

Introduction: Climate, transition and macro-financial dynamics

Climate macro & finance course 2022 - Lecture 1

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University of Bologna

Aim of the course

- Present and discuss the research investigating the macro-financial implications of climate change and the low-carbon transition
- Two climate-related phenomena:
 - Climate change impacts (acute and gradual)
 - Structural change from high- to low-carbon economic system
- Macro-financial perspective
 - Some proper finance (e.g. asset pricing)..
 - ..but mostly macroeconomics with finance in it
 - Econ, finance, but also political economy and interdisciplinary research
 - Slightly more focus on transition side

Course structure

- First part
 - Six hours for both Frontiers and Econ
 - Frontiers: module within the D020 course
 - Two lectures of three hours
 - 15 and 22 February
- Second part
 - Nine hours for Econ
 - Frontiers very welcome to audit
 - Three lectures of three hours
 - 1, 8 and 15 of March

Course outline (1st part)

- Lecture 1: Setting the scene
 - Intro to course + introductions
 - Motivation and research background
 - The basics of climate change and decarbonisation+
 - Approaches to studying macro-financial implications of climate and transition
- Lecture 2: Conceptual and empirical approaches
 - Current conceptual understanding of climate-related impacts
 - Risk drivers; economic/financial transmission channels; macro impacts
 - Exposure to physical and financial asset stranding
 - Asset pricing and internalization of transition risks
 - Production and financial networks

Course outline (2nd part)

- Lecture 3: Climate economic modelling
 - Lecture 3. Climate economic modelling
 - The DICE model: structure and functioning
 - Integrated assessment modelling, large and small
 - Climate/transition scenarios
- Lecture 4: Macro-financial transition modelling
 - What do we need to understand
 - Overview of modelling approaches
 - Equilibrium modelling: CGE, DSGE, CAPM
 - Complexity modelling: SFC, ABM
- Lecture 5: Addressing macro-financial climate-related risks
 - Policy options: carbon pricing and beyond
 - Institutional implications of climate-related financial policies
 - Central banks and climate change

Main readings (on Teams)

- Closest paper to the course:
 - Campiglio and van der Ploeg 2022. Macroeconomic and Financial Risks of the Transition to a Low-Carbon Economy. *Review of Environmental Economics and Policy* (forthcoming)
- Other connected papers:
 - Bolton et al. 2020. The green swan. Central banking and financial stability in the age of climate change. Bank of International Settlements. ([Link](#))
 - Semieniuk et al. 2021. Low-carbon transition risks for finance. *WIREs Climate Change* 12, e678. ([Link](#))
 - Campiglio et al. 2018. Climate change challenges for central banks and financial regulators. *Nature Climate Change* 8, 462-468. ([Link](#))
 - Baer, M., Campiglio, E., Deyris, J., 2021. It takes two to dance: Institutional dynamics and climate-related financial policies. *Ecological Economics* 190, 107210. [Link](#)

Students' role

- Diversity of backgrounds, knowledge and interests
 - → Some basics today
- Contributions welcome
 - Do you know a good paper on this?
- Short presentations in 2nd part of course
 - Based on relevant paper, part of the lecture
 - Papers to be discussed together
- Please be on time:
 - We start 5 mins, we end 5 mins to
- Please keep video on

Assessment

- Essay at the end of course
 - Reflections on topics/literature
 - Research-oriented
 - Options from me + topic proposals welcome
- Timeline
 - Topics by 15 March
 - Deadline: 30 March

Introductions

A bit more about me

- Associate prof. DSE since Sept 2020
- Assistant prof. at WU Vienna: 2016-2020
 - Research area on Climate Economics and Finance
- Postdoc at LSE: 2012-206
 - Grantham Research Institute + Geography Department
- PhD in Economics in Pavia: 2008-2012
 - Three essays on the sustainability of economic growth
- Researcher at New Economics Foundation: 2010-2012
 - The 'Great Transition' modelling project
- Bachelor and Master in International development and cooperation
 - Bocconi + Pavia

A bit more about my work

- Main research focus at the moment:
 - Dynamic links between low-carbon transitions and macro-financial dynamics
 - Policies and institutions for a rapid and smooth decarbonisation
- Main thread: SMOOTH project
 - ERC Starting Grant (2020-25)
 - University of Bologna and European Institute on Economics and the Environment
 - ‘Sustainable finance for a smooth low-carbon transition’
 - [Link to project website](#)
- Personal research profiles:
 - [Google Scholar](#)
 - [ResearchGate](#)

A bit about you

- Who are you? What did you study?
- What is your PhD on?
- How much do you know about climate and technology?
- How much do you know about climate economics?
- What are you looking for in this course?

What are we studying?

Today's lecture outline

- Intro to course + introductions
- Motivation and research background
 - What the general problem is: Environmental constraints to human prosperity
 - Environmental and ecological econ: what do they study?
- Climate change and the low-carbon transition
 - Climate change: the physical basis
 - GHG emissions and the decarbonisation strategy
 - What implications do they have on macro-financial dynamics
- How do we study these issues?
 - Different methodological approaches: conceptual, empirical, modelling, political economy

