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ECO-IMPACT AND CO2 FOOTPRINTS OF GEOPOLYMER (GP VS OPC)

Baturalp Yalcinkaya,

Milan Bouša, Petr Louda, Piotr Łoś, Katarzyna Buczkowska.

Department of Material Science

Technical University of Liberec

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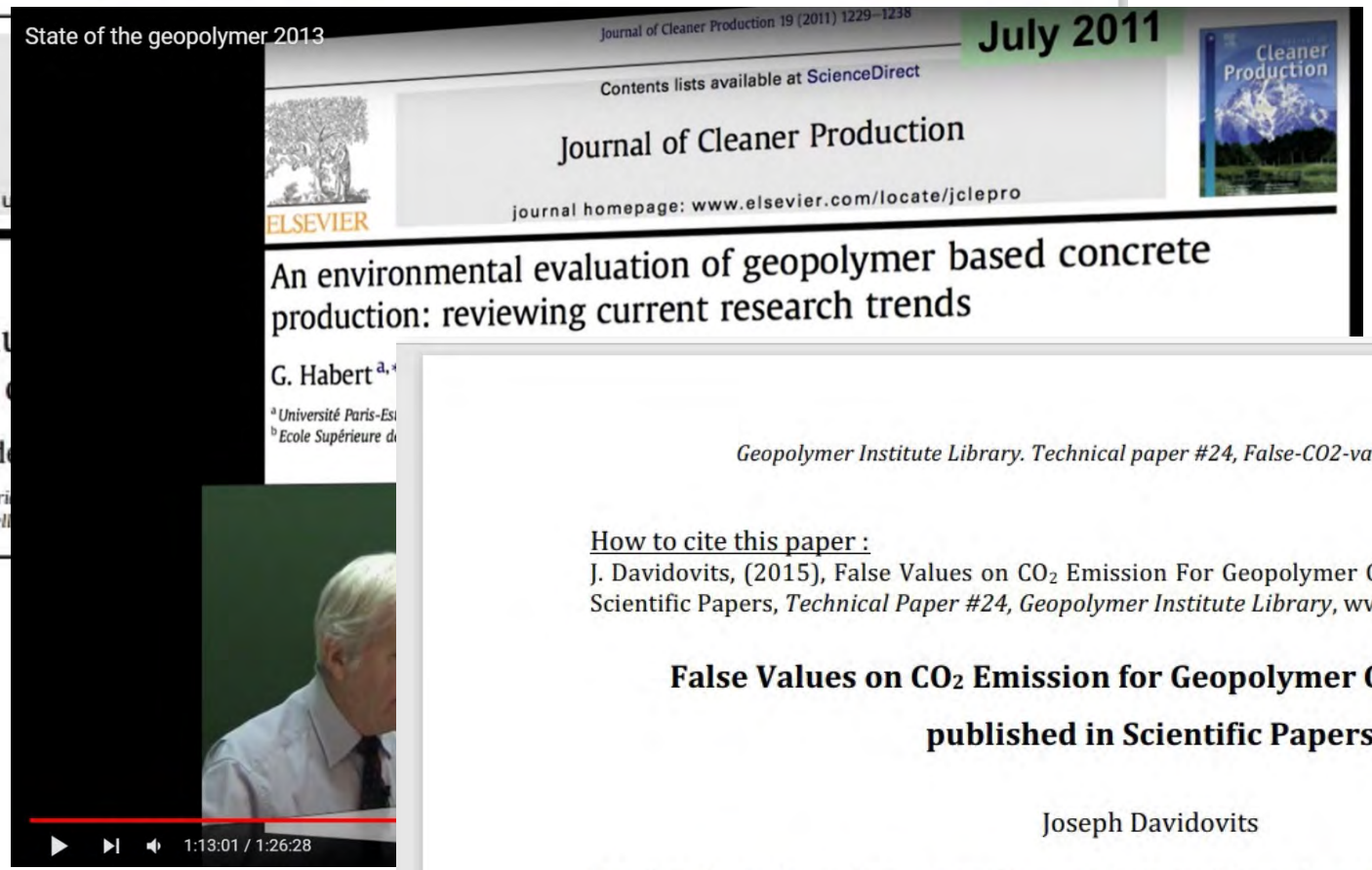
ELSEVIER

An environmental evalu
production: reviewing

G. Habert [a,*], J.B. d'Espinose d

[a] Université Paris-Est, IFSTTAR, Département Matéri
[b] Ecole Supérieure de Physique et Chimie Industriell

State of the geopolymer 2013



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False Values on CO_2 Emission for Geopolymer Cement/Concrete published in Scientific Papers

Joseph Davidovits

Adapted from the article originally published in Elsevier's internet site *materialstoday* at http://www.materialstoday.com/polymers-soft-materials/features/environmental-implications-of-geopolymers/, 29 June 2015, titled *Environmental implications of Geopolymers*. See also the presentation at the Geopolymer Camp 2015.


“We want to save the world, right?”

