Lecture 1.a: Introduction to climate change

Thomas Douenne – University of Amsterdam

September 6, 2022

Who I am

- Thomas Douenne, Assistant professor in Economics at the University of Amsterdam.
- Background: PhD at the Paris School of Economics (2020).
- Specialization: Environmental Economics, and more specifically:
  - distributional effects of environmental policies;
  - public support for environmental policies;
  - focus on households rather than firms;
  - both theoretical and empirical work, both micro and macro.

A few questions for you

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2. How would you describe climate change as a phenomenon?
3. What are the issues economists study related to climate change?
4. What is your view on the prospects of climate change?

Structure of the course

1. Week 1: Introduction to climate economics (T. Douenne)
   - a. Introduction to climate change;
   - b. Climate change in economic models.
2. Week 2: Instrument choice for climate policies (T. Douenne)
   - a. Instrument choice: efficiency;
   - b. Instrument choice: equity.
3. Week 3: Climate policies beyond *Homo Economicus* (T. Douenne)
   - a. Instrument choice: public support;
   - b. Instrument choice: behavioral policies.
4. Week 4: to be announced
5. Week 5: to be announced
6. Week 6: to be announced

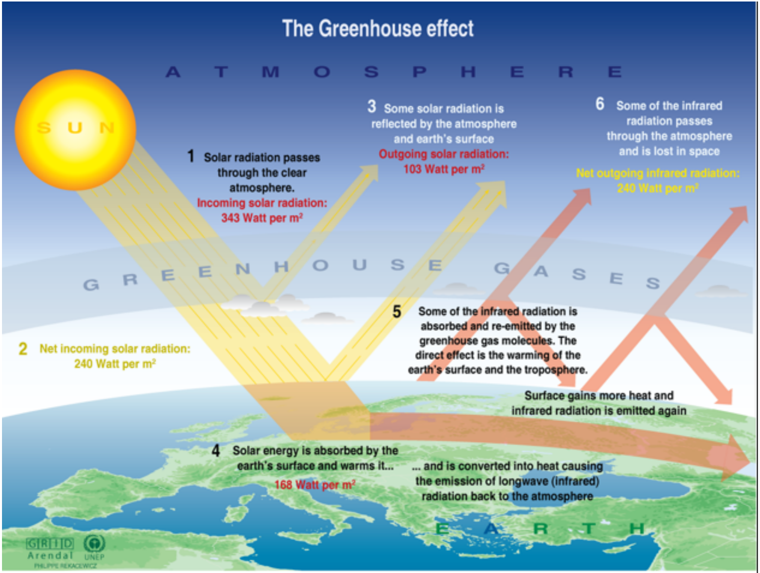
Assessment

- Group exercise 1:
  - 20% of total grade;
  - Due on September 21 (week 3);
  - Groups of 3 or 4;
  - Tutorial exercise to be handed.
- Group exercise 2:
  - 20% of total grade;
  - Due on week 6;
  - Format to be announced.
- Final exam:
  - 60% of total grade;
  - Part 1: multiple choice questions;
  - Part 2: Document analysis.

Today's road map

Table of Contents

Climate change: an illustration



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Greenhouse gases

Greenhouse gases are like a sweater around the earth: the more they accumulate, the more they keep it warm.

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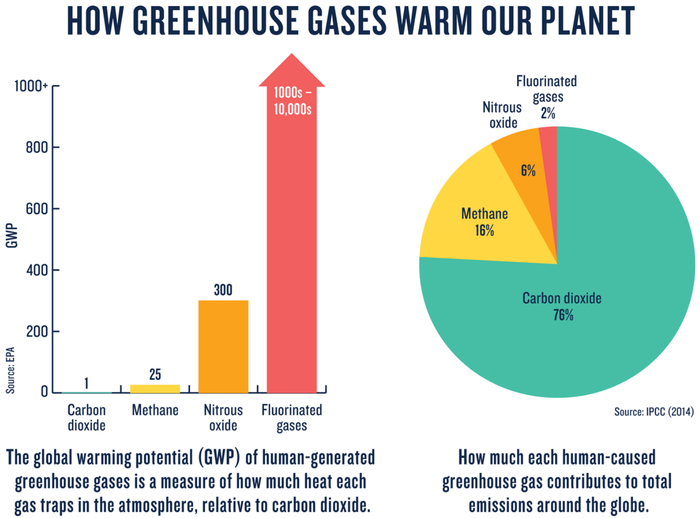
The most important greenhouse gases are:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- fluorinated gases (*e.g.* HFCs);
- water vapor.

