3rd LATIN AMERICAN CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

3rd LA SDEWES Conference SÃO PAULO 2022

ENERGY TRANSITION: IMPACTS OF DECARBONIZATION AND ELECTRIFICATION

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AGENDA

ENERGY TRANSITION

CARBON BUDGET TIMING ENERGY TRANSITION

DECARBONIZATION

ELECTRIFICATION

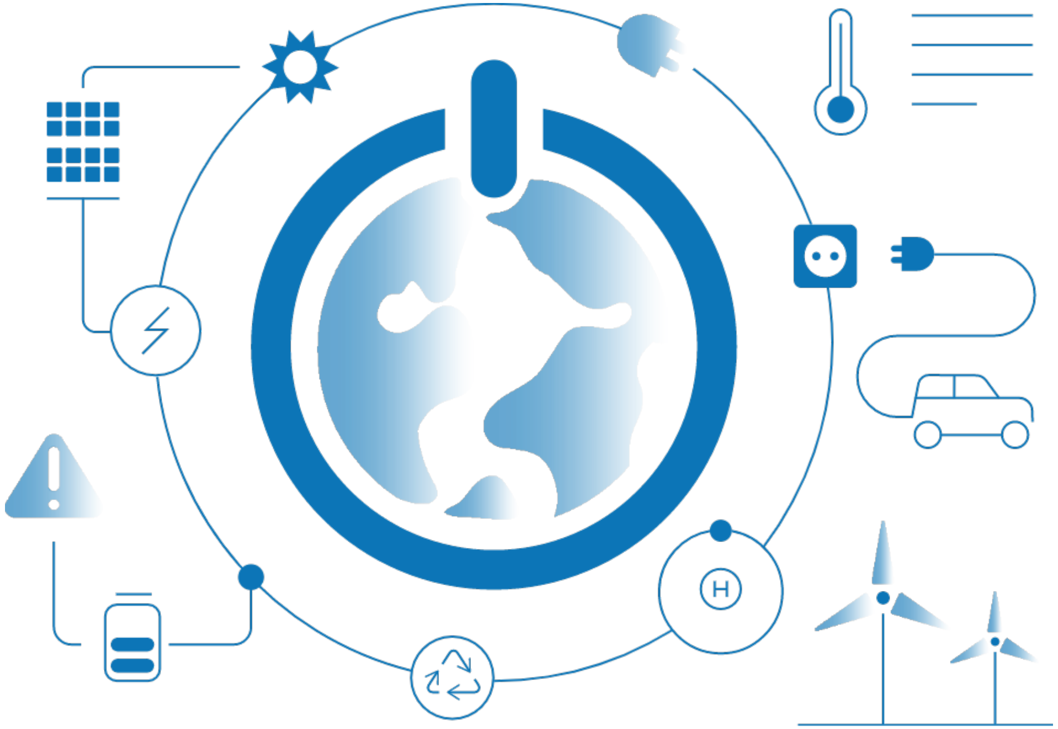
HYDROGEN

MAKE ENERGY TRANSITION SUSTAINABLE

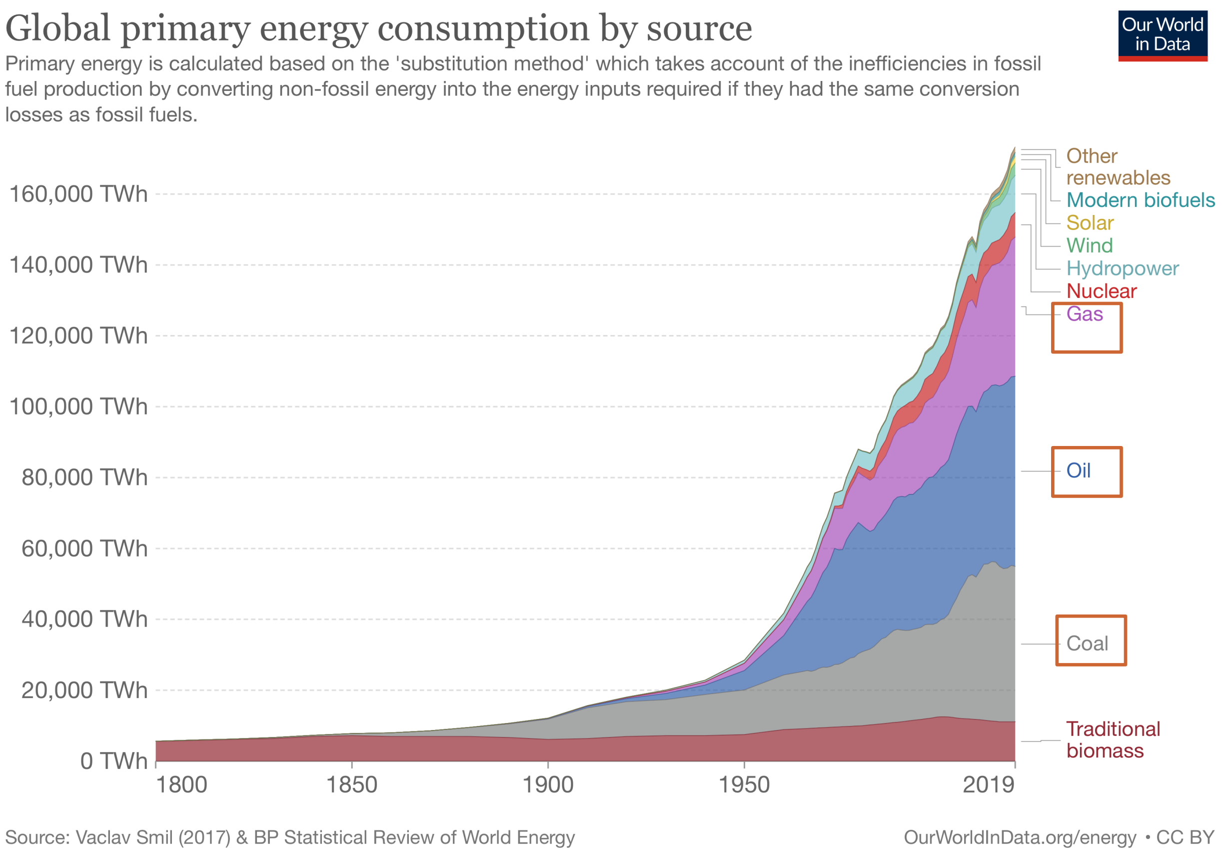
FINAL REMARKS

UFRJ

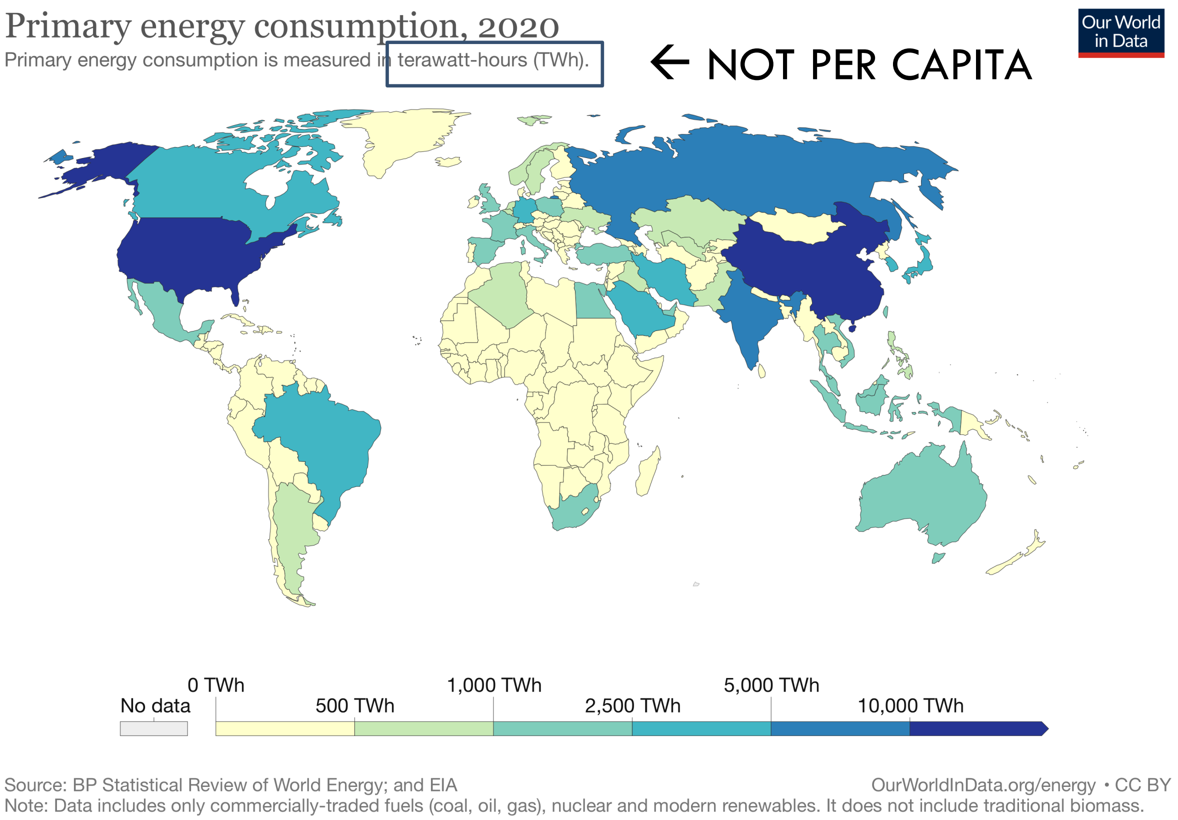
ENERGY TRANSITION



PRIMARY ENERGY CONSUMPTION



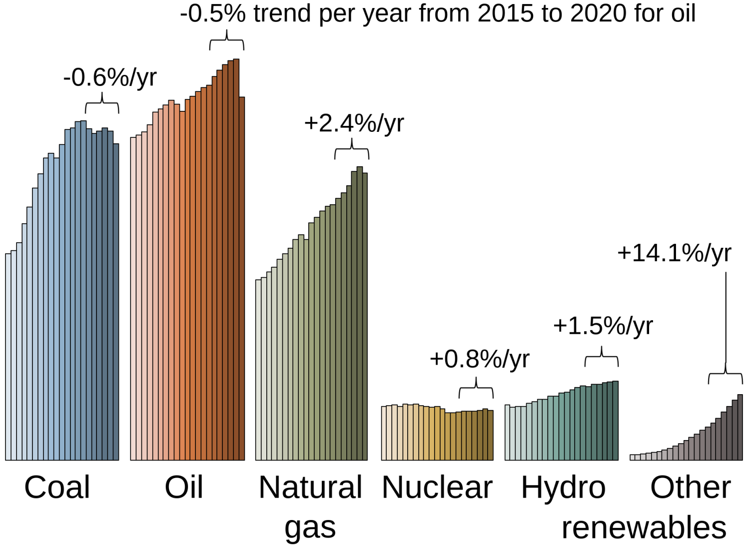
https://ourworldindata.org/energy-mix



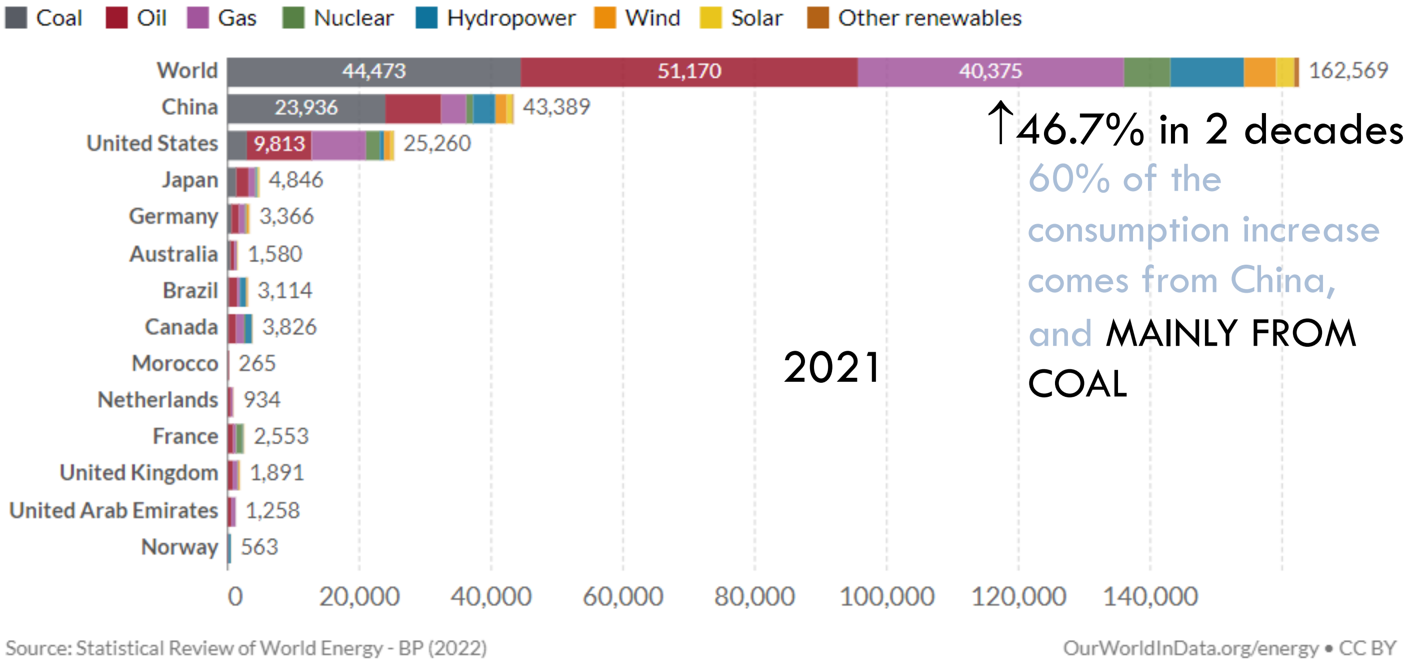
https://ourworldindata.org/explorers/energy?facet=none&country=USA~GBR~CHN~OWID_WRL~IND~BRA~ZAF&Total+or+Breakdown=Total&Energy+or+Electricity=Primary+energy&Metric=Annual+consumption

ENERGY SOURCES WITH CONSUMPTION'S EXPANSION

Global energy consumption, 2000 to 2020

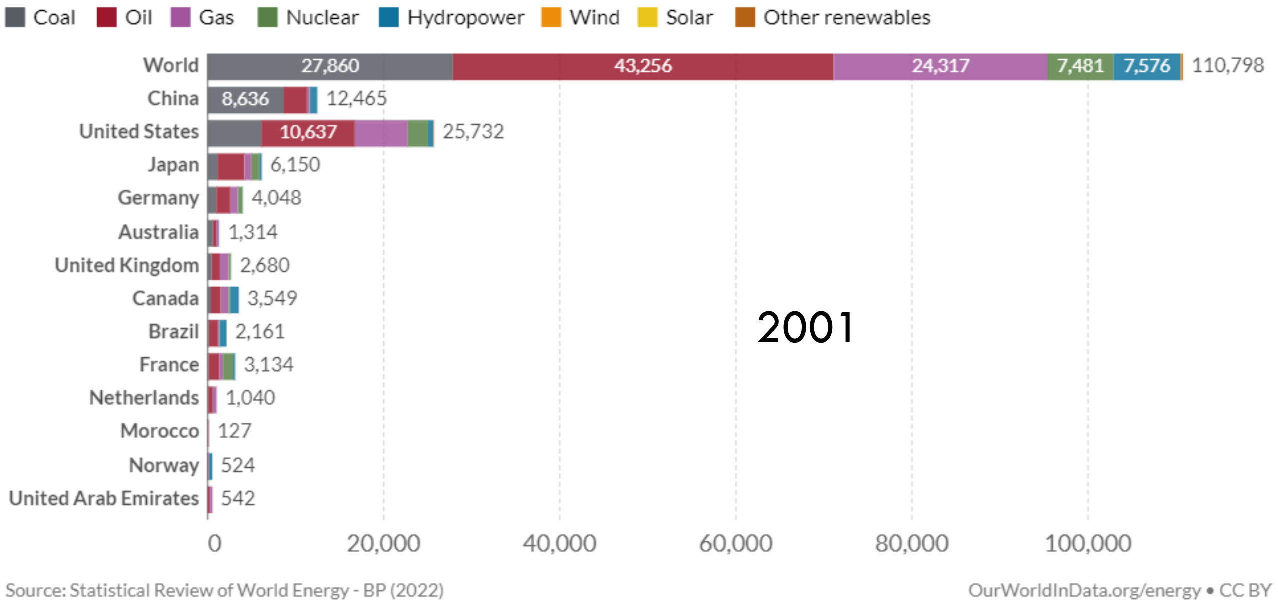


https://en.wikipedia.org/wiki/Climate_change_mitigation#/media/File:Global_Energy_Consumption.svg

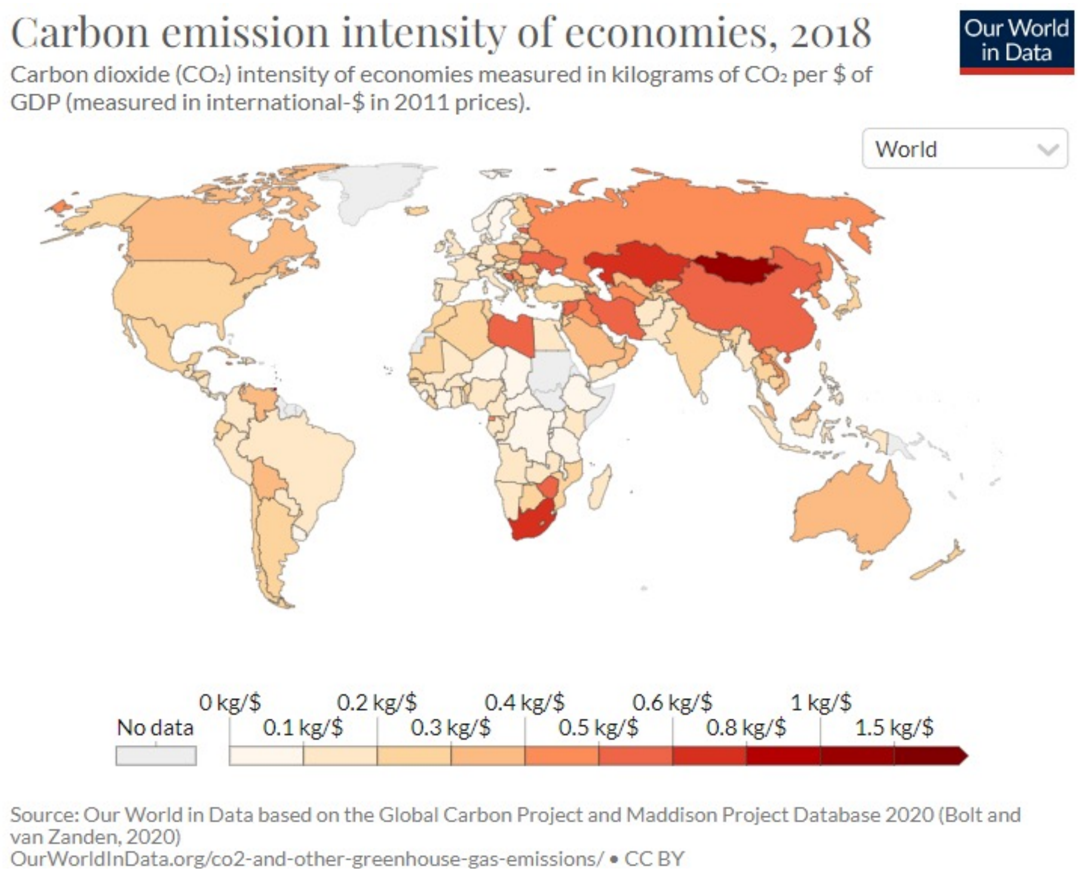


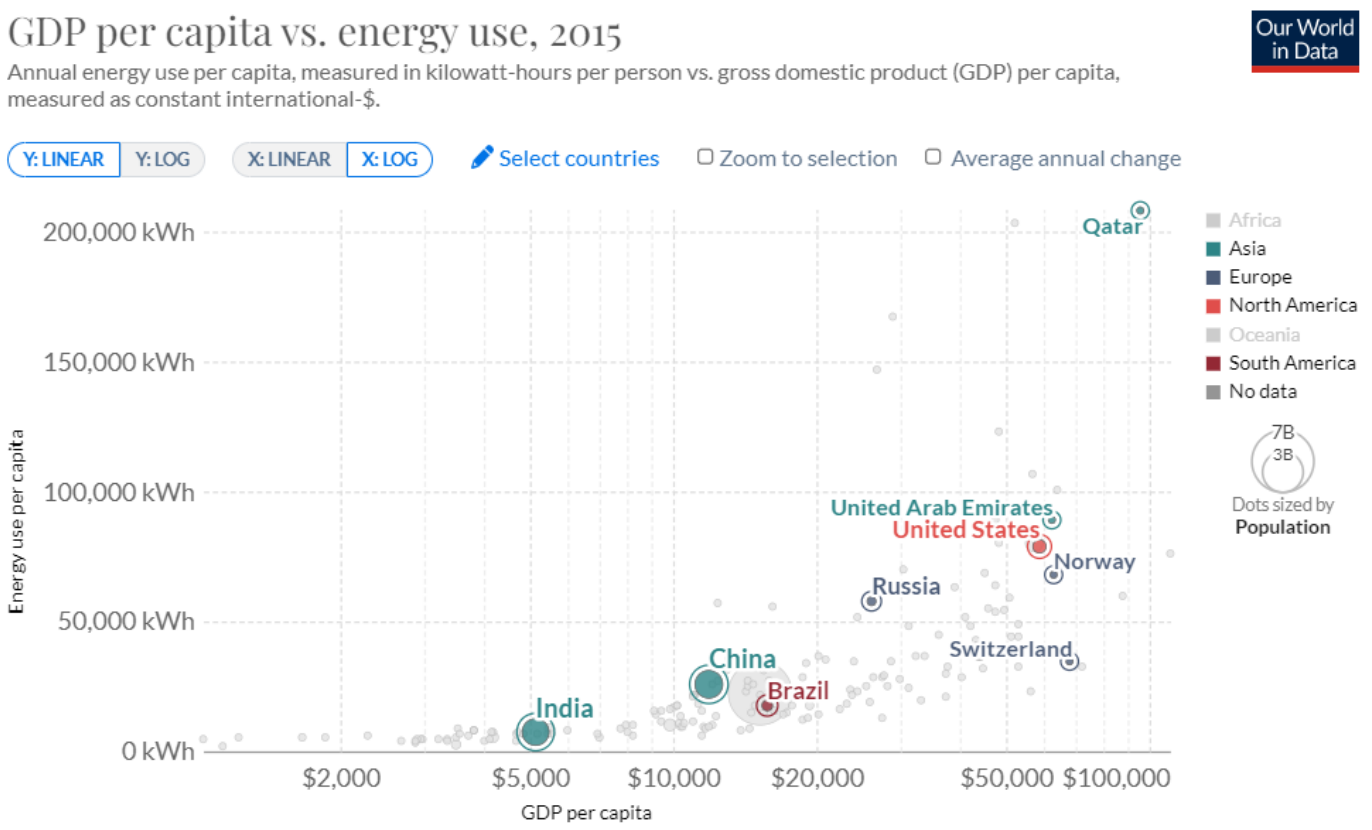
↑46.7% in 2 decades

60% of the consumption increase comes from China, and MAINLY FROM COAL



CARBON EMISSION INTENSITY: NEXUS ENERGY-GDP





$$\frac{CO_2}{GDP}$$

$$\frac{Energy}{GDP}$$

ECONOMY X ENERGY X CO2 EMISSIONS

The "Kaya identity" expresses global CO_2 emissions based on the main governing factors (Kaya, 1995):