TUL

ECO-IMPACT AND CO2 FOOTPRINTS OF GEOPOLYMER

(CEMENT AND GEOPOLYMER)

TUL

STATE OF ECO AND CO2

OUTLINE OF THE PRESENTATION

- 1. Tragic
- 2. Optimistic
- 3. GP vs OPC
- 4. Sad

TUL

1. TRAGIC PART

FOUR KEY CLIMATE CHANGE INDICATORS BREAK RECORDS IN 2021

1. Greenhouse Gas Concentrations

Reached a new global high in 2021, when the concentration of carbon dioxide (CO_2) reached **413.2 parts per million (ppm)** globally, or 149% of the pre-industrial level. Data from specific locations indicate that they continued to increase in early 2022

2. Sea Level Rise

reached a new record high in 2021, after increasing at an average 4.5 mm per year over the period 2013 - 2021. This is more than double the rate between 1993 and 2002 and is mainly due to the accelerated loss of ice mass from the ice sheets.

3. O***cean*** H***eat*** Rise

was record high. The upper 2000m depth of the ocean continued to warm in 2021 and it is expected that it will continue to warm in the future – **a change which is irreversible on centennial to millennial time scales.**

4. O***cean*** A***cidification***

Open ocean surface pH is now the lowest it has been for at least 26,000 years and current rates of pH change are unprecedented since at least that time.

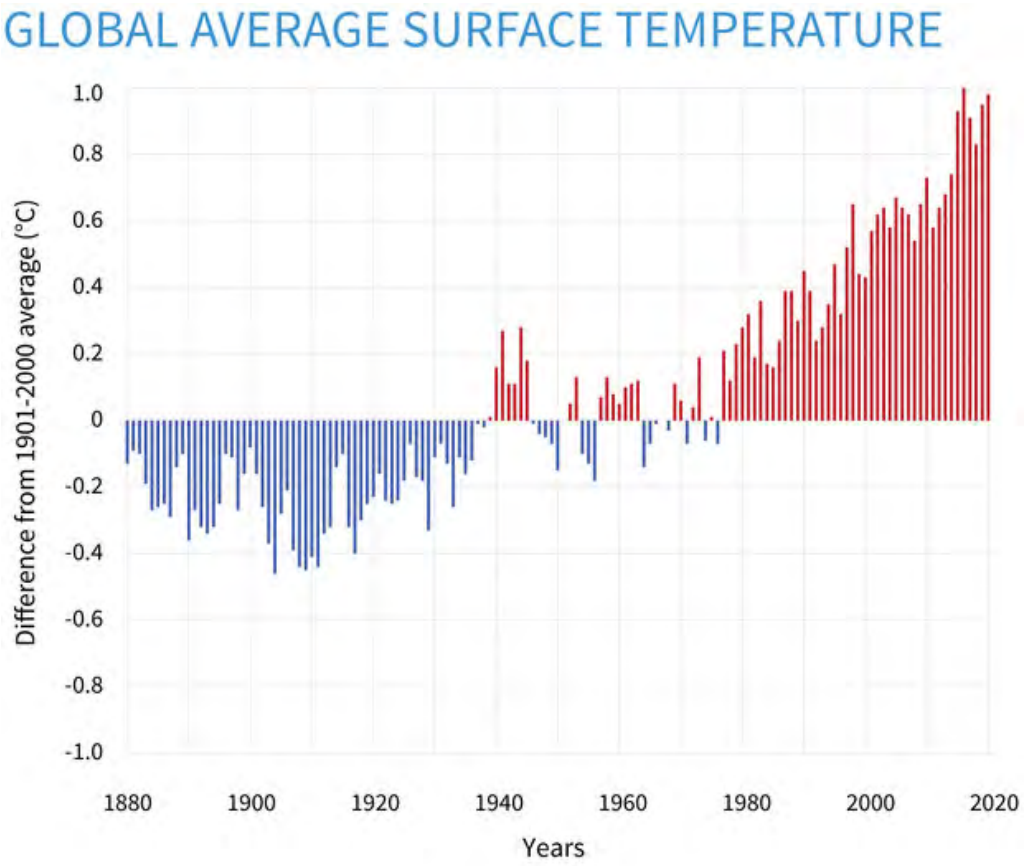
WMO, 2022

FURTHER INDICATORS 2021

- The most recent seven years, 2015 to 2021, were the seven warmest years on record.
- The Antarctic ozone hole reached a maximum area of 24.8 million km^2 in 2021.
- Greenland experienced an exceptional mid-August melt event.
- Exceptional heatwaves broke records across western North America and the Mediterranean.
- Hurricane *Ida* was the most significant of the North Atlantic season.
- Deadly and costly flooding induced economic losses of US$ 17.7 billion in Henan province of China, and Western Europe experienced some of its most severe flooding on record in mid-July.

GLOBAL AVERAGE SURFACE TEMPERATURE

- As of 2022 the global average temperature has risen 1.2 degrees Celsius compared to preindustrial times.
- Limiting warming to 1.5 degrees was the most ambitious goal of the Paris agreement but we are not likely to meet it.



WMO, 2022
UN, 2021

OUR WORLD IS BURNING

- Already with the warming we have today,

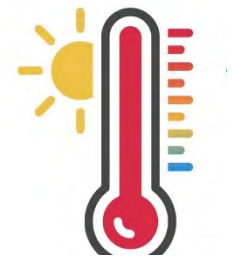
hot places will get hotter

wet places wetter

and the risk and strength of extreme weather events increase significantly.