Fluorinated gases are synthetic, but all others occur naturally. Still, human activity affects their level.

Greenhouse gases and climate change



The case of CO_2

The main source of anthropogenic (*i.e.* human made) GhG emissions is carbon dioxide (CO_2). But how do we emit CO_2?

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The main cause is the burning of fossil fuels, like coal, oil, or natural gas.

- Fossil fuels are fossils used to produce energy.
- As fossils, mostly made of carbon (C).
- To release energy, need to burn them.
- The combustion uses (di)oxygen (O_2), which pairs with carbon to create CO_2.

Lifetime of CO_2 in the atmosphere is extremely long: 40% remains after 100 years, 20% after 1,000 years, and 10% as long as 10,000 years later (source: NRDC).

The case of other greenhouse gases

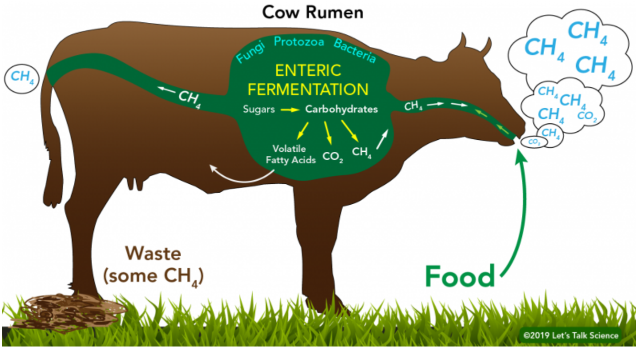
- Methane (CH_4) is also released from the exploitation of fossil fuels. In addition, livestock (and in particular beef production) are key sources of emissions.

- Nitrous oxide (N_2O) mostly generated through agricultural and some industrial activities.

- Fluorinated gases are emitted from more specific applications and processes (*e.g.*, used as refrigerants).

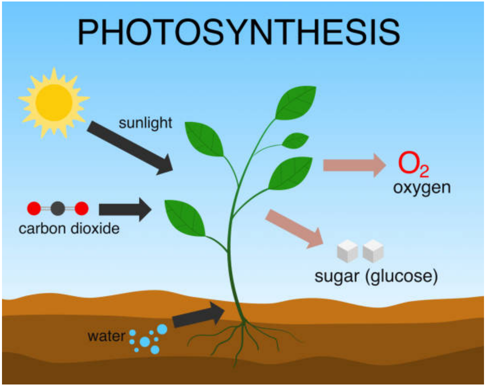
- Water vapor is not emitted by humans, but its concentration is still indirectly affected by human activities. Ambiguous effects:
  - emissions of other GhG warm the planet and oceans, which through evaporation increases the quantity of water vapor;
  - the higher quantity of clouds makes the planet "whiter" which reflects the sun's energy away from earth.

Methane production from ruminants



Chemical reaction: process called enteric fermentation → Microorganisms (bacteria) break down complex carbohydrates into simple sugars used as energy by the ruminant, and various gases including methane (CH_4).

Carbon dioxide absorption from photosynthesis

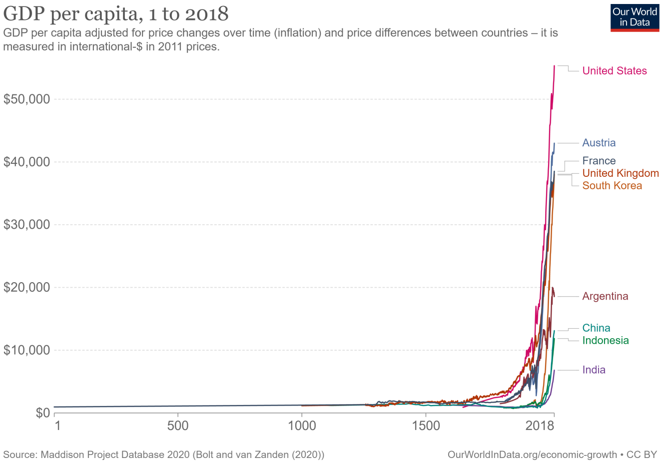


Chemical reaction: $6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O2$.

