Climate change and human health: impacts and opportunities

Changement climatique et santé humaine: des impacts aux opportunités pour la santé publique

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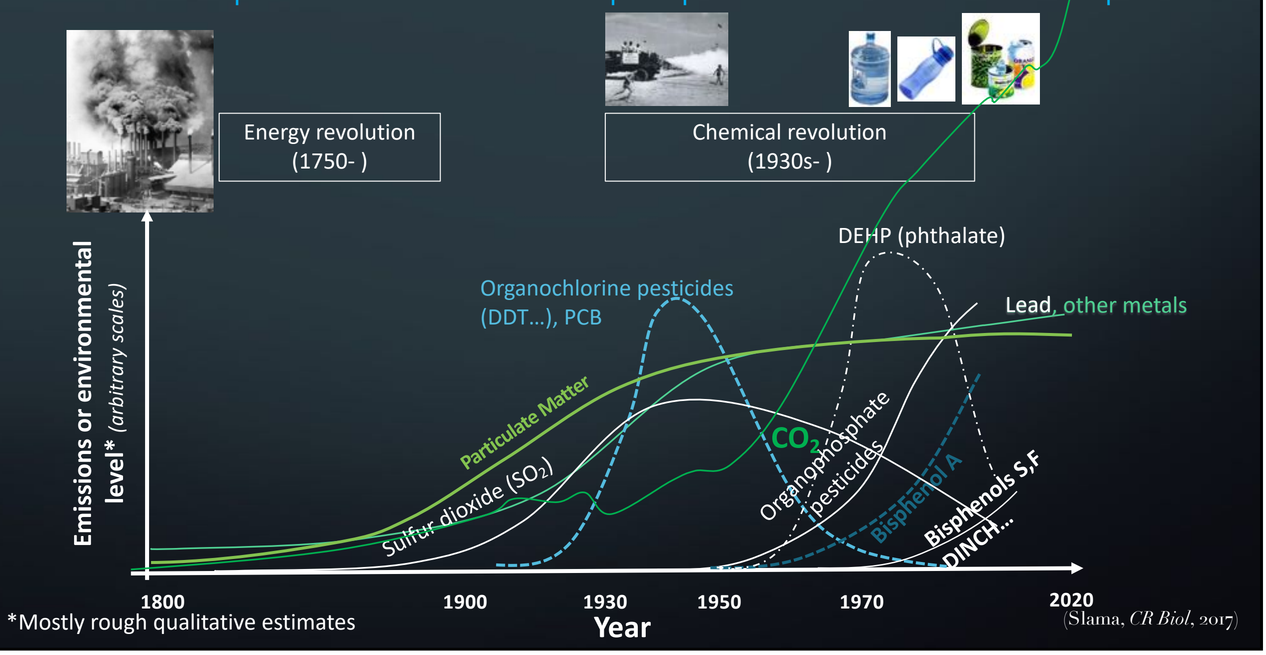
Collège de France & Inserm

The relations between human health and the environment in the Anthropocene

Lecture #9 – 8 June 2022

1

The Anthropocene seen from the perspective of environmental pollution



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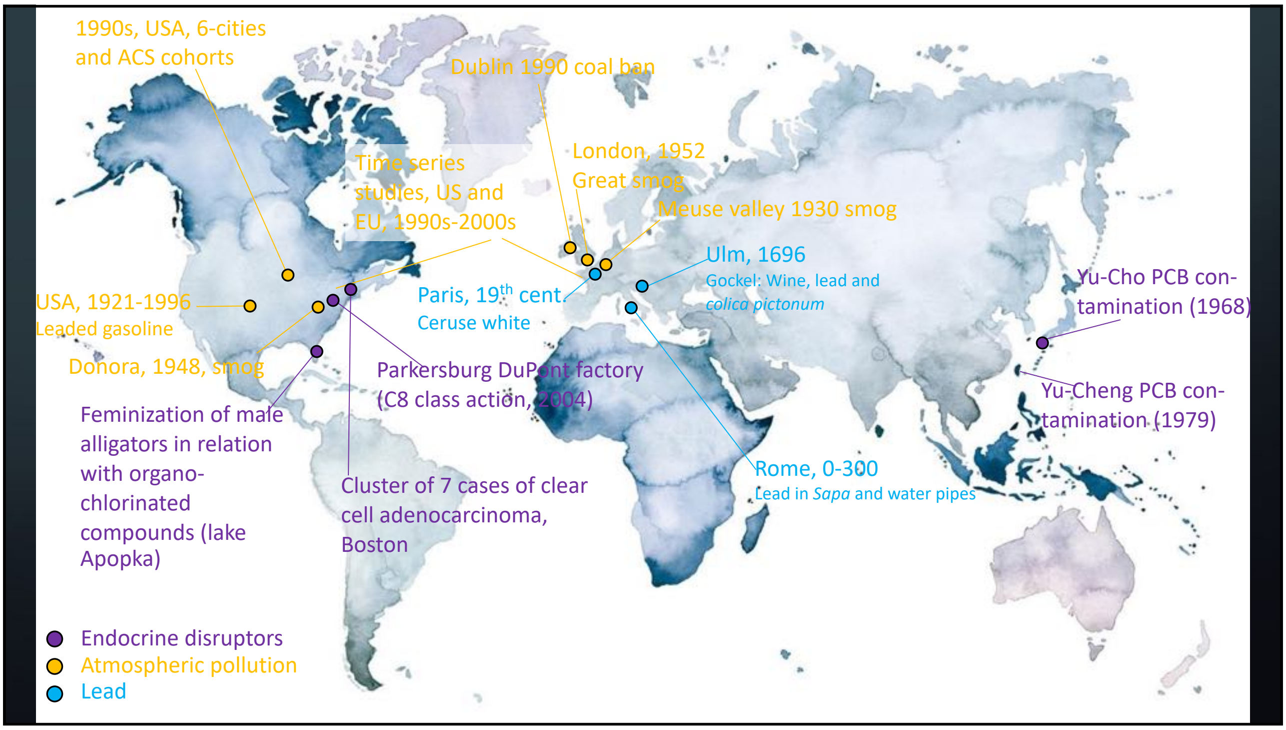

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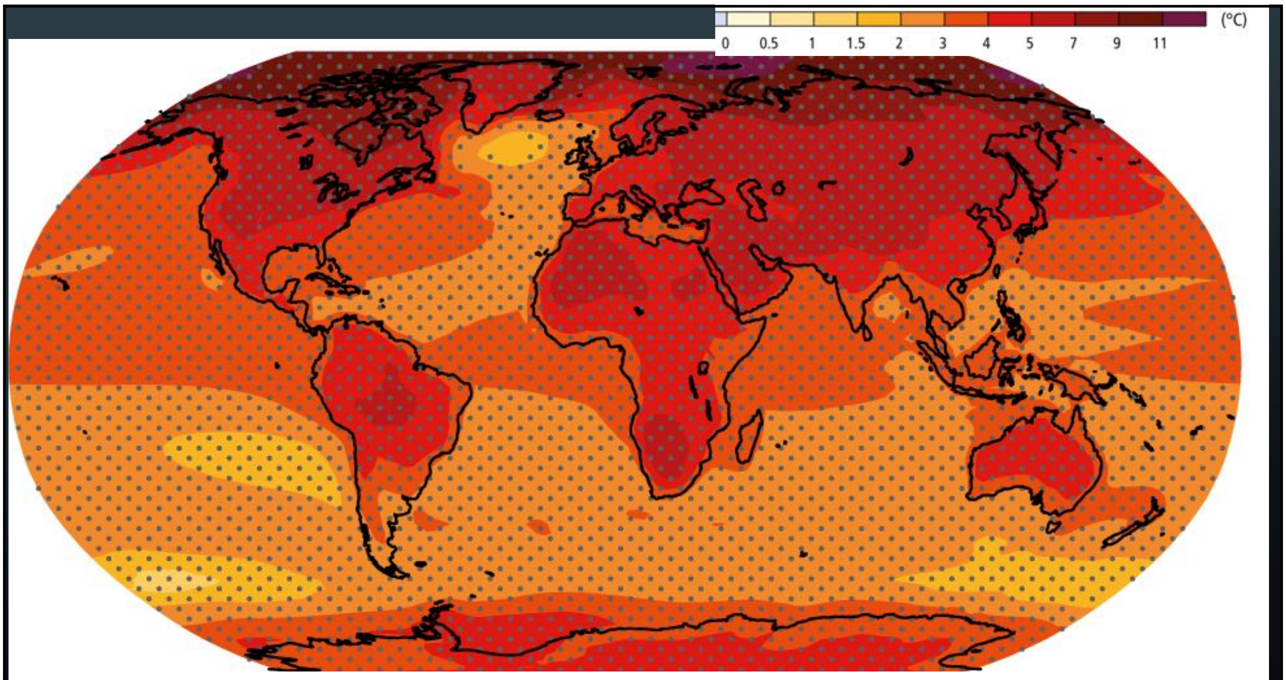

Change in average surface temperature based on multi-model mean projections for 2081–2100 relative to 1986-2005 under the RCP8.5 scenario

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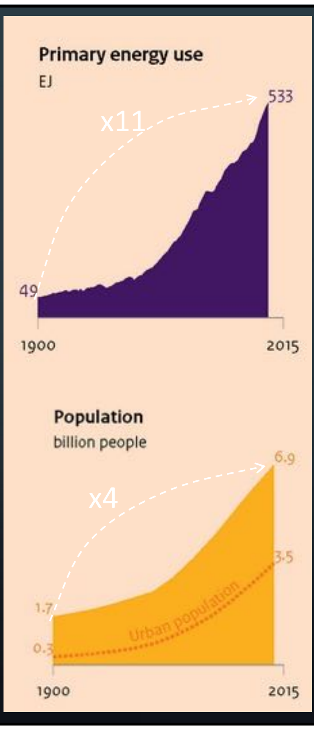

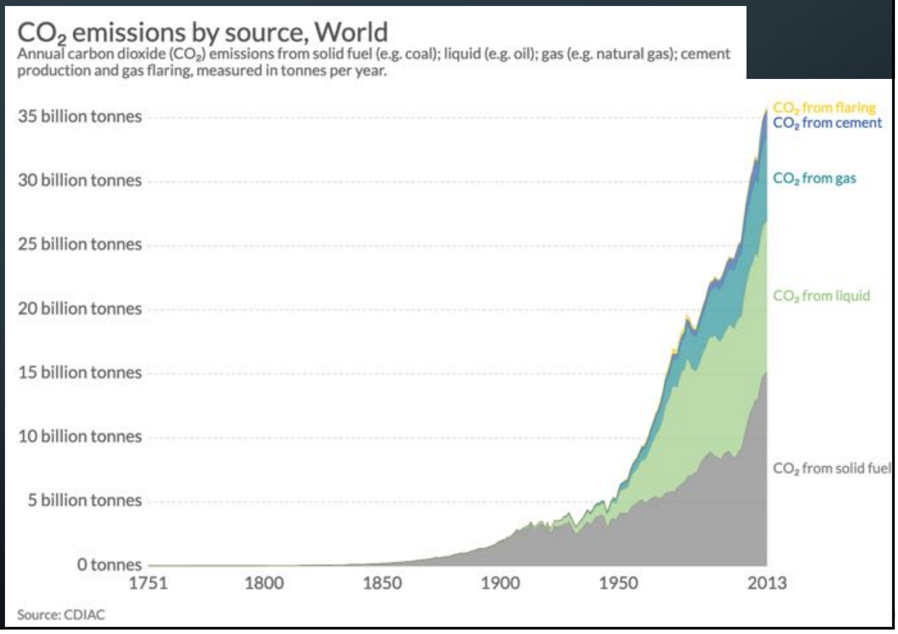

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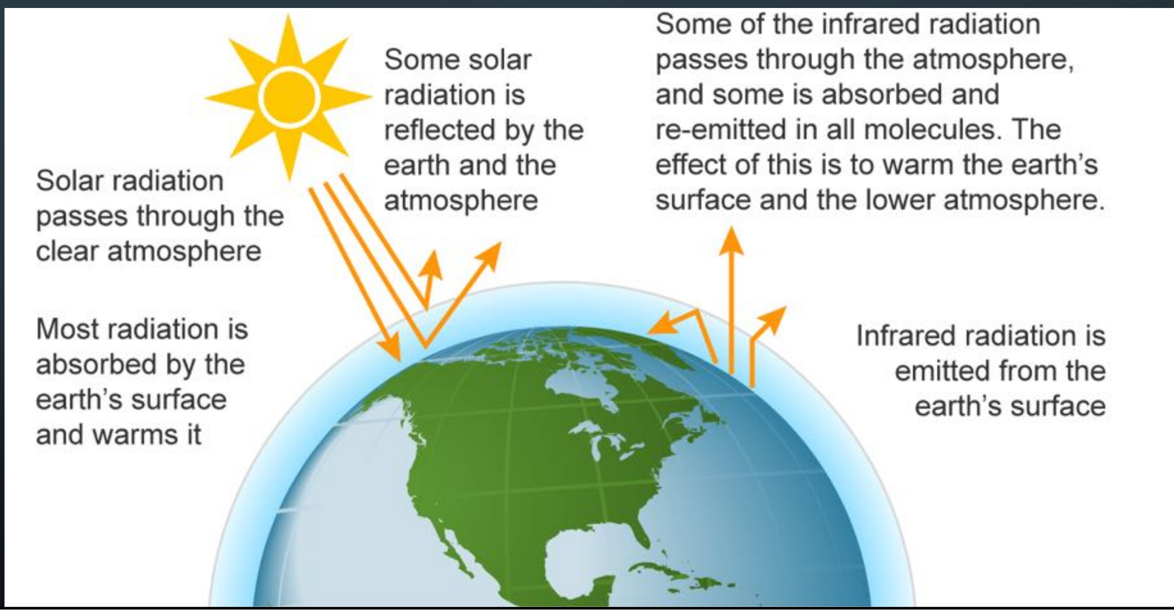
The greenhouse effect

(J Fourier, "Remarques Generales sur les Temperatures Du Globe Terrestre et des Espaces Planetaires". *Annales de Chimie et de Physique, 1824)*



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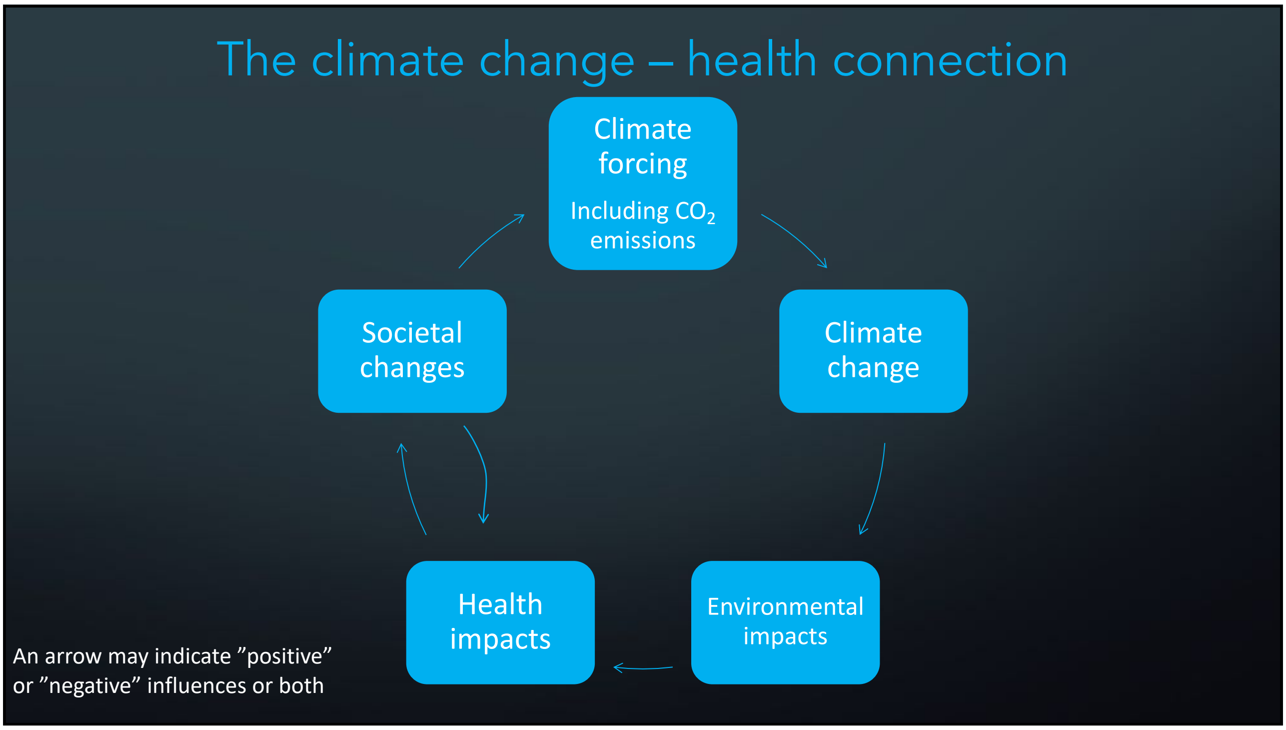

