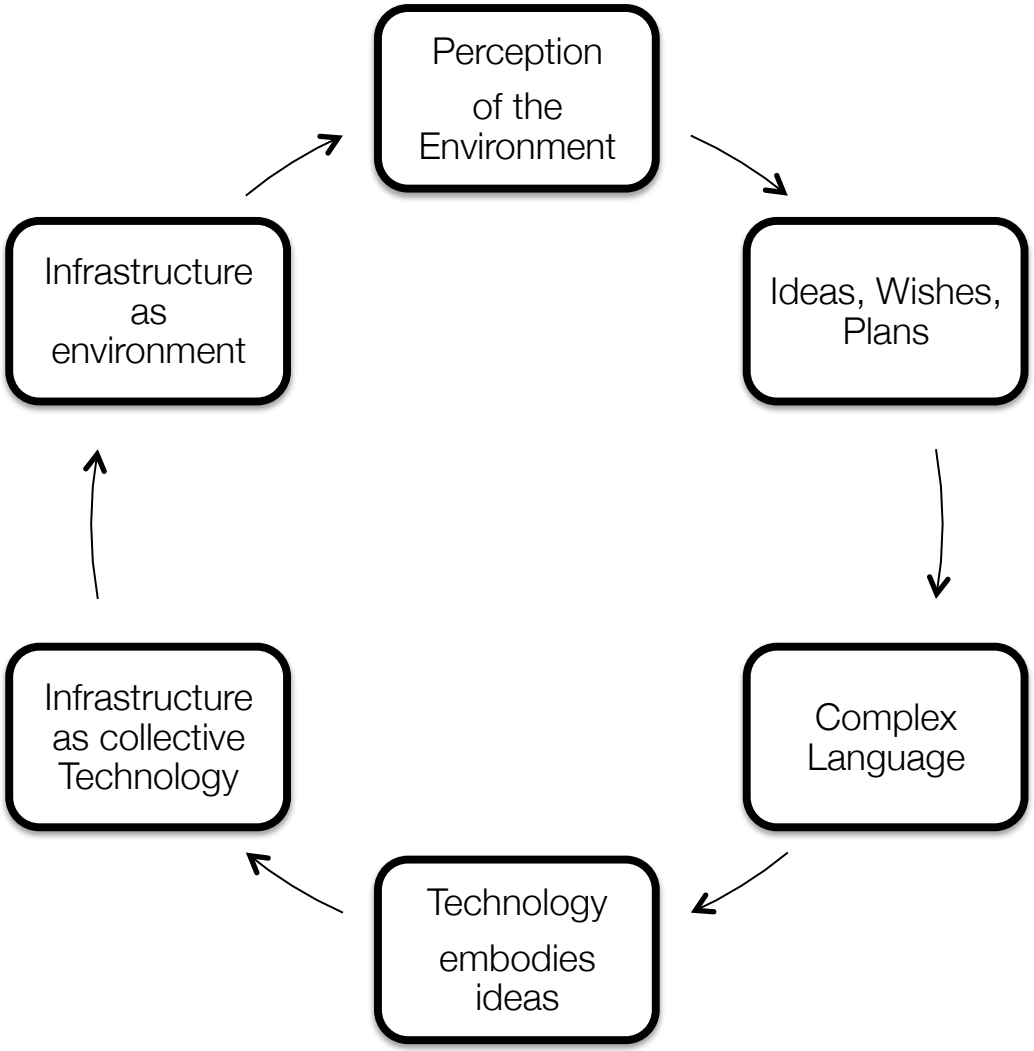
- Limited controllability
- The possibilities of projection, and planning are limited.
- An adaptive, inclusive, recursive management practise is required. (Robust rather then optimal decisions.)
- The role of modelling as forcasting has to be replaced.
- Model development as evolution of an “eco-system of models”

A convergence of fields

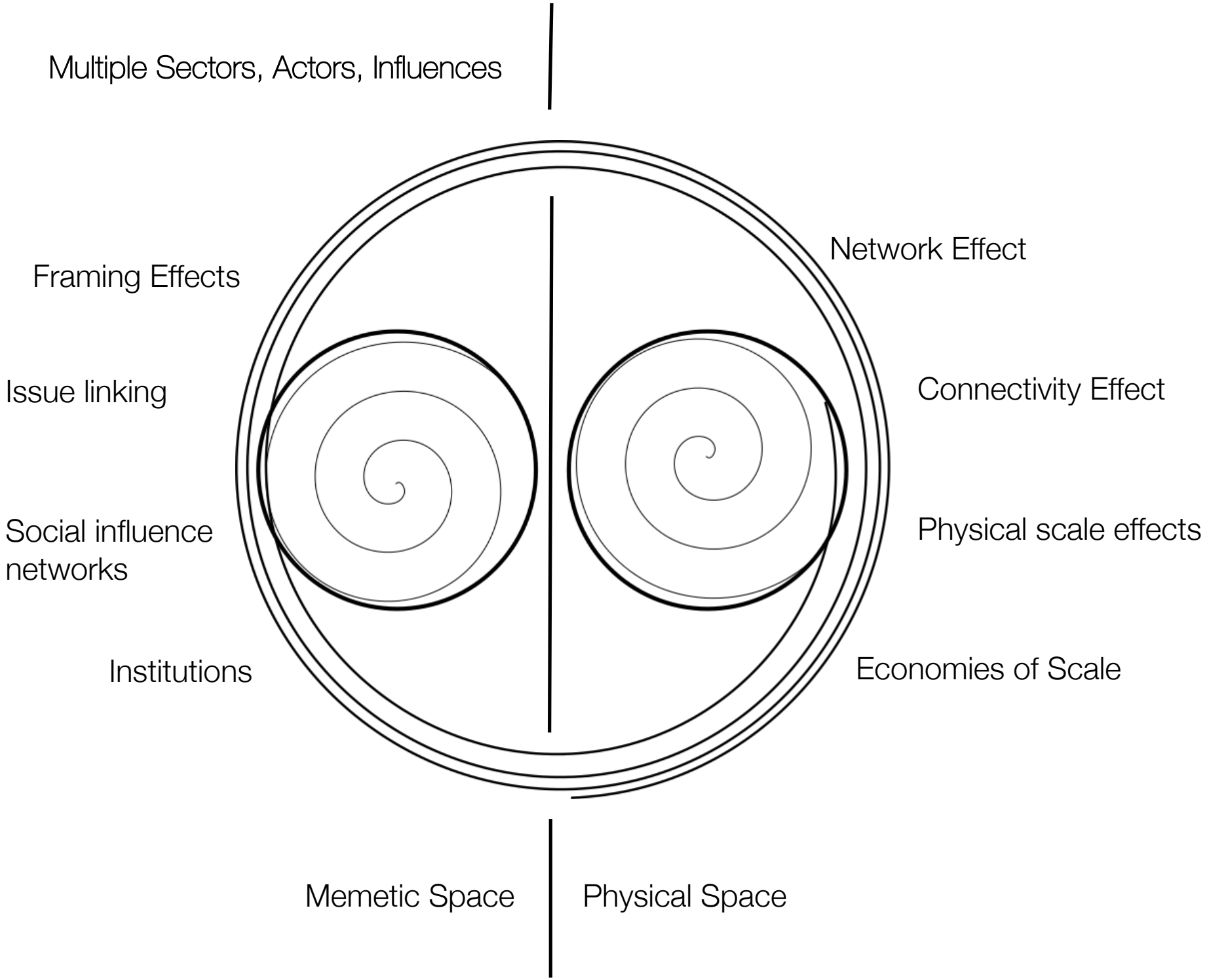


The Power of auto-catalysis

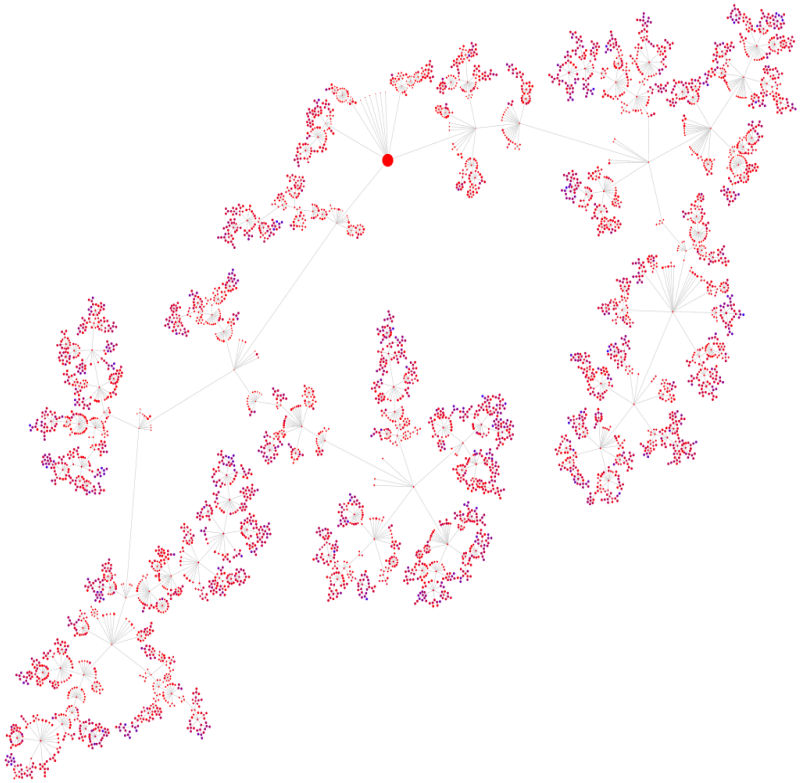
The Physical-Memetic Loop



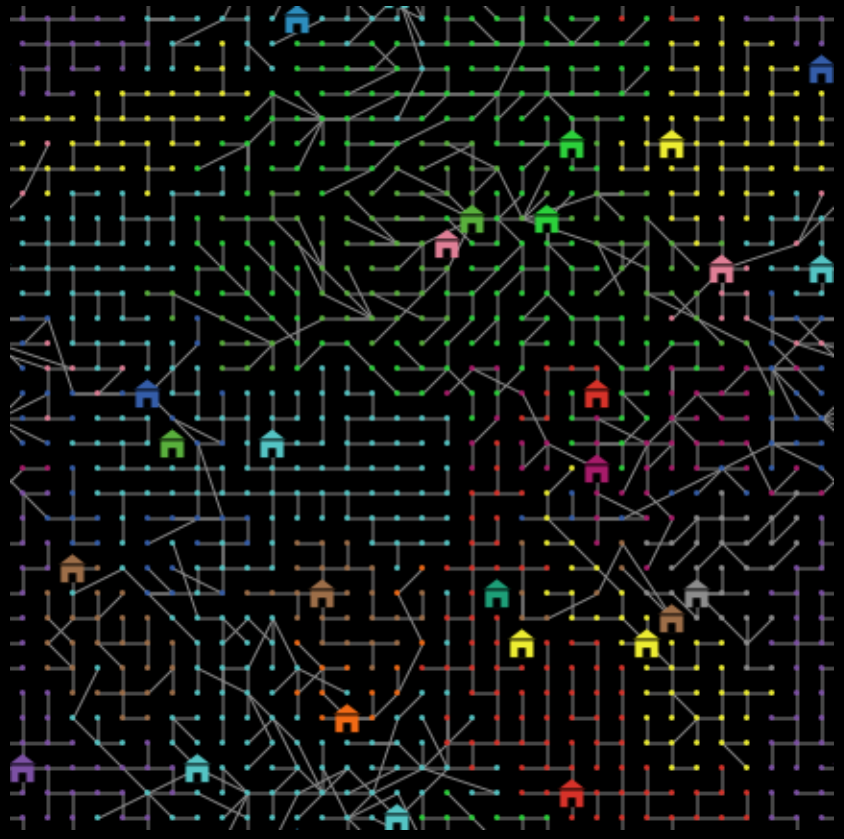
(Pinker, 2012)


Multiple Sectors, Actors, Influences
Framing Effects
Network Effect
Issue linking
Connectivity Effect
Social influence networks
Physical scale effects
Institutions
Economies of Scale
Memetic Space
Physical Space

A Generic Model of Infrastructure System Evolution

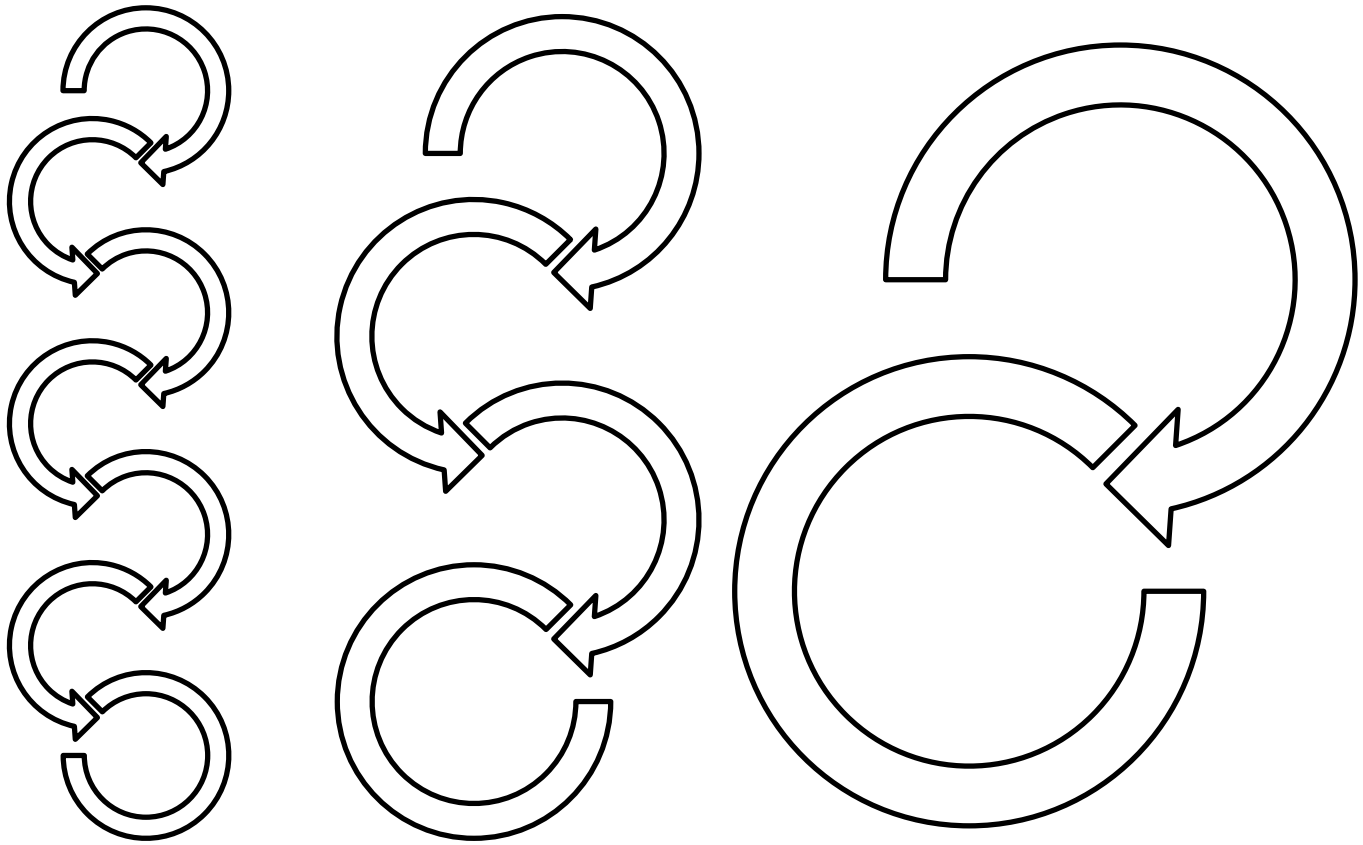


Memetic space



Exergy space

Timescales of Change

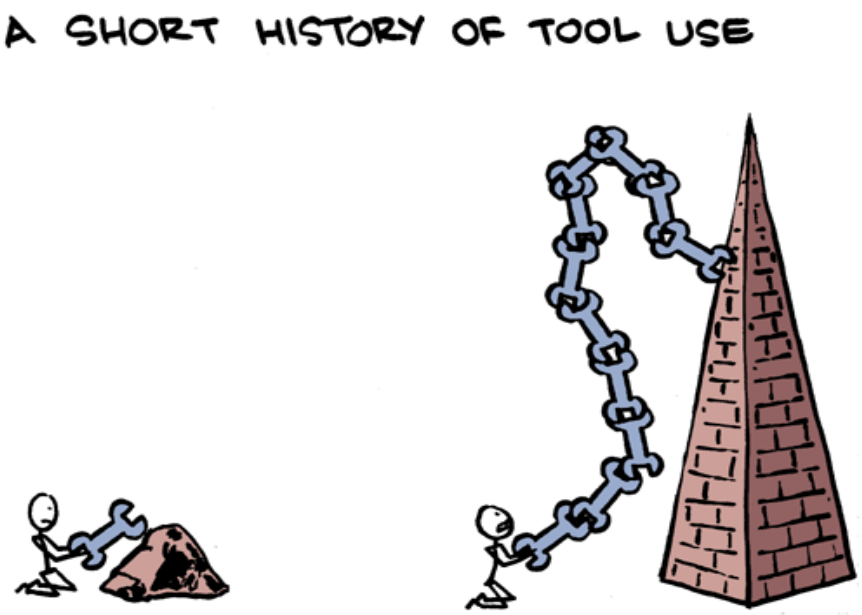


Companies Climate Institutions

Technologies Infrastructures Culture

Thank You!

alexander.otto@ouce.ox.ac.uk

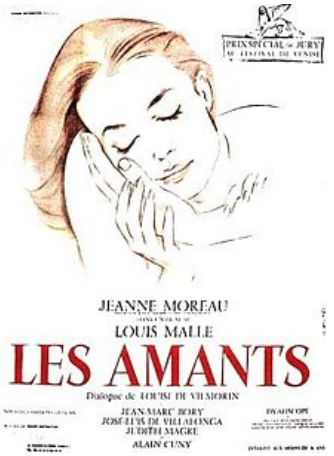


What is infrastructure?