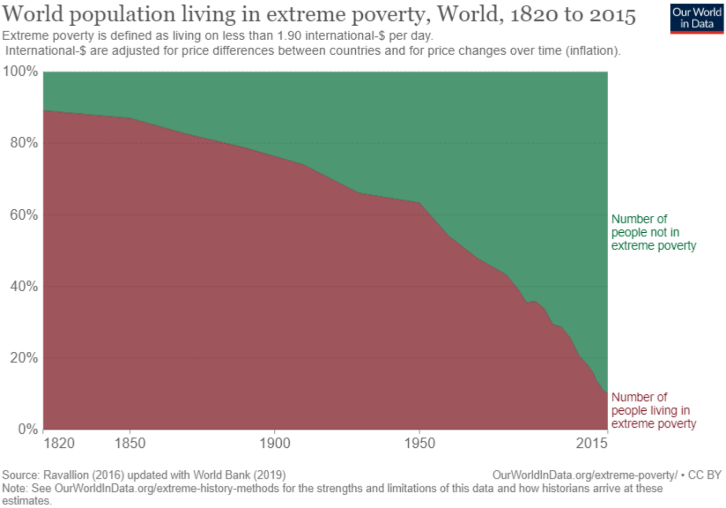
Light enables carbon dioxide and water to generate chemical energy ($C_6H_{12}O_6$) and (di)oxygen ($O2$).

Table of Contents

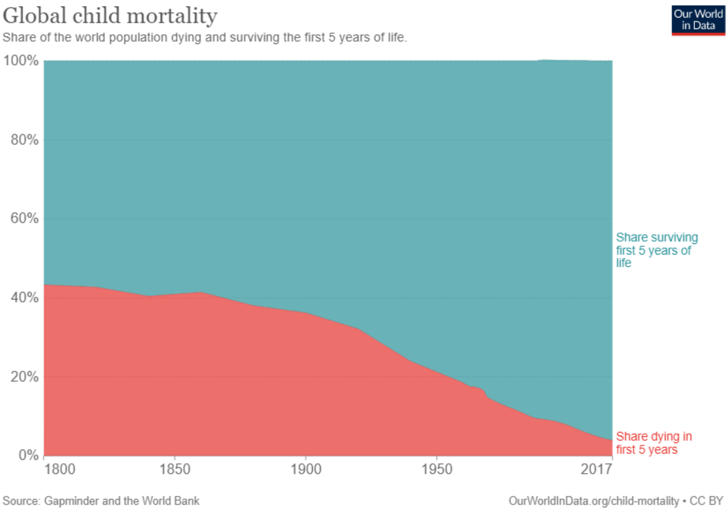
GDP over the long run



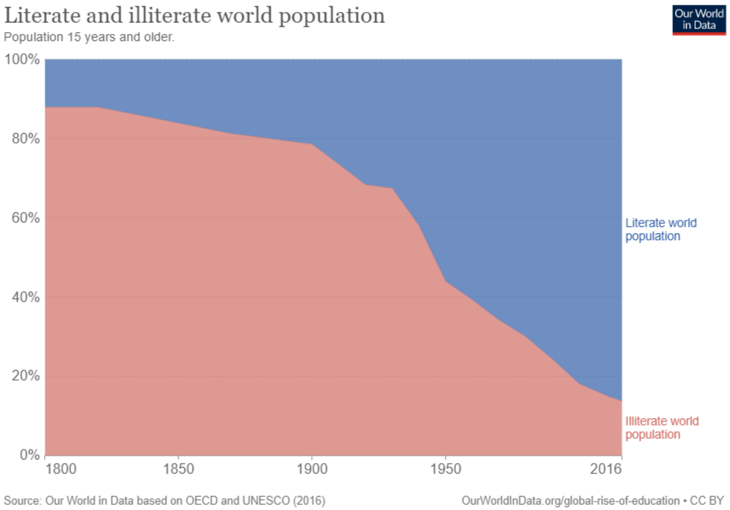
Economic growth took off in the late XVIIIth century: unprecedented phenomenon.