The climate change – health connection
Climate forcing
Including CO_2 emissions
Climate change
Environmental impacts
Health impacts
Societal changes
An arrow may indicate "positive" or "negative" influences or both

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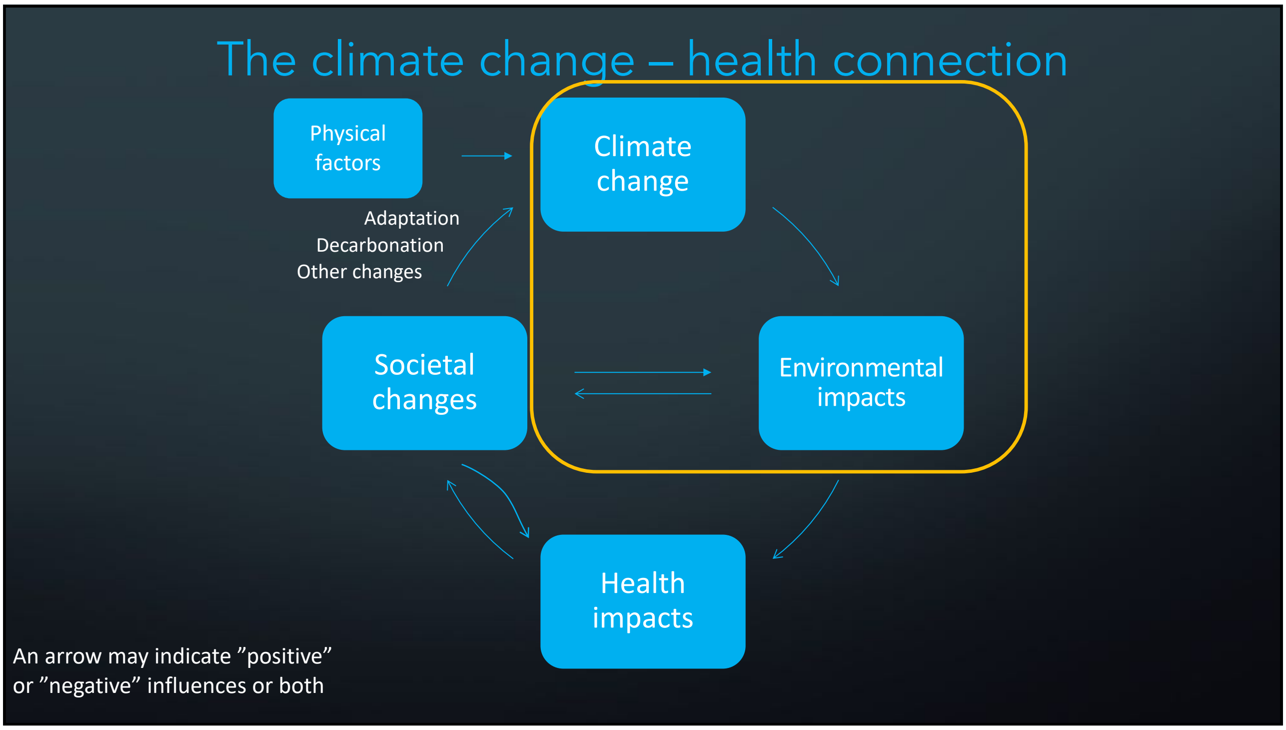

The climate change – health connection
Physical factors
Climate change
Adaptation
Decarbonation
Other changes
Societal changes
Environmental impacts
Health impacts
An arrow may indicate "positive" or "negative" influences or both

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A. Physical and environmental nature of climate change

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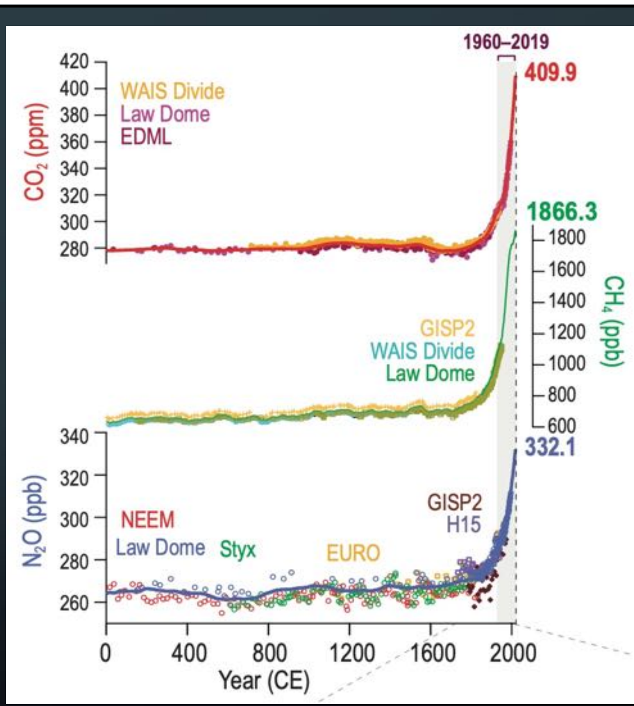
Greenhouse gas atmospheric levels



"Last time CO_2 levels were as high as present was at least 2 million years ago"
(IPCC 6th report, technical summary, 2021)

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Climate change – level one consequences

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(Source: IPCC, 2022)

Climate change – *level one* manifestations (physical environment)

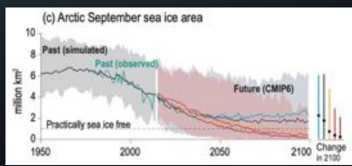
Atmosphere

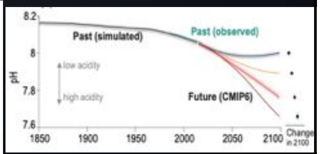
Land

Cryosphere

Oceans

- Concentration of greenhouse gases (GHG)
- Warming of the troposphere
- Temperature change
- Precipitations
- Extreme weather events
- Greenland ice sheet mass loss
- Arctic and Antarctic sea ice loss
- Reduction in Northern hemisphere spring snow cover
- Retreat of glaciers
- Ocean acidification
- Ocean heat content
- Rising sea levels





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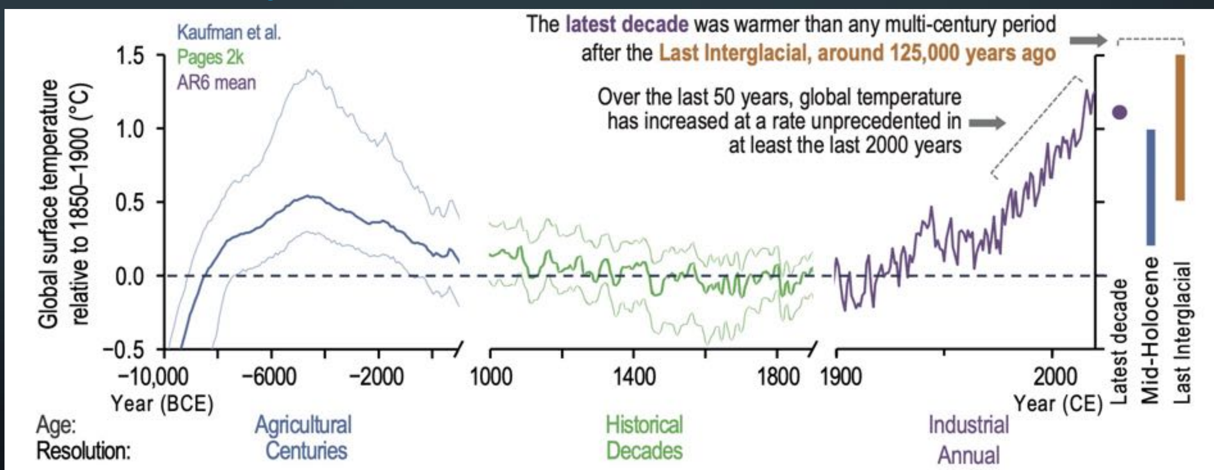
Over the last 50 years, global surface temperature has increased at a rate unprecedented in at least the last 2000 years



(IPCC 6th report, technical summary, 2021)

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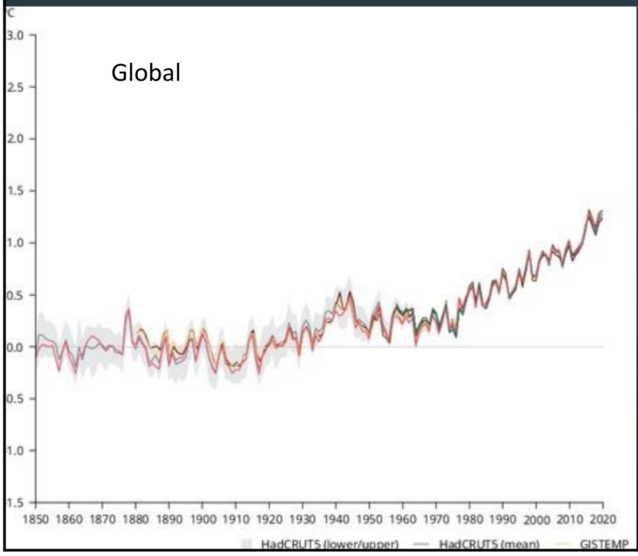
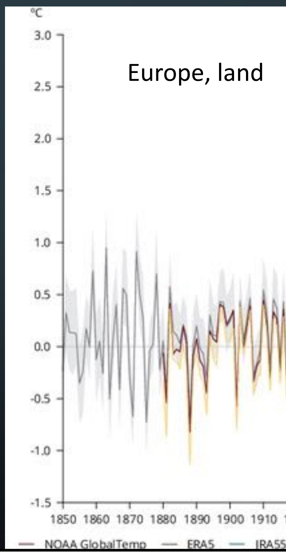
(Source: European Environment Agency)

Changes in mean temperature (1850-2020)





The mean annual temperature over European land areas in the last decade was 1.94 to 2.01°C warmer than during the pre-industrial period.

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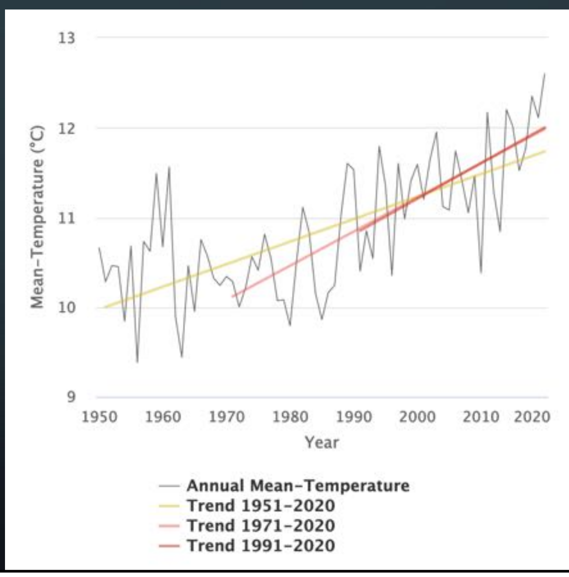
France: Change in mean temperature (1950-2020)



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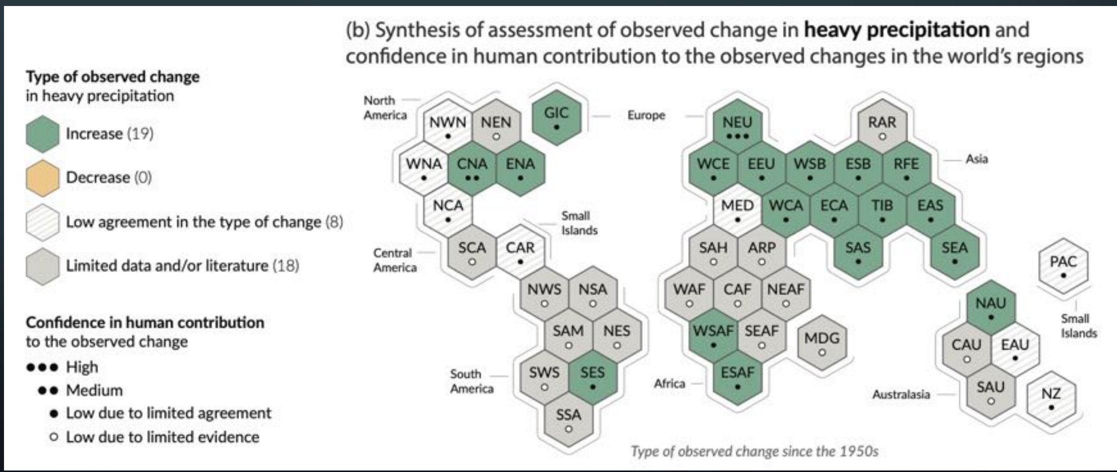
Change in heavy precipitations by region



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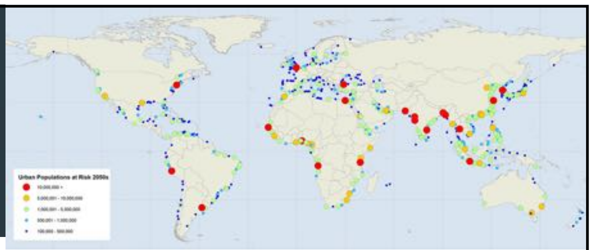
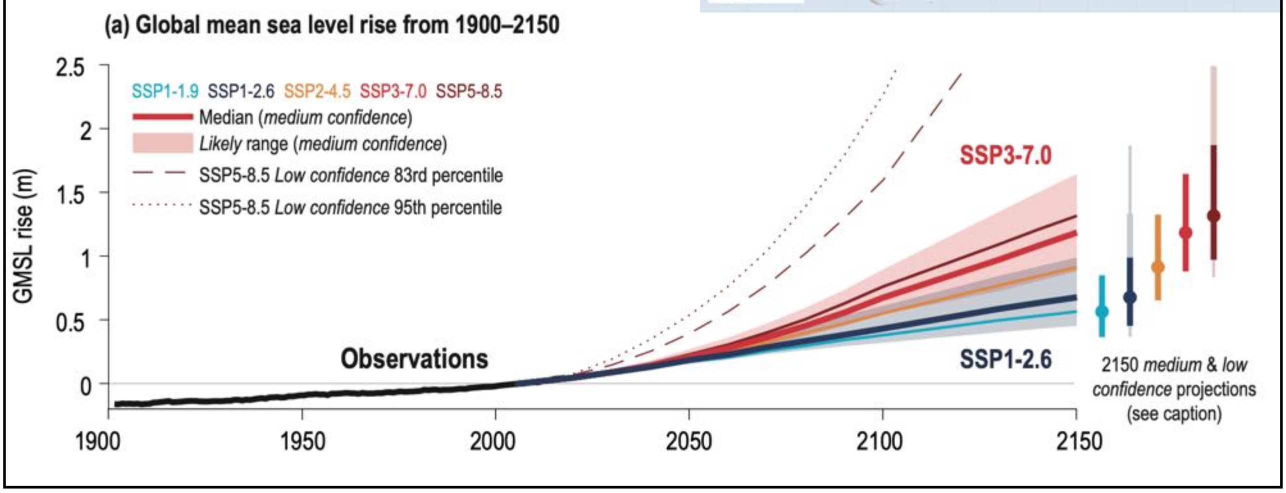
Sea level rise

