"ICT & Environment"

Introduction - Anthropocene - GES - IPCC

I3S Lab, G. Urvoy-Keller, L. Deneire

Why this course

- ICT is responsible for **3.5 %** of greenhouse gasses (GHG)[1]
- more or less equivalent to the impact of air transport
- ... with an increase of **6 %** per year !
- We (you) have to act to lower the GHG
- This course will
  - Expose the problem
  - Give some elements of the solution

Hopefully, you will be the solution

1. Que peut le numérique pour la transistion écologique, The Shift Project, March 2021

Agenda

1. The Anthropocentric age
2. Background on Energy and ICT
3. Measuring ICT and Internet Footprint
   - Production vs. Usage - Ecological impact (minerals, air, water)
   - LCA, STERM Model – Smart Technologies Energy Relevance ModelMeasuring IT devices and Internet electrical consumption
   - Practical Assessment of Internet Browsing CO2 footprint Hands-on session
4. Green Algorithm Design
5. Eco-friendly software design **Hands-on session**
6. Law, Environment and Digital world
7. Oral presentation of **personal projects**

Agenda of this lecture

- **Anthropocene** : Man provokes a new Geological Era, man's activities changes Climate. Rajouter biodiversité, plastiques, etc.
  Faire le bilan des consommations + lien avec le climat
- **What is the Greenhouse Effect** : makes our planet livable, but increase in GHG induces *less livable* planet.
- **A good information source : IPCC** : Intergovernmental Panel on Planet Climate, how does this work, why is it a reliable information source.

Anthropocene : man's geological Era

The Anthropocene Epoch is an unofficial unit of geologic time, used to describe the most recent period in Earth's history when human activity started to have a significant impact on the planet's climate and ecosystems[2]

Will Steffen (American Chemist, Climate Council ANU, IPCC reviewer, ...)
Paul Crutzen (Nobel Prize, 1995, †Jan 2021)

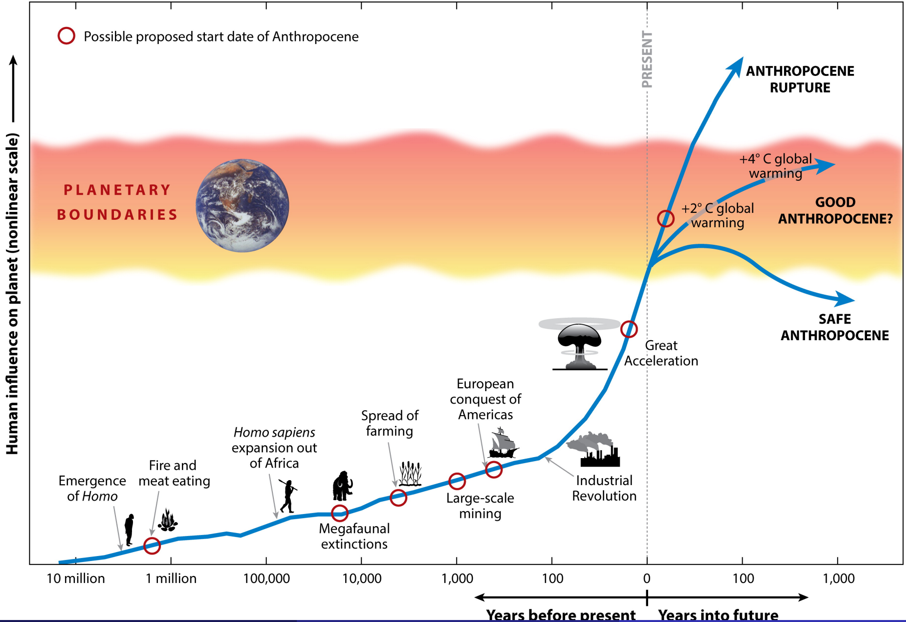
2. "*The Anthropocene : Are Humans Now Over-whelming the Great Forces of Nature ?*" by Will Steffen, Paul J. Crutzen, and John R. McNeill was originally published in Ambio 36, 8 (December 2007) : 614– 21.

Le mot du philosophe

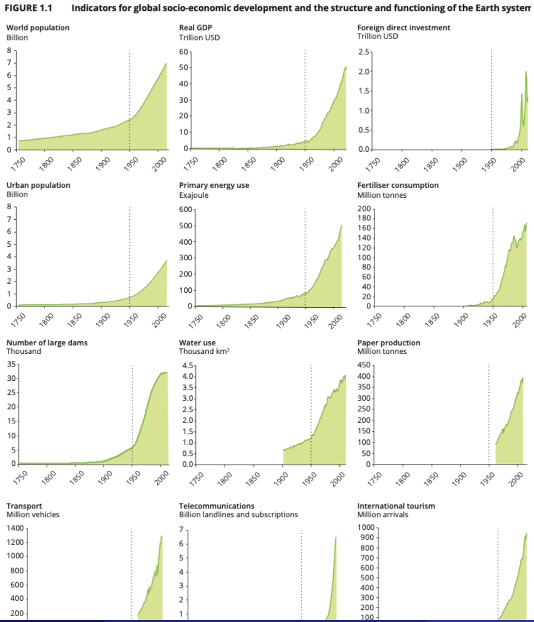
Imaginez cette fable : une espèce fait sécession. Elle déclare que les dix millions d'autres espèces de la Terre, ses parentes, sont de la "nature". À savoir : non pas des êtres mais des choses, non pas des acteurs mais le décor, des ressources à portée de main. Une espèce d'un côté, dix millions de l'autre, et pourtant une seule famille, un seul monde. Cette fiction est notre héritage. Sa violence a contribué aux bouleversements écologiques. C'est pourquoi nous avons une bataille culturelle à mener quant à l'importance à restituer au vivant.

Baptiste Morizot Philosophe, Maitre de Conférences à l'université d'Aix-Marseille

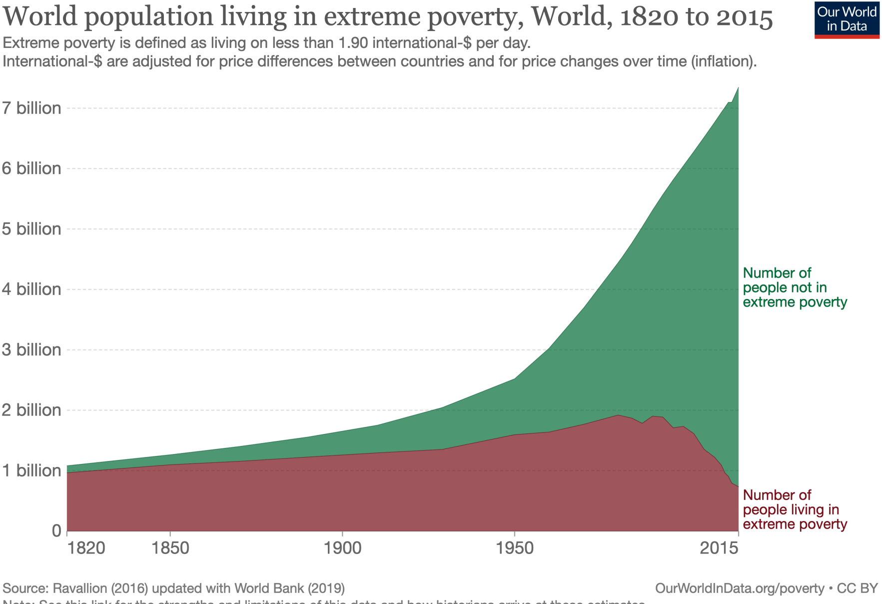
Anthropocène : Evolution



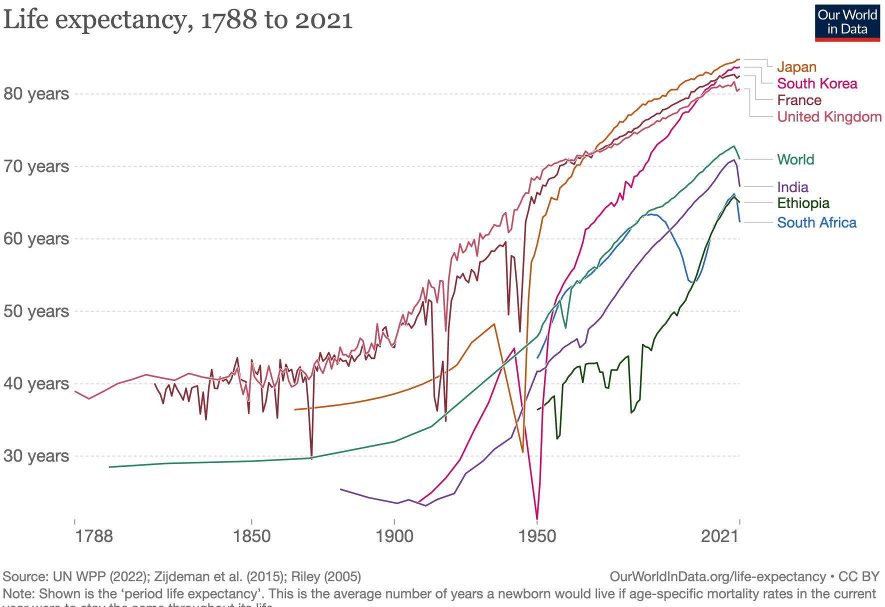
La Grande accélaration - socio-économique



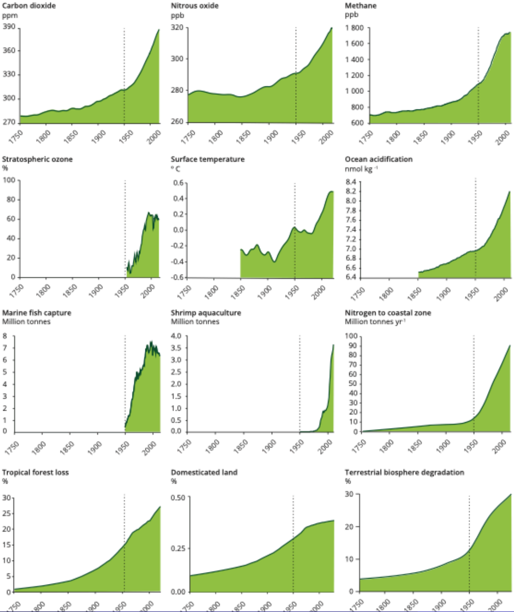
Population et pauvreté



Population et santé



La Grande accélaration - Conséquences



En 2 générations, l'humanité à dépassé la capacité

de la terre à continuer à soutenir ses activités de manière stable

- +++ Progrès scientifiques et techniques
- - - - Prélèvements de ressources naturelles non renouvelables
- - - - Impacts sur la géologie, l'environnement, le climat, les écosystèmes terrestres

La prospérité humaine

Passe par le développement économique

Nécessite beaucoup d'énergie

Transforme le métabolisme de la biosphère

Ce qui diminue la capacité de la Terre à nous accueillir

Les limites physiques : la matière

Principe de conservation de la matière - Lavoisier

Rien ne se perd, Rien ne se crée

Tout se transforme

La quantité de matière est constante sur le système terre
(à quelques astéroïdes près :))

Loi de la conservation de l'énergie (1^{er} principe)

Dans un système fermé, on ne crée pas de l'énergie

On la transforme

.

L'énergie est une mesure de la capacité d'un système à modifier un état, à produire un travail.

.

Mouvement, rayonnement, chaleur, ...

Le désordre (entropie) augmente (2^{eme} principe)

Dans un système fermé, l'entropie augmente toujours

- Le désordre augmente
- La qualité de l'énergie a tendance à se dégrader
- L'énergie reste constante, mais sous des formes plus ou moins "intéressantes" (pertes par chaleur par exemple)
- Processus **Irréversibles**

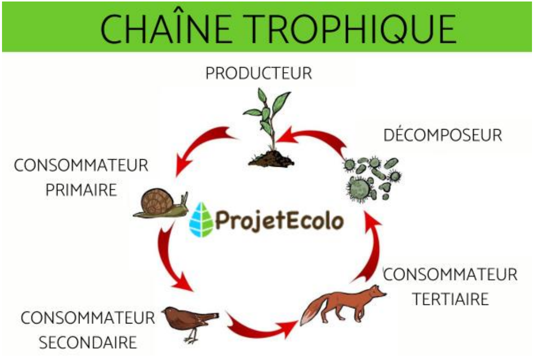
Pourtant le vivant garde sa forme ....