The Pornography Definition

I shall not today attempt further to define the kinds of material I understand to be embraced within that shorthand description ["hard-core pornography"]; and perhaps I could never succeed in intelligibly doing so. But **I know it when I see it**, and the motion picture involved in this case is not that.

—Justice Potter Stewart,
Concurring opinion in Jacobellis v. Ohio 278 U.S. 184 (1964)



Part I

What is integrated assessment?

Part I

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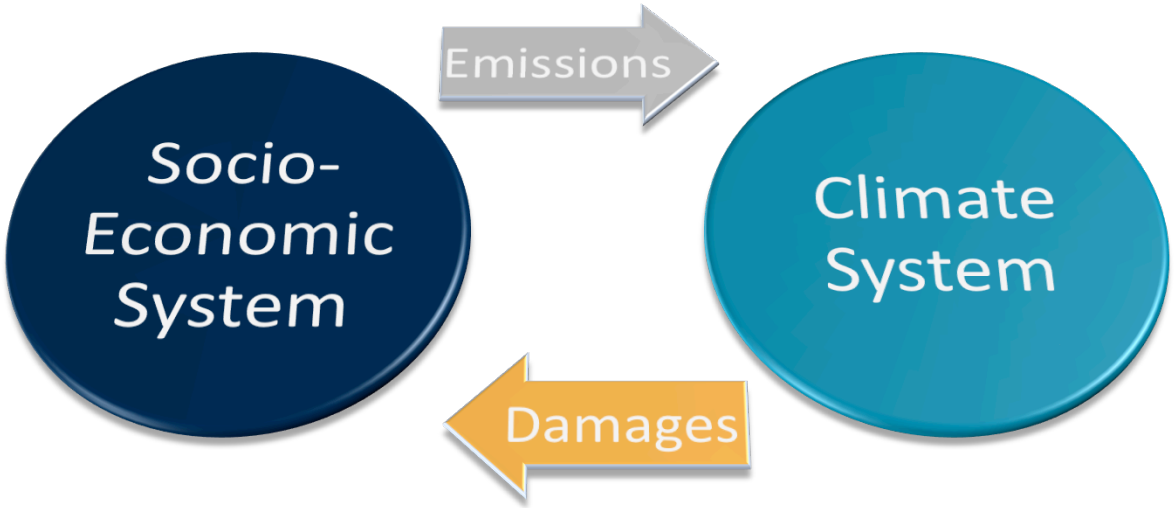
What is integrated assessment?

What is integrated assessment

Integrating knowledge from different disciplines into a single framework

Aims to provide useful information for policy makers by **assessing** policy options



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The Climate Scientist's perspective

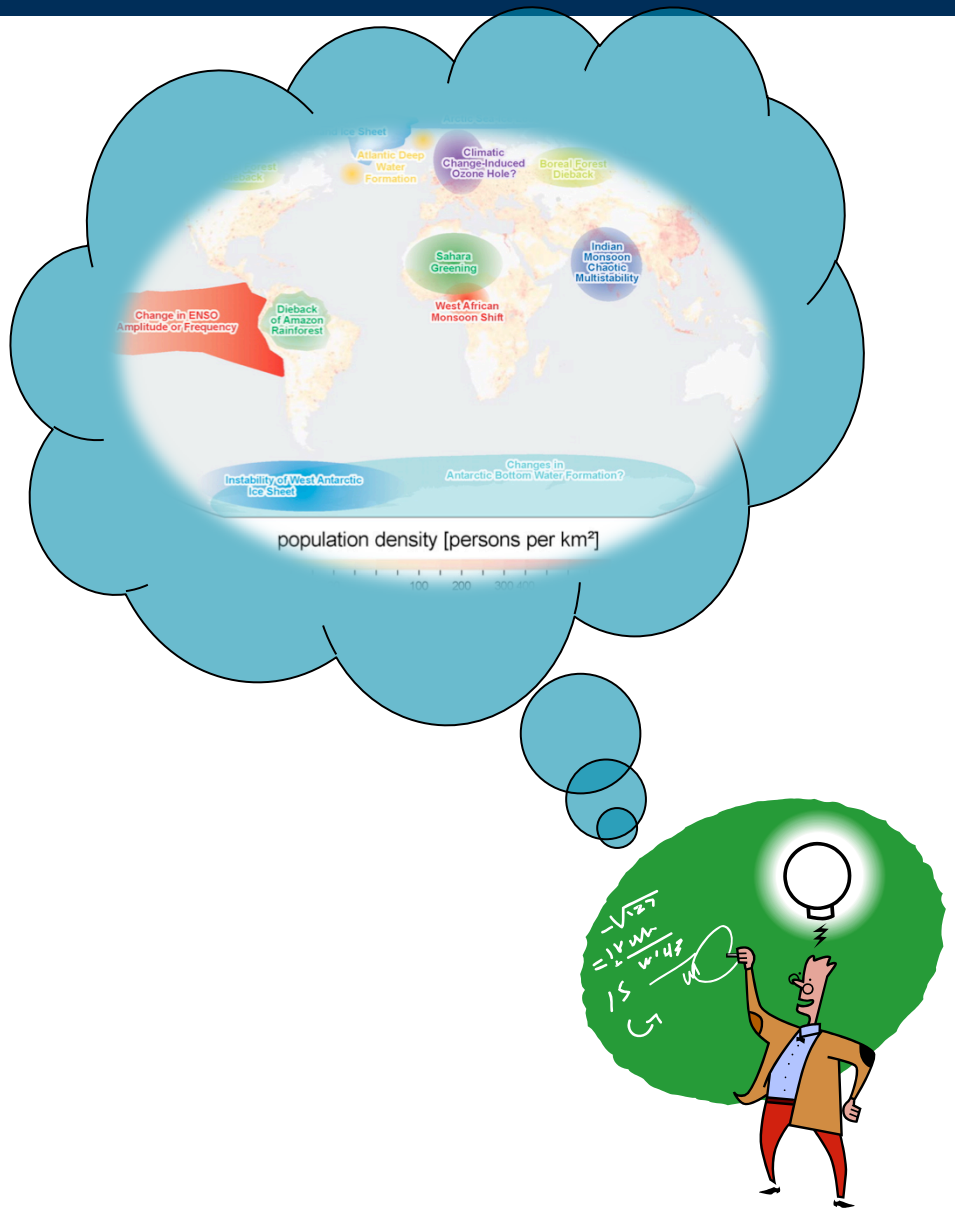
The Earth-System...

... is vastly complex...

... with massive interactions across all scales...

... with non-linear dynamics, and potentially abrupt transitions...

... combined with huge uncertainties.



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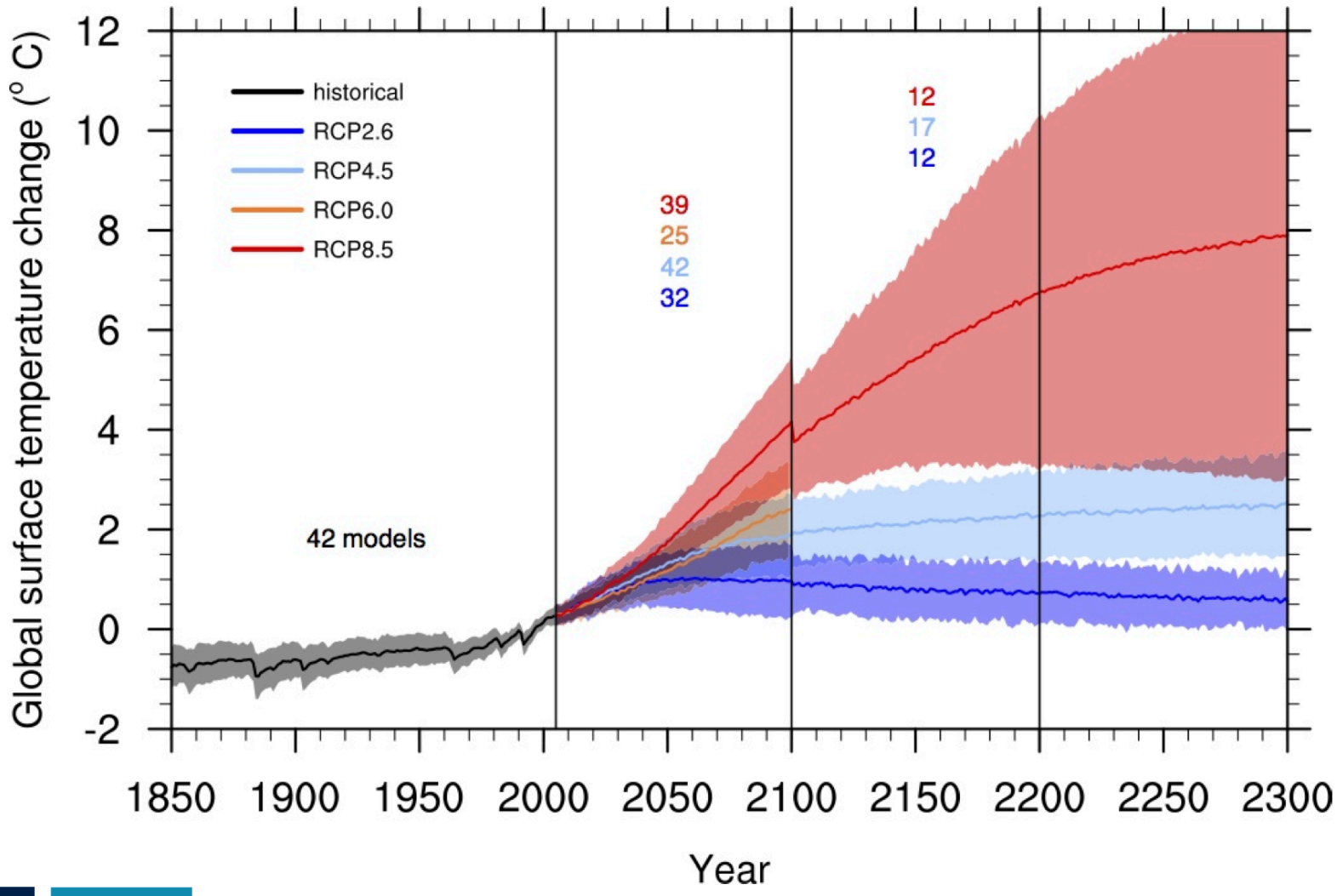
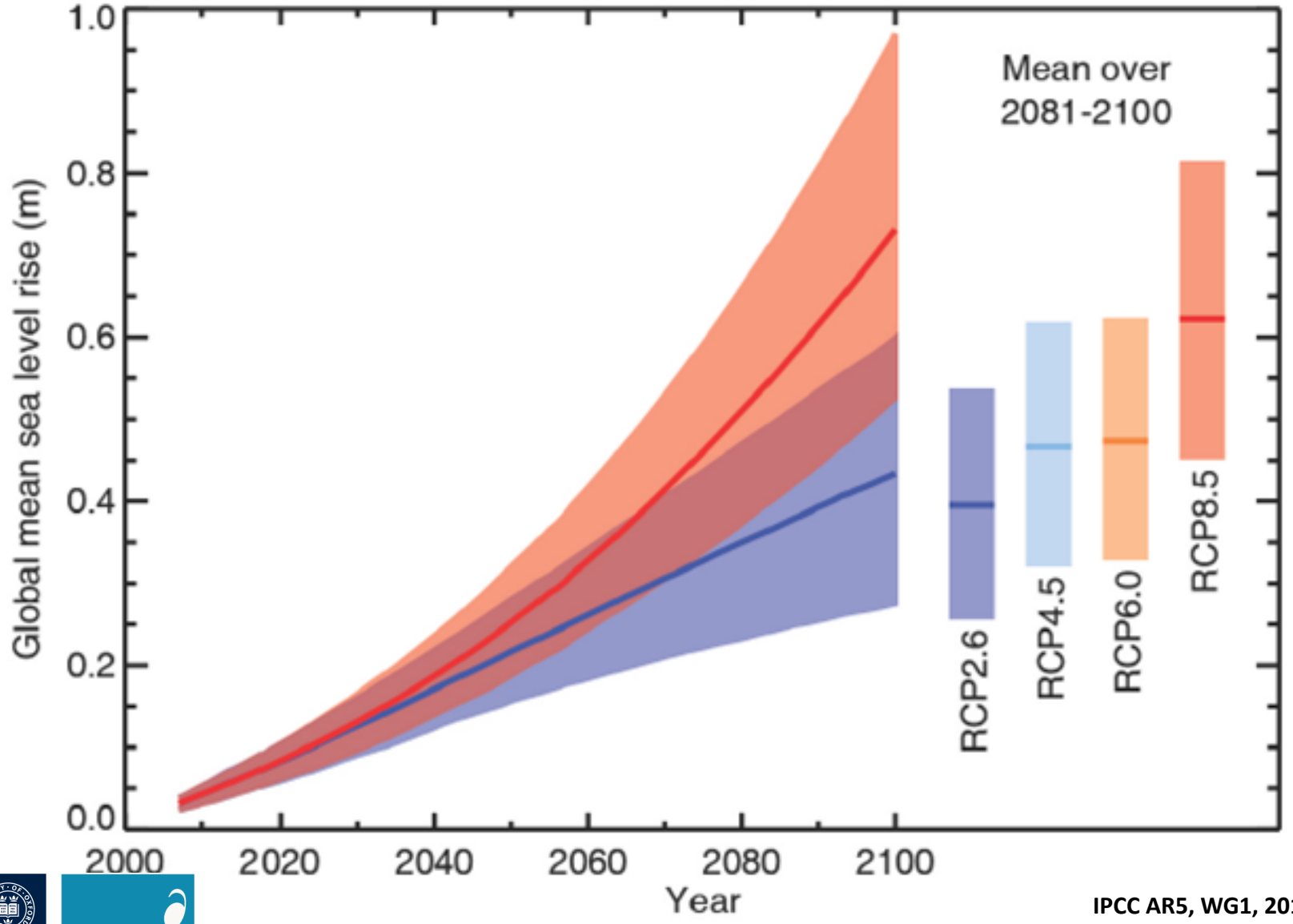
Global surface temperature change and uncertainty