Cities a risk from sea level rise of 0.5 m by 2050s





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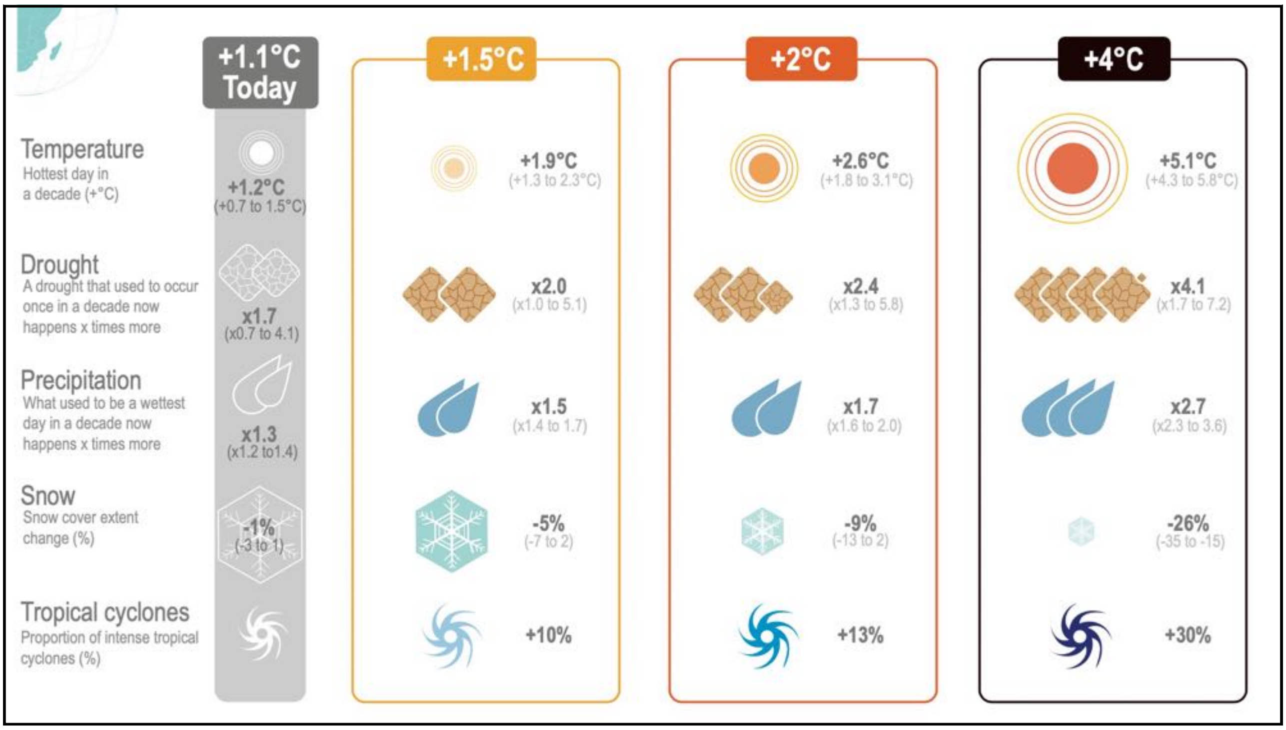

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(Source: IPCC, 2022)

Some *level two* manifestations (living environment)

Atmosphere | Land | Cryosphere | Oceans

Land species

Water species

- Wildfires

- Change in ecosystem structure
- Species range shift
- Changes in timing

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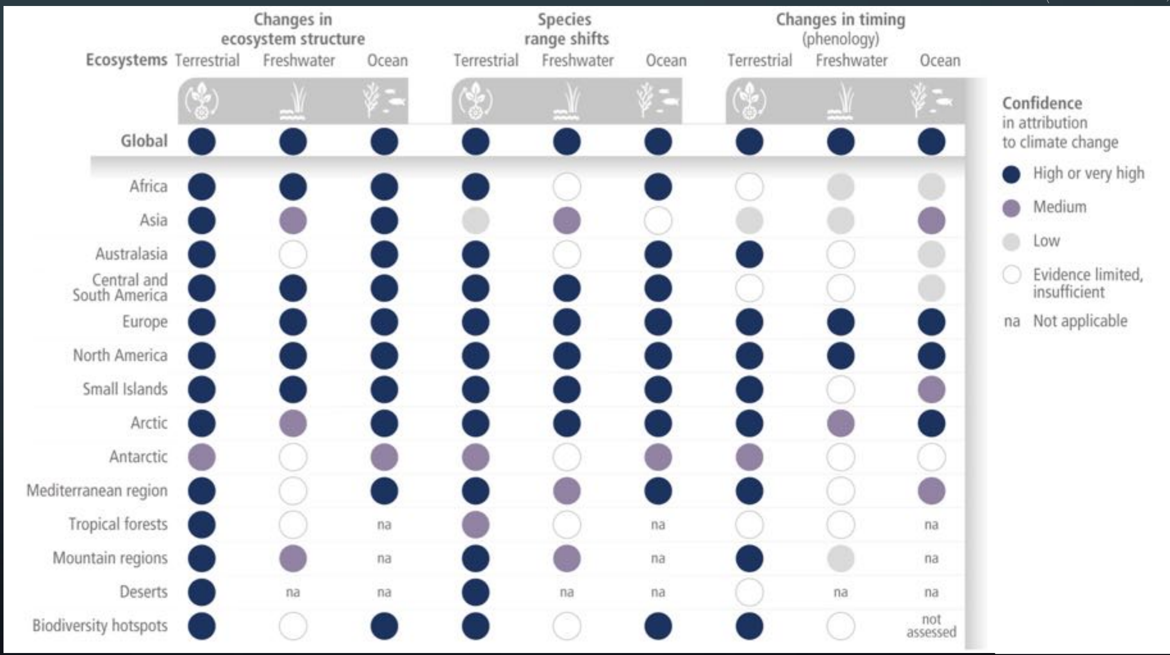
(Source: IPCC, 2022)



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Wildfire risk

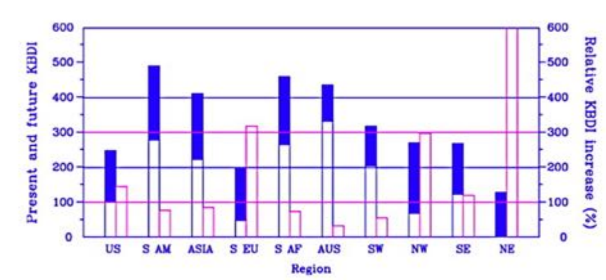

Figure 38. Model-estimated regional changes in wildfire risk due to climate change. Results are shown as the magnitude of regional Keetch–Byram drought index (KBDI) for 1961–1990 (present, open bars) and 2070–2100 (future, shaded bars). The percentage change between these two periods is shown on the right axis. The future KBDI changes were calculated using the climate change projected by the HadCM3 (Hadley Centre Coupled Model) with the A2a emissions scenario (Liu et al., 2010).

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Particularities of climate change among other health hazards

- Inertia of the CO_2 cycle / long-term impacts
- Some actions on emissions may have little short-term visible impact
- Long-range effects: local actions are unlikely to provide efficient solutions
- Systemic nature
- Multiplicity of sources; connection with a large number of economic and activity sectors
- Multiplicity of pathways of effect

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B. Expected health impacts of climate change

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Effects mediated by CC-related changes in the physical environment

Atmosphere

Land

Cryosphere

Oceans

- Concentration of greenhouse gases (GHG)
- Warming of the troposphere
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- Precipitations
- Extreme weather events

- Greenland ice sheet mass loss
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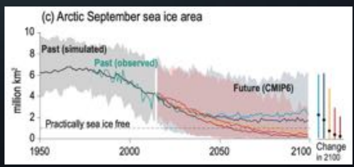
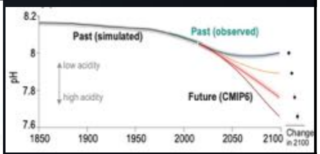
- Rising sea levels





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The temperature-mortality causal chain

Temperature → Health effects

Greenhouse gas emissions → • Temperature change → Health impact

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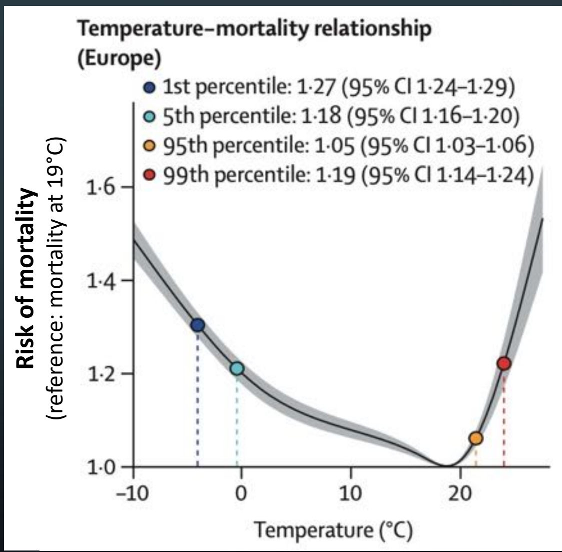
On the short-term: daily temperatures generally influence all-cause mortality following a U-shape relation

Time-series analysis based on daily mortality and temperature data (Europe)



Both
➔ "unusually" high and
➔ "unusually" low
temperatures increase mortality.

How does this relation vary
- Across space (heterogeneity in city resilience)?
- Across diseases?
- Across time (adaptation)?

(Martinez-Solanas, *Lancet Plan Health*, 2021)

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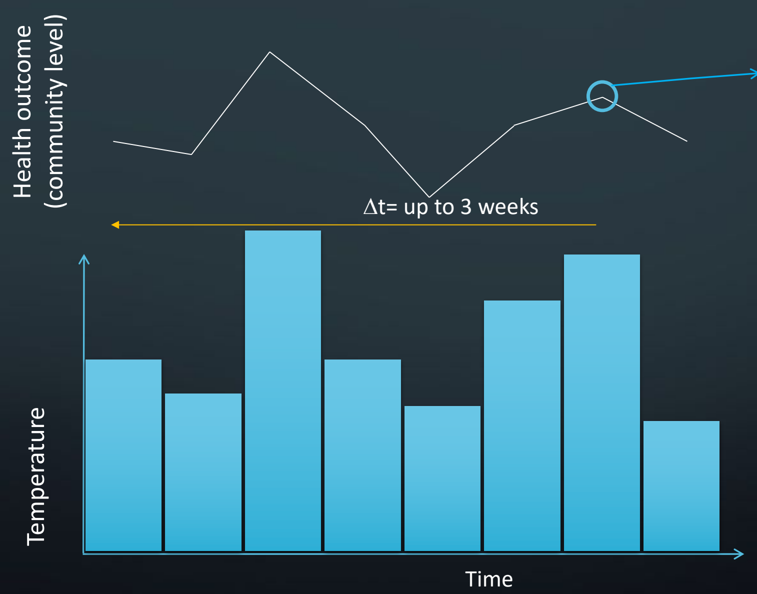
Time series analyses with distributed lag model: principle



Principle:
Number of (death) cases Y(t) on a given day t are modelled as a function of
- Temperature the previous days (up to 21 days generally)
- Long-term trends (to correct for intra- and inter-annual trends in mortality (e.g., epidemics…)
- Possibly local characteristics

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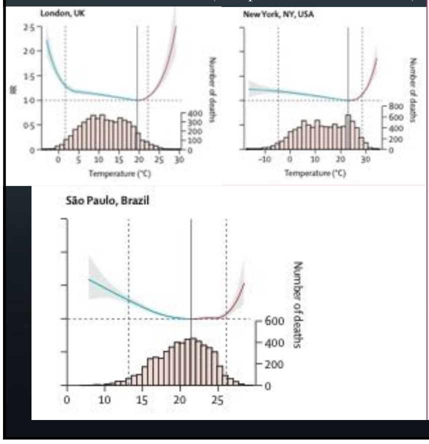
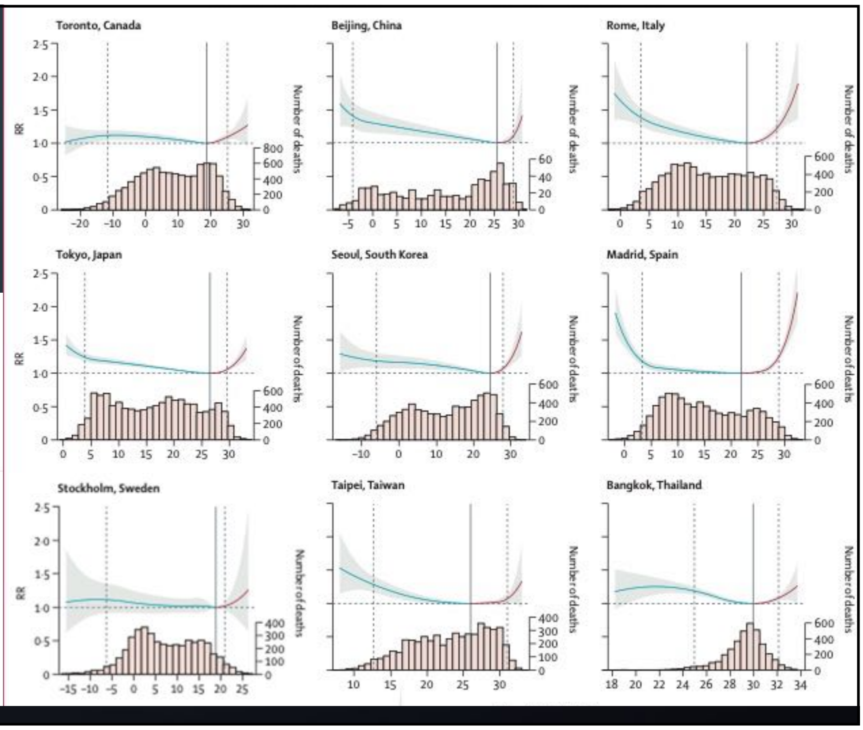
Temperature-mortality short-term relation across the globe (Metropolitan areas)

(Gasparrini, *Lancet*, 2015)





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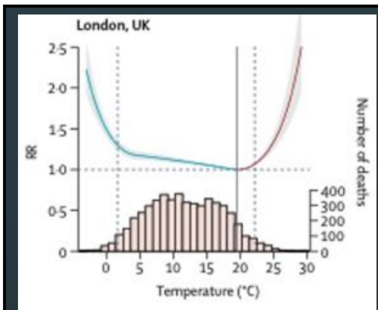

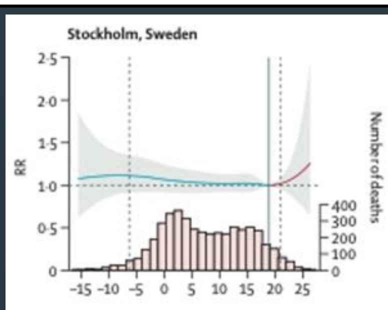

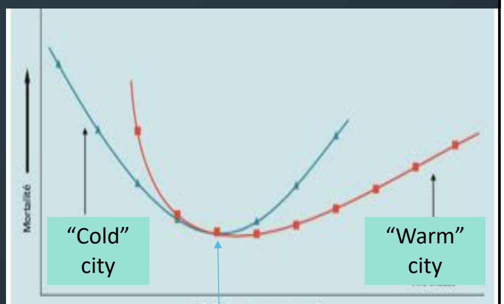

(Kinney, BEH, 2012)

Minimum mortality generally in the 80th-90th local temperature centile
(Gasparrini, *Lancet*, 2015)