F=P*(G/P)*(E/G)*(F/E)

F = global CO_2 emissions;
P = global population growth;
G = global GDP;
E = global energy consumption.

$$\frac{CO_2}{GDP} = \frac{Energy}{GDP} \times \frac{CO_2}{Energy}$$

per capita economic activity (G/P)

energy intensity (kWh/$) (E/G)

carbon intensity (kg CO_2/kWh) (F/E)

TECHNOLOGY → energy intensity, carbon intensity

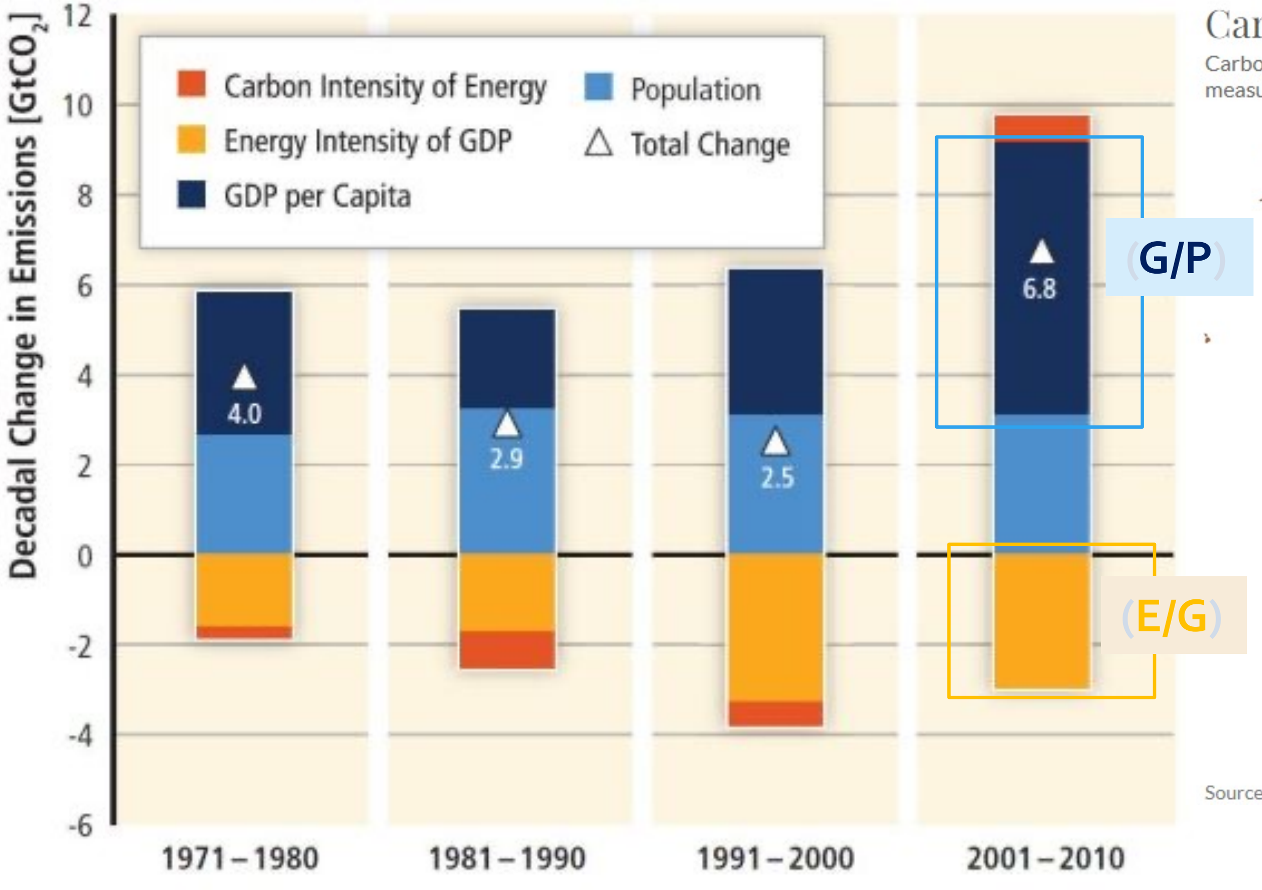
Reduce Carbon Intensity of Fossil Energy → TECHNOLOGY

Expand Renewable Share in Energy → TECHNOLOGY

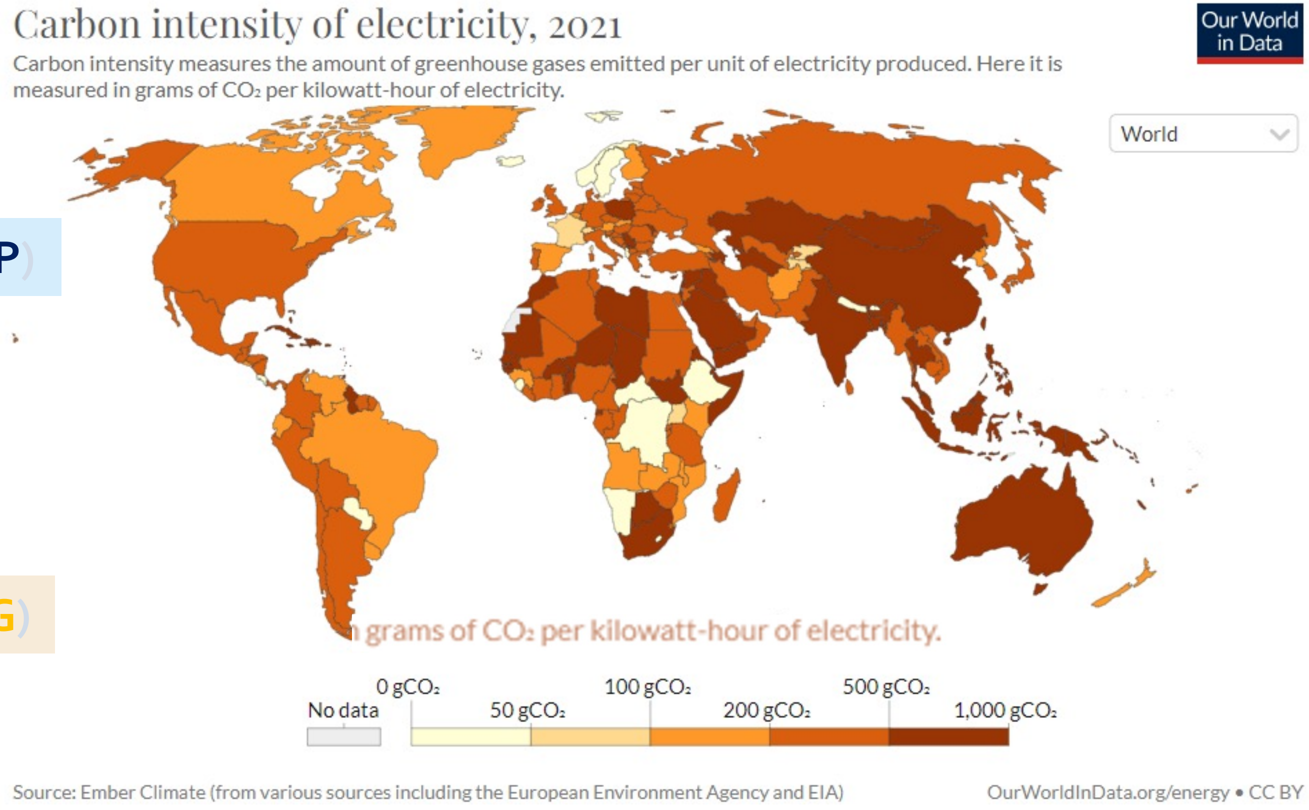
It´s not just science (technically feasible) but mainly of economic feasibility at the demanded scale!

CARBON INTENSITY OF ELECTRICITY

F= P*(G/P)*(E/G)*(F/E)



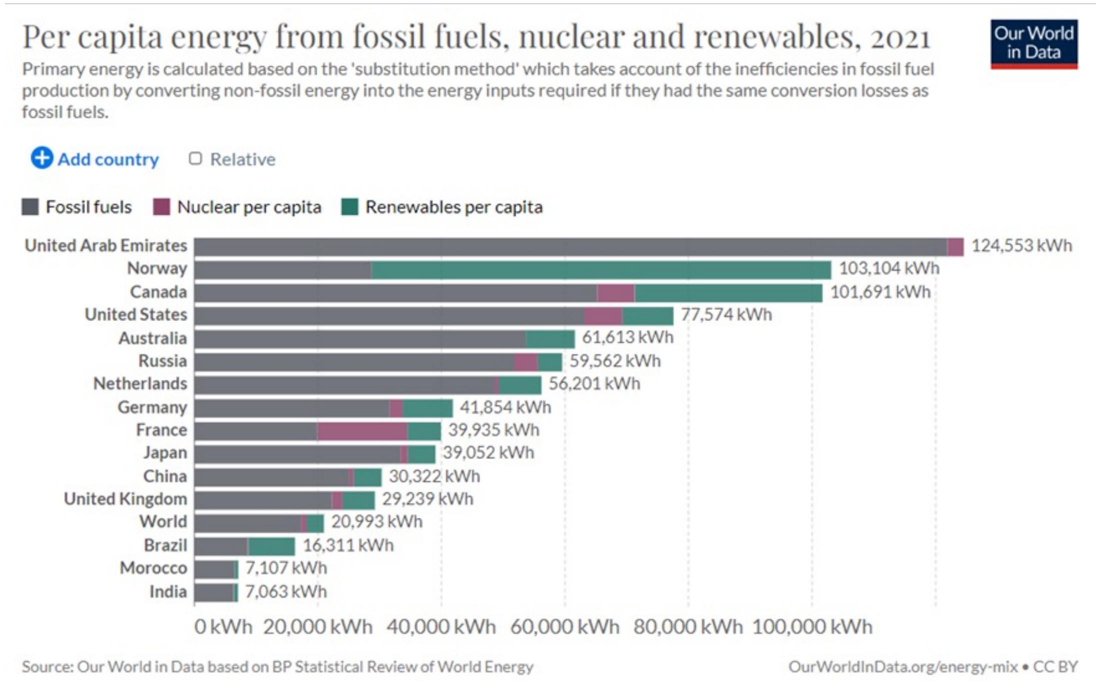
https://onclimatechangepolicydotorg.wordpress.com/policy-context-2/2-the-elements-of-the-emissions-reduction-challenge/