IPCC AR5, WG1, 2013

Global mean sea level rise and uncertainty



IPCC AR5, WG1, 2013

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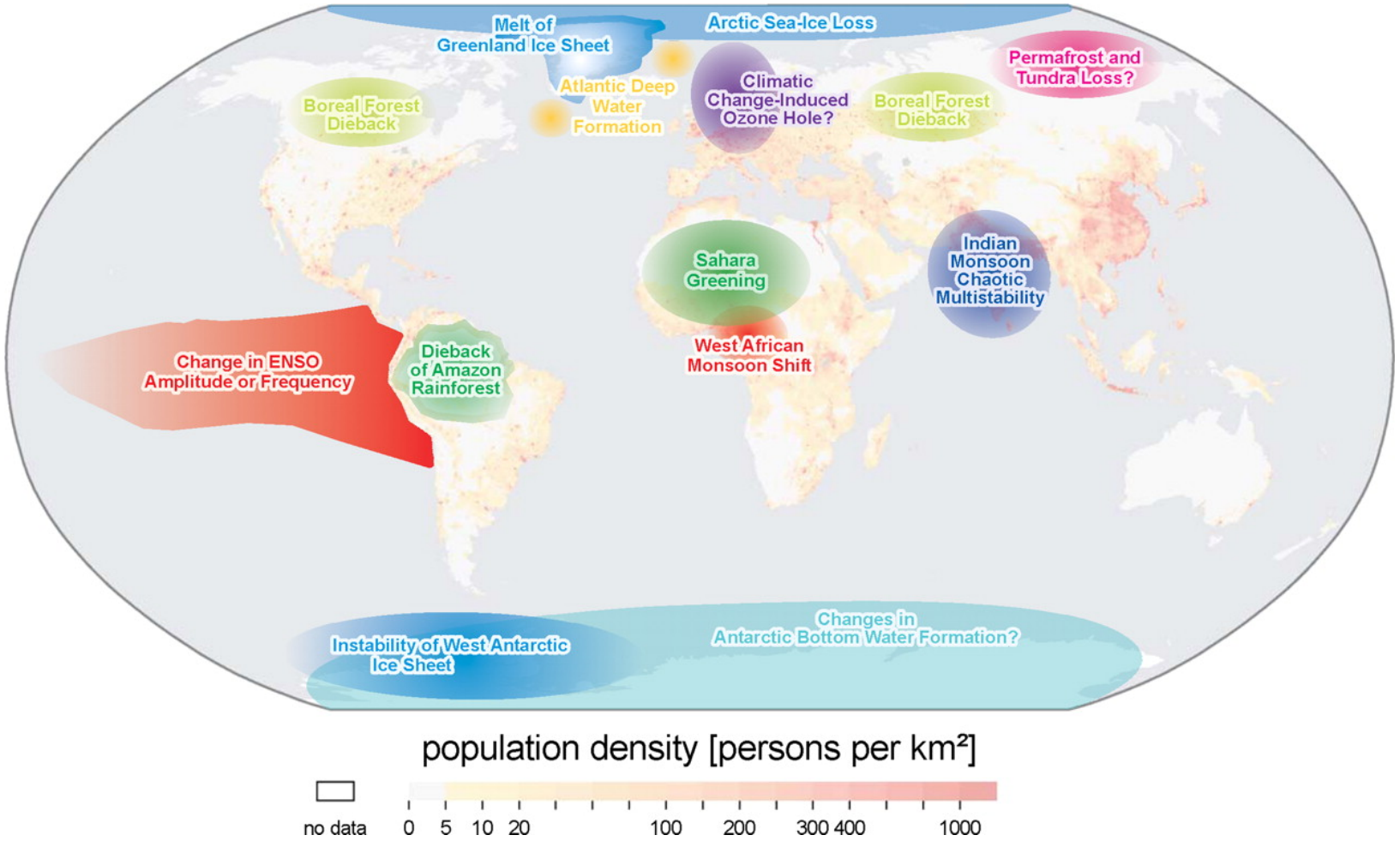
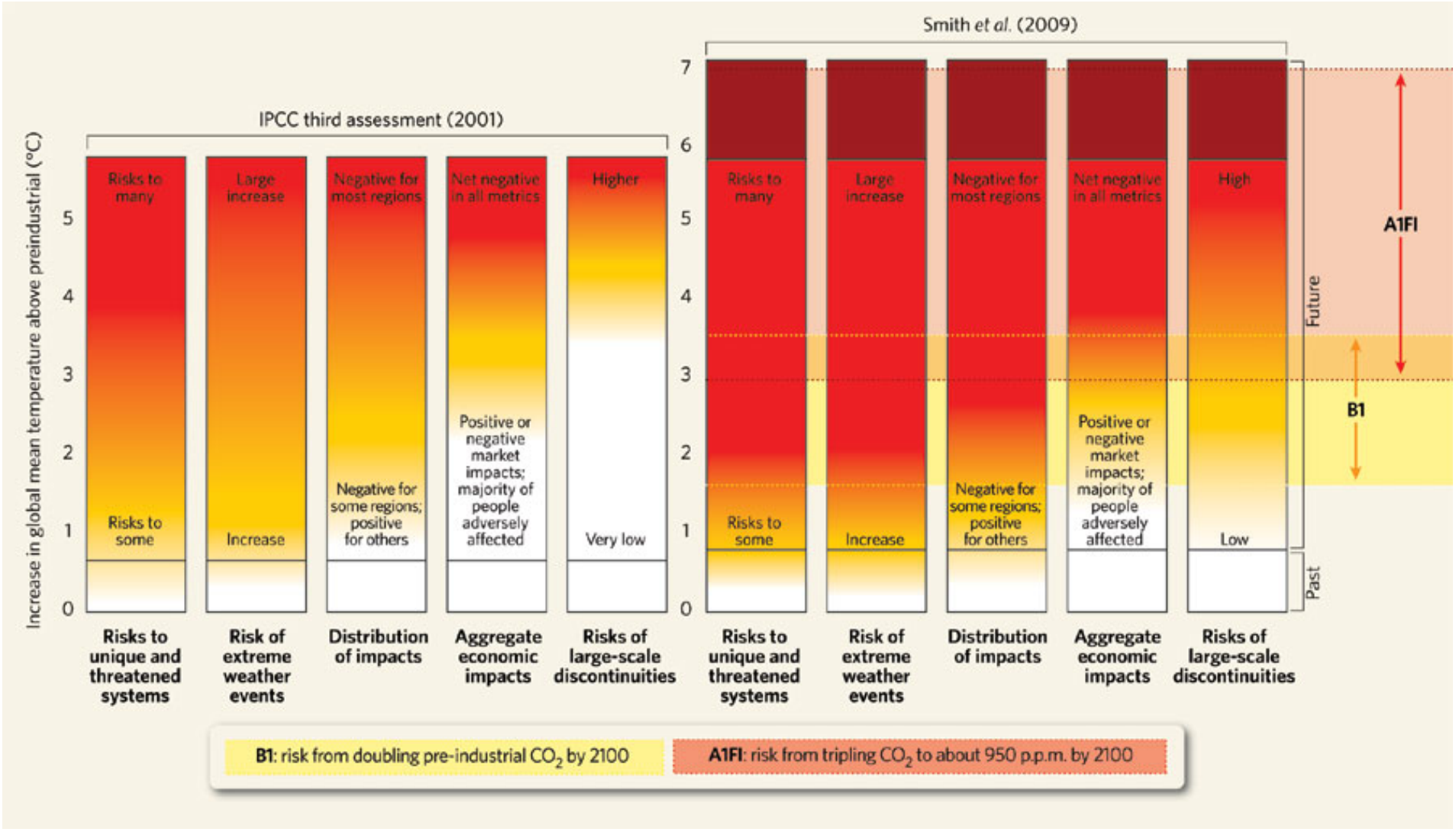
Tipping points and non-linearities



Lenton T M et al. PNAS 2008;105:1786-1793

Increasing risk of climate change

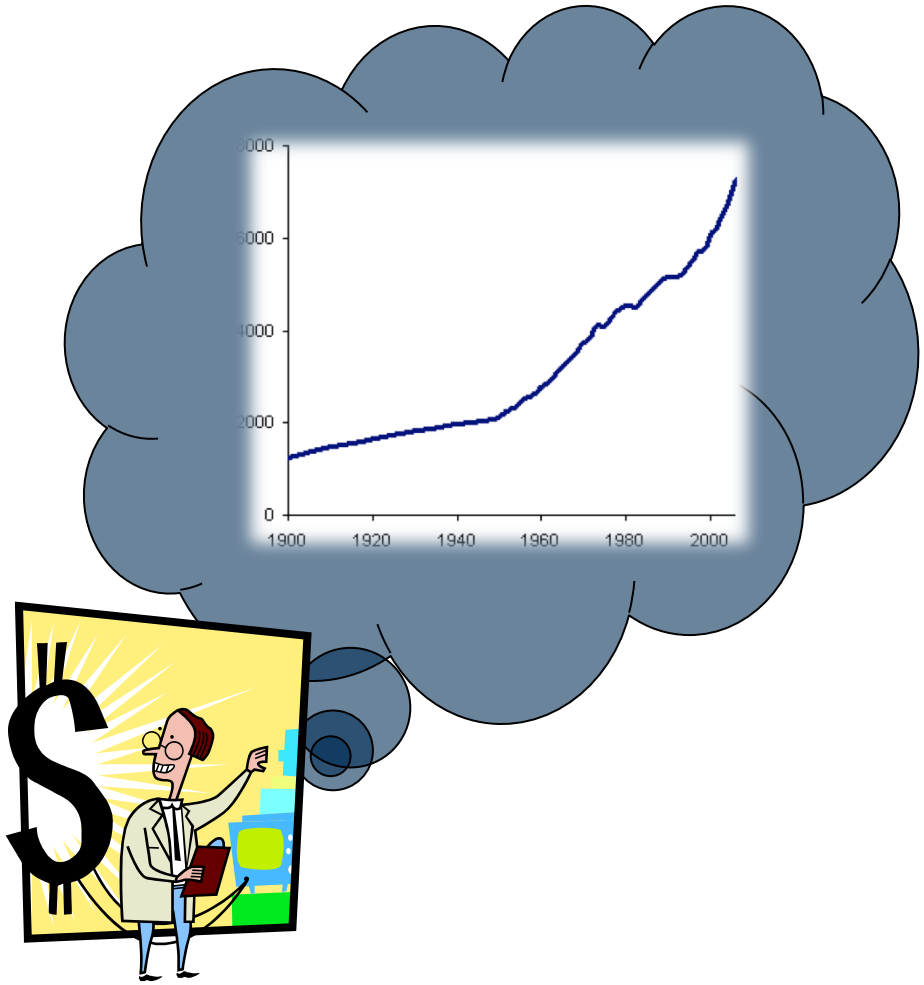


Stephen Schneider, *Nature* **458**, 1104-1105(30 April 2009)

Adaptation limits

Dutch cow ready for sea level rise?

The (neoclassical) Economist's perspective



The global economy…

… is growing very robustly…

… characterised by substitution of scarce resources through technological progress…

… has "just" to be informed about externalities like climate change by appropriate price signals.

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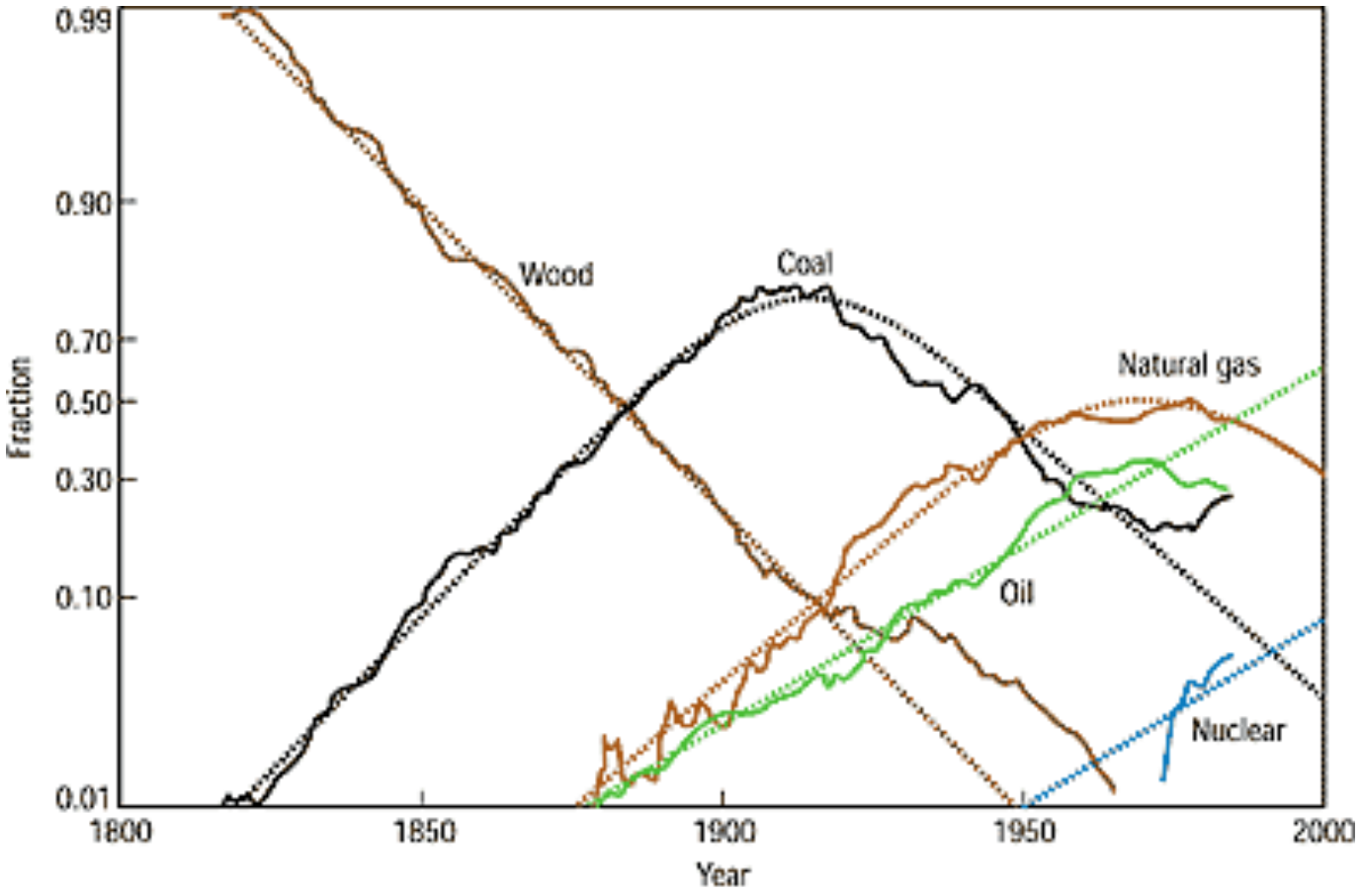
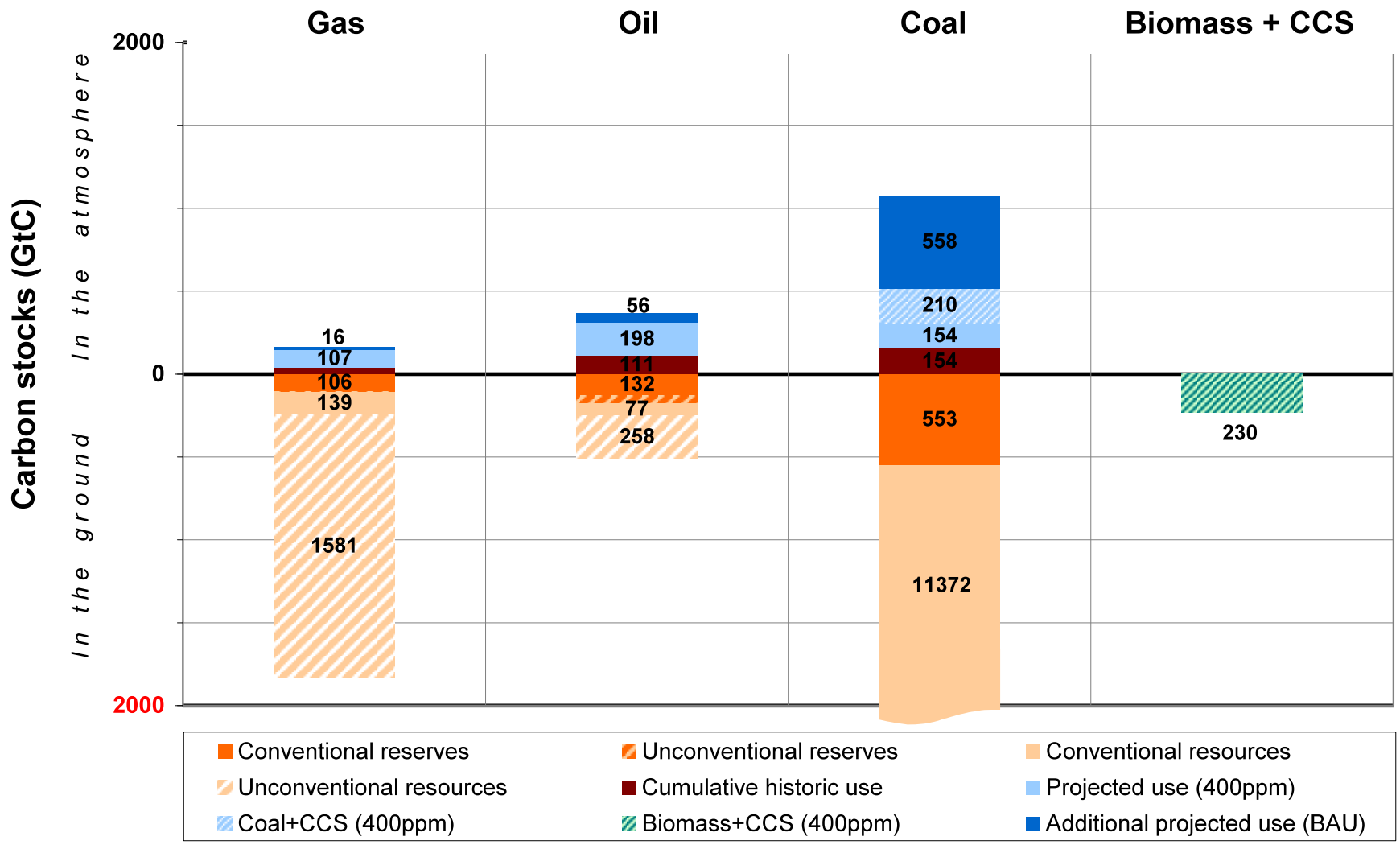
Substitution of inputs



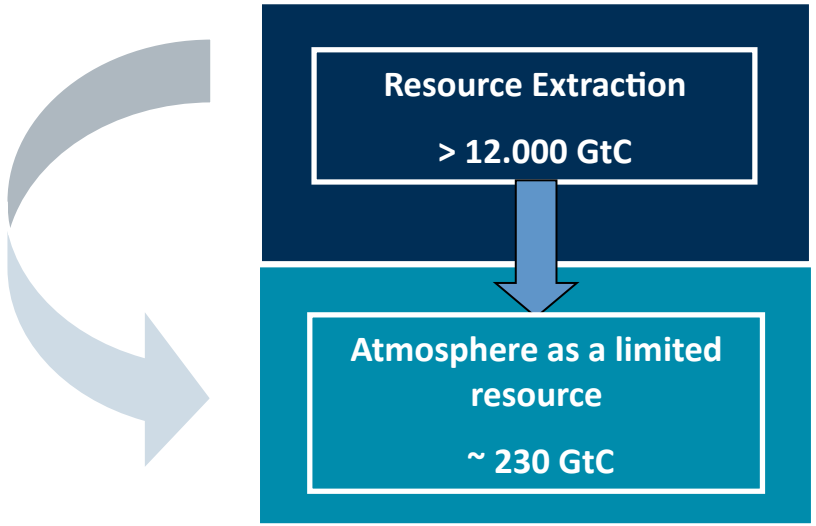
Nakicenovic, N. In *Cities and Their Vital Systems: Infrastructure Past, Present, and Future;* Ausubel, J. H., Herman, R., Eds.; National Academy Press: Washington, DC, 1988; pp 175–231.