Dose-response functions somewhat vary across cities

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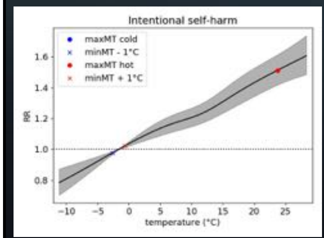
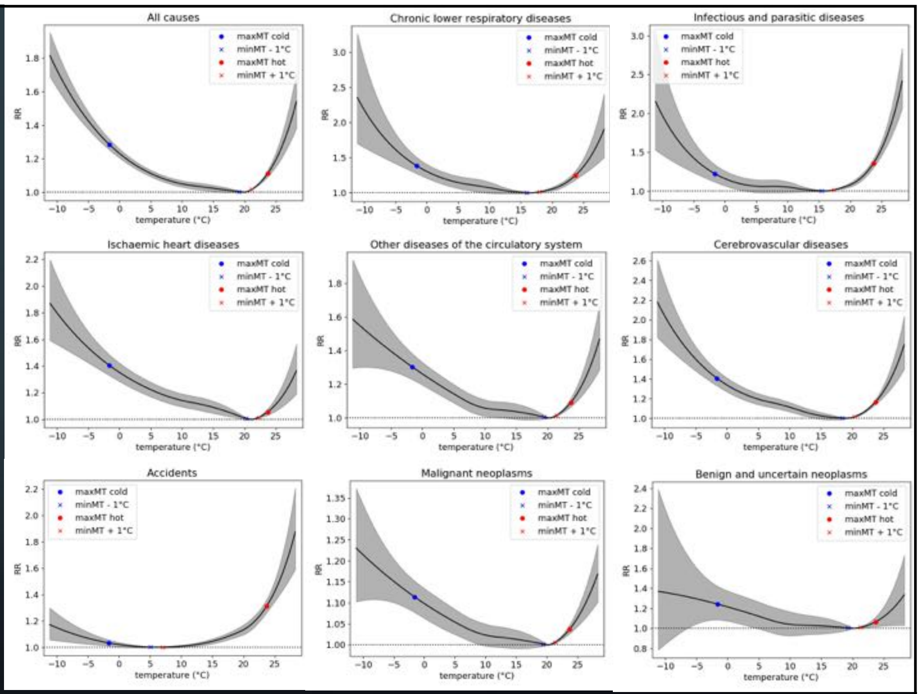
Temperature-mortality short-term relations across causes of death (France, 1968-2016)

(Lehmann, *Am J Epid*, in press)

Suicide as the only large cause of death following a monotonous relation





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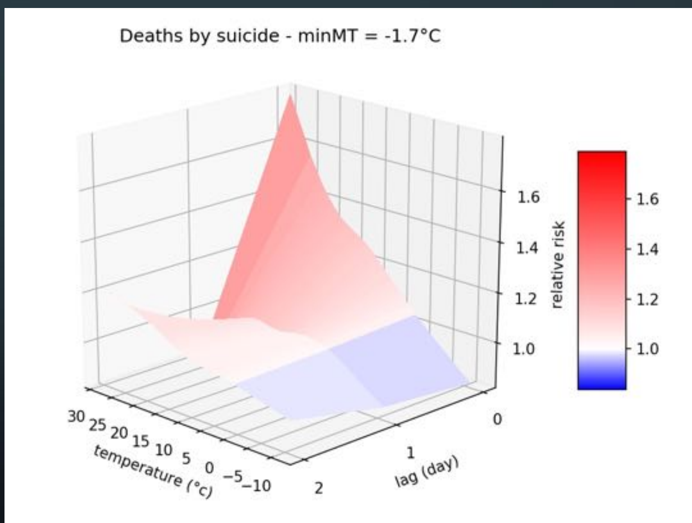
The temperature-suicide mortality relation corresponds to a very short-term association



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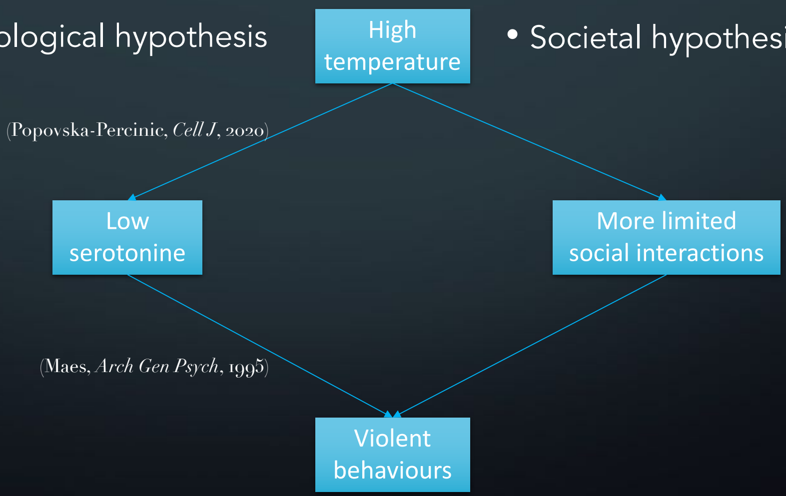
Temperature-suicide mortality relation: Hypothesized mechanisms

- Biological hypothesis
- Societal hypothesis



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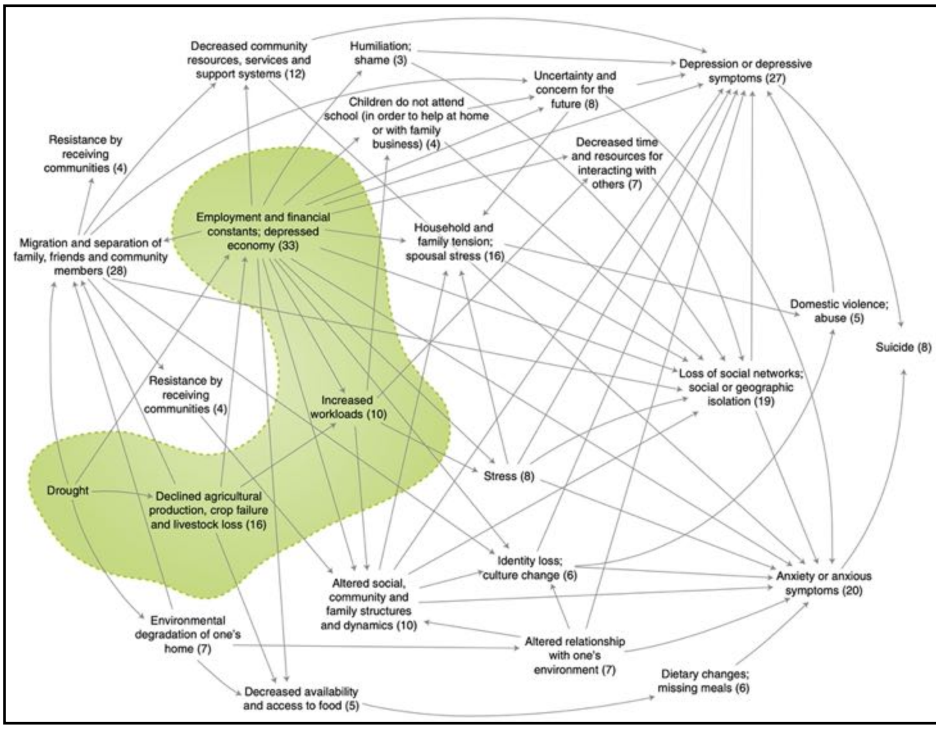

Climate change and mental health: *Multiple indirect paths*

(Berry, *Nature Clim Ch*, 2018)

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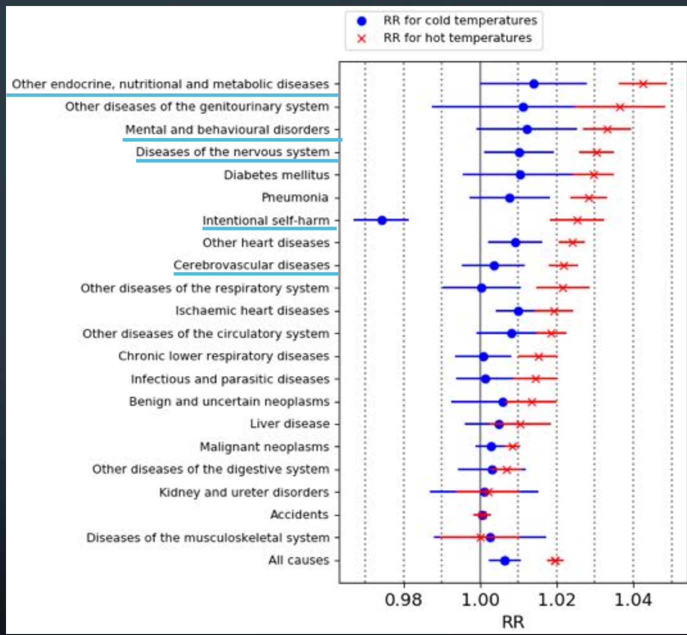
Which causes of death are most sensitive to heat or cold?



(Lehmann, *Am J Epid*, in press)

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The temperature-mortality causal chain

Temperature → Health effects

Greenhouse gas emissions → • Temperature change → Health impact → Current impact

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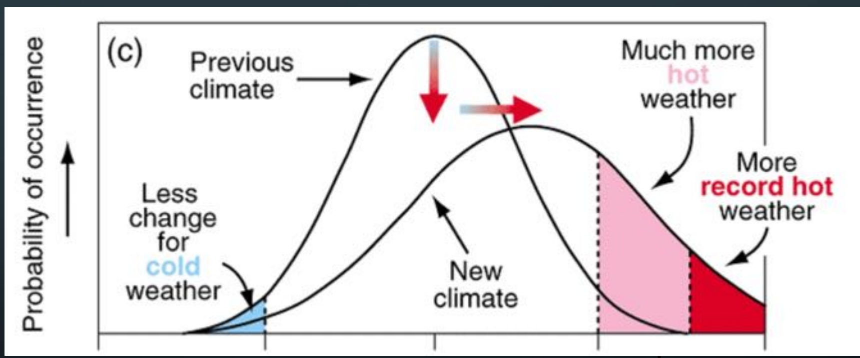
A relatively slight change in the mean temperature can induce large changes in the number of days with extreme temperatures



Decrease in the number of days with a cold temperature

Increase in the number of days with an "extremely hot" temperature

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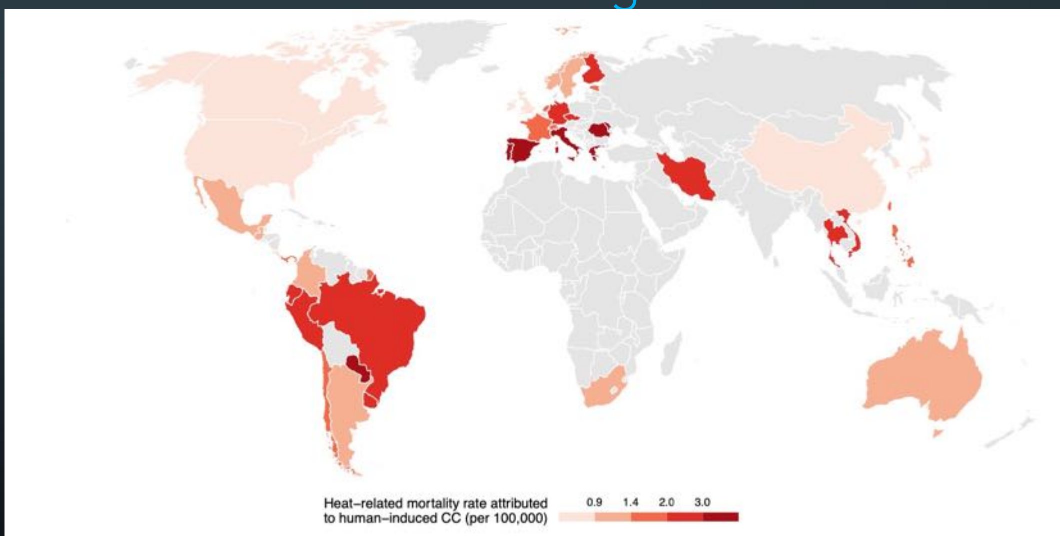
Share of the *current* heat-related mortality attributable to climate change



(Vicedo-Cabrera, *Nature Clim Ch*, 2018)

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The temperature-mortality causal chain

Temperature → Health effects

Greenhouse gas emissions → • Temperature change → Health impact

Current impact

Future impact

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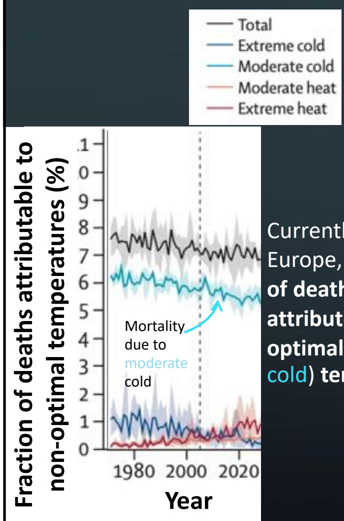
Predicted changes in the mortality attributable to extreme temperatures in Europe under various scenarios



Currently, in Europe, about **7% of deaths are attributed to non-optimal** (mostly cold) **temperatures**

(Martinez-Solanas, *Lancet Plan Health*, 2021)

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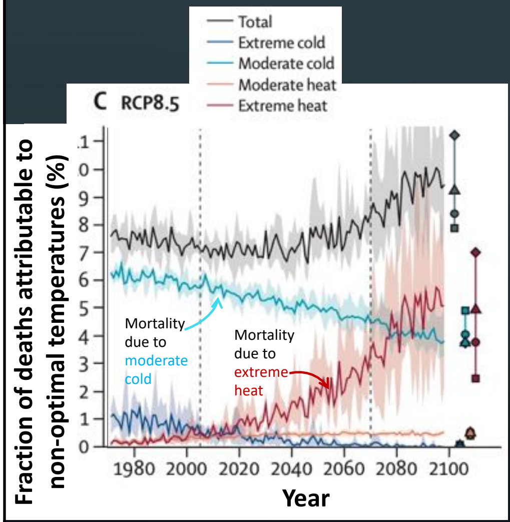
Predicted changes in the mortality attributable to extreme temperatures in Europe under *RCP8.5* scenario



(no strong action against climate change)

Without action against climate change and greenhouse gas emissions (RCP8.5 emission scenario), in Europe,

- deaths attributed to cold temperatures temperatures are likely to decrease,
- and those attributable to extremely hot temperatures will increase even more,

so that without control of GHG emissions, **mortality attributed to non-optimal temperatures is likely to increase in the 2nd half of the century.**

Similar situations are expected in areas with currently temperate or warm climates.

