Amardeo Sarma

THE FUTURE OF CLIMATE AND ENERGY

From Science Denial to Solutions

Why do skeptics bother?

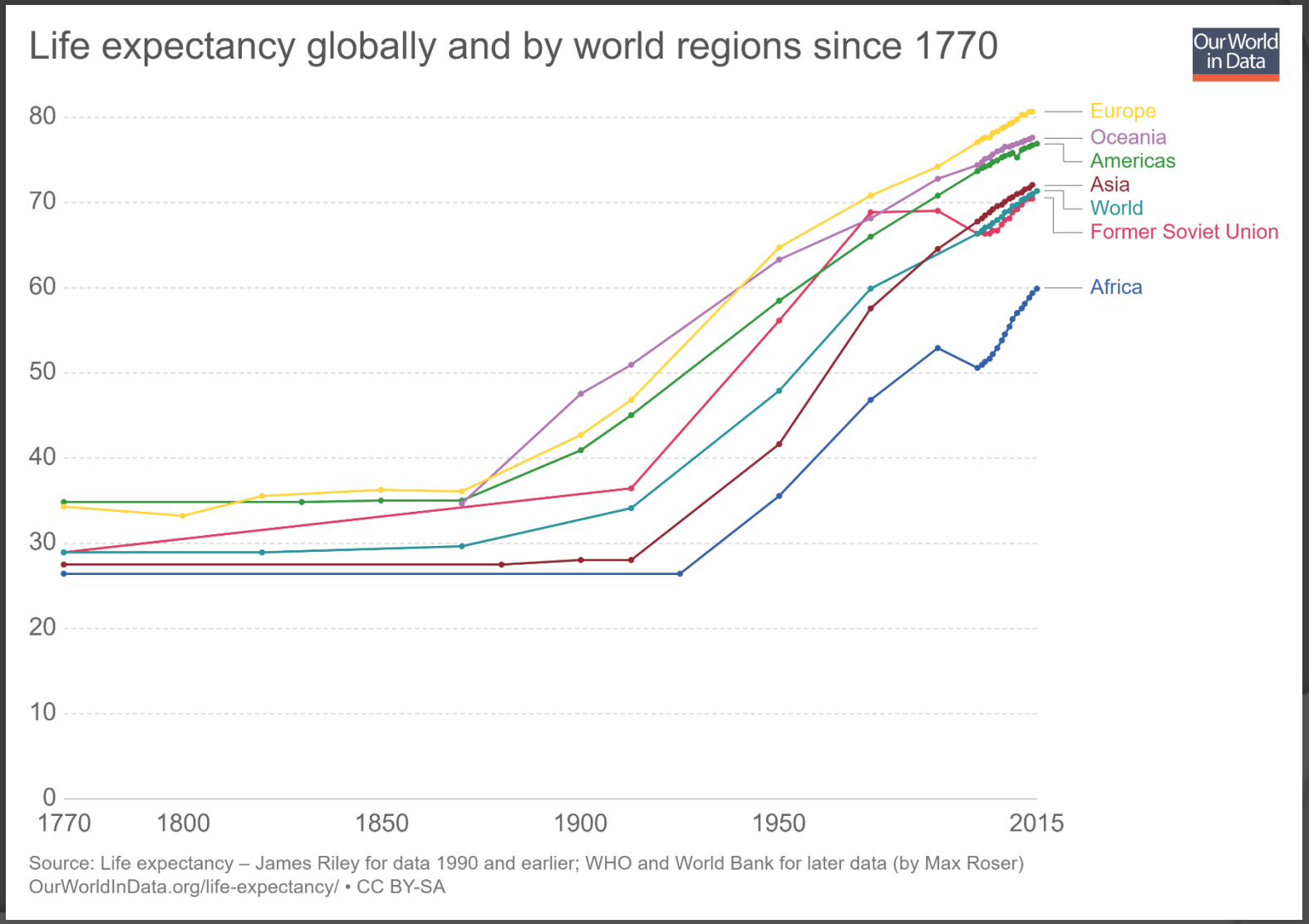
Disclaimer: Scientific skeptics are not climate „skeptics“ or denialists

Skeptics strive for a world in which pseudoscientific claims do not deceive or harm anyone.

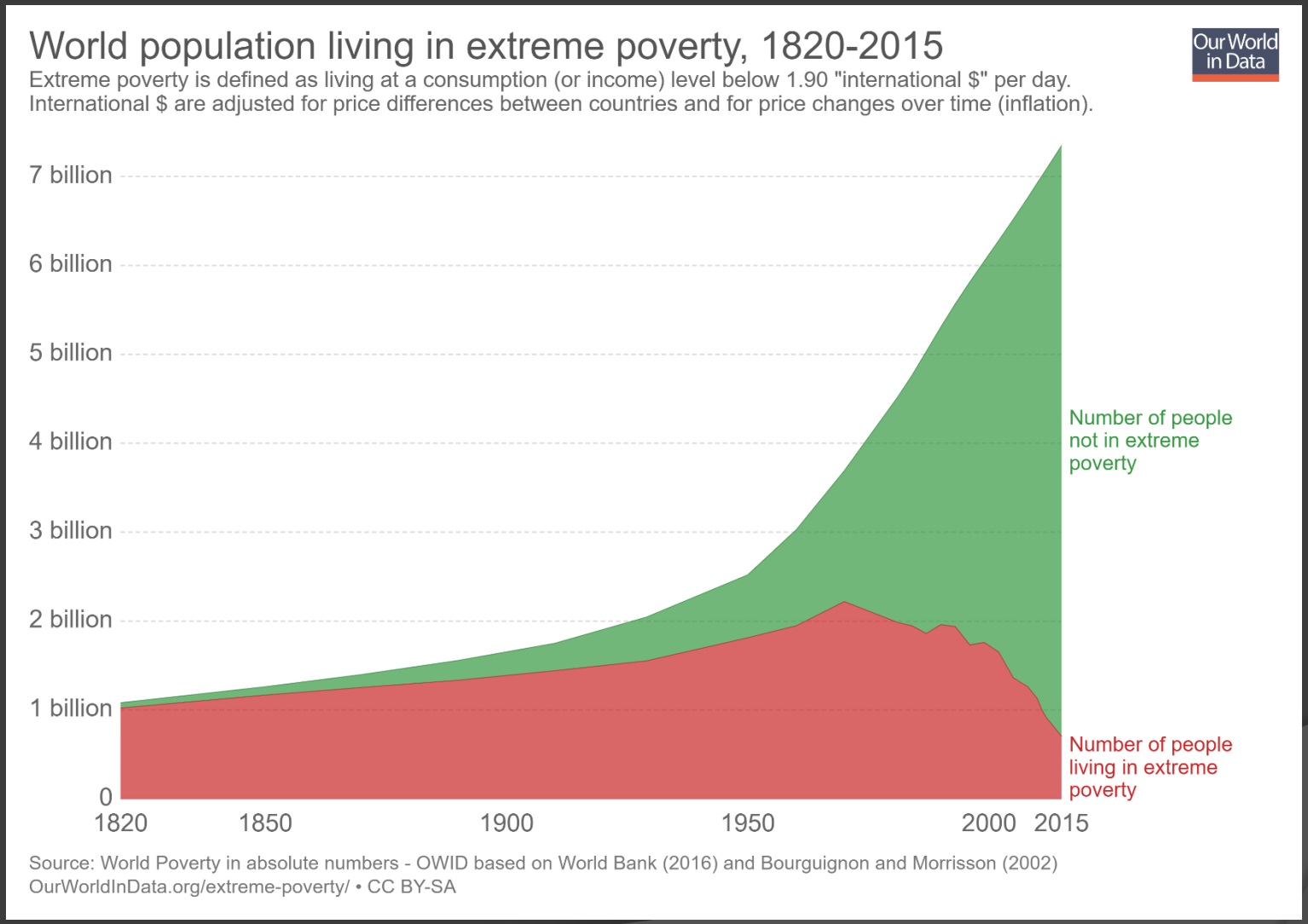
Our mission is to provide reliable information on claims that contradict science and the tools of skeptical inquiry to evaluate and investigate them.

Reference: Skepticism Reloaded: https://www.ecso.org/skepticism-reloaded/

The developing world



The developing world



Why has the world improved overall?

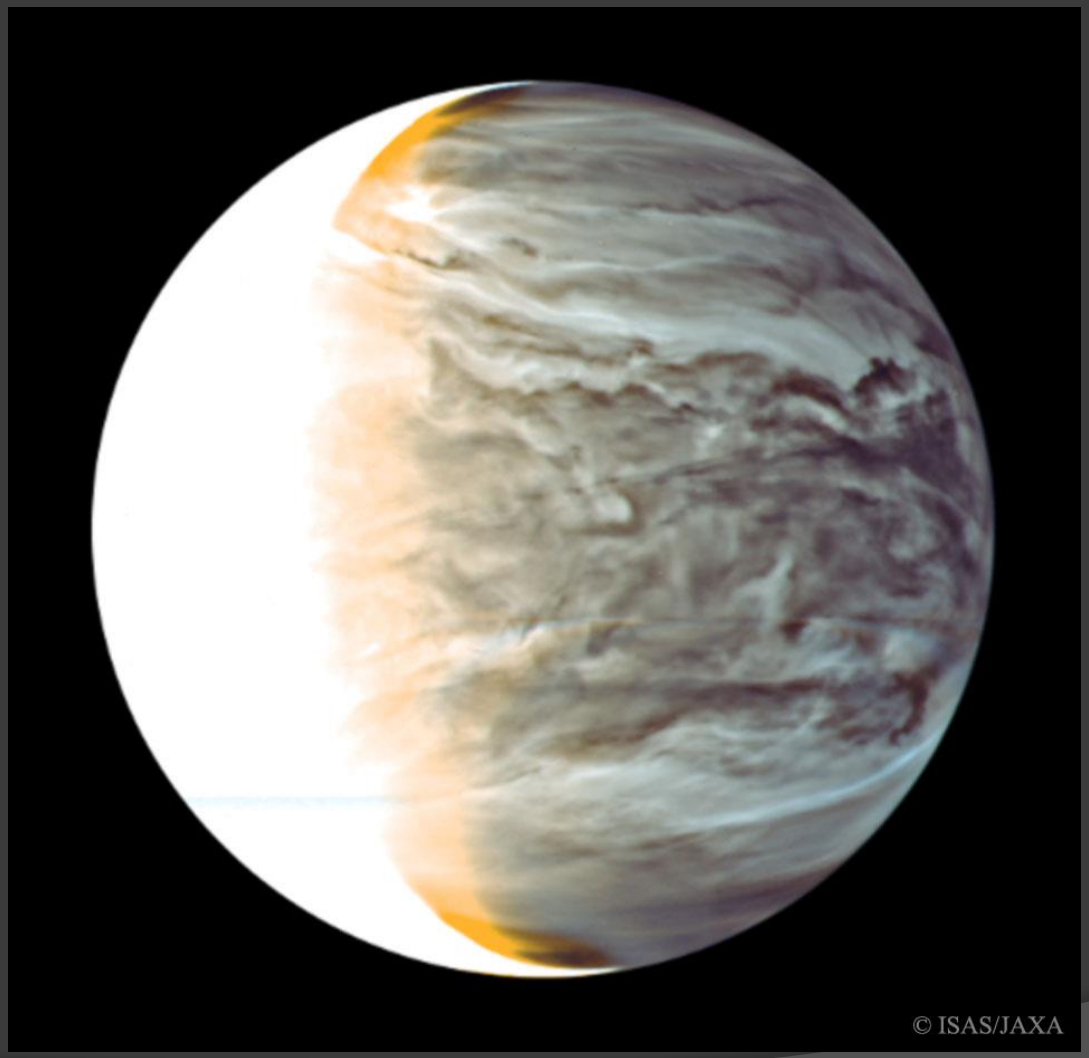
- The industrial revolution gave us energy
- The medical revolution has reduced deaths from diseases
- The Green revolution has drastically improved food production

Still Two Major Global Challenges

- Feed the World
  - Still 800 Million of 7 Billion undernourished
  - 9 Billion in 2050, perhaps 11 Billion 2100
- Give the World Sufficient Energy
  - Every family in the world should have a washing machine and refrigerator
  - So we need more energy than ever before
    - Fossil Fuels gave us a higher standard of life
    - But can we continue burning fossil fuels?

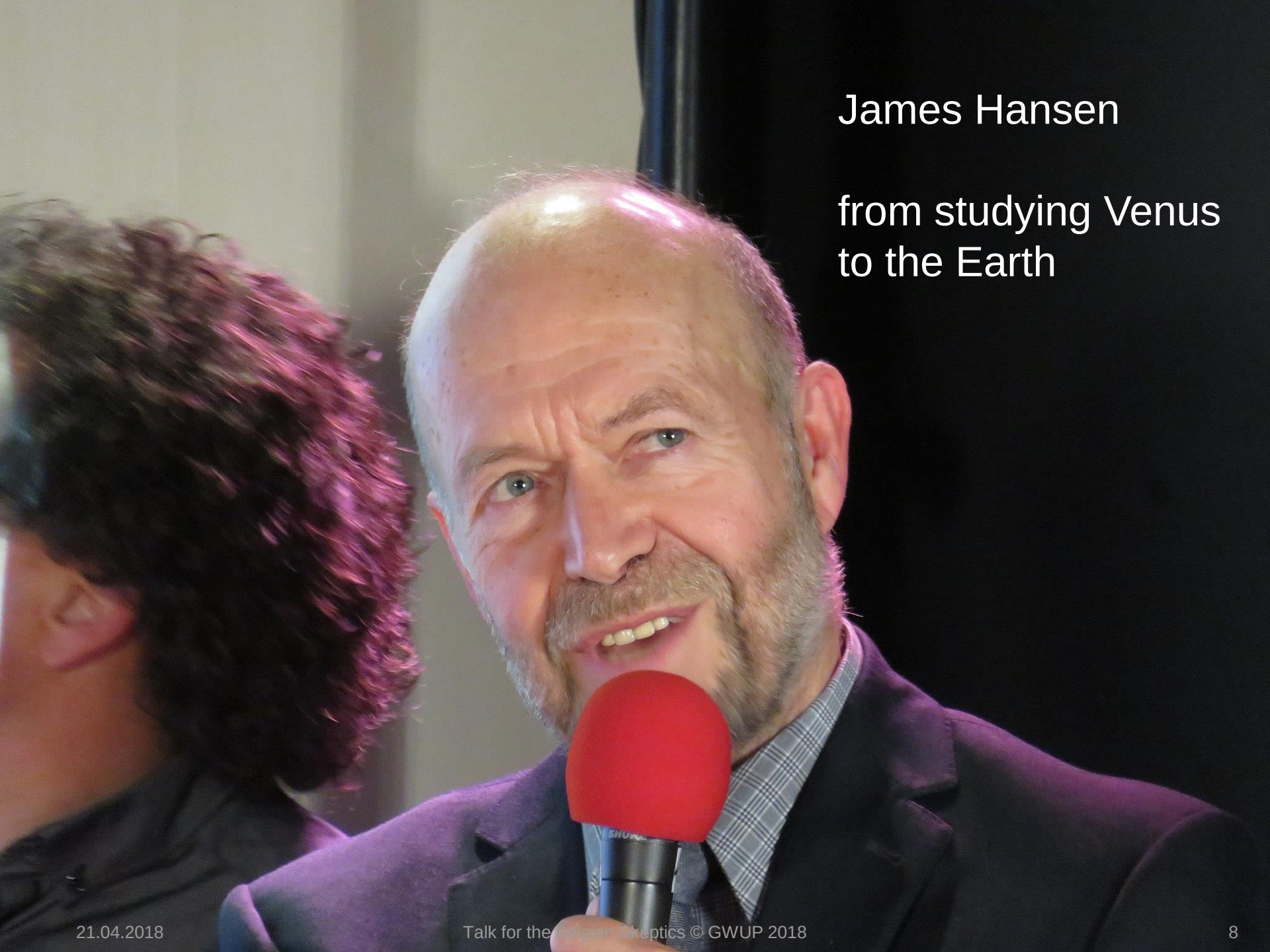
Unfortunately no free lunch!

