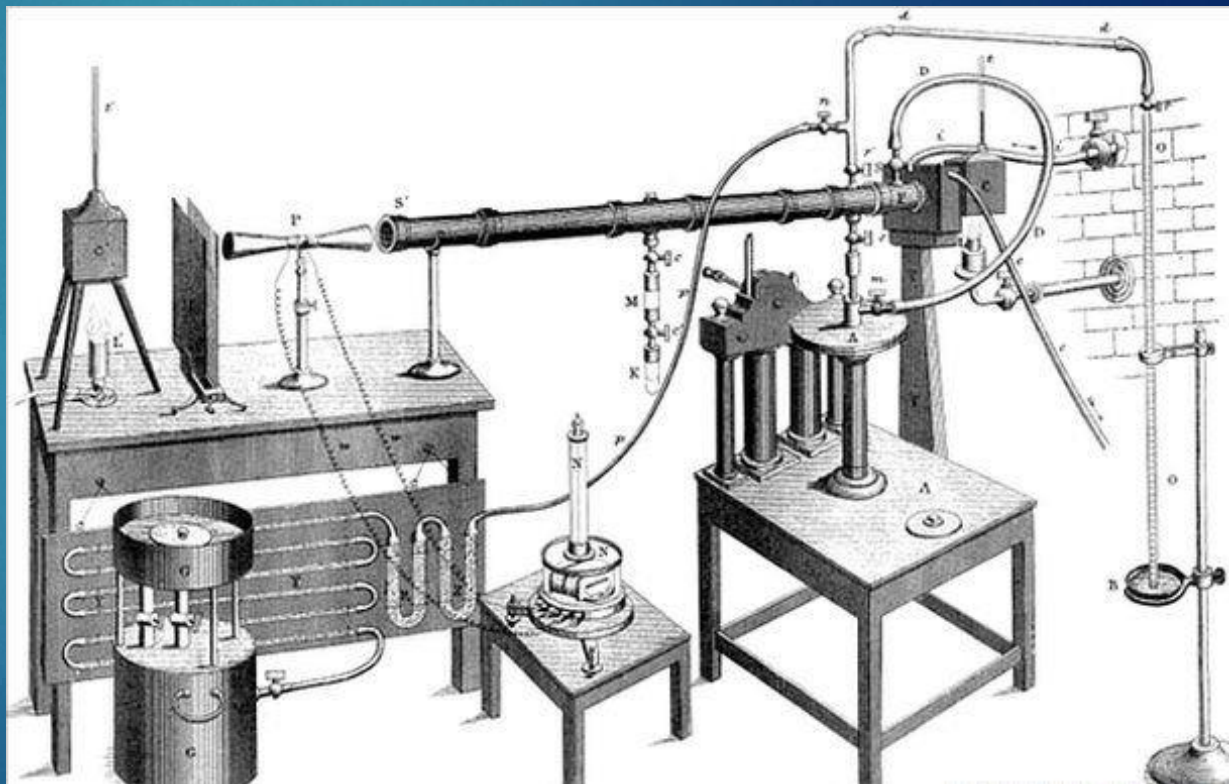
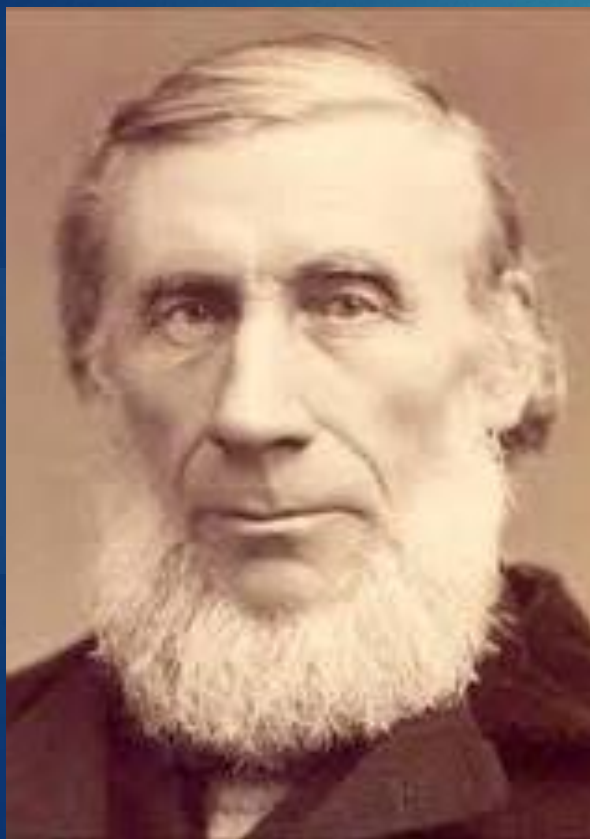


# The Governed Planet? Climate Change Targets and the Role of Carbon Negative Technologies

THE GRADUATE INSTITUTE

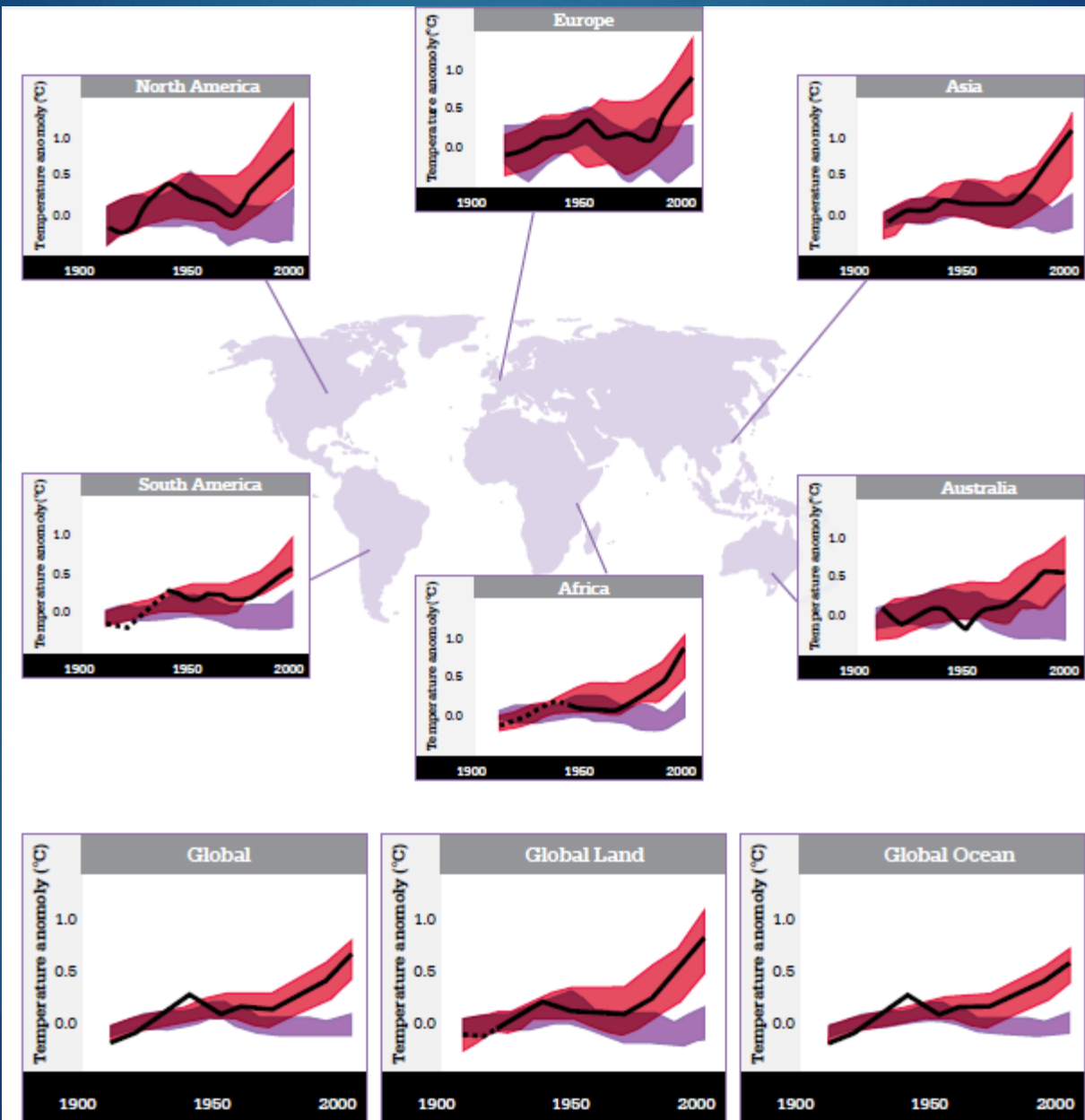
*Professor Tim Flannery*  
Melbourne Sustainable Society Institute  
University of Melbourne