Devaluation of fossil resources



Kalkuhl & Edenhofer 2010

Devaluation of fossil resources



- Atmosphere is a scarce resource – fossil carbon is not
- How to determine scarcity price on carbon?
  - Assigning property rights according to the scarcity of the atmosphere
  - Distributing the emission rights according to principles of fairness and justice

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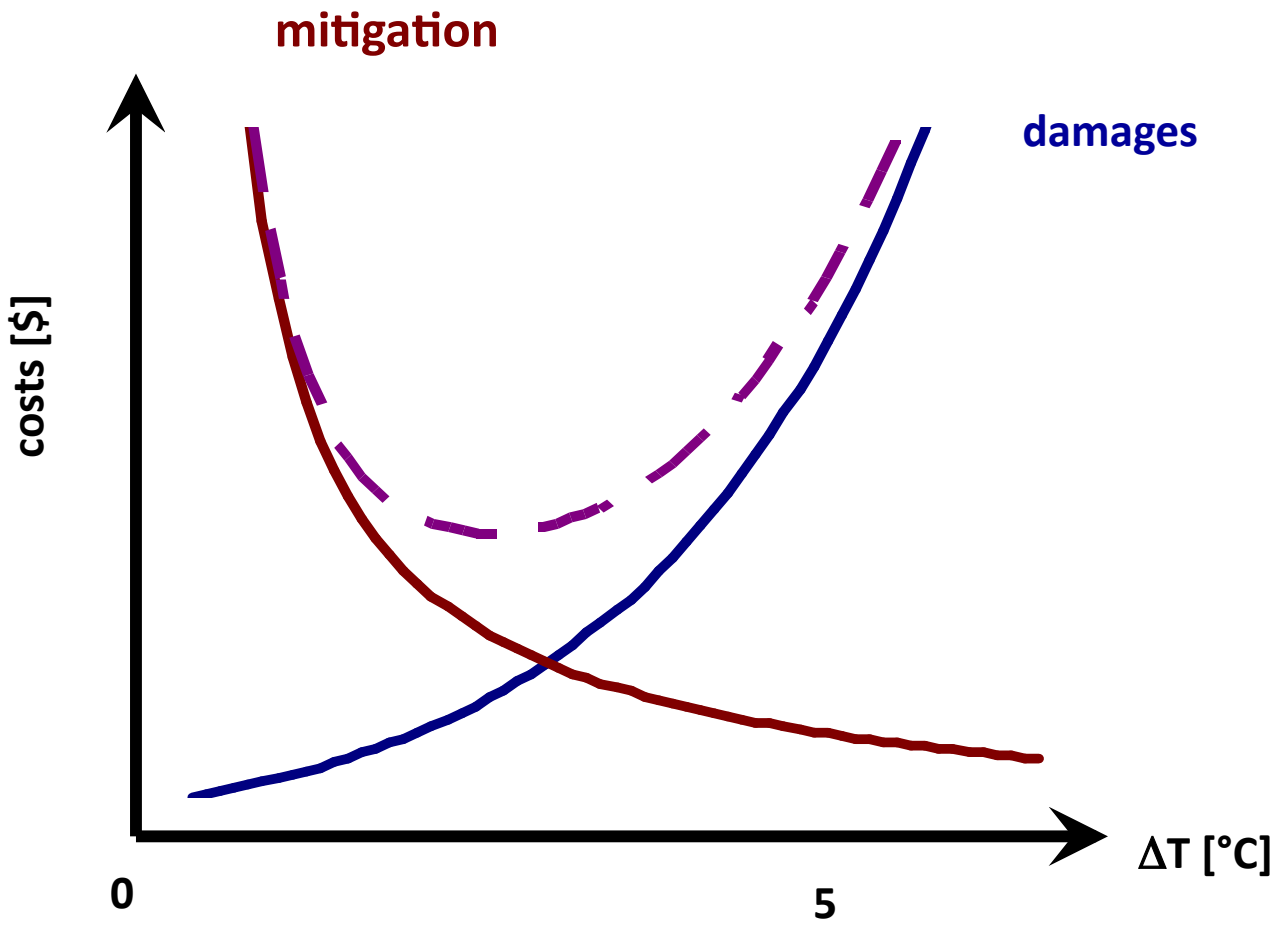
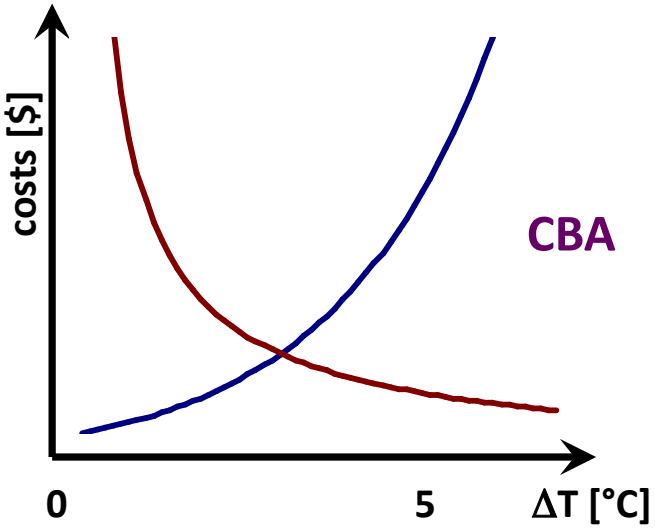
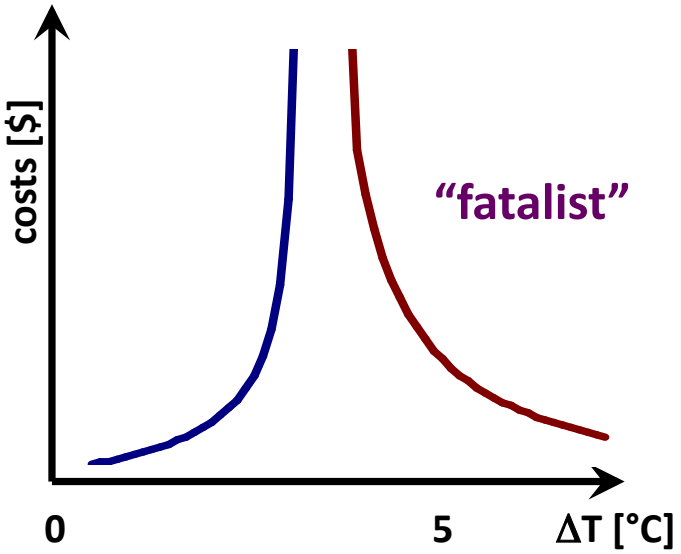
Cost Benefit analysis



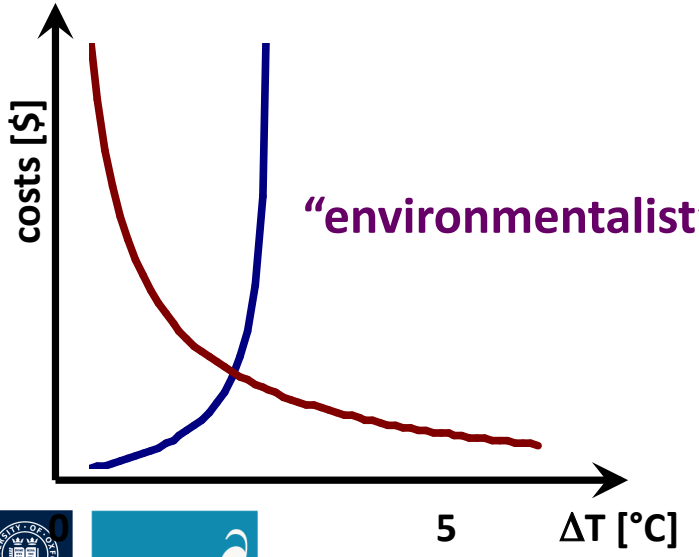
Framing different perceptions of Climate Change within CBA



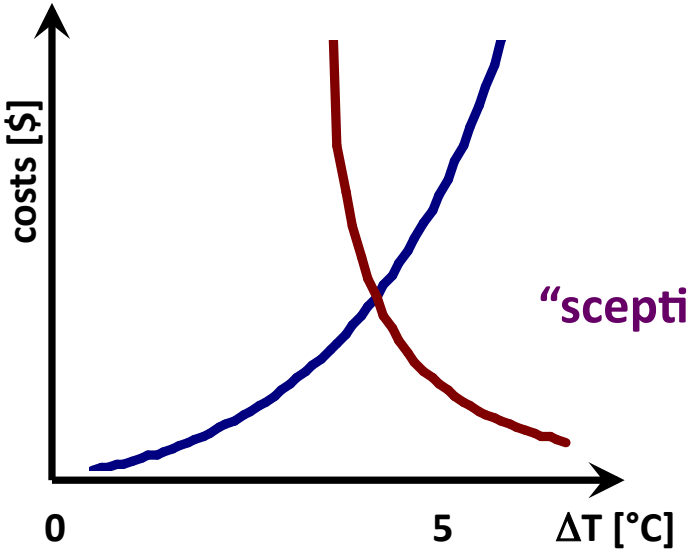
CBA



"fatalist"



"environmentalist"



"sceptic"

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Part II

Integrated Assessments of Climate Change

Questions for an IA of Climate Change

What is the optimal trade-off between mitigation and adaptation?

What is the social cost (net benefit) of a specific climate regime?

What is the relative importance of different mitigation options?

What is the (mitigation) cost of climate policy and how is it distributed?

Who are winners and losers of different climate regimes?

What are efficient strategies to implement climate mitigation policies?

How can we stabilise a climate coalition?

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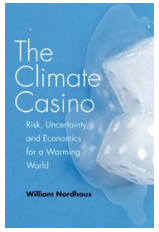
Examples of Integrated Assessments

Nordhaus



Stern Review

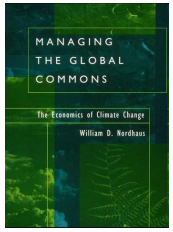
STERN review
ON THE ECONOMICS OF CLIMATE CHANGE

IPCC AR5

WG3

WG2

Bill Nordhaus



IPCC AR4
Synthesis report

1994 2000 2007 2014

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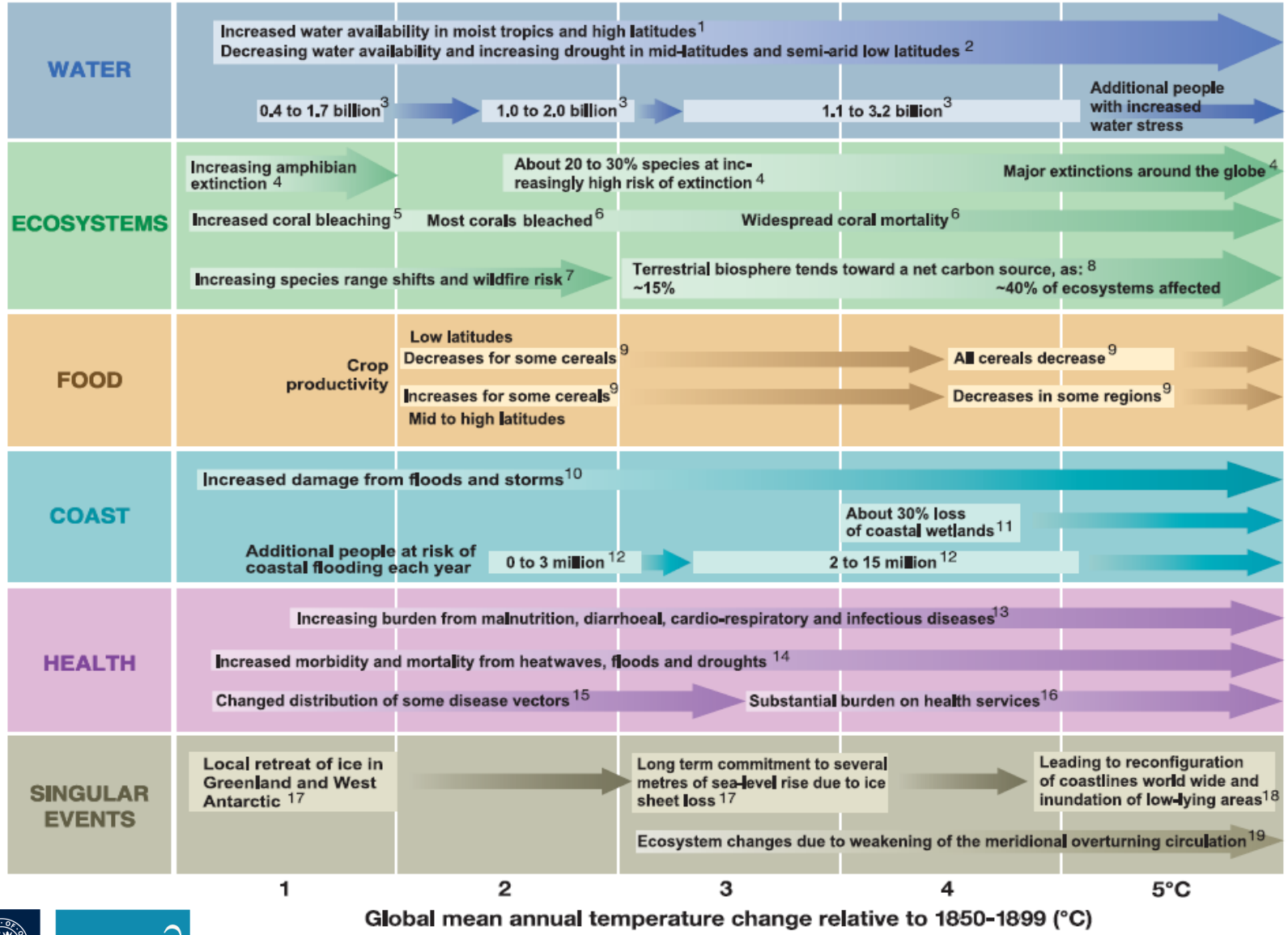
Framing different perceptions of Climate Change within CBA



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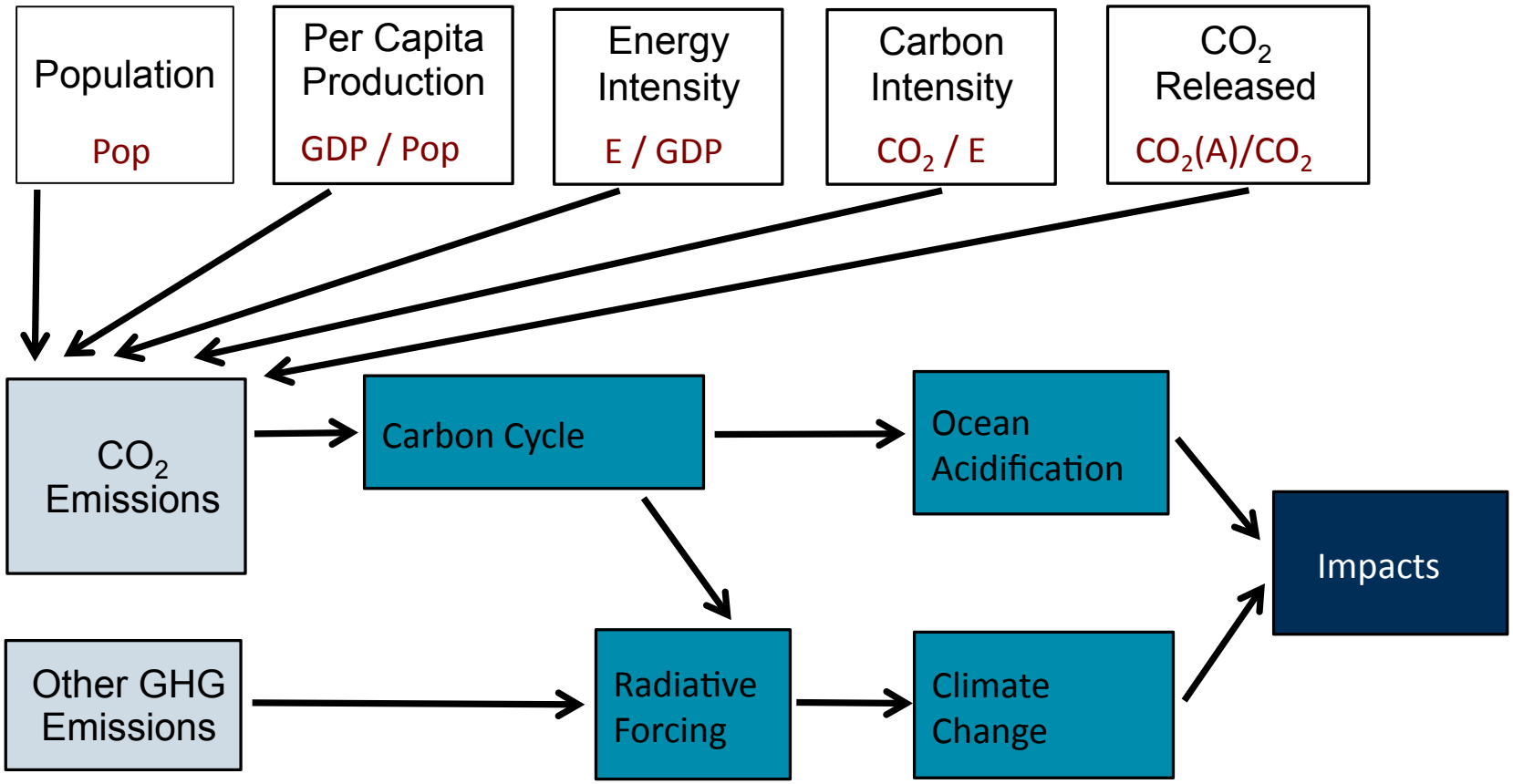
The Climate Change Cause-Effect Chain