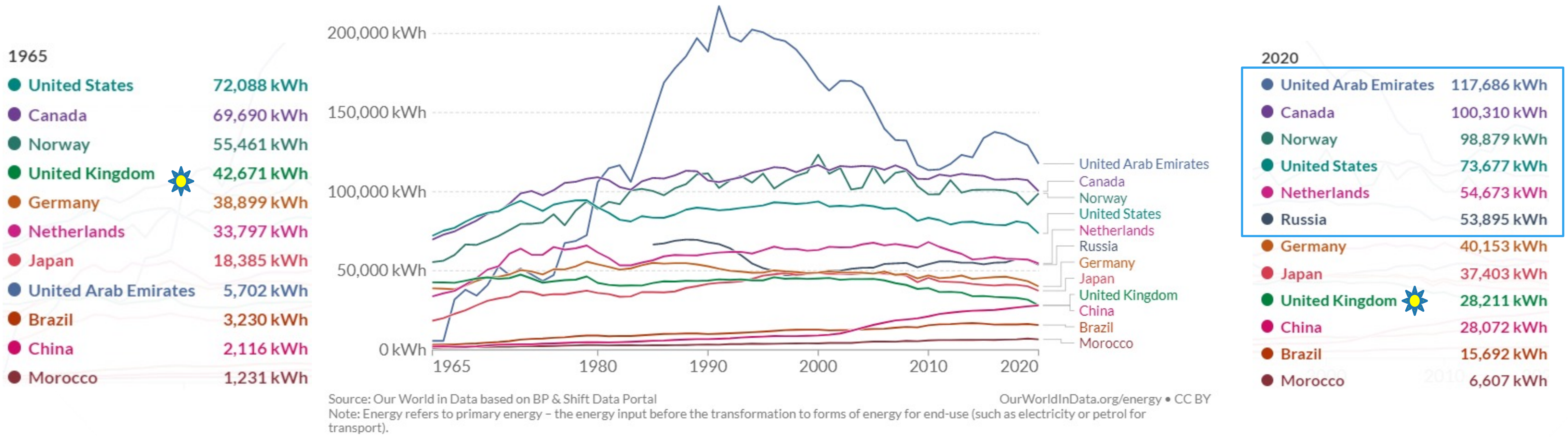


https://ourworldindata.org/grapher/carbon-intensity-electricity

$(G/P)*(E/G)$

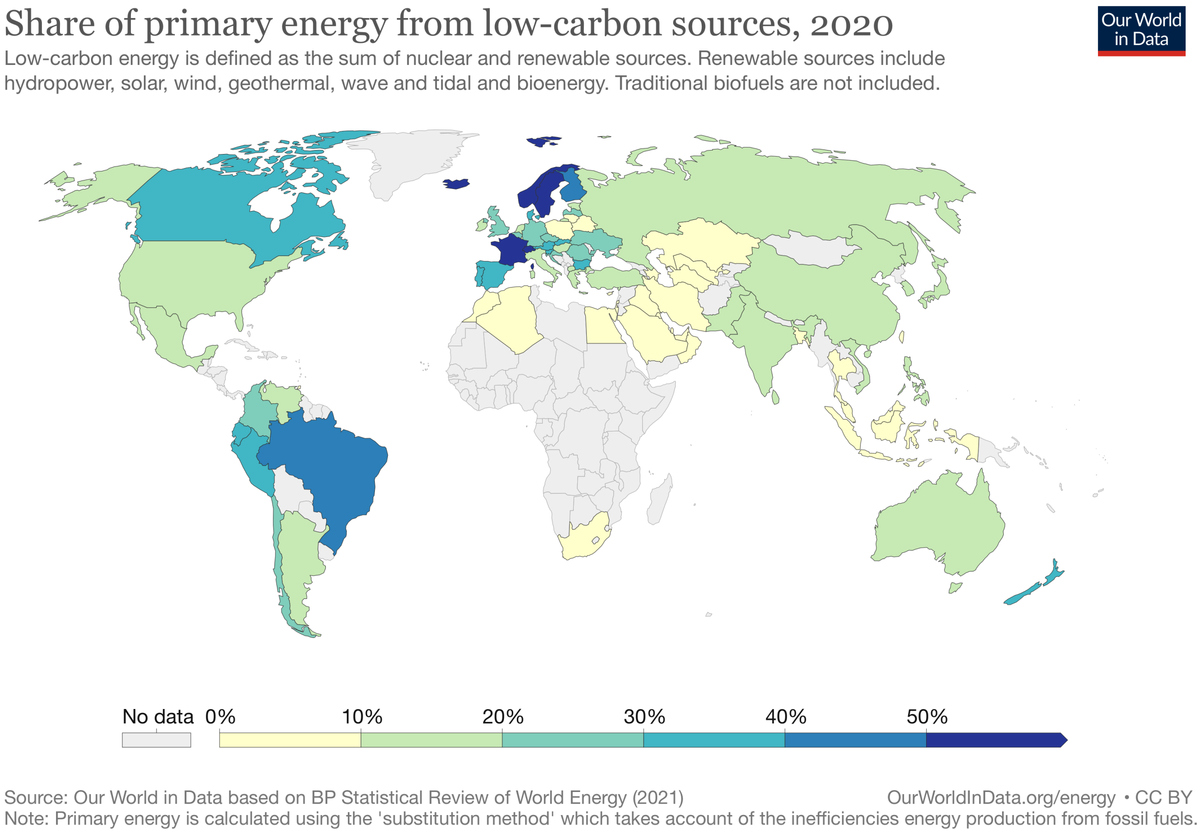
ENERGY USE PER PERSON

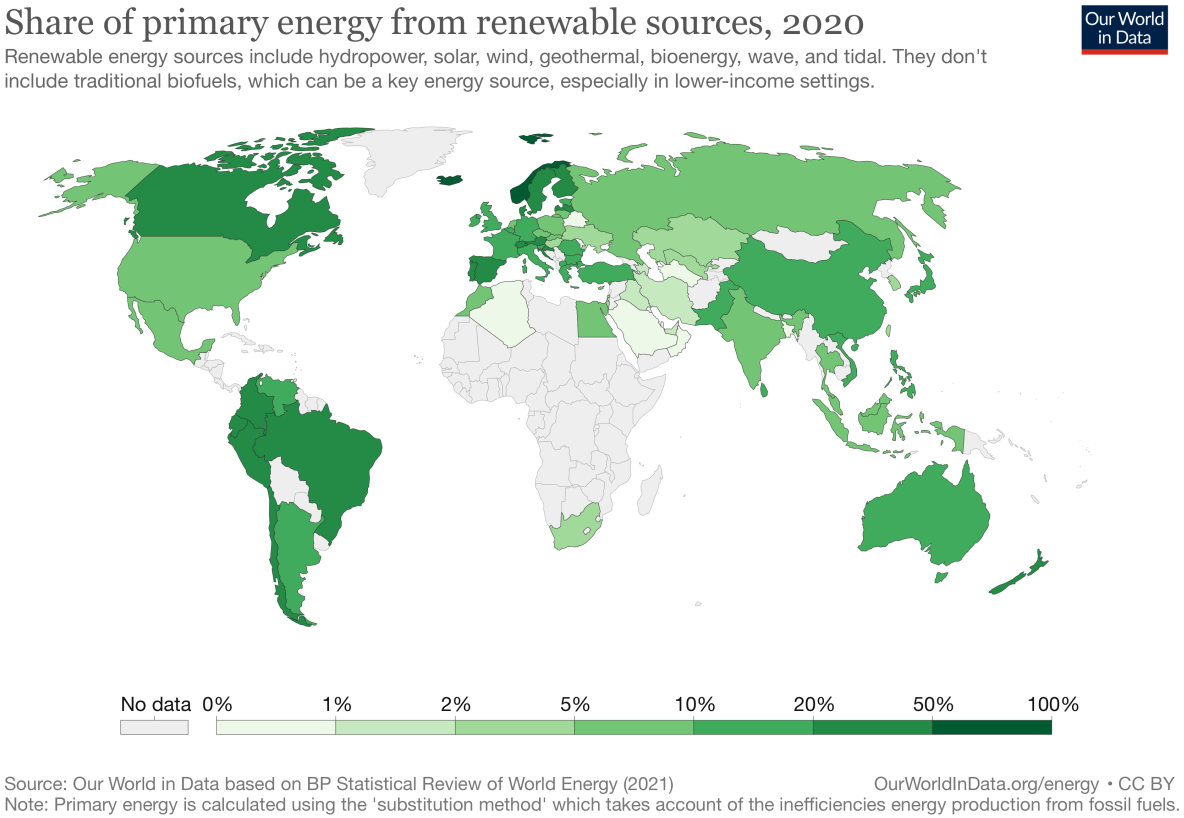




https://ourworldindata.org/energy-key-charts

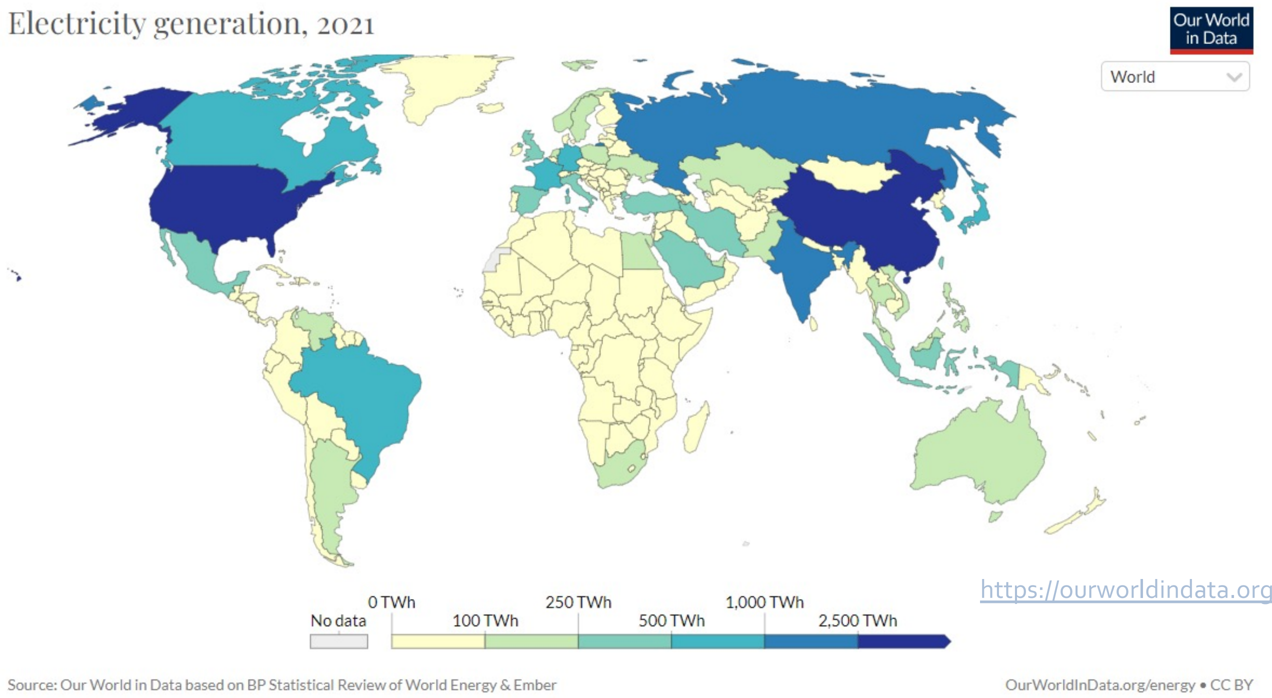
SHARE OF LOW-CARBON ENERGY SOURCES



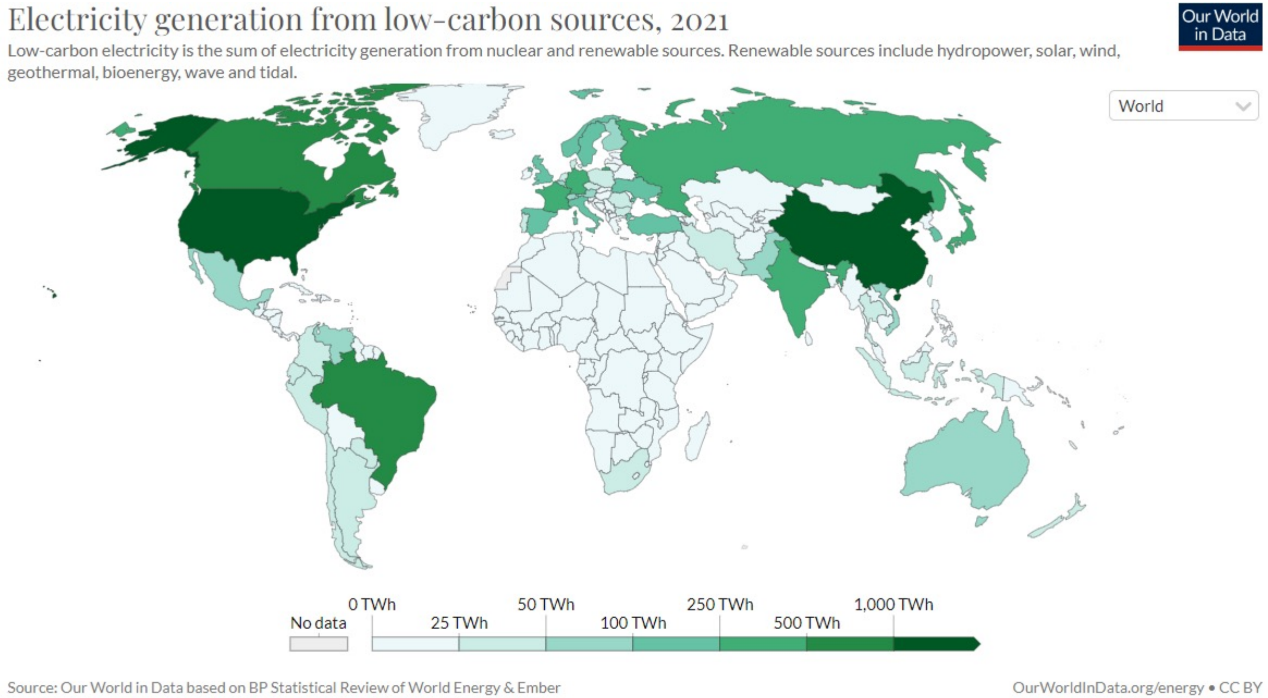


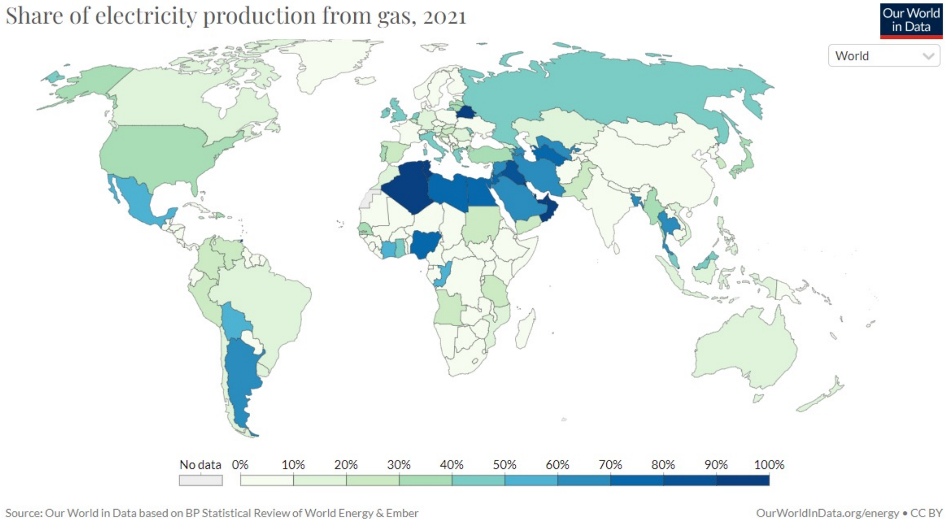
https://ourworldindata.org/energy-key-charts

ELECTRICITY GENERATION

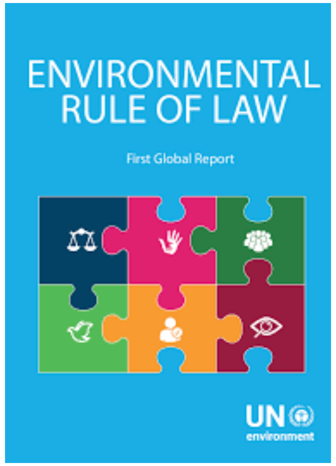


https://ourworldindata.org/energy-key-charts





CARBON BUDGET TIMING ENERGY TRANSITION

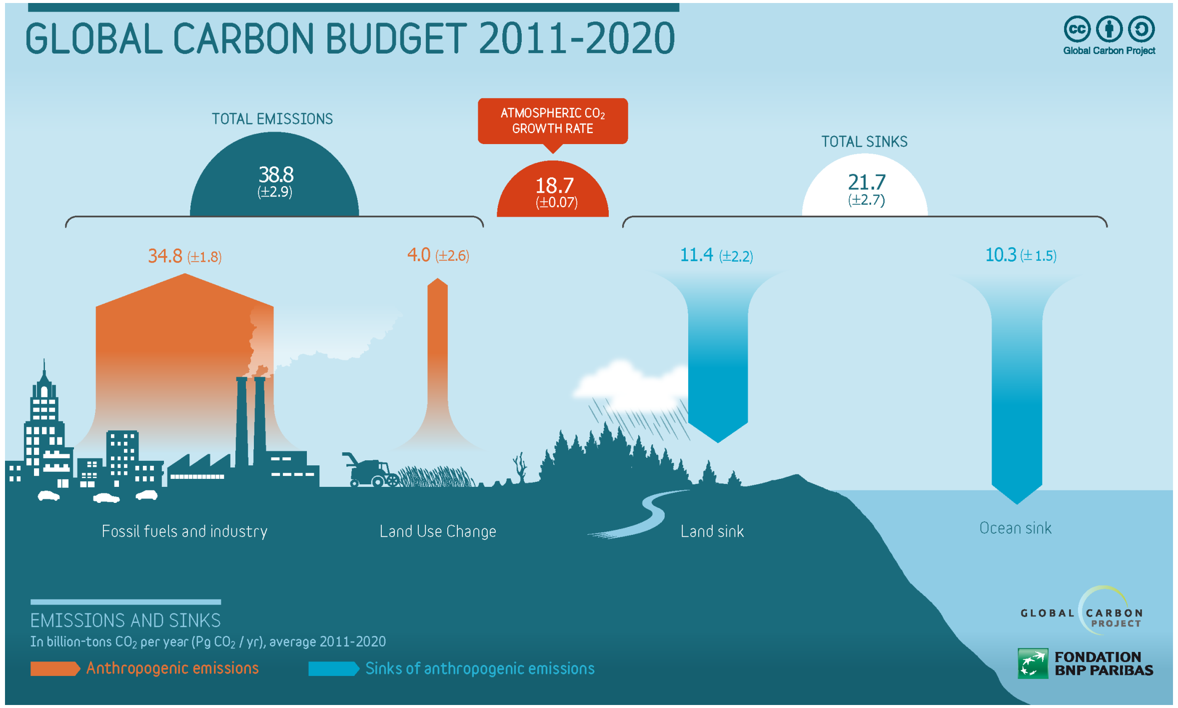


CARBON BUDGET

BAU	3°C Warming	2°C Warming
763 Gt CO_2	319 Gt CO_2	225 Gt CO_2

SOURCE: WUPPERTAL INSTITUT | 80% CHANCE OF ATTAINING GOAL

https://www.power-and-beyond.com/what-is-renewable-energy-definition-types-and-challenges-a-1027368/



http://www.globalcarbonatlas.org/en/content/global-carbon-budget

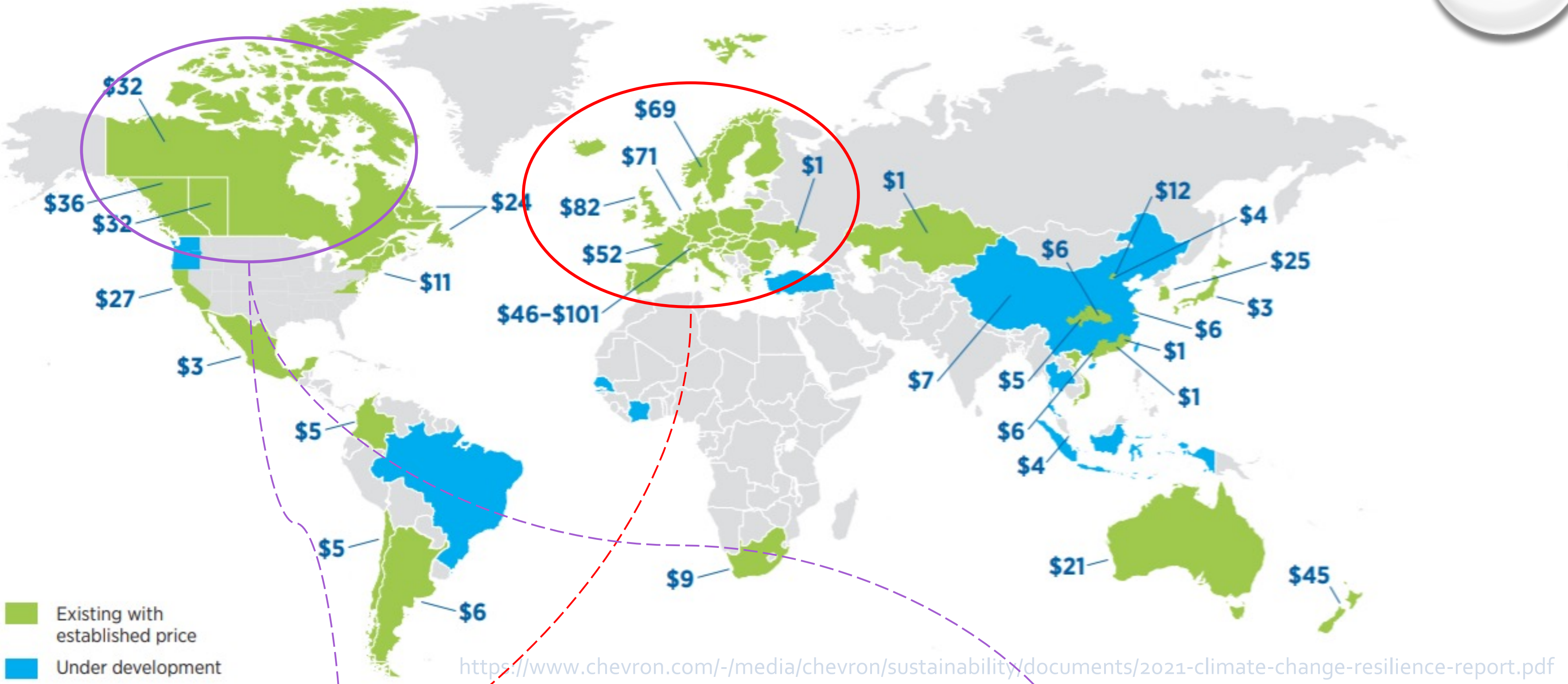
SHORT TO MID -TERM TRANSITION (BROWNFIELD)

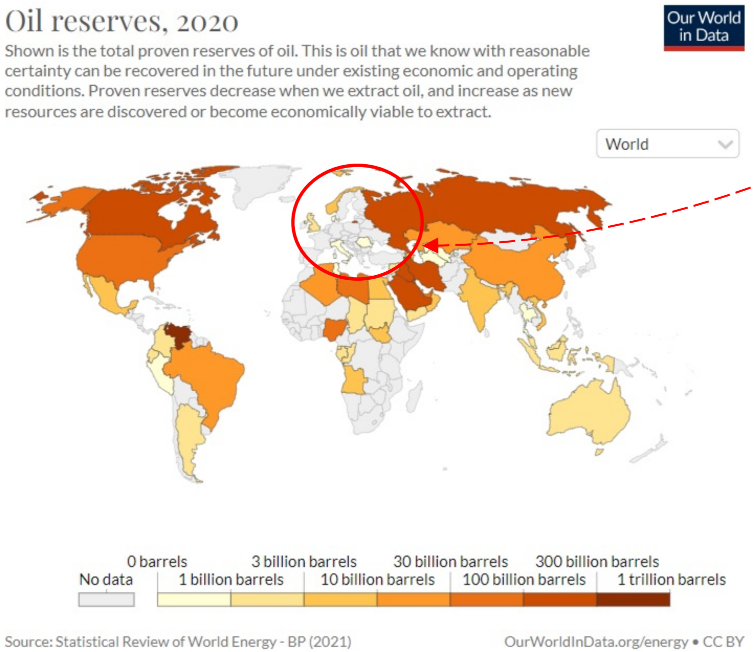
- ❑ Energy efficiency
- ❑ Anthropic CO2 sinks: CCS, CCU, BECCS

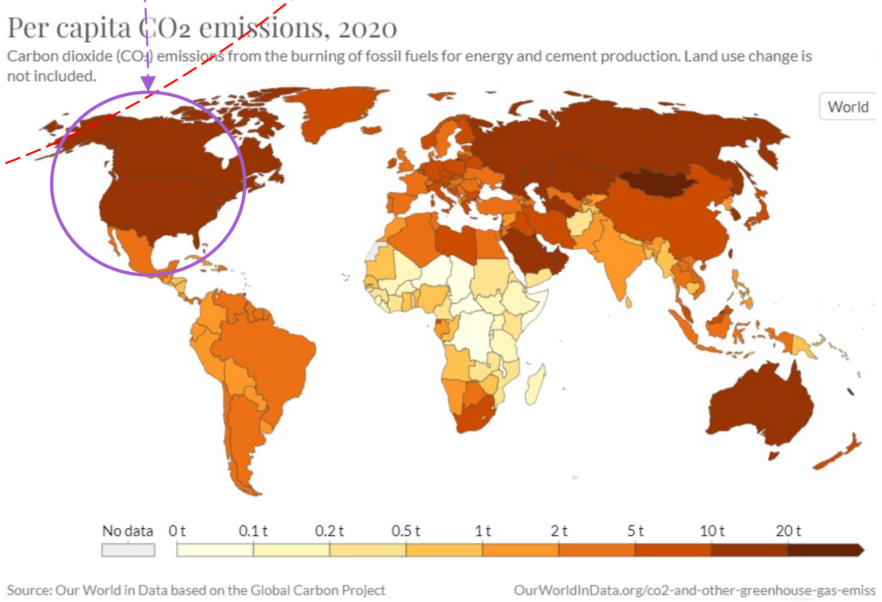
LONG-TERM TRANSITION (GREENFIELD)

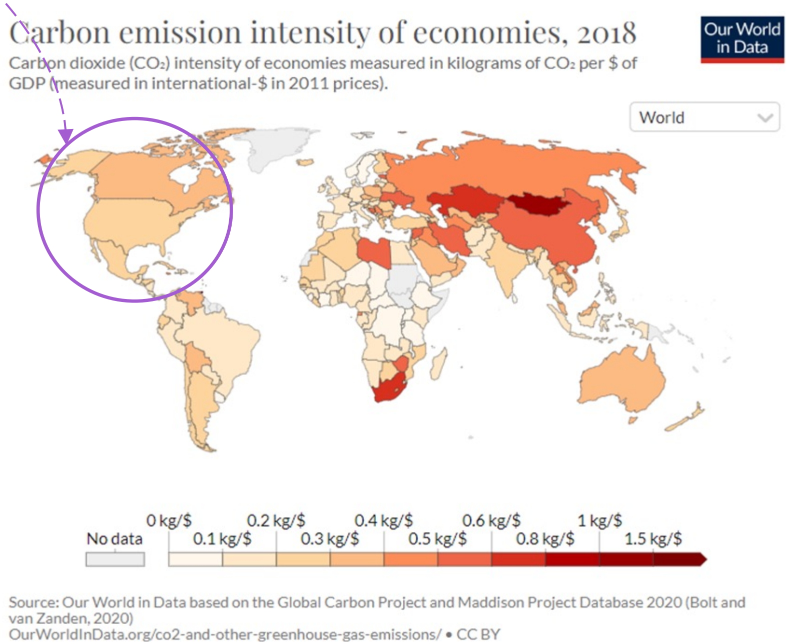
- ❑ Substitution
- ❑ Electrification
- ❑ CDR (CARBON DIOXIDE REMOVAL)