"Notre" Métabolisme

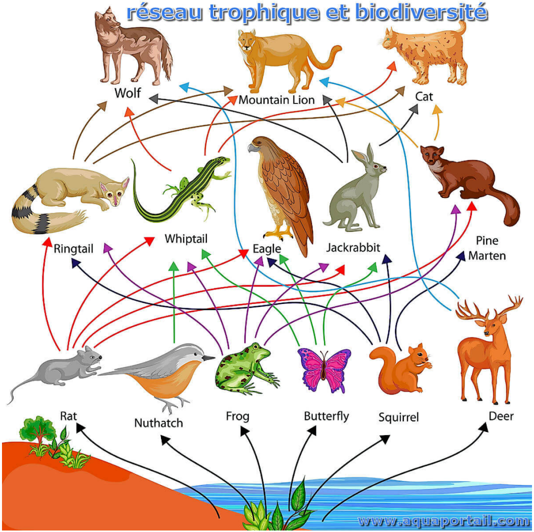
Pour garder "la forme" (y compris reproduction, adaptation, ...) le vivant :

- Utilise de l'énergie (pour diminuer l'entropie)
- Puise des matières
- Produit des déchets
- Produit de la chaleur (dégradation d'énergie)

Energie pour le métabolisme "Terre"

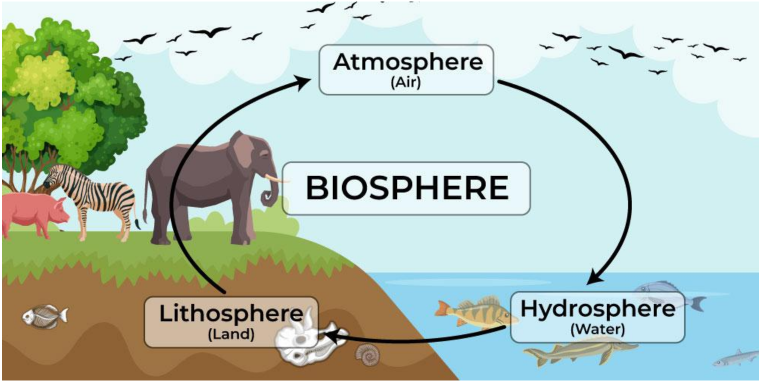


Energie pour le métabolisme "Terre" : Photosynthèse

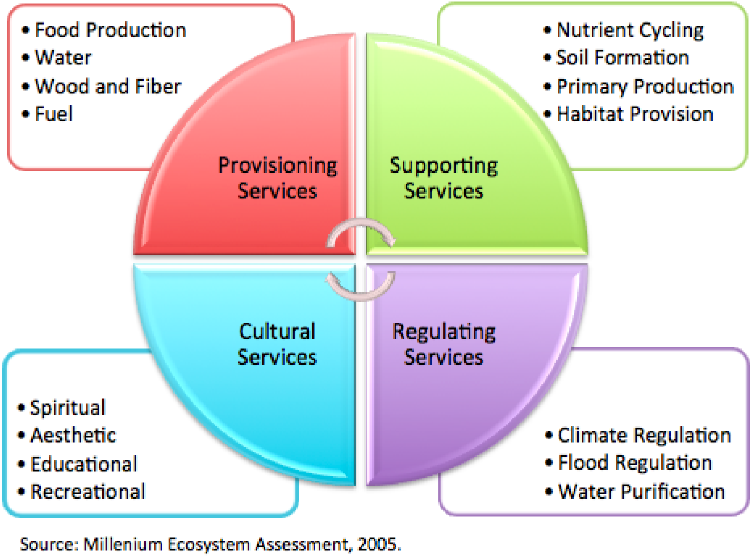


Note : il existe également de la Chimiosynthèse Océanique

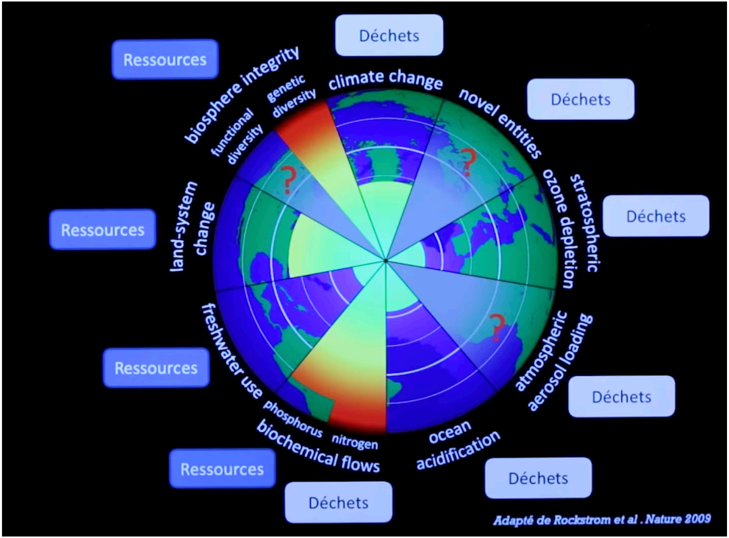
Metabolisme et Biosphere (+ matière)



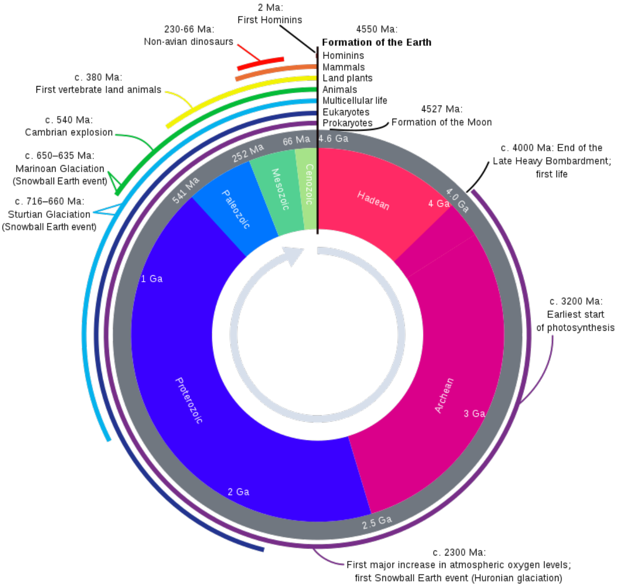
Fonctions de la biosphère



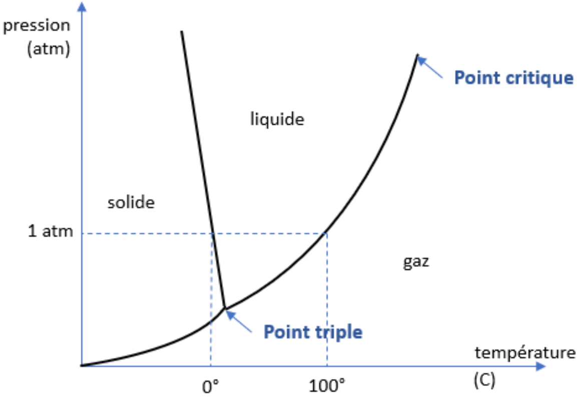
D'où on tire les limites planétaires



Anthropocène - Eres Géologiques



Limites planétaires et point de bascule



9 Limites planétaires

Planetary Boundaries:

Exploring the safe operating space for humanity in the Anthropocene

(*Nature*, 461 : 472 –

nature Vol 461|24 September 2009

FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years[1–3]. This period of stability — known to geologists as the Holocene — has seen human civilizations arise, develop and thrive. Such stability may now be under threat. Since the Industrial Revolution, a new era has arisen, the Anthropocene[4], in which human actions have become the main driver of global environmental change[5]. This could see human activities push the Earth system outside the stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world.

During the Holocene, environmental change occurred naturally and Earth's regulatory capacity maintained the conditions that enabled human development. Regular temperatures, freshwater availability and biogeochemical flows all stayed within a relatively narrow range. Now, largely because of a rapidly growing reliance on fossil fuels and industrialized forms of agriculture, human activities have reached a level that could damage the systems that keep Earth in the desirable Holocene state. The result could be irreversible and, in some cases, abrupt environmental change, leading to a state less conducive to human development[6]. Without pressure from humans, the Holocene is expected to continue for at least several thousands of years[7].

ROAD TO COPENHAGEN

SUMMARY

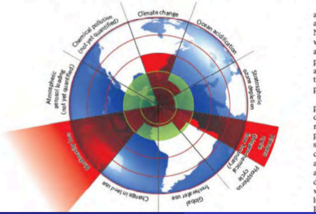
- New approach proposed for defining preconditions for human development
- Crossing certain biophysical thresholds could have disastrous consequences for humanity
- Three of nine interlinked planetary boundaries have already been overstepped

Planetary boundaries

To meet the challenge of maintaining the Holocene state, we propose a framework based on 'planetary boundaries'. These boundaries define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes. Although Earth's complex systems sometimes respond smoothly to changing pressures, it seems that this will prove to be the exception rather than the rule. Many subsystems of Earth react in a nonlinear, often abrupt, way, and are particularly sensitive around threshold levels of certain key variables. If these thresholds are crossed, then important subsystems, such as a monsoon system, could shift into a new state, often with deleterious or potentially even disastrous consequences for humans[8,9].

Most of these thresholds can be defined by a critical value for one or more control variables, such as carbon dioxide concentration. Not all processes or subsystems on Earth have well-defined thresholds, although human actions that undermine the resilience of such processes or subsystems — for example, land and water degradation — can increase the risk that thresholds will also be crossed in other processes, such as the climate system.

We have tried to identify the Earth-system processes and associated thresholds which, if crossed, could generate unacceptable environmental change. We have found nine such processes for which we believe it is necessary to define planetary boundaries: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading (see Fig. 1 and Table).

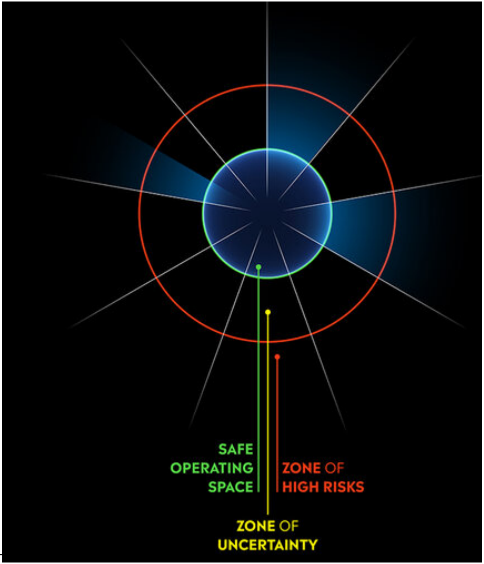


9 planet limitations

1. **Climate Change** : global warming, GHG, ice smelting, permafrost
2. **Biosphere integrity** : biodiversity loss (due to deforestation, massive cattle grow, break of food chain ...
3. **Change of land systems** : monocultures (e.g. soja, palm oil) soil looses it's properties (retaining water, capturing carbon, ...)
4. **Use of freshwater, hydrologic cycles** - "water wars", more dry land
5. **Biogeochemical flows** : Intensive agriculture - pollution - changes the species balance
6. **Ocean acidification** : CO_2 dissolves in the ocean, changes pH threatens numerous species
7. **Aerosol concentration** : changes the cloud (real !) systems (e.g. monsoon) and solar absorption, hence climate
8. **Ozone layer** : filter UV. Looks this has been settled.
9. **New chemical entities** (man made, like radio-active waste)

Gauthier Roussilhe, *Situer le numérique* November 2020, available online - citing Will Steffen : `http://dx.doi.org/10.1126/science.1259855`

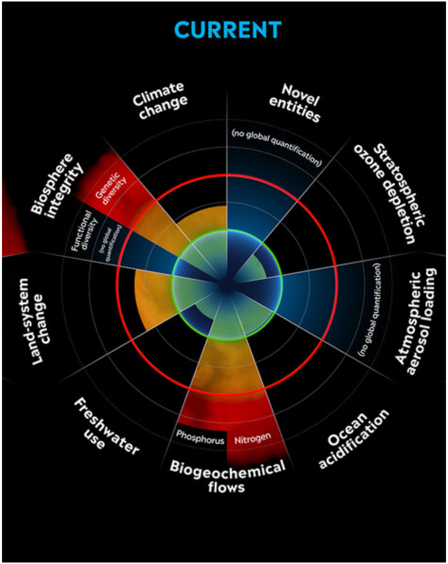
Status of the 9 planet boundaries : Radar view



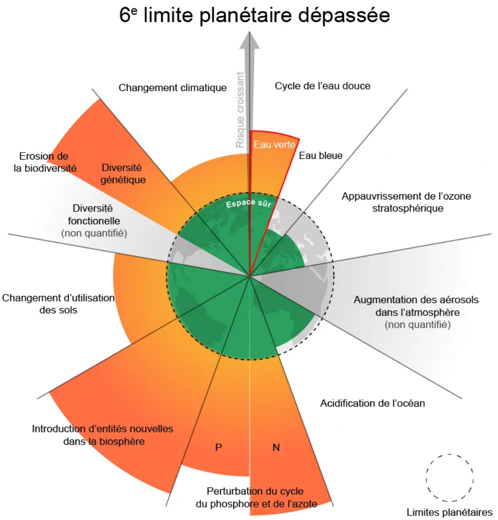
[3]

3. https ://globaia.org/planetary-boundaries

Status of the 9 planet boundaries : Still OK ?

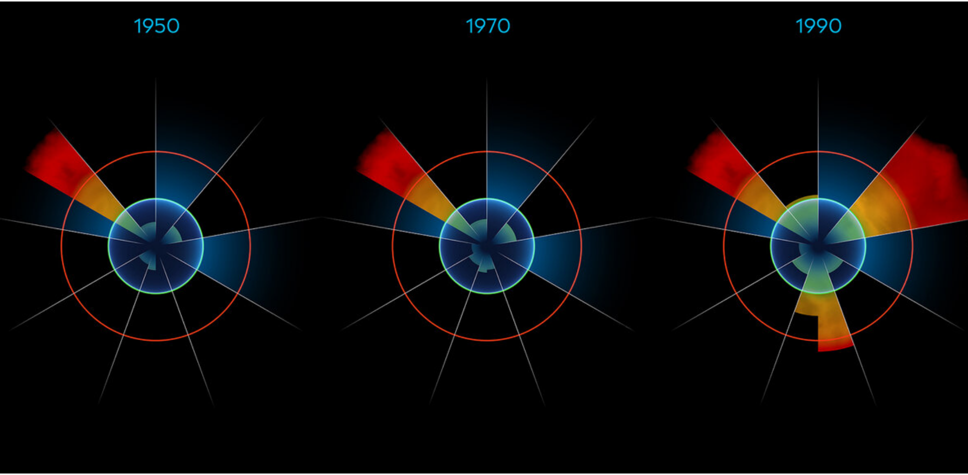


Status of the 9 planet boundaries : Still OK - 2022

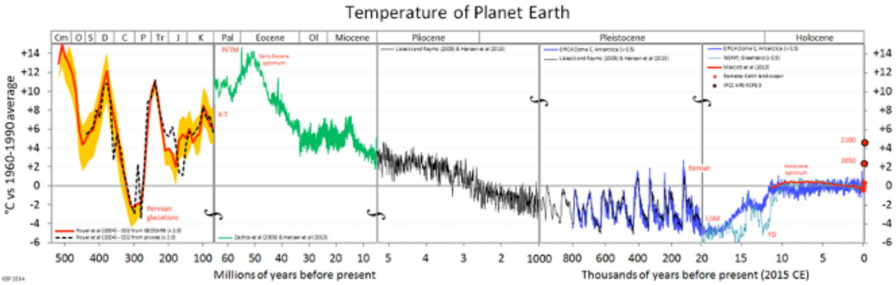


La limite planétaire concernant l'utilisation d'eau douce (eau verte) a été franchie. Elle rejoint les 5 autres déjà dépassées, dont la dernière avait été officiellement dépassée en janvier 2022.