Where we are

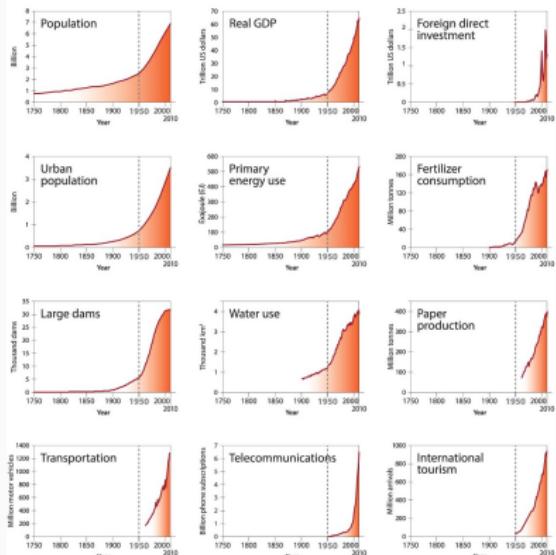


Space rock with atmosphere ([Figure source](#))

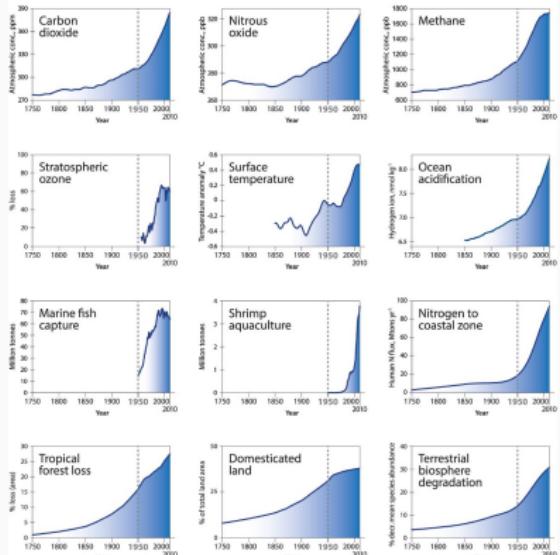
- We don't control any of that. And for million years: no significant human impact on planet dynamics.
- → Enter fossil fuels!

The great acceleration (Steffen et al. 2015)

Socio-economic trends

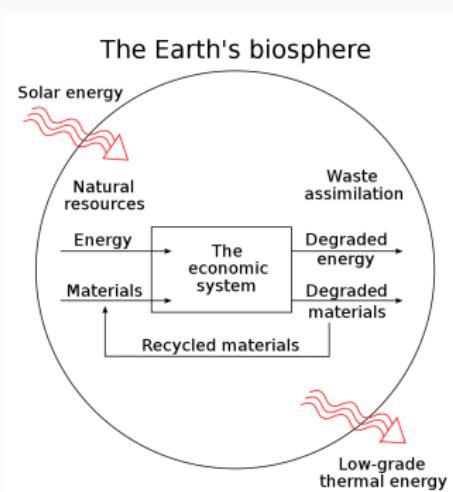


Earth system trends



What the problem is

- Environmental constraints to human prosperity
- Environmental constraints:
 - Inputs: materials, energy services, prices
 - Sinks: waste, air pollution, climate change
- Human prosperity:
 - What are the objectives of human societies?
 - Income, satisfaction of needs, human development



Source: [Wikimedia](#); Originally in Hall et al (1986)

When was the problem posed? (I)

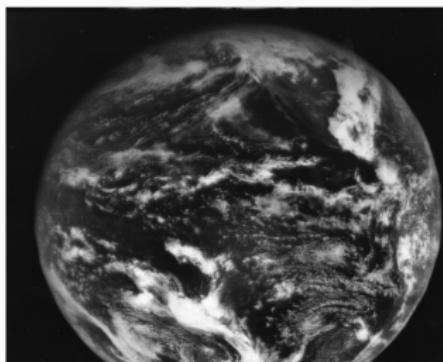
- Roots in classical political
 - T.R. Malthus (1798) 'An Essay on the principle of population'
 - J.S. Mill (1848) on a stationary state
 - Jevons (1865) on 'The coal question' and the Jevons paradox
 - A.C. Pigou (1920) on externalities and the Pigouvian taxes
 - H. Hotelling (1931) 'The Economics of Exhaustible Resources' and the Hotelling rule
- To go deeper:
 - Sandmo 2015 on REEP: 'The early history of environmental economics'

When was the problem posed? (II)

- From the 50s: increased environmental awareness
 - Great Smog of London in 1952 → UK Clean Air Act 1956
 - R. Carson (1962) 'The Silent Spring' on chemical pollution
 - First pictures of Earth from space → Moon landing in 1969
 - Oil crises in 1973 and 1979



Great smog of London, 1952; Source: Britannica



1966 image of Earth from ATS-1 satellite; Source: NESDIS

How was the issue addressed?

- Two large avenues of contributions
 - Environmental economics
 - Ecological economics
- Controversy born around substitutability of capital stocks
 - Capital approach to sustainable development
 - Man-made, human, natural and social capital
- Weak sustainability
 - High degree of substitutability
 - Solow 1974 ([link](#)) : '(..) earlier generations are entitled to draw down the pool (optimally, of course!) so long as they add (optimally, of course!) to the stock of reproducible capital.'
- Strong sustainability
 - Low degree of substitutability
 - In particular, irreversibility of natural capital depletion

- Economists analysing environment-related problems:
 - P. Dasgupta, G. Heal, W. Nordhaus, J. Stiglitz, J. Hartwick, M. Weitzman..
 - Focus on markets, prices, technology, growth, substitutability, smoothness, efficiency
- Some problems:
 - Optimal resource depletion plans
 - Economic value of environmental goods and services
 - Cost-benefit analysis; discounting
 - Externalities and optimal policies
- Main academic community:
 - AERE (US); EAERE (Europe)
 - EAERE2022 organised by UniBo! ([Link](#))
- To go deeper
 - Pearce 2002 on AREE: '[An Intellectual History of Environmental Economics](#)'