IPCC, 2018
Buis, 2019

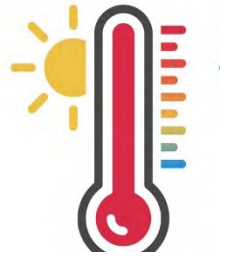
2 °C



- Warming beyond 2 degrees makes all of these extremes more extreme.

IPCC, 2021
Arnell et all., 2019
UNEP, 2021

3 °C



- At 3 degrees significant parts of earth, especially in developing countries, might become unable to feed their populations.
- Heat waves will become a major global issue.
- The scale and frequency of hurricanes, fires and droughts will further increase and cause trillions in damage.
- Hundreds of millions of people will need to leave their homes.

IPCC, 2021
Arnell et all., 2019
UNEP, 2021

4 - 8 ºC

- In the 4-8 degree range the apocalypse begins.
- The hothouse earth, where things change so quickly, may become unable to support our large human population.
- Billions may perish, leaving the rest on a hostile alien planet.

Andrew et al., 2018
Sherwood & Huberb, 2010

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2. OPTIMISTIC PART

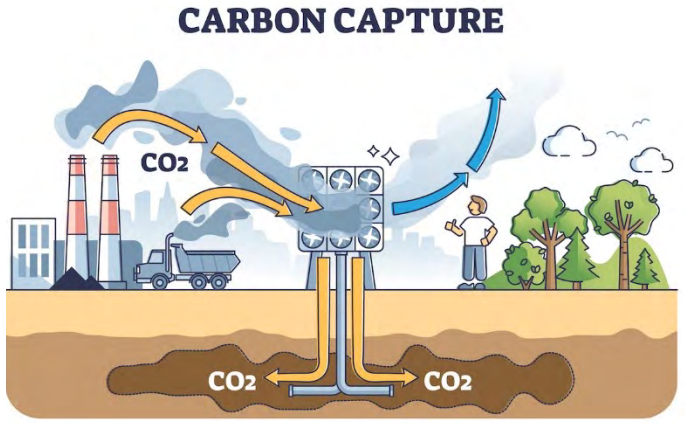
ARE WE DOOMED?

- A decade ago, for lack of action and perspective, many scientists assumed a 4+ degree world was our future.
- In the last decade, we have seen enough progress that most scientists now think that we have likely avoided apocalyptic climate change.
- We're likely to end up with a warming of 3 °C by 2100.
- What has changed over the last ten years and is this really good news?


Solar energy


Wind energy


Hydroelectricity

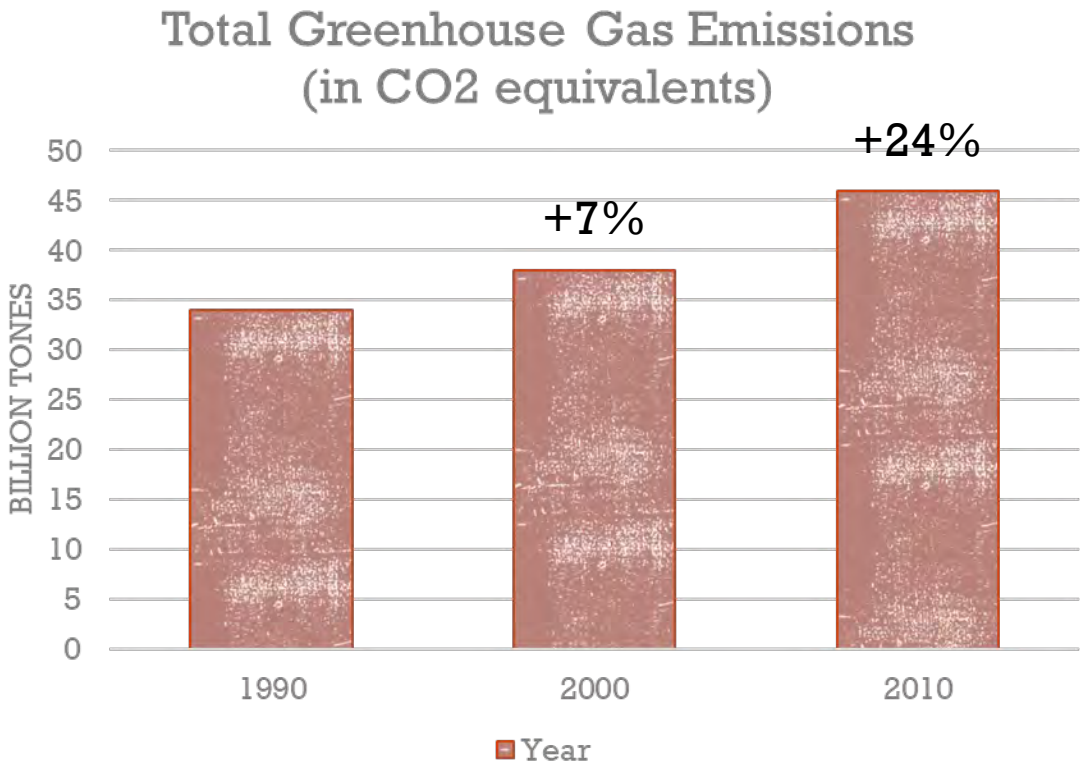


CAT, 2021
IPCC, 2021
I4CE, 2019

Peters et al., 2012
IPCC, 2013

HOW?