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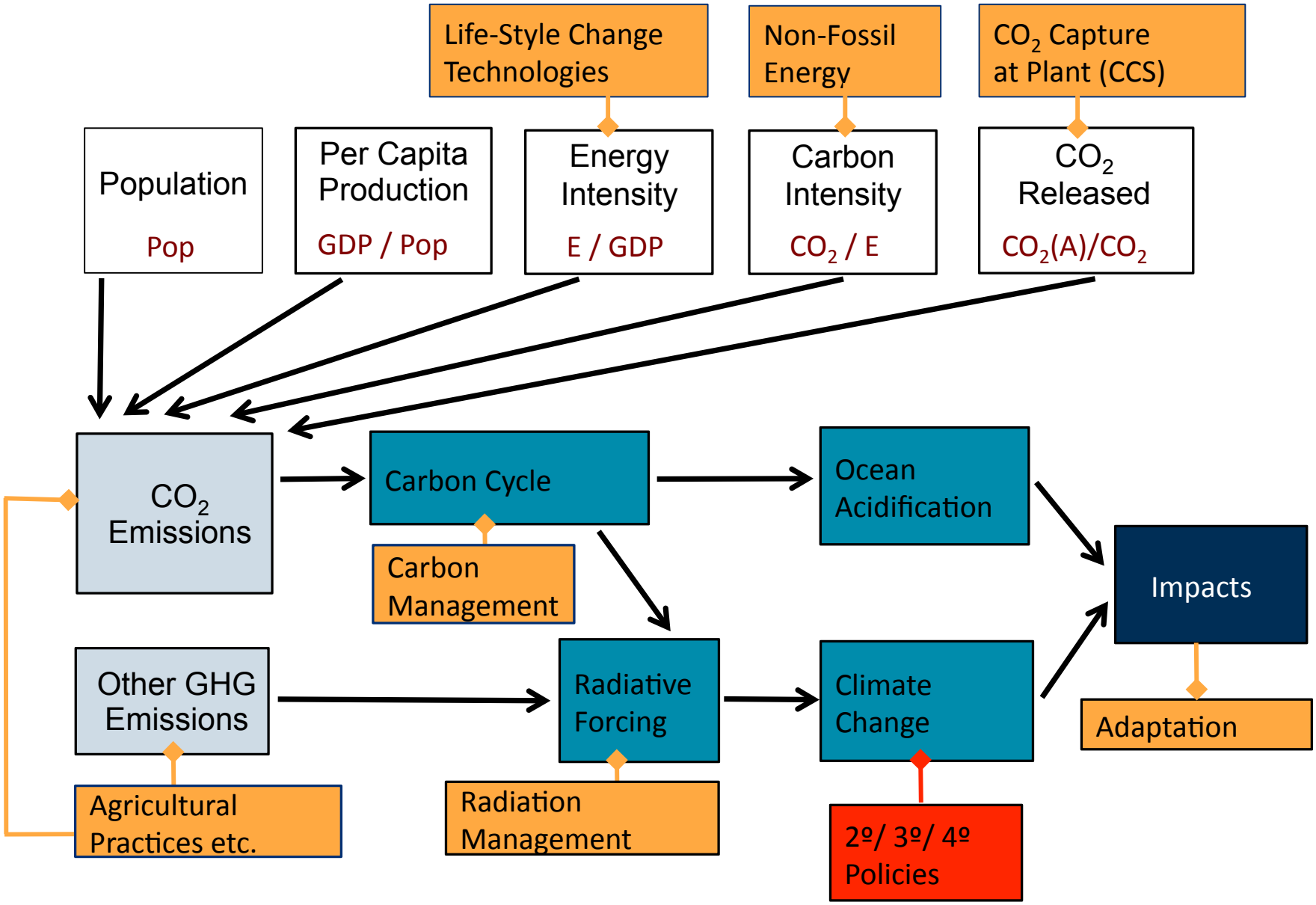
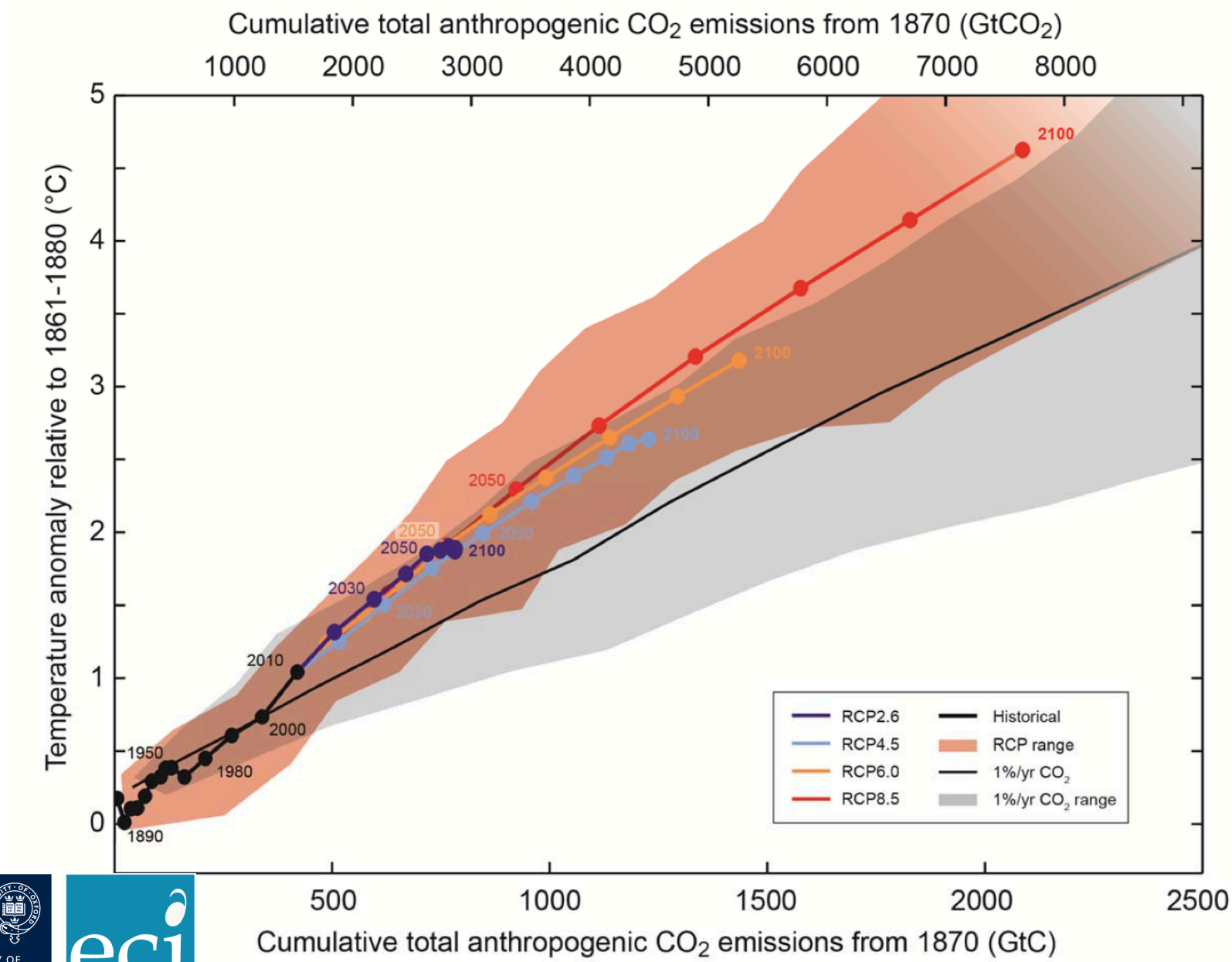
Connection points for mitigation action



The cumulative picture… allows decoupling?

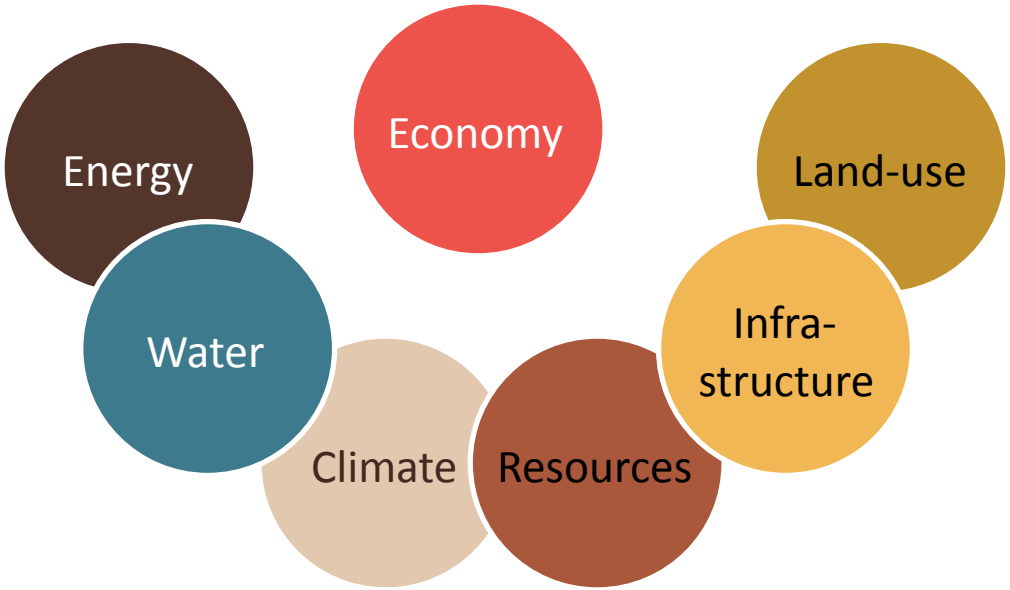


IPCC AR5, SPM

Part III

Integrated Assessment Modelling

Sectors incorporated in current IAMs



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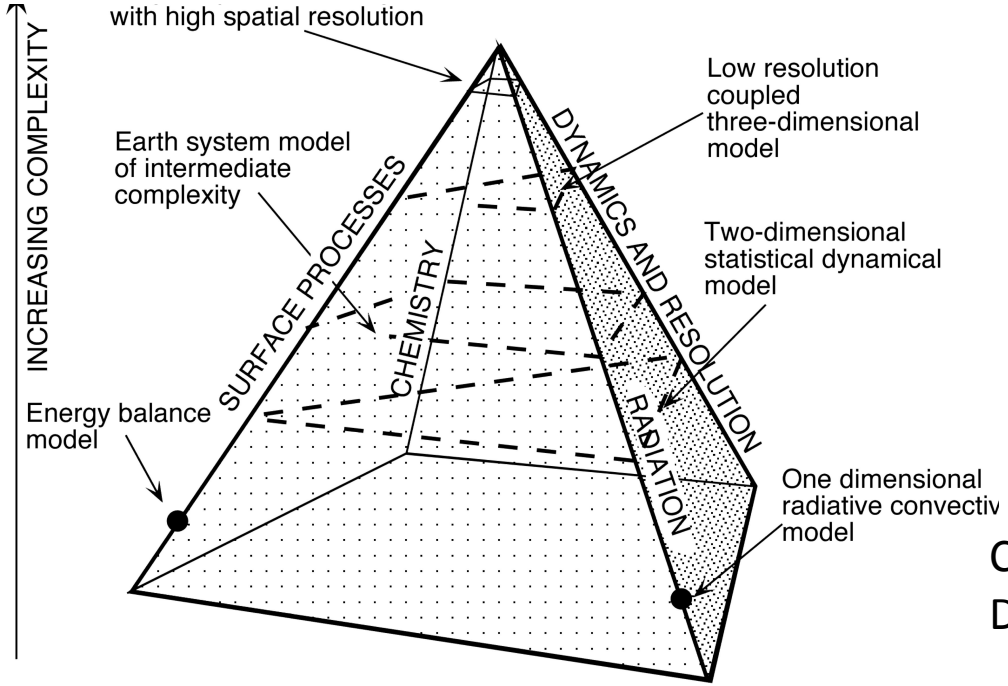
The ecosystem of models



McGuffie & Henderson-Sellers, 2005, p51

Physical Complexity

ABMs?

global land use Models (MagPie, LPMJ-ML)