(Estimates assume lack of varying adaptation to warm or cold temperatures as climate gets warmer)

RCP: Representative concentration pathway

(Martinez-Solanas, *Lancet Plan Health*, 2021)

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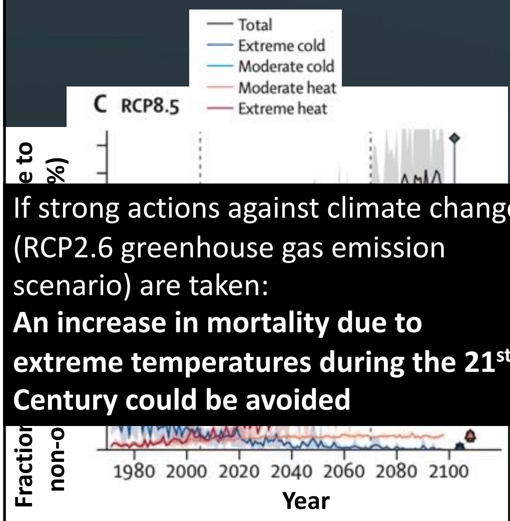
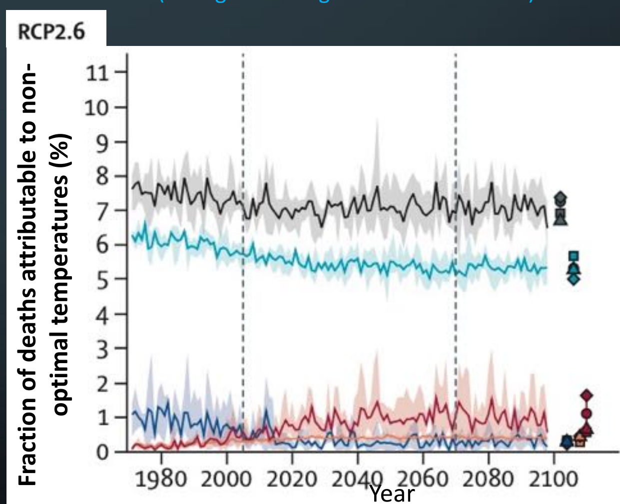
Predicted changes in the mortality attributable to extreme temperatures in Europe under *RCP2.6* scenario

(strong actions against GHG emissions)



If strong actions against climate change (RCP2.6 greenhouse gas emission scenario) are taken:

An increase in mortality due to extreme temperatures during the 21st Century could be avoided



RCP: Representative concentration pathway

(Martinez-Solanas, *Lancet Plan Health*, 2021)

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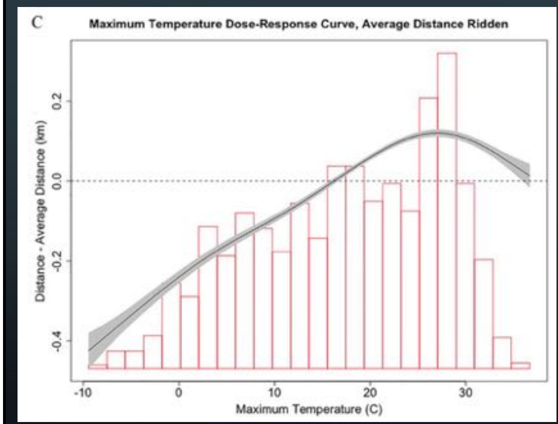
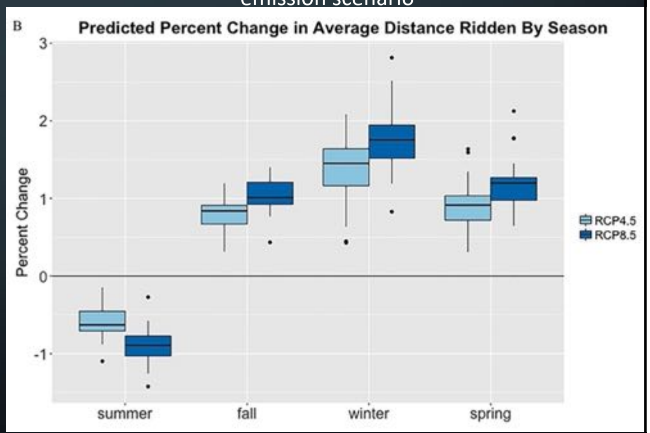
Temperature and physical activity: A case study based on New-York bike sharing system



Predicted long-term impact on distance ridden according to emission scenario



(Heaney, *EHP*, 2019)

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Effects mediated by CC-related changes in the living environment

Atmosphere

Land

Cryosphere

Oceans

Land species

Water species

- Wildfires

- Change in ecosystem structure
- Species range shift
- Changes in timing

Crop production

Vector-borne diseases

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Climate and infectious diseases

- Many infectious pathogens are sensitive to climate
  - In Europe, 63% of the pathogens with the largest health impact are climate sensitive (in particular to rainfall and temperature)(McIntyre, *Sci Rep*, 2018)
- Vector-borne, soil-borne, water-borne and foodborne pathogens are more likely to be influenced by climate (McIntyre, *Sci Rep*, 2018)
- For example, the life cycle of mosquitoes is strongly influenced by temperature and humidity (e.g., Anopheles, responsible of malaria transmission)
- Some of the most frequent climatic drivers of pathogens include temperature, rainfall, humidity, wind speed, which are all likely to be influenced by climate change

→ Could climate change influence the incidence of infectious diseases or at least vector/soil/water/food-borne infectious diseases?

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Possible consequences of climate change on malaria transmission

[Mathematica models of malaria transmission] have reached divergent conclusions (…)

- some predicting a large *expansion* in the continental land area suitable for transmission (Martens 1999; Caminade 2014; Tanser 2003) and in the number of people at risk of malaria (Martens 1999; Patz 1996; Pascual 2006),
- while others predict only modest poleward (and altitudinal) *shifts* in the burden of disease, with little net effect (Gething, 2010; Rogers and Randolph 2000; Hay, 2002)

(Eikenberry, *J Math Biol*, 2018)

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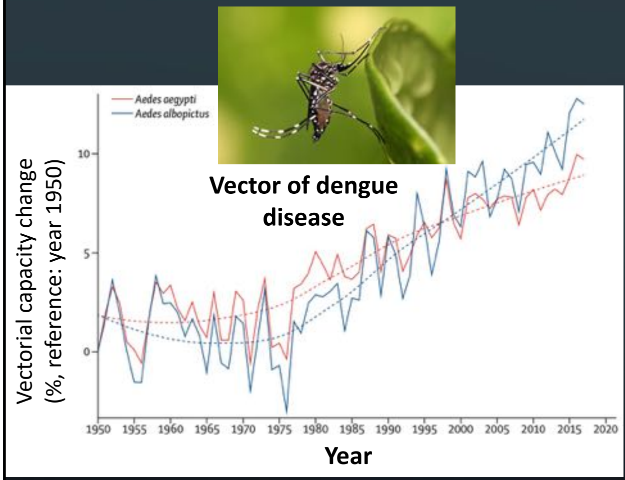
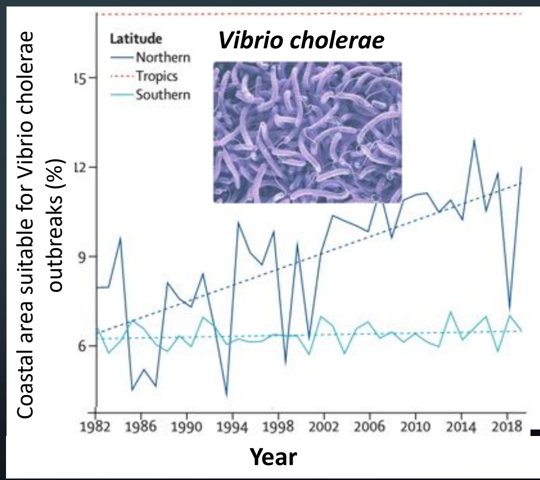
The suitability of climate for the transmission of specific infectious diseases has increased in some areas





(Watts, *The Lancet*, 2019)

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Production of ambroisia pollen (Ambroisia artemisiifolia)

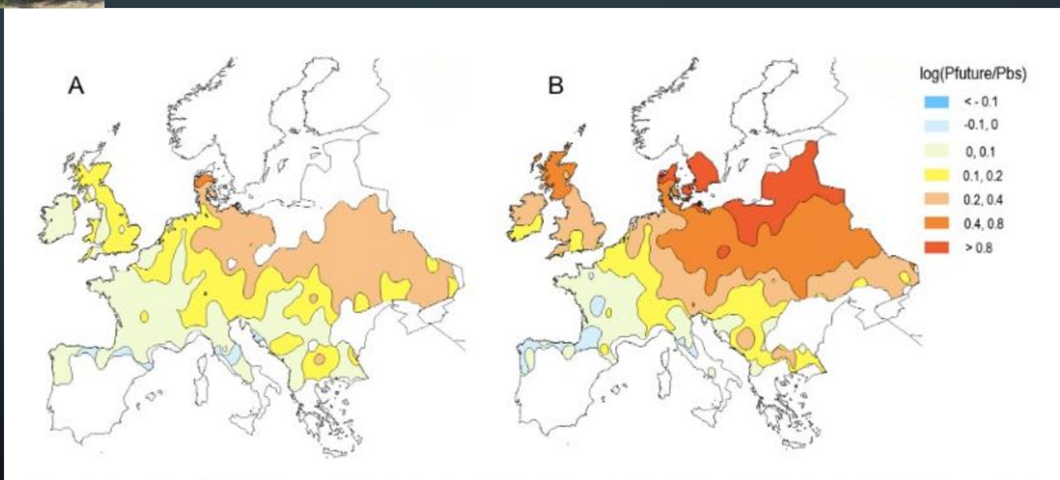

Figure 4. Logarithm of relative increase in *Ambrosia artemisiifolia* pollen production, Pfuture/Pbs, for the HadCM3 (A1B) scenarios. A.

(Storkey, *Plos One*, 2014)

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Climate change and agriculture

« Climate change impacts are stressing agriculture, forestry, fisheries, and aquaculture, increasingly hindering efforts to meet human needs (*high confidence*). »

Expected impacts:
-make some current food production areas unsuitable (*high confidence*)
-increasingly expose outdoor workers and animals to heat stress, reducing labour capacity, animal health, and dairy and meat production *(high confidence)*
-negative impact on food safety *(high confidence)*

(IPCC 6th assessment report, Chapter 5, final draft, 2021)

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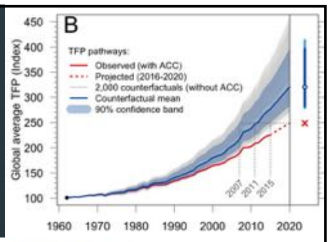
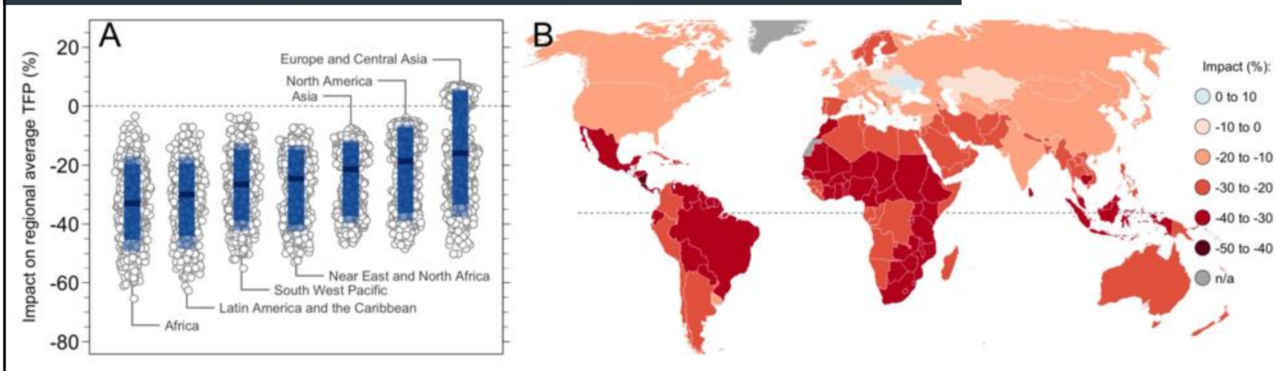
Climate-change effects on agriculture (1961-2015)





Anthropogenic climate change is estimated to have reduced global agricultural productivity (total factor productivity, TFP) by about 21% since 1961.
The impact is more severe in warmer regions (Africa, Latin America…).

(Ortiz-Bobea, *Nature Clim Change*, 2021)

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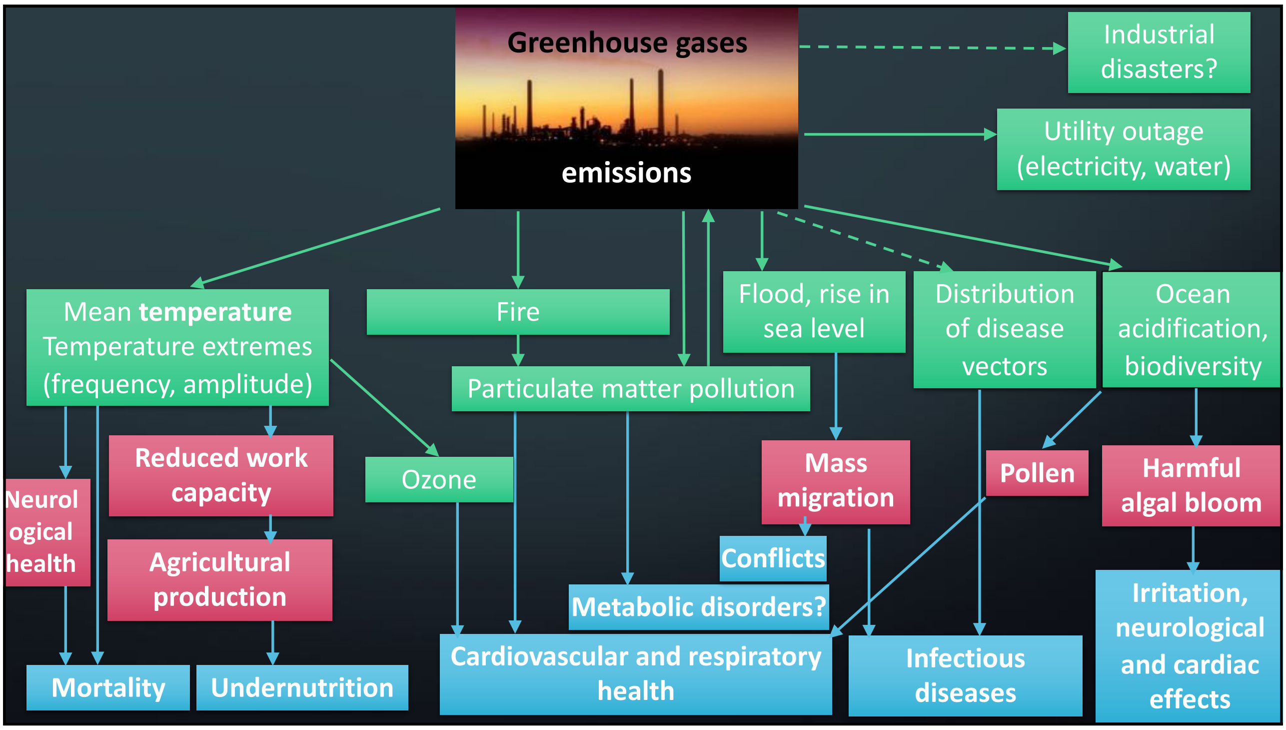
Greenhouse gases
emissions
Industrial disasters?
Utility outage (electricity, water)
Mean temperature
Temperature extremes (frequency, amplitude)
Fire
Flood, rise in sea level
Distribution of disease vectors
Ocean acidification, biodiversity
Particulate matter pollution
Reduced work capacity
Ozone
Mass migration
Pollen
Harmful algal bloom
Neurol ogical health
Agricultural production
Conflicts
Metabolic disorders?
Irritation, neurological and cardiac effects
Mortality
Undernutrition
Cardiovascular and respiratory health
Infectious diseases

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C. Managing climate change risks