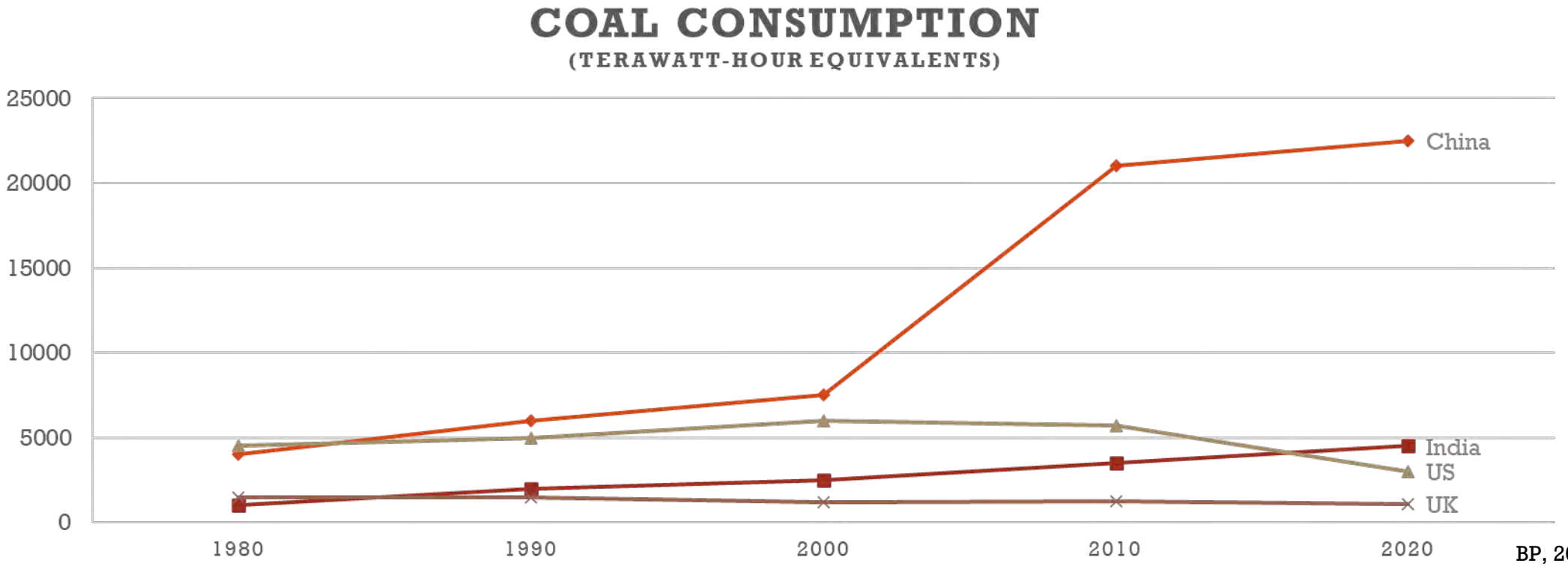
- Let us go back 20 years to see why today is so different:
- In 2010, many people expected these trends to continue.



Climate Watch, 2022

STATE OF COAL CONSUMPTION

- Instead of decreasing fossil fuel use its consumption would rise. The next decade turned out to be very different though.