CARBON PRICING

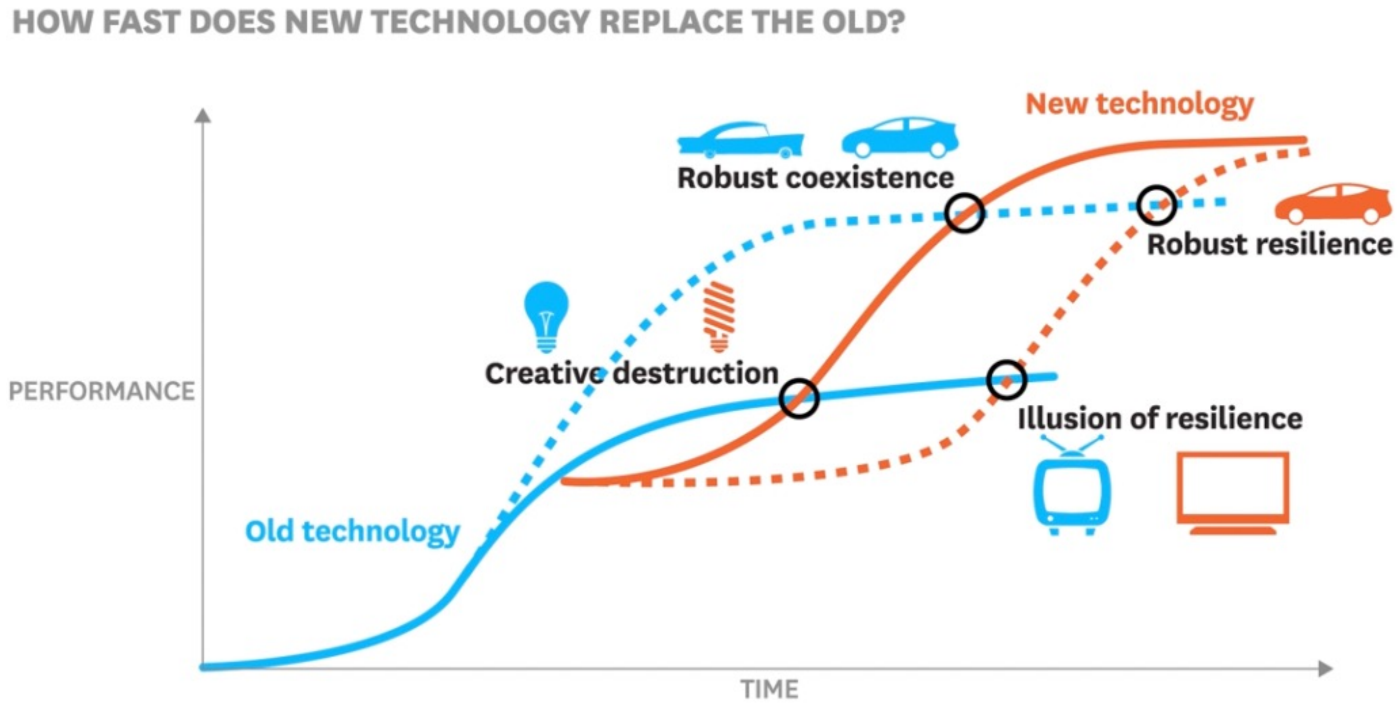




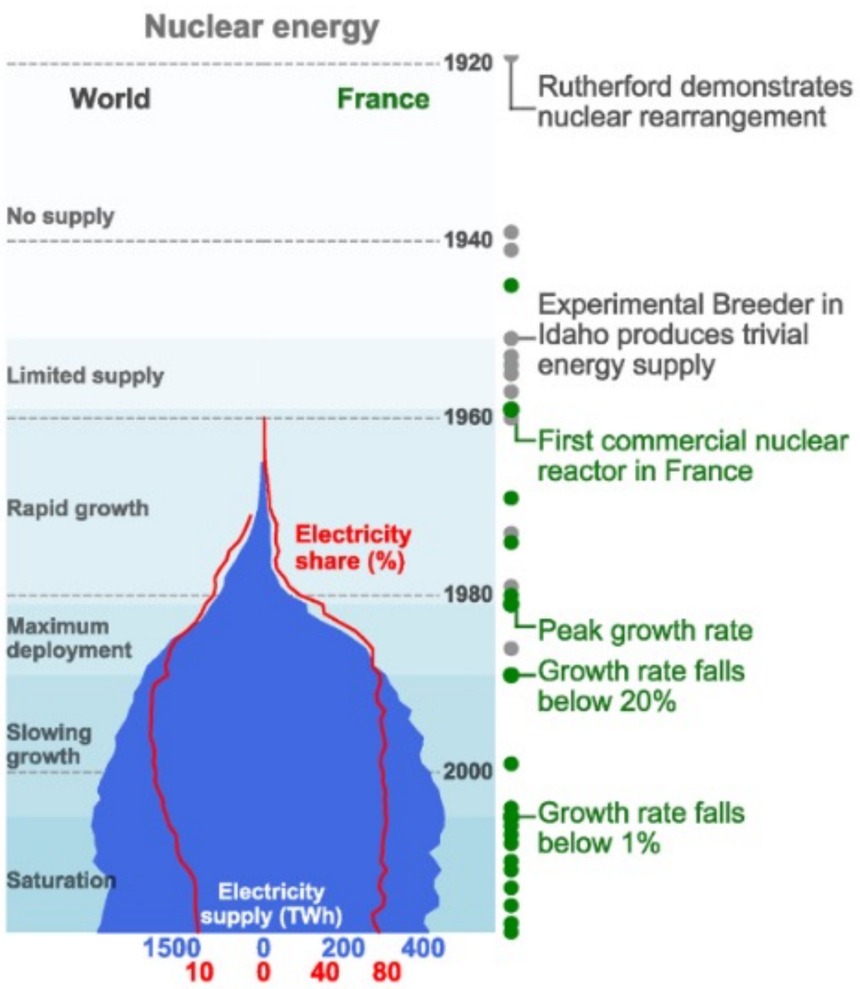




TRANSITIONS TAKE TIME

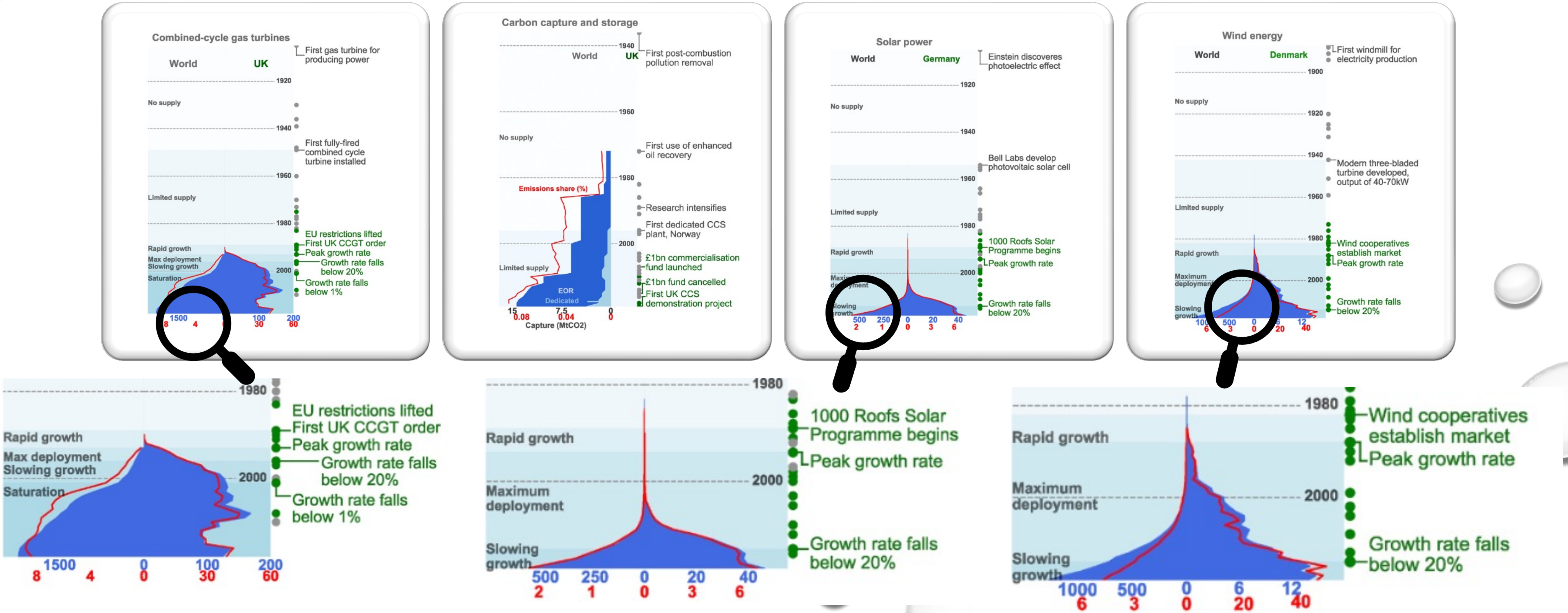


https://hbr.org/2016/11/right-tech-wrong-time



https://doi.org/10.1016/j.enpol.2021.112155

TRANSITIONS TAKE TIME



https://doi.org/10.1016/j.enpol.2021.112155

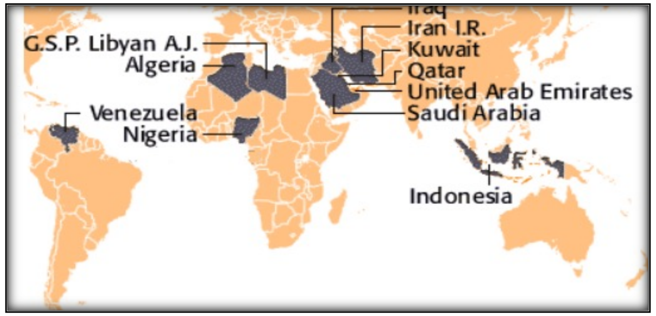
FOSSIL RESERVES

https://www.gov.br/anp/pt-br/canais_atendimento/imprensa/noticias-comunicados/reservas-provadas-de-petroleo-no-brasil-crescem-11-em-2021

Old-dated geopolitics.

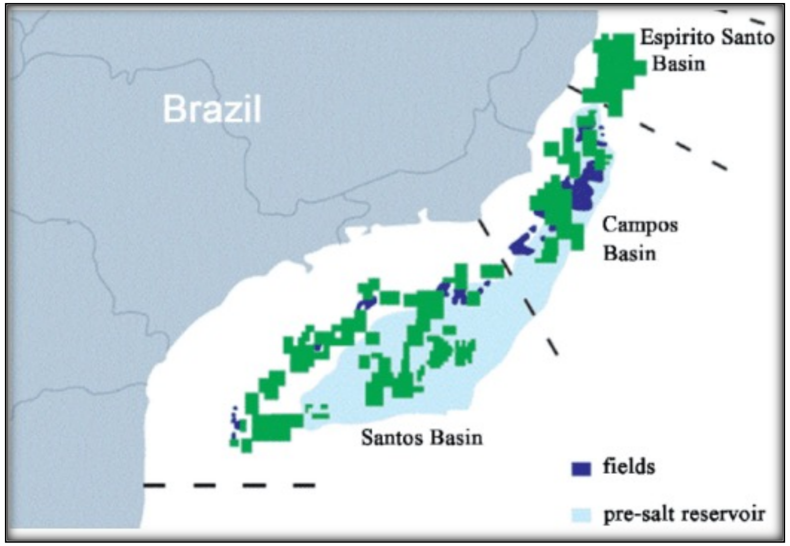
Rank	Country	Barrels (bbl)
1	Venezuela	298,400,000,000
2	Saudi A.	268,300,000,000
3	Canada	171,000,000,000
4	Iran	157,800,000,000
5	Iraq	144,200,000,000
6	Kuwait	104,000,000,000
7	Russia	103,200,000,000
8	UAE	97,800,000,000
9	Libya	48,360,000,000
10	Nigeria	37,070,000,000
11	United States	36,520,000,000
12	Kazakhstan	30,000,000,000
13	Qatar	25,240,000,000
14	China	24,650,000,000
15	**Brazil**	**15,310,000,000**
16	Algeria	12,200,000,000
17	Guyana	10,000,000,000
18	Mexico	9,812,000,000
19	Angola	9,011,000,000
20	Ecuador	8,832,000,000

-country/



https://oilnow.gy/featured/petrobras-makes-new-oil-find-in-campos-basin/

PROVEN RESERVES + PROBABLE + POSSIBLE (3P) = **24 billions boe**



https://oilnow.gy/featured/brazil-to-increase-oil-production-by-300000-barrels-per-day-this-year-ami/

BUZIOS

Ganha o leilão quem oferecer o maior percentual de óleo-lucro, ou seja, a empresa que aceitar destinar à União a maior parcela de seu lucro na exploração do campo

A Petrobras já exerceu o direito de preferência e será operadora nas áreas de Búzios e Itapu

Área leiloada	Poços já perfurados	Produção atual	Bônus que será pago no leilão	Alíquota mínima do lucro que as empresas terão que destinar ao governo
Área de Sépia	7 poços	Sem produção ainda	**R$ 22,859 bilhões**	27,88%
Área de Atapu	12 poços	Sem produção ainda	**R$ 13,742 bilhões**	26,23%
Área de Itapu	3 poços	Sem produção ainda	**R$ 1,766 bilhões**	18,15%
Área de Búzios	54 poços	424 milhões barris de petróleo por dia*	**R$ 68,194 bilhões**	23,24%

Sobre Búzios
É o segundo maior campo produtor do país e a área mais atrativa do leilão

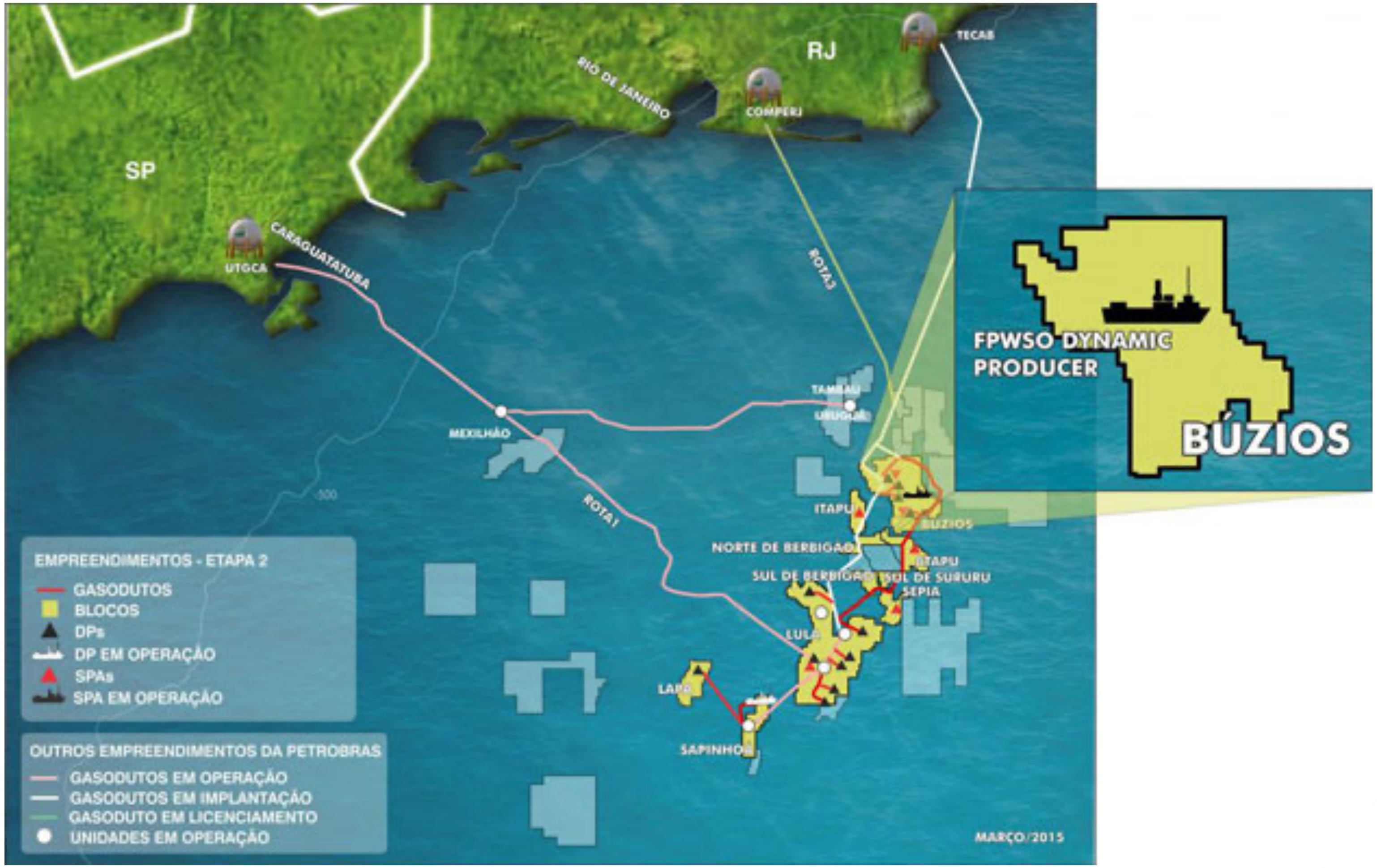
10 bilhões de barris de petróleo é a reserva estimada, o que pode fazer deste o sétimo maior campo no mar do mundo**

https://oglobo.globo.com/economia/buzios-com-potencial-para-ser-setimo-maior-campo-em-mar-do-mundo-a-estrela-do-megaleilao-1-24063878

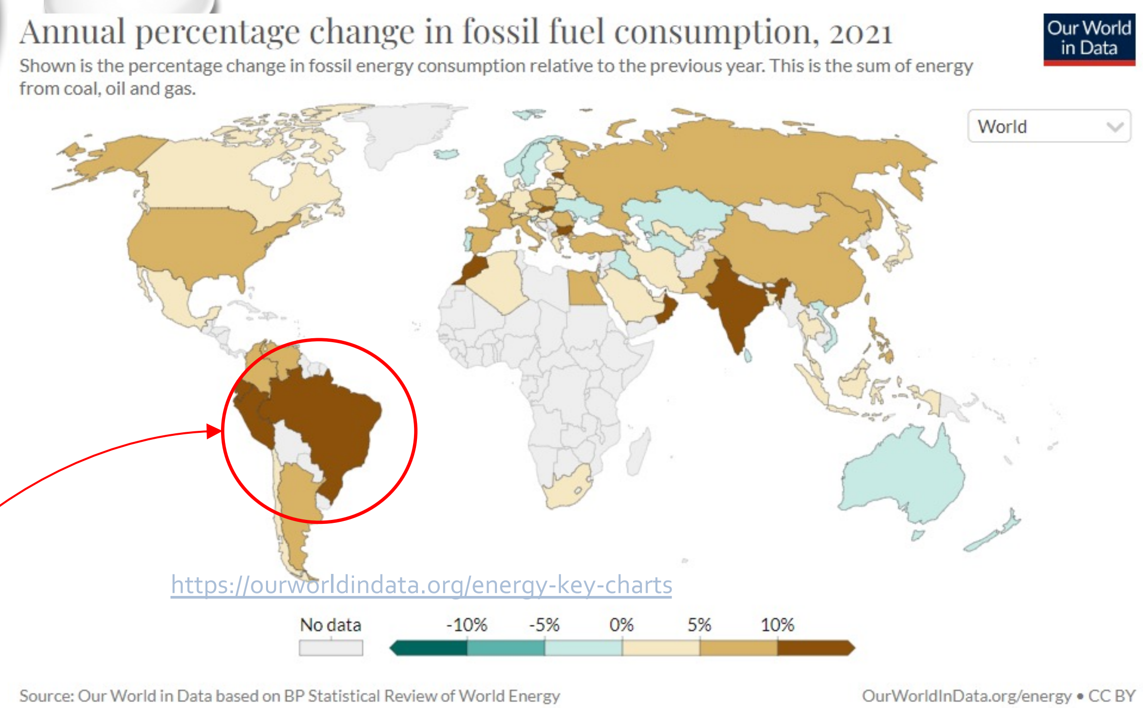
*Critério boe (barril de óleo equivalente, que inclui gás e petróleo)
**Estimativas da Wood Mackenzie

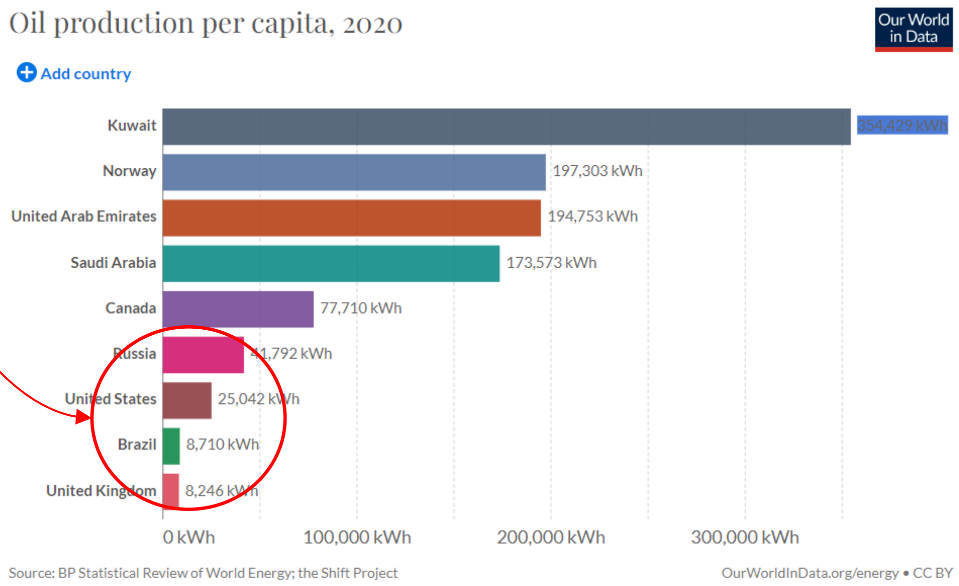
Fonte: ANP

O GLOBO



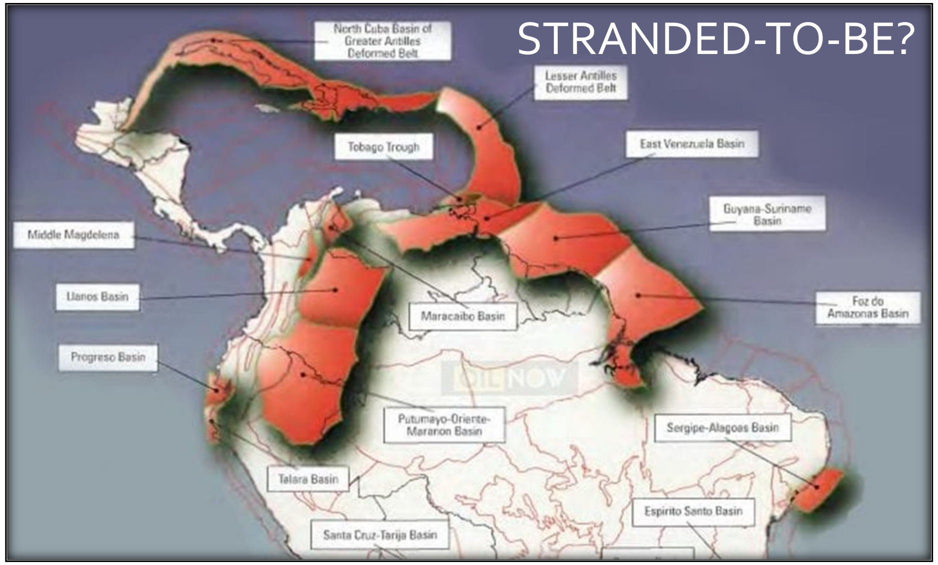
BUZIOS + ITAPU + ATAPU + SEPIA = 15 billion boe = 80% NORWEGIAN OIL RESERVES



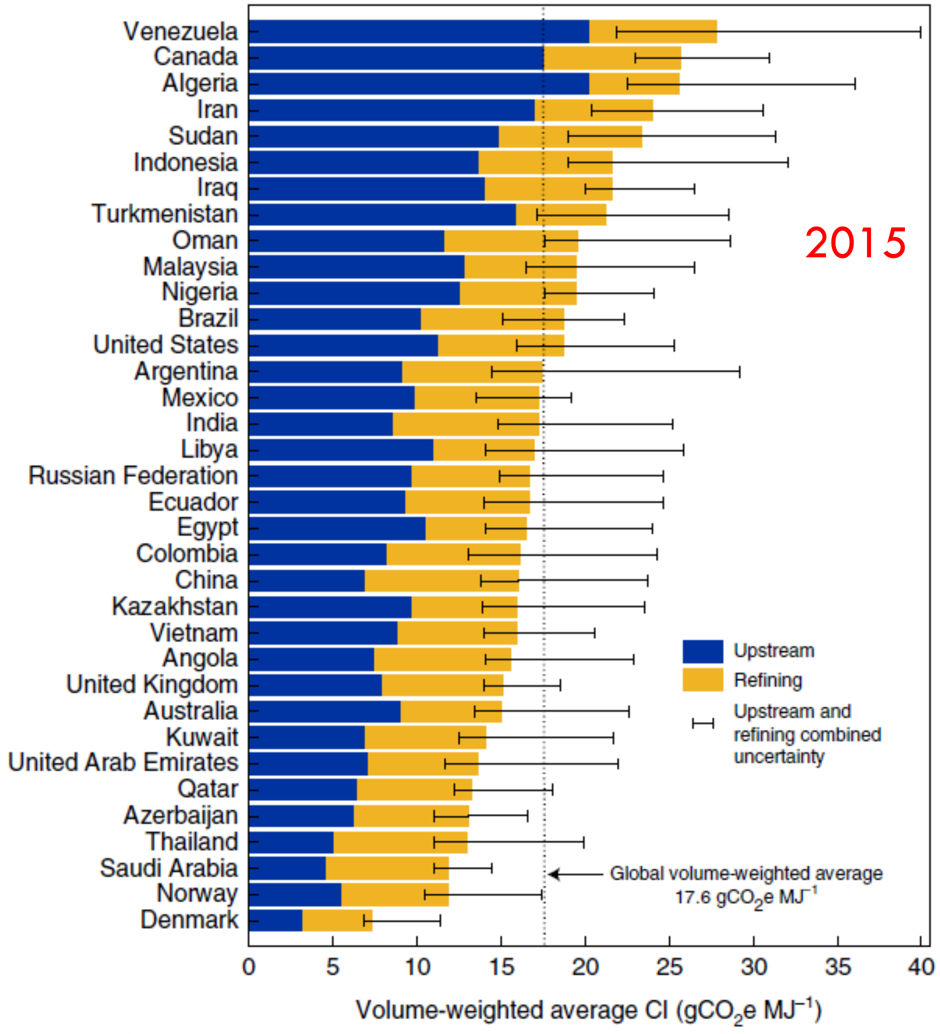


https://ourworldindata.org/grapher/oil-prod-per-capita?country=USA~SAU~KWT~CAN~RUS~ARE~BRA~NOR~GBR~DEU~NLD~JPN

FOSSIL RESOURCES



(UP, MID AND DOWNSTREAM (SCOPE 3) EMISSIONS: O&G HAVE DISTINCT CARBON INTENSITIES (CI)



Nature Climate Change, https://doi.org/10.1038/s41558-020-0775-3

$F=P*(G/P)*(E/G)*(F/E)$

=> 1g CO2 / MJ = 6 kg CO_2 / bbl (1bbl ≡ 6000MJ)

Canada O&G emits ~160 kg CO_2 / bbl (2015)

Brazil O&G emits ~120 kg CO_2 / bbl (2015)

Global average is **~100 kg CO_2 / bbl** (2015)

Nature Climate Change, https://doi.org/10.1038/s41558-020-0775-3

Present CI in the Brazilian E&P: **20 - 30 kg CO_2 / bbl.**

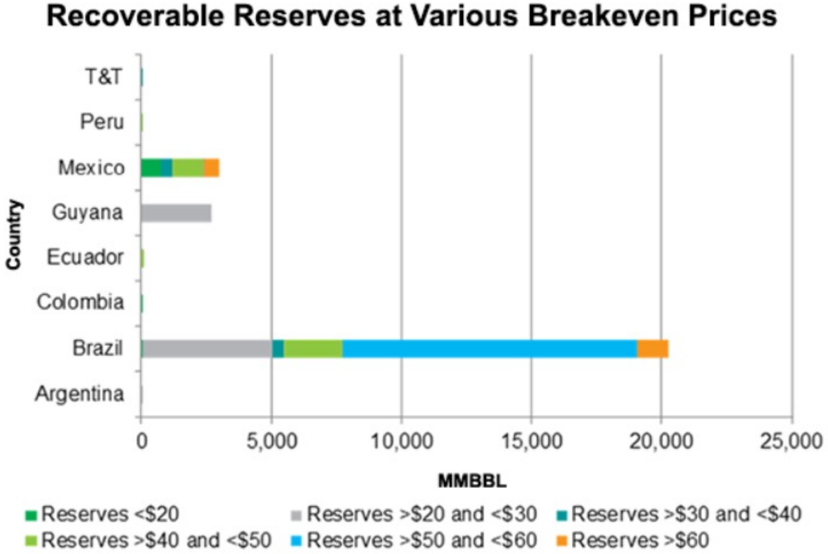
PETROBRAS targets **15 kg CO_2 / bbl** by 2030.