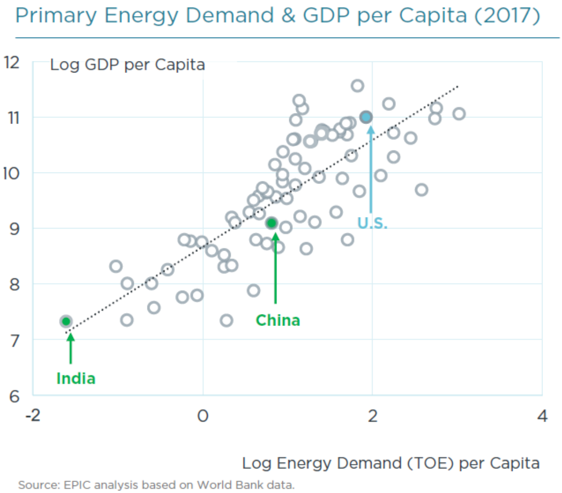
At the same time, many people lifted out of extreme poverty (...)



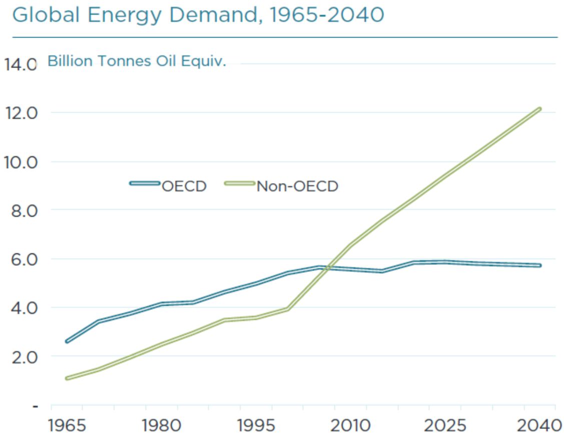
(...) which also led to better health conditions (...)



(...) and other benefits such as higher levels of education.

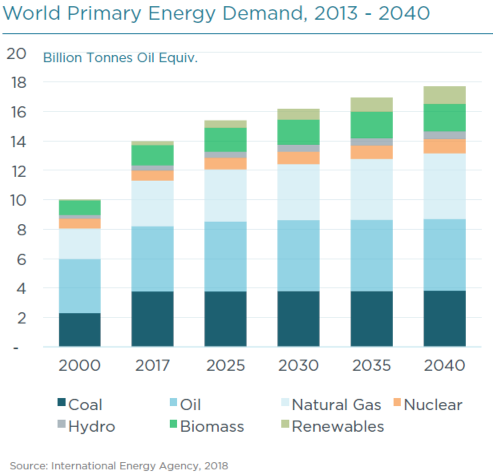


Economic growth has gone hand in hand with energy demand. So far, weak evidence of absolute "decoupling" (...)



Source: EPIC analysis based on data from BP
Statistical Review 2018 and BP Energy Outlook 2019

(...) and so we can forecast even greater energy demand in the coming decades.

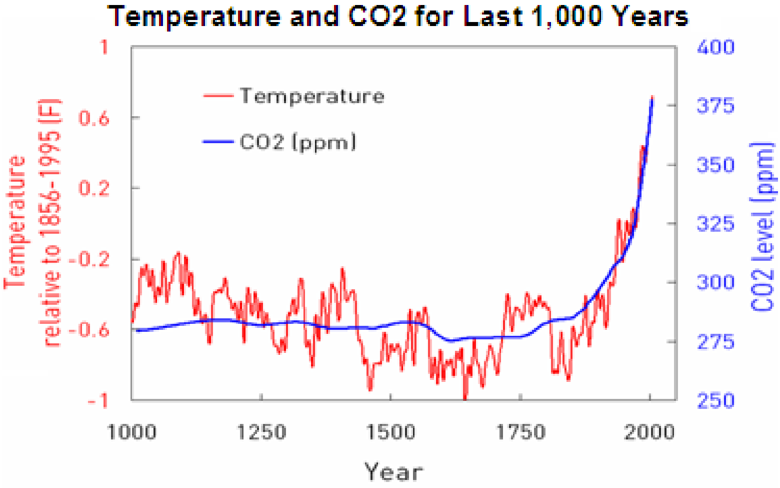


Forecasts also suggest that this demand will in part be met by more fossil fuels. Of course, the likelihood of this scenario largely depends on which policies are implemented in between.