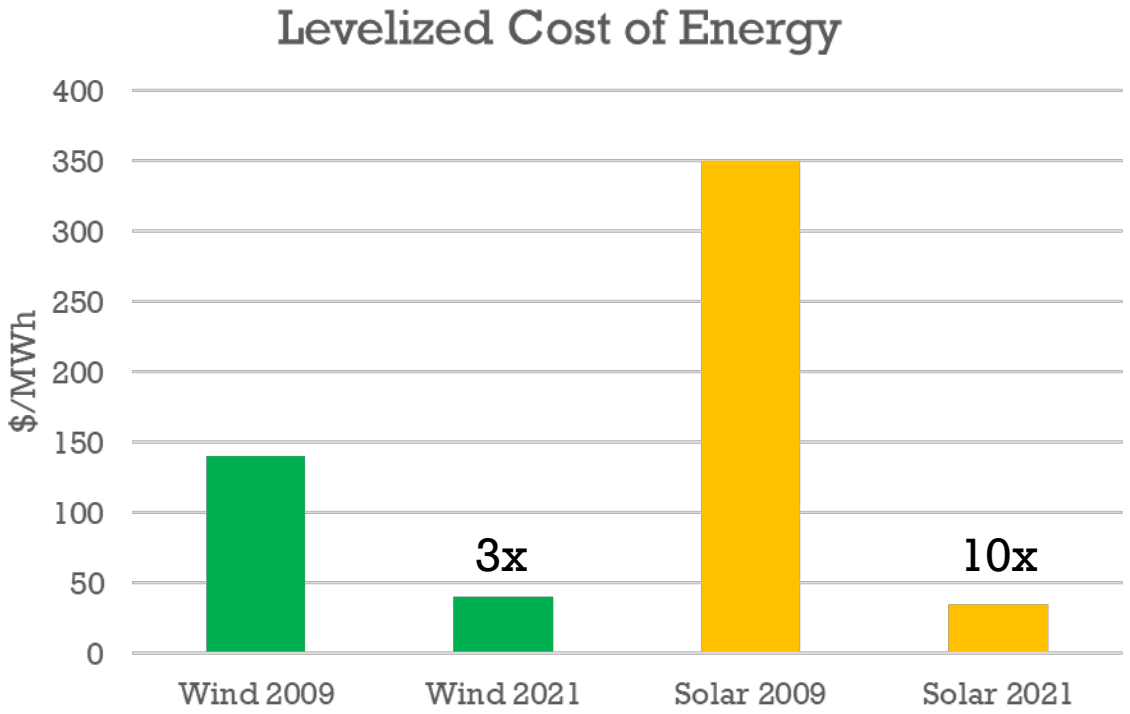
BP, 2021

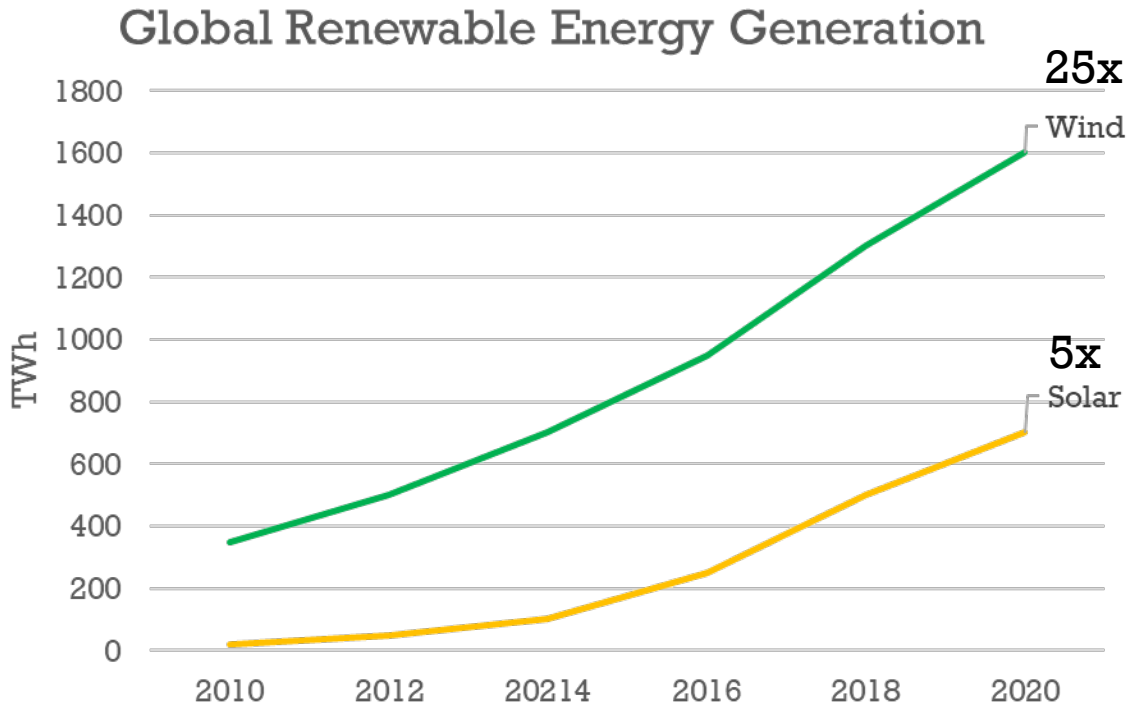
STOP COAL NOW!

- Since 2015 three-quarters of planned coal plants have been canceled and 44 countries have committed to stop building them.

RENEWABLE ELECTRICITY

- Technologies we thought would remain expensive matured rapidly instead.