- Economists, but also social and environmental scientists
 - Multi- and inter-disciplinary approach
 - Focus on finiteness, limits, scale, stationarity, irreversibility
- Relevant contributions:
 - K. Boulding (1966) and 'The coming spaceship Earth'
 - N. Georgescu-Roegen (1971) 'The entropy law and the economic process'
 - Meadows et al. (1972) 'The Limits to Growth'
 - H. Daly (1977) 'Steady-state economics'
- Main academic community:
 - ISEE (intl.), ESEE (Europe)
- To go deeper
 - I. Ropke 2004-2005 on EcolEcon: 'The early history of modern ecological economics'; 'Trends in the development of ecological economics from the late 1980s to the early 2000s'

80s: Shift of focus from inputs..

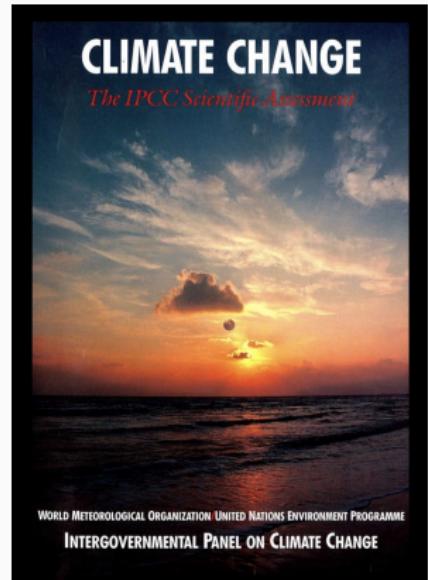
- Resource scarcity less biting
 - Technological innovations
 - Exploration: large expansion of reserves
 - Energy-saving technologies, mass mobility
- Oil price fluctuations still relevant
- Geopolitical implications still relevant
- Main material constraints now:
 - Rare metals for electronics
 - Water

.. to sinks

- The Ozone layer scare
 - Montreal Protocol (1987)
- Environmental concerns
 - Oil spill and disasters
 - Loss of biodiversity
- Climate change
 - 1990: first IPCC report
 - → Main focus of this course



Exxon Valdez spill (1989) Source: [NOAA](#)

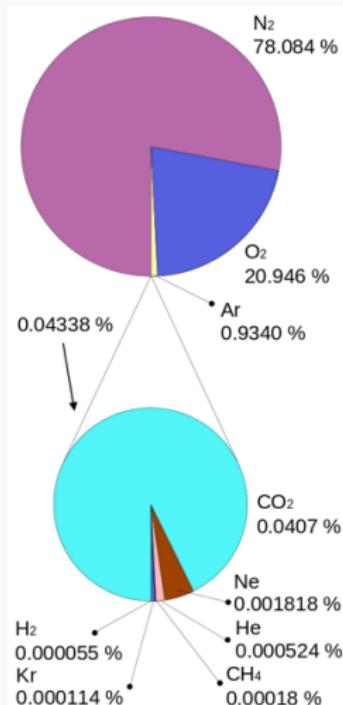


Source: [IPCC 1990](#)

Climate change

Atmospheric composition

- Mostly nitrogen (N_2), oxygen (O_2), argon (Ar) + 'trace gases' + water vapour
- Some trace gases and water vapour are 'greenhouse gases' (GHG)
 - Able to absorb and emit infrared radiation
 - Responsible for the Earth's greenhouse effect (without them average temperature 30°C lower..)



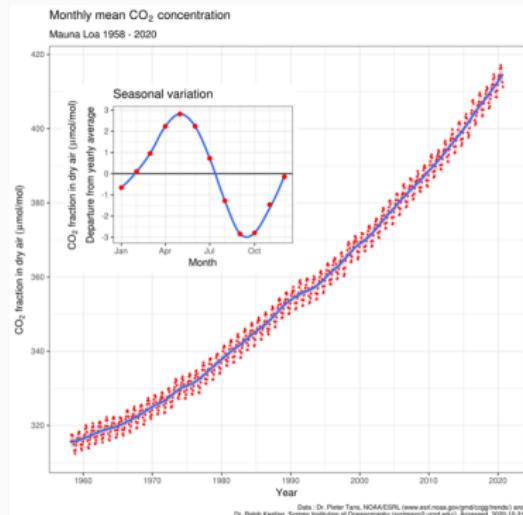
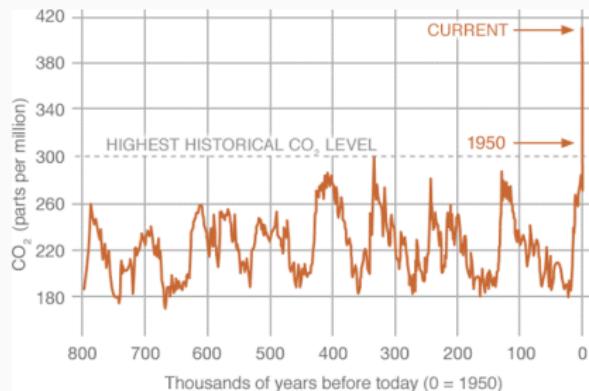
Composition of Earth's atmosphere by volume (dry air). Source: [Wikimedia](#)