EQUINOR targets **6 kg CO2 / bbl** by 2030

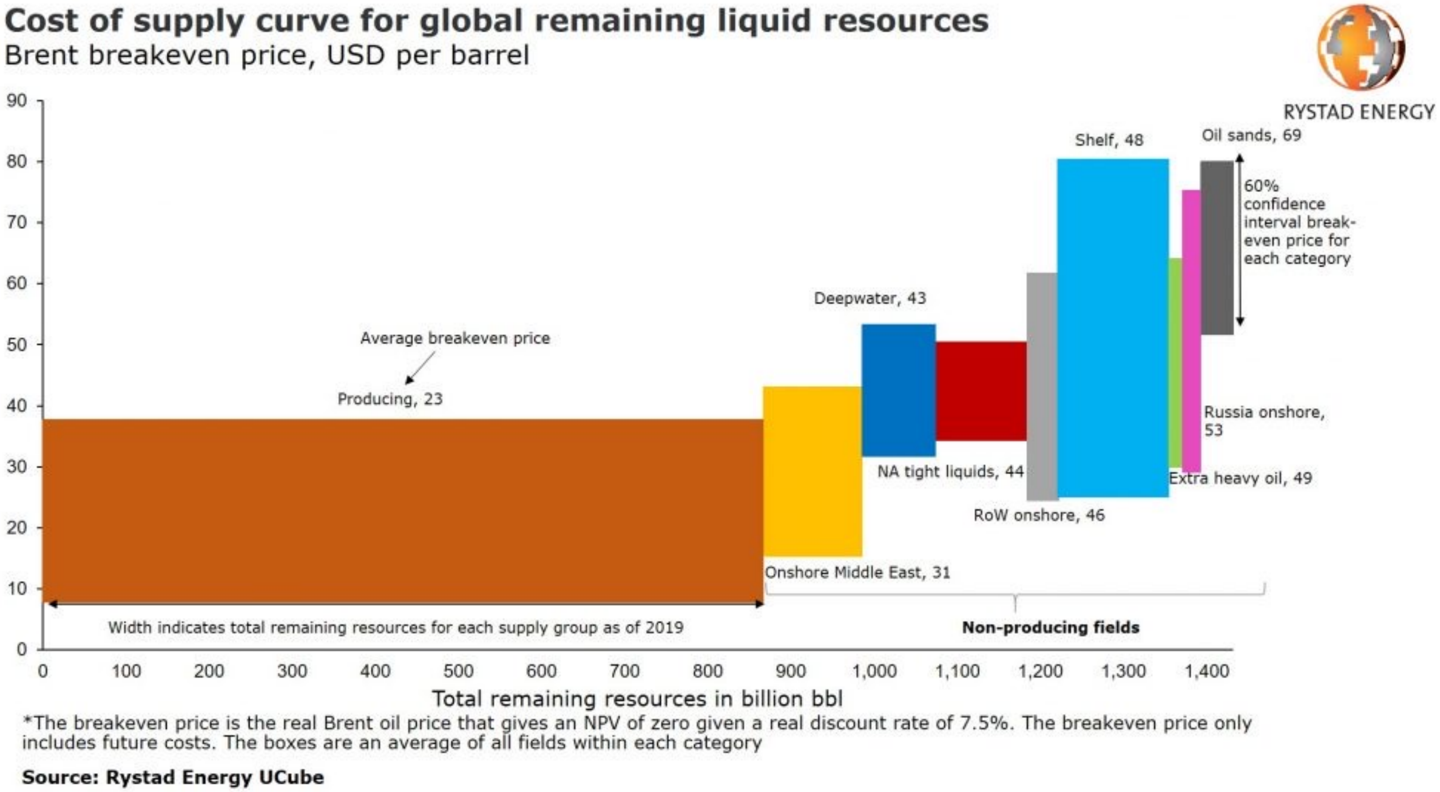
https://www.udop.com.br/noticia/2021/11/25/o-que-as-petroleiras-estao-fazendo-para-descarbonizar-o-pre-saly.html

O&G RESERVES

Offshore: cost improvements and supply potential.

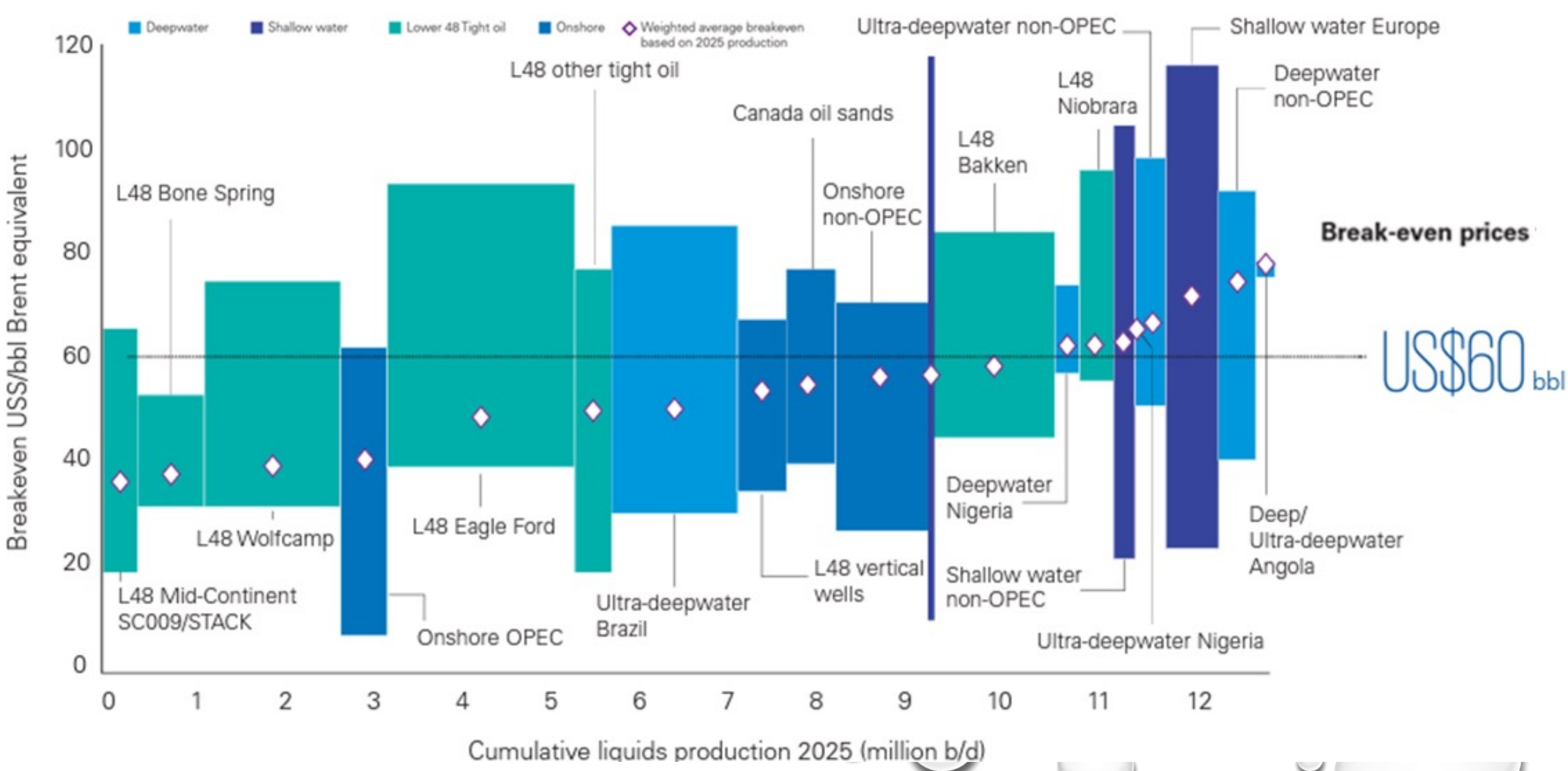


https://www.naturalgasintel.com/latin-american-oil-gas-exploration-expected-to-be-slammed-by-low-price-environment/



https://www.offshore-energy.biz/offshore-deepwater-oil-production-one-of-cheapest-sources-of-new-supply-as-costs-reach-new-low-rystad-says/

O&G RECOVERABLE RESERVES

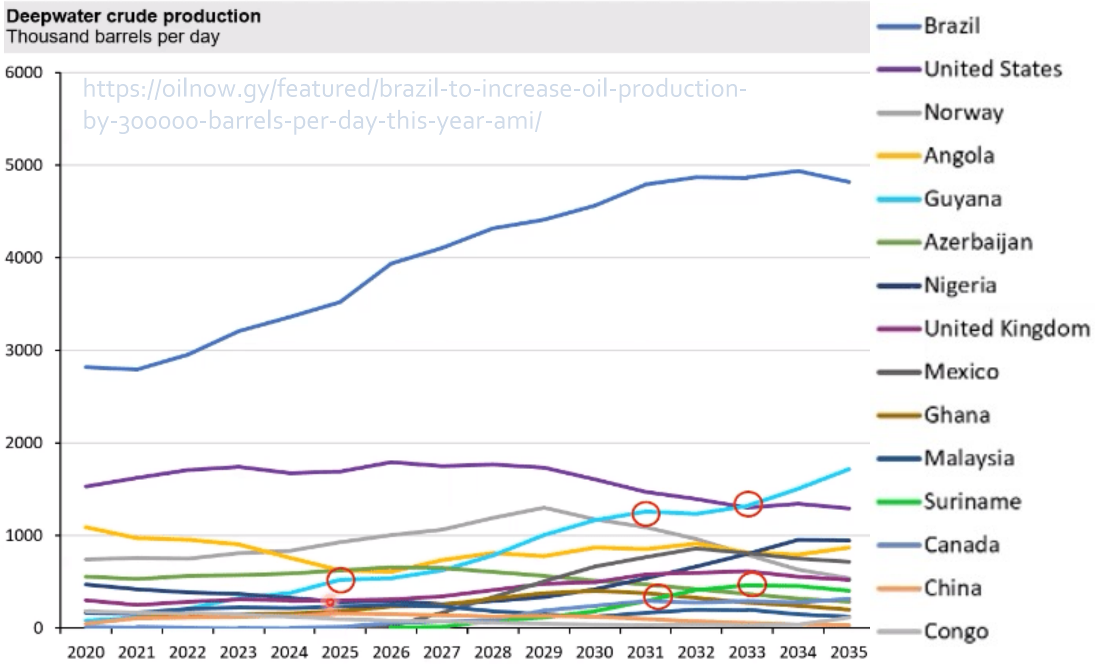


https://assets.kpmg/content/dam/kpmg/xx/pdf/2017/12/delivering-long-term-value-in-e-and-p.pdf

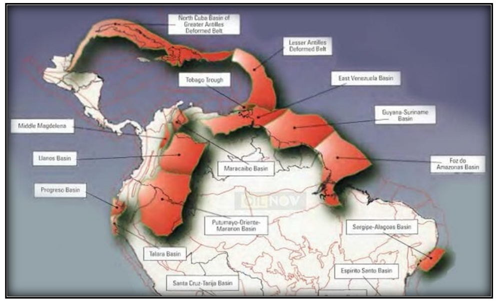
OPEC … & LATIN AMERICA

"The IEA now predicts crude consumption will reach 99.53 million barrels per day in 2022, up from 96.2 million this year, and more or less back to pre-pandemic levels. Consequently, carbon emissions are on track to rise by 16 percent by 2030 according to the UN, rather than fall by half, the reduction required to keep global warming below the Paris Agreement limit of 1.5C."

https://www.arabnews.com/node/1997051/business-economy



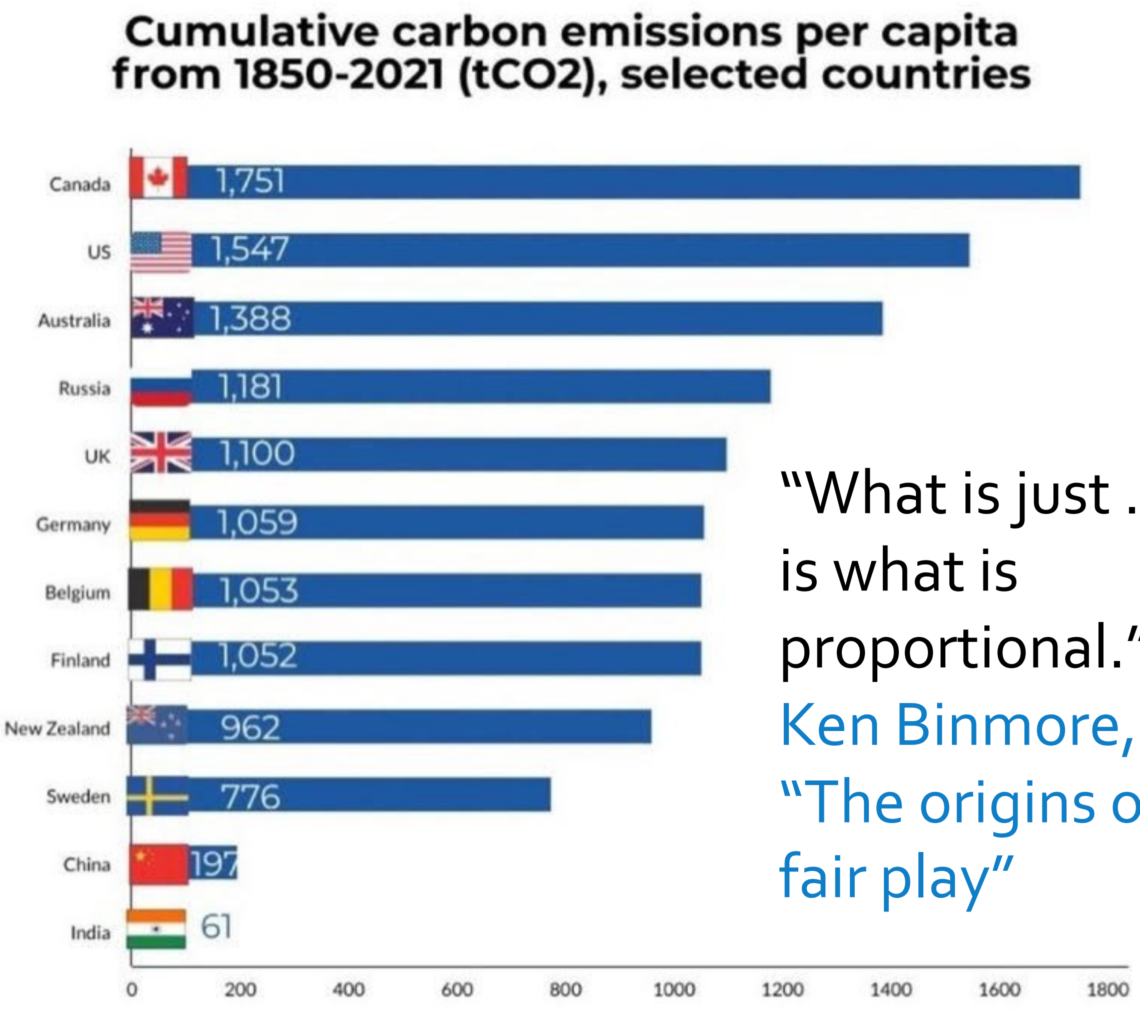
https://oilnow.gy/featured/brazil-to-increase-oil-production-by-300000-barrels-per-day-this-year-ami/



"THAT LATIN AMERICA IS ABOUT TO BOOM IS RELATIVELY CERTAIN. (…) LATIN AMERICA IS RICH WITH THE RESOURCES THE REST OF THE WORLD NEEDS"

https://www.thelykeion.com/the-investment-case-for-latin-america/

TRASITION TIME HAS MANY TIME FRAMES AND PAST LIABILITIES



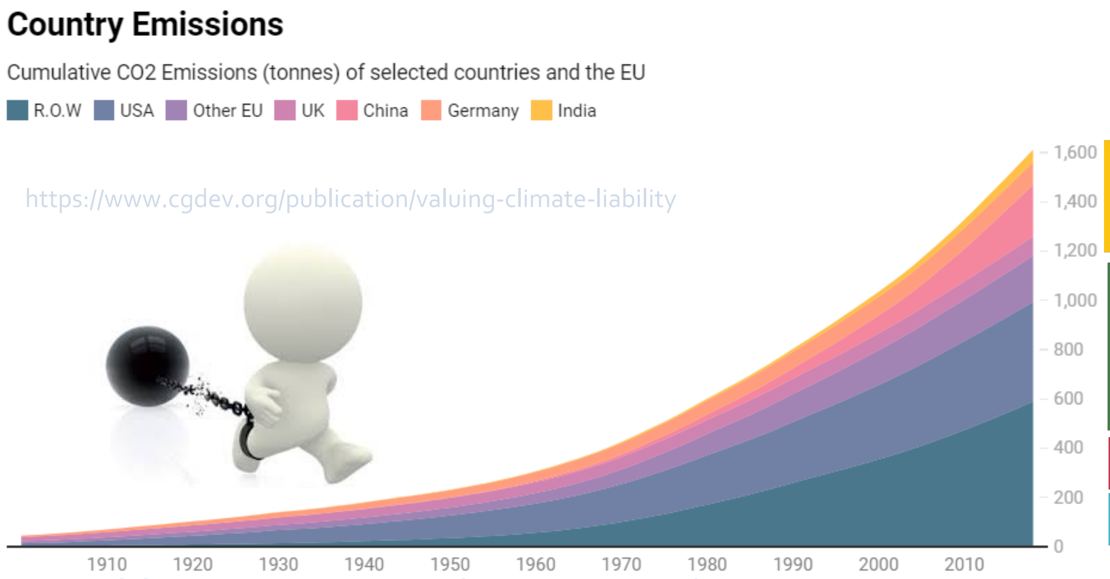
Source: Carbon Brief

"What is just . . . is what is proportional."

Ken Binmore, "The origins of fair play"

https://www.econstor.eu/handle/10419/31845

CARBON LIABILITY (DEBT)



https://www.cgdev.org/publication/valuing-climate-liability

Country climate liabilities
The cost of the damage likely to be caused by emissions to date, and which countries are responsible for that damage.

The cost of carbon
The concept of "externality" motivates the concept of a "**shadow price**" of carbon, which puts a per-unit value on that externality

	Cumulative Emissions			Liability			
	[illegible]al (Gt)	Share of Total	Per Capita (tonnes)	Liability ($bn)	Share of Total	Per Capita ($)	Liability/ GNI
World	1,612	100.0%	212	26,401	100.0%	3,476	30.7%
OECD	672	41.7%	515	11,710	44.4%	8,983	22.2%
EU-28	356	22.1%	694	3,616	13.7%	7,045	19.3%
U[illegible]tates	405	25.1%	1,237	5,054	19.1%	15,449	24.6%
China	210	13.0%	151	5,629	21.3%	4,041	41.4%
United Kingdom	77	4.8%	1,165	469	1.8%	7,057	16.4%
[illegible]	101	6.2%	697	1,501	5.7%	10,391	90.6%
India	[illegible]	3.2%	38	1,309	5.0%	968	48.1%
South Africa	20	1.3%	351	378	1.4%	6,538	102.6%
Brazil	15	0.9%	70	325	1.2%	1,554	17.4%

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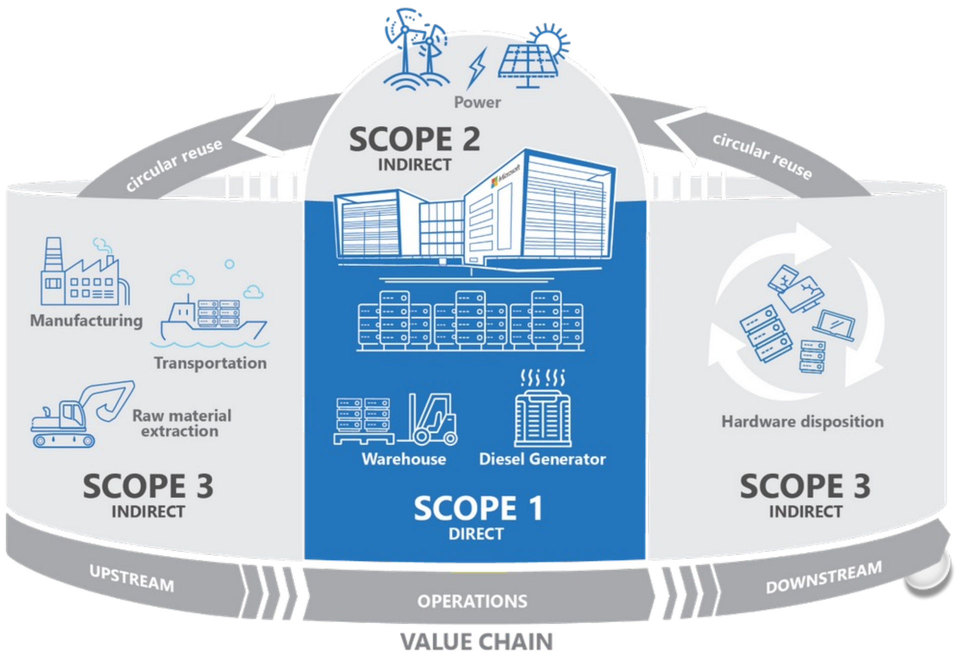
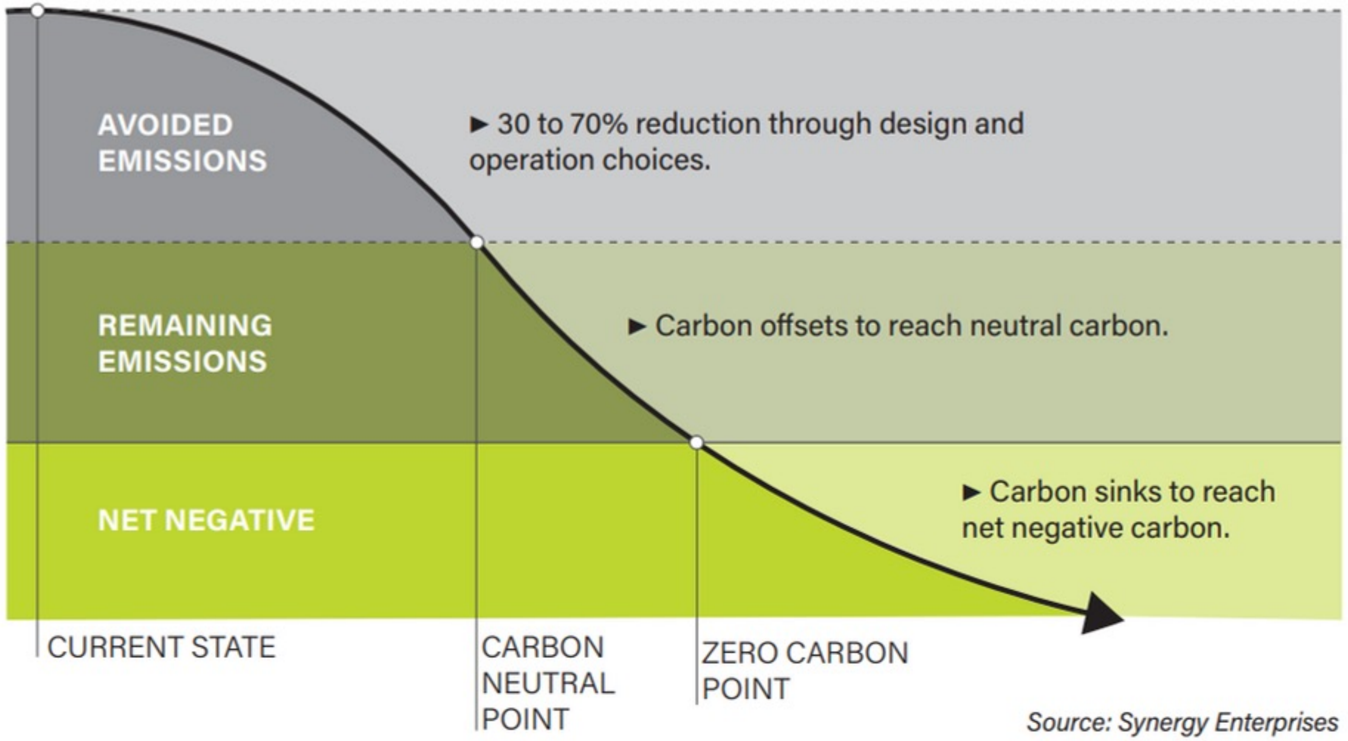
DECARBONIZATION



https://rmi.org/insight/regulatory-solutions-for-building-decarbonization/

PATHWAYS TO DECARBONIZATION



https://www.synergyenterprises.ca/post/how-to-create-a-decarbonization-strategy

- ❑ **Energy efficiency**
- ❑ **Leak detection**
- ❑ **Zero Flare in normal operation**

- ❑ **CCU**
- ❑ **CCS**
- ❑ **Carbon trading**

CDR alternatives:
- ❑ **DACCS** (Direct air carbon capture and storage);
- ❑ **Reforestation**;
- ❑ **BECCS** (Bioenergy with carbon capture and storage).