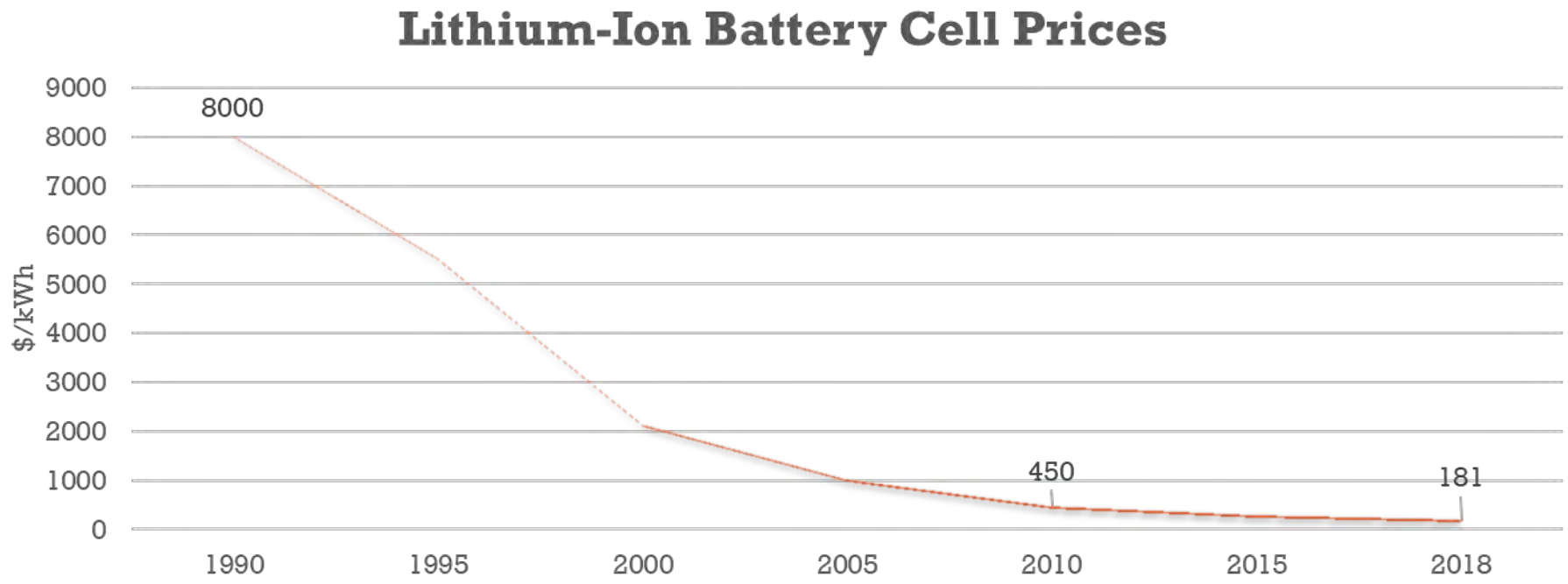




IMF, 2021
Lazard, 2021
BP, 2021

BATTERY

- Renewables need a lot of energy storage to be a reliable power source, like expensive batteries.



97% cheaper

Ziegler & Trancik, 2021
OWID, 2021

RENEWABLES, IS THAT ALL?

We replaced old bulbs with 10 times more efficient LED

7 /10 Electric or Hybrid car, 2020
8 /10 Electric or Hybrid car, 2021

Better insulation and heating

Ships travel at half speed to save fuel.

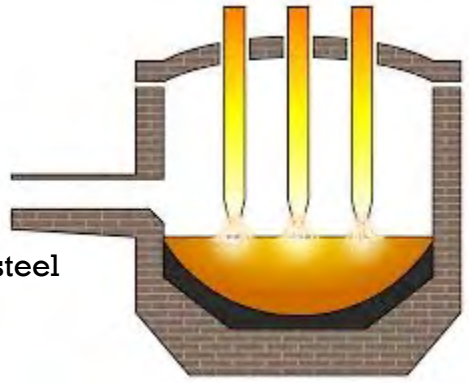
GeoCamp – 4-6. 07 . 2022

AND WHAT IS MORE…

- Wherever you look you find scientists, engineers and entrepreneurs trying to solve some aspect of climate change.

Electronic and steel

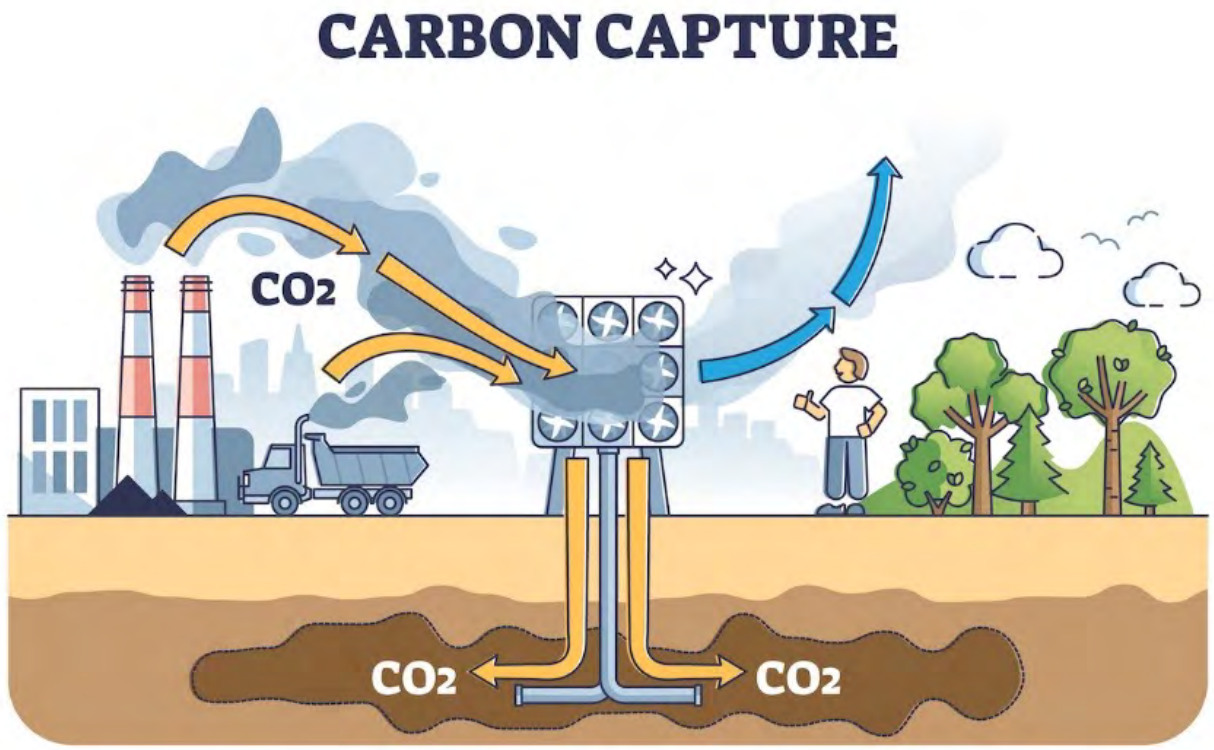
Artificial meat



Carbon capture technology

Low-carbon production of cement or concrete

CARBON CAPTURE TECHNOLOGY



- Basically, capture technology separates CO_2 emissions from the process, after which the compressed CO_2 is transported to a suitable geological storage location and injected.