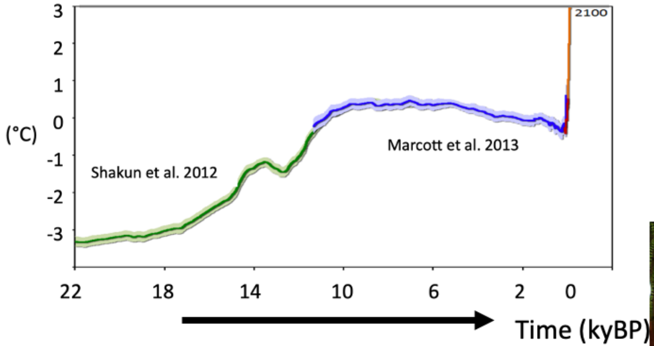
The 9 planet boundaries : Evolution



Let's focus on "late" temperature



Pleistocene Holocene Anthropocene



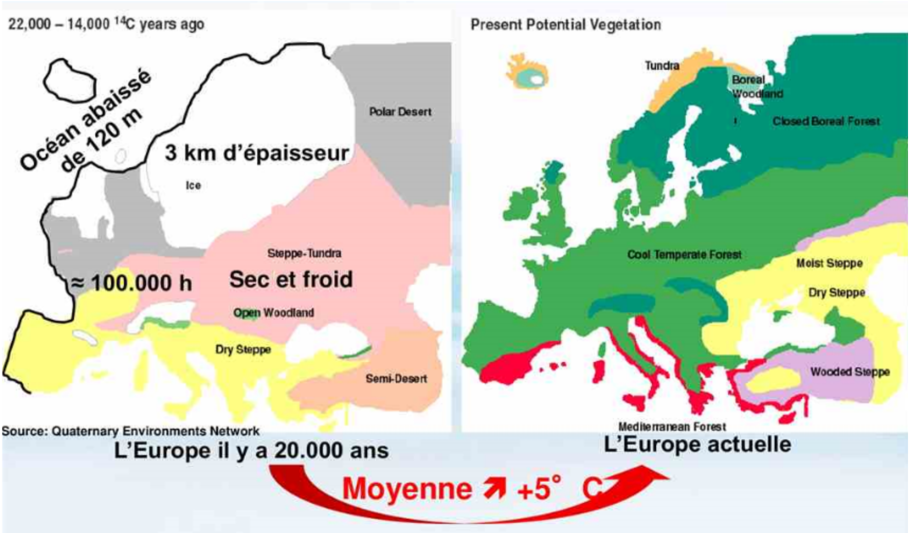
Psychozoïc

Molysmocène
(= dust-bin era !)

...

Anti-carboniferous

What does 5 degrees difference mean



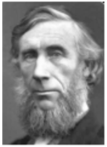
Theory for Ice Ages

(J. Fourier, 1824) CO_2

Astronomy (3rd mouvement of the Eart
Hipparque, 127 BC)

Ebelmen, 1845

Adhémar, 1842

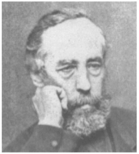


Tyndall,
1861, 1863

Arrhenius,
1896

Ekholm, 1901

Croll,
1864,1867



Milankoviç,
1920, 1941

Chamberlin,
1897,1899

Callendar,
1938

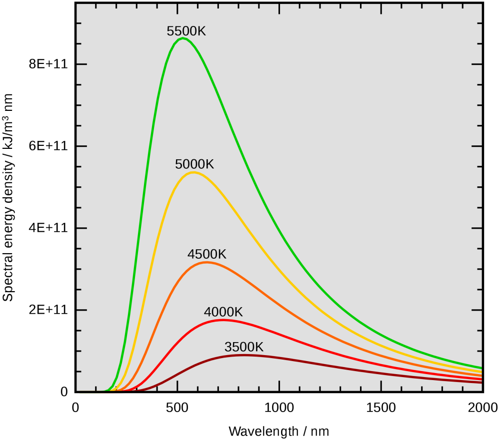
Fourier (1924) : Sun is not enough

Fourier

- Computes the Temperature on earth vs distance to Sun : is much lower
- Hence something else keeps us warm
- He makes the following hypothesis :
  - *Luminous heat* comes on the earth (traverses atmosphere)
  - *Non luminous heat* (infrared) is emitted (bounced) by earth
  - this non luminous heat is trapped by atmosphere, and heats the earth
  - there is a sort of "blanket" that keeps us warm

-21 degrees on earth ?

- **Wien's Law** Black-body radiation : $\lambda_{max} = \frac{2.89710^{-3}}{T} m.K$



- Sun temperature $\simeq$ 6000 K : $\lambda_{max} \simeq$ 500 nm : Visible light
- Earth temparature $\simeq 300K$: $\lambda_{max} \simeq 10\mu m$: Infrared

-21 degrees on earth ?

- **Stefan-Boltzmann Law** Black-body radiated power : $\frac{\text{Power}}{\text{Area}} = \sigma T^4$; $\sigma = 5.6710^{-8} m^{-2} K^{-4}$
- Intercepted Solar Power per area : $S = 1380 W/m^2$
- Intercepted Solar Power : $S\pi R^2$
- Reflection : albedo of a=0.33
- Received total solar power : $S\pi R^2(1-a)$
- Infra-red total emitted power by earth (assuming uniform T) : $\sigma T^4 \times 4\pi R^2$
- Energy conservation : $S\pi R^2(1-a) = \sigma T^4 \times 4\pi R^2 \Rightarrow T = 252K$

Arrhenius : link CO_2 – temperature

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

Arrhenius, 1896

I should certainly not have undertaken these tedious calculations if an extraordinary interest had not been connected with them. In the Physical Society of Stockholm there have been occasionally very lively discussions on the probable causes of the Ice Age; and these discussions have, in my opinion, led to the conclusion that there exists as yet no satisfactory hypothesis that could explain how the climatic conditions

0.67xCO_2 2.0xCO_2

266 Prof. S. Arrhenius *on the Influence of Carbonic Acid*

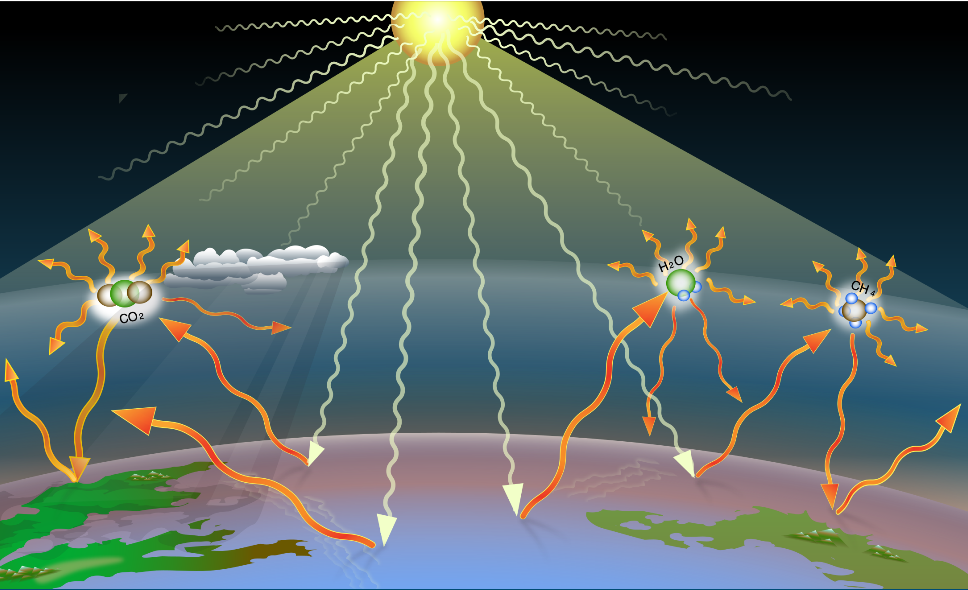
Latitude.	Carbonic Acid=0·67.					Carbonic Acid=1·5.					Carbonic Acid=2·0.					Carbonic Acid=2·5.					Carbonic Acid=3·0.				
	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.
70	−2·9	−3·0	−3·4	−3·1	−3·1	3·3	3·4	3·8	3·6	3·52	6·0	6·1	6·0	6·1	6·05	7·9	8·0	7·9	8·0	7·95	9·1	9·3	9·4	9·4	9·3
60	−3·0	−3·2	−3·4	−3·3	−3·22	3·4	3·7	3·6	3·8	3·62	6·1	6·1	5·8	6·1	6·02	8·0	8·0	7·6	7·9	7·87	9·3	9·5	8·9	9·5	9·3
50	−3·2	−3·3	−3·3	−3·4	−3·3	3·7	3·8	3·4	3·7	3·65	6·1	6·1	5·5	6·0	5·92	8·0	7·9	7·0	7·9	7·7	9·5	9·4	8·6	9·2	9·17
40	−3·4	−3·4	−3·2	−3·3	−3·32	3·7	3·6	3·3	3·5	3·52	6·0	5·8	5·4	5·6	5·7	7·9	7·6	6·9	7·3	7·42	9·3	9·0	8·2	8·8	8·82
30	−3·3	−3·2	−3·1	−3·1	−3·17	3·5	3·3	3·2	3·5	3·47	5·6	5·4	5·0	5·2	5·3	7·2	7·0	6·6	6·7	6·87	8·7	8·3	7·5	7·9	8·1
20	−3·1	−3·1	−3·0	−3·1	−3·07	3·5	3·2	3·1	3·2	3·25	5·2	5·0	4·9	5·0	5·02	6·7	6·6	6·3	6·6	6·52	7·9	7·5	7·2	7·5	7·52
10	−3·1	−3·0	−3·0	−3·0	−3·02	3·2	3·2	3·1	3·1	3·15	5·0	5·0	4·9	4·9	4·95	6·6	6·4	6·3	6·4	6·42	7·4	7·3	7·2	7·3	7·3
0	−3·0	−3·0	−3·1	−3·0	−3·02	3·1	3·1	3·2	3·2	3·15	4·9	4·9	5·0	5·0	4·95	6·4	6·4	6·6	6·6	6·5	7·3	7·3	7·4	7·4	7·35
−10	−3·1	−3·1	−3·2	−3·1	−3·12	3·2	3·2	3·2	3·2	3·2	5·0	5·0	5·2	5·1	5·07	6·6	6·6	6·7	6·7	6·65	7·4	7·5	8·0	7·6	7·62
−20	−3·1	−3·2	−3·3	−3·2	−3·2	3·2	3·2	3·4	3·3	3·27	5·2	5·3	5·5	5·4	5·35	6·7	6·8	7·0	7·0	6·87	7·9	8·1	8·6	8·3	8·22
−30	−3·3	−3·3	−3·4	−3·4	−3·35	3·4	3·5	3·7	3·5	3·52	5·5	5·6	5·8	5·6	5·62	7·0	7·2	7·7	7·4	7·32	8·6	8·7	9·1	8·8	8·8
−40	−3·4	−3·4	−3·3	−3·4	−3·37	3·6	3·7	3·8	3·7	3·7	5·8	6·0	6·0	6·0	5·95	7·7	7·9	7·9	7·9	7·85	9·1	9·2	9·4	9·3	9·25
−50	−3·2	−3·3	—	—	—	3·8	3·7	—	—	—	6·0	6·1	—	—	—	7·9	8·0	—	—	—	9·4	9·5	—	—	—
−60																									

-3°C +5°C

Arrhenius : link CO_2 – temperature

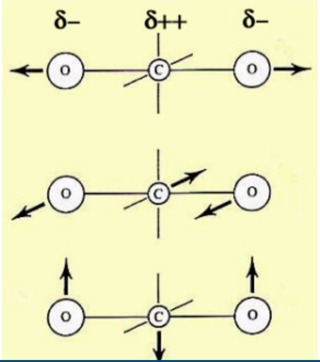
- **Arrhenius :**
  - Forecasts that doubling CO_2 doubling induces an increase in T^o 4 degrees
  - Temperature increases more at the poles
  - Temperature increases faster at night
  - Temperature increases faster in winter
- **Lewis Fry Richardson** Tries to model climate with physical equations
- **Computers (Eniac - 1950)** Used to predict weather (and later climate)

A GreenHouse Gas absorbs IR

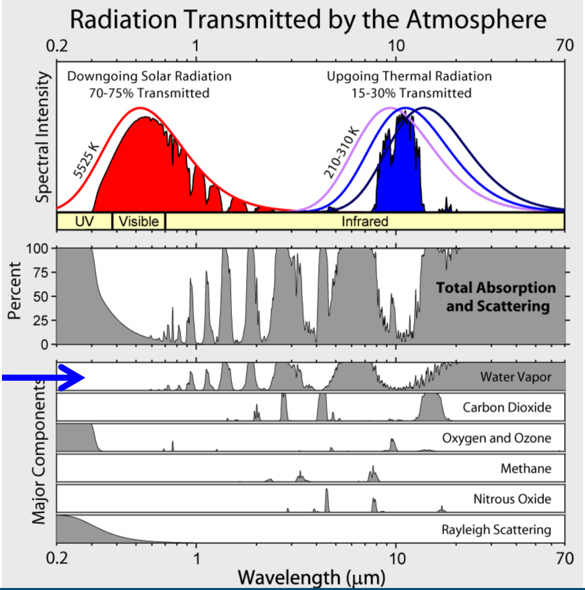


Some Gasses absorb IR (and some not)

In order for molecular vibrations to absorb IR energy, the vibrational motions must change the dipole moment of the molecule. All molecules with three or more atoms meet this criterion and are IR absorbers. While the Earth's (dry) atmosphere is predominantly composed of non-IR absorbers, N2 (78%), O2 (21%), and Ar (0.9%), the 0.1% of remaining trace gases contains many species that absorb IR.