Human activity can change atmospheric composition

- Human production/consumption activities produce greenhouse gases (GWP: global warming potential)
 - Carbon dioxide (CO_2); GWP=1
 - Methane (CH_4); GWP=28
 - Nitrous oxide (N_2O); GWP=265
 - Fluorinated gases (SF_6 , HFCs, PFCs); GWP up to 23500
- CO_2e (' CO_2 equivalent'): GHGs weighted by their GWP
 - E.g. 1 ton of CH_4 = 28 tons of CO_2e
- CO_2e is 3.67 heavier than carbon (C)
 - I.e. 1 tC corresponds to 3.67 t CO_2

CO₂ concentration

- February 2022 concentration: 418ppm (Source: NASA)



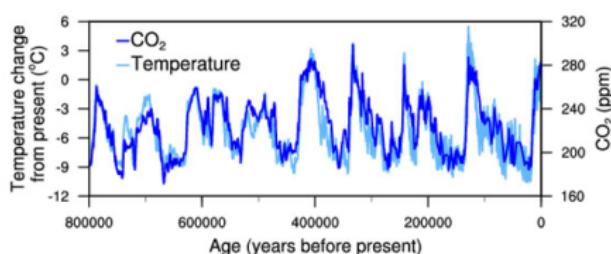
Sources: NASA (left); Wikimedia (right)

Climate impacts

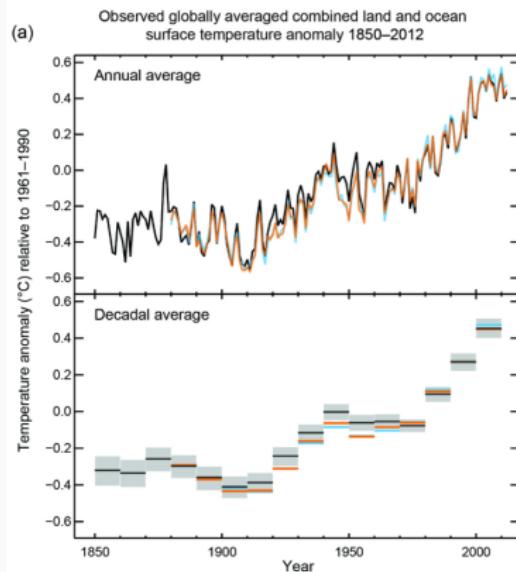
- Acute hazards: point events triggered/exacerbated by climate
 - Extreme weather events (hurricanes, heat waves)
 - Floods, wildfires
- Chronic hazards: progressive shifts in climate patterns
 - Increase in temperatures
 - Rise of sea levels
 - Changes in precipitation and humidity patterns
 - Biodiversity loss (e.g. due to ocean acidification)
- Impacts on human societies
 - Changes in agricultural productivity (crop yields)
 - Availability of water
 - Effects on human health and labour productivity
 - Human security (climate-driven conflicts and displacement)

Temperature rise

- CO₂ concentration associated with higher temperatures (and viceversa)
- Other temperature drivers exist (e.g. Milankovitch cycles)



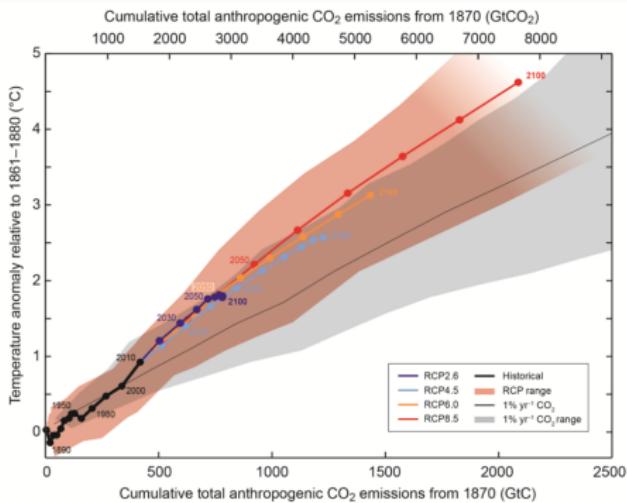
Source: NOAA



Source: IPCC (2013)

Temperature and cumulative emissions

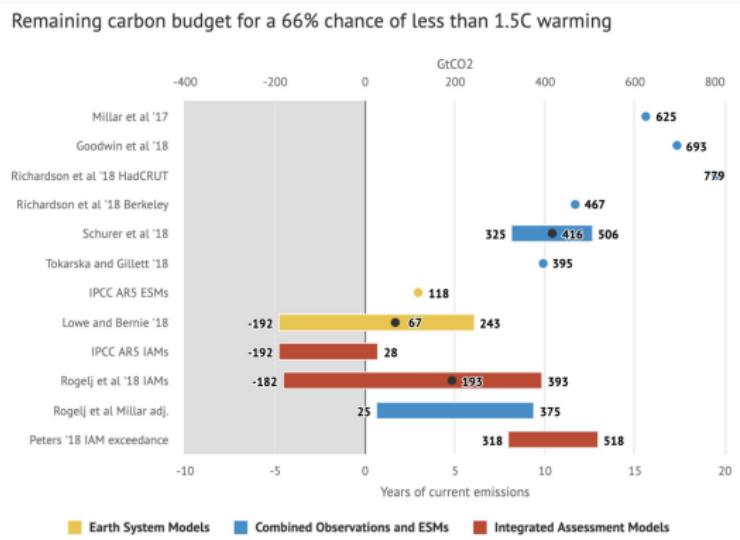
- Temperature change is a roughly linear function of cumulative CO₂ emissions
- Transient Climate Response to Cumulative Emissions (TCRE) is independent of time and concentration
- Matthews et al. (2018): TCRE in the 0.8-2.4°C range per trillion tons of carbon