Welfare Optimising

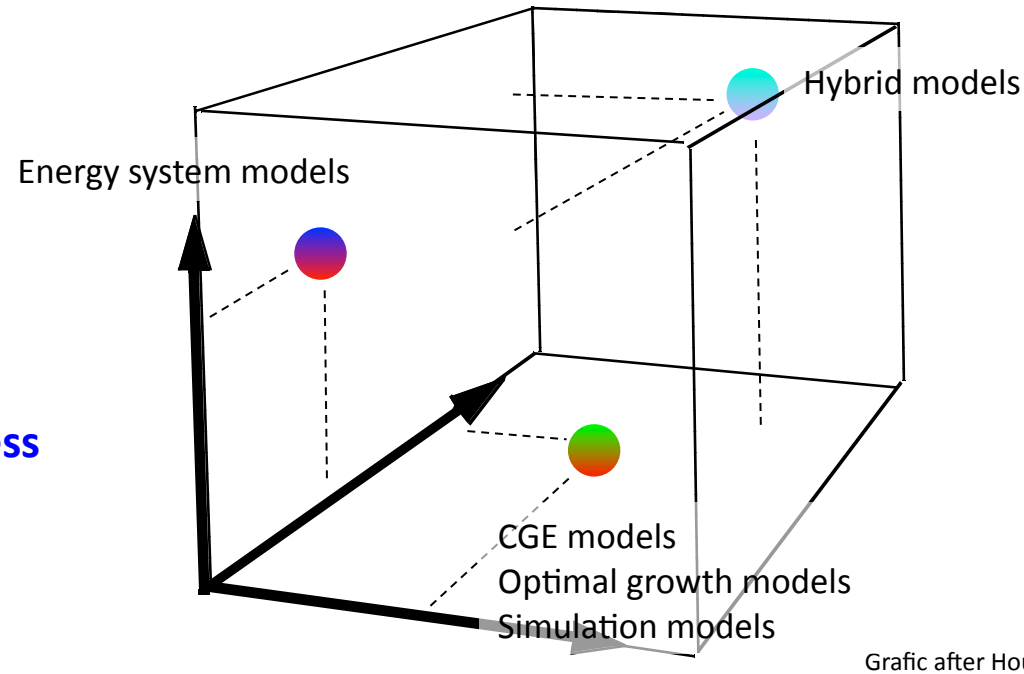
CBA – models: DICE, FUND, PAGE

CGE models

Economic Complexity

The three dimensions of modelling

Marcoeconomic completeness

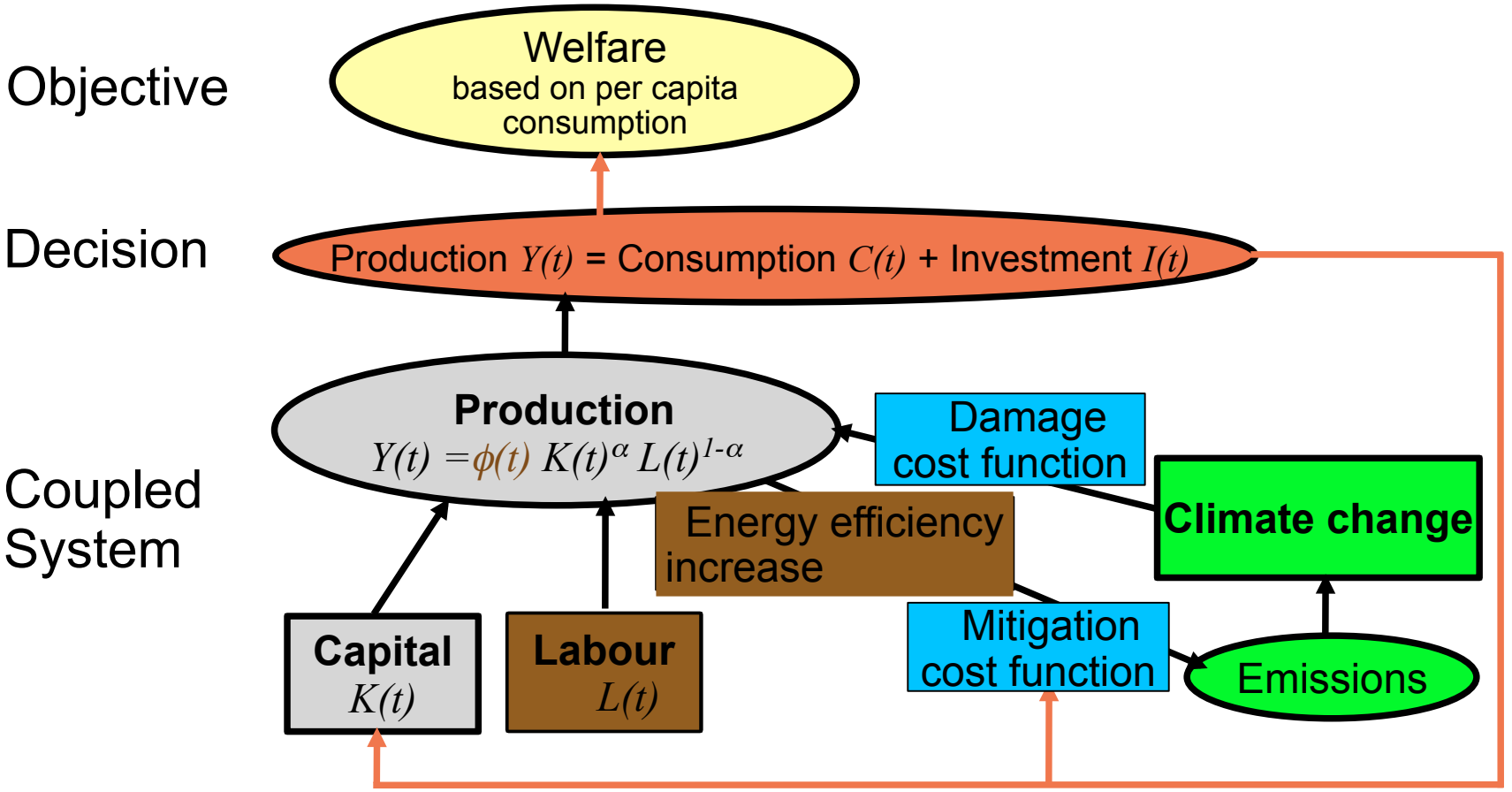


Technical explicitness

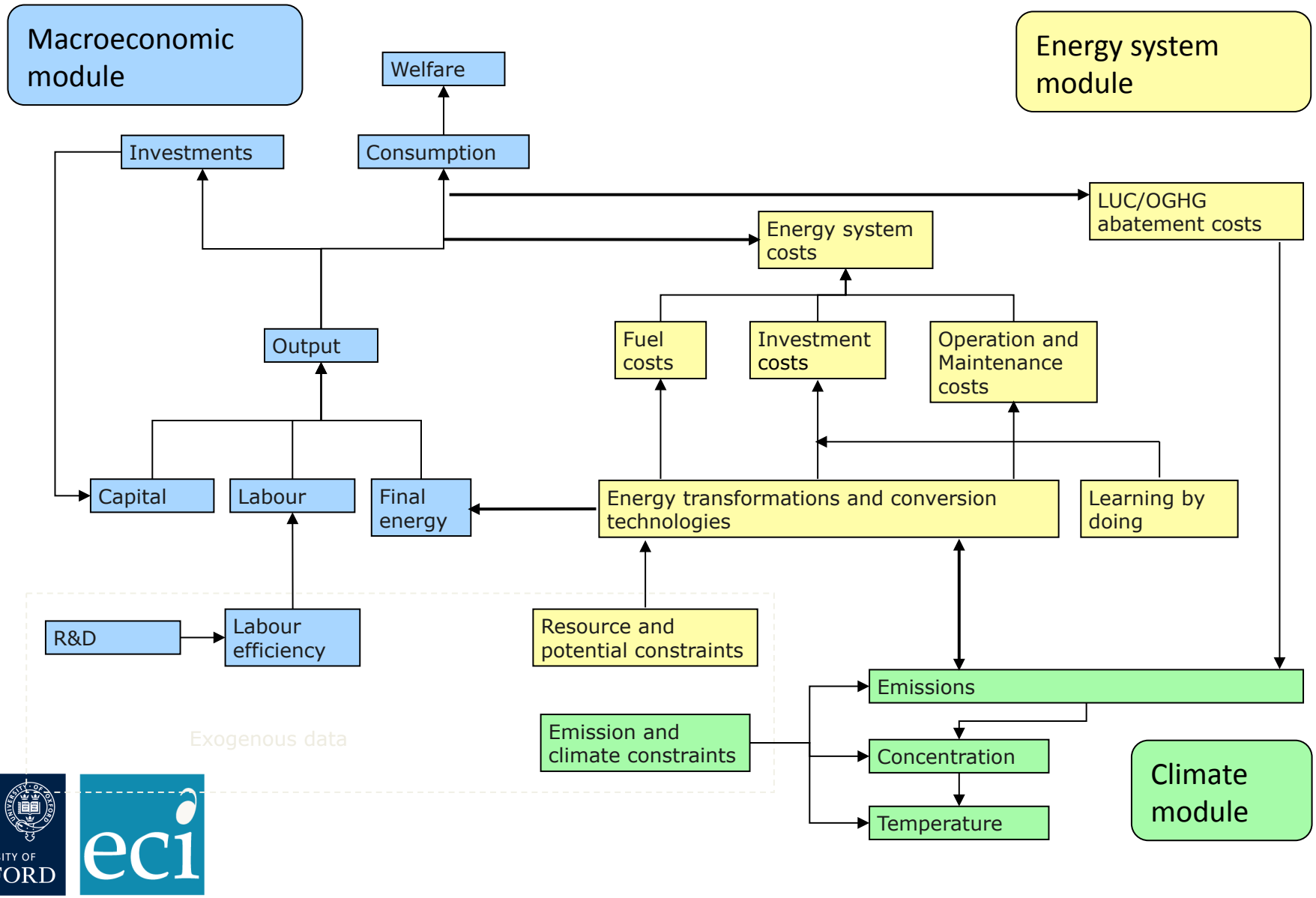
Grafic after Hourcade et al. (2006)

Macroeconomic realism

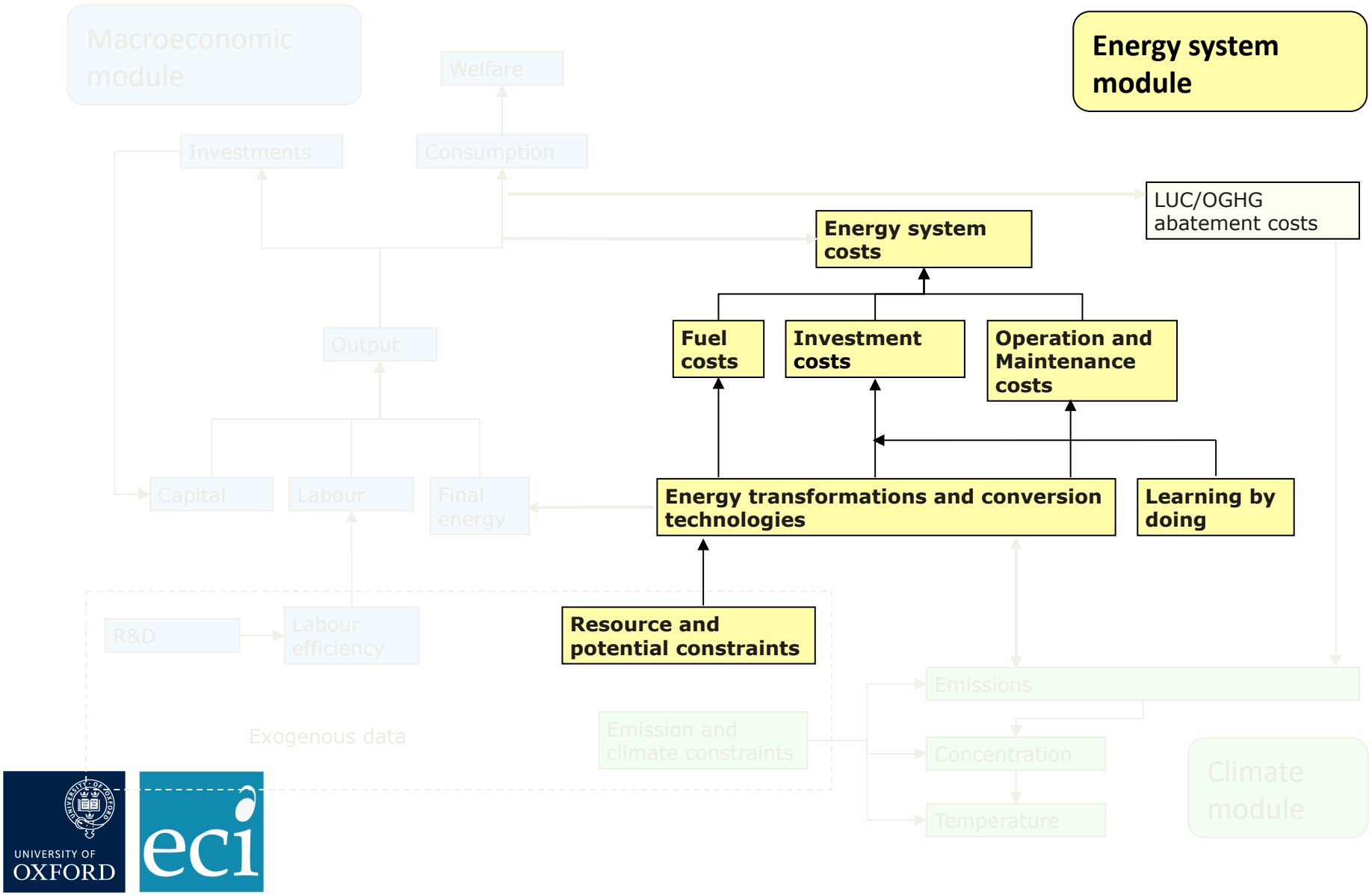
DICE model (Nordhaus, 1992)



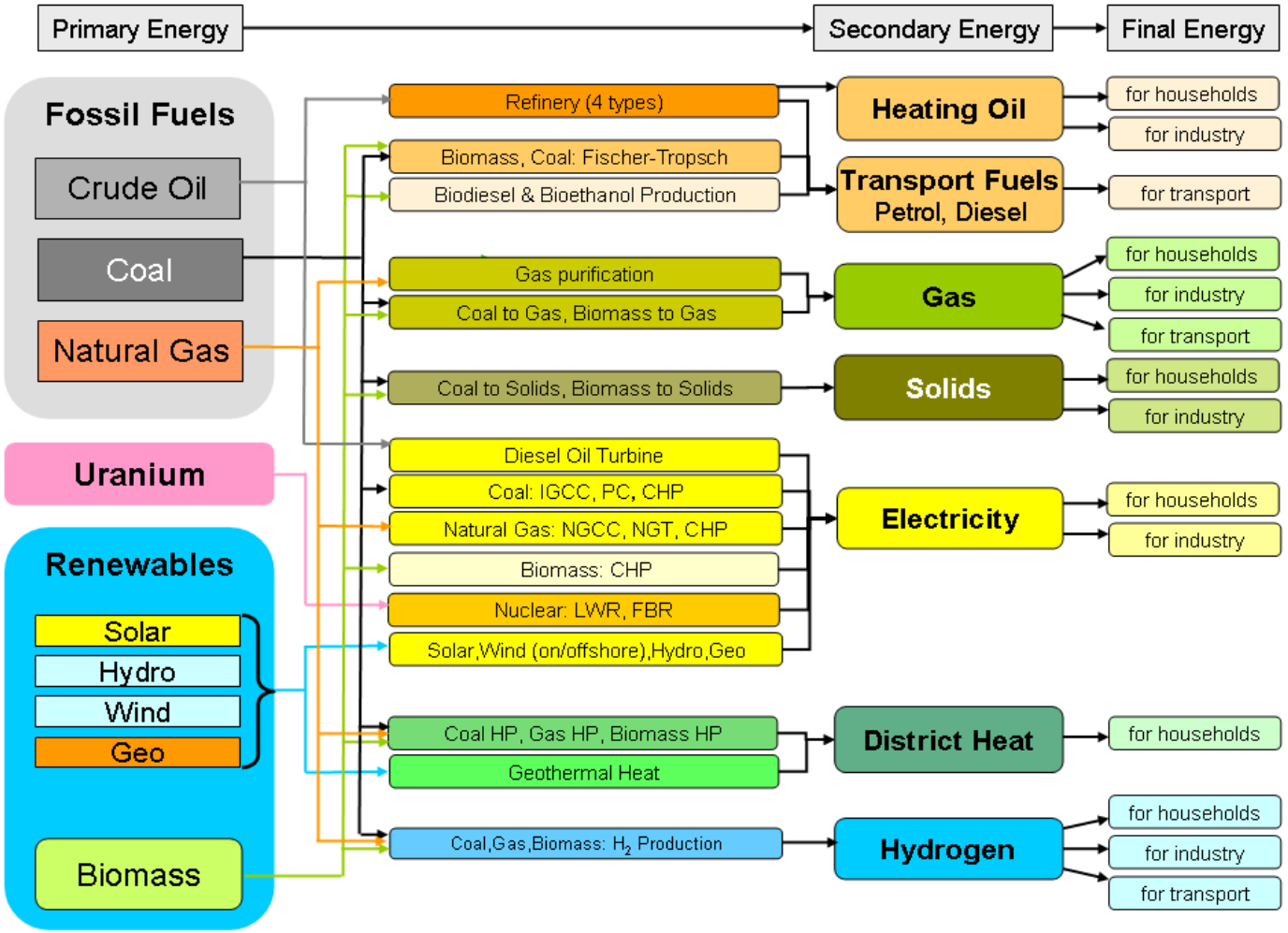
An example of an Economy-Energy-Climate model (REMIND)



An example of an Economy-Energy-Climate model (REMIND)



The energy system in REMIND



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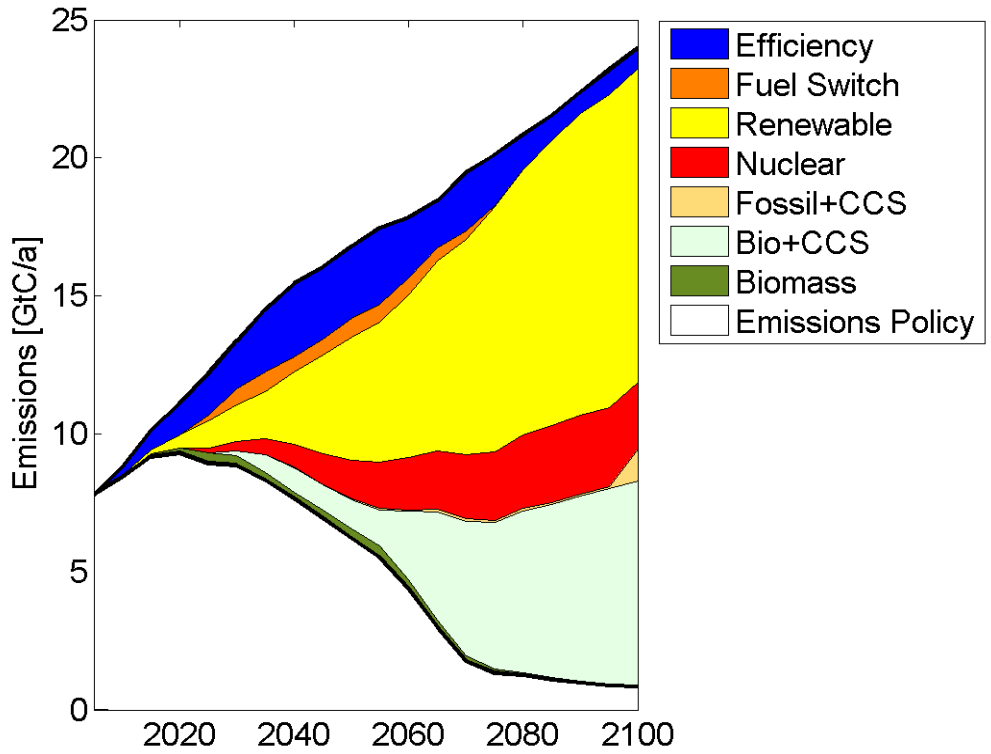
Business-as-usual vs. 2°C policy target