Light transparent and Infrared "opaque"



Greenhouse Gas (GHG)

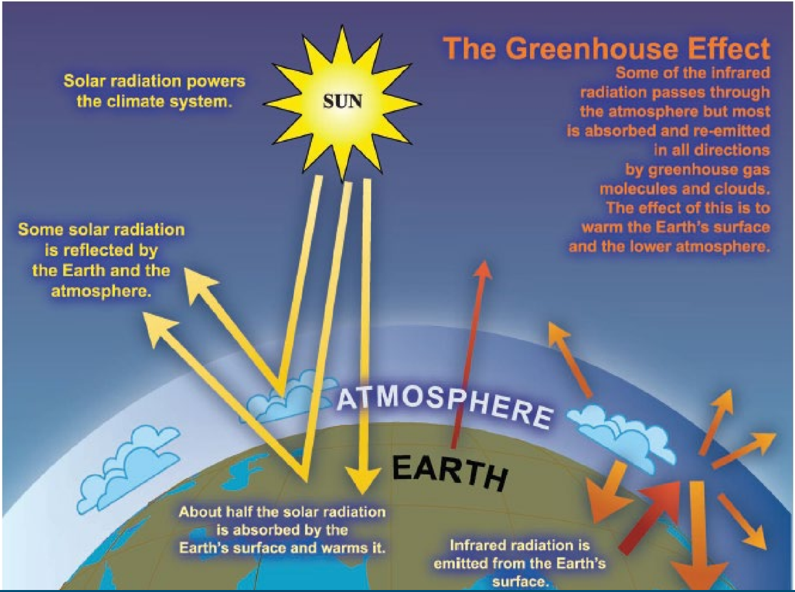
A gas that can absorb the infrared radiation emitted by Earth

- H_2O vapor (55 % - 17 % clouds) Half-life (50 %) $<$ some days
- Carbon dioxide : CO_2 - Half-life (50 %) : 20 to 100 yrs
- Methan : CH_4 - Half-life (50 %) : $<$ 10 yrs – GWP [4] $\simeq$ 28
- Nitrous Oxide : N_2O - Half-life (50 %) : $\simeq$ 120 yrs – GWP $\simeq$ 273
- Halocarbons : $C_xH_yF_zCl_t$ - Half-life (50 %) 15 to 500 yrs – GWP in the order of 1000 to 20,000

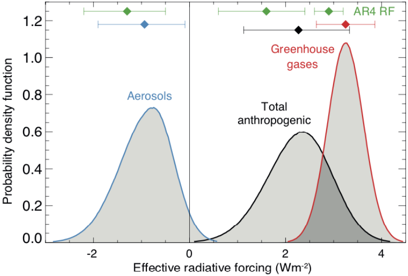
Arose 4.5 Billions years B.C. (primitive atmosphere produced by degassing of volcanoes)

4. measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time (100 years), relative to the emissions of 1 ton of carbon dioxide (CO2)

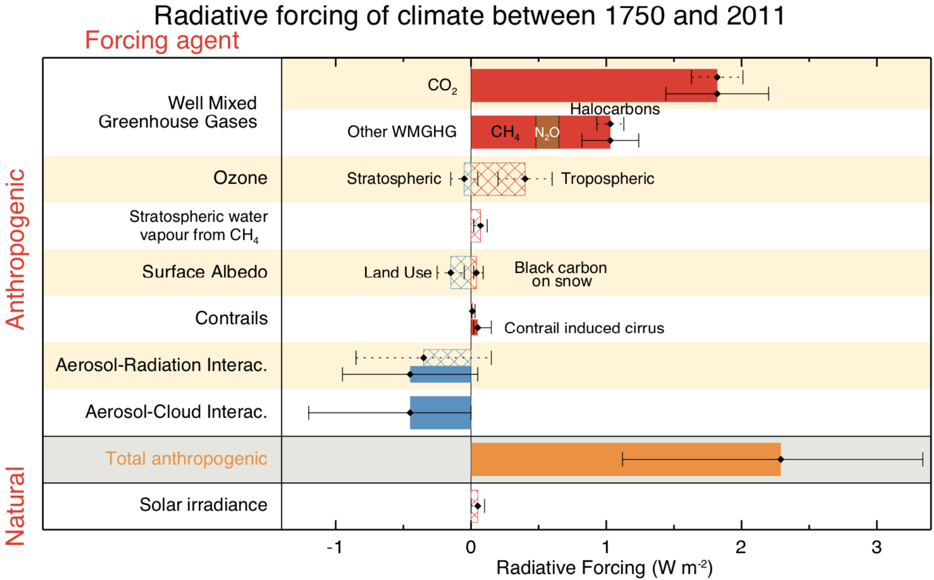
Greenhouse Effect : a simple reminder



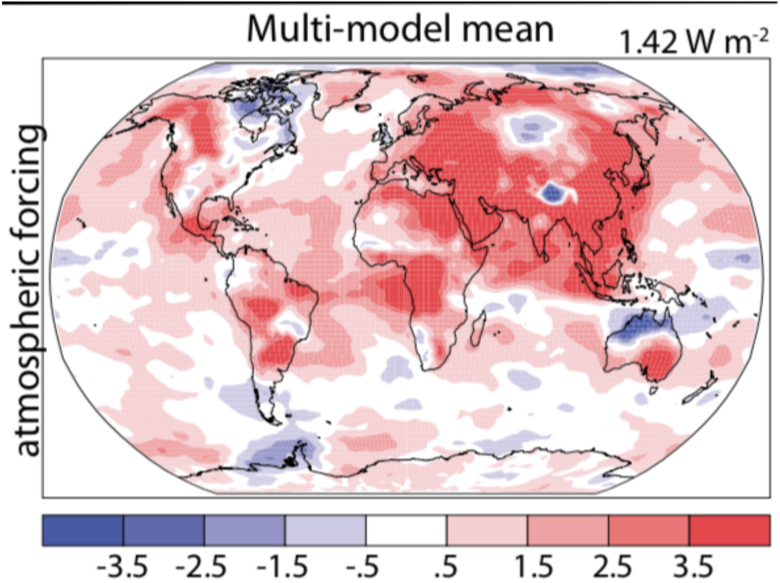
- On the long run **S = IR** (**S** : incoming solar radiation, **IR** outgoing longwave radiation)
- **Radiative Forcing** is a (big) change in **S** and/or **IR** : **RF = S - IR**
- If **RF** increases, earth's surface warms up ...
- Greenhouse Gas increase leads to an increase in **RF**
- Aerosol increase leads to a decrease in **RF**



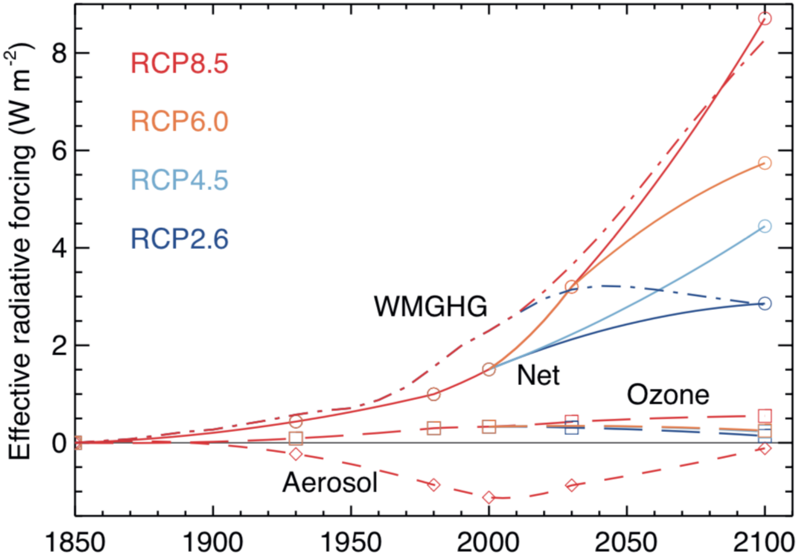
Radiative Forcing (RF) : Anthropogenic



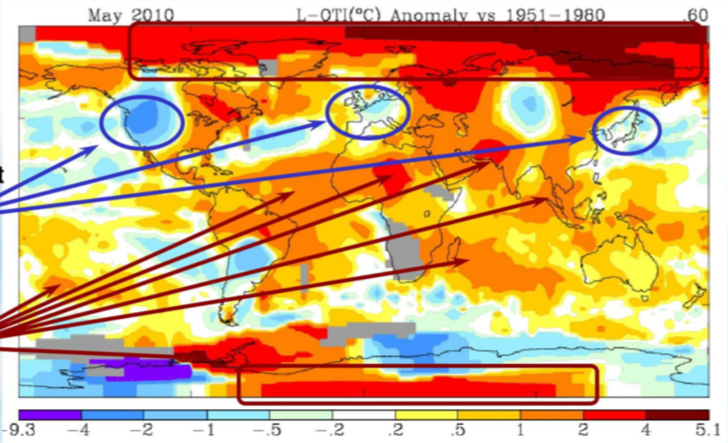
Radiative Forcing (RF) : from 1850 to now



Radiative Forcing (RF) : Future trend



Temperature view



Des journalistes et du « bon sens près de chez vous »

Personne, et pas beaucoup d'agences de presse !

Températures de Mai 2010 comparées à la moyenne du mois de mai sur la période 1951-1980. Source GISS/NASA

Climate sensitivity

- Defined as the temperature change under :
  - Doubling of CO_2 or
  - $1W/m^2$ increase in radiative forcing
- Doubling of CO_2 is approximately an RF increase of 3.7 W/m^2
- Compact way to compare models and paleoclimate data
- Illustrates the role of climate feedback

Climate sensitivity

- **Black body sensitivity** : Stefan-Boltzmann Law only, no feedbacks
- **Charney sensitivity** : short term equilibrium including water vapor feedback, snow/albedo and cloud feedback. No deep ocian, ice sheet or CO_2 changes.
- **Long Term sensitivity** : includes adjustments to deep ocean temperature, Ice sheet, sea level, biomass, CO_2
- Illustrates the role of climate feedback

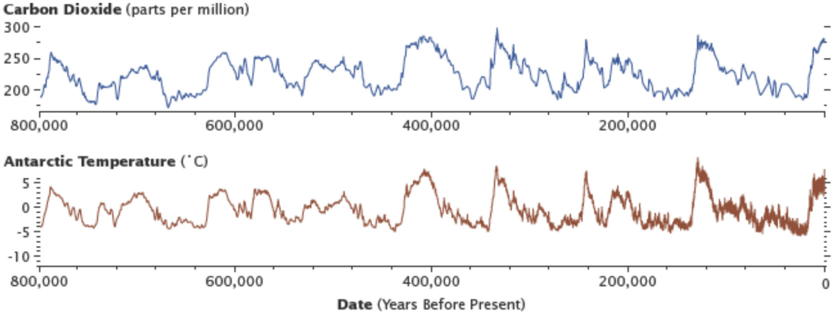
Sensitivity numbers

- **Black body sensitivity** :

$$F = \sigma T^4 \Rightarrow \frac{dT}{dF} = (4\sigma T^3)^{-1} = 0.19K/Wm^{-2}$$

- But, warming about 0.8 K in the last 100 years for F = 1.5 W/m^2
- Sensitivity of $0.8/1.6 = 0.5\ K/Wm^{-2}$
- Sensitivity of 1.9 K per CO_2 doubling

Historical Carbon and sensitivity



Historical Carbon and sensitivity

- Warming about 5 K.
- Estimated change in long wave forcing : 7.1 W/m^2.
- Sensitivity : 0.7 K/Wm^{-2}
- Sensitivity : 2.6 K per CO_2 doubling
- includes more feedback

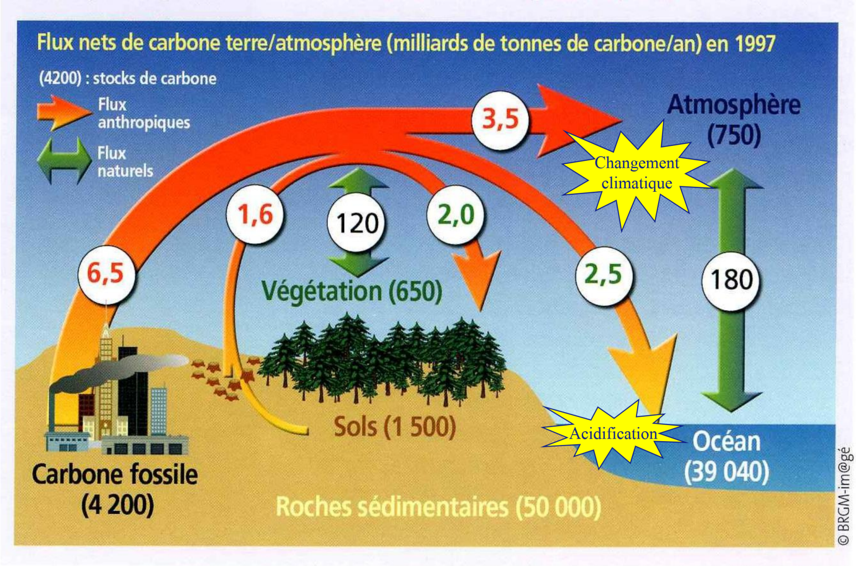
CO_2 emission chemistry

- $C+O_2 \rightarrow CO_2$ (burning coal)
- $CH_4 + 2\ O_2 \rightarrow 2\ H_2O + CO_2$ (burning methane)
- $C_3H_8 + 5\ O_2 \rightarrow 4\ H_2O + 3\ CO_2$ (burning propane)
- $CaCO_3 \rightarrow CaO + H_2O + CO_2$ (making cement)
- Fossil Fuel Combustion (oil + all above) + Cement = 29 Gt CO_2/ year