Before we look at our World



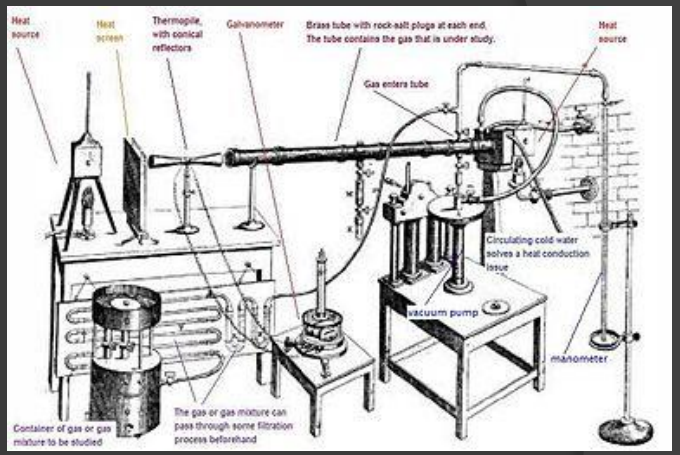
Venus

- 450°C
- 92 bar
- CO_2: 96.5%
- N_2: 3.5%
- SO_2: 0.015%
- H_2O: 20ppm


James Hansen
from studying Venus
to the Earth

Jean-Baptiste Fourier (1768 – 1830)
discovered the greenhouse effect

John Tyndall (1820 – 1893)
identified the greenhouse gases



Svante Arrhenius (1859 – 1927)
predicted a climate sensitivity of
5 – 6°C for a doubling of
atmospheric CO_2

Charles David Keeling (1928 – 2005)
started regularly measuring
atmospheric CO_2
now known as the “Keeling Curve”

Atmospheric Gases

Greenhouse

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Water Vapour (H_2O)
- Ozone (O_3)
- Chlorofluorocarbon (CFC)

Non-Greenhouse

- Nitrogen (N_2)
- Oxygen (O_2)
- Argon (Ar)
- Neon (Ne)
- Helium (He)
- Xenon
- Krypton

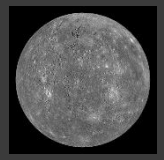
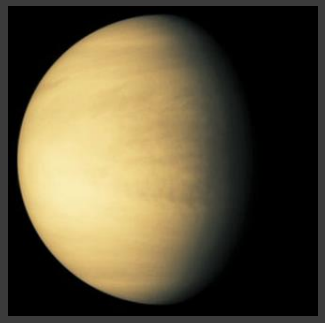
The Temperature on Earth

- Incoming sunlight warms the Earth
- Outgoing infra-red radiation cools it
- Equilibrium when the incoming equals the outgoing radiation
- Calculated temperature: -19°C

The actual average temperature is +15°C

The 34°C difference is due to greenhouse gases

Inner Planets and the Moon


$$L\,(1-\alpha) \times \pi R^2 = \varepsilon\sigma T^4 * 4\pi R^2$$

$$T = \sqrt[4]{\frac{L(1-\alpha)}{4\varepsilon\sigma}}$$

Planet	L	α	T Calc	T real	Δ T
Mercury	9160	0,162	168 °C	177 °C	9 °C
Venus	2648	0,750	-41 °C	452 °C	493 °C
Earth	1366	0,306	-19 °C	15 °C	34 °C
Moon	1366	0,120	-3 °C	0 °C	3 °C
Mars	580	0,250	-64 °C	-55 °C	9 °C

The Charney Report: First official scientific assessment

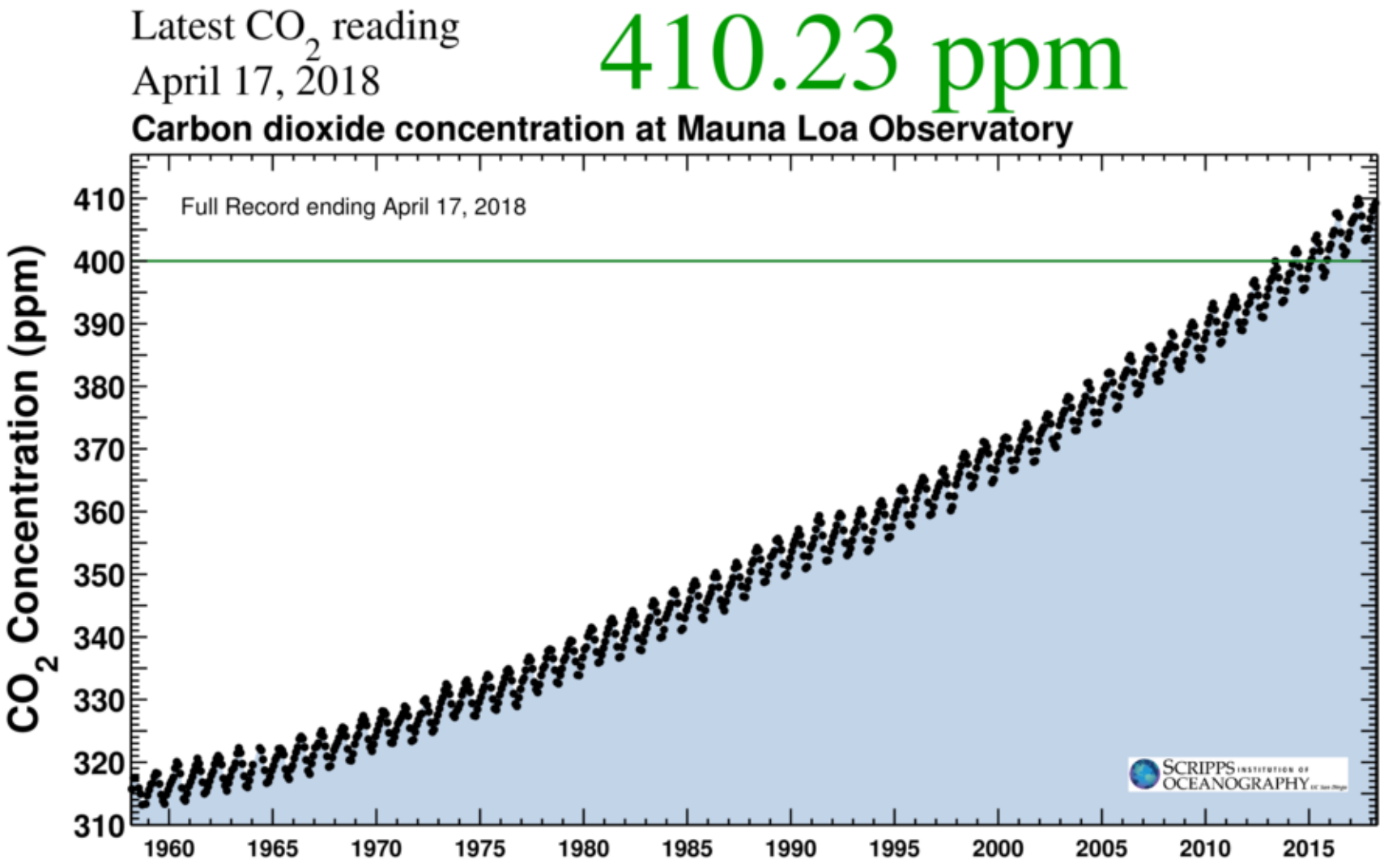
Carbon dioxide and climate: A scientific assessment (1979)

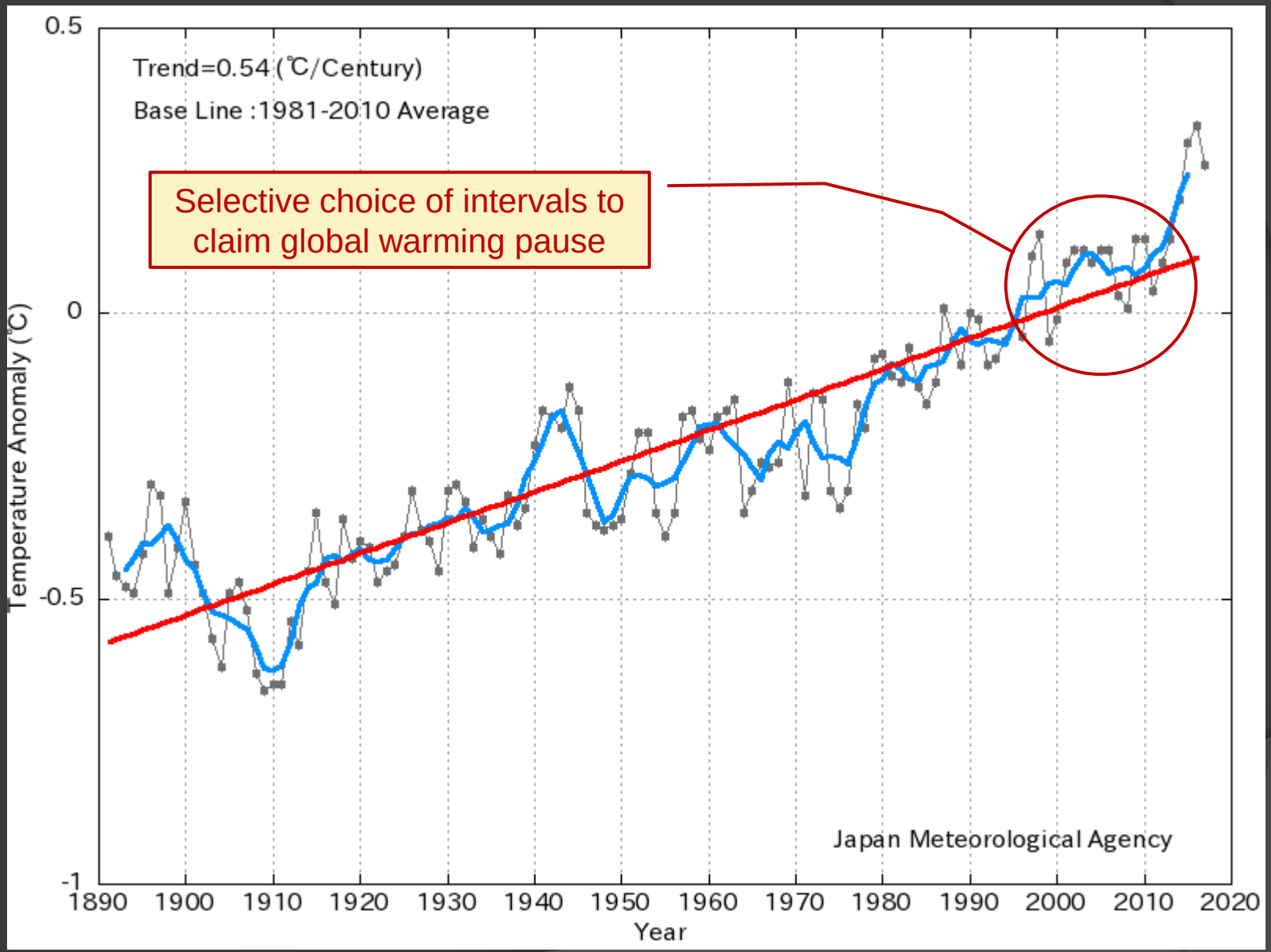
Report to the Climate Research Board, Assembly of Mathematical and Physical Sciences, National Research Council

"We estimate the most probable global warming for a doubling of CO_2 to be near 3°C with a probable error of ± 1.5°C."

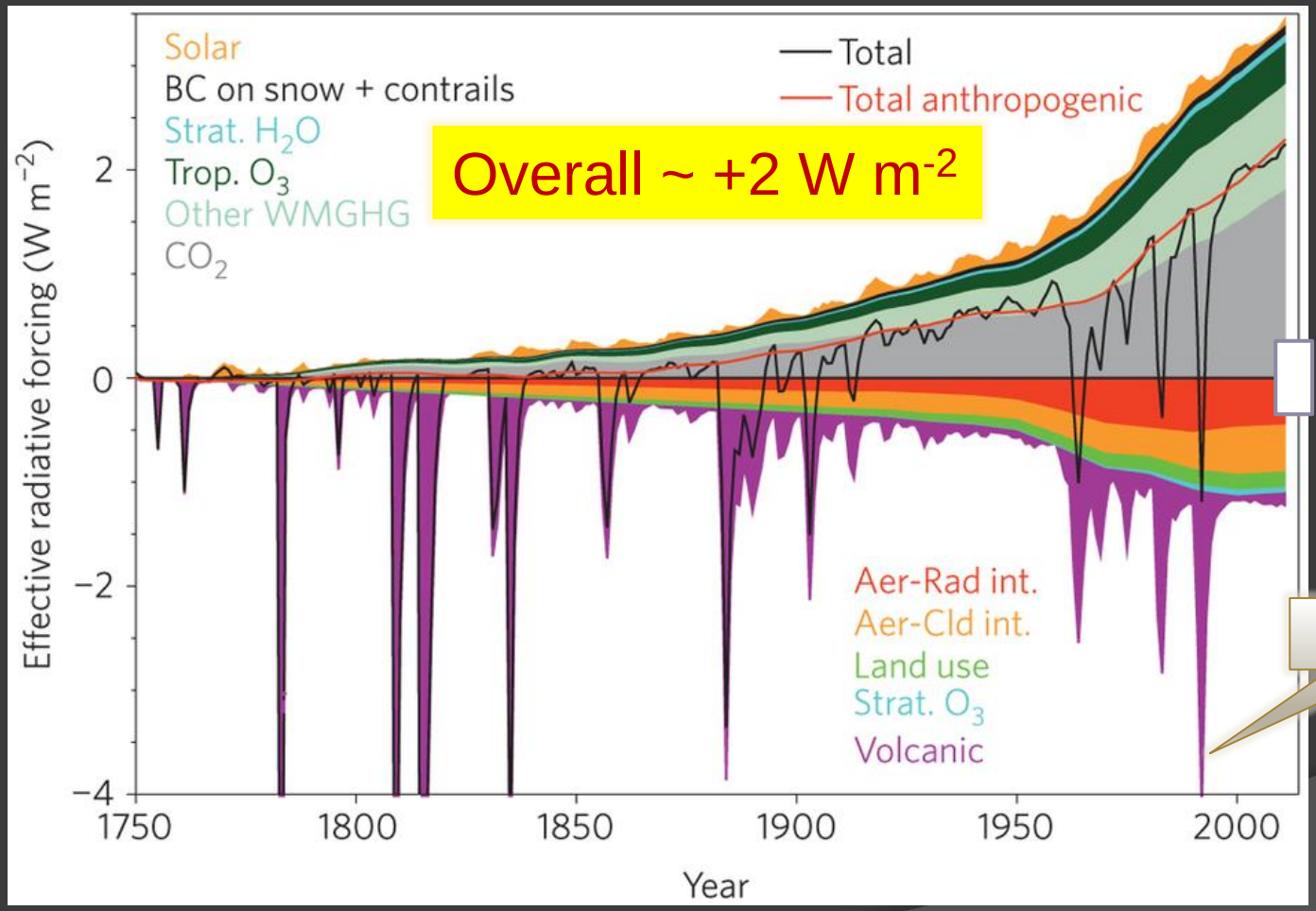
Jule Gregory Charney (1917 – 1981)