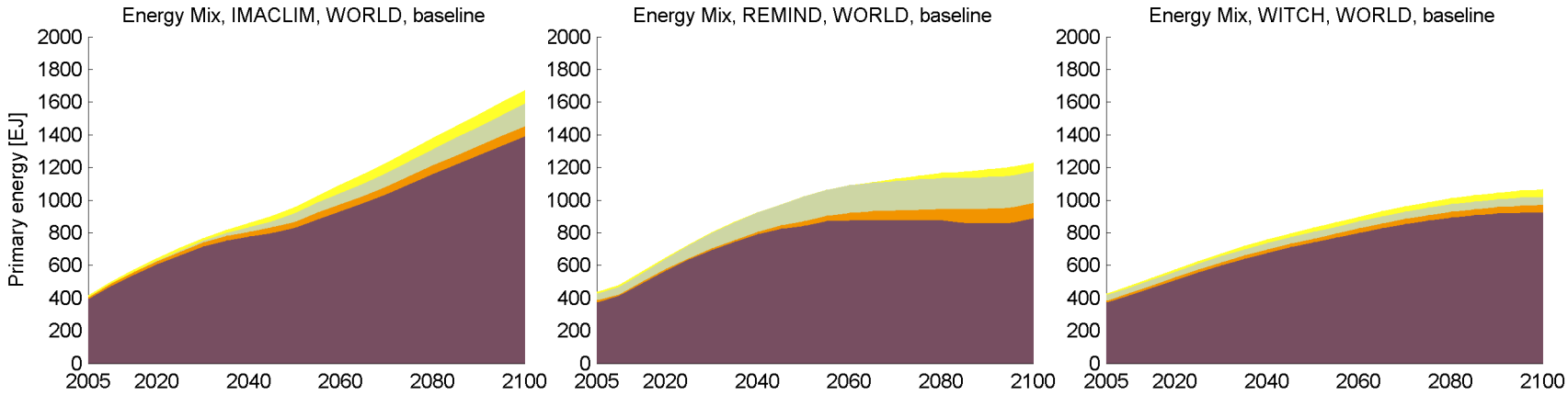
ReMIND model results
Bauer et al., 2010

Inter-model comparisons - RECIPE

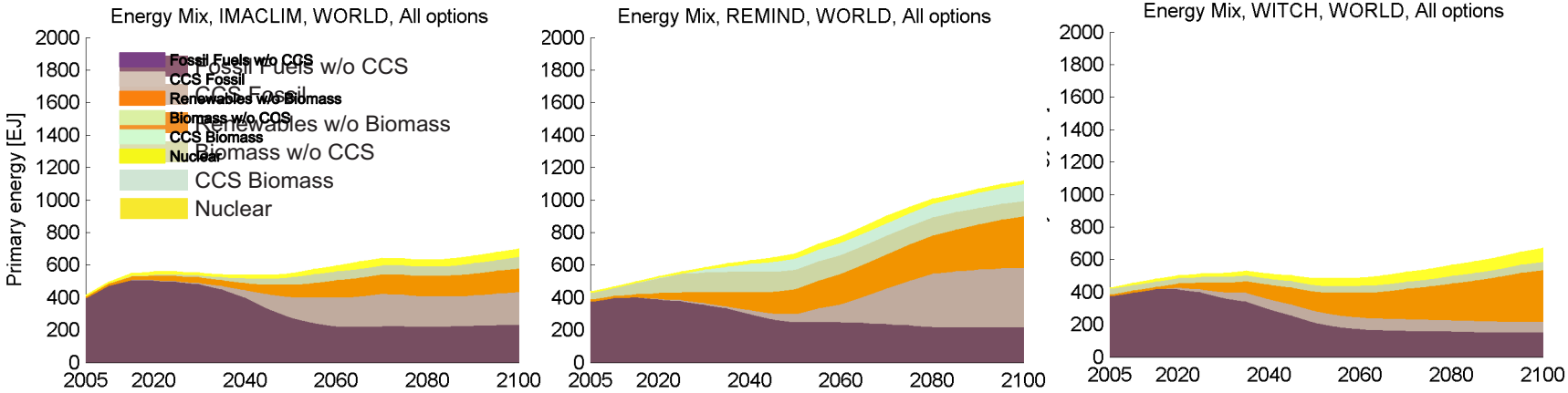
Primary Energy Mix

IMACLIM-R | **ReMIND-R** | **WITCH**

Baseline



450 ppm CO_2



Luderer et al., 2009

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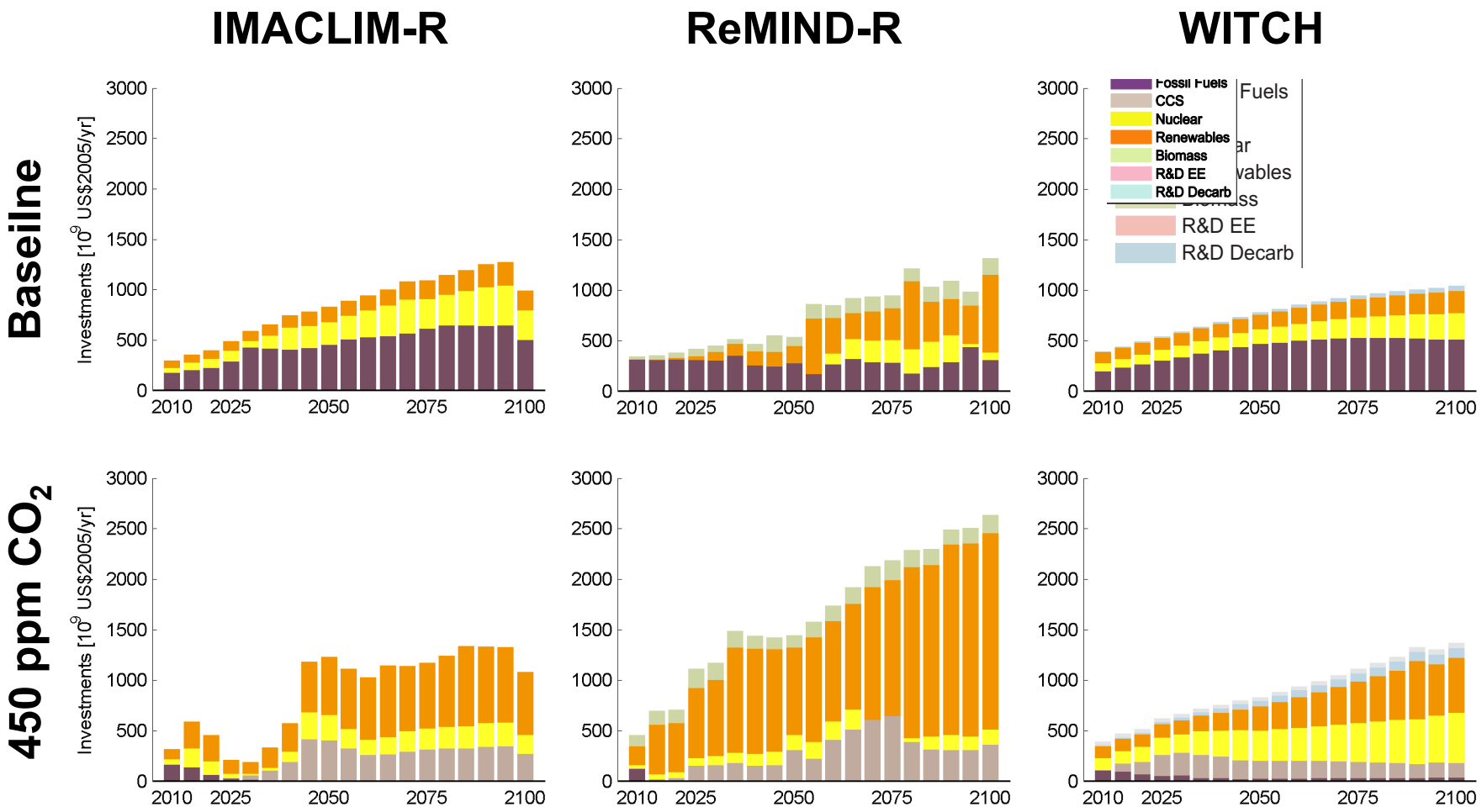
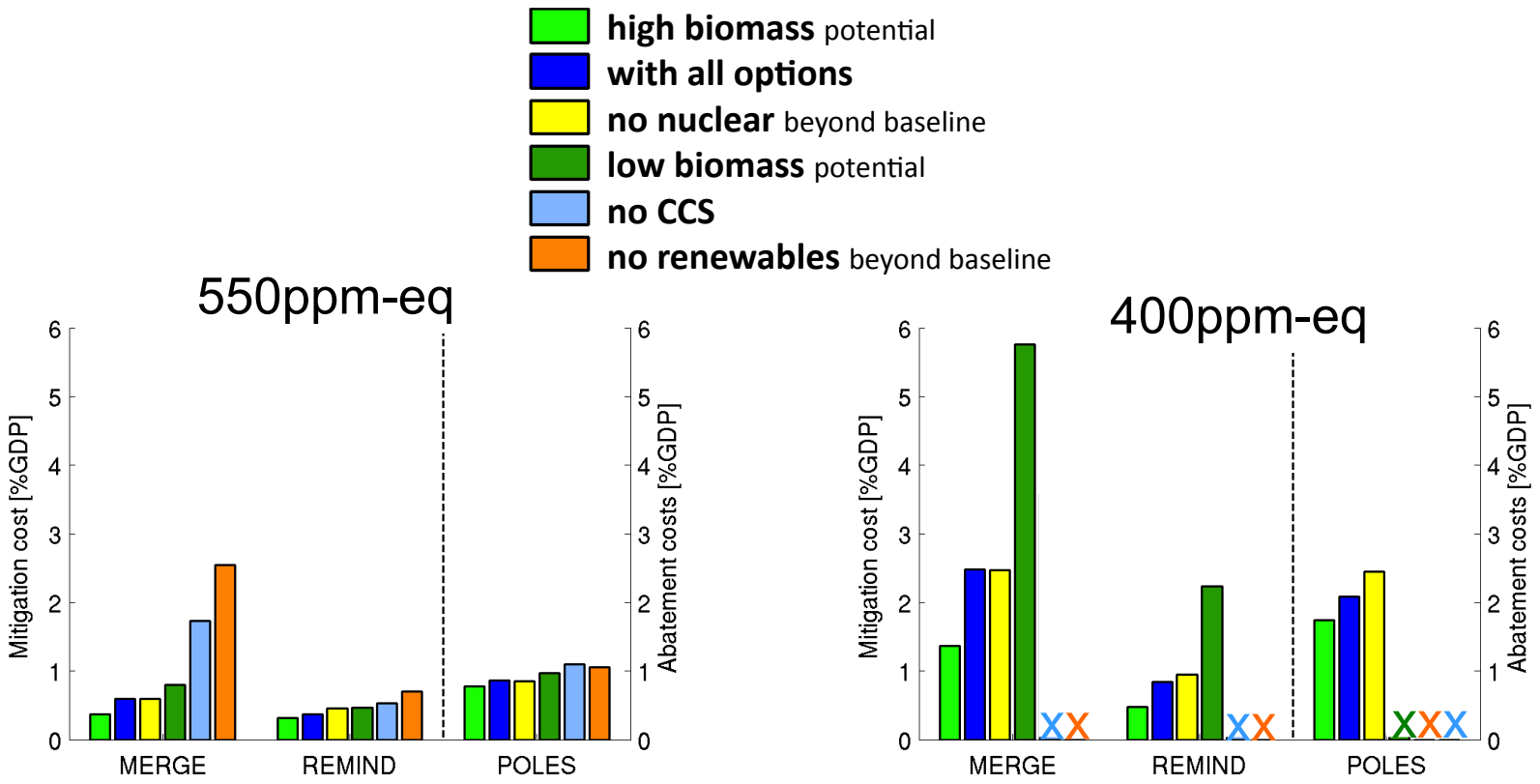
Inter-model comparisons - RECIPE

Investment Mix



Luderer et al., 2009

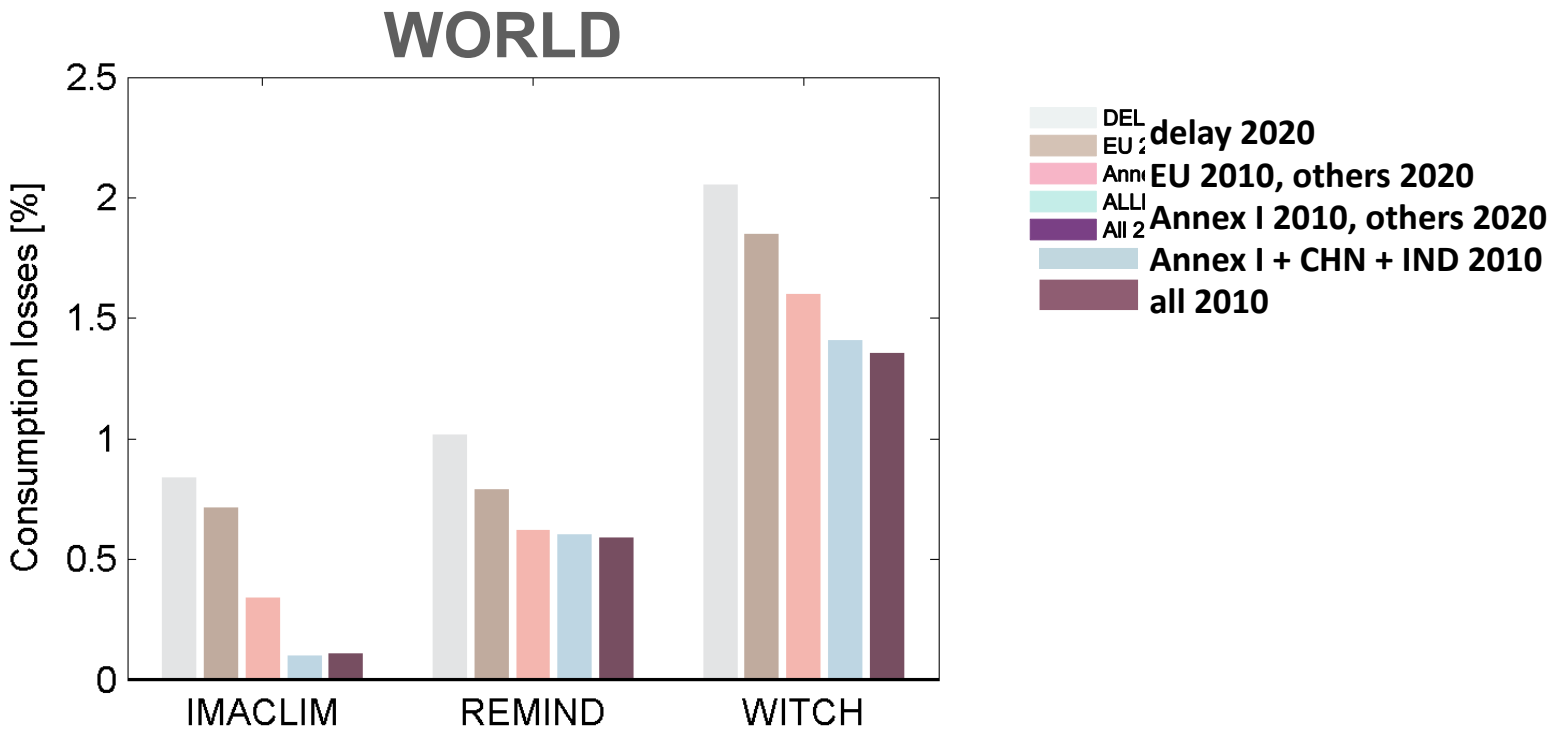
Feasibility and Cost of meeting climate targets



Knopf et al. (2009)
Edenhofer et al. (2010)

➔ 400 ppm neither achievable without CCS nor without extension of renew
➔ Biomass potential dominates the mitigation costs of low stabilisation

The cost of delayed action



Luderer et al., 2009;
Jakob et al., 2011.

➔ delay of action beyond 2020 makes climate target unachievable

➔ decreasing costs with increasing participation in climate coalition

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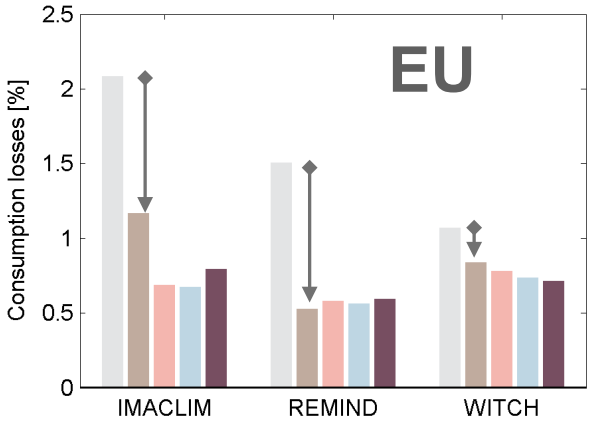
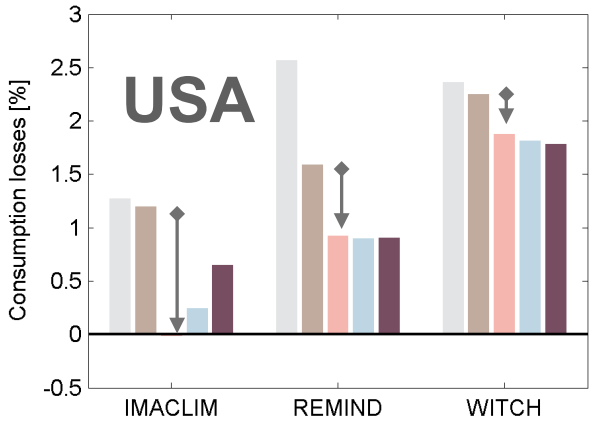
The case for early action





delay 2020
EU 2010, others 2020
Annex I 2010, others 2020
Annex I + CHN + IND 2010
all 2010

Luderer et al., 2009;
Jakob et al., 2011.