# John Tyndall, 1859



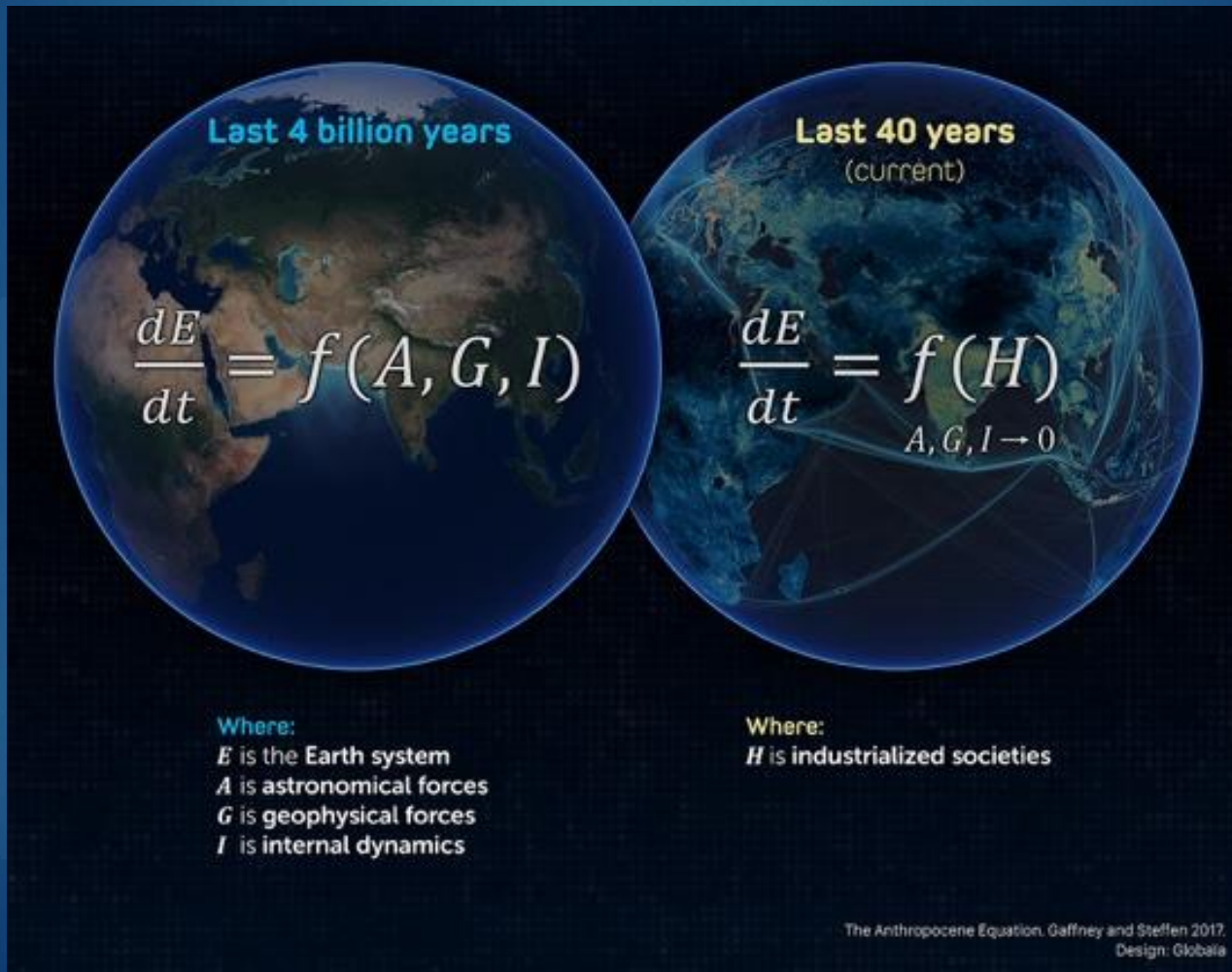
# The Human Influence

3



Source: IPCC, 2007

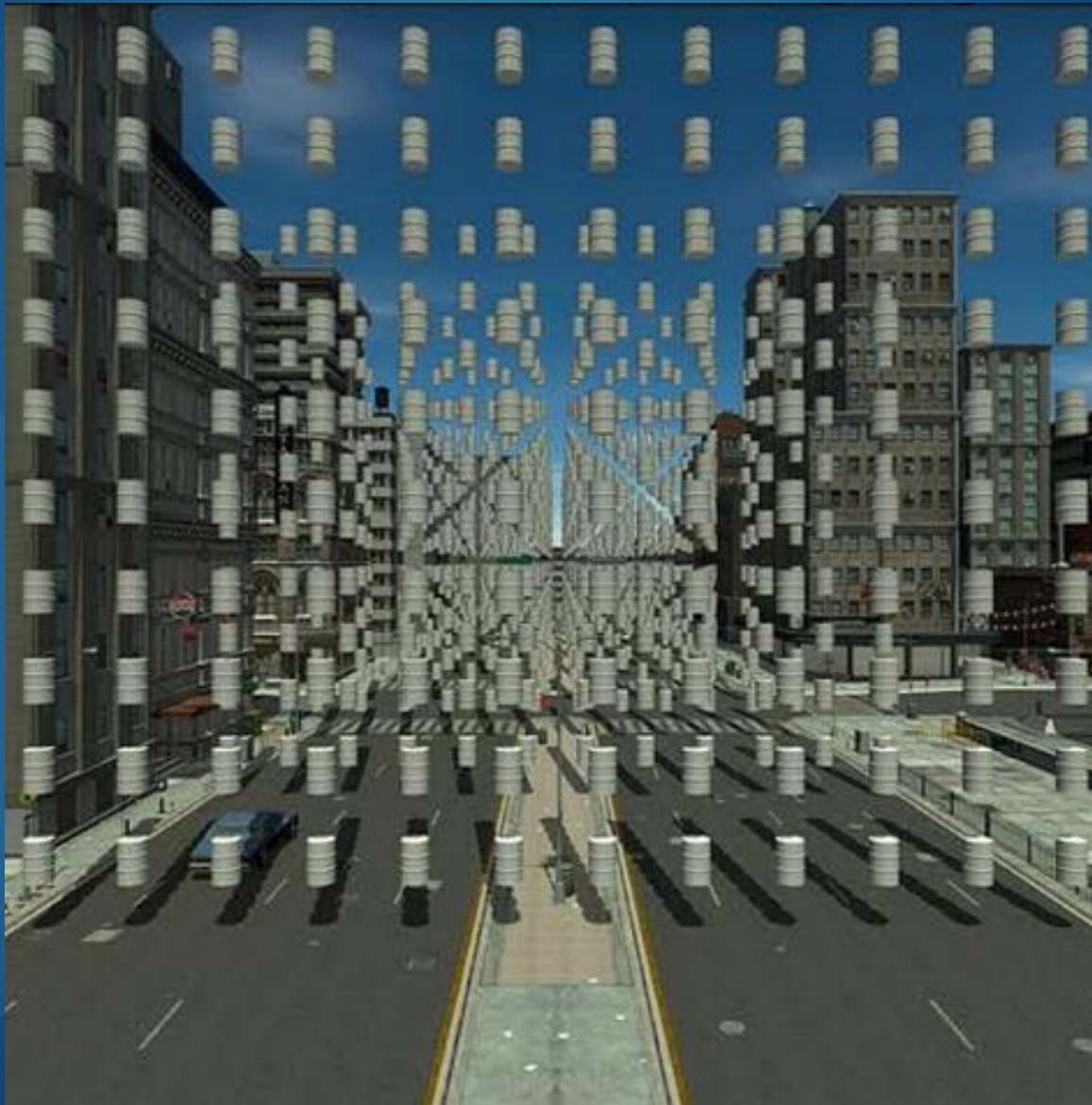
# The Anthropocene Equation



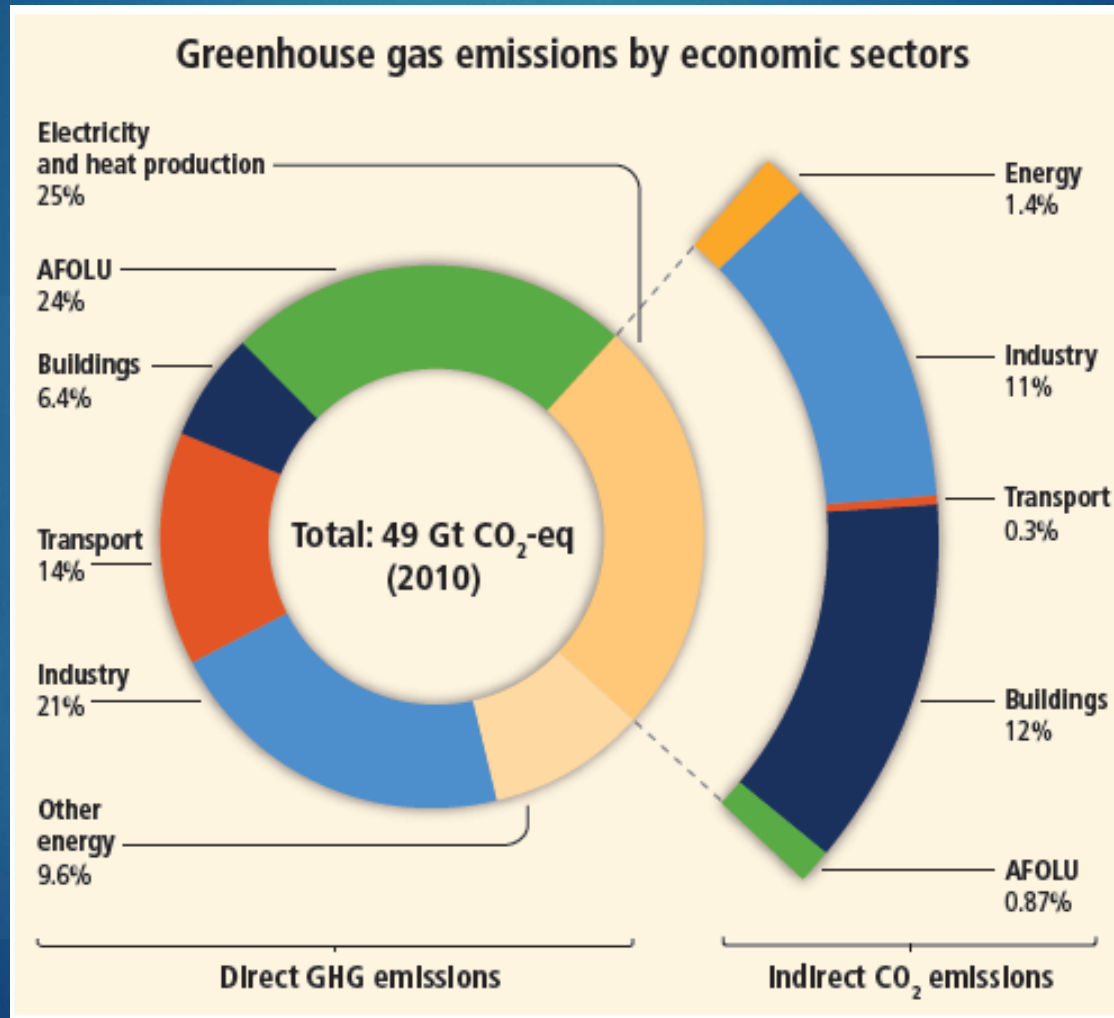


# Steve Halley: One Second

5

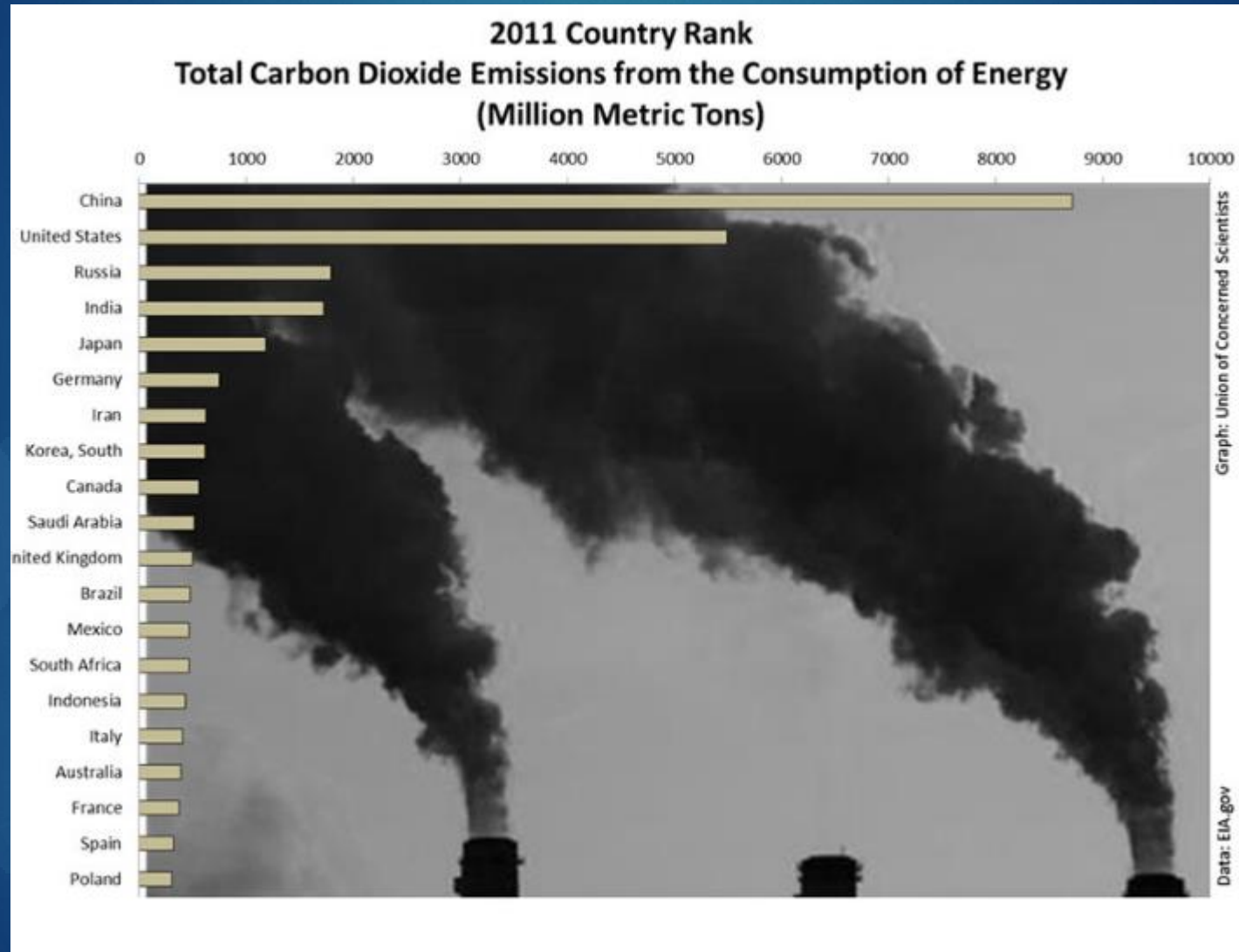


# Global Greenhouse Gas Emissions by Sector



# Who is Responsible?

7

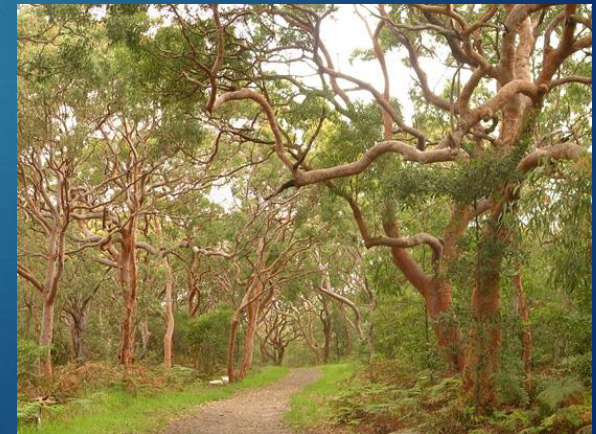




# Which ecosystems are affected?



- ' Climate change **impacts** have now been documented across **every ecosystem** on Earth '





# Coral reefs: doomed to extinction?

9



# Alpine ecosystems

10

- ▶ In New Guinea, tree-lines rise by 300m per 1C temperature increase.





# Are the fish shrinking?

11



Source: <https://www.abdn.ac.uk/news/5731/>



# YES

12

- Up to eight **commercial fish** species in the North Sea (haddock, whiting, herring, Norway pout, plaice, sole) have **shrunk** in size....
- This is over a **40 year** period
- Coincides with a **1-2 °C** increase in temperature
- Resulting in a **23%** decrease in yield