REDUCTION OF CARBON INTENSITY & CCUS ADD RESILIENCE TO CARBON PRICING

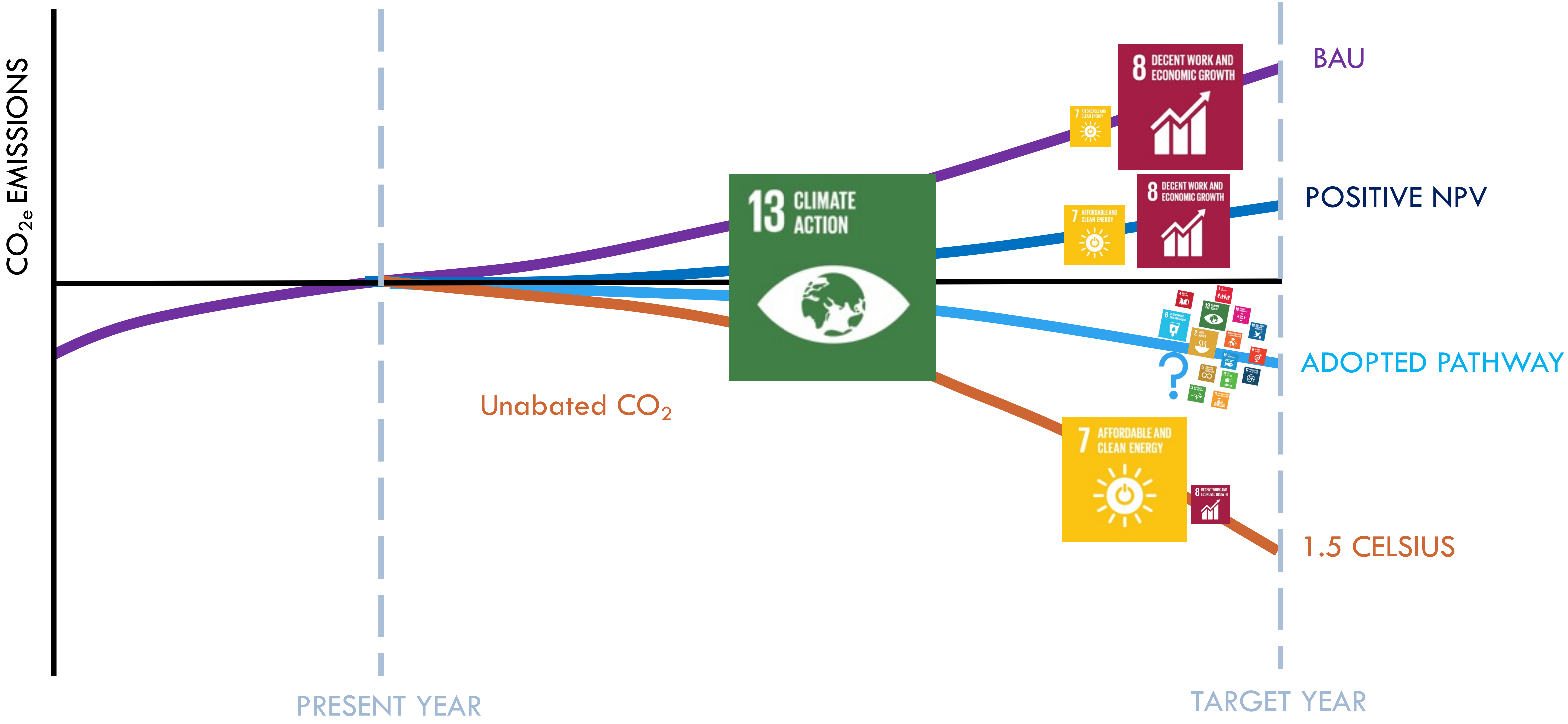
- ❑ Pre-Salt E&P (lifting) cost: $5 / bbl
- ❑ Additional cost from CO_2 emission: $40-$80 / tCO_2

CARBON INTENSITY= **0.06 t CO_2/bbl**
2.4 – 4.8 $ / bbl (**48%-96% increase**)

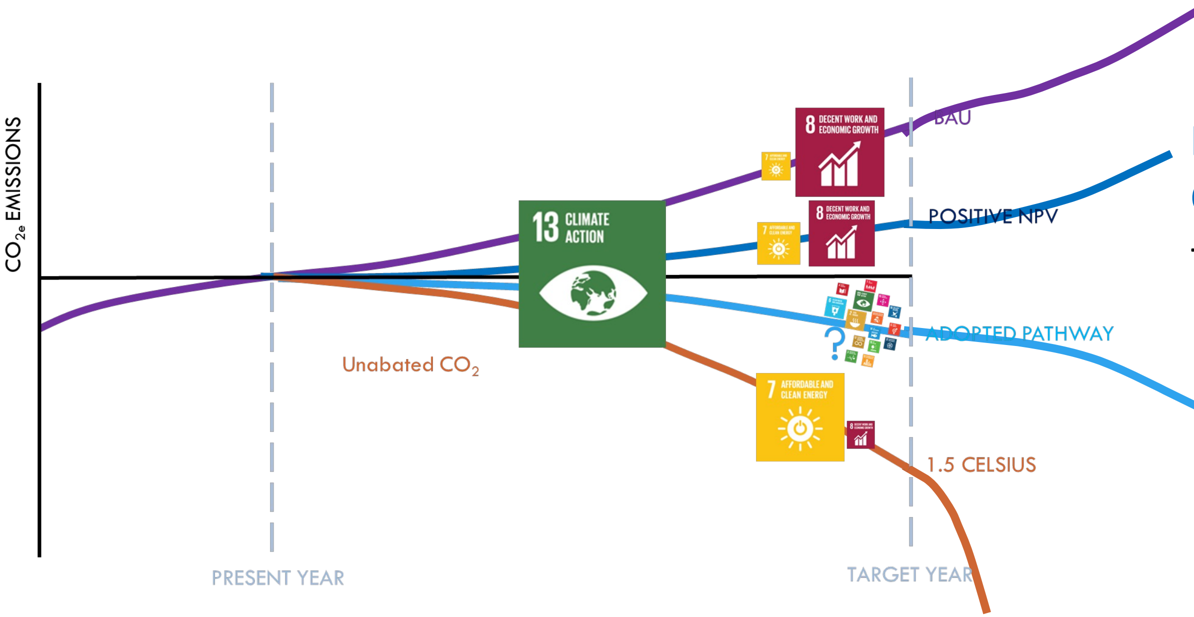
CARBON INTENSITY = **0.009 t CO_2/bbl**
$0.36 - 0.70 $ / bbl (**7%-14% increase**)

$$\uparrow Energy\ Price = \frac{CO_2}{Energy} \times \frac{\$}{CO_2}$$

MITIGATION PATHWAYS



ENABLING TECHNOLOGIES & POLICIES



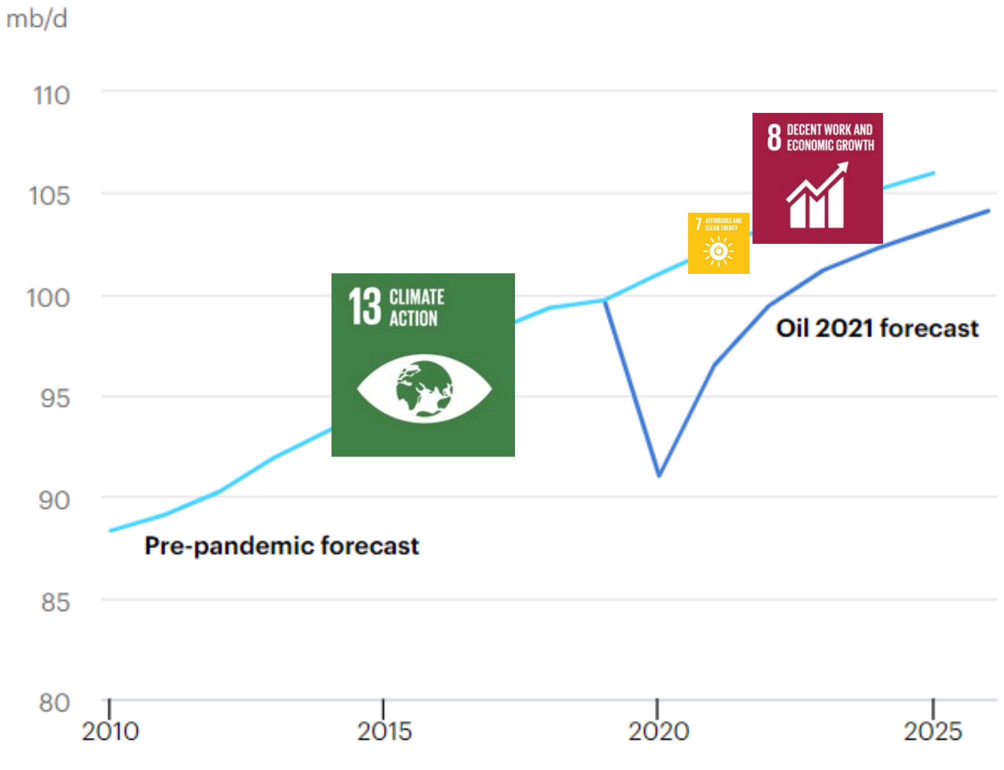
BAU + CARBON CREDIT – The "compensated CO_{2e} EMISSIONS" remains unabated within the company's value chain.

LOW- TO MID_SCALE MITIGATION TECHNOLOGY WITH CARBON UTILIZATION – The technology adds value to the "avoided CO_{2e} EMISSIONS".

MID-SCALE MITIGATION TECHNOLOGY WITH CARBON STORAGE – The technology adds costs to achieve "reduced or negative CO_{2e} EMISSIONS".

LARGE-SCALE CARBON MITIGATION TECHNOLOGY OR AVOIDANCE OF CARBON EMISSIONS – The technology adds costs to achieve "reduced CO_{2e} EMISSIONS", reducing or eliminating sources of emissions associated with the operations of a company and its value chain.

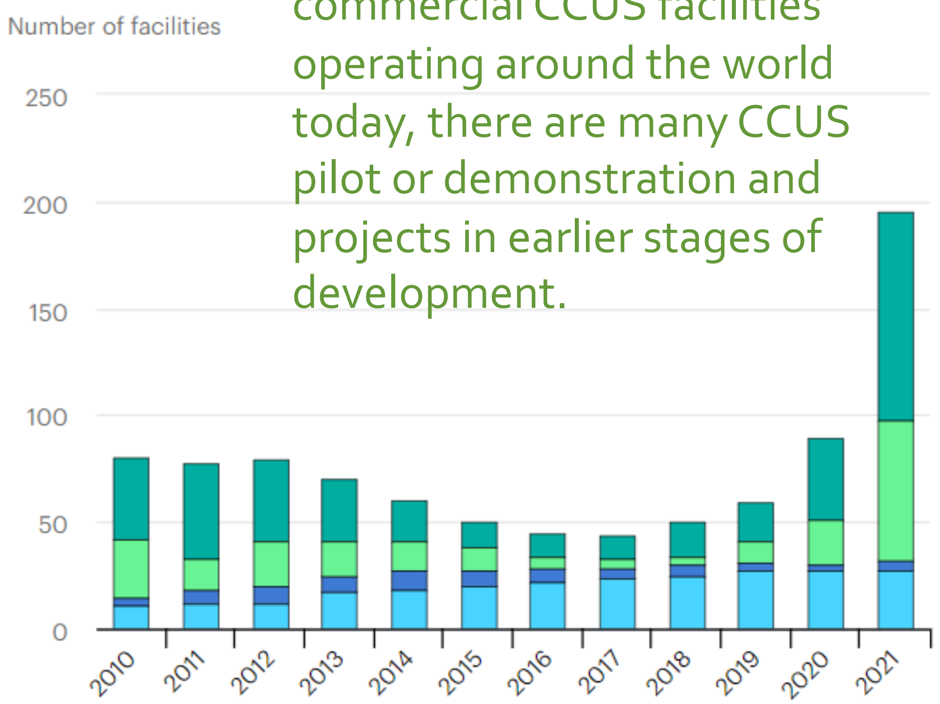
OIL DEMAND & CCUS



Pre-pandemic forecast   Oil 2021 forecast

https://www.iea.org/fuels-and-technologies/oil

Global pipeline of commercial CCUS facilities operating and in development, 2010-2021



In addition to the commercial CCUS facilities operating around the world today, there are many CCUS pilot or demonstration and projects in earlier stages of development.

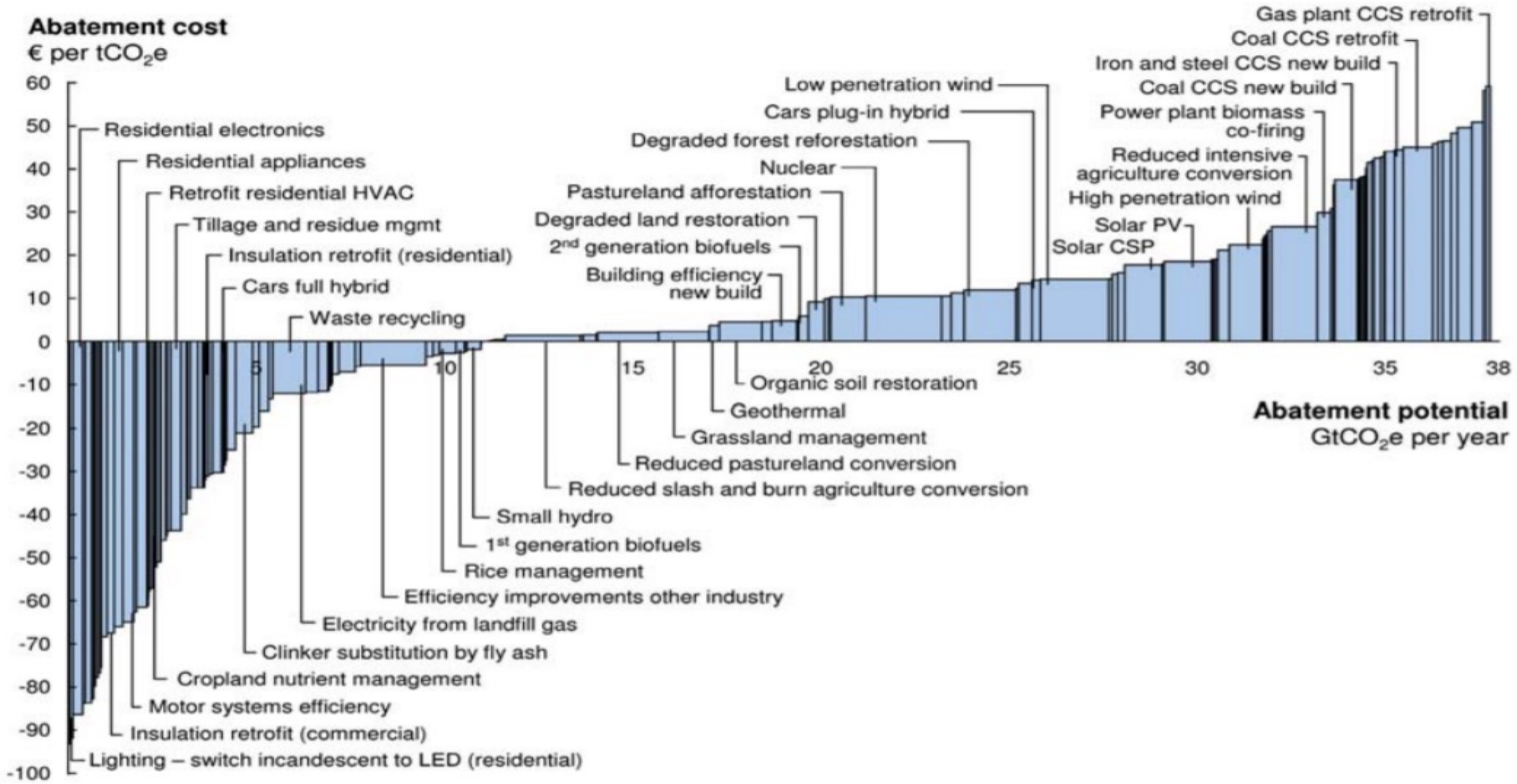
https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage

MARGINAL ABATEMENT COST (MAC) CURVE

The MAC curve will show projects with a positive net present value (NPV) alongside the opportunities that may have a negative NPV.