Keeling Curve since the late 50s

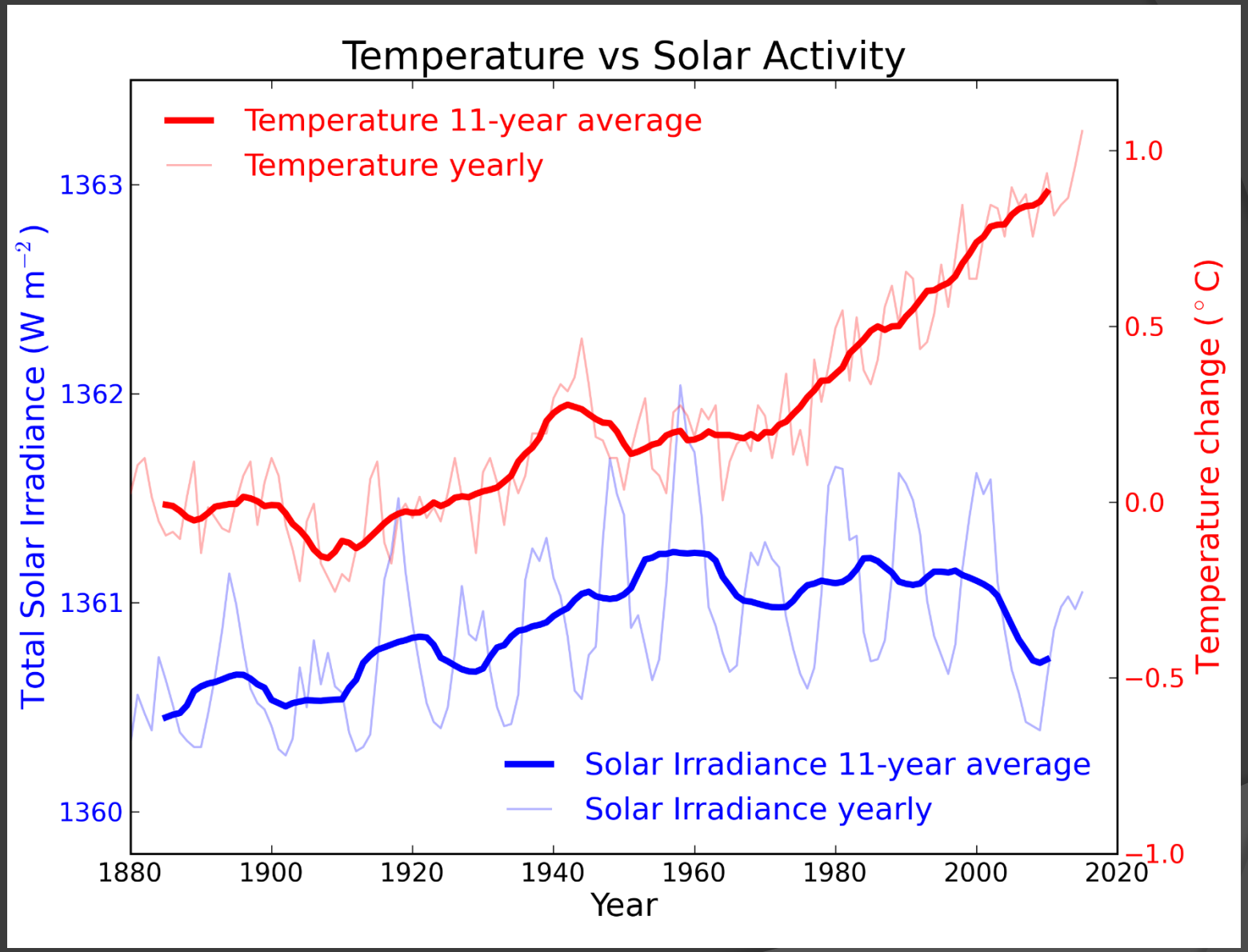



Trend=0.54 (℃/Century)
Base Line :1981-2010 Average
Selective choice of intervals to claim global warming pause
Temperature Anomaly (℃)
0.5
0
-0.5
-1
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Japan Meteorological Agency

Energy Imbalance

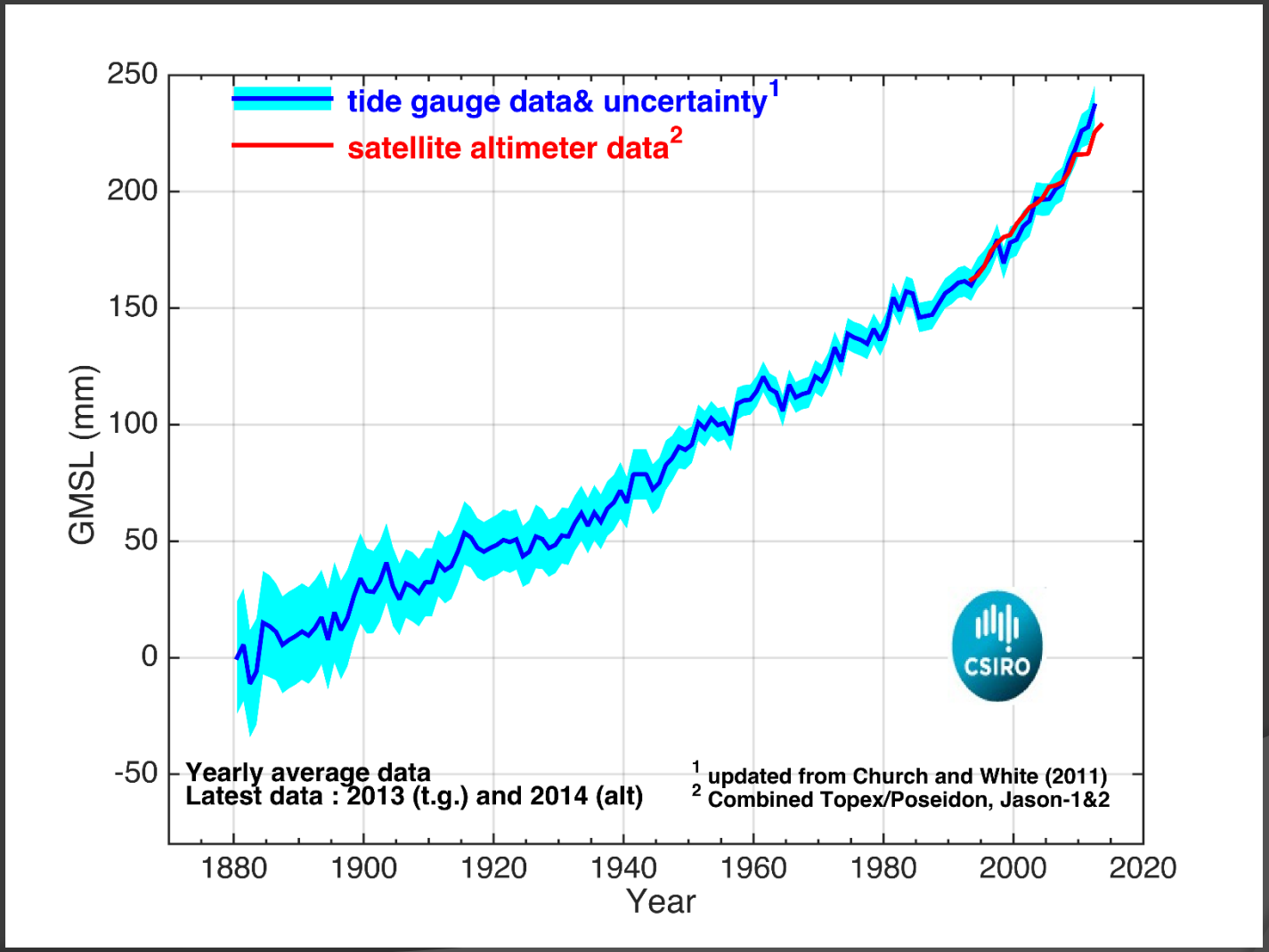


K. von Schuckmann et al, An imperative to monitor Earth's energy imbalance Nature Climate Change, 6, 138–144, (2016) doi:10.1038/nclimate2876

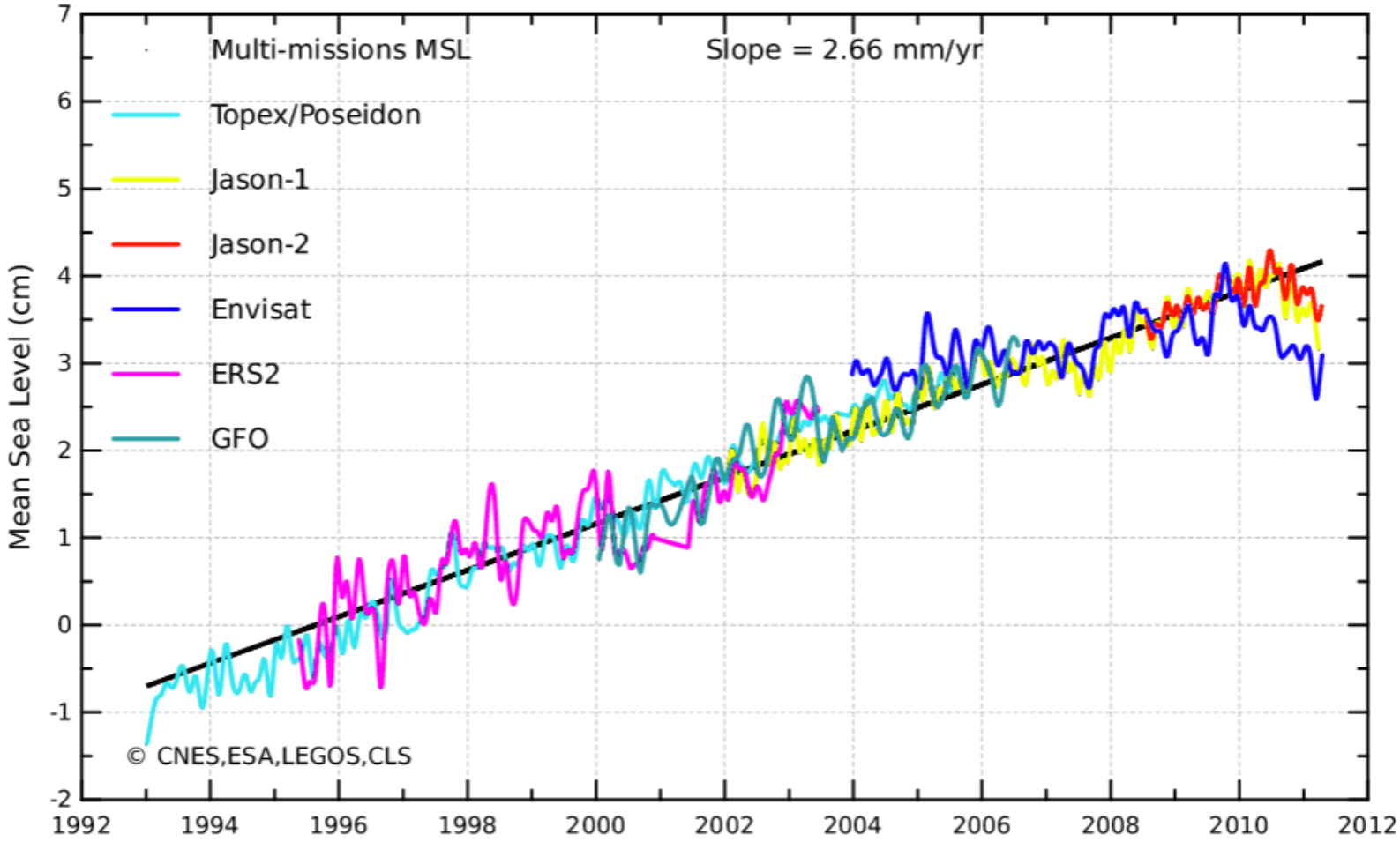


Source: Skeptical Science

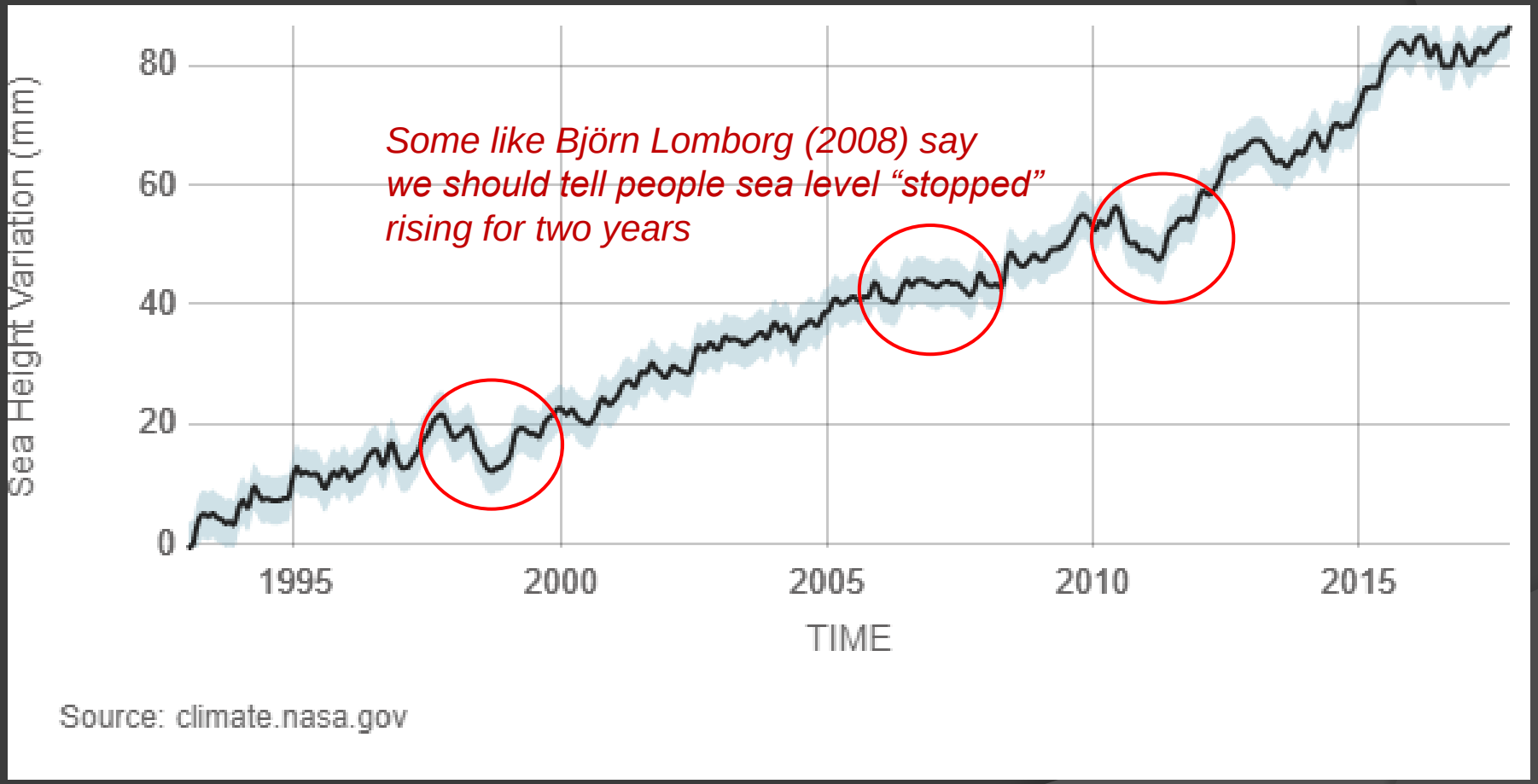
Sea-level rise since 1880



Denialist view



NASA full graph



1m sea-level rise Europe (NASA)

http://climate.nasa.gov/interactives/climate-time-machine

2m sea-level rise Europe (NASA)