Source: IPCC (2013)

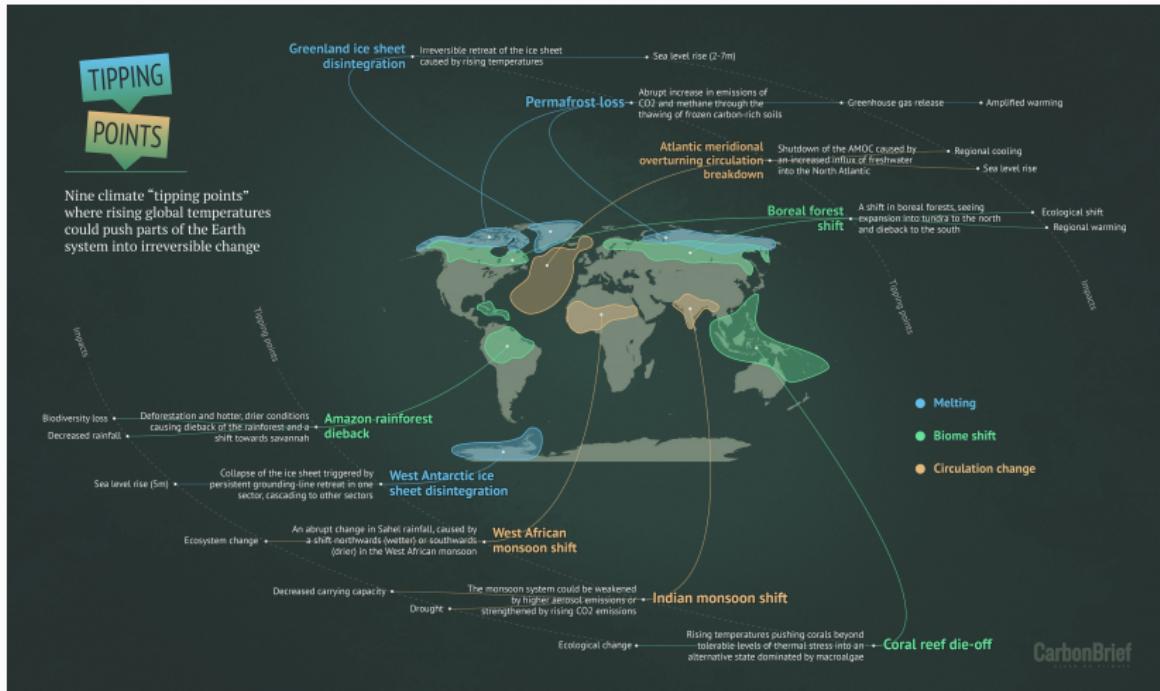
Temperature targets → Cumulative emission limits

- 'Carbon budget' concept
 - Allen et al. (2009), Meinshausen et al. (2009)
 - Roughly linear relationship (Matthews et al, 2009)
 - Large uncertainties on values (see Rogelj et al, 2019)



Source: Carbon Brief (2018)

Tipping points



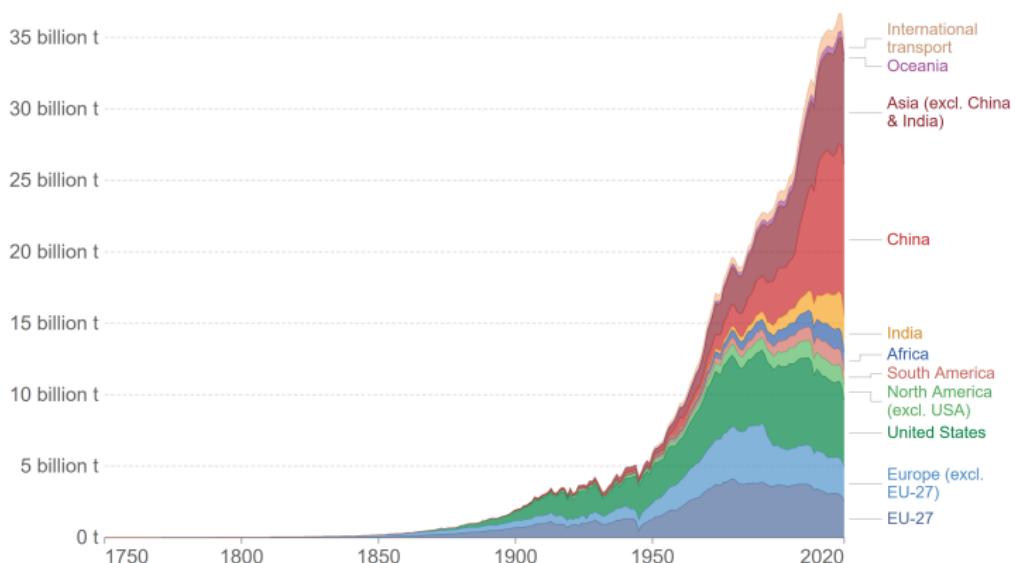
Source: Carbon Brief (2020)

Decarbonisation

How have emissions changed in the past?