The Carbon cycle

- Emissions
- Forest and ocean update
- Recent history of atmospheric CO_2
- The Keeling Curve
- Carbon isotopes

Greenhouse Effect : Carbon view



BRGM — SERVICE GÉOLOGIQUE NATIONAL — WWW.BRGM.FR

CO_2 emission chemistry

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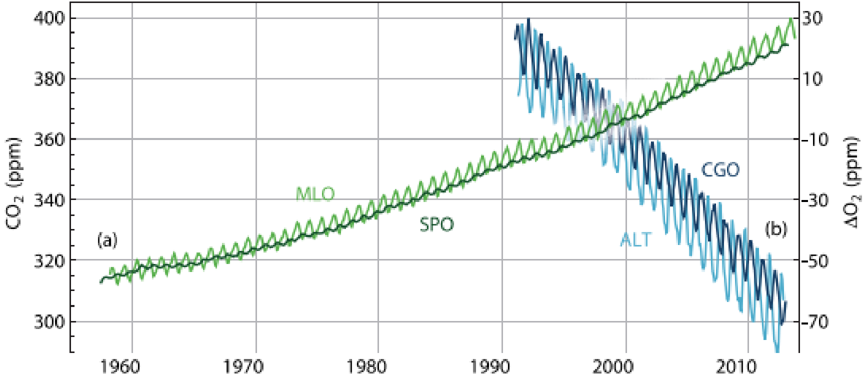
- $CaCO_3 \rightarrow CaO + H_2O + CO_2$ (making cement)
- Fossil Fuel Combustion (oil + all above) + Cement = 29 Gt CO_2/ year

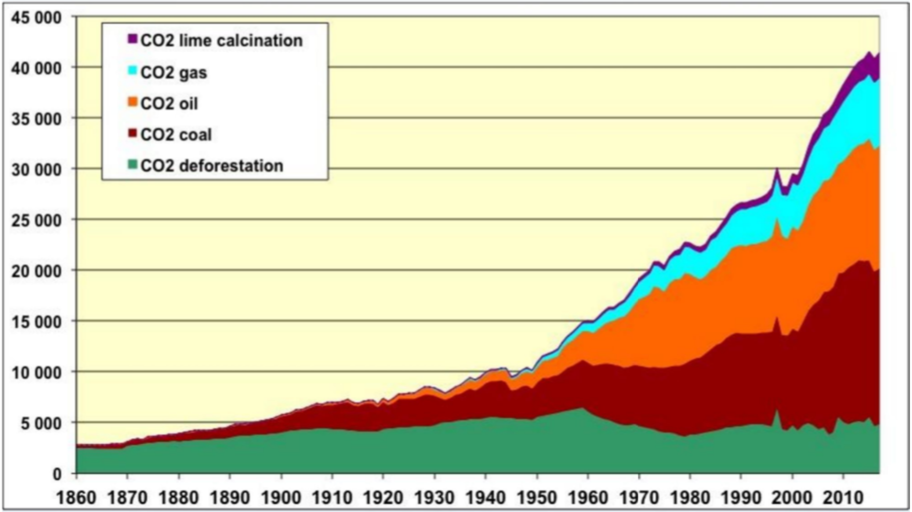
Carbon : Anthropocenic source

Remember that burning produces CO_2 and consumes O_2 (so does respiration, ...)

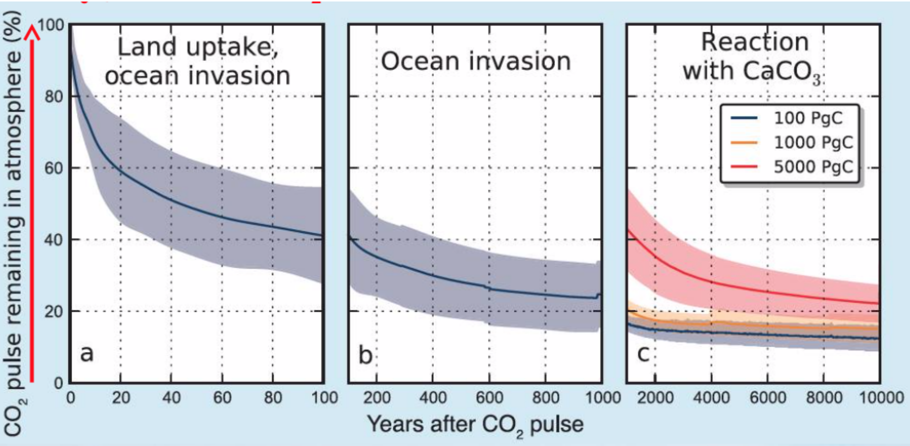


IPCC AR5

Jancovici 2019



Remember CO_2 is **very** stable



IPCC AR5

So why do we produce CO_2 ?

Carbon and Energy

Burning produces Energy and CO_2 **So what is ENERGY ?**

Energy is a physical quantity that transforms the state of a system

- Modifies temperature
- Modifies speed
- Modifies shape
- Modifies the chemical nature
- Modifies the position in a field (electrical motor)
- modifies the atomic composition ...

Energy is a MACHINE

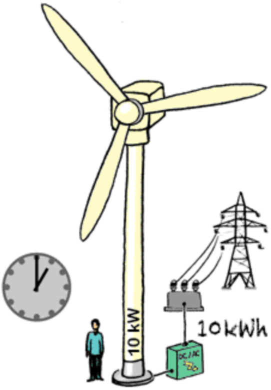
Energy transition since ... ages

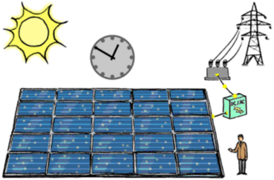
- Taming Fire (quite some time ago ...)
- Wood, wind, sun, water, animals
- Oil known by Sumerians (3000 BC)
- Coal in China, 1000 BC
- Modern times : nothing new (except nuclear), but much bigger

Et l'énergie dans la vie de tous les jours

- 2 heures d'aspirateur : 1 jour de nourriture (2kWh)
- 1 heure de four classique : 2 jours ...
- Une famille de 2-3 personnes, sans chauffage : (min) 4.000 kWh/an

Et la production : 10 kWh (4 jours)

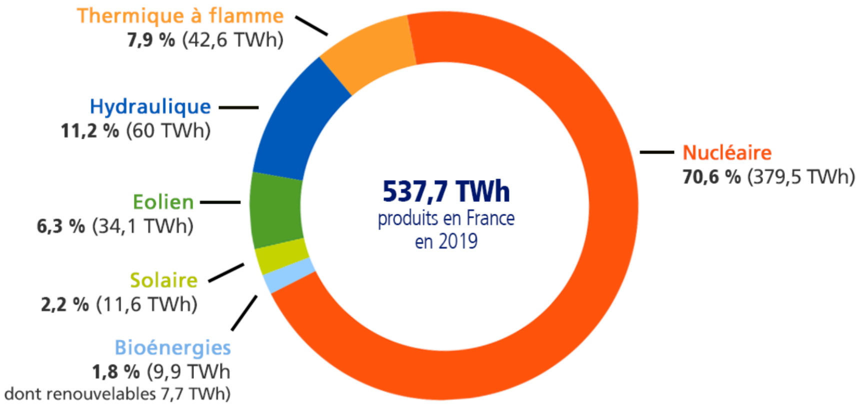




50 m^2 - 1 h. – www.energie-environnement.ch

Production électrique française

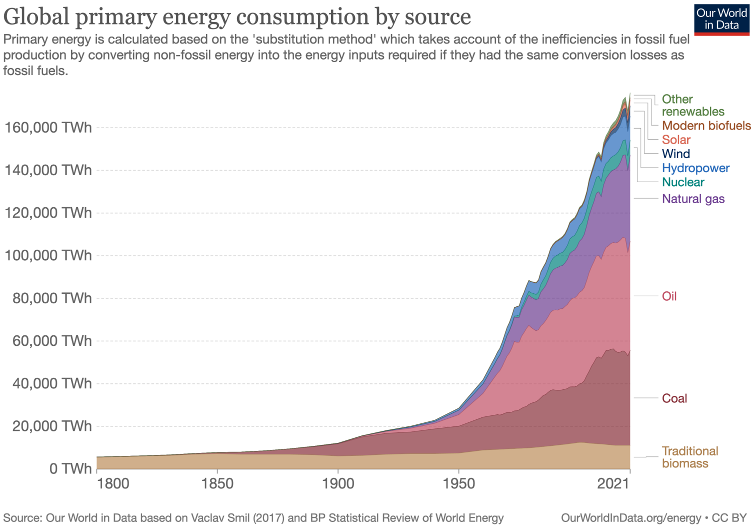
400 TWh/an : serait 100 millions de ménages !
Manque également toute les autres énergies ... 2600 TWh/an en 2021



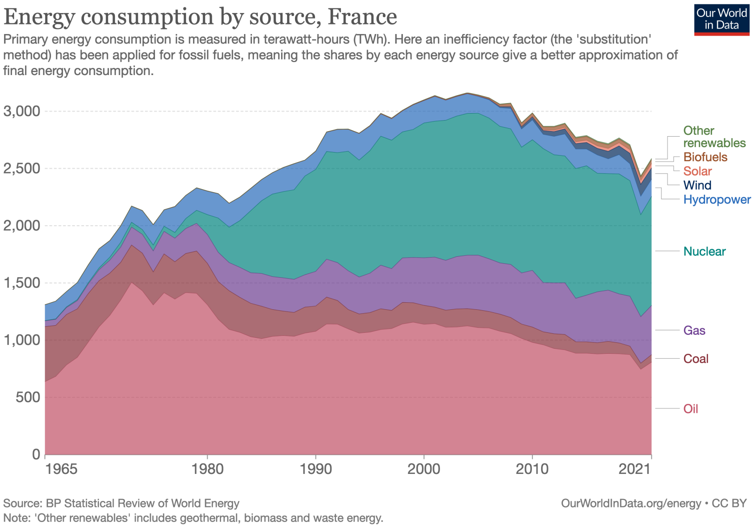
La production française d'électricité en 2019

Source RTE - bilan électrique 2019

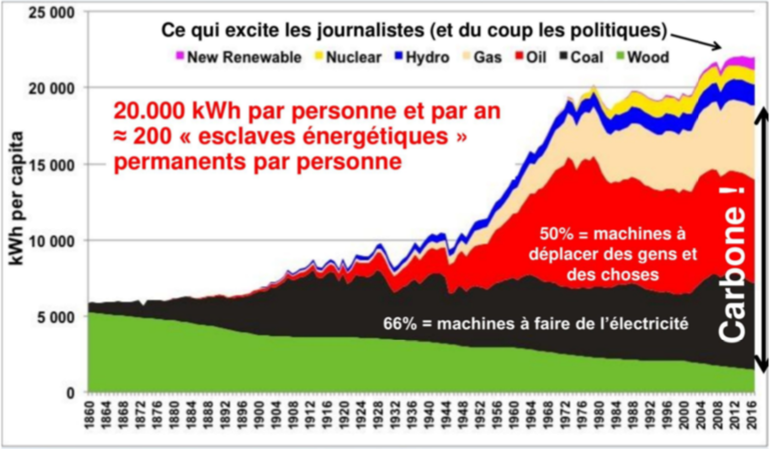
Population X6 – Energie X 30 - 80 % de fossiles



La consommation Française



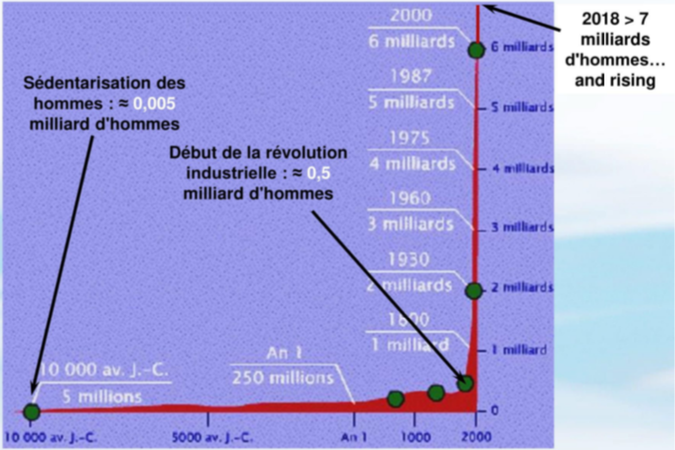
Energy Per person



Consommation d'énergie par personne, moyenne mondiale 1860-2017. Jancovici, 2018

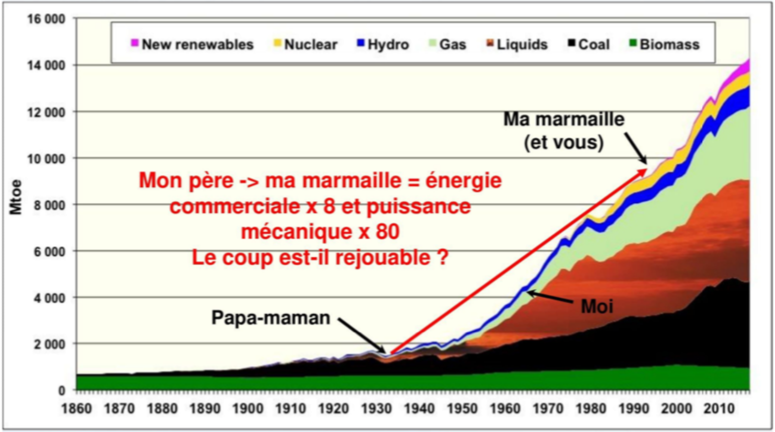
We each have 200 slaves at our disposal (600 in Europe) ...