Trends in carbon concentration: the Keeling curve

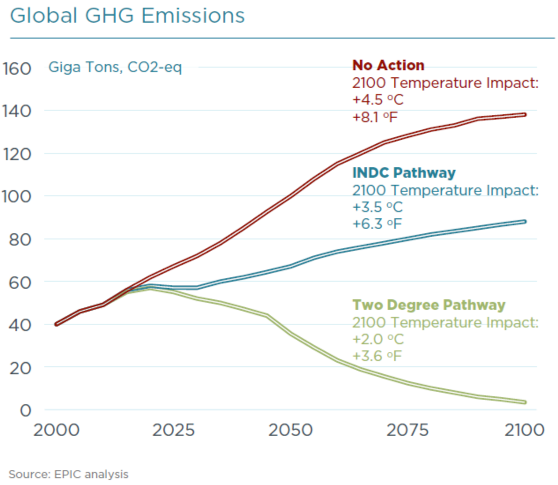
- The Keeling curve depicts the level of carbon dioxide in the Earth's atmosphere over time.
- Named after Charles David Keeling who started continuous measurement of carbon concentration at the Mauna Loa Observatory in Hawaii in 1958.
- How does it work?
  - Short run GhG concentrations from frequently collected samples
- And what about the distant past?
  - Long run GhG concentrations from ice sheet
- What do we learn?
  - Trends in atmospheric carbon concentration

Trends in CO_2 concentration and global average temperature



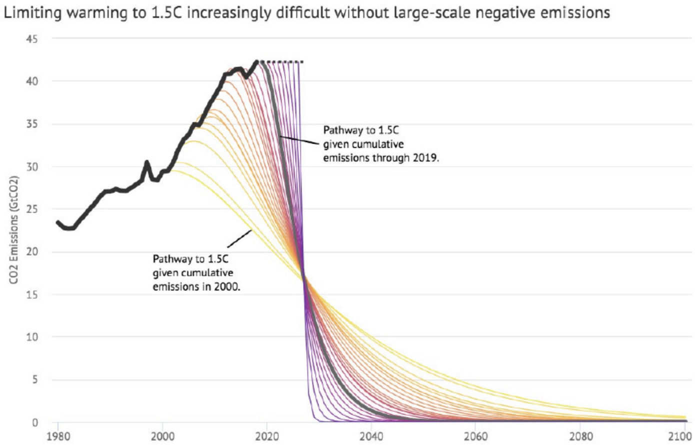
Source: Environmental Defense Fund

Climate change: what is to be expected



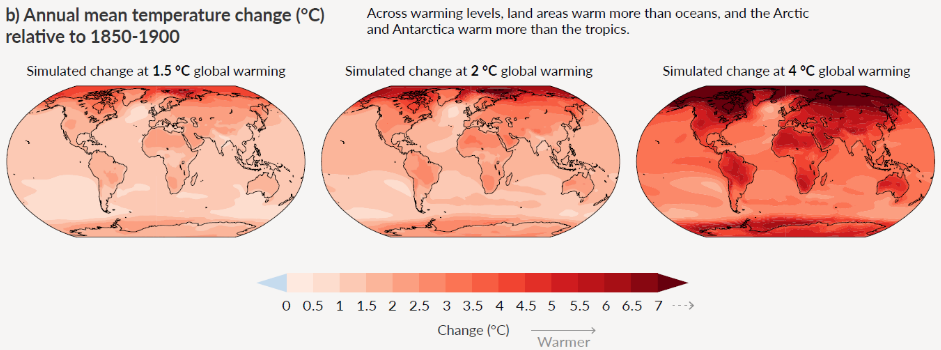
Different future scenarios are possible. Note: these figures mask great uncertainty, especially as emissions increase.

Climate change: pathways to $+1.5°C$ limit warming



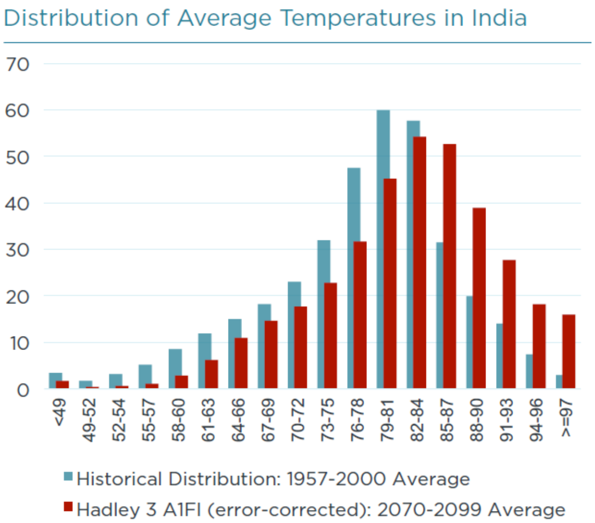
The $+1.5°C$ target is extremely unlikely to be achieved without negative emissions.