Annual CO₂ emissions from fossil fuels, by world region

Our World
in Data



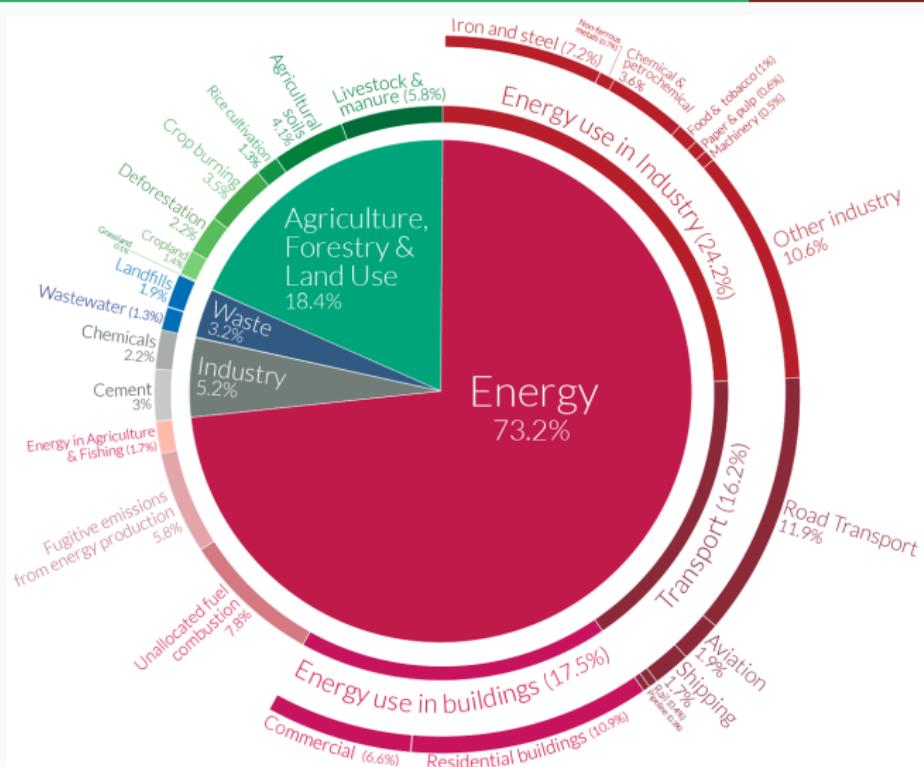
Source: Global Carbon Project

Note: This measures CO₂ emissions from fossil fuels and cement production only – land use change is not included. 'Statistical differences' (included in the GCP dataset) are not included here.

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

CO₂ emissions from fossils and cement. Source: [Our World in Data](#)

Where do emissions come from now?



Global GHG emissions by sector in 2016. Source: Our World in Data

How should emissions change in the future?

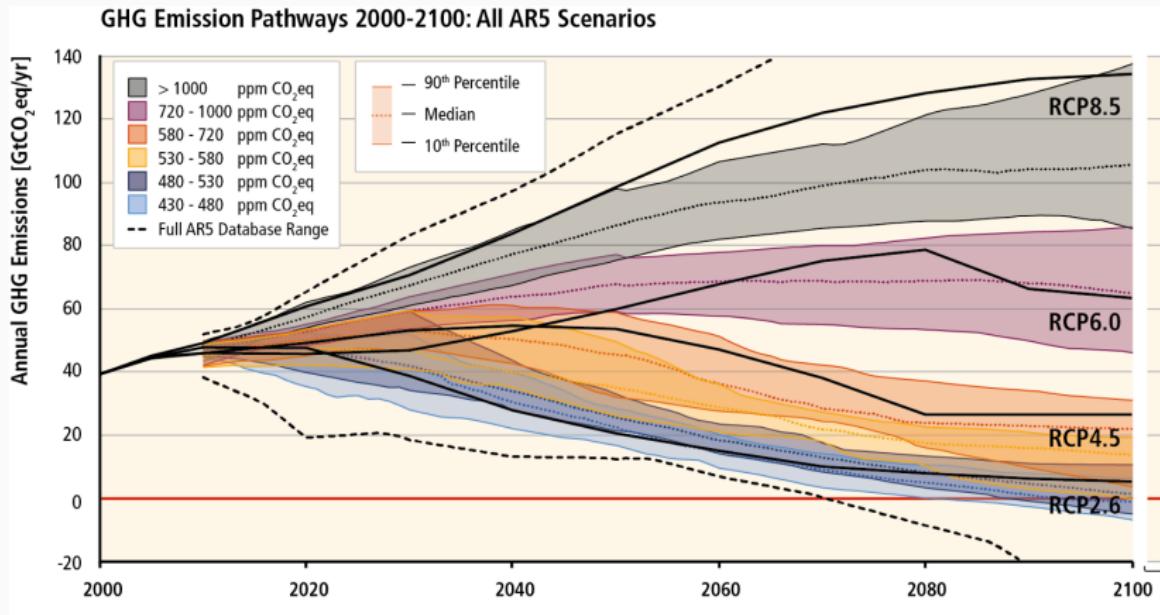


Figure: Emission reduction pathways. Source: [IPCC \(2014\)](#)

GHG Emission drivers

- Kaya identity $CO_2 \equiv P \frac{Y}{P} \frac{E}{Y} \frac{CO_2}{E}$
 - CO_2 : emissions; P : population; Y : income; E : energy