➔ Early action advantage: Benefit of anticipation outweighs costs of more ambitious abatement

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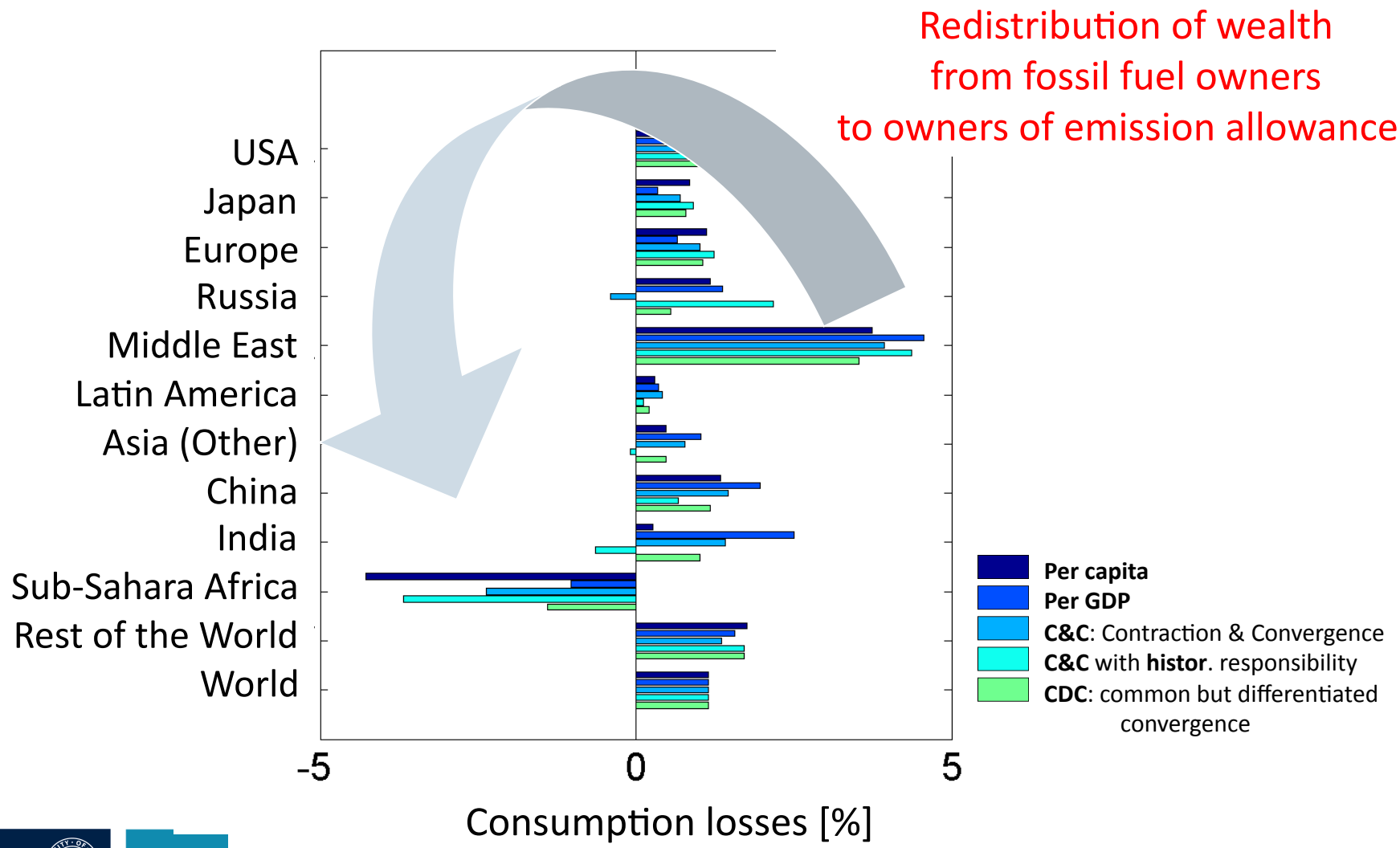
Mitigation implies redistribution of wealth



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Part IV

Criticism, Challenges, and next steps

Increasing realism:

- Integrating uncertainty & Learning
- Multiple decision makers
- Multiple externalities
- Second best solutions & policy instruments
- The growth framework
- Higher spatial & Sectoral resolution
- Robustness and adaptive decision making

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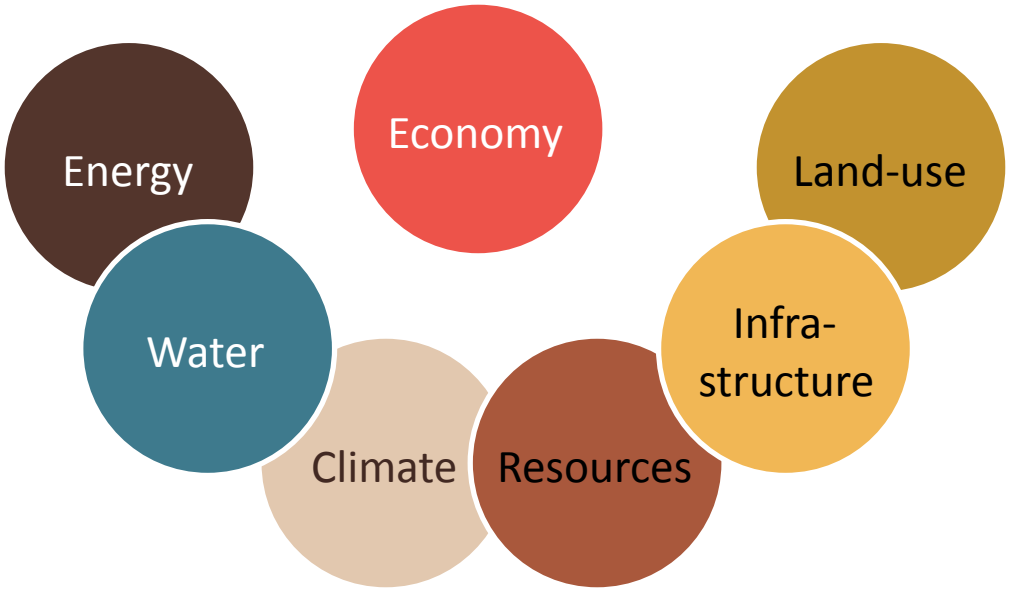
Essential components for a comprehensive integrated assessment

Energy
Information
Infrastructure
Resources
Innovation
Non-rationality
Imperfect economy
Uncertainty
Monetary policy
…



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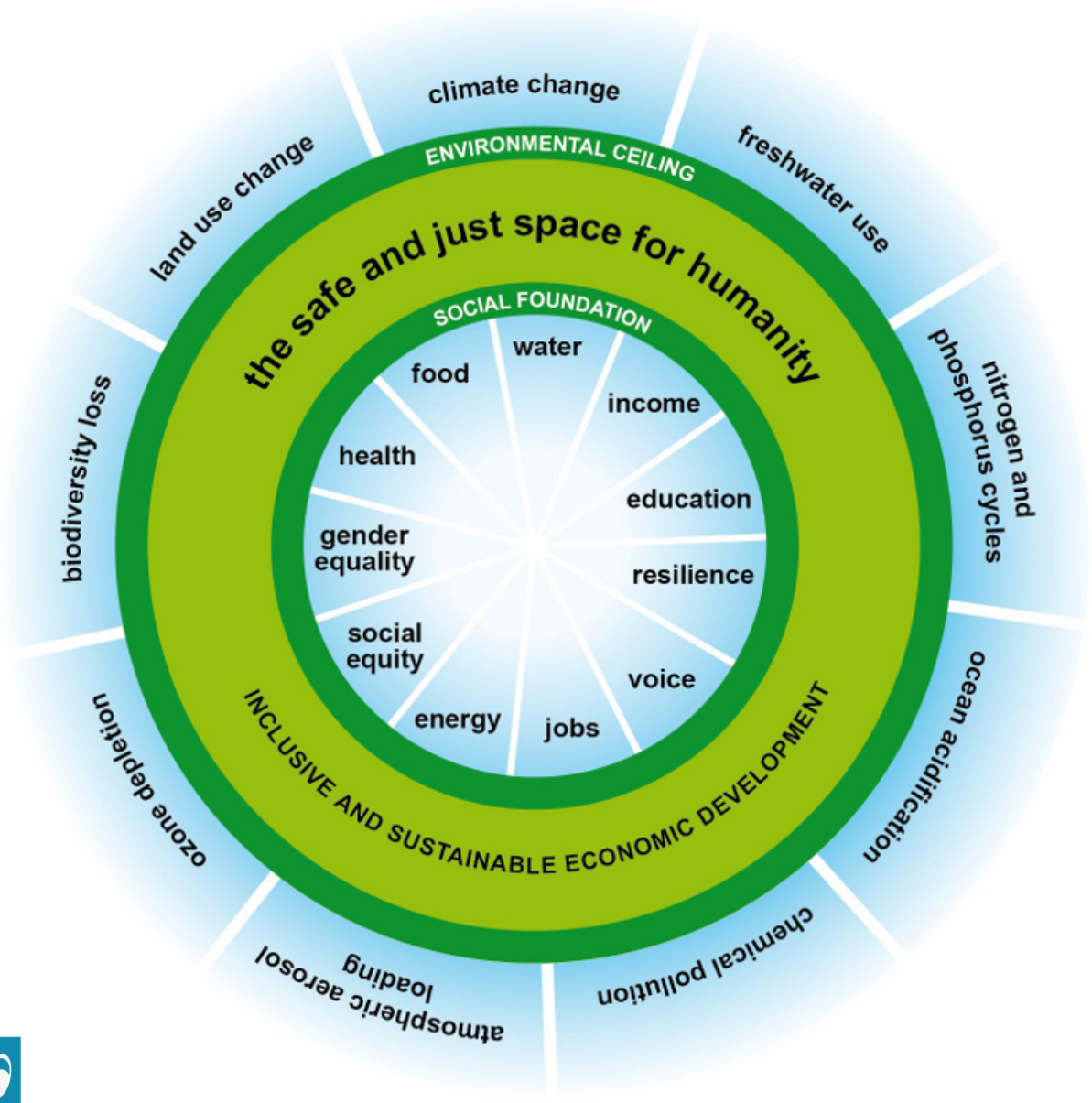
The doughnut economy



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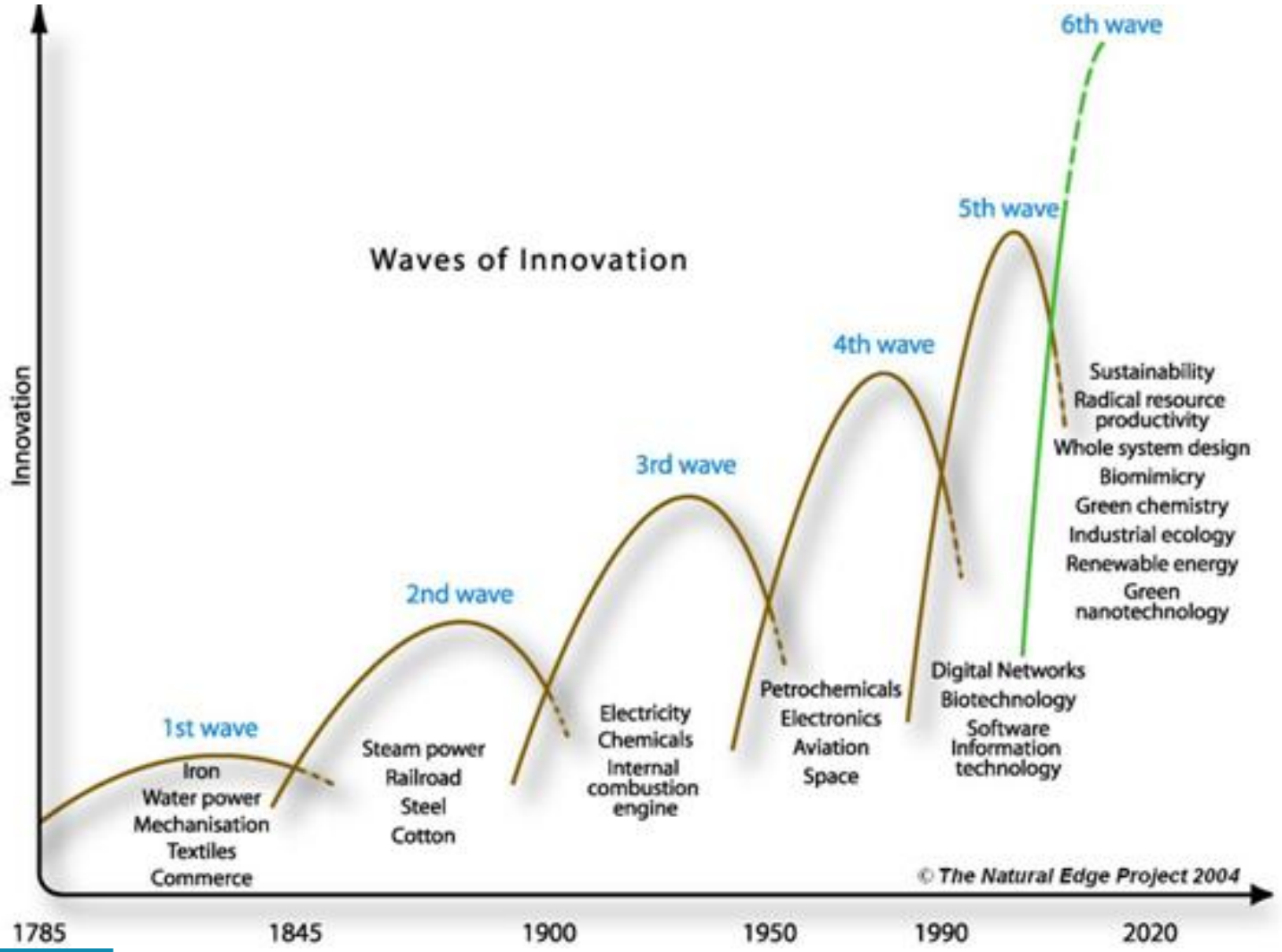
Innovation , Information, Technology



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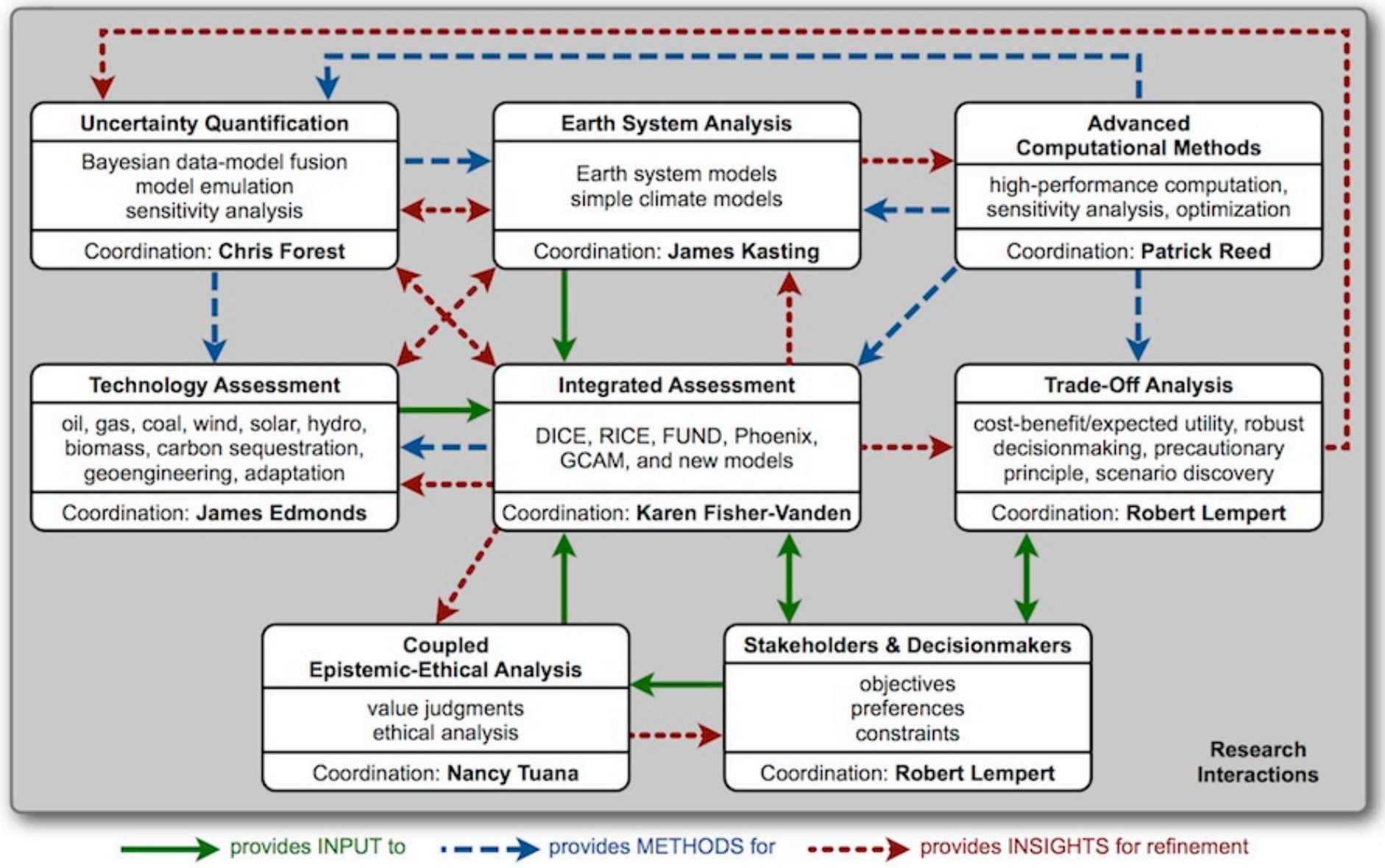
Next Steps – e.g. The SCRiM project



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Summary

The integrated Assessment of Climate Change is bringing together different perspectives on the climate problem.

It can give formal insights into necessary trade-offs for optimal global mitigation strategies.

It can emphasise the political and technological challenges of climate change.

It cannot (yet) derive “practical solutions”.

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Entry points to further reading

Integrated Assessment of Climate Change

Janetos, A., 2009. ***Science Challenges and Future Directions: Climate Change Integrated Assessment Research.***
IPCC AR5, Summary for Policy Makers (www.ipcc.ch)

Climate Impacts

Impact model intercomparison (
http://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-cross-cutting-activities/isi-mip)

Integrated Assessment Models / Limitations

Community Integrated Assessment System (CIAS) (http://www.tyndall.ac.uk/research/cias)

A list of the current integrated assessment models with short introductions:
http://sedac.ciesin.columbia.edu/mva/iamcc.tg/mva-questions.html

Pindyck, R.S., 2014, Climate Change Policy: What do the models tell us?, NBER WP 19244

Stern. N., 2013, The structure of economic modeling of potential impacts of climate change: grafting gross underestimation of risk onto already narrow science models, Journal of Economic Literature

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