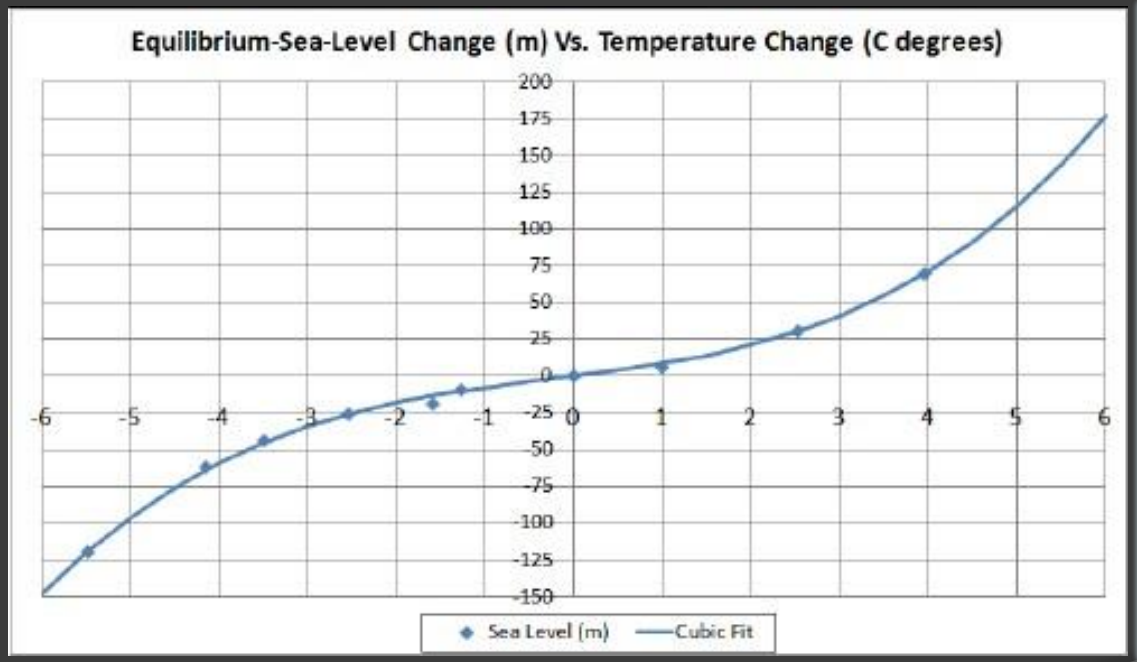
http://climate.nasa.gov/interactives/climate-time-machine

3m sea-level rise Europe (NASA)

http://climate.nasa.gov/interactives/climate-time-machine

What does 2 – 3 °C more mean for sea levels?

- Das Pliocene (5.3 – 2.6 Million years ago) was 2.5 °C warmer than today
- Sea level was 25m higher than today



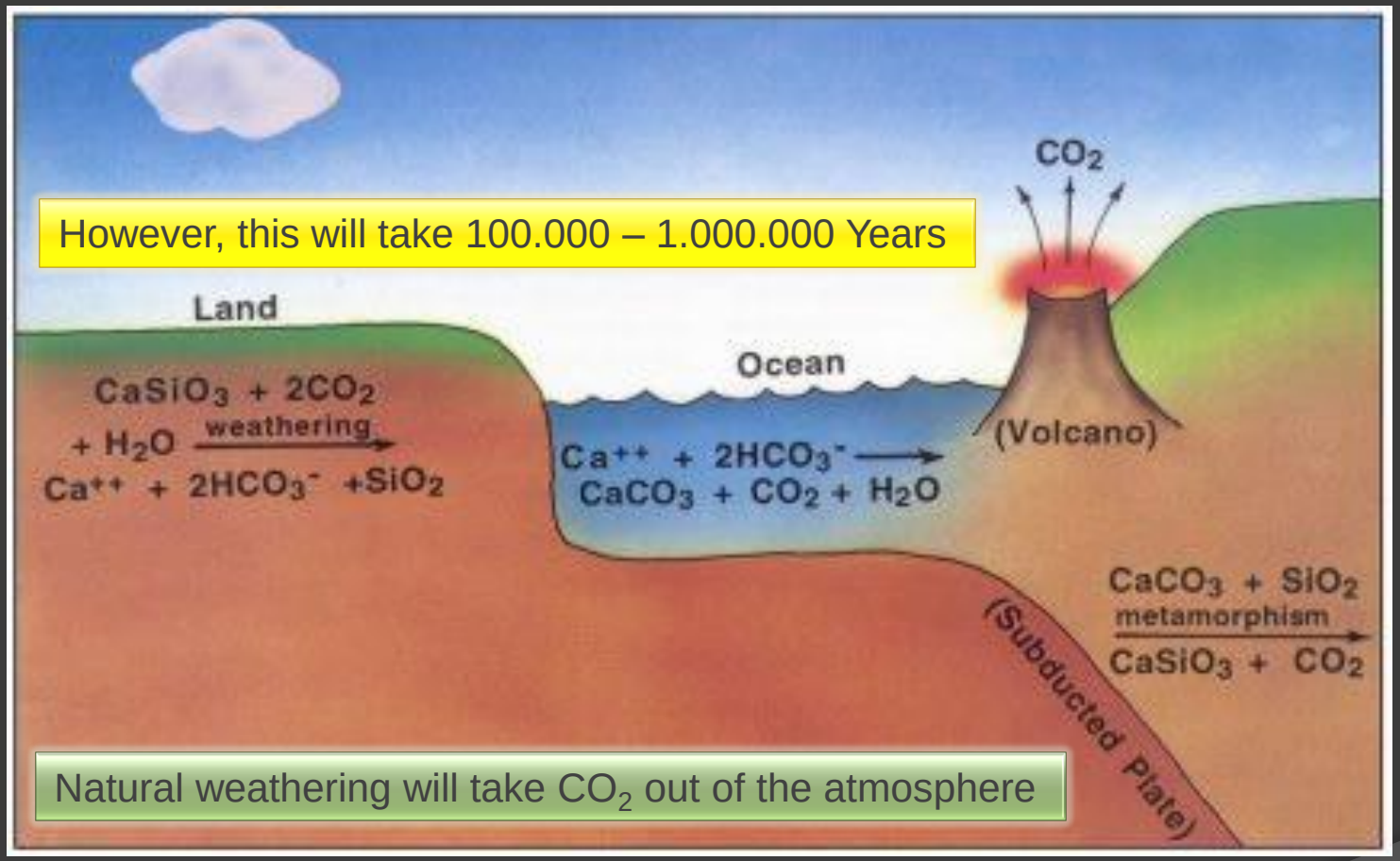
- It could take centuries to reach equilibrium
- An increase of +0.85 °C implies an equilibrium of +6.5 m
- Of course, changes are non-linear, so we don't know with certainty whether it will be less or more

Source: L. David Roper, http://www.roperld.com/science/sealevelvstemperature.htm

One statement from many

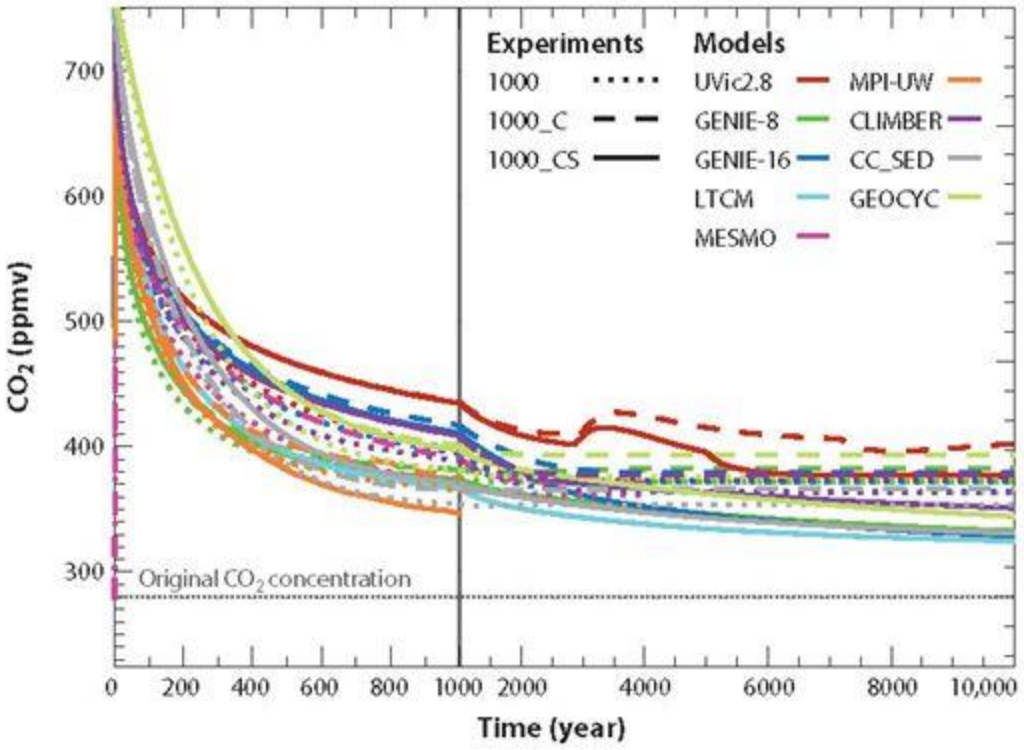
"The scientific evidence is clear: **global climate change caused by human activities is occurring now**, and it is a growing threat to society. Accumulating data from across the globe reveal a wide array of effects: rapidly melting glaciers, destabilization of major ice sheets, increases in extreme weather, rising sea level, shifts in species ranges, and more. The pace of change and the evidence of harm have increased markedly over the last five years. **The time to control greenhouse gas emissions is now.**"

Is this just temporary?



Source: J. F. Kasting, Science Spectra, 1995, Issue 2, 32-36 posted on J.F. Kasting's research interests webpage: http://www3.geosc.psu.edu/~jfk4/PersonalPage/ResInt2.htm.

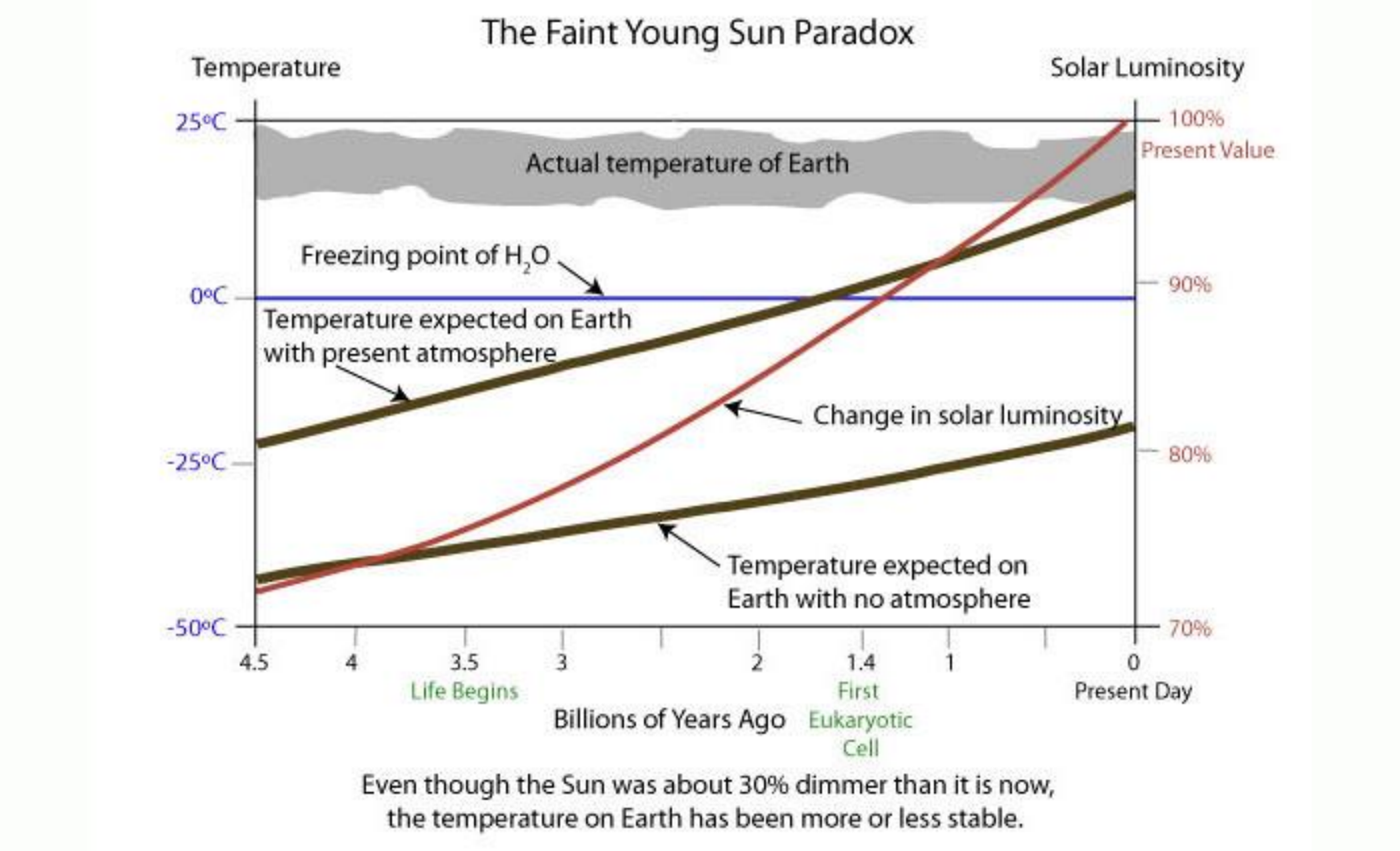
Long Tail Model Intercomparison Project
LTMIP



Natural processes will take 1000 centuries, not one to return CO_2 to "normal"