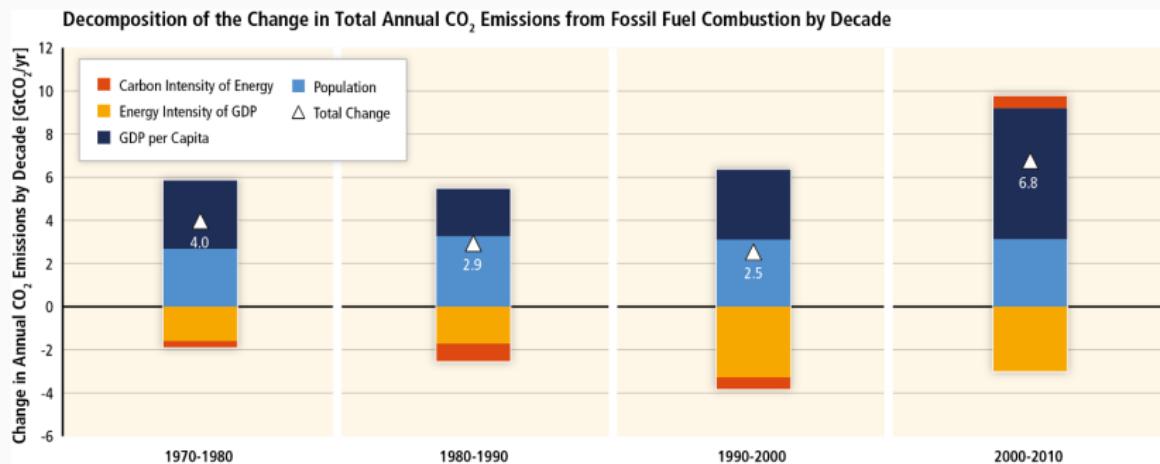
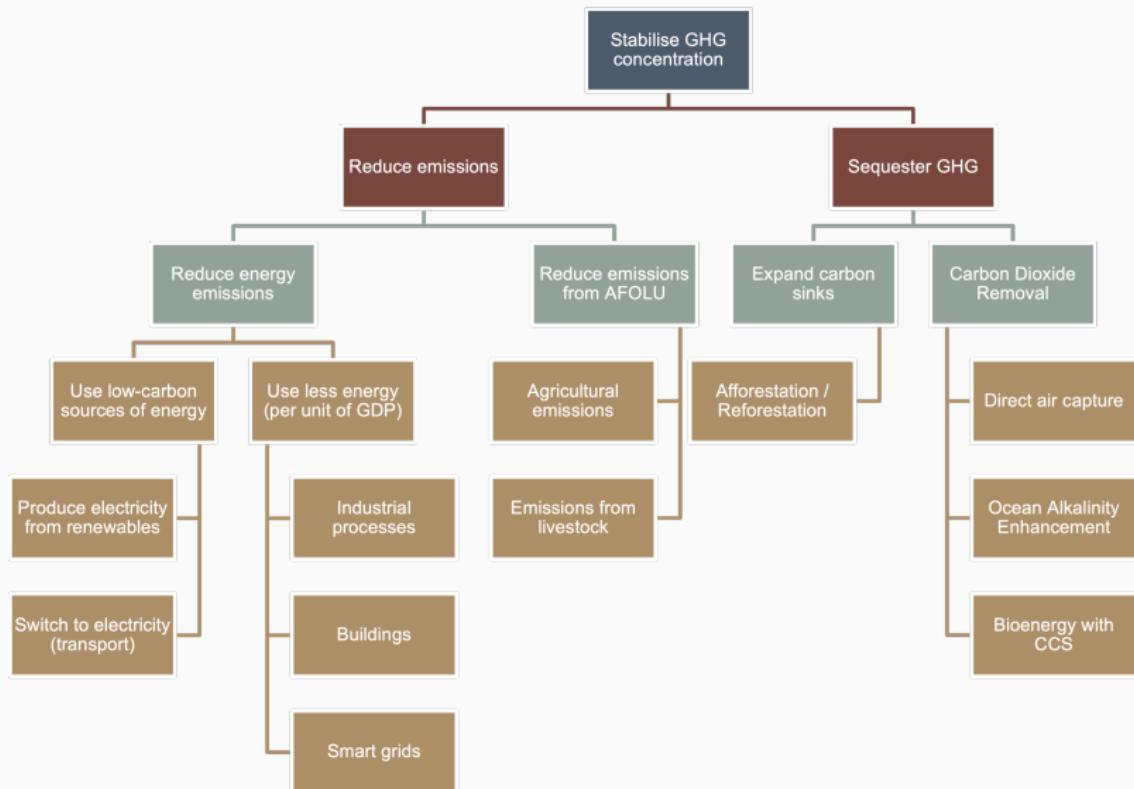


Figure: Source: IPCC (2014)

Levers to reduce emissions

- Reduce population
 - Population control measures, but very slow
 - Freedom issues (eg. one child policy in China)
- Reduce income
 - Degrowth; discussion on income-welfare links
 - Politically unpalatable and only applicable to high-income countries
- Improve production processes
 - Reduce energy intensity of GDP
 - Reduce emissions intensity of energy
 - This is what we refer to as 'green growth' or 'decoupling'

Technological mitigation options



The tree of technological options to stabilise GHG concentration

What does a low-carbon transition mean?

- Decarbonise electricity
 - Wind, solar and other renewable energies
- Electrification
 - E.g. Electric vehicles. But what about international transport
- New manufacturing processes
 - E.g. Electric arc furnaces; bio-plastics
- New agricultural/farming techniques
 - E.g. Nitrogen-fixing rotations ([More details](#))
- Negative emission technologies
 - Carbon capture and storage
 - Direct air capture
- Radical breakthroughs
 - Geoengineering
 - Nuclear fusion

What does this mean for us?