CARBON CAPTURE IN CEMENT 300 - 800 USD/tonne of CO2

1POINTFIVE

1 million tones of CO2 each year

400.000 tones of CO2 each year

AKER CARBON CAPTURE

Carbon Clean Solutions CCS

Cost effective: 30 USD/tonne

1 tonne CO2/day

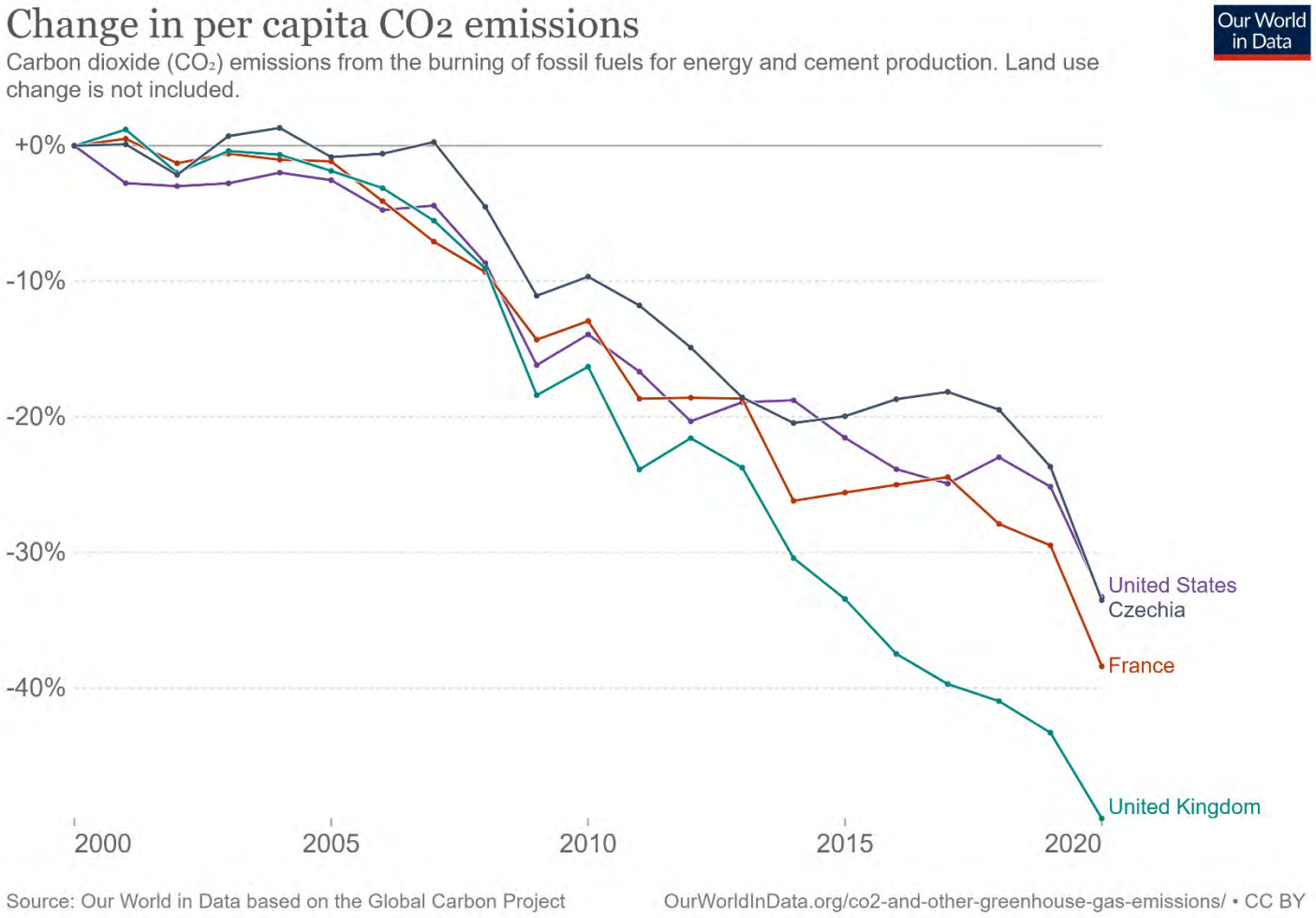
MTR MEMBRANE TECHNOLOGY & RESEARCH

FLSmidth

Carbon8 Systems' Accelerated Carbonation Technology (ACT) is available to the cement industry today.

CO2 EMISSIONS

- Since the year 2000, the US as a whole shows a 33% decrease, Czechia 34%, France 38%, the UK 49%.