Average temperature increase masks spatial heterogeneity (...)

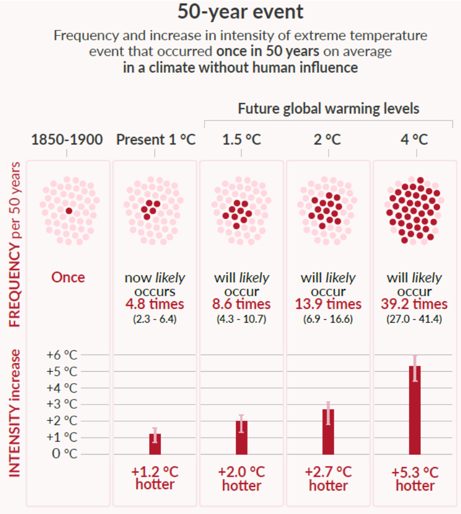


Source: IPCC, AR6

(...) as well as time heterogeneity

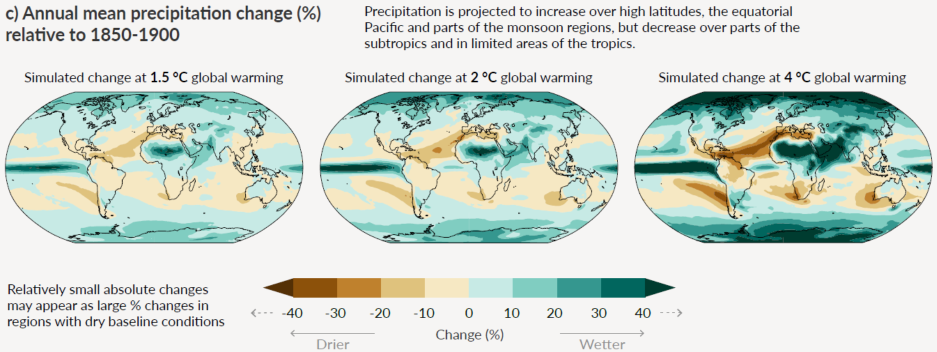


Expected frequency of extreme temperatures



Source: IPCC, AR6

Beyond temperatures, precipitations are greatly affected as well

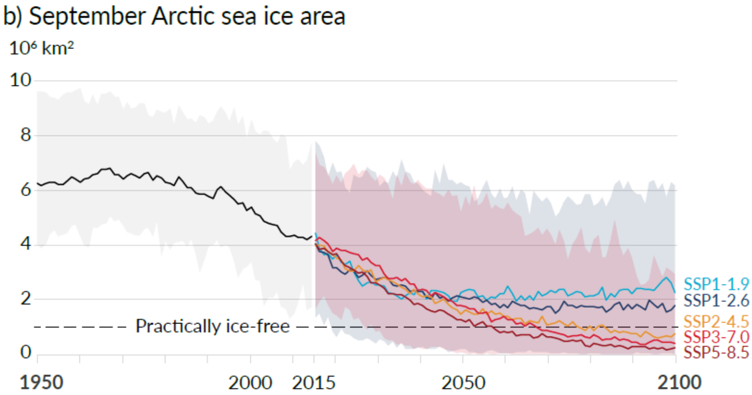


Source: IPCC, AR6

The consequences of heat and humidity

- Frequently used measure to describe interaction between heat and humidity: wet-bulb temperature.
- If the relative humidity is 100%, the wet-bulb temperature is equal to the air temperature (dry-bulb temperature); if humidity is lower, the wet-bulb temperature is lower than the dry-bulb temperature.
- With extreme heat waves and more humid atmosphere, major health risks.
- Why? When the air is too hot and too humid, the transpiration does not evaporate and the body cannot cool.
  - Major consequences already observed in several parts of the world: see video