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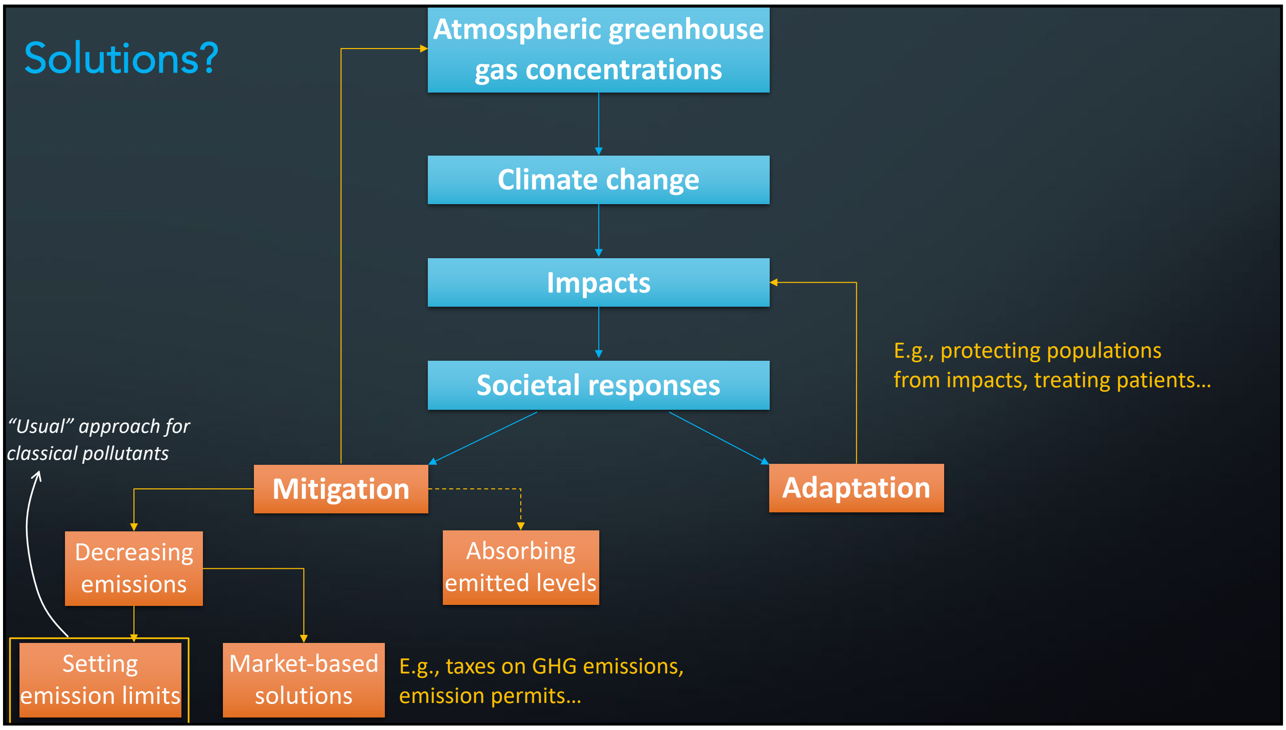

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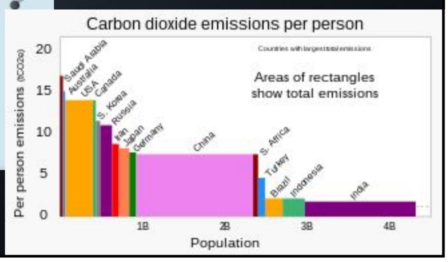
Geographic differences in CO_2 emissions/person

Expected impact on agricultural productivity



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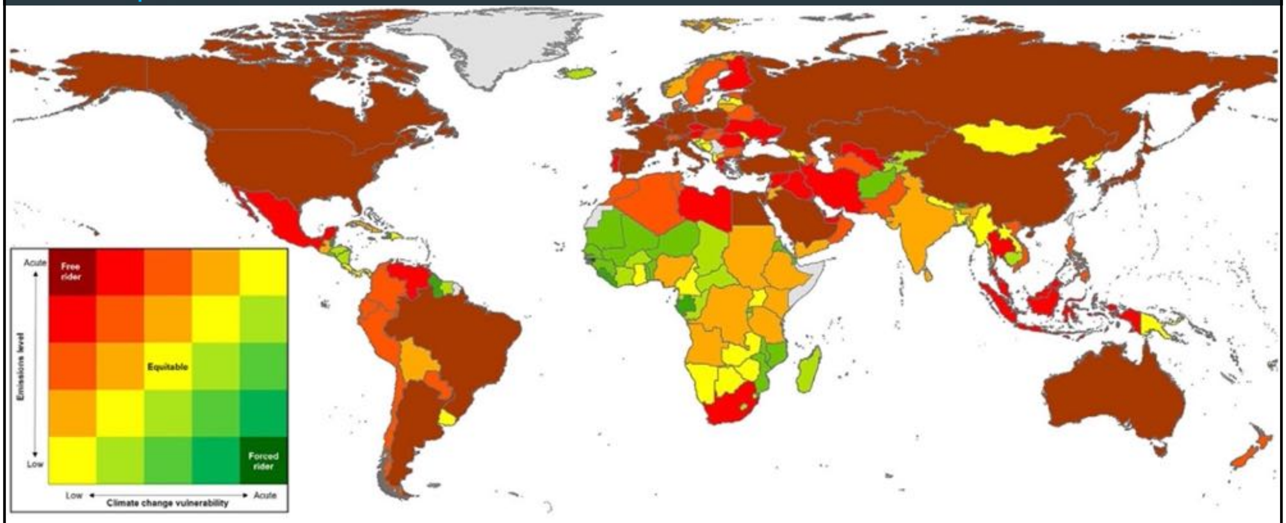
Comparing GHG emissions and climate change vulnerability



20 of the 36 highest emitting countries are among the least vulnerable to negative impacts of future climate change. Conversely, 11 of the 17 countries with low or moderate GHG emissions, are acutely vulnerable to negative impacts of CC. In 2010, only 28 (16%) countries had an equitable balance between emissions and vulnerability.

(Althor, *Sci Rep*, 2016)

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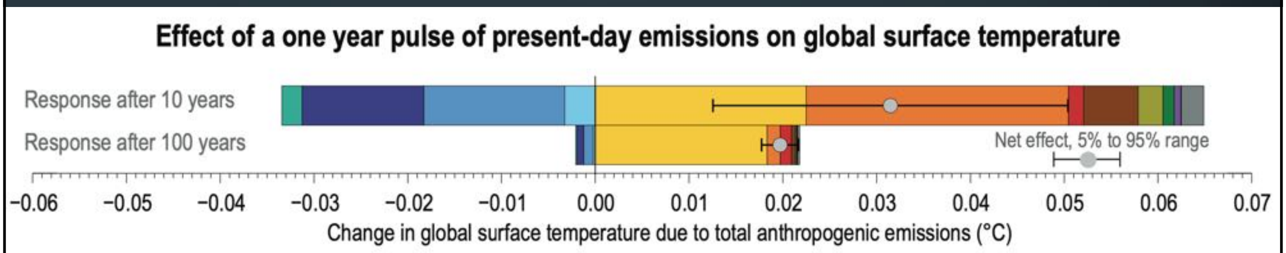

(Source: IPCC, 2022)

57

D. Evidence regarding adaptation to climate change

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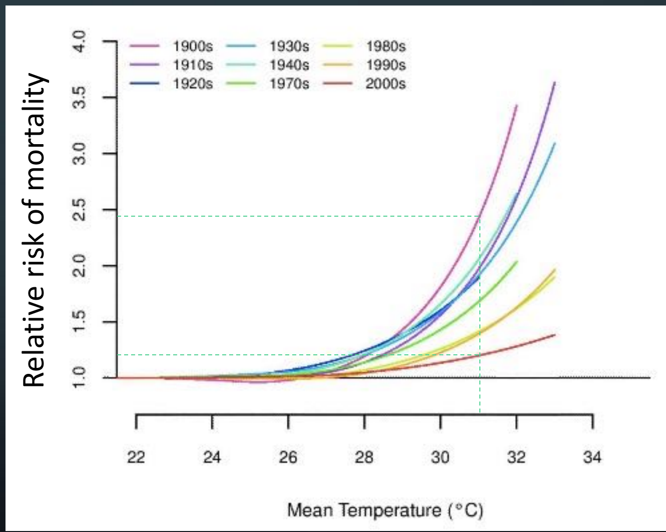
High temperatures and mortality: **Is adaptation of societies possible? New-York city example**



(Petkova, *Epidemiology*, 2014)

60

Increasing the number of homes with air conditioning allowed to limit **heat-related mortality** while increasing CO_2 emissions*

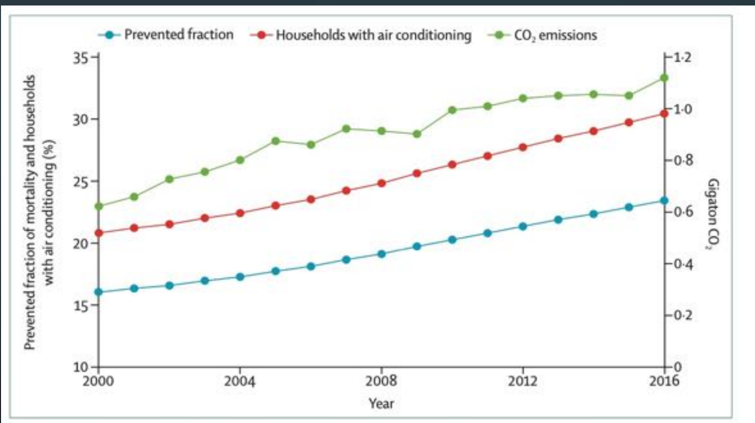


Figure 10: **Global proportion of households with air conditioning (red line), prevented fraction of heatwave-related mortality due to air conditioning (blue line), and CO2 emissions from air conditioning (green line) 2000–16**
CO_2=carbon dioxide.

*Because a large fraction of air conditioning devices run on fossil fuel energy.

(Watts, *The Lancet*, 2019)

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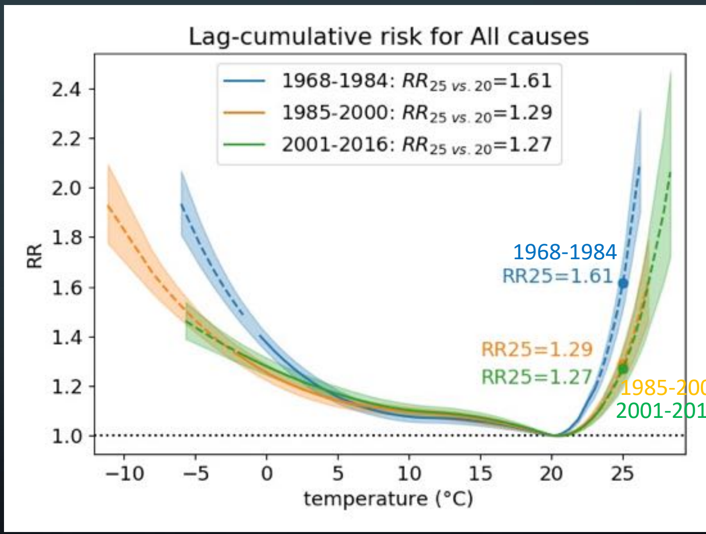
Evidence for adaptation in temperature effects on mortality: the French case (1968-2016)



(Lehmann, *Am J Epid*, in press)

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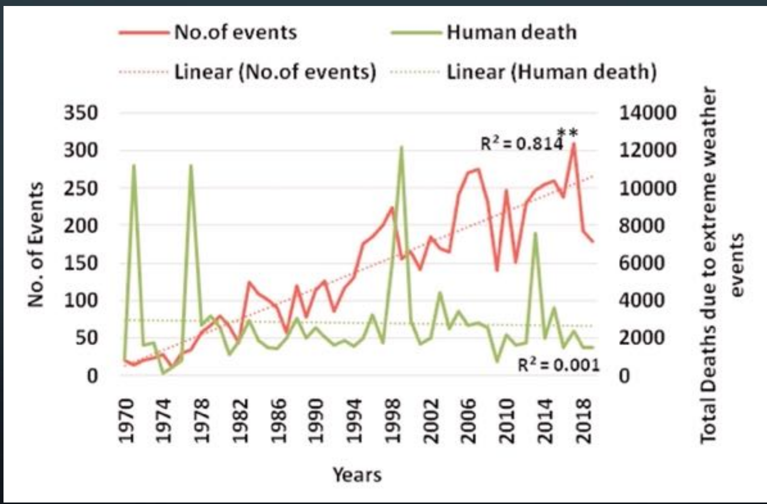
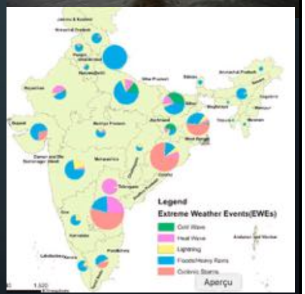
Deaths due to extreme weather events (past trends, India)



(Ray, *Weather Climate Extremes*, 2021)



At the international level, in 2019:

396 extreme weather events
11,755 deaths,
95 million people affected
Cost: $130 Billion

(Ebi, *Ann Rev Pub Health*, 2021 and CRED)

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Adaptation to climate change impact

- Adaptation (in terms of impact on mortality) to some key components of climate change has been evidenced in some areas of the world
  - In particular in relation to high temperatures or extreme weather events
  - Adaptation can be very costly
- The ability to adapt is not distributed homogeneously within and across countries
- Some means of adaptation to high temperatures or extreme weather events used so far have led to increased emissions of GHG, pollutants and possibly social inequalities in environmental exposures
- Current estimates indicate that it would be cheaper to limit greenhouse gas emissions than to adapt to climate change (Burke, *Nature*, 2018)

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E. Climate change societal reaction as an opportunity for public health:
identifying decarbonation pathways with public health co-benefits

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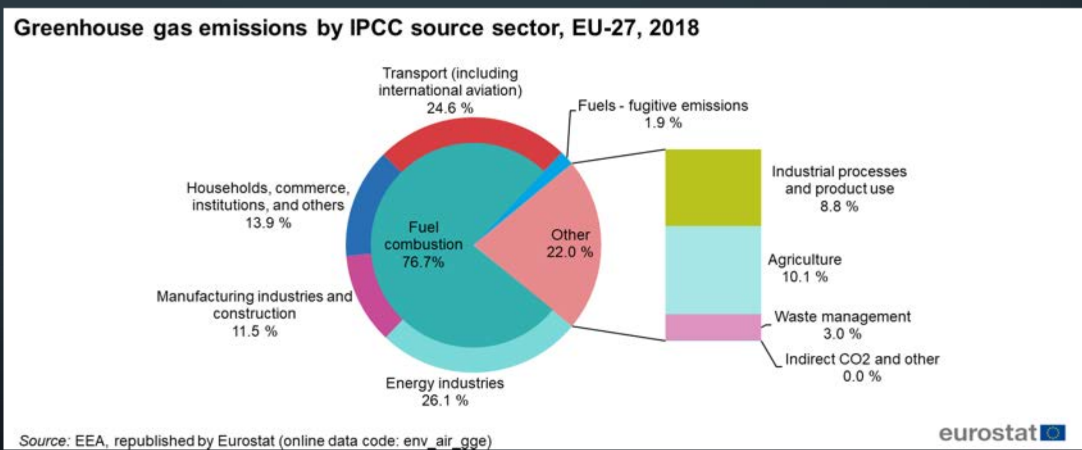
Greenhouse gas emissions in the EU (2017)



(Source: Eurostat)

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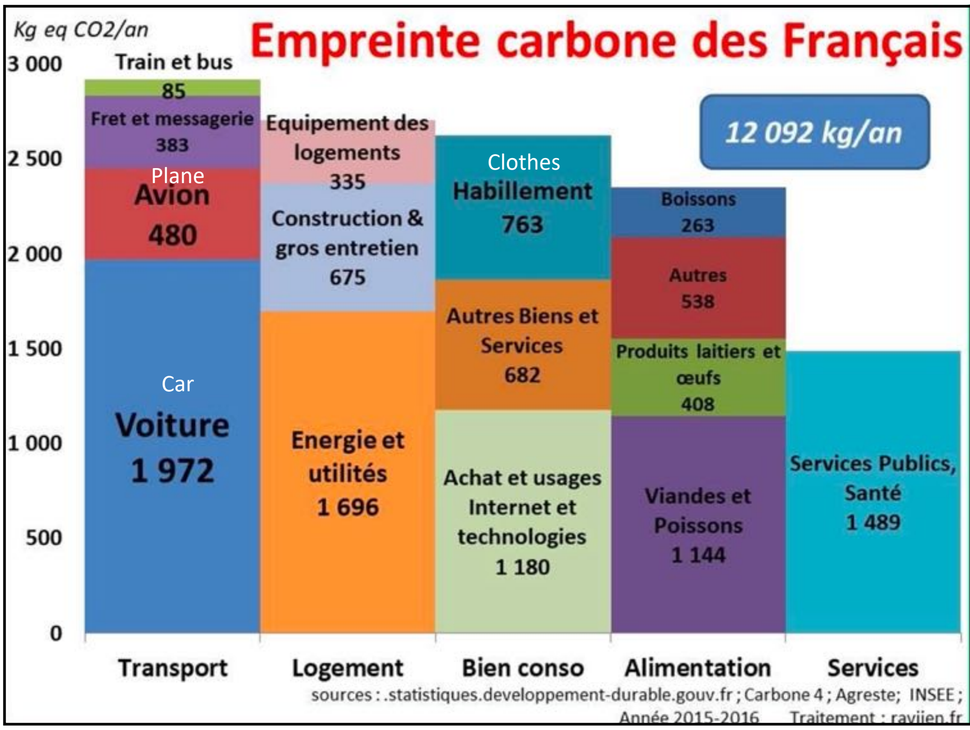