OWID, 2021

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3. GP VS OPC

CO2 EMISSION OPC VS GEOPOLYMER

- Values for Concrete

Material Name Reinforced Concrete	Weight (kg)	Weight Ratio	Density kg/m^3	Emission Faktor kg CO_2 eqv./kg
Mixture of Sands	303.4	30.3%	1650	0.147
Cement (75 Pa)	298.4.6	29.8%	3050	1.250
Water	276.5	27.7%	1000	0.0
Binder mixture	8.7	0.9%	2685	3.210
Steel Rod	112.8	11.3	7850	2.890
Total weight	1000.0		2596.6	
Total kg CO_2				771.7
kg CO_2 eqv./kg				0.772

- Values for Geopolymer

Material Name Geopolymer	Weight (kg)	Weight Ratio	Density (kg/m^3)	Emission Faktor (kg CO_2 eqv./kg)
Metakaolin BLk	292.9	29.3%	1850	0.245
Glass water	287.2	28.7%	1050	0.0
SiO2	31.4	3.1%	319	2.890
Carbon fiber	8.01	0.8%	350	0.051
Sands	94.3	9.4%	1650	0.147
Ash	283	28.3%	425	0.0
Total weight	1000.0			
Total kg CO_2				215.7
kg CO_2 eqv./kg				0.216

- ***From*** 771.7 ***kg of*** equivalent CO2 OPC-based concrete, the geopolymer concrete releases 215.7 kg of equivalent CO2, which represents a saving of 72.5 % for concrete.

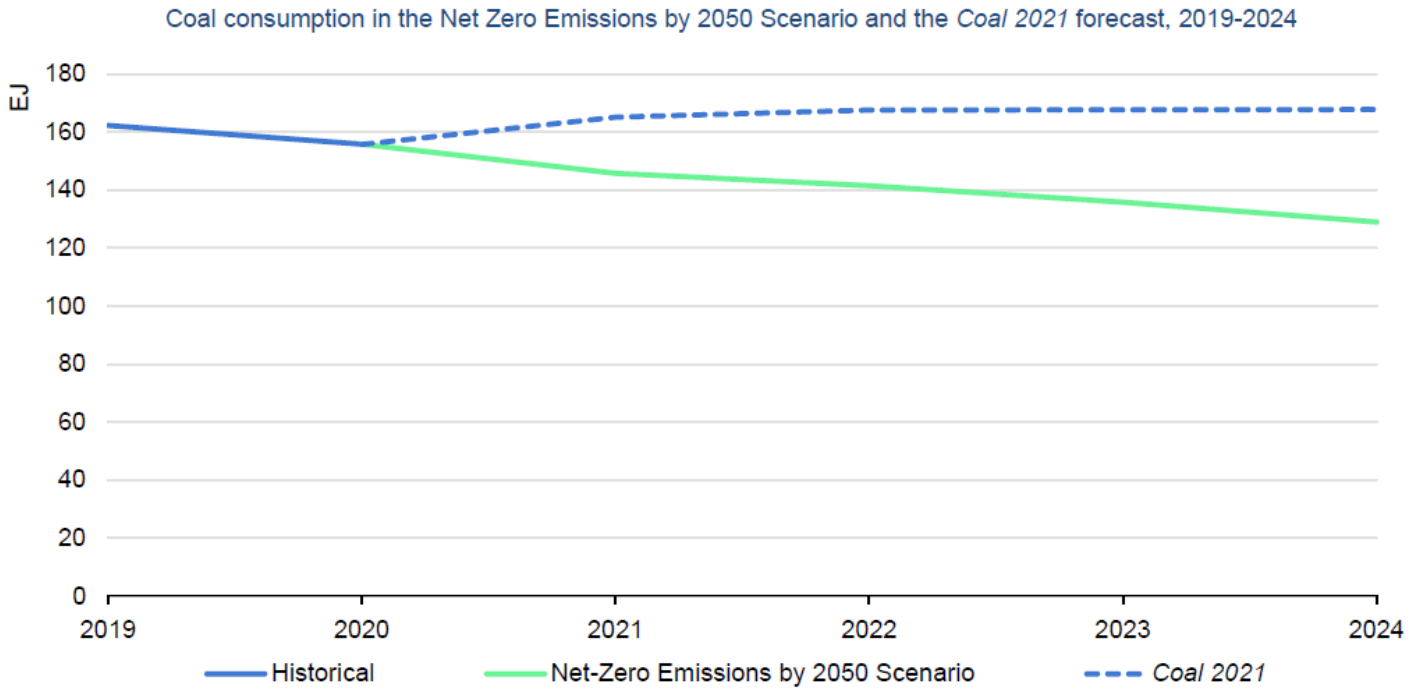
EPA and IPCC emission factor database

TUL

4. SAD PART

THEN 2021 HAPPENED

- Over the past decade, most of the emissions cuts have come from cheap natural gas replacing coal. But last year, rising natural gas prices helped resuscitate the dirtiest fossil fuel.
- Last year, the world burnt the largest amount ever of coal to produce electricity.



OWID, 2021

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THANK YOU FOR YOUR ATTENTION

This work was supported by Technology Agency of the Czech Republic within the Epsilon Program, in the Call 2021 M-ERA.Net2 registration number TH8002007 „Development of geopolymer composites as a material for protection of hazardous wrecks and other critical underwater structures against corrosion"