# Wine Anyone?



13





# Global food security?

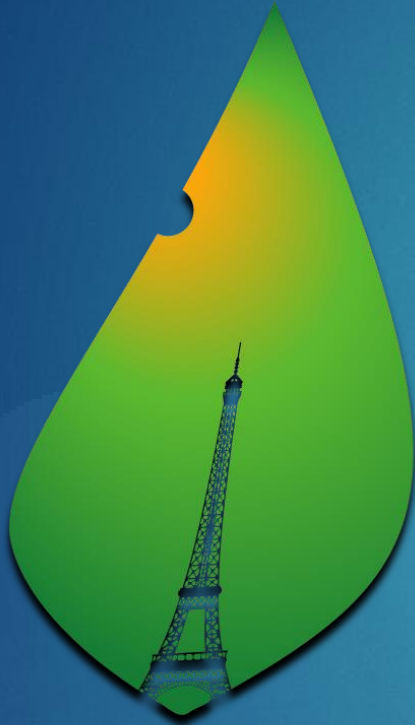
14



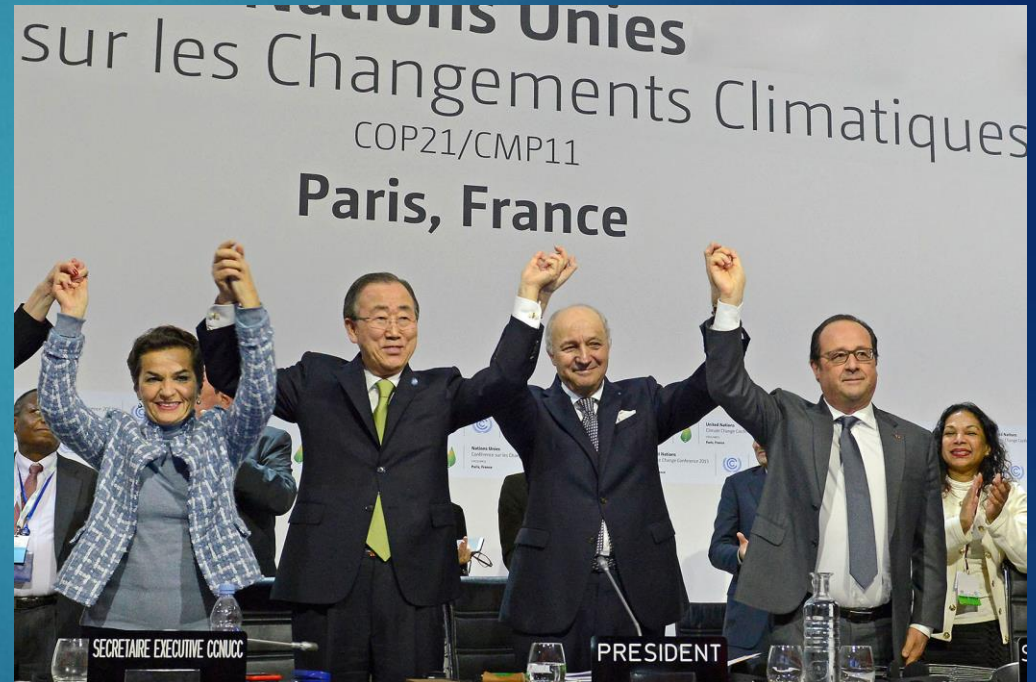


# The Paris Agreement

15

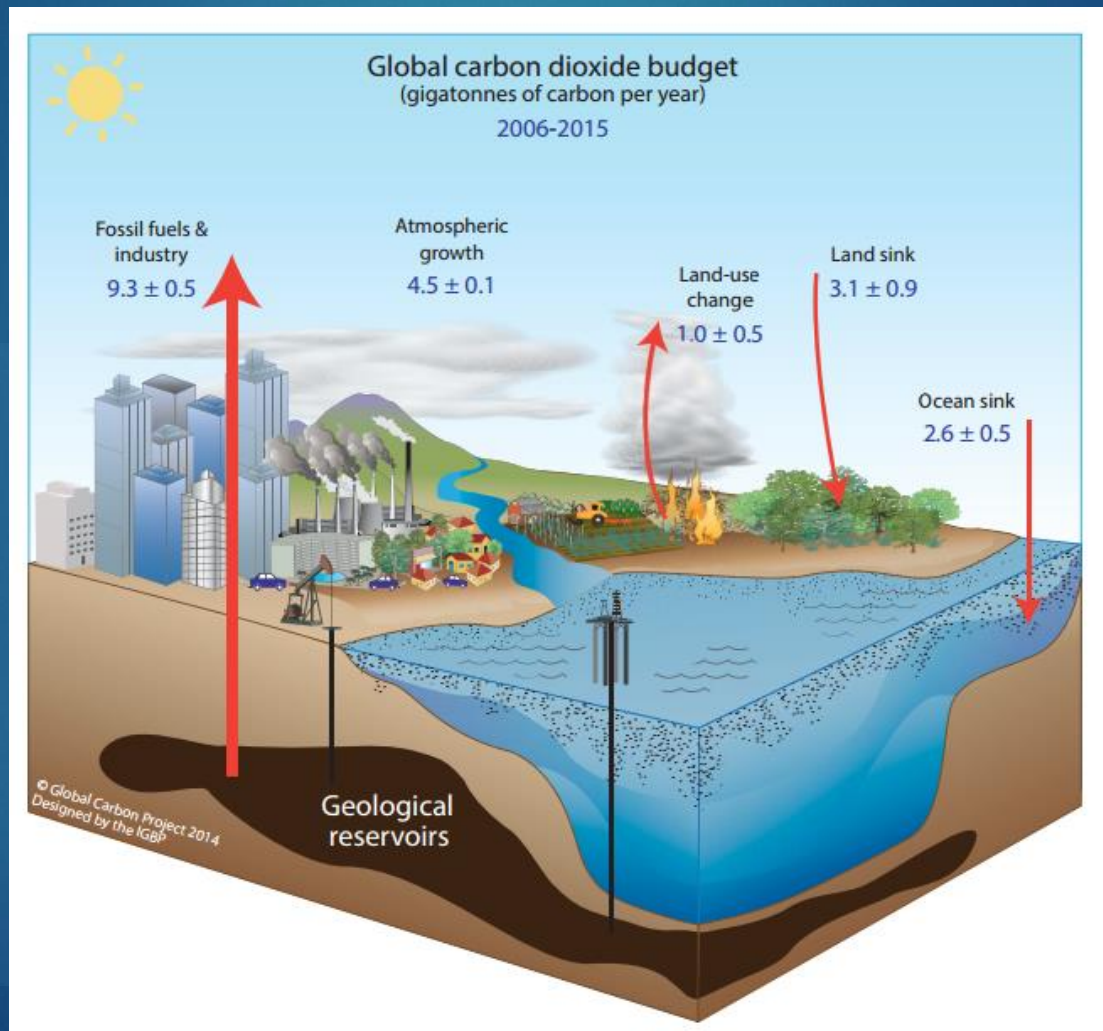


**PARIS2015**  
UN CLIMATE CHANGE CONFERENCE  
**COP21·CMP11**



# The Global Carbon Budget

16



Source:  
Climate  
Council  
Global  
Carbon  
Budget  
Report

# Biosphere Feedbacks

17

Biosphere climate-carbon cycle feedbacks that could be activated by a ~ 2°C increase in global average temperature.

Biosphere climate-carbon cycle feedback process	Additional carbon emitted by 2100 (GtC) <sup>1</sup>	Corresponding global temperature increase (°C) <sup>2</sup>	References/notes (see SI for details)
Relative weakening of land and ocean C sinks	125 (65-185)	0.25 (0.13-0.37)	Rescaling of results from RCP4.5 "compatible emissions" scenario (Ciais et al. 2013).
Permafrost thawing, CO <sub>2</sub> and CH <sub>4</sub> release	45 (20-80)	0.09 (0.04-0.16)	Estimates based on Schaefer et al. (2014), Schneider von Deimling et al. (2015), Koven et al. (2015).
Amazon forest dieback	25 (15-55)	0.05 (0.03-0.11)	Based on extrapolation of observed changes and model projections of dieback (Jones et al. 2009).
Boreal forest dieback	30 (10-40)	0.06 (0.02-0.10)	Based on extrapolation of observed changes and model projections of dieback.
Increased bacterial respiration in the ocean	10	0.02	Rescaling of RCP8.5 results (Segsneider and Bendtsen 2013, Bendtsen et al., 2015)
<b>Total</b>	<b>235 (120-380)</b>	<b>0.47 (0.24-0.76)</b>	

<sup>1</sup>Rounded to the nearest 5 GtC

<sup>2</sup>To convert the climate-carbon cycle feedbacks from amounts of carbon emitted to an equivalent temperature rise, we assume a 2°C temperature rise per 1000 GtC added to the atmosphere.



# CO<sub>2</sub> is Not The Only Greenhouse Gas

- ▶ **Methane** and **nitrous oxide** are not included in the carbon budget because their warming impact is offset by particulate pollution
- ▶ Both China and India are clamping down on **particulate pollution**
- ▶ Carbon Dioxide ~81%, Methane ~11%, Nitrous Oxide ~6% (<https://www.epa.gov/ghgemissions/overview-greenhouse-gases>)

# OUT OF CARBON BUDGET

19

“Our central estimate gives a total loss of **235GtC** equivalent...[This] would consume the entire remaining carbon budget of **225GtC** and generate a slight deficit, **thus requiring negative emissions technologies to respect the 2C Paris guardrail.**”

## **Biosphere climate-carbon cycle feedbacks and the 2°C Paris guardrail**

Johan Rockström<sup>1</sup>, Will Steffen<sup>1,2</sup>, Katherine Richardson<sup>3</sup>,  
Timothy M. Lenton<sup>4</sup>