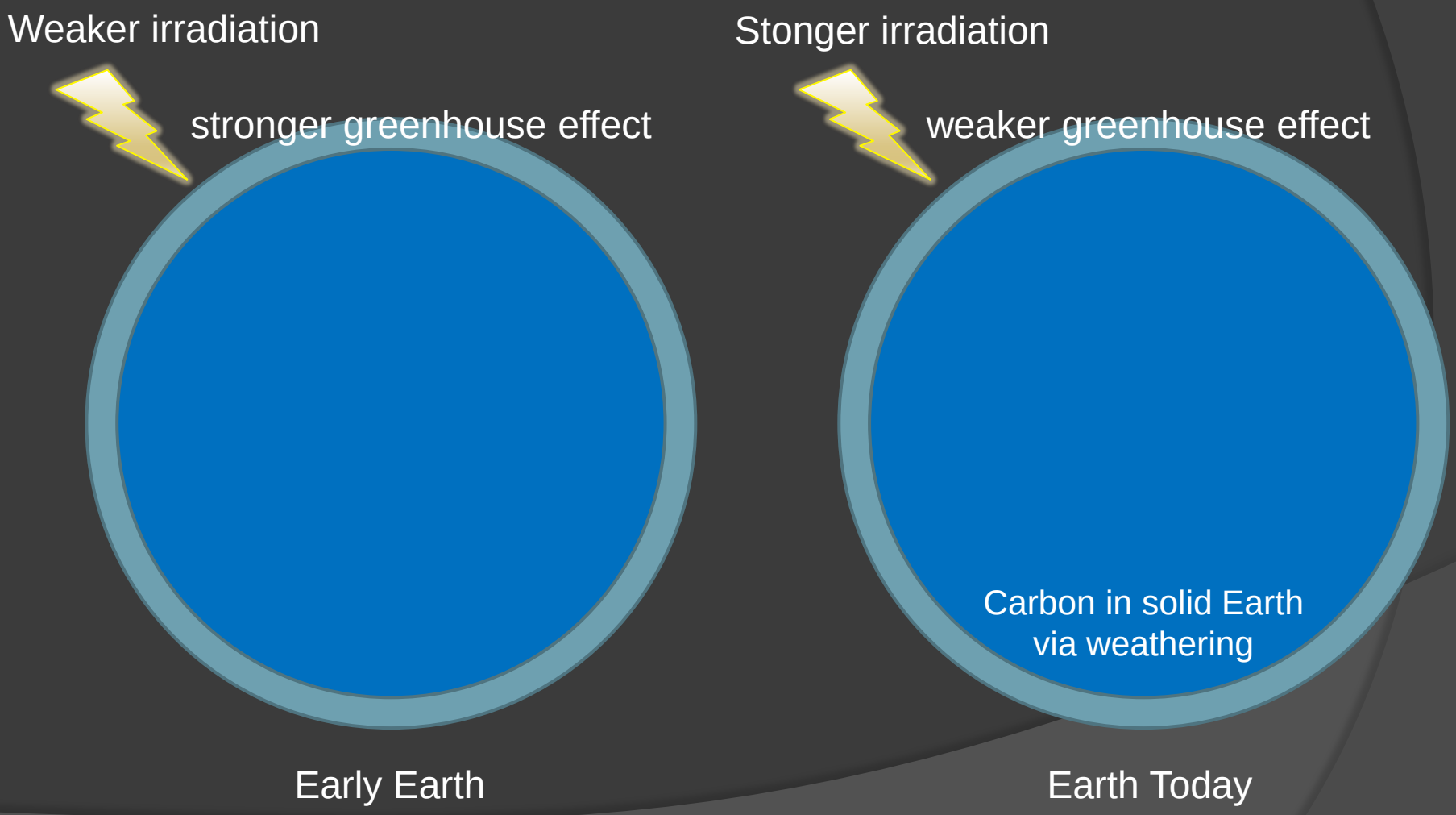
D. Archer, M.I Eby, V. Brovkin, A. Ridgwell, L. Cao, U. Mikolajewicz, K. Caldeira, K. Matsumoto, G. Munhoven, A. Montenegro, *Ann. Rev. Earth Sciences, 2009*.

Our Past: Faint Young Sun Paradox

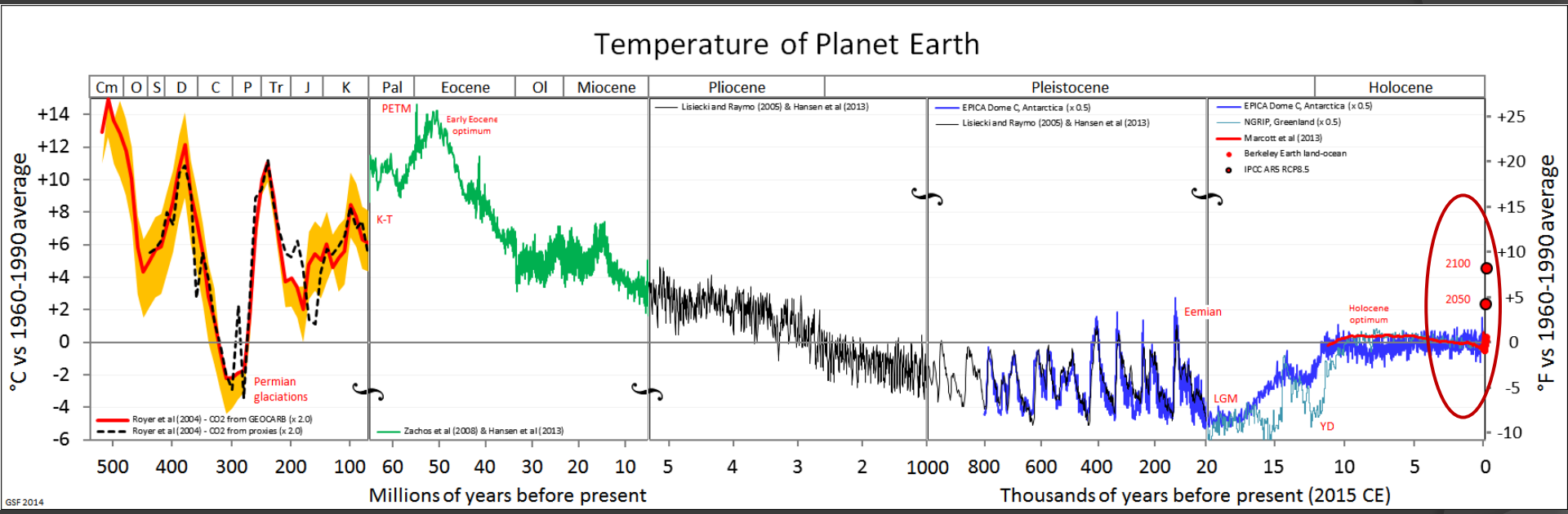


Source: The Annenberg Foundation, https://www.learner.org

Earth‘s greenhouse effect



Temperatures 500 million years

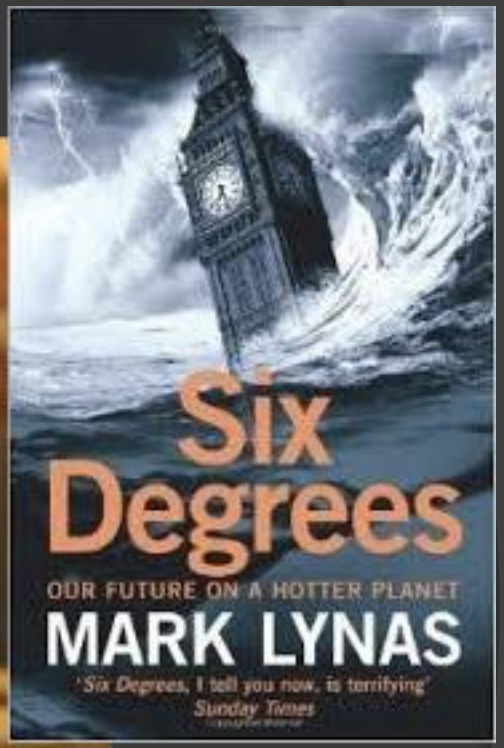


http://gergs.net/2015/06/updating-the-geological-temperature-plot/all_palaeotemps/
https://commons.wikimedia.org/wiki/File:All_palaeotemps.png

The Problem: recognising the crisis

- The Earth has a massive inertia – it takes time for the changes to occur
- Much of today's warming is still in the pipeline – the Earth will continue to warm even if we stop all emissions now
- Amplifying "positive" feedbacks well-known from Earth's history
- 2 or 3 degrees more mean more than most imagine

Recommended Read



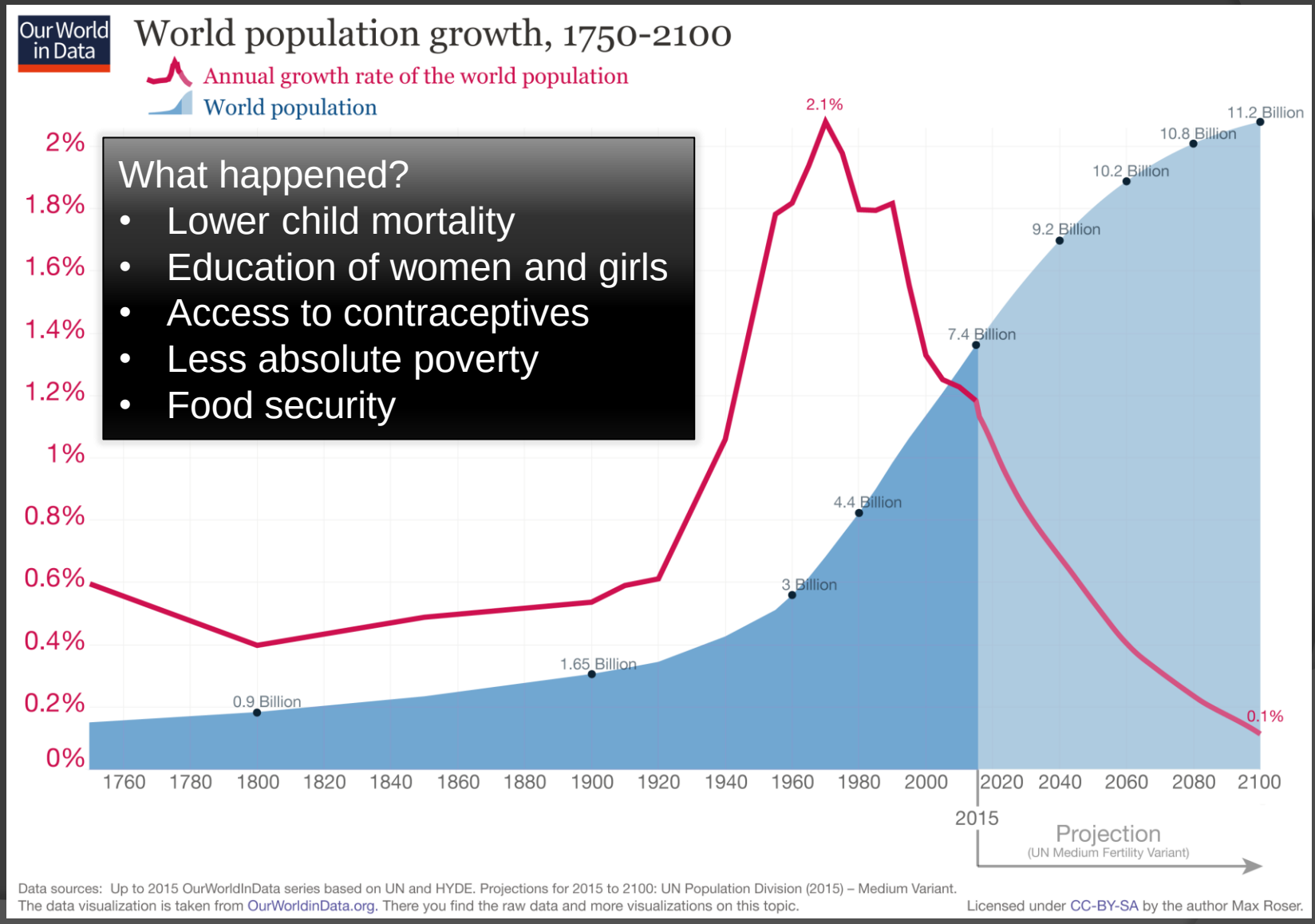
World Population

Do we have a population bomb?

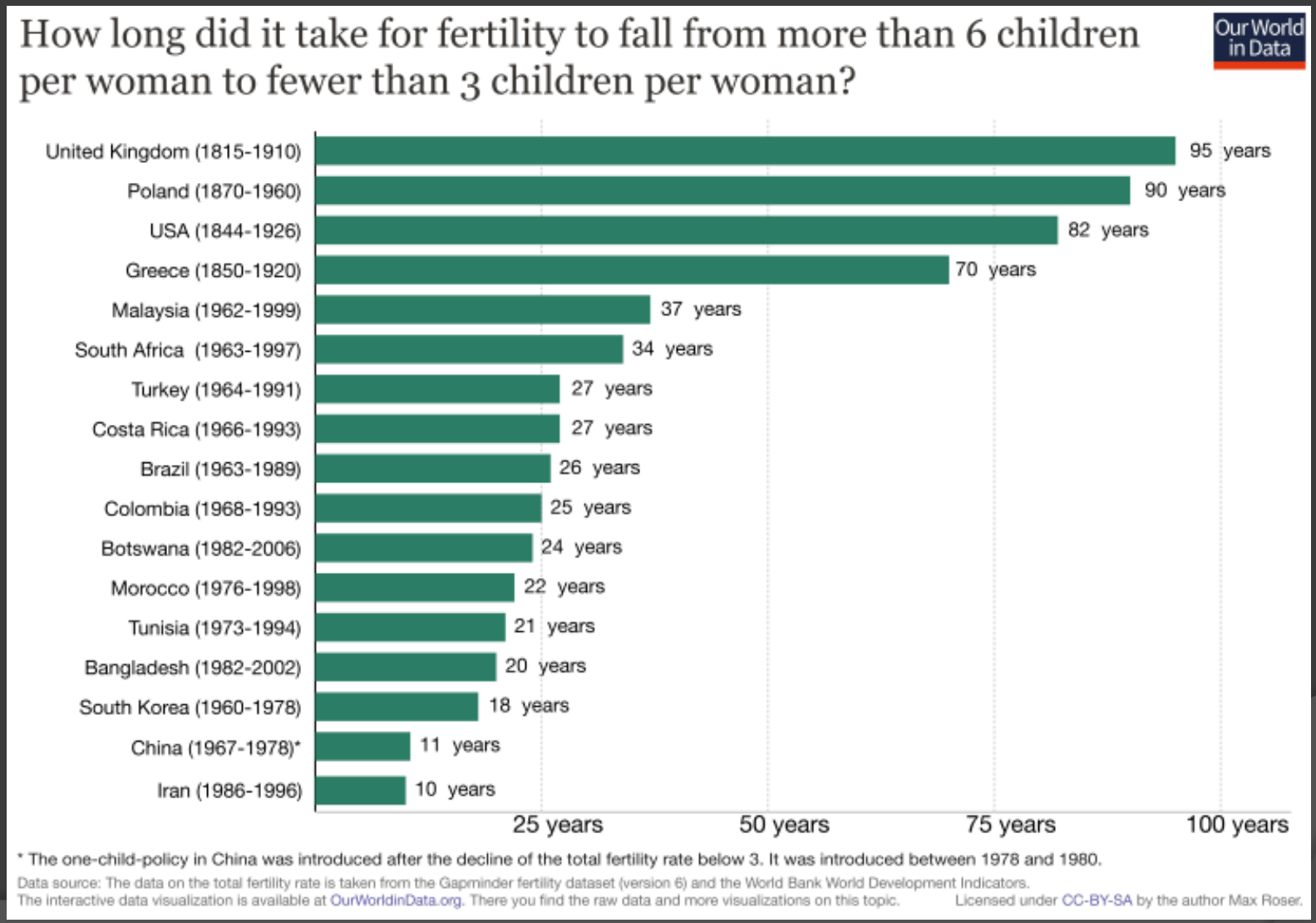
The Population Bomb (Myth)

Paul Ehrlich (1968): *The battle to feed all of humanity is over. In the 1970s* ***hundreds of millions of people will starve to death*** *in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate...*