Carbon footprint (France)

Source:
The Shift project

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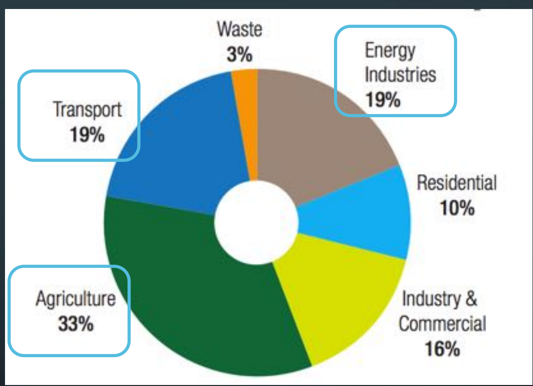
Greenhouse gas emissions (2015)



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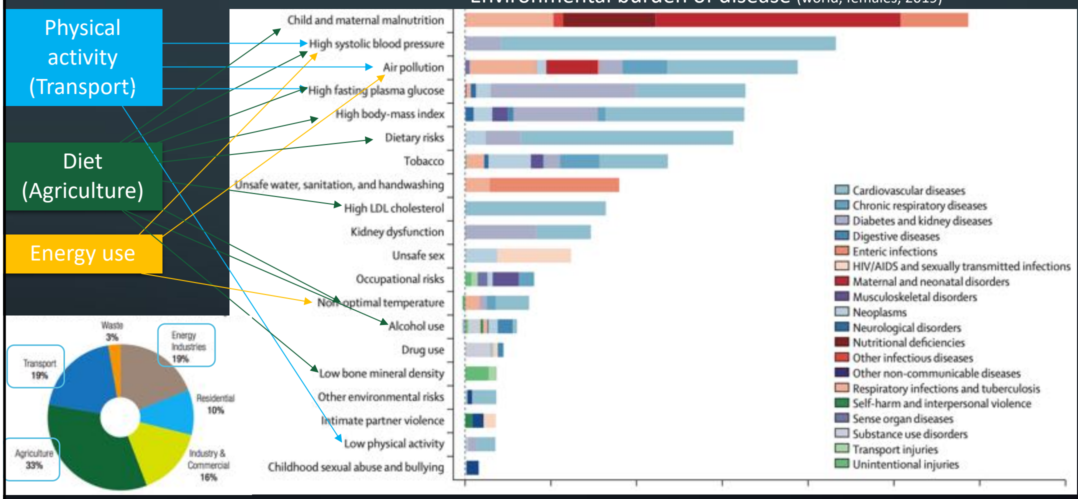
The sectors with the largest greenhouse gases emissions also contribute strongly to the disease burden

Environmental burden of disease (world, females, 2019)



DALYs (Disability-adjusted Life Years) lost

➔ By acting on sectors emitting GHG emissions we will also influence health – possibly positively

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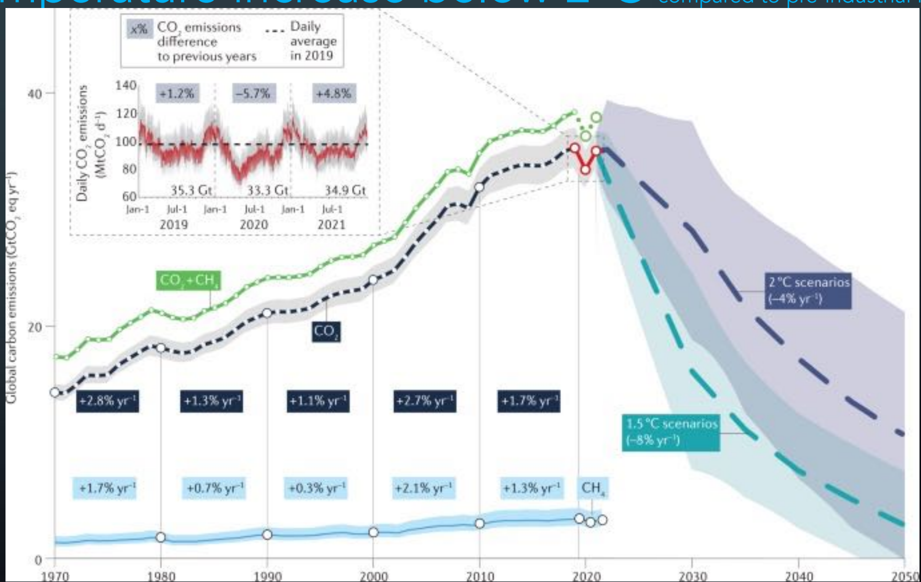
CO_2 emission trajectory to limit the mean temperature increase below 2°C compared to pre-industrial levels

Global CO_2 and CH_4 emissions (Gt CO_2 equivalent/year)



(Liu, *Nat Rev Health Env*, 2022)

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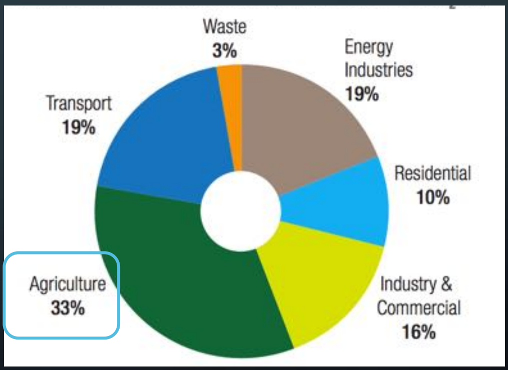
Greenhouse gas emissions (2015)



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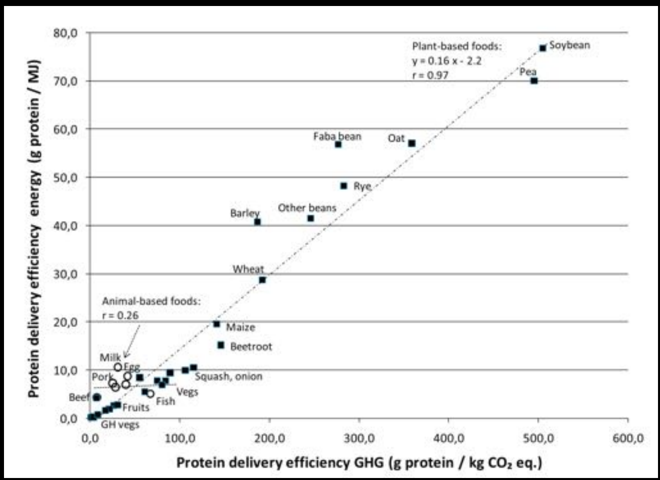
Decarbonization pathways: *Agriculture*



(Gonzalez, *Food policy*, 2011)

versus

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Simulating the impacts of shifting to more sustainable diets on mortality and greenhouse gas emissions

« shifts towards universally sustainable diets could lead to co-benefits, such as minimising diet-related greenhouse gas emissions and land use, reducing the environmental footprint, aiding in climate change mitigation, and improving population health »

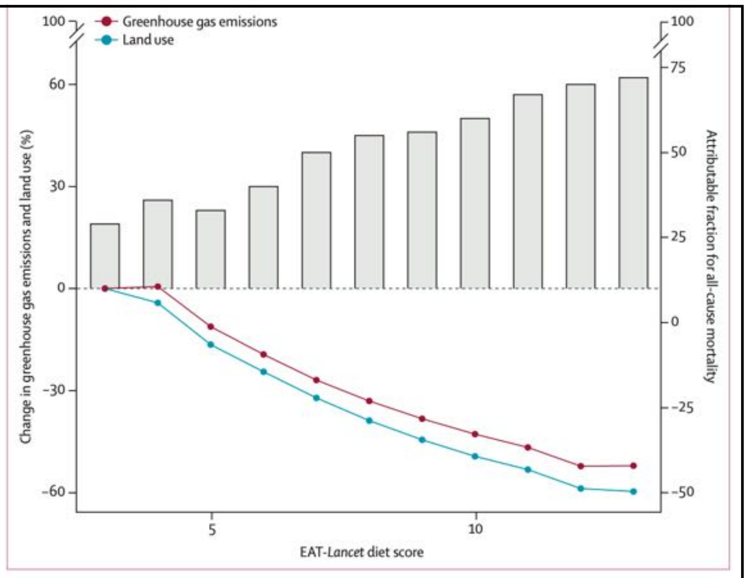

***Figure 2*: Co-benefits of the EAT–*Lancet* diet score**
Lines represent the proportion of greenhouse gas emissions and land use that would change with adherence to EAT–*Lancet* diet scores (compared to lower adherence: ie, a score of 3) and the bars represent the counterfactual attributable fraction from modelling shifts in diets and in deaths (ie, all-cause mortality) that could be prevented over a 20-year risk period from adhering to a higher score of the EAT–*Lancet* reference diet.

(Laine, *Lancet Pub Health*, 2021)

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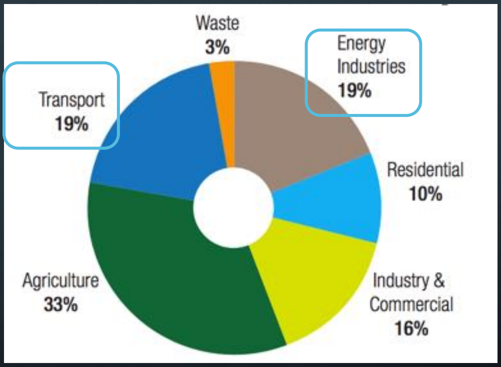
Greenhouse gas emissions (2015)



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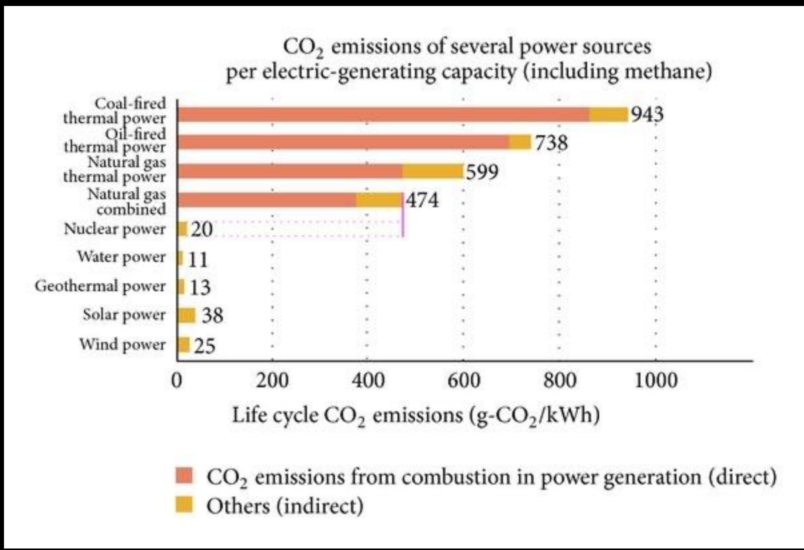
Decarbonization pathways: *energy sector*



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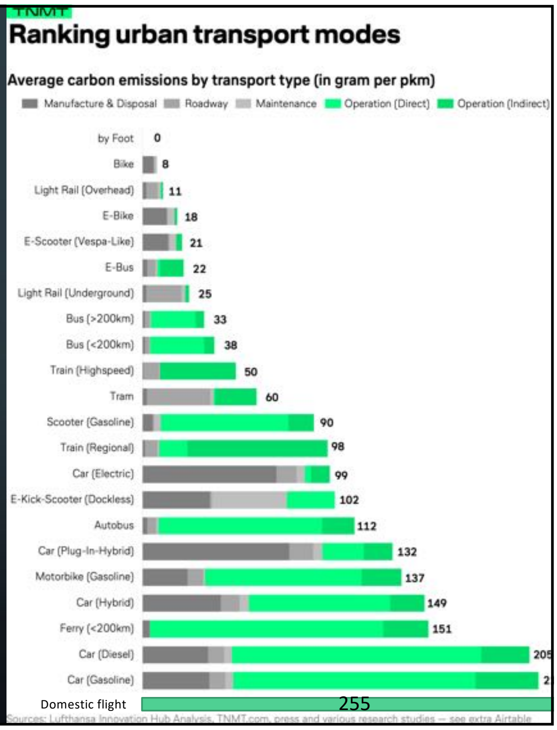
Carbon emissions by transport type

The most carbon-intensive modes of transportation also tend to be those associated with negative health externalities (decreased physical activity and increase noise, atmospheric pollution emission and space occupation)



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The temperature-mortality causal chain

Fossil fuel burning → Greenhouse gas emissions → Temperature change → **Health impact**

Fossil fuel burning → Particulate matter levels → **Health impact**

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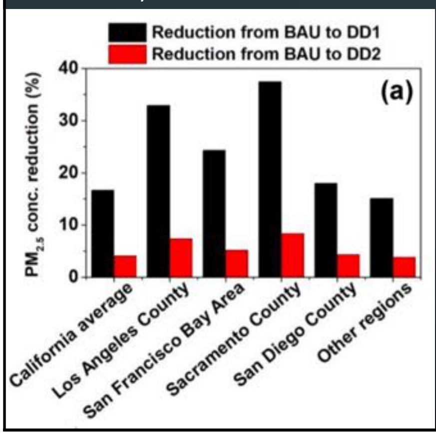
An illustration of the expected co-benefits of decarbonizing the energy and transport sectors (California)

BAU: Business as usual
DD: Deep decarbonization pathways
DD1: Electrification and clean renewable energy
DD2: Mainly combustible renewable fuels



" ...achievement of the 80% (California) GHG reduction target would bring substantial air quality and health cobenefits. The cobenefits, however, highly depend on the selected technology pathway

Compared with the business-as-usual levels, a decarbonization pathway that focuses on electrification and clean renewable energy is estimated to reduce concentrations of $PM_{2.5}$ by 18–37% in major metropolitan areas of California and subsequently avoid about 12 100 (9600–14 600) premature deaths.
In contrast, only a quarter of such health cobenefits, i.e., 2800 (2300–3400) avoided deaths, can be achieved through a pathway focusing more on combustible renewable fuels."
After subtracting the cost, the net monetized benefit of the electrification-focused pathway still exceeds that of the renewable fuel-focused pathway

(Zhao, *Env Sci Tech*, 2019)

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Decreasing greenhouse gas emissions in urban areas can entail strong co-benefits for health

Example of scenarios on mobility in the UK

(Woodcock J *et al.*, *PLoS One*, 2013)