Submitted Nature

# The Virgin Earth Challenge

20





# Biological and Chemical Pathways to remove CO<sub>2</sub>

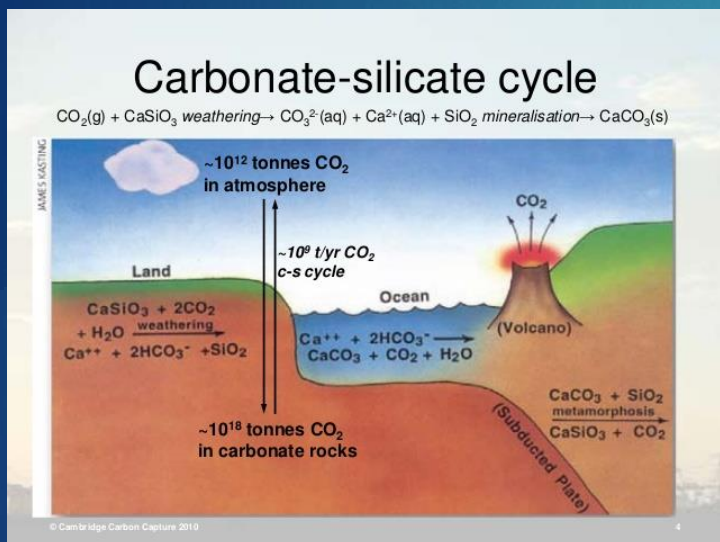


Reafforestation



Seaweed Farming

# Biological and Chemical Pathways to remove CO<sub>2</sub>

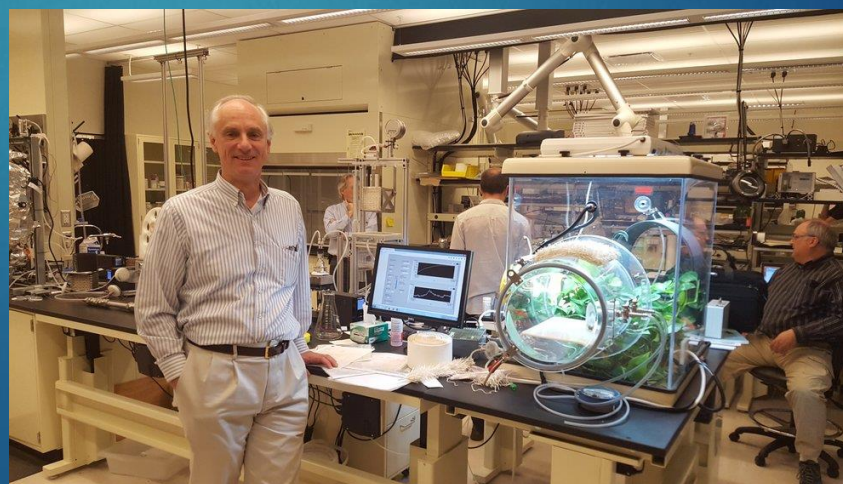


Silicate  
Rocks



Carbon  
Negative  
Concrete

Direct Air  
Capture to  
make plastics,  
carbon fibres



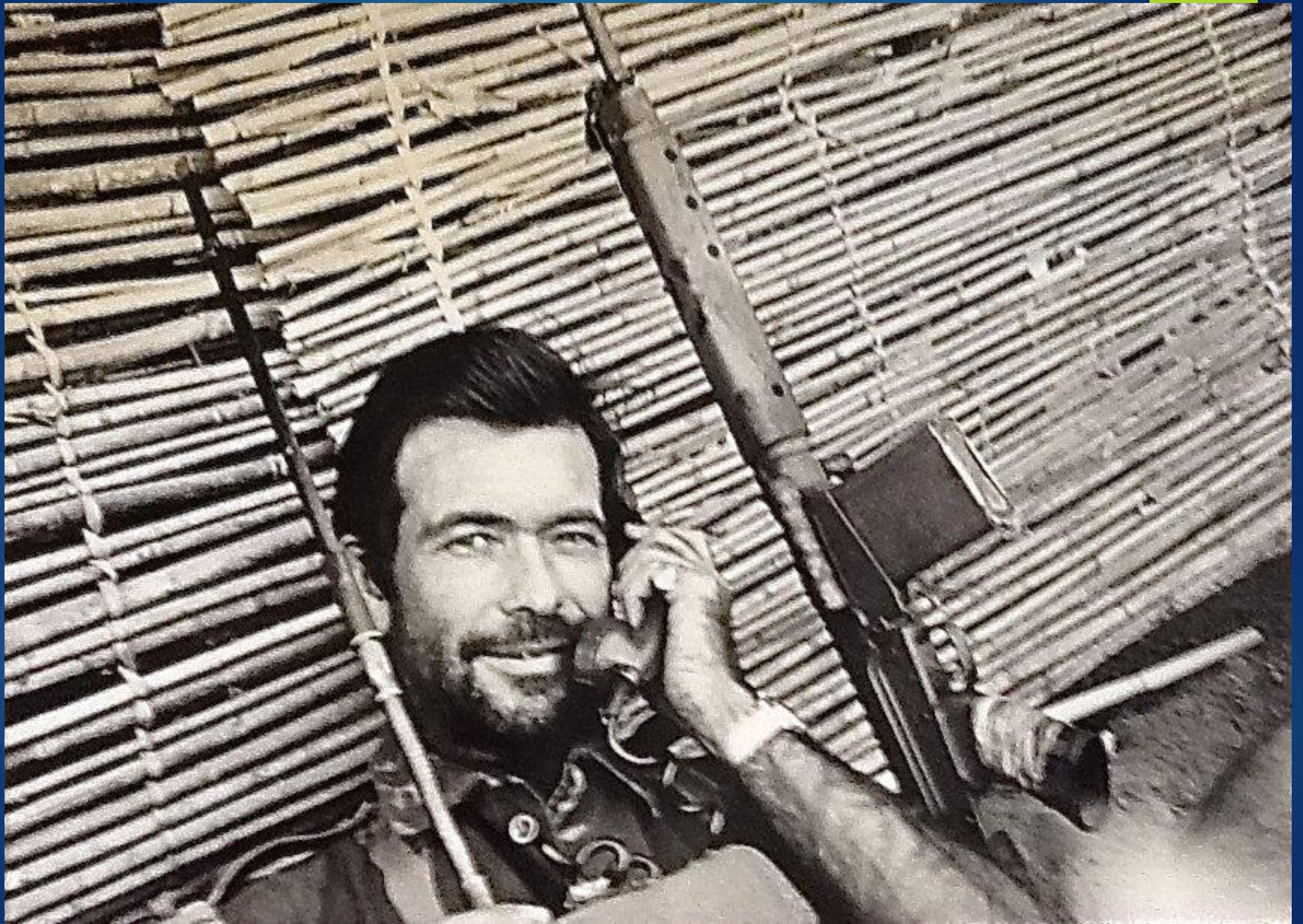


# North America

23









# Kelp Farm

25



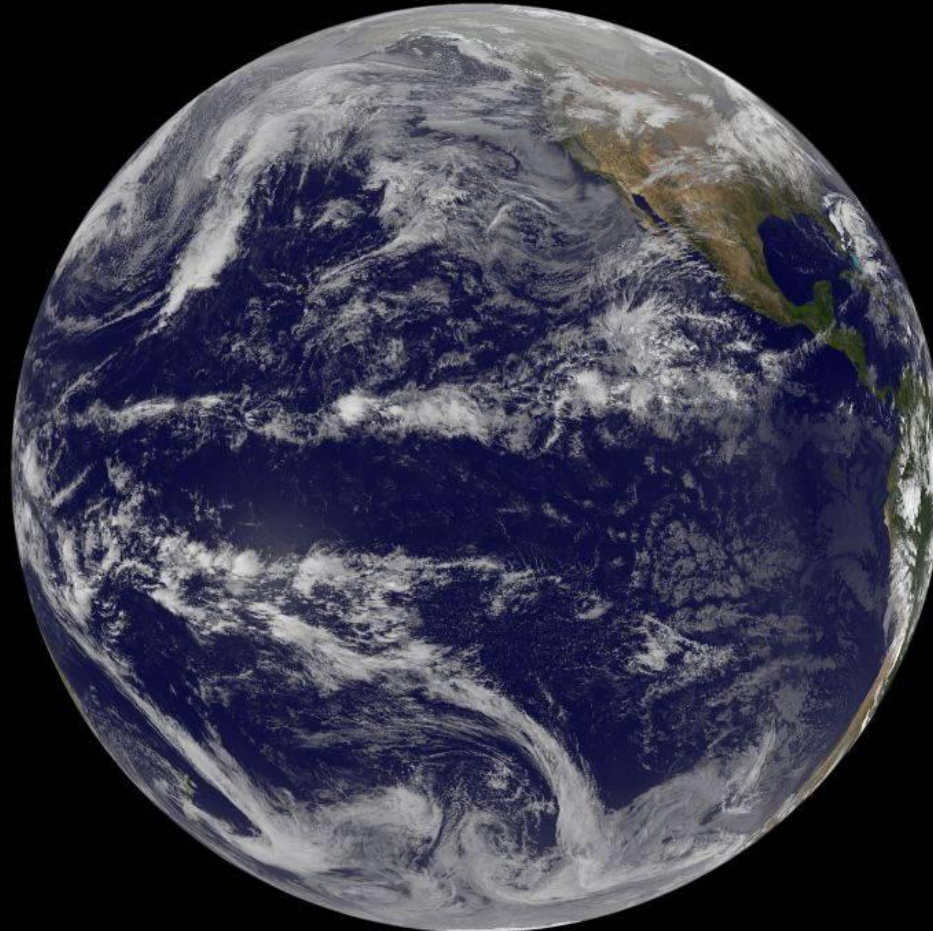
# Mid Pacific Ocean

26

NOAA GOES 15

121207 0000 UTC

NASA GSFC GOES Project



**Cloud-free Equator**



# Only mid-ocean kelp farming offers storage

- ▶ If **9%** of the ocean could be covered in seaweed farms, the farmed seaweed could produce 12 gigatonnes per year of biodigested methane for use as natural gas, while storing 19 gigatonnes of CO<sub>2</sub>. A further 34 gigatonnes per year of CO<sub>2</sub> could be captured if the methane is burned to generate electricity.
- ▶ This would produce sufficient biomethane to replace all of today's needs in fossil fuel energy, while **removing 53 billion tonnes of CO<sub>2</sub> per year from the atmosphere**...This amount of biomass could also increase sustainable fish production to potentially provide 200 kilograms per year, per person, for 10 billion people. Additional benefits are reduction in ocean acidification and increased ocean primary productivity and biodiversity.
- ▶ N'Yeurt, A. et al., (2012). 'Negative Carbon via Ocean Afforestation', *Process Safety and Environmental Protection* 90, 467–74, 2012.