This is reality



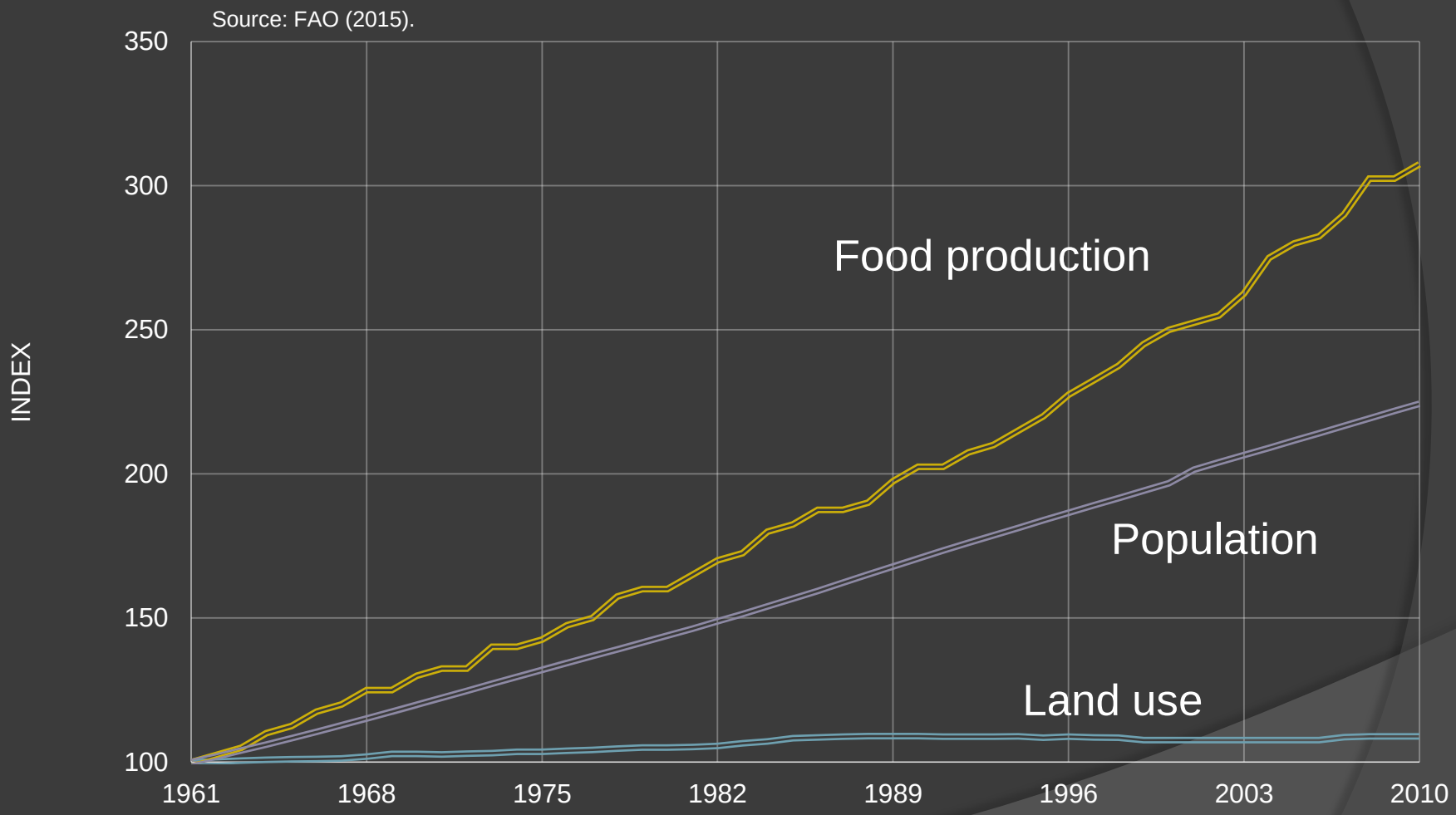
Development of fertility



Norman Borlaug (1914 – 2009)

Nobel Peace Prize 1970: His research led to the green revolution → Ehrlich's prediction defeated

Food and population trends since 1960



At what level will population peak?

- We will likely end up with between 9 and 15 Billion people on Earth
- It will be less the better the people are off, the less child mortality we have and the more girls and women are educated and have access to contraceptives
- What is needed here is another story and not part of the talk

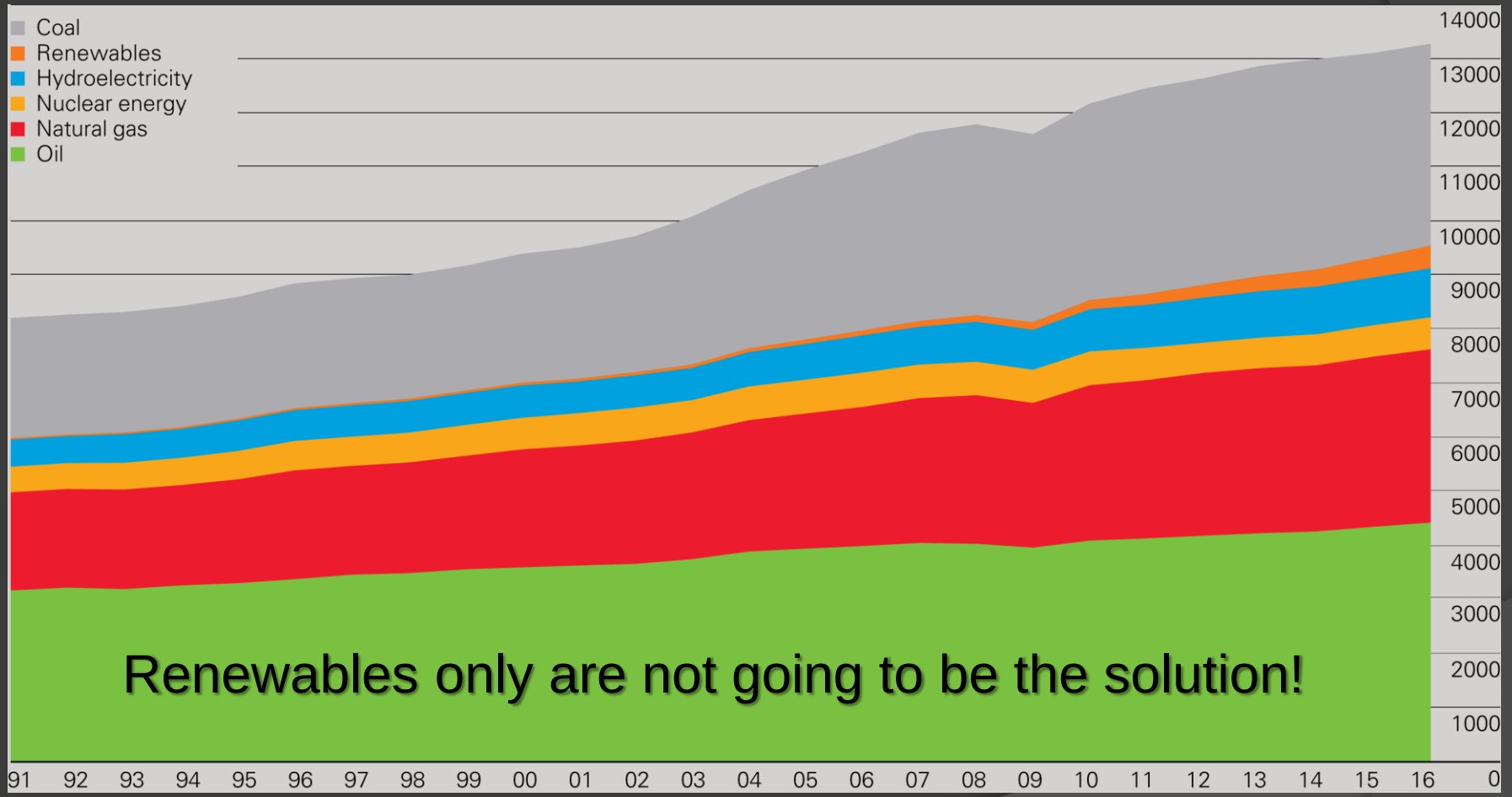
The next 100 – 1000 years

What next?

How much energy do we need?

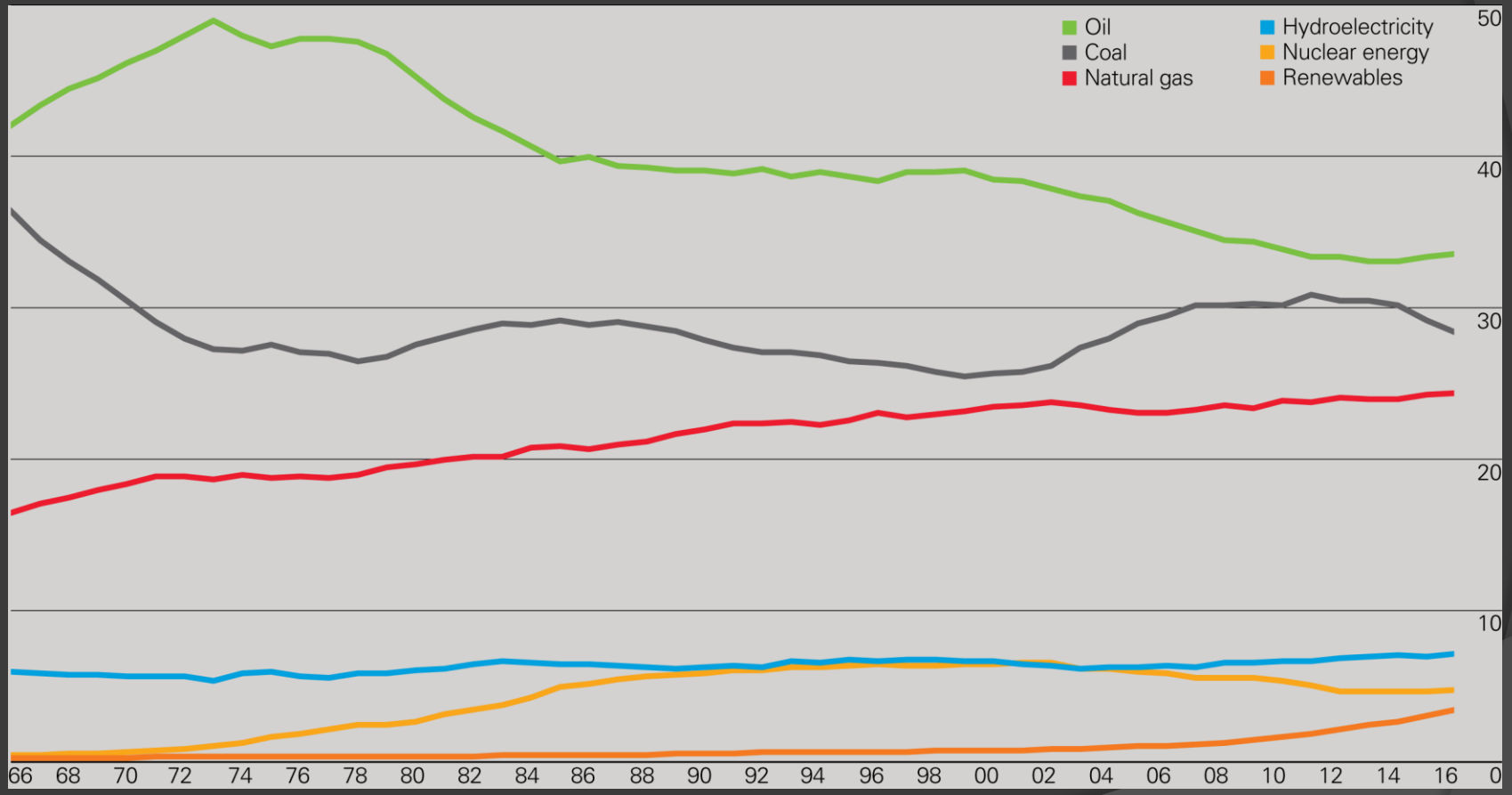
- 2014 globally: 157,500 TWh per year =
  - 18 TW average power for all of humanity
  - 2400 W per person for 7 billion
  - USA: 10,000 W, Europe: 4,500 W
  - China: 2,100 W, India: 720W
- 2100 with optimal energy savings:
  - 2000 W pro Person minimum
  - 20 TW or more likely something like 30 TW
- At the same time, we need to reduce emissions by at least 90%

Primary energy world consumption - Million tonnes oil equivalent



BP Statistical Review of World Energy 2017 © BP p.l.c. 2017

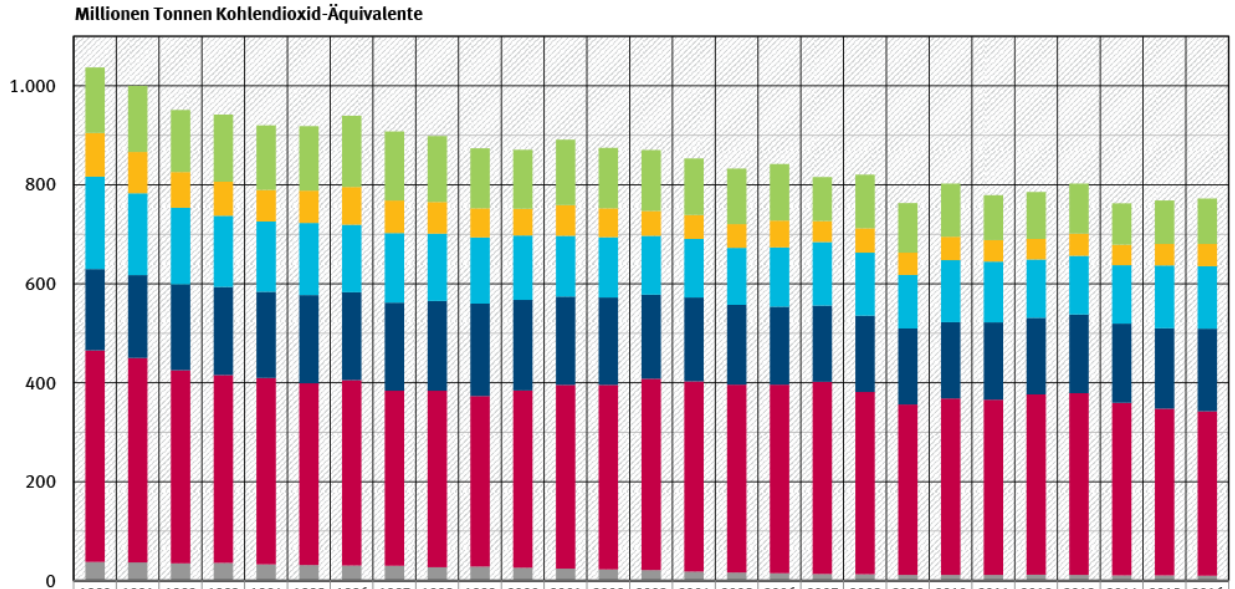
Shares of global primary energy consumption - Percentage