- Human productive activities currently based on fossil fuels
- For some activities, there are alternatives:
 - Electricity: renewable energies
 - Manufacturing: electric arc furnaces; bioplastic
 - Heating/cooking: electrification
 - International transport?
- Costs: these technologies are expensive!
 - Fossil-based technologies often still more convenient
- All of these produce essential intermediate inputs for all other sectors
 - Systemic implications of defossilisation?

This is not the first technological shift (UK example)

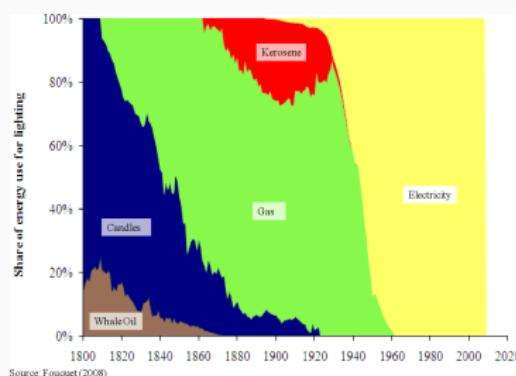
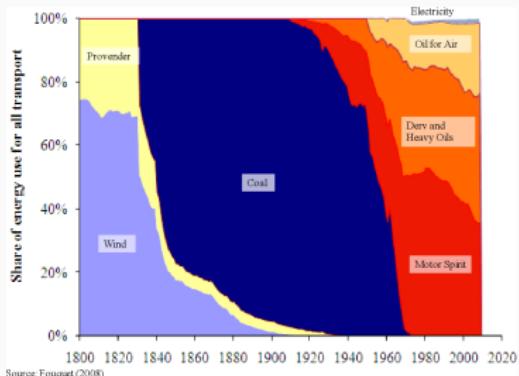
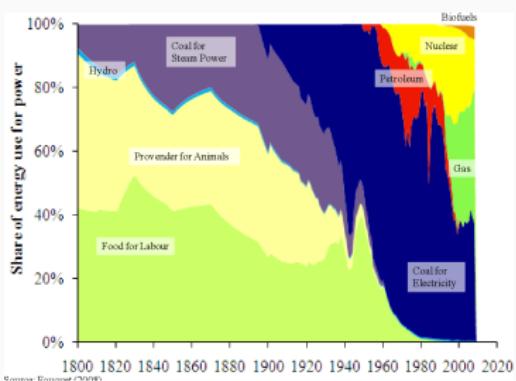
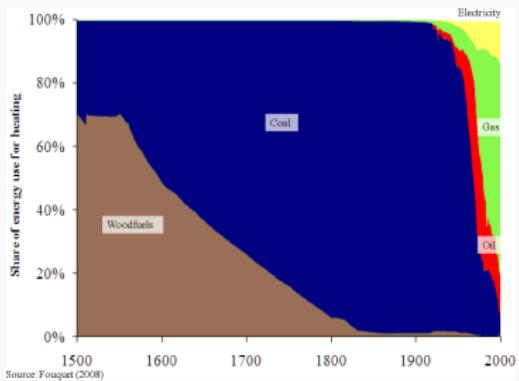


Figure: Source: Fouquet (2008)

However, a major difference

- Technological transitions historically driven by the emergence of new, more productive, more profitable technologies
 - Market players move there by their own
 - There will be losers, but societal gains outweigh costs
- Low-carbon transition likely to require strong policy interventions to promote (still) unattractive technologies
 - Market players need to be pushed there
 - There will be losers; who benefits?

The big trade-off

- Two seemingly contrasting objectives
 - Limit chances of disruptive climate-driven impacts
 - Limit chances of prosperity loss due to technological transition
- Two extreme scenarios
 - BAU: we continue with fossil-based technologies → climate damages
 - Immediate transition: we stop using fossil fuels today → economic disruptions
- Window of opportunity
 - A rapid and smooth transition: is it possible?

Studying macro-financial transitions

Approaches to study macro-financial transitions

- 1. Conceptual frameworks and qualitative approaches
 - How could climate/transition affect macro-financial dynamics?
 - E.g. what channels to inflation? what channels to financial instability?
 - → Development of conceptual/theoretical frameworks (eg. Green Swan, Climate Minsky moment, orderly/disorderly transition, green bubble, etc.)
 - Lecture 2
 - Main reading: Semieniuk et al. (2021)

Approaches to study macro-financial transitions

- 2. Empirical analysis
 - How relevant/likely are the theoretical transition patterns above?
 - → Study the empirical evidence.
 - Three main categories
 - Exposure of physical assets to the risk of stranding
 - Exposure of financial institutions
 - Econometrics and asset pricing (are risk internalised?)
 - Lecture 2
 - Main reading: Campiglio and van der Ploeg (2022)

Approaches to study macro-financial transitions

- 3. Prospective modelling
 - Methodologies to explore the future
 - → Attach dynamic behavioural assumptions to starting set of data
 - Different ways to do that: modelling schools of thought
 - Two main sets of approaches
 - Equilibrium modelling: IAM, CGE, DSGE, CAPM
 - Complexity modelling: SFC, ABM
 - Lectures 3 and 4
 - Main reading: Campiglio and van der Ploeg (2022)

Approaches to study macro-financial transitions

- 4. Political economy implications
 - Ok, so what to do we do about it?
 - → Policy analysis; policy coordination; social acceptability
 - The current status of climate-related financial policies:
geographical heterogeneity
 - Can the most promising policies be implemented?
 - → Institutional analysis; Institutional change
 - Lecture 5
 - Main reading: Baer et al. (2021)

**Next lecture: 22 February,
14.00CET**