And number of persons



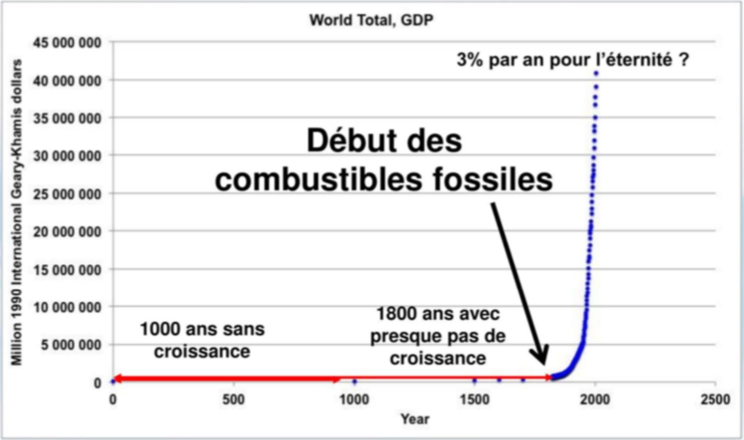
Évolution démographique depuis le néolithique (découverte de l'agriculture). Source : Musée de l'Homme

Global Energy explosion



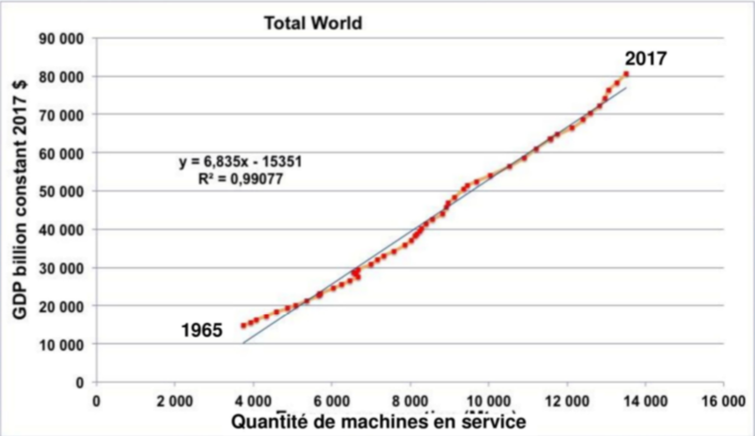
Parc de machines en service ÷ 10 dans le monde 1860-2016. Jancovici, 2017

A link between GDP and Energy



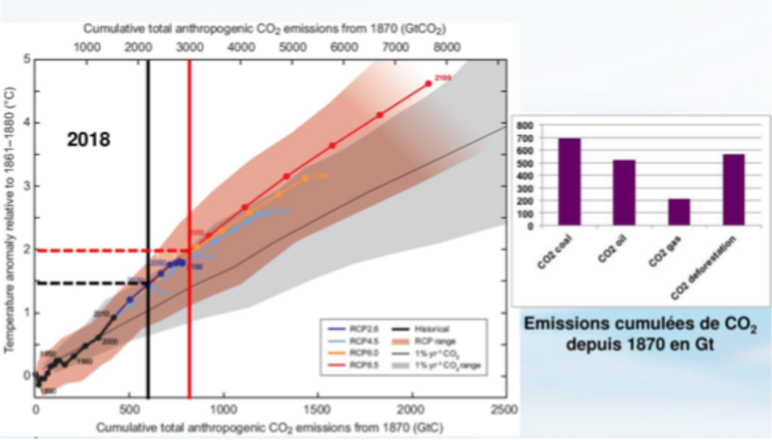
PIB mondial reconstitué de l'an 0 à 2003. Source : Angus Maddison

A link between GDP and Energy



Energie consommée (en abscisse) et PIB en dollars constants (ordonnée) pour le monde. Données primaires World Bank pour le PIB et BP stat pour l'énergie

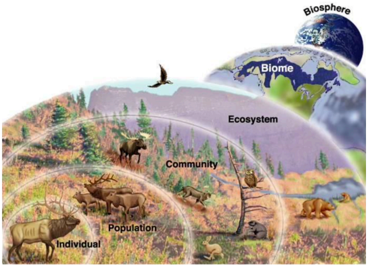
Temperature if GDP increases



What is Biodiversity

This part inspired by EEA and Céline Bellard, EcoClim2021

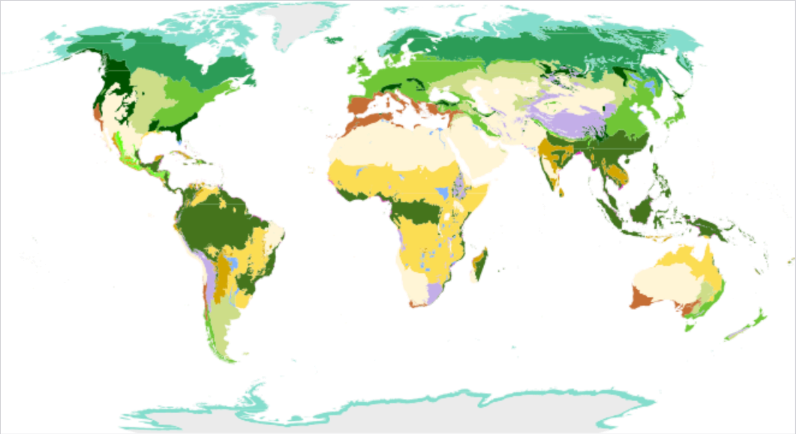
- Diversity of all life forms [5]
- From individuals to biomes



5 to 50 Million species on Earth
2.3 Million Species known (Eukaryota)
1 900 000 Animal species
400 000 Vegetal species

[5] Concept formalized in 1980 - 1986 (Thomas Lovejoy)

Terrestrial Biomes (Wikipedia)



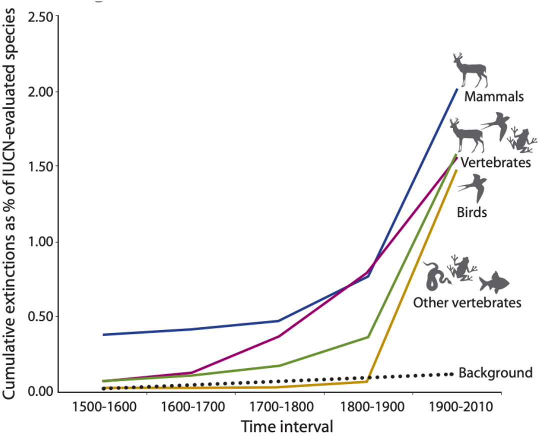
Les 14 biomes terrestres, selon le WWF.

- 01. Forêts décidues humides tropicales et subtropicales
- 02. Forêts décidues sèches tropicales et subtropicales
- 03. Forêts de conifères tropicales et subtropicales
- 04. forêts tempérées décidues et mixtes
- 05. Forêts de conifères tempérées
- 06. Taïga
- 07. Prairies, savanes et terres arbustives tropicales et
- 08. Prairies, savanes et terres arbustives tempérées
- 09. Prairies et savanes inondées
- 10. Prairies et terres arbustives de montagne
- 11. Toundra
- 12. Forêts, terres boisées et broussailles méditerranéennes
- 13. Déserts et terres arbustives xériques
- 14. Mangroves

Why is Biodiversity Important ?

1. Instrumental
   - Food : 12 species feed 75 % of world food
   - Energy : Wood for 2 Billion peoples energy, clothes, ...
   - Medicine : Chemicals and plants
   - Services : Climate mitigation (forests)
     Air and water purification (forests, rivers, ...)
     Pollination (bees ...)
2. Intrinsic value (for itself (and for it's survival))

Extinction Rate Increasing Dramatically

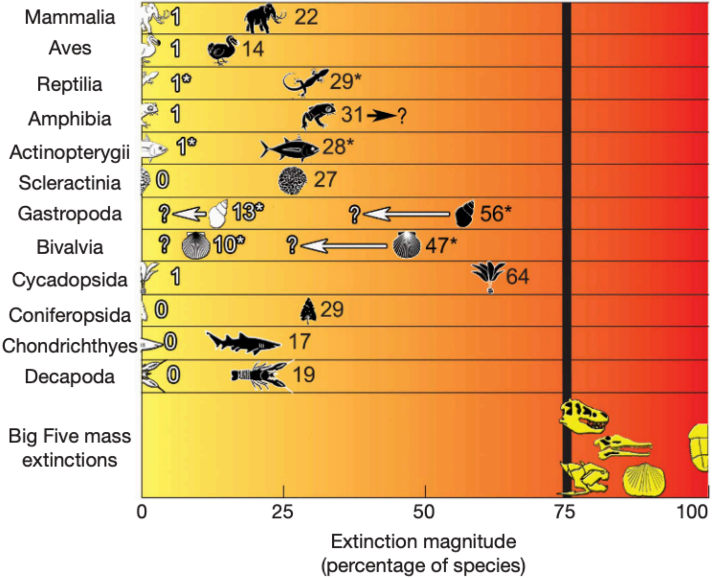


6

Background on
Hypotheses 2 E/MSY
Extinction rate raised by a factor 100
1100 Species disappeared in the last 500 Years
Among which
617 Vertebrates

[6] Ceballos *et al.* Science (2015)

Extinction Rate Increasing Dramatically



7

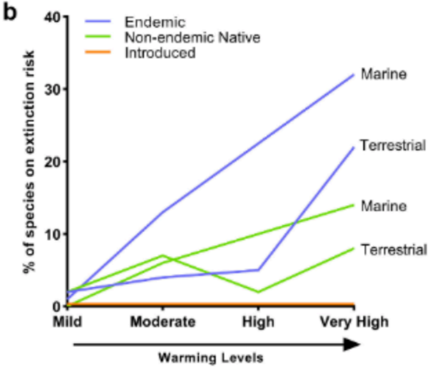
Numbers in white : extinct species / in black : in high danger

Influence of Climate on biodiversity

1. Change in Biological rythms
   - Longer and earlier summer : example of vine - drought / freeze
   - Mismatch in cycles (food - caterpillars for birds) (pollinators and plants)
2. Geographic areas of trees (a.o.) change –¿ impact on fauna

Influence of Climate on biodiversity

- Climate change is projected to negatively impact 273 biodiversity-rich areas globally.
- 34% of land and 54% of marine endemic's, risk extinction.
- 100% of island, 84% of mountain species risk extinction due to climate change.



8

[8] Manes *et al.*, Biological Conservation (2021)

A focus on Europe (and some hope)

TABLE 3.2 Summary assessment — terrestrial protected areas

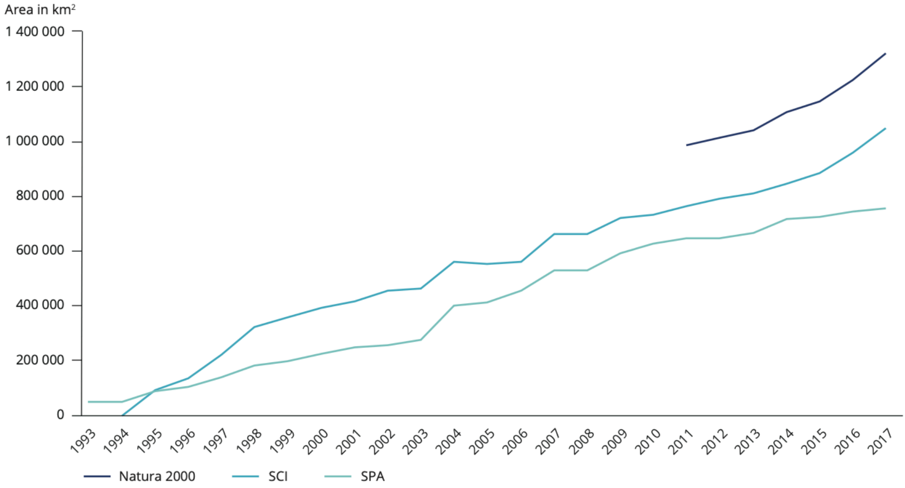
Past trends and outlook		
Past trends (10-15 years)		There has been a steady increase in the cumulative area of the Natura 2000 network in EU Member States in the last 10 years, along with consistent growth in protected areas in all European countries.
Outlook to 2030		Designation of protected areas is not in itself a guarantee of effective biodiversity protection. Establishing or fully implementing conservation measures and management plans to achieve effectively managed, ecologically representative and well-connected systems of protected areas are crucially important and remain a challenge up to 2030.
Prospects of meeting policy objectives/targets		
2020	☑	The global Aichi biodiversity target 11 of 17 % of terrestrial areas conserved has been reached in Europe. In the EU, the Natura 2000 network already covers 18 % of the land area.
Robustness		Long-term data on the coverage of nationally designated protected areas in the EEA member countries and candidate countries (EEA-39) and consistent data on the Natura 2000 area are available. Information is lacking on the effectiveness of conservation measures in Europe's protected areas and how well biodiversity is protected there. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

[9]

[9] The European environment — state and outlook 2020 Knowledge for transition to a sustainable Europe - EEA

A focus on Europe (and some hope)

FIGURE 3.1 **Area of Natura 2000 sites designated under the EU Habitats and Birds Directives in 2017**



A focus on Europe (and some hope)