BP Statistical Review of World Energy 2017 © BP p.l.c. 2017

Germany is failing

Entwicklung der energiebedingten Treibhausgas-Emissionen[1] nach Quellgruppen

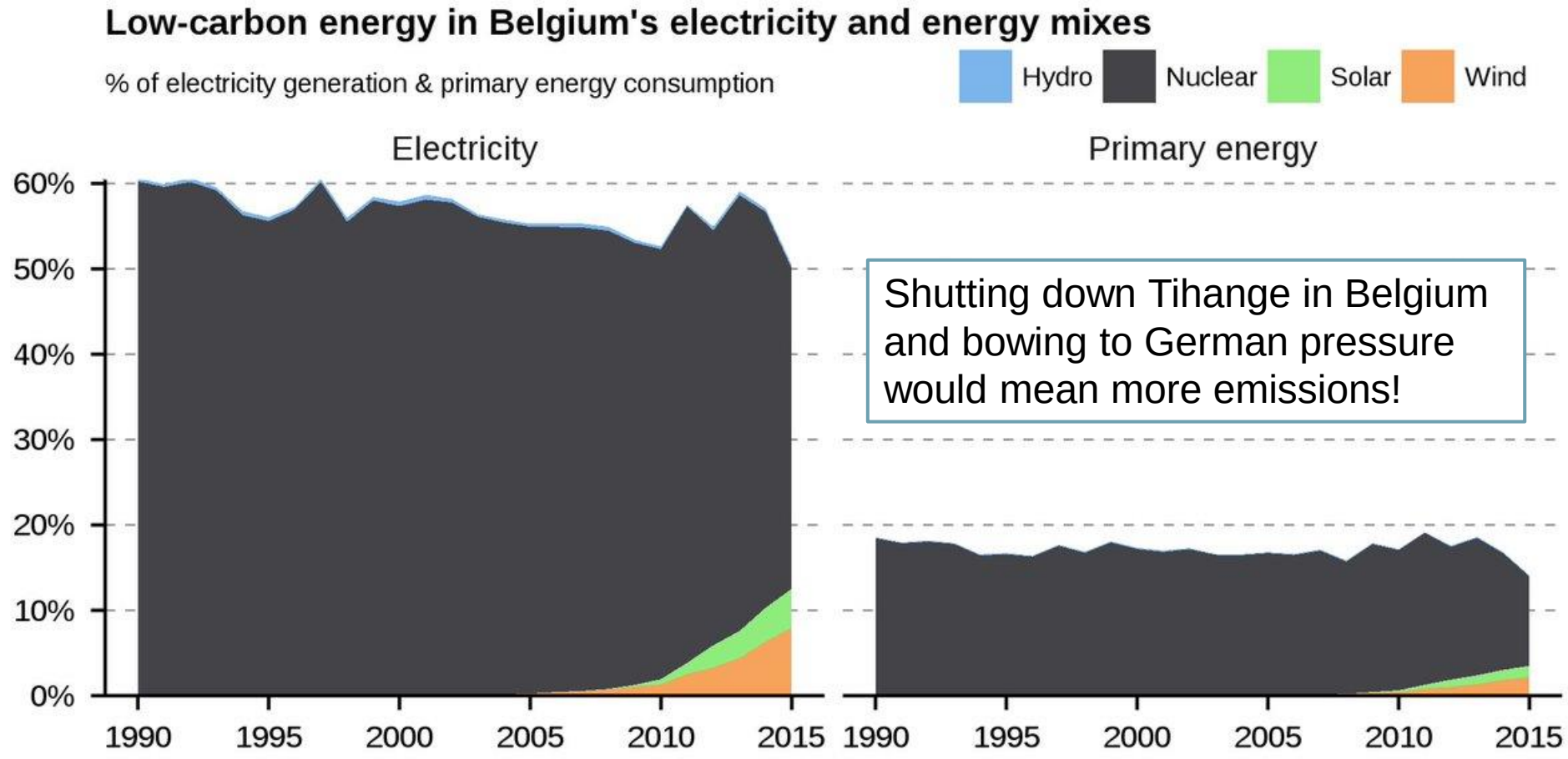


	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Haushalte	132	134	125	136	130	130	144	140	133	121	119	132	122	123	114	112	114	89	108	100	107	91	95	101	83	88	91
Gewerbe, Handel, Dienstleistung [2]	88	83	72	69	64	65	76	66	64	59	54	62	58	50	48	48	54	42	50	45	48	43	42	45	42	43	45
Industrie [3]	187	165	155	144	142	146	136	140	136	134	130	123	122	119	118	115	120	128	127	109	125	123	118	119	118	127	126
Verkehr	164	167	173	178	174	178	178	178	182	187	183	179	177	170	170	161	157	154	154	153	154	156	155	159	160	163	167
Energiewirtschaft	427	413	391	380	377	368	375	354	356	345	358	371	373	387	384	379	381	388	368	345	357	354	364	367	349	337	332
Diffuse Emissionen [4]	38	37	35	36	33	31	31	30	27	28	26	24	23	21	18	16	15	13	13	11	11	11	12	12	10	11	10
Summe	1037	1000	951	942	920	918	939	908	898	874	871	891	875	870	853	832	842	816	820	763	802	779	785	802	762	768	772

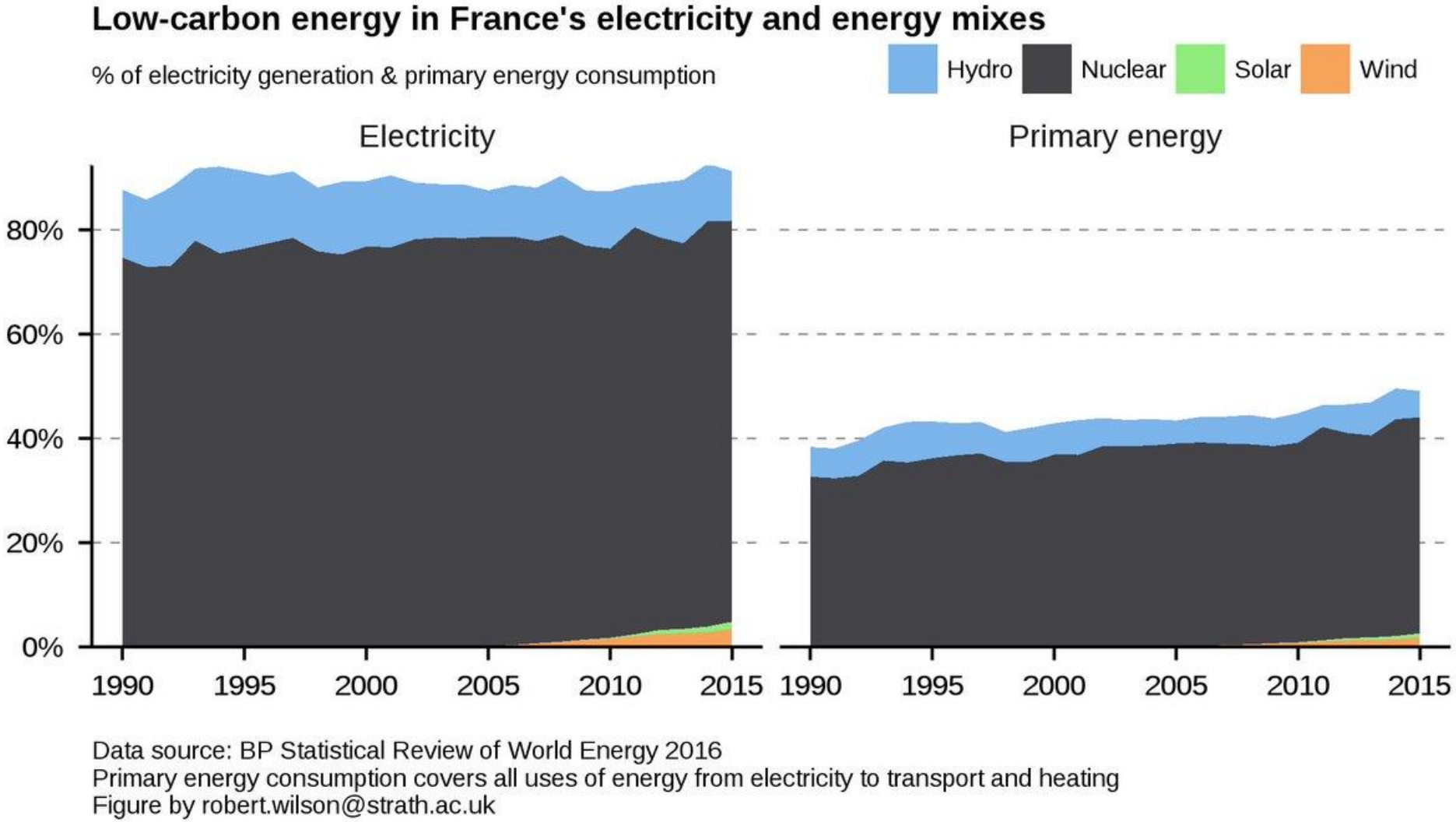
[1] in Kohlendioxid-Äquivalenten, berücksichtigt sind Kohlendioxid (CO_2), Methan (CH_4) und Lachgas (N_2O)
[2] einschließlich Militär und Landwirtschaft (energiebedingt)
[3] enthält nur Emissionen aus Industriefeuerungen, keine Prozessemissionen
[4] durch Gewinnung, Umwandlung und Verteilung von Brennstoffen

Quelle: Umweltbundesamt: Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen 1990-2016, Stand 01/2018