# The Deep Sea

28



# Wind Turbines in the Antarctic

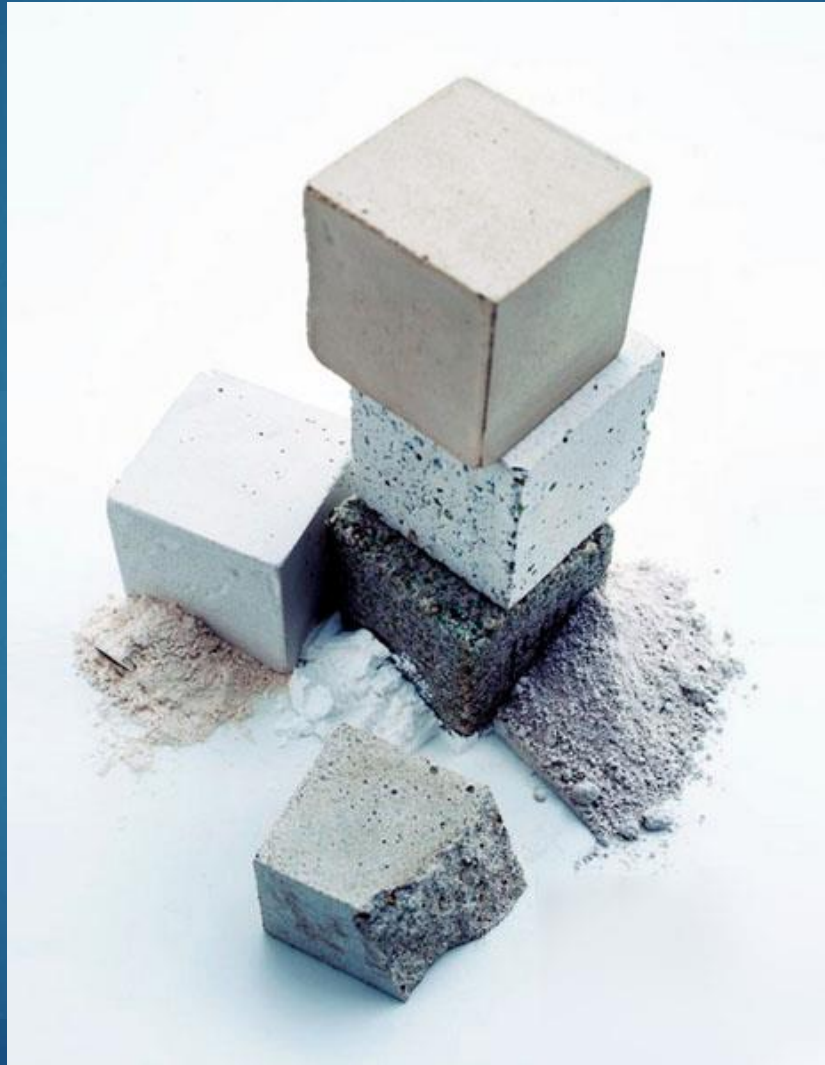
29





# Carbon negative concrete

30



# Silicate Rocks

31



## International Journal of Greenhouse Gas Control

Volume 3, Issue 6, December 2009, Pages 757–767



### Coastal spreading of olivine to control atmospheric CO<sub>2</sub> concentrations: A critical analysis of viability

Suzanne J.T. Hangx  , Christopher J. Spiers



Sim Sepp/Alamy

nature

International weekly journal of science

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[Archive](#) > [Volume 505](#) > [Issue 7484](#) > [News](#) > [Article](#)

NATURE | NEWS

## Rock's power to mop up carbon revisited

Experts push for more research into olivine weathering.

Daniel Cressey

21 January 2014

# James Hanson et al. see a solution

32

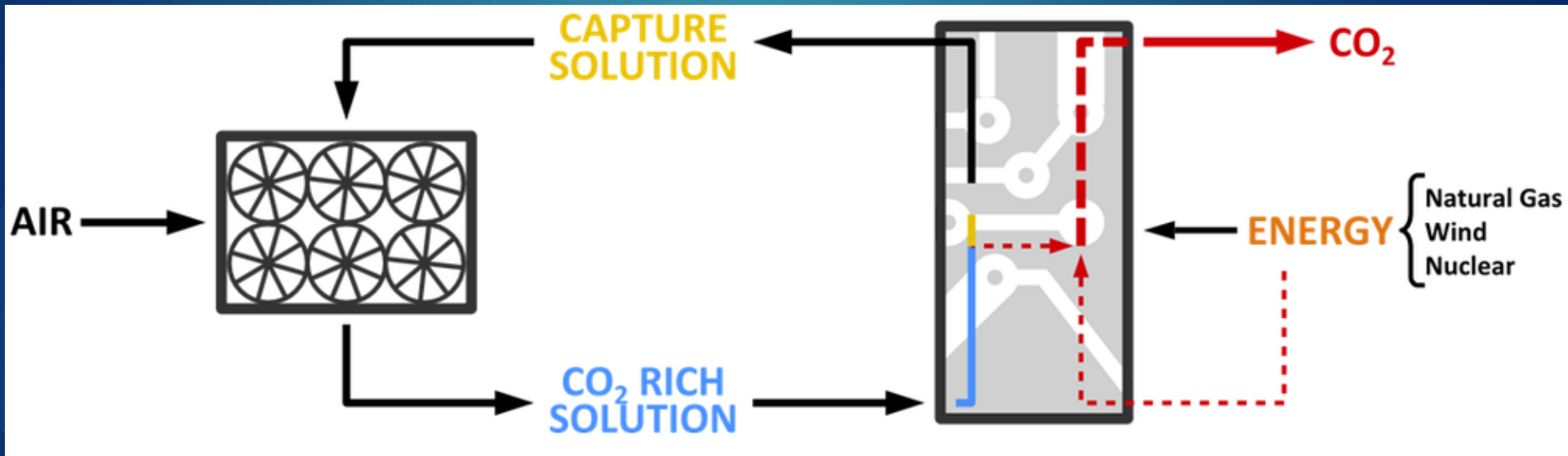
**Enhanced weathering could lower atmospheric CO<sub>2</sub> by 30–300 ppm by 2100**, depending mainly on silicate rock application rate (1 kg or 5 kg m<sup>-2</sup> yr<sup>-1</sup>) and composition. At the higher application rate, end-of-century ocean acidification is reversed under RCP4.5 and reduced by about two-thirds under RCP8.5. Additionally, surface ocean aragonite saturation state, a key control on coral calcification rates, is maintained above 3.5 throughout the low latitudes, thereby helping maintain the viability of tropical coral reef ecosystems

Layla et al (2016). Enhanced Weathering strategies for stabilising climate... Nature Climate Change 6:204-6