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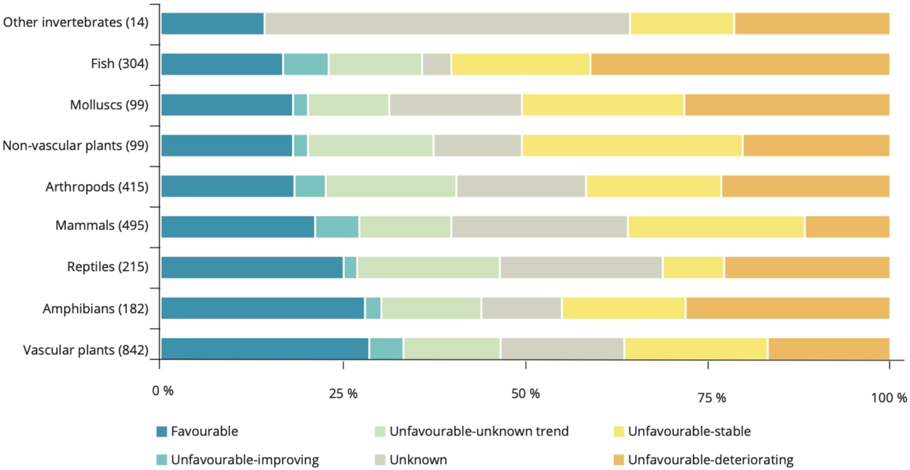
A focus on Europe (and some hope)

FIGURE 3.3 **Trends in conservation status of assessed non-bird species at EU level**

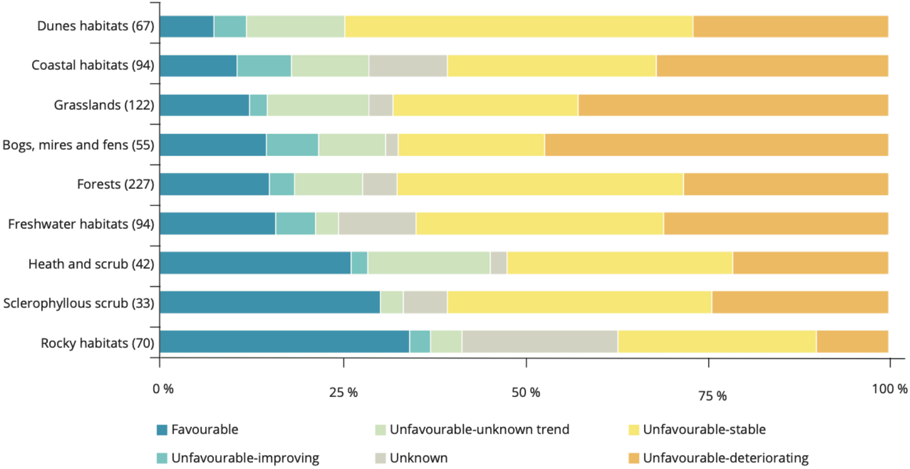


Note: These are species from the Habitats Directive. The number of assessments is indicated in parenthesis. The total number of assessments is 2 665.

Source: EEA (2016e), based on conservation status of habitat types and species reporting (Article 17, Habitats Directive 92/43/EEC).

A focus on Europe (and some hope)

FIGURE 3.4 Trends in conservation status of assessed habitats at EU level



Note: The number of assessments is indicated in parenthesis. The total number of assessments is 804.

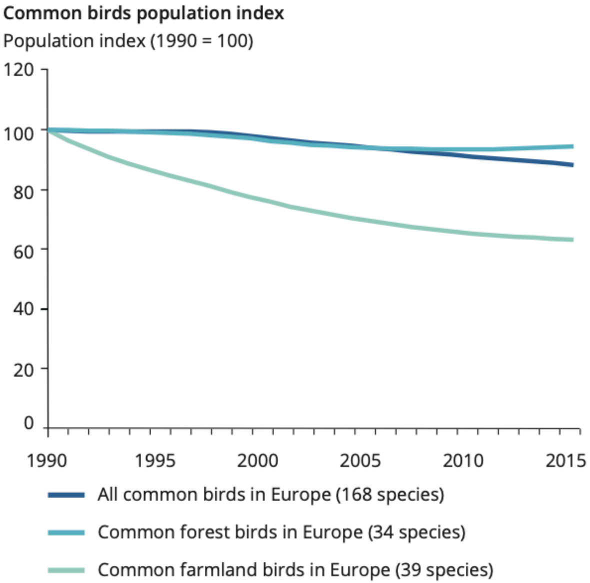
Source: EEA (2016b), based on conservation status of habitat types and species reporting (Article 17, Habitats Directive 92/43/EEC).

A focus on Europe (and some hope)

TABLE 3.3 **Summary assessment — EU protected species and habitats**

Past trends and outlook		
Past trends (10-15 years)		A high proportion of protected species and habitats are in unfavourable condition, although there have been some limited improvements in the last 10 years.
Outlook to 2030		The underlying drivers of biodiversity loss are not changing favourably so, without significant conservation efforts, current trends will not be reversed and pressures will continue to increase.
Prospects of meeting policy objectives/targets		
2020	☒	The EU is not on track to meet the 2020 target of improving the conservation status of EU protected species and habitats and the cumulative pressures remain high.
Robustness		Despite the increasing quality of information delivered by the nature directives reporting, data gaps remain, as a proportion of the assessments report unknown conservation status of species and habitats, unknown population status of birds and unknown trends for species or habitats assessed as unfavourable. The available outlook information is limited so the assessment of the outlook relies primarily on expert judgement.

A focus on Europe (and some hope)



A focus on Europe (and some hope)

TABLE 3.4 Summary assessment — common species (birds and butterflies)

Past trends and outlook		
Past trends (> 25 years)		Since 1990 there has been a continuing downward trend in populations of common birds. Although this has levelled off since 2000 for some species, no trend towards recovery has been observed. The most pronounced declines were observed in farmland birds and grassland butterflies.
Outlook to 2030		The underlying drivers of the decline in common species are not changing favourably. Full implementation of a range of policy measures, including sectoral policies, is required to deliver improvements.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the 2020 target of halting biodiversity loss.
Robustness		Data collection methods are scientifically sound and the methods used by skilled volunteers are harmonised. However, wide monitoring schemes currently exist for only two species groups. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

Biosphere Integrity : Boundaries

Variables *Genetic diversity* :Extinction rate
Functional diversity : Biodiversity Intactness Index (BII)

Thresholds $<$ 10 E/MSY [10] (10-100 E/MSY) but with an aspirational goal of ca. 1 E/MSY (the background rate of extinction loss).
Maintain BII at 90 % (90-30%) or above, assessed geographically by biomes/large regional areas (e.g. southernAfrica), major marine ecosystems (e.g., coral reefs) or by large functional groups

Current Values 100-1000 E/MSY
84%, applied to southern Africa only

[10] E/MSY =extinctions per million species-years : if species last for 10^6 to 10^7 years, then their extinction rate is 1 to 0.1 E/MSY

Land Systems : usage, link to pollution

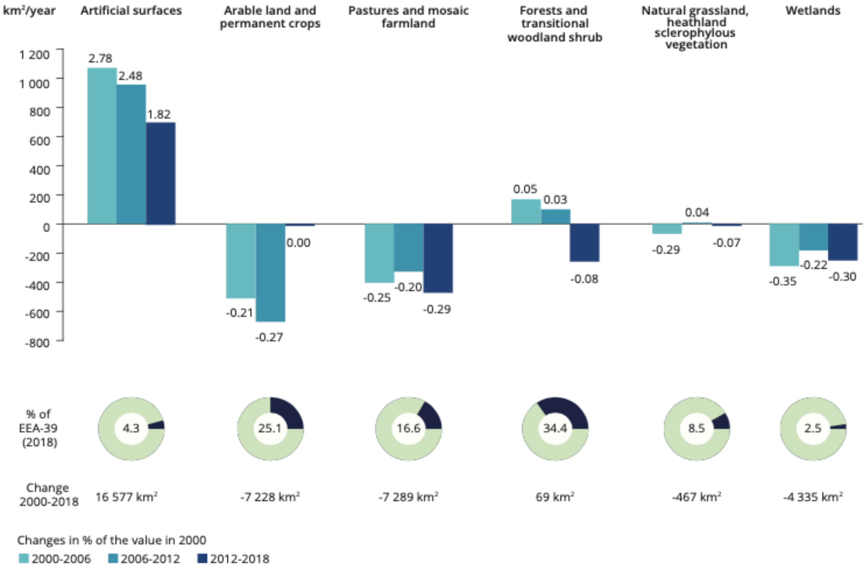
Parameters
- Amount of N_2 (Nitrogen) removed from atmosphere (million tonnes per year)
- Quantity of P (Phosphore) flowing into Ocean (million tonnes per year)
- Percentage of global land cover converted to cropland

Boundary
- Nitrogen : 35 MT/year
- Phosphore : 11 MT/year
- Land use : 15 %

Status (as of 2009)
- Nitrogen : 121 MT/year
- Phosphore : 8.5-9.5 MT/year
- Land use : 11.7 %

Land systems : Land surfaces decrease :(

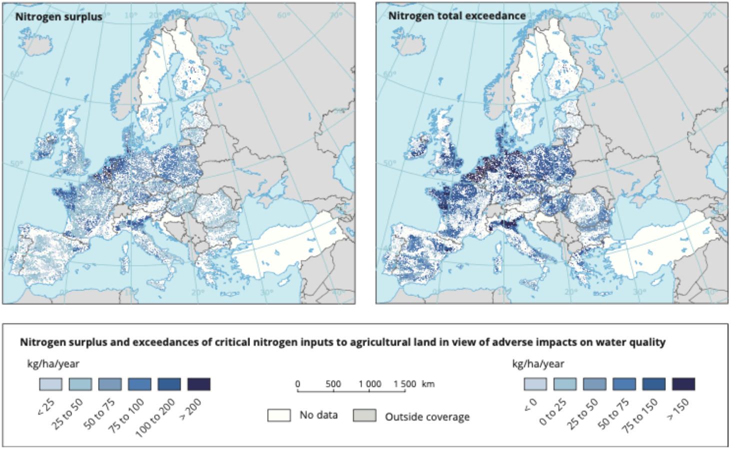
FIGURE 5.1 Change in six major land cover types in the EEA-39 during the period 2000-2018



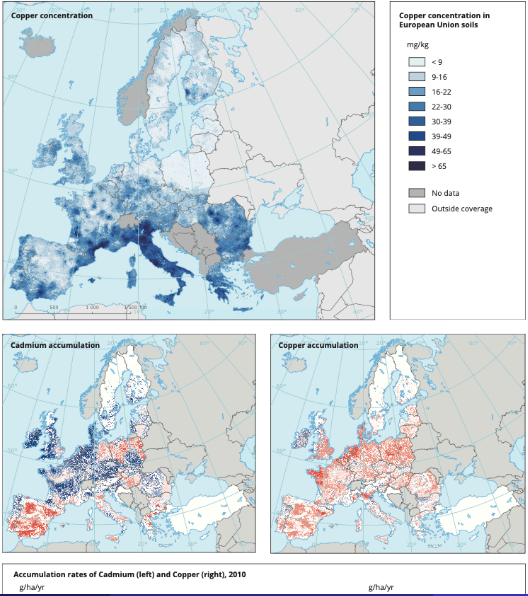
Intensive Agriculture : Pollutants

Intensive Agriculture leads to accumulation of (up to 166 different) pollutants (think of the infamous glyphosate) + Nitrogen, which has adversial effects on Biodiversity

MAP 5.5 **Calculated nitrogen surplus (inputs vs outputs) (left) and exceedances of critical nitrogen inputs to agricultural land in view of adverse impacts on the environment (right)**



MAP 5.4 Copper concentration in EU soils, and accumulation rates of cadmium and copper



Fourth Boundary : Freswhater

Parameters Consumption of freshwater by humans (km^3 per year)

Boundary 4,000

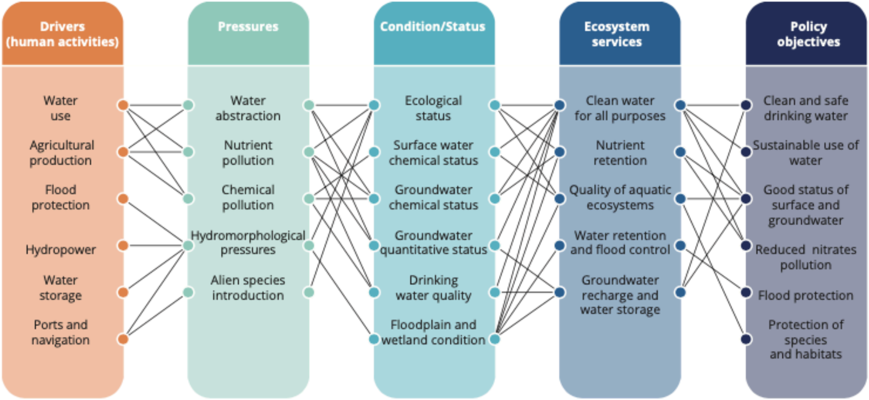
Status (as of 2009) 2 600 (preindustrial : 415)

But a lot of other factors, for example in Europe :

- 40 % of water bodies in Europe have a good ecological status.
- 38 % of water bodies in Europe have a good chemical status.
- 89 % of groundwater bodies in Europe are in good quantitative status.
- 95 % of bathing sites in Europe meet excellent quality standars.

A more complex view

FIGURE 4.1 **Selection of links between drivers, pressures, condition, ecosystem services and policy objectives**

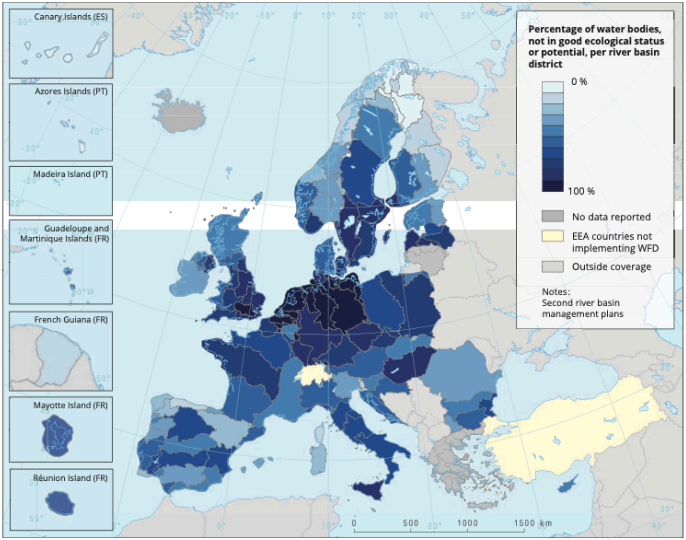


Note: BOD, biological oxygen demand.