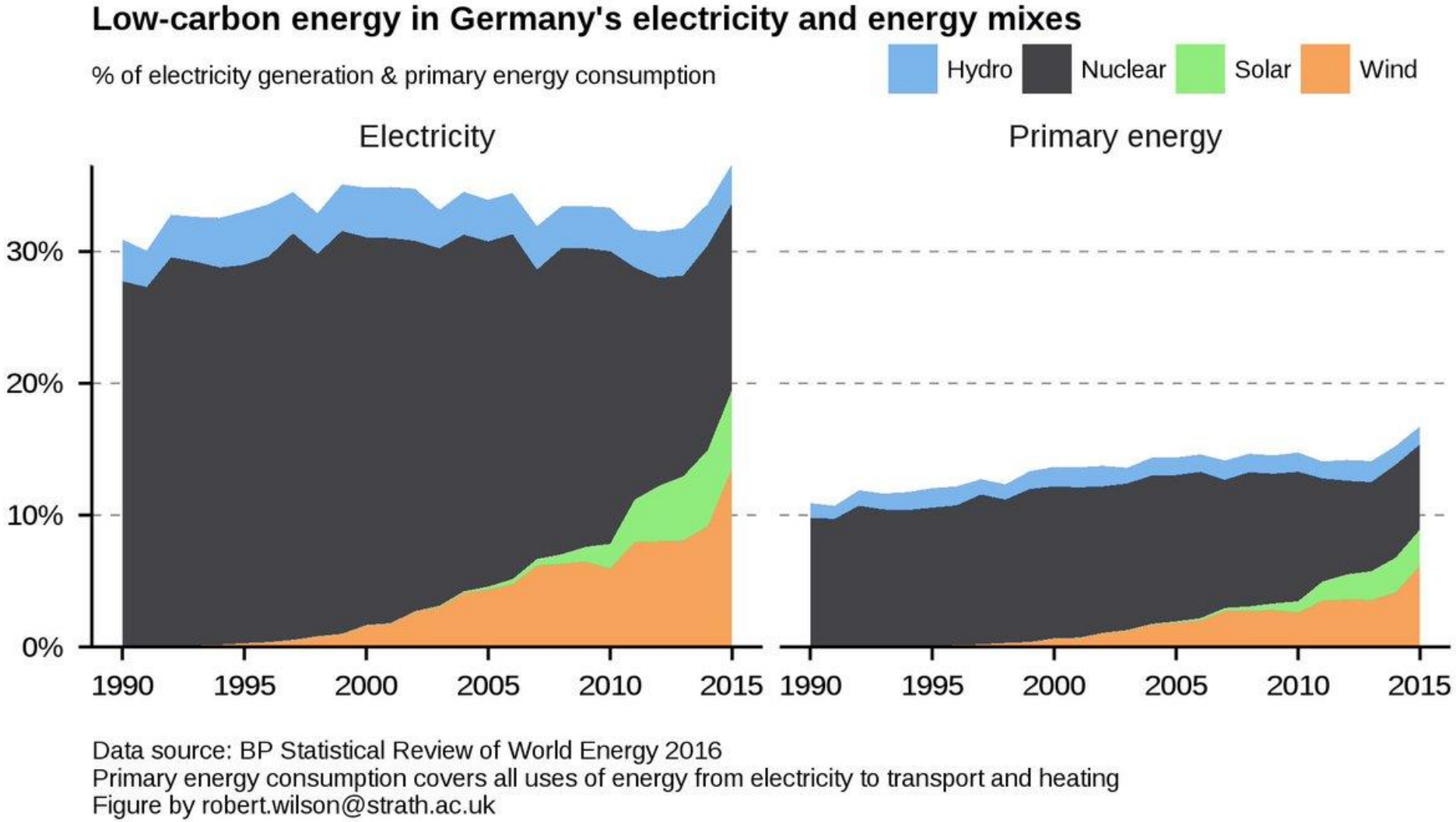
Example Belgium



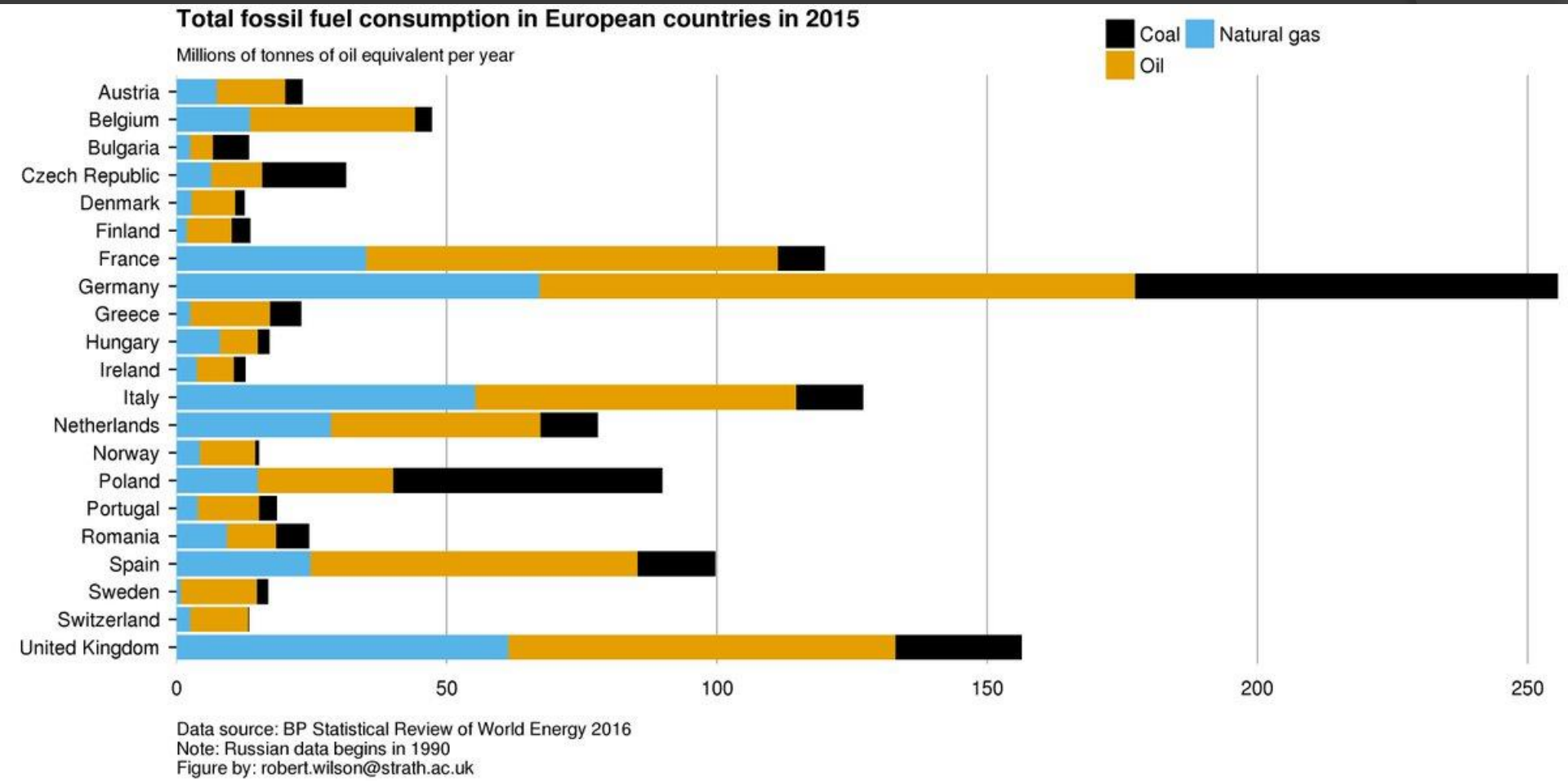
Example France



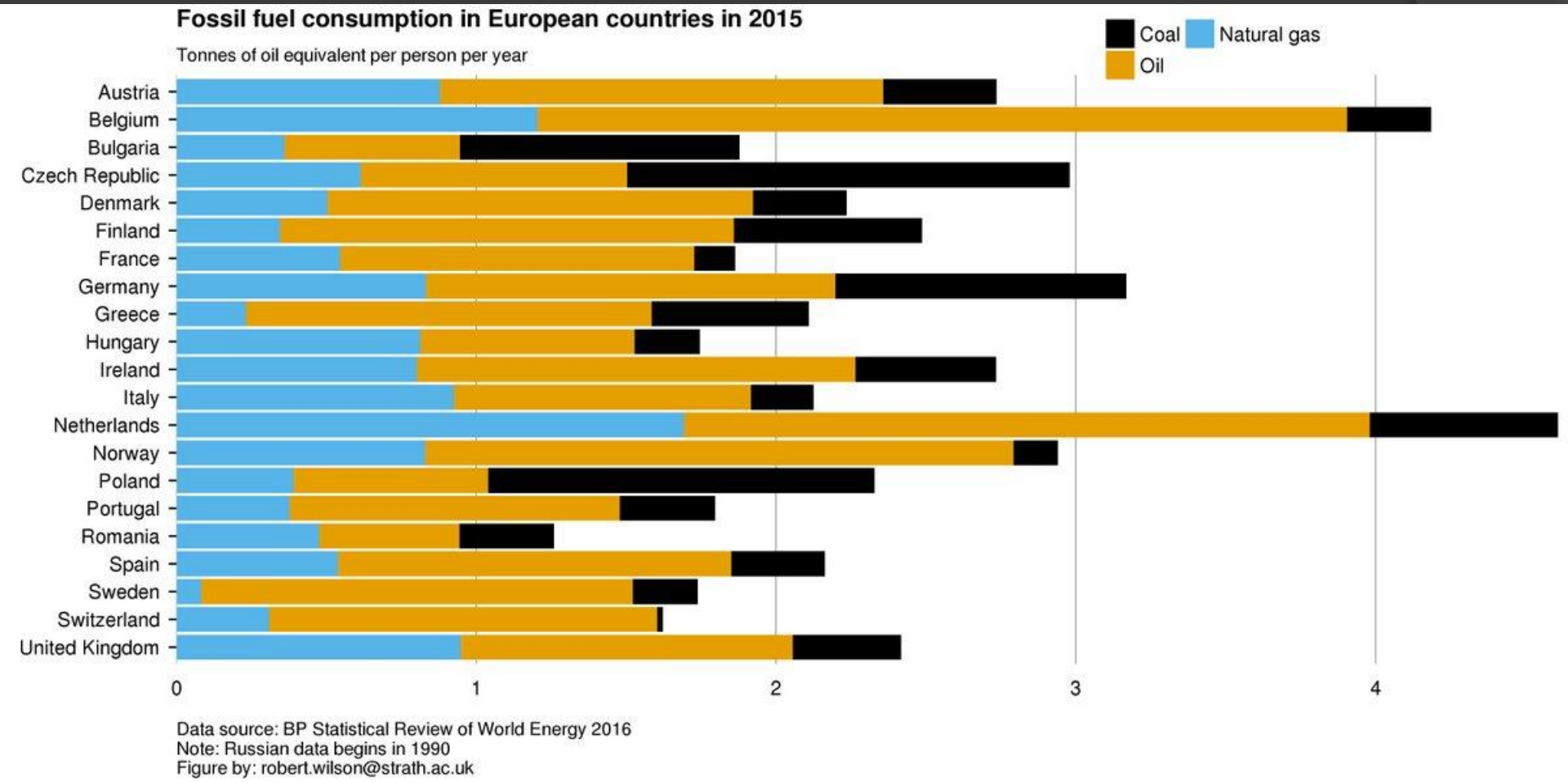
Example Germany



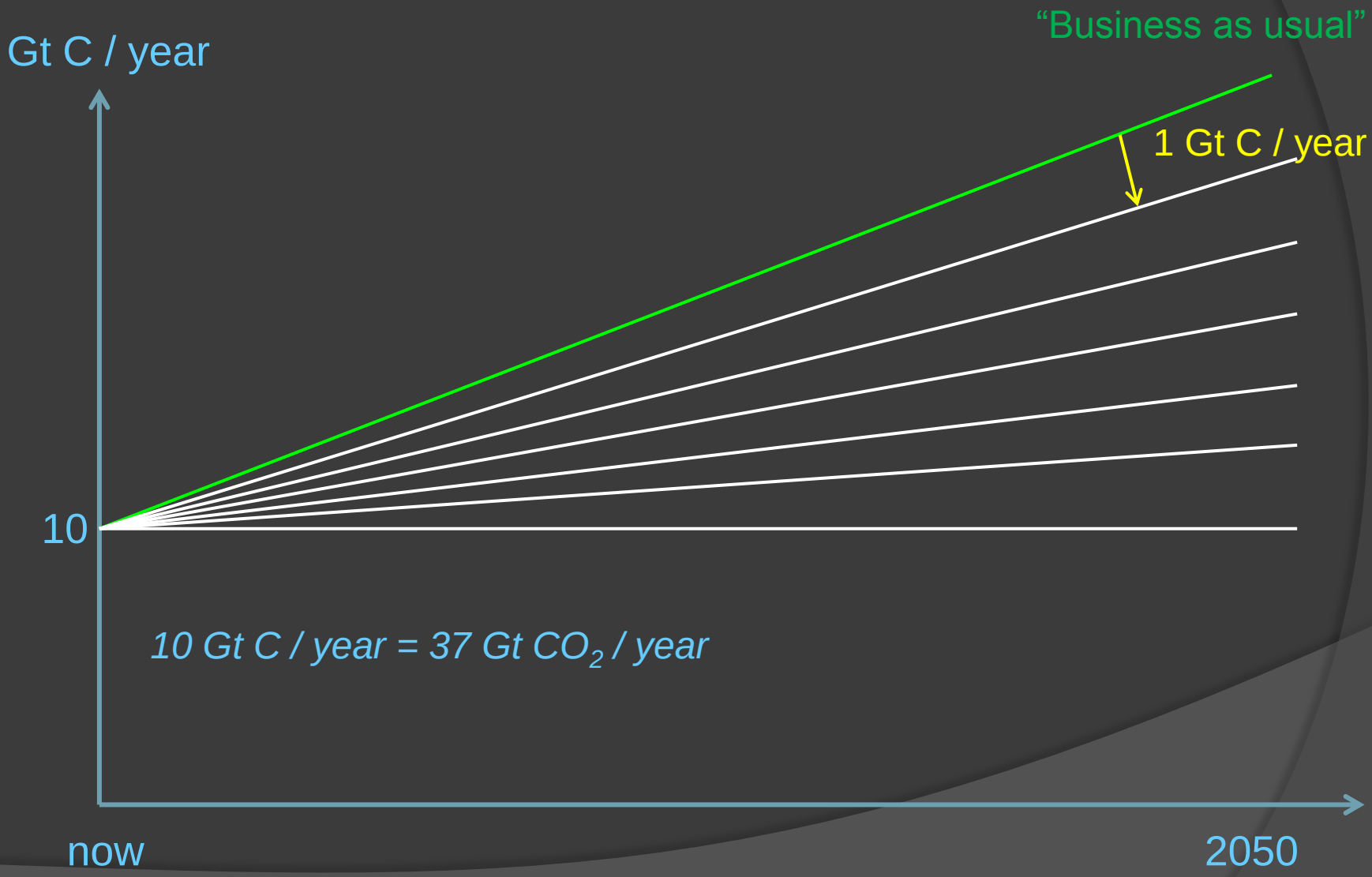
Fossil Fuel Consumption EU



Fossil Fuel Consumption / Person



We will need several Wedges



One approach: 2000 Watt Society

2000-Watt Gesellschaft
EnergieSchweiz für Gemeinden

Institute of Design Research Vienna, Ausstellungsansicht Werkzeuge für die Design-Revolution, 2012 © Wolfgang Thaler

http://www.2000watt.ch/die-2000-watt-gesellschaft/

Carbon Tax*

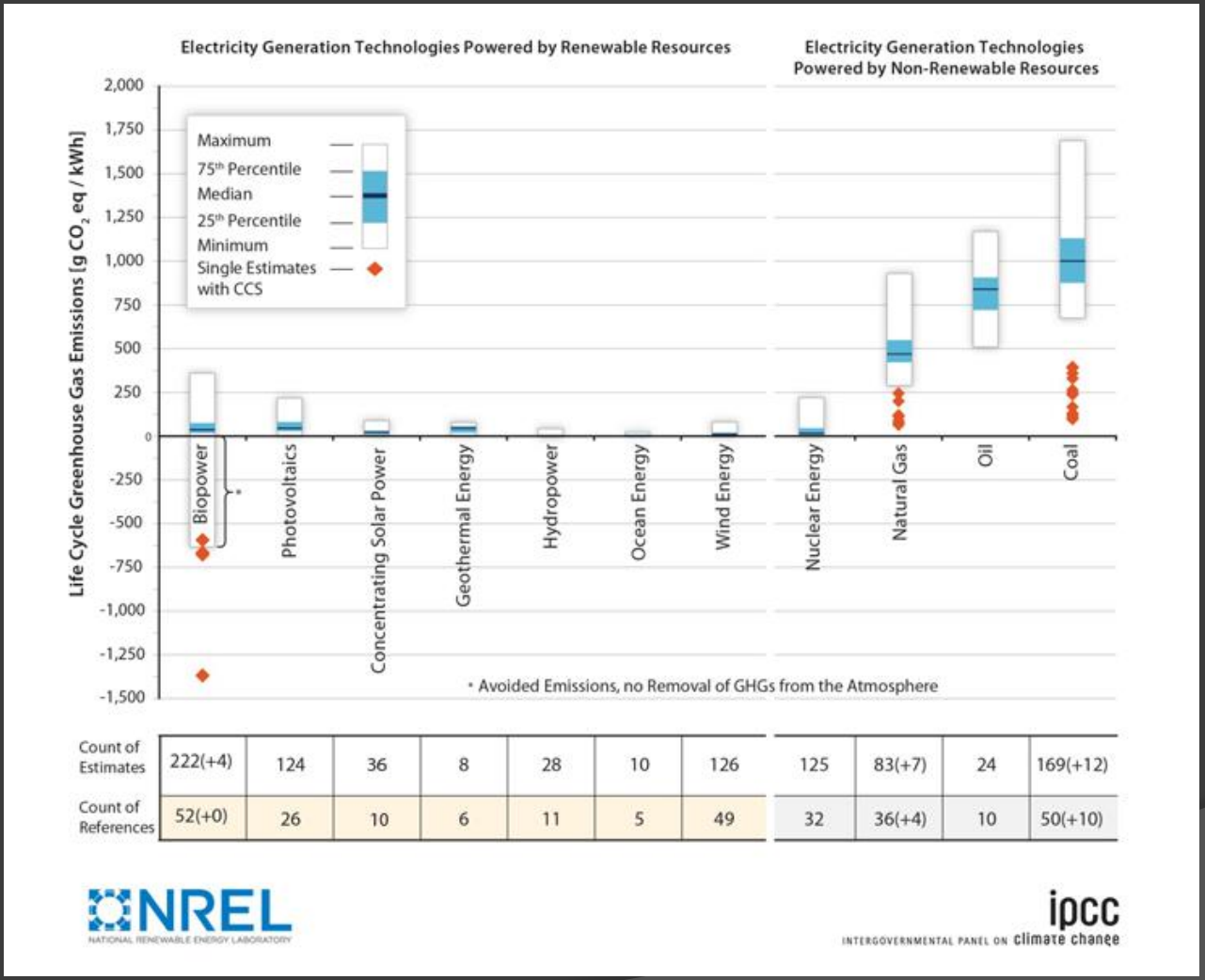
- Collected at the source for all fossil fuels: coal, oil and gas
- For imports, carbon tax unless the country of origin has at least the same level of tax
- Distribute equally to all residents in the country
- Advantages
  - No complicated bureaucracy → it goes to the people, not to interest groups
  - The real cost of fossil fuel becomes transparent, no more externalization of future costs

** As suggested by James Hansen*

The war between the proponents of nuclear energy and those promoting solar and wind must stop.

Even these are an essential, but only part of the solution

Emissions compared



Mitigation measures	Effect on additional objectives/concerns			
	Economic	Social (including health)	Environmental	Other
Nuclear replacing coal power	↑ Energy security (reduced exposure to fuel price volatility)[1] ↑ Local employment impact (but uncertain net effect)[2] ↑ Legacy cost of waste and abandoned reactors[3]	Health impact via ↓ Air pollution[4] and coal-mining accidents[5] ↑ Nuclear accidents[6] and waste treatment, uranium mining and milling[7] ↑ Safety and waste concerns[8]	Ecosystem impact via ↓ Air pollution[9] and coal mining[10] ↑ Nuclear accidents[11]	Proliferation risk[12]
RE (wind, PV, CSP, hydro, geothermal, bioenergy) replacing coal	↑ Energy security (resource sufficiency, diversity in the near/medium term)[13] ↑ Local employment impact (but uncertain net effect)[14] ↑ Irrigation, flood control, navigation, water availability (for multipurpose use of reservoirs and regulated rivers)[15] ↑ Extra measures to match demand (for PV, wind, and some CSP)[16]	Health impact via ↓ Air pollution (except bioenergy)[17] ↓ Coal-mining accidents[18] ↑ Contribution to (off-grid) energy access[19] ? Project-specific public acceptance concerns (e.g., visibility of wind)[20] ↑ Threat of displacement (for large hydro)[21]	Ecosystem impact via ↓ Air pollution (except bioenergy)[22] ↓ Coal mining[23] ↑ Habitat impacts (for some hydro)[24] ↑ Landscape and wildlife impact (for wind)[25] ↓ Water use (for wind and PV)[26] ↑ Water use (for bioenergy, CSP, geo-thermal, and reservoir hydro)[27]	Higher use of critical metals for PV and direct drive wind turbines[28]
Fossil CCS replacing coal	↑↑ Preservation vs. lock-in of human and physical capital in the fossil industry[29]	Health impact via ↑ Risk of CO_2 leakage[30] ↑ Upstream supply-chain activities[31] ↑ Safety concerns (CO_2 storage and transport)[32]	↑ Ecosystem impact via upstream supply-chain activities[33] ↑ Water use[34]	Long-term monitoring of CO_2 storage[35]
BECCS replacing coal	*See fossil CCS where applicable. For possible upstream effect of biomass supply, see Sections 11.7 and 11.13.6*			
Methane leakage prevention, capture, or treatment	↑ Energy security (potential to use gas in some cases)[36]	↑ Occupational safety at coal mines[37] ↓ Health impact via reduced air pollution[38]	↓ Ecosystem impact via reduced air pollution[39]	

IPCC AR5 WG3 Table 7.3

Using Energy has side effects

- We need to move from an arbitrary precautionary principle to one that objectively compares risks and benefits
- Not doing something also has a risk
- Fossil fuels cause more human deaths per day than nuclear, wind and solar together have ever caused.
- Most importantly: We need energy for human welfare

Rational and science-based approaches

- Focus on public transportation and speed limits in Germany
- Renewables, CCS, nuclear energy *and much more*
  - Those who regularly quote the IPCC should not selectively forget what it says about nuclear
- Next generation biofuels, including plants, such as Jatropha, algae and cyanobacteria
- More wedges needed, we need to encourage more innovation
- Fund science for mitigation and adaptation


James Hansen
Looking forward to his new book Sophie’s planet

Summary

- We are in deep shit
- But we have the means to get out of it
- …. if we act fast and use the best science and technology available
- …. and if we invest in science and technology for even better solutions

Amardeo Sarma

THE FUTURE OF CLIMATE AND ENERGY

From Science Denial to Solutions