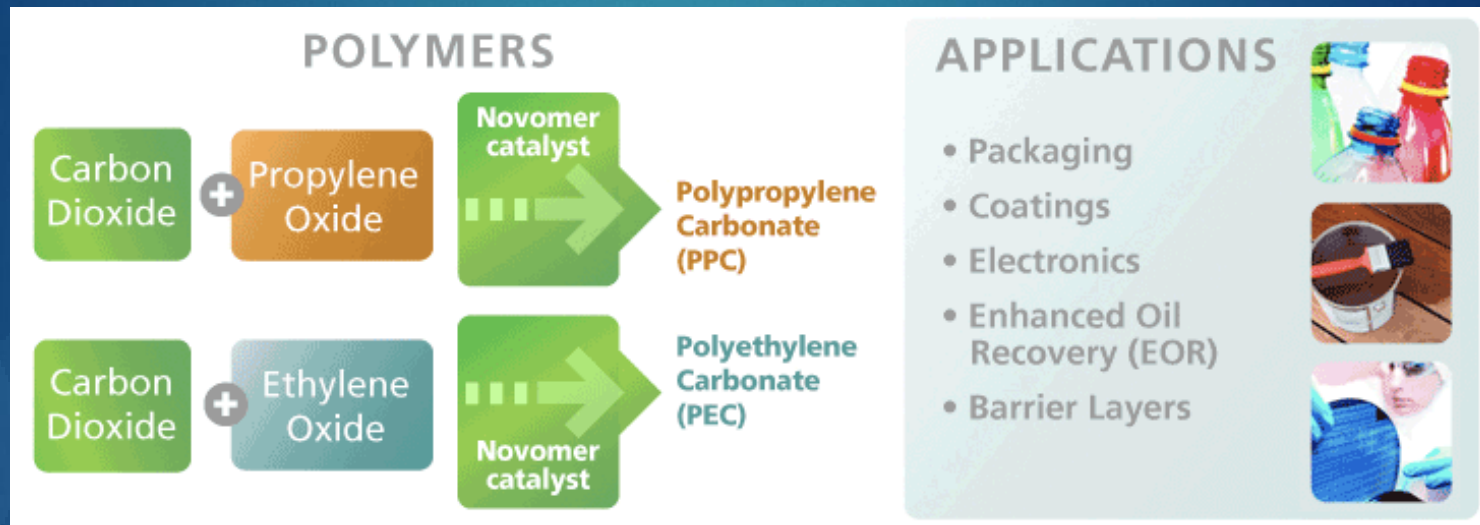
# Direct Air Capture CO<sub>2</sub>

33



Source: <http://carbonengineering.com/air-capture/>

# Bioplastics (Plastics from CO<sub>2</sub>)

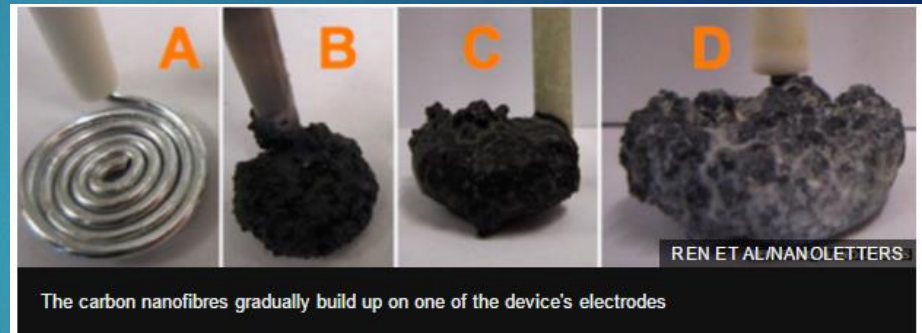
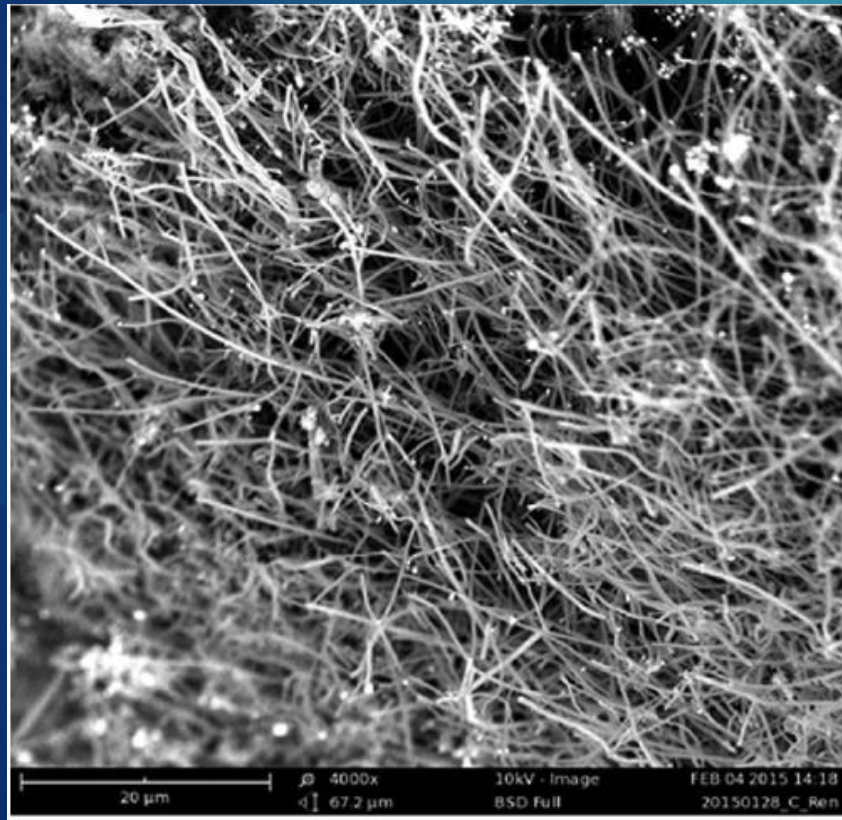


Source: <http://bioplasticolor.blogspot.com.au/2011/03/polymers-from-carbon-dioxide.html>

Source: <http://www.climate-kic.org/case-studies/plastics-project-potential-co2-reduction-of-2-9m-tons>

# Sahara CST Licht Technologies: CO<sub>2</sub> and Nanofibres

35



Source: **One-Pot Synthesis of Carbon Nanofibers from CO<sub>2</sub>**  
Jiawen Ren, Fang-Fang Li, Jason Lau, Luis González-Urbina, and Stuart  
Licht, *Nano Letters* **2015** 15 (9), 6142-6148



# Artificial photosynthesis?

36

## REPORT

### A synthetic pathway for the fixation of carbon dioxide in vitro

Thomas Schwander<sup>1</sup>, Lennart Schada von Borzyskowski<sup>1,2</sup>, Simon Burgener<sup>1,2</sup>, Niña Socorro Cortina<sup>1</sup>, Tobias J....

+ See all authors and affiliations

*Science* 18 Nov 2016:  
Vol. 354, Issue 6314, pp. 900-904  
DOI: 10.1126/science.aah5237



Peer Reviewed  
← see details

- ▶ Optimised in vitro photosynthetic pathway using 17 enzymes (3 engineered)
- ▶ 5 times more efficient than existing pathways

# London 1917

37







FREEDOM

FRATERNITY

FEDERATION

MAP OF THE WORLD  
SHOWING THE EXTENT OF THE BRITISH TERRITORIES IN 1786.

Public Library  
of the  
City of Boston.

WORLD

IMPERIAL FEDERATION - MAP OF THE WORLD SHOWING THE EXTENT OF THE BRITISH EMPIRE IN 1886.

STATISTICAL INFORMATION FURNISHED BY CAPTAIN J. C. COLOMB, M.P. FORMERLY R.M.A. BRITISH TERRITORIES COLOURED RED



# Image Geneva 1950

39



# Jet Aircraft 1950

40





# Electrification of the Home 1950

41





# Nuclear Blast 1950

42



# What will 2050 be like? We are all connected...