Source: Modified from Maes et al. (2018).

Water Bodies Status in Europe

MAP 4.1 **Country comparison — results of assessment under the Water Framework Directive of ecological status or potential shown by river basin district**



Notes: Caution is advised when comparing results among Member States as the results are affected by the methods used to collect and

Fifth Boundary : The Marine Environment

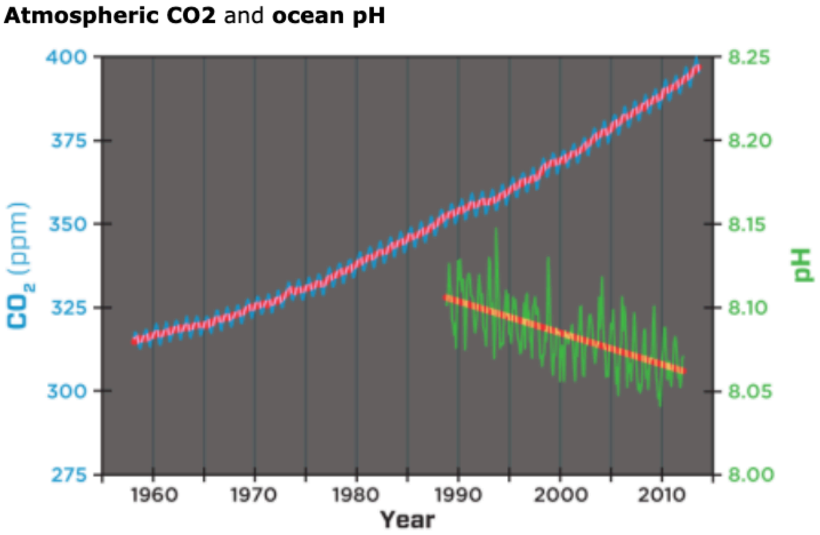
Parameters Global mean saturation state of aragonite ($CaCO_3$) in surface sea water 

Boundary 2.75

Status (as of 2009) 2.9 (preindustrial : 3.44)

Aragonite concentration decreases with ocean acidification induced by CO_2 (shells made of Aragonite and Calcite –¿ can be dissolved and animals in them are not protected any more)

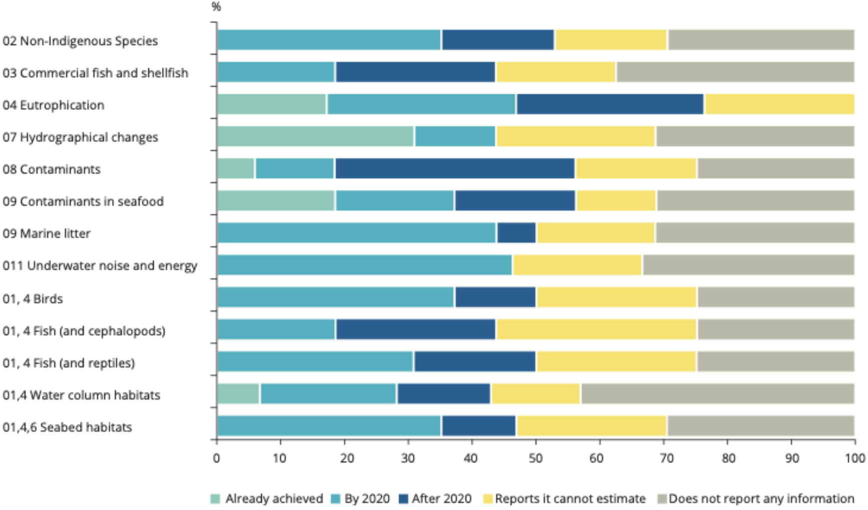
Ocean acidification



Observations of CO2 (parts per million) in the atmosphere and pH of surface seawater from Mauna Loa and Hawaii Ocean Time-series (HOT) Station Aloha, Hawaii, North Pacific.

Marine : A lot of topics

FIGURE 6.7 **Timelines for achieving good environmental status as reported by Member States**

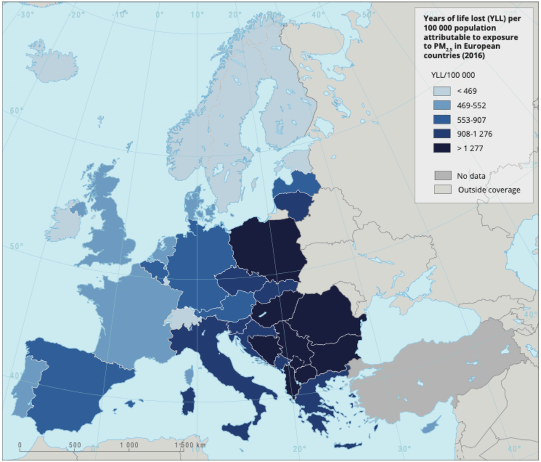


Note: Member States integrated national, EU and international policies during their implementation of the MSFD to identify existing management measures and gaps in current management. New or additional measures were assigned to fill the gaps identified to address all relevant pressures on the marine environment. Assessment showed that many pressures had not been addressed in

Air Pollution

Air Polluton ($PM_{2.5}$, PM_{10}, NO_x SO_2, Volatile Organic, CO, NH_3 ....)
Globally decrease (in Europe) but ...

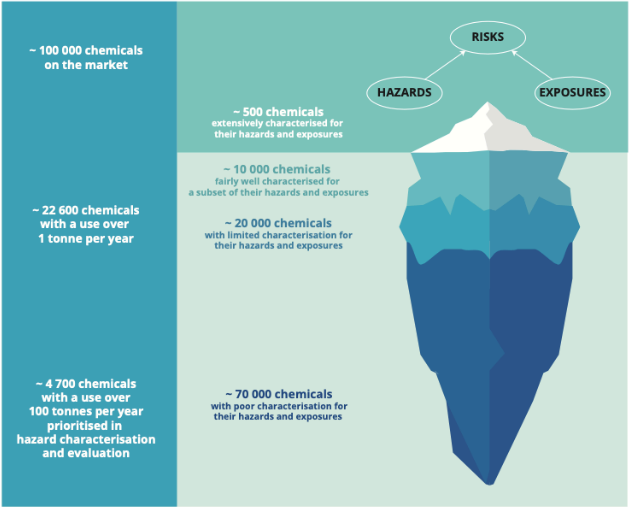
MAP 8.2 **Estimated years of life lost per 100 000 population attributable to exposure to $PM_{2.5}$ in European countries in 2016**



Note: YLL, years of life lost. The classification of values in map legends is quantiles, so one fifth of countries fall in each class. The calculations are made for all of Europe and they may differ for specific studies at country level.

(New) chemical entites

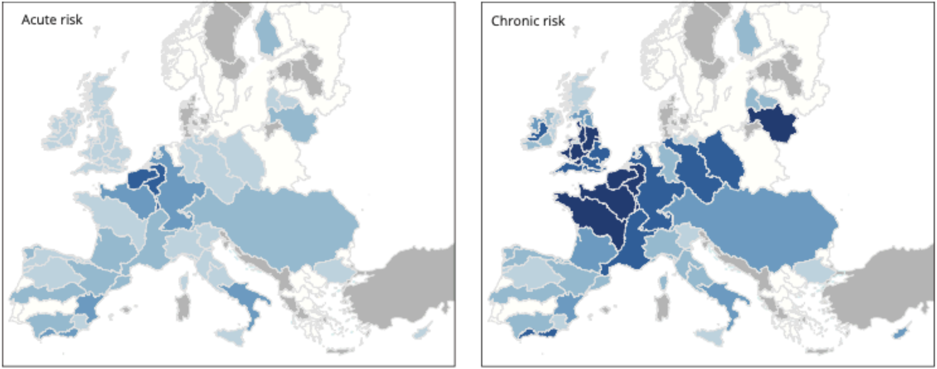
FIGURE 10.2 The unknown territory of chemical risks



Note: The numbers in the figure do not include impurities, transformation products or structural variants (isomers) of chemicals placed on the market. ~ 500 chemicals: Chemicals which are considered sufficiently regulated (ECHA, 2019b), typically legacy and well-known chemicals characterised for most known hazards, which have limit values and are regularly are monitored by quantitative methods in most media. ~ 10 000 chemicals: Chemicals on EU or national legislation lists which are characterised for some but not for all known hazards, which have specific limit values, and are monitored quantitatively, but irregularly across time, media or space. ~ 20 000

Acute and Chemical risks

MAP 10.1 **Acute and chronic chemical risk estimates in European river basins**

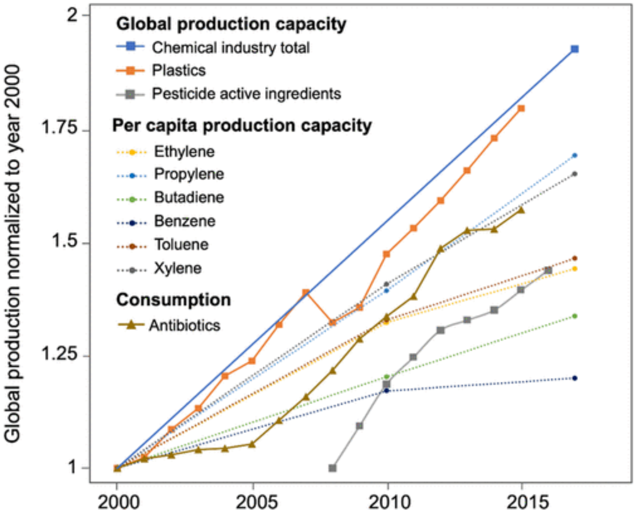


Chemical risk estimates for European river basins (%)

< 10 | 10-25 | 25-50 | 50-75 | 75-100 | < 6 sites | No data

Note: The map displays the fraction of sites where the maximum chemical concentration exceeds the *acute risk* threshold, and the mean chemical concentration exceeds the *chronic risk* threshold for any organism group. The calculations are based on reported chemical monitoring data and calculated using risk estimates for individual compounds. The colours indicate low chemical risk (light blue) to high chemical risk (dark

Figure 2



11

[11] "Outside the Safe Operating Space of the Planetary Boundary for Novel Entities" in

So we have to spend less ...

- **Efficiency** : Same services with less energy
- **Sobriety** : Less services (smaller car, less trips, smaller house / temperature, less meat ...
- **Poverty** : If we don't do anything, that's going to happen ...

Intergovernmental Panel on Climate Change

http://showyourstripes.info

Based on a presentation by

https://fr.wikipedia.org/wiki/Valerie_Masson-Delmotte

how much, when, how serious, who ?

IPCC's role

- Born in 1988, Intergov body of United Nations
- It's role is to evaluate scientific, social, economic ant technical information
  - to understand the scientific bases of the climate change risks due to humans
  - it's potential impacts
  - how to attenuate impacts and to adapt
- In a way that is :
  - **exhaustive**
  - **objective**
  - **transparent**
  - **rigorous and robust**

  - provide a relevant evaluation
  - to help political choices
  - it is non prescriptive

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IPCC is not a research body

IPCC is not a research body. It fosters the production of new knowledge and maturation of scientific knowledge.

IPCC reports and Climate policies

- The First Assessment Report (FAR : 1990) let to the birth of the United Nations Framework Convention on Climate Change, (UNFCCC)
- SAR (1995) gave elements to the Kyoto protocol
- TAR (2001) drew the attention to impacts and need for adaptation
- AR4 (2007) led to the 2 Celsius goal
- AR5 (2013) gave elements to the Paris agreement

- Traceability of conclusions : evaluation of scientific knowledge, papers
- Confidence level of conclusions

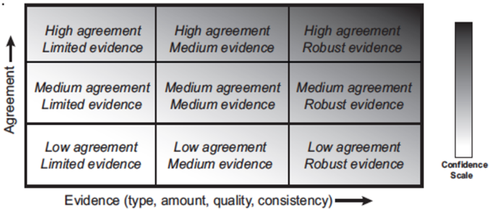


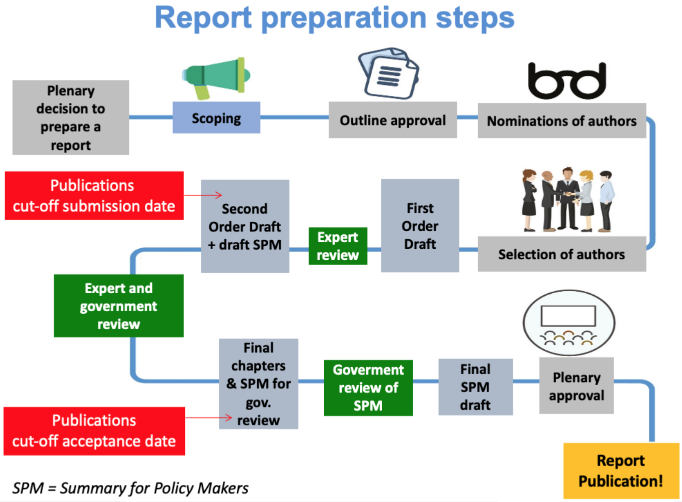
Table 1. Likelihood Scale

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

A huge communication effort

- A lot of effort on visual style, effective communication, author case studies https://climateoutreach.org/case-studies-from-ipcc-authors/
- several external educational material :http://citoyenspourleclimat.org http://www.oce.global http://www.c40.org

The publication process



AR6 : some numbers

https://www.ipcc.ch/assessment-report/ar6/

AR6 : the different reports