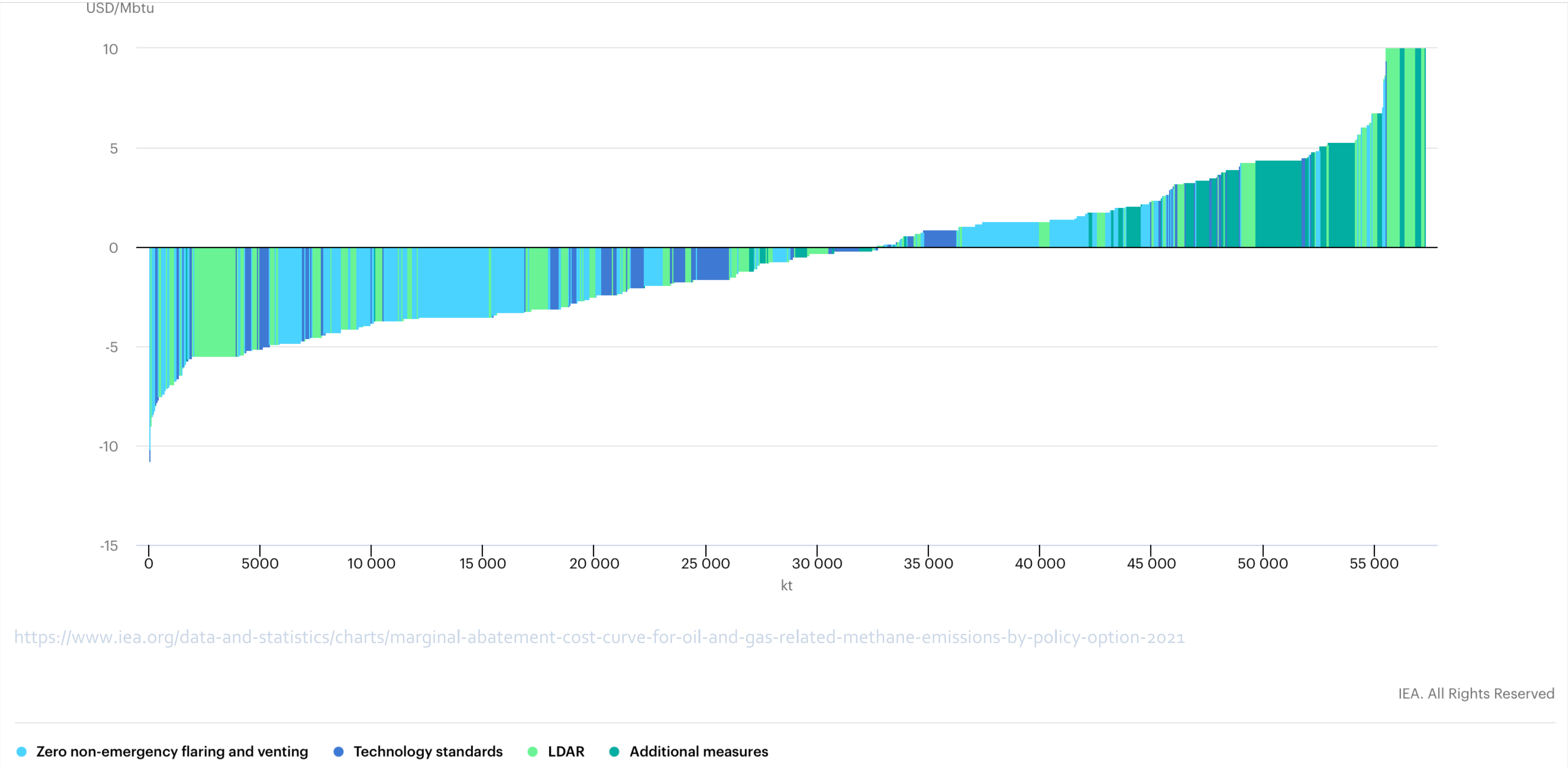
https://www.sinaitechnologies.com/post/carbon-and-cash-flow-statements-built-with-mac-curves _Chapter02.pdf

COSTS AND SCALES OF ENABLING TECHNOLOGIES



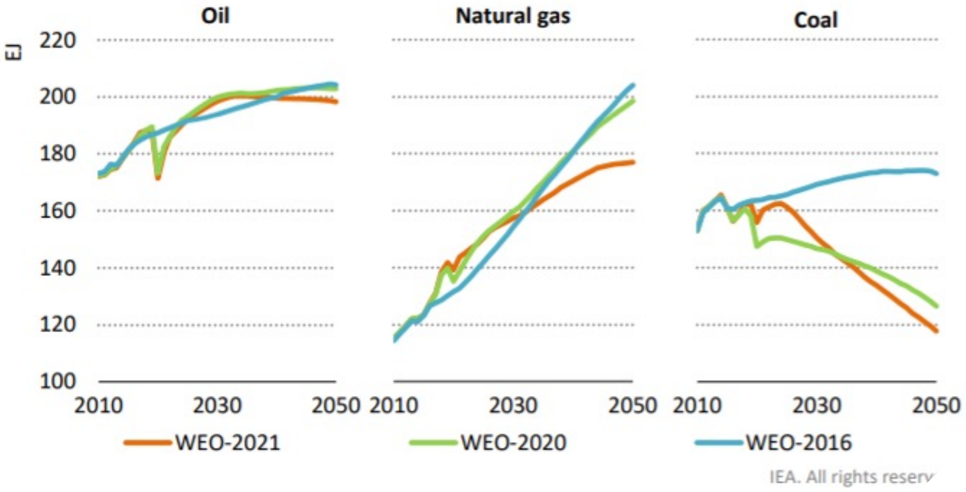
https://www.sustainablefuels.eu/assets/uploads/2018/10/2009_-_Innovations_for_Greenhouse_Gas_Reductions.pdf

MAC CURVE FOR OIL & GAS-RELATED METHANE EMISSIONS BY POLICY OPTION, 2021

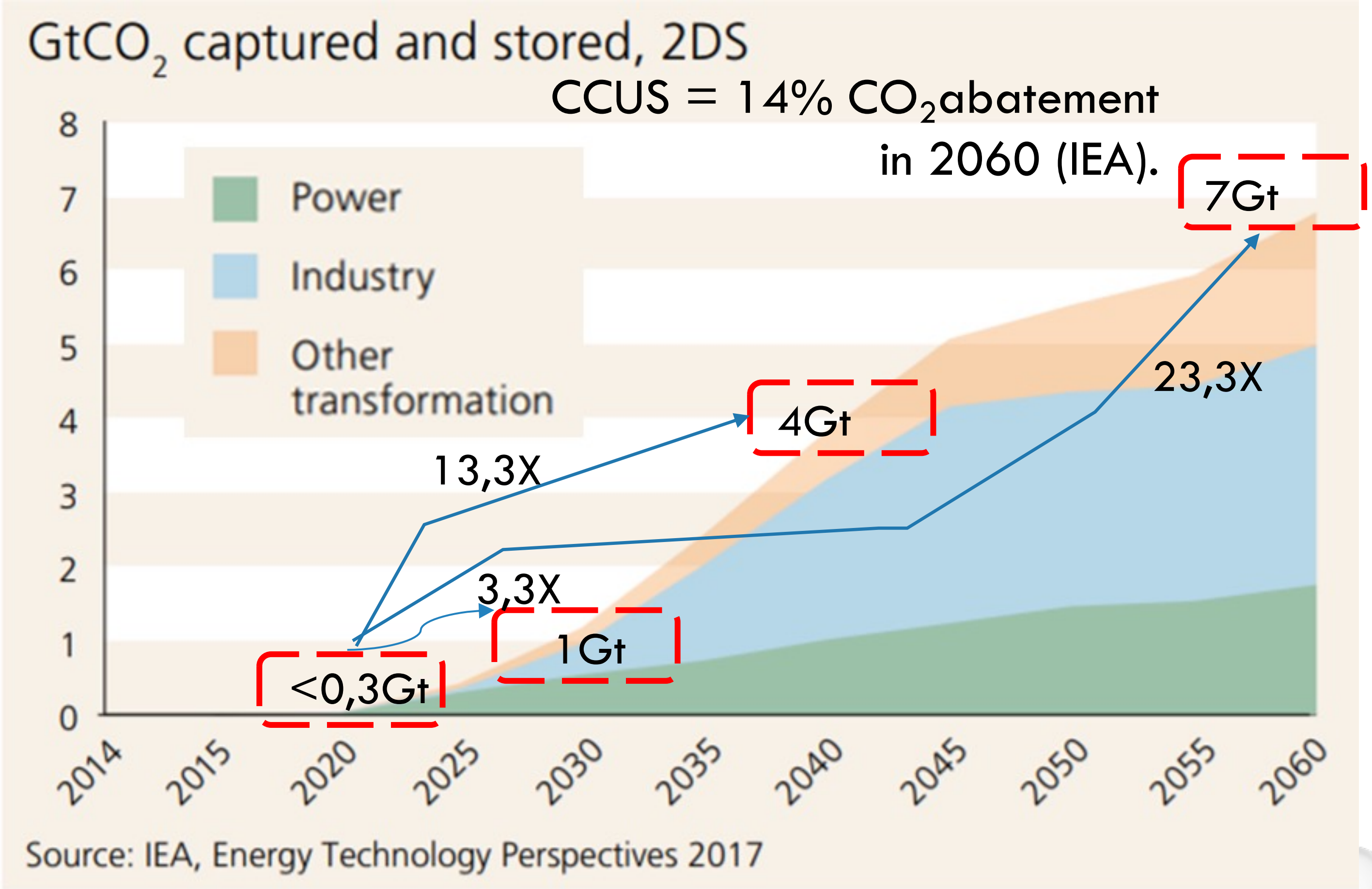


https://www.iea.org/data-and-statistics/charts/marginal-abatement-cost-curve-for-oil-and-gas-related-methane-emissions-by-policy-option-2021

CHALLENGE: LARGE SCALE CCS

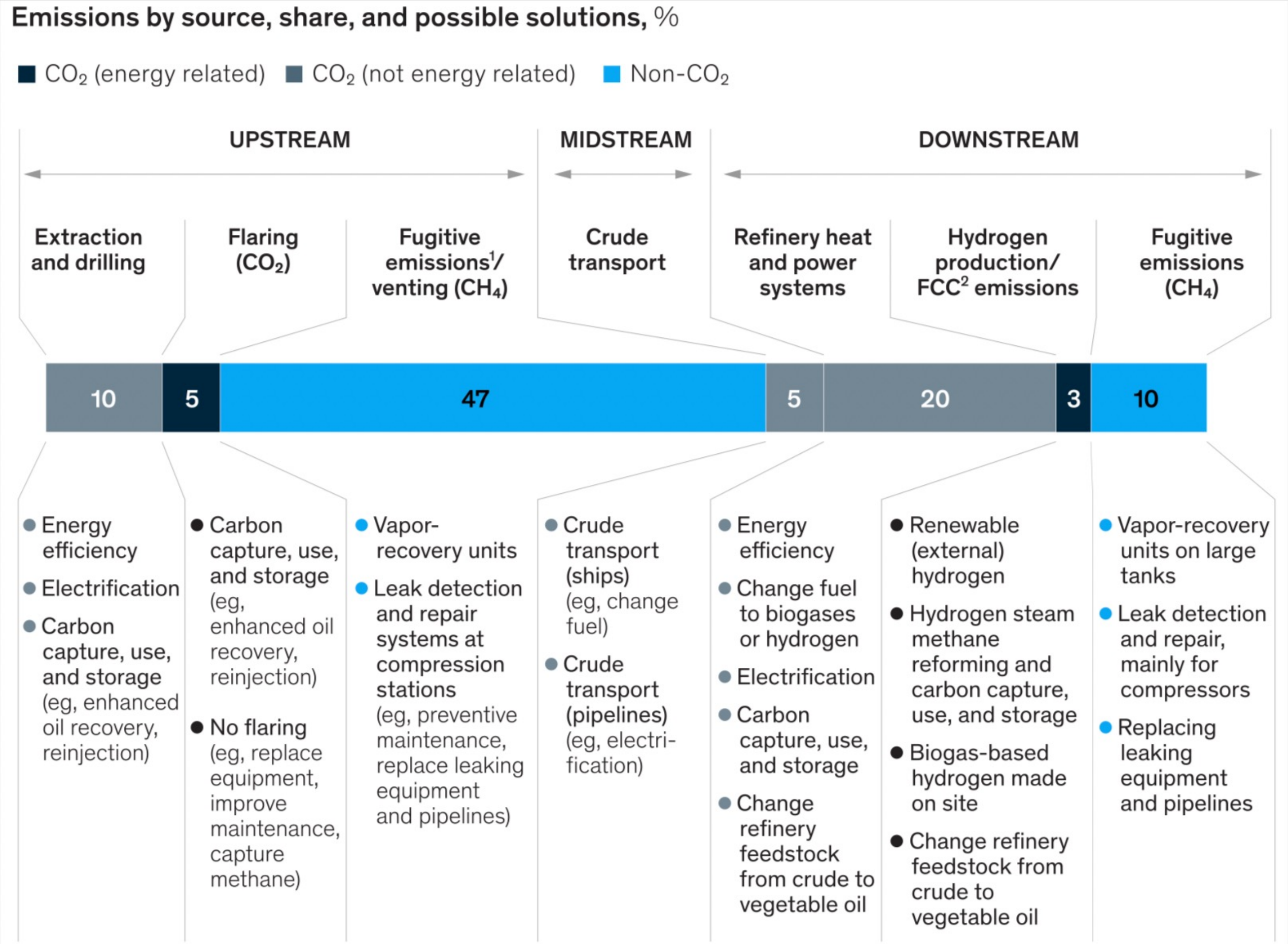


https://iea.blob.core.windows.net/assets/88dec0c7-3a11-4d3b-99dc-8323ebfb388b/WorldEnergyOutlook2021.pdf



http://oilandgasclimateinitiative.com/wp-content/uploads/2017/10/OGCI-2017-Report.pdf

O&G DECARBONIZATION



Changing power sources

Smart refinery

Digitalization

Electrification

Rebalancing portfolios

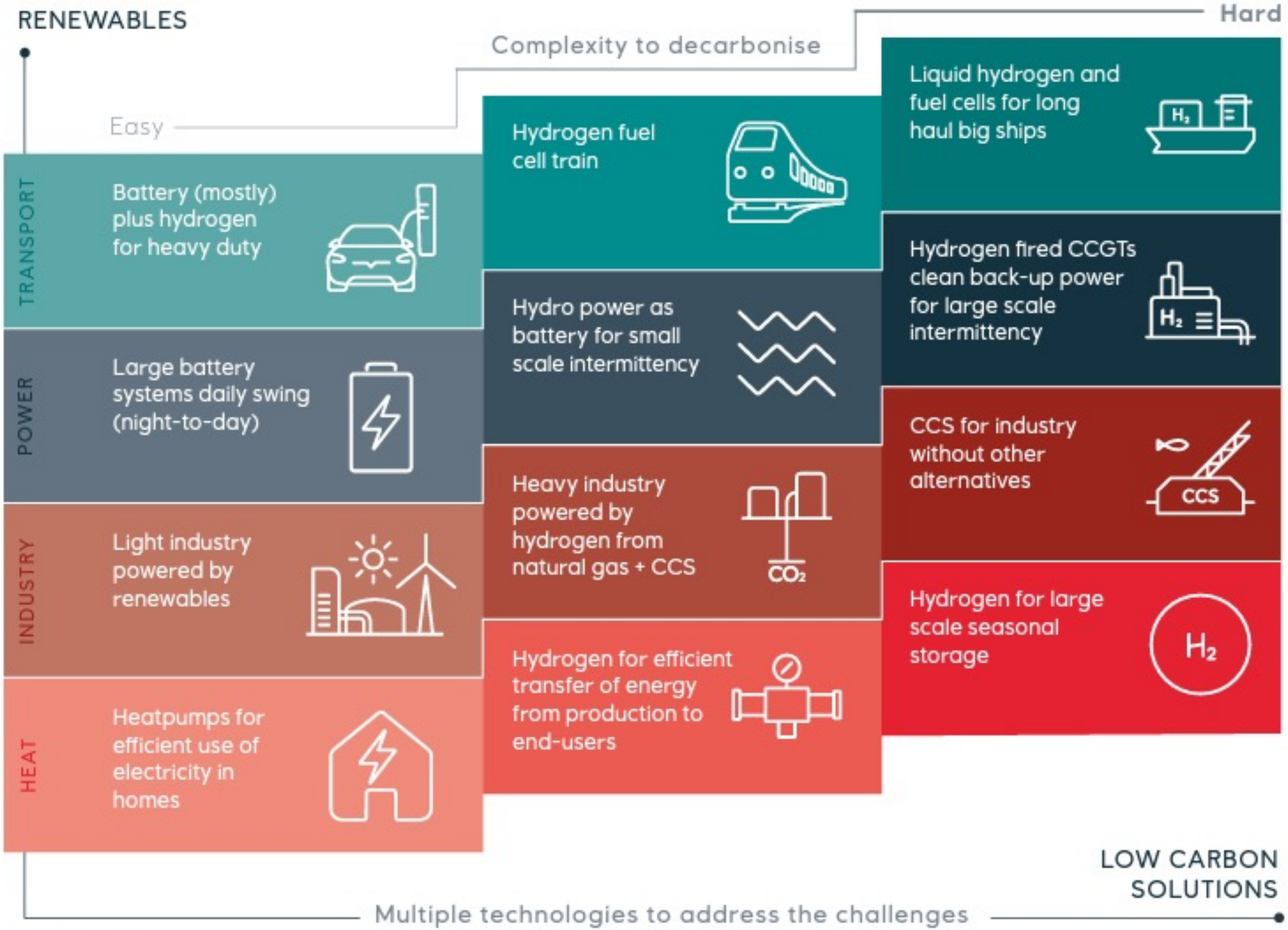
Vapor Recovery Units

Reducing fugitive emissions (Leak detection)

Increasing carbon capture, use, and storage (CCUS)

Reducing routine flaring

https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-is-now-how-oil-and-gas-companies-can-decarbonize

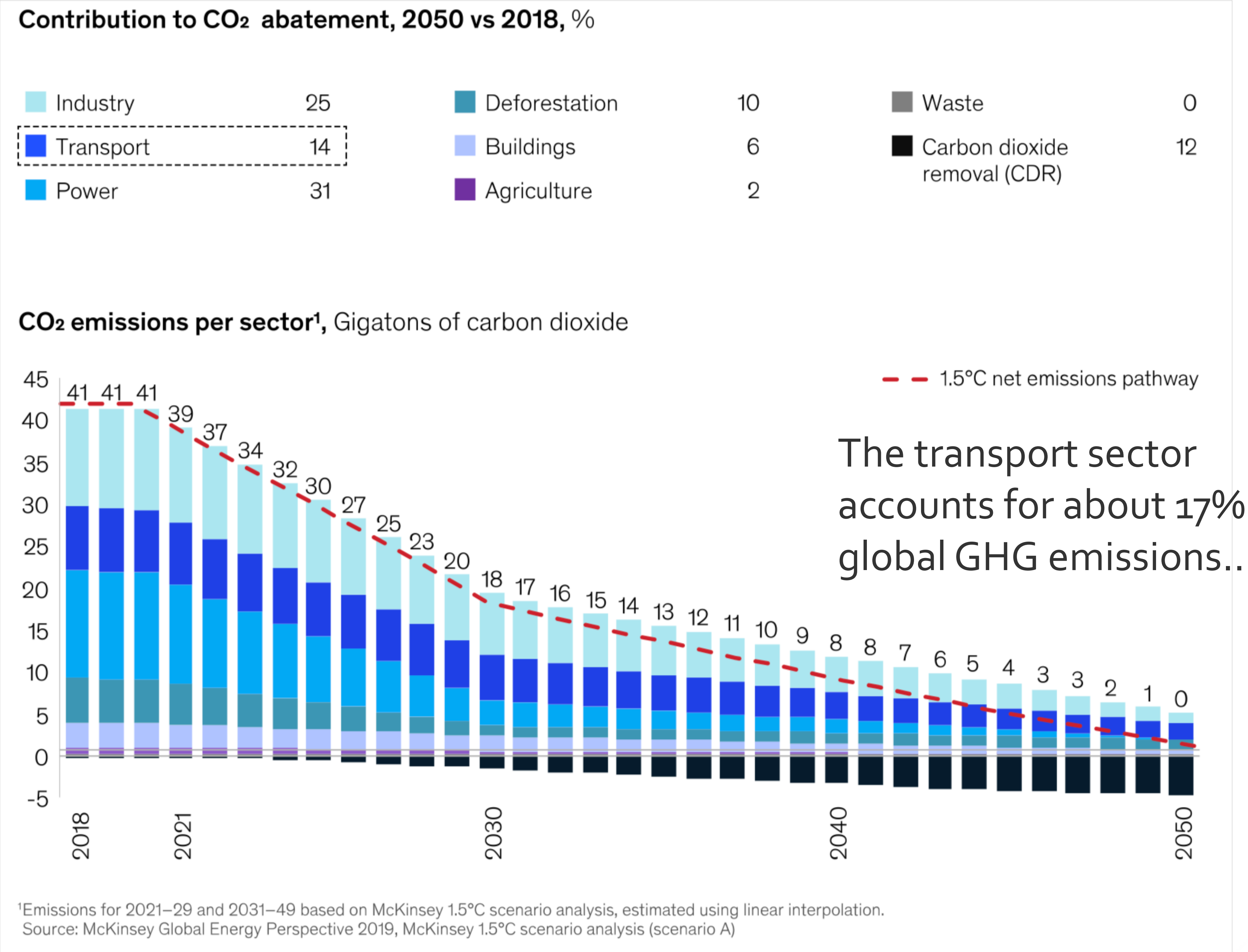


1. Equity share

https://cdn.sanity.io/files/h61q9gi9/global/6a64fb766c58f70ef37807deca2ee036a3f4096b.pdf?energy-transition-plan-2022-equinor.pdf

ELECTRIFICATION

EV



The transport sector accounts for about 17% of global GHG emissions..

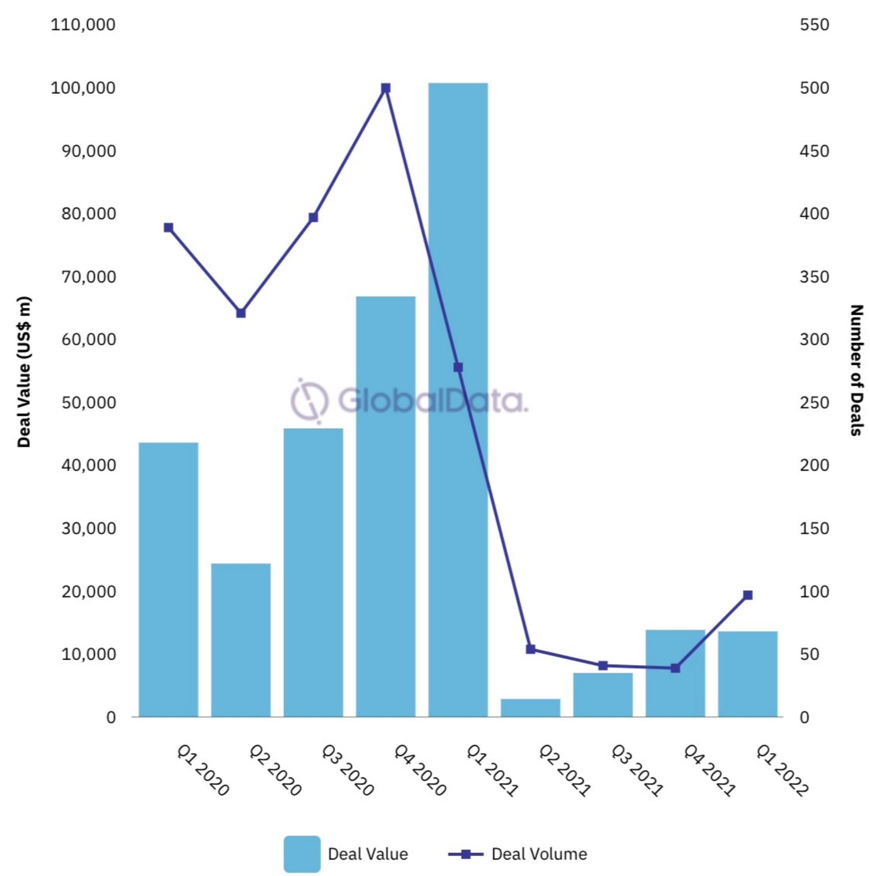
MORE POWER IS NEEDED FOR ELECTRIFICATION, ENERGY SECURITY AND GROWTH

EU Parliament allows gas and nuclear projects green funding

Projects will soon be allowed to access significant EU decarbonisation funds.