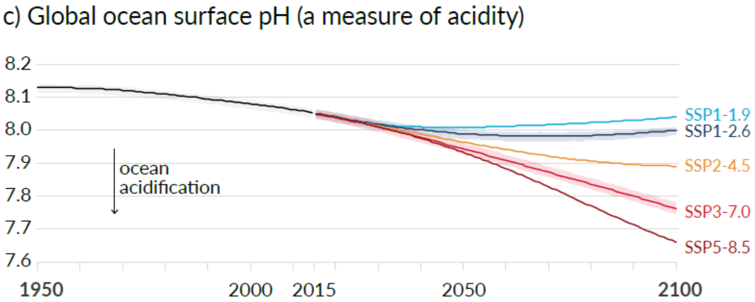
Expected evolution of Arctic ice



Source: IPCC, AR6

The melting is a self-reinforcing mechanism: the white sheet is replaced by water or dust → darker sheet that absorbs more light (see video).

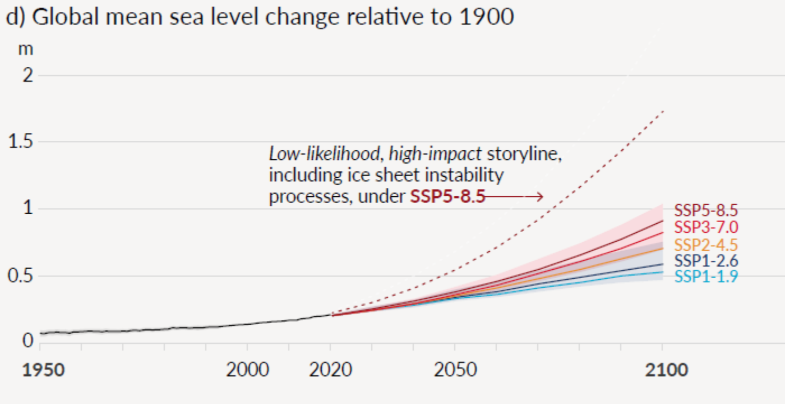
Expected acidification of oceans



Source: IPCC, AR6

Oceans become more acid (*i.e.* their pH decreases) as they absorb more CO_2. Great impact on ecosystems.

Sea level rise



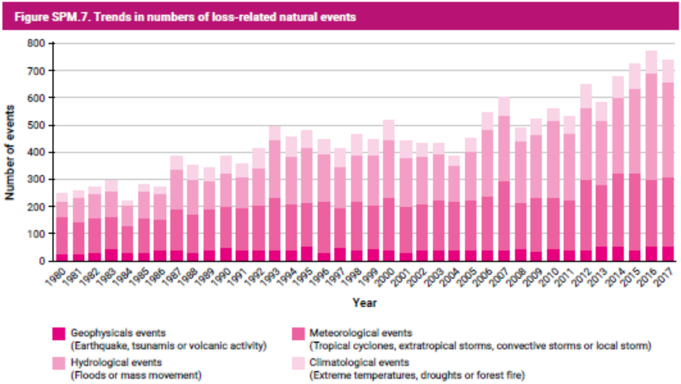
Source: IPCC, AR6

Very slow process, that will continue well beyond the XXIth century. By 2300, great uncertainty: "sea level rise greater than 15m cannot be ruled out with high emissions" (IPCC, AR6).

Some consequences of +7 meters

And some consequences of even limited sea-level rise: see video.

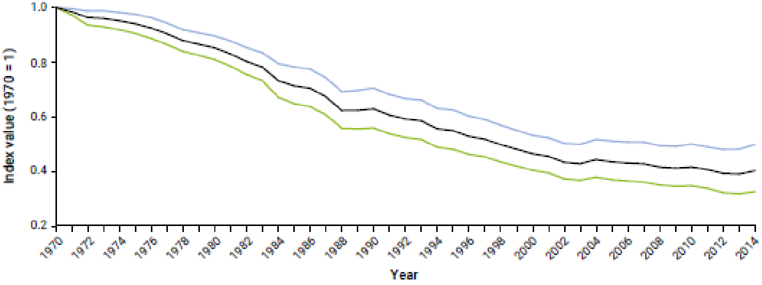
Short-term evolution of environmental disasters



Source: Munich Re (2017).