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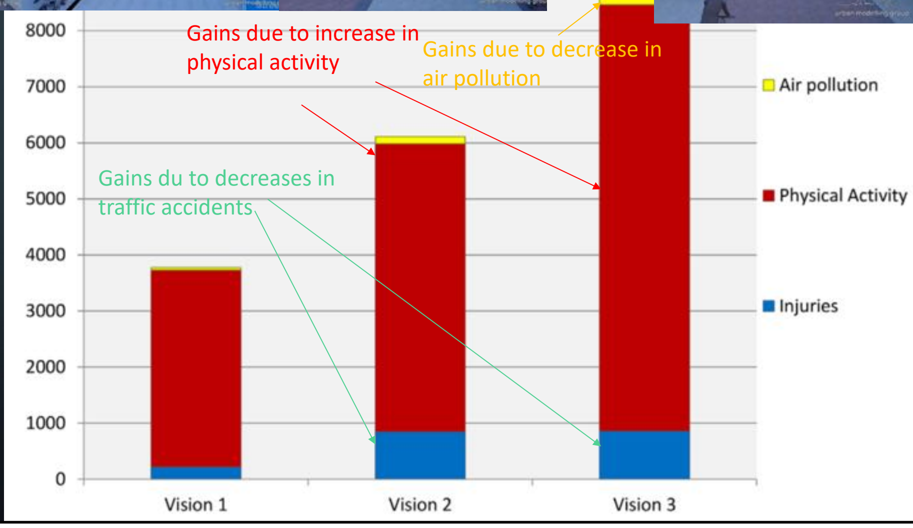
Health gains, in DALYs
(Disability-Adjusted Healthy life-years gained)



(Woodcock, *PLoS One*, 2013)

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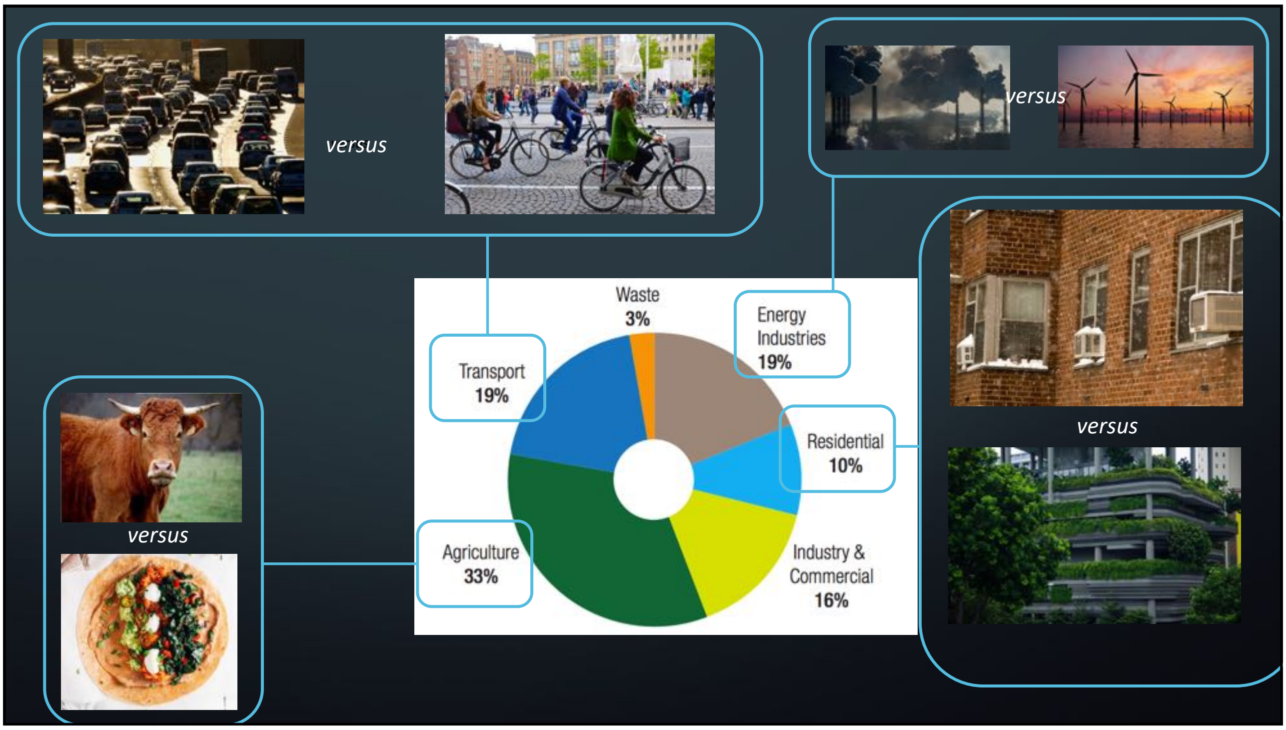

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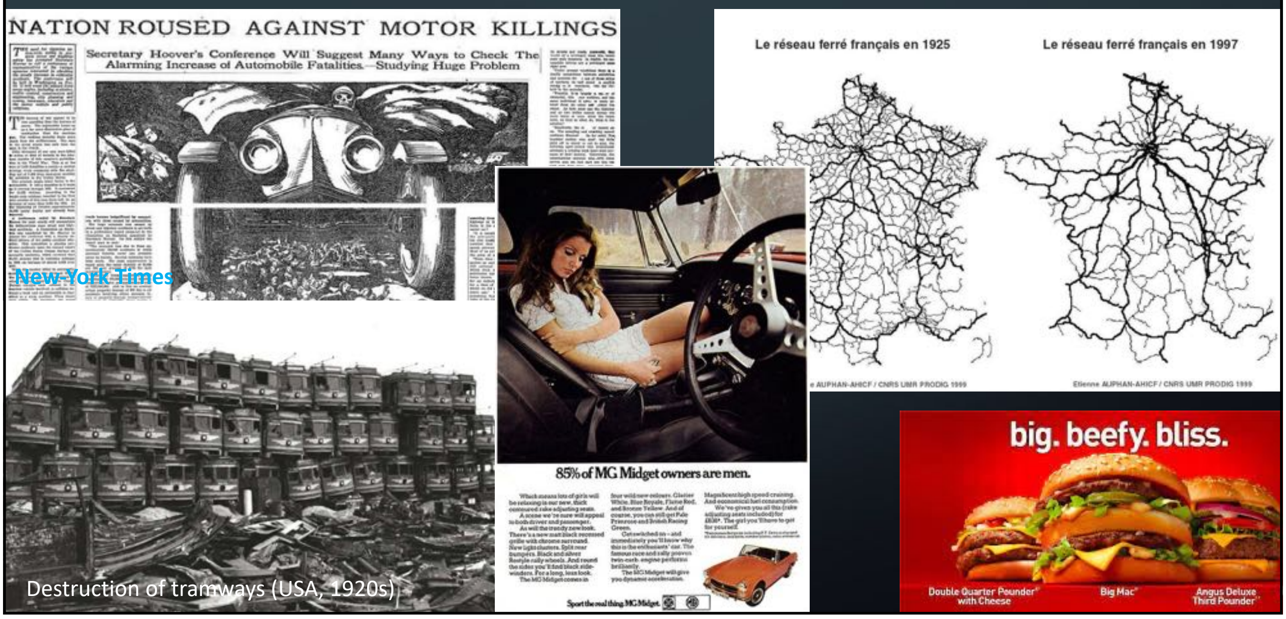
Making (quick) choices relevant for health and society



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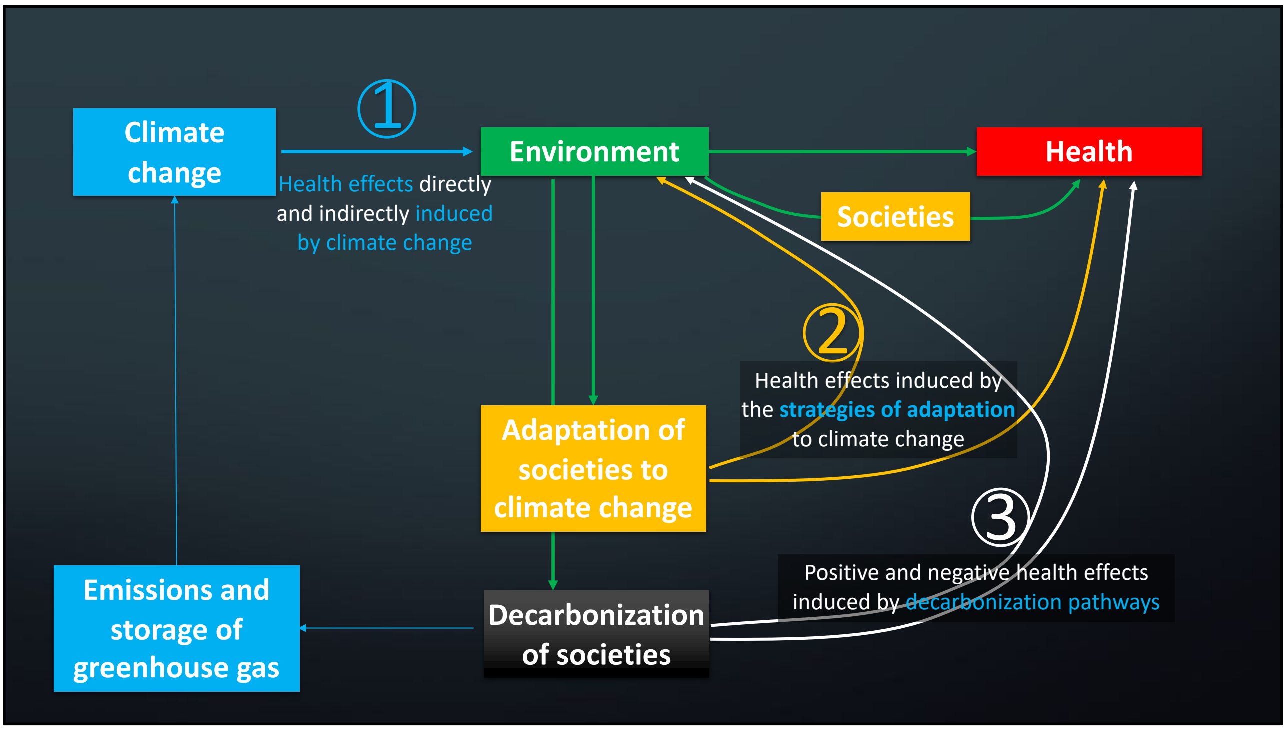

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Conclusion: Climate change as a threat, decarbonization as an opportunity for health

- *Climate* has always influenced human well-being, as well as the living environment as a whole
- *Climate change* can influence health and social and geographic inequalities by multiple pathways – it actually already started doing so
- Adaptation is necessary as a short- or mid-term solution and possible in some areas
  - it cannot constitute the unique long-term answer: issues related to equity, cost, long-term viability
- In most key emission sectors, decarbonization may constitute an opportunity to improve health
  - E.g., huge expected co-benefits in moving away from fossil fuel burning, "one person" car model…
- Research efforts are needed to define the pathways towards carbon neutrality entailing the largest benefits in terms of health improvement and inequality reduction
- Health has been to a large extent ignored when adopting fossil fuels – it wouldn't be wise not to consider it in the process aiming at phasing them out
- Climate change constitutes a huge challenge for science, health, democracy

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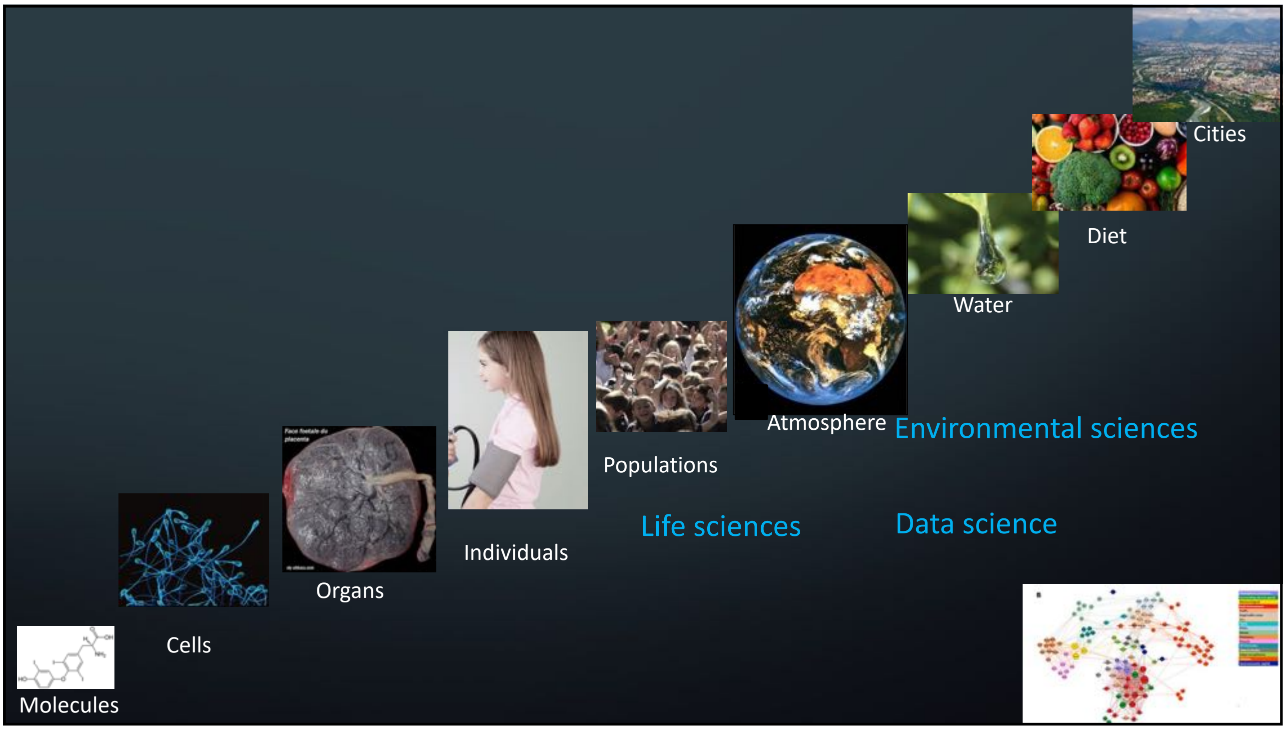

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The relations between human health and the environment in the Anthropocene

Course overview

COLLÈGE DE FRANCE 1530

#1 – 31 March 2022
Inaugural lecture: Causes and external conditions of diseases and health

#2 - 6 April 2022
Lead: the oldest enemy of human health

Seminar: **Lead, legal poison: uses and regulations of toxic in the nineteenth century**
Pr. Judith Rainhorn, Université Paris-1 Panthéon-Sorbonne (Paris)

#3 - 13 April 2022
Fine particulate matter: effects on mortality and cardiovascular and respiratory morbidity

Seminar: Air pollution effects on the central nervous system
Pr. Marc Weisskopf, Cecil K. and Philip Drinker Professor of Environmental Epidemiology and Physiology, Harvard TH Chan School of Public Health (Boston)

#4 - 20 April 2022
Fine particulate matter: new metrics, recently identified targets

Seminar: The Human Sensor – Toxicology in Real People in the Real World
Pr. Ian Mudway, Imperial College London, MRC for Environment and Health (London)

#5 - 11 May 2022
'Legacy' endocrine disruptors: the convergence between basic biology, (eco)toxicology, clinical research and epidemiology

Seminar: Endocrine disruption and nuclear receptors: mechanisms and impact on health
Dr. William Bourget, Centre de Biologie Structurale, Univ Montpellier, CNRS, Inserm (Montpellier)

#6 - 18 May 2022
Contemporary endocrine disruptors: assessing the health effects of non-persistent compounds

Seminar: Bad cocktails – the evaluation of combined exposures
Pr. Andreas Kortenkamp, Brunell University (London)

#7 - 25 May 2022
The Exposome: Promises and Challenges of a New Concept

Seminar: Protéger la santé des populations exposées aux substances chimiques - Enseignement et perspectives du programme national de biosurveillance
Dr. Clémence Fillol, Santé publique France

#8 – 1 June 2022
A Global Vision: The Burden of Disease Attributable to the Environment

Seminar: Causal pluralism and public health.
Pr. Federica Russo, Philosophe des Sciences, Techniques, et Information, Université d'Amsterdam

#9 - 8 June 2022
Climate change and human health

Seminar: L'anthropocène est un accumulocène
Dr. Jean-Baptiste Fressoz, CNRS et EHESS

Santé publique France

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