Short-term evolution of biodiversity

Figure SPM.2. Global Living Planet Index

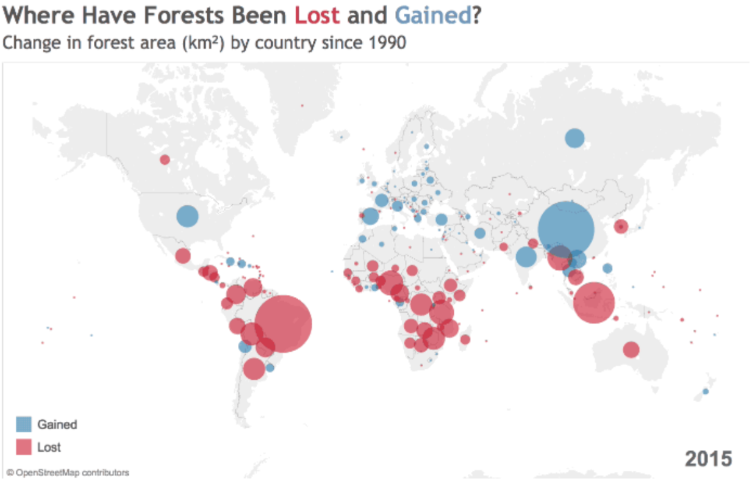


Source: World Wide Fund for Nature and Zoological Society of London (2018).

Note: The centre line shows the index values, indicating a 60 per cent decline between 1970 and 2014, and the upper and lower lines represent the 95 per cent confidence limits surrounding the trend. This is the average change in population size of 4,005 vertebrate species, based on data from 16,704 times series from terrestrial, freshwater and marine habitats.

Multiple causes: deforestation, land use, agricultural practices (c.f. *Silent Spring*), climate change, etc.

Deforestation around the world



Source: World bank data. Note: new forests do not substitute for the old-growth forests that have much richer ecosystems.

Water scarcity and women labor

→ Economic development has lifted out of poverty billions of people in the past decades. Still, in several regions of the world living conditions remain difficult and may be further impacted by environmental degradation, such as droughts and reduced agricultural yields. Tight link between environmental and livig conditions.

Table of Contents

A paradoxical field?

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Many people see **economics** and the **environment** as two very distant – if not opposed – subjects. So what is environmental economics exactly?

Let's first define economics: one can find many definitions of economics as a field, such as:

- a relatively narrow one: "the way in which trade, industry, or money is organized, or the study of this" (Cambridge Dictionary);
- a relatively broad one: "the science which studies human behaviour as a relationship between (given) ends and scarce means which have alternative uses" (Lionel Robbins).

$\rightarrow$ As the study of the allocation of scarce resources, economics is clearly concerned with natural resources and the environment!

What about the climate? $\rightarrow$ Resource affecting other scarce resources, hence many economic questions!

Example of topics in climate economics

- How do temperatures affect agricultural yields?
- What is the impact of higher temperature on workers' productivity? On students' test scores? On mortality?
- How does the anticipation of climate disasters impact the housing market? Are people's anticipations accurate?
- Who wins/loses from carbon pricing? How should we adjust the rest of the fiscal system to mitigate adverse distributional effects?
- Why do citizens generally oppose carbon pricing? Which type of climate policy do they support more?
- How does carbon pricing affect firms' green innovations? How does it affect their output?
- How can countries coordinate on global climate action?

$\rightarrow$ Very wide set of topics and tools.

Examples of academic journals publishing climate economics papers

A few papers published in general interest economic journals (*e.g. American Economic Review*, *American Economic Journal*s, *Journal of Political Economy*, *Journal of the European Economic Association*, *Economic Journal*, etc.).

More specialized environmental economic outlets include:

- *Review of Environmental Economics and Policy*;
- *Journal of Environmental Economics and Management*;
- *Journal of the Association of Environmental and Resource Economics*;
- *Ecological Economics*;
- *Environmental and Resource Economics*.

Relevant climate econ research can also be found in more multidisciplinary journals, such as *Nature Climate Change*.

Climate or environmental economics?

Climate economics: sub-field of environmental economics. Environmental degradation can take many forms. Examples:

- biodiversity losses;
- land use;
- air pollution (*e.g.* from particulate matter);
- water pollution;
- wastes (*e.g.* nuclear);
- rising sea levels;
- extreme weather events;
- non-renewable resource depletion (*e.g.* oil, some minerals used for batteries);
- renewable resource depletion (*e.g.* fish stocks, forests);
- etc.

Although they may have a common cause, not all these problems are due to climate change. **This course:** focus on climate change, but these other issues will be indirectly involved.