By Matt Farmer

Environmental Sustainability Deals in the power sector: Q1 2020 – Q1 2022



Source: **GlobalData Deals Database**

https://www.power-technology.com/environment-sustainability-in-power/

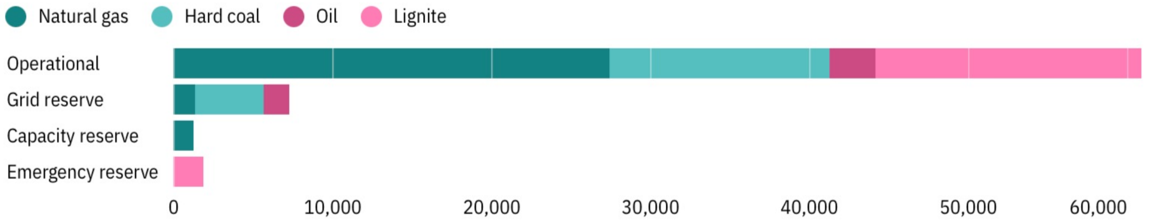
The birth of the carbon removal market

The Intergovernmental Panel on Climate Change's (IPCC) latest report revealed that all pathways to limit global warming to 1.5°C depend on carbon removal. Carbon removal, or CO2 removal, encompasses both natural solutions, such as sequestering...

https://www.power-technology.com/environment-sustainability-in-power/

Germany's fossil fuel reserves cover around a third of its total operational gas capacity

Capacity of natural gas, hard coal, oil and lignite power plants by status in MW



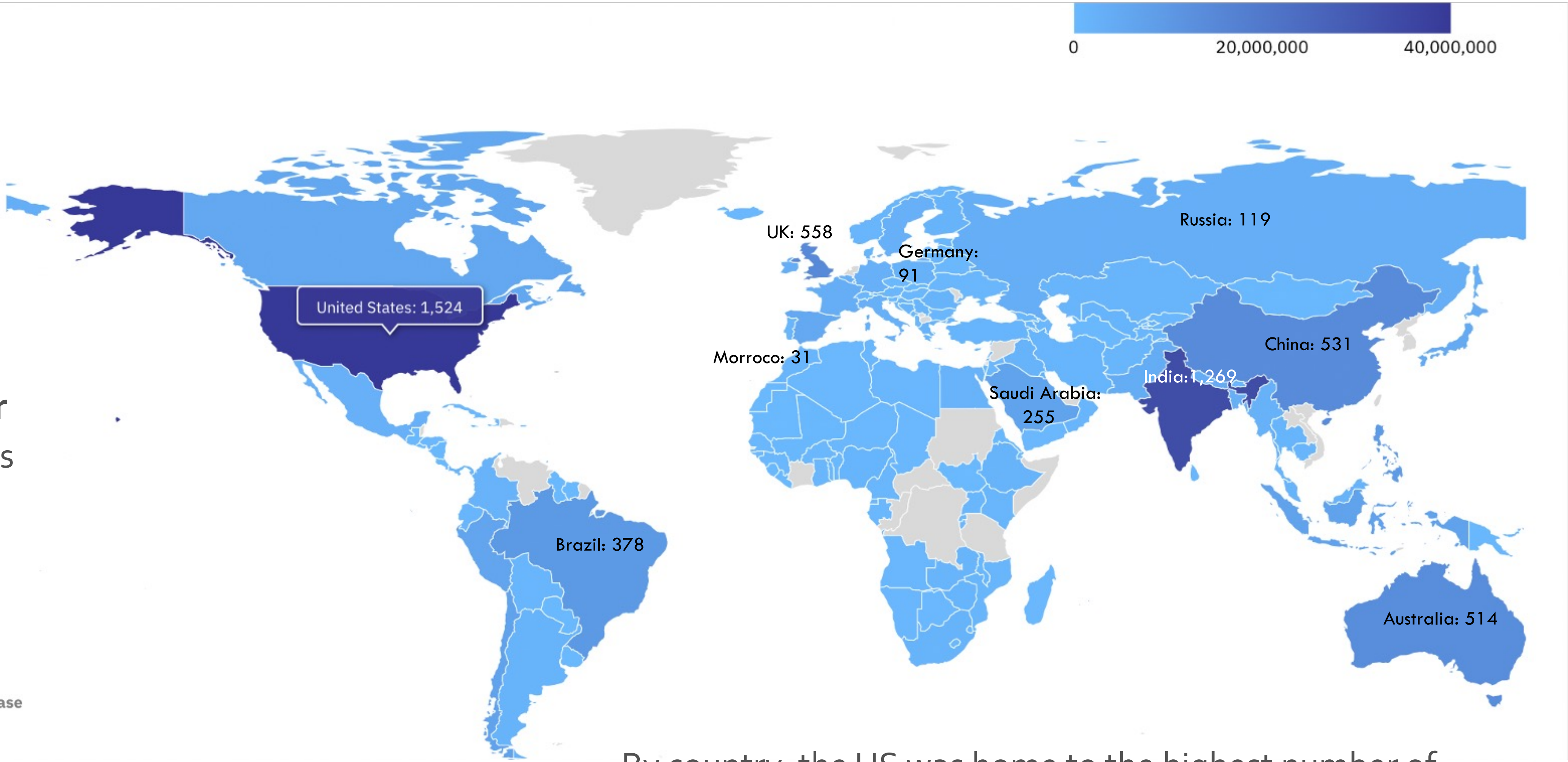
Source: Bundesnetzagentur

POWER TECHNOLOGY

https://www.power-technology.com/analysis/germanys-emergency-gas-plan-explained/

POWER CONSTRUCTION PROJECT PIPELINE VALUE

As at the start of 2022, Power Technology had identified **11,043 power projects over $25m** at various stages of development, including 2,871 in execution.



Source: **GlobalData Construction Projects Database**

https://www.power-technology.com/power-construction-projects/

By country, the US was home to the highest number of power projects with 1,437 projects, followed by India and China with 1,233 and 531 projects, respectively.

MOROCCO-UK POWER PROJECT, MOROCCO

1,500km² in the Guelmim Oued Noun region of Morocco

10.5GW of energy, of which 3.6GW is planned to be transmitted to the UK to meet up to 8% of its electricity demand

A **20GWh/5GW battery storage facility** will also be built on-site, as part of the project, to store and deliver reliable energy to the UK when required

The first 1.8GW system of the HVDC interconnector project is expected to be connected to the UK's electricity network by 2027.

The cable will take a subsea route from north-west of the city of Tantan, Morocco, up the Strait of Gibraltar, and along the coasts of Portugal, Spain and France, before going around the isles of Scilly off the coast of Cornwall, UK. It will pass through the exclusive waters of the UK and make landfall at Devon.

The converter station at the Morocco end will convert the electricity generated from wind and solar resources from HVAC to HVDC

The power transmission between Morocco and the UK will take place through onshore and subsea cables

A converter station in Devon, UK, will convert the exported electricity back from HVDC to HVAC before feeding it into the British transmission network.

Four subsea cables, each measuring **3,800km long**, will be laid to provide exclusive connection to the UK, depths between 100m and 250m

SIZEWELL C NUCLEAR PLANT IN UK RECEIVES CONSENT

3.2GW of electricity, which is enough to power six million homes.

Local anti-nuclear campaigners have raised several objections to the nuclear project, including its **planned location next to the Minsmere nature reserve.**

According to a government statement, the Sizewell C plant's development will increase the UK's low-carbon electricity production capacity and help the country achieve its net-zero targets.

https://www.power-technology.com/news/sizewell-c-nuclear-consent/

MORAY WEST OFFSHORE WIND FARM, SCOTLAND

882 MW Offshore wind farm (60 turbines)

Moray Firth, Scotland

First Power: 2024

Ownership
Ocean Wind (95%) and Ignitis Group (5%)
Developer
Ocean Wind

It is expected to contribute to Scotland's ambition of achieving net zero emissions of all greenhouse gases by 2045. The project is estimated to provide a reduction in carbon dioxide (CO_2) emissions of 1.1 million tonnes

To be located 22km from the coast, the wind farm will be developed over an **area of 225km².** It will be equipped with 60 Siemens Gamesa SG 14-222 DD offshore wind turbines installed on fixed monopile seabed foundations.

The project will use 220kV high-voltage alternating current (HVAC) subsea and onshore export cable systems.

MENDUBIM SOLAR PV POWER PROJECT, RIO GRANDE DO NORTE, BRAZIL

531 MW SOLAR PV POWER PLANT

Start of Construction: 2022
Comissioning: 2023
Estimated Investment: US$ 430M

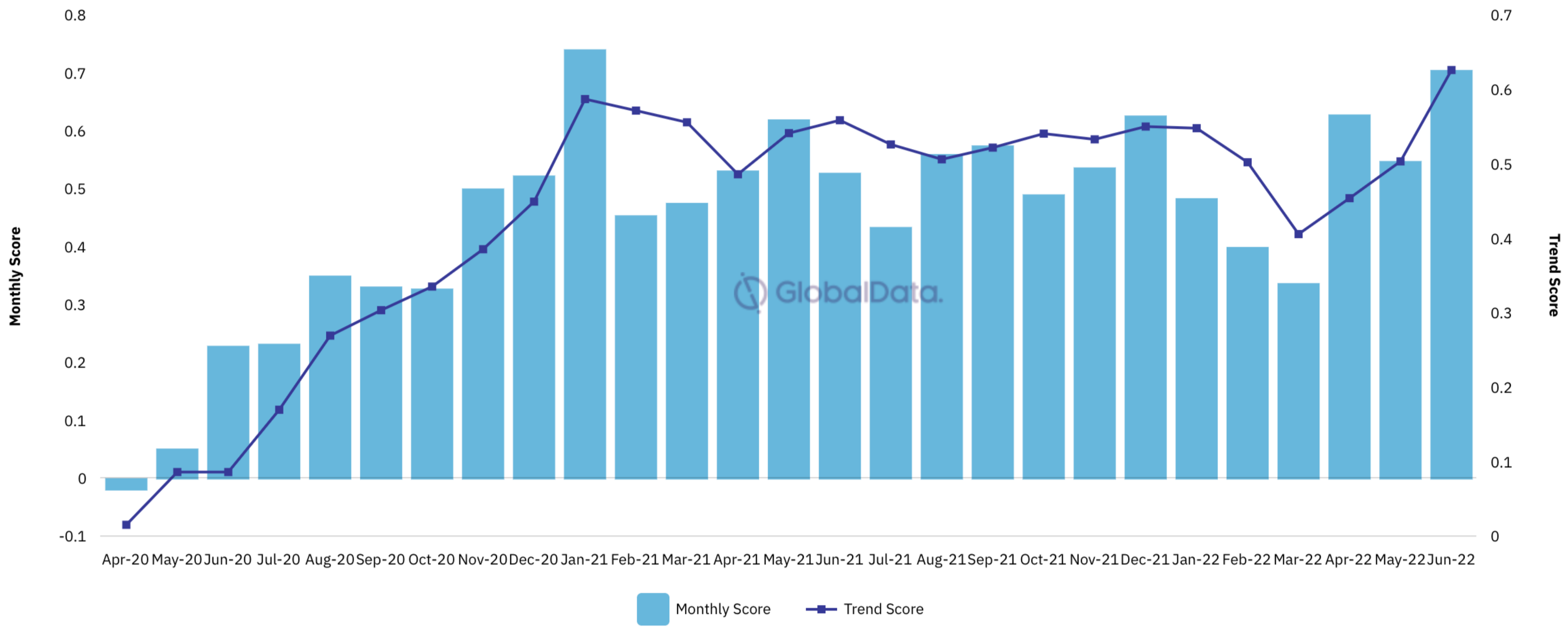
Owners: Scatec, **Hydro Rein** and Equinor

About 60% of the solar power produced from the project will be supplied to Alunorte, an alumina refinery located in Barcarena in the state of Para, under a 20-year power purchase agreement (PPA) signed with the developers in July 2022. **Alunorte is a subsidiary of Hydro**.

The greenhouse gas (GHG) emissions from the project are estimated to be **159,005t of carbon dioxide (CO_2) equivalent during the construction phase, mainly due to deforestation**. The emissions are expected to be reduced to about 2,200t of CO_2 equivalent in the second year of construction and will drop further during the operational phase to approximately 450t.

FLOATING SOLAR FARMS IN CALIFORNIA

GLOBAL POWER CONSTRUCTION PROJECTS MOMENTUM INDEX



Source: **GlobalData Construction Projects Momentum Index**

https://www.power-technology.com/power-construction-projects/

The momentum index is based on scoring the latest developments on projects from +5 to -5 based on the degree to which a development is positive, such as construction commencing or a contract awarded, or negative, such as delays or cancellations. The overall momentum score is the average score of all project developments in each month, weighted by the project values.

HYDROGEN

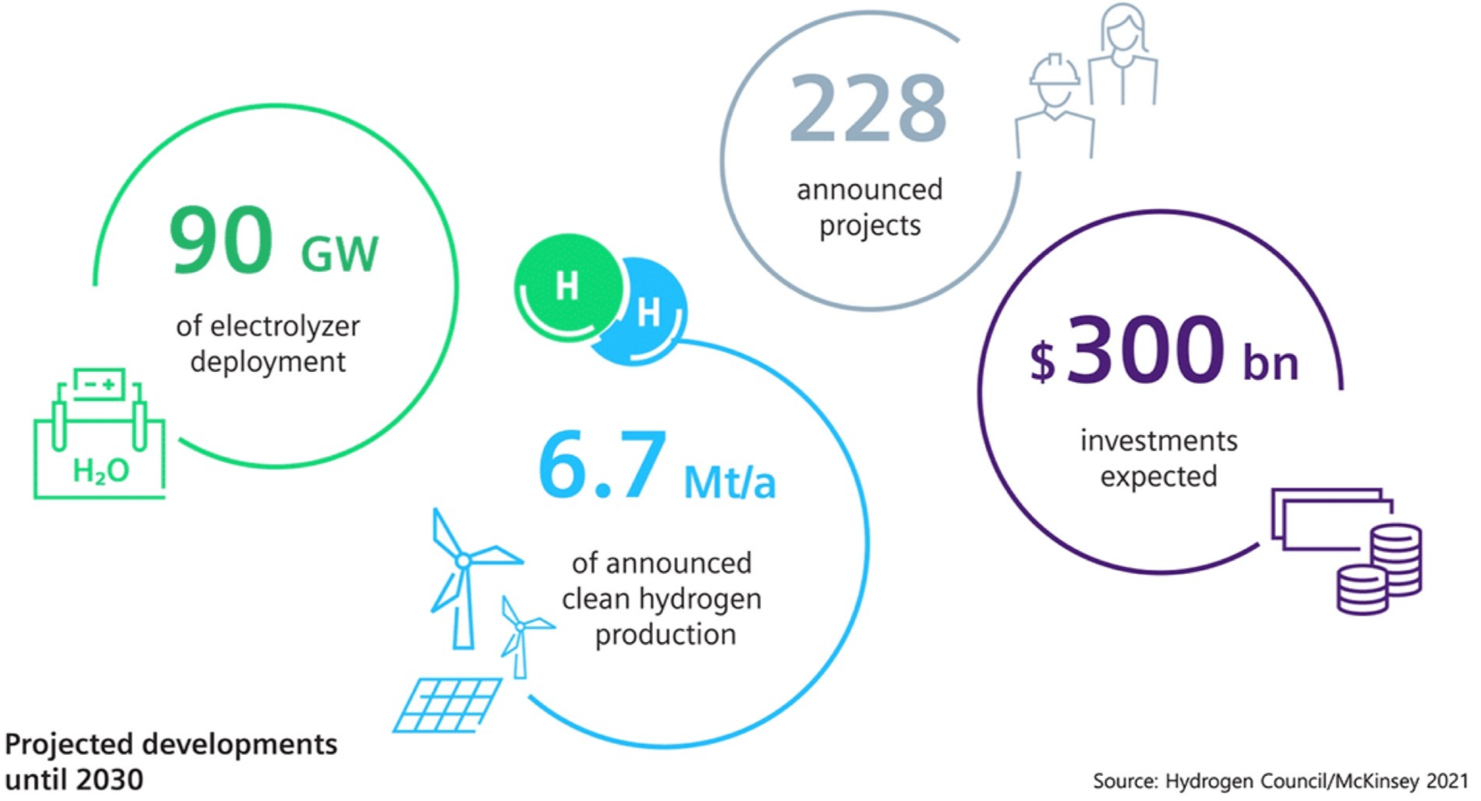
HYDROGEN

Hydrogen as a versatile energy carrier

- zero carbon energy source
- large scale and long-term storage media
- important industrial feedstock
- basis for all kinds of e-fuels

Hydrogen for various sectors

- Industry
- Transport
- Buildings
- Agriculture



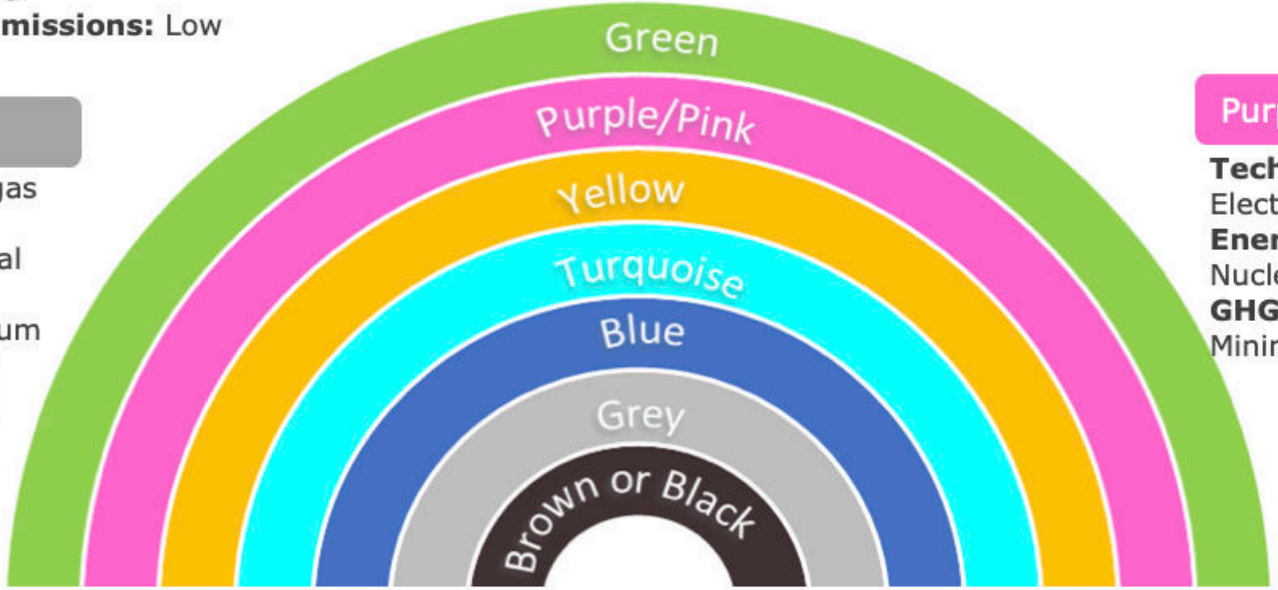
NOT ALL HYDROGEN IS CREATED THE SAME

Turquoise hydrogen
Technology: Pyrolysis
Energy source: Natural gas
GHG emissions: Solid carbon (by-product)

Blue hydrogen
Technology: Natural gas reforming + CCUS gasification +CCUS
Energy source: Natural gas, coal
GHG emissions: Low

Yellow hydrogen
Technology: Electrolysis
Energy source: Mixed-origin grid energy
GHG emissions: Medium

Grey hydrogen
Technology: Natural gas reforming
Energy source: Natural gas
GHG emissions: Medium



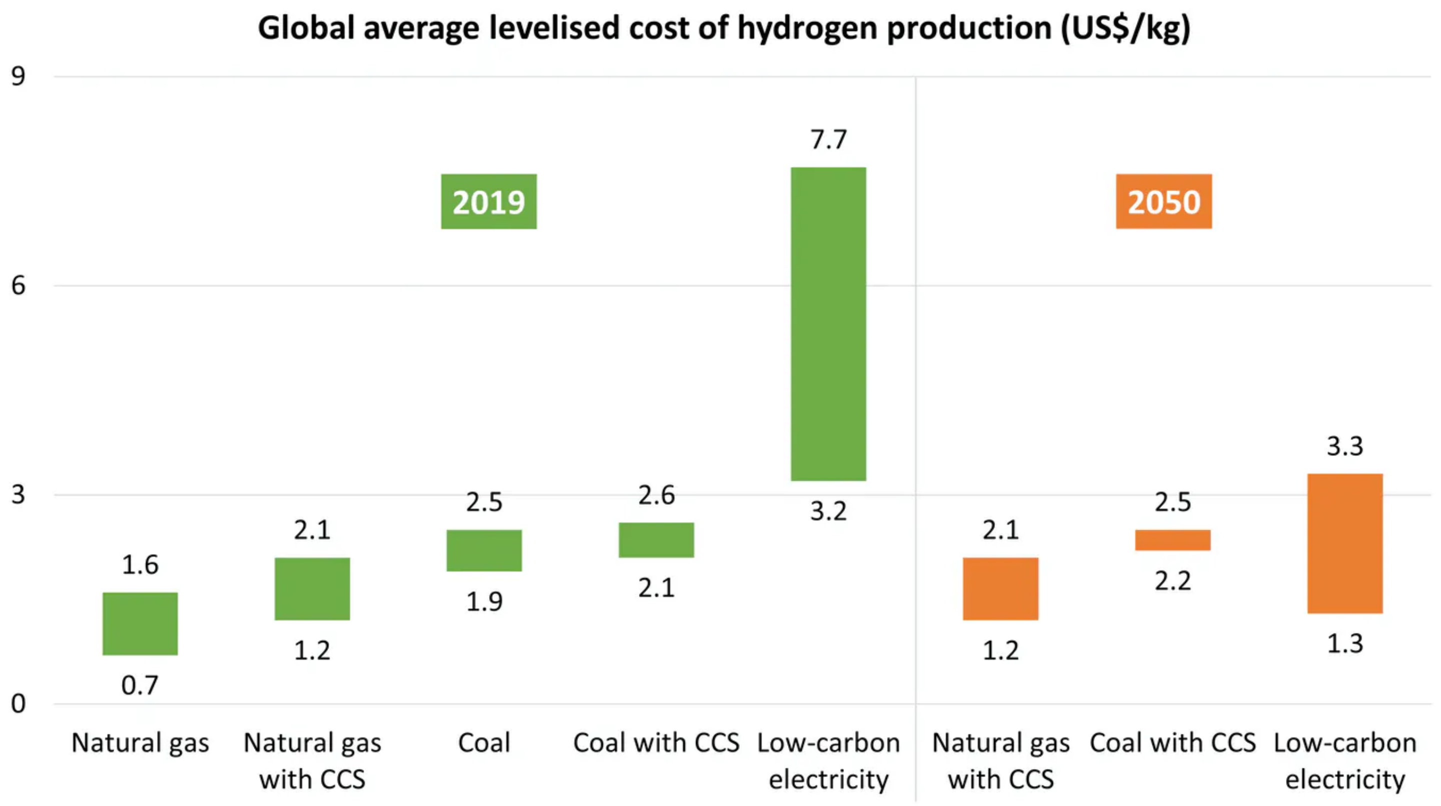
Purple/Pink hydrogen
Technology: Electrolysis
Energy source: Nuclear
GHG emissions: Minimal

Brown/Black hydrogen
Technology: Gasification
Energy source: Black/ brown coal (lignite)
GHG emissions: High

Green hydrogen
Technology: Electrolysis
Energy source: Wind, Solar, Hydro, Geothermal
GHG emissions: Minimal

https://www.tecnicasreunidas.es/articulo/hydrogen-present-and-future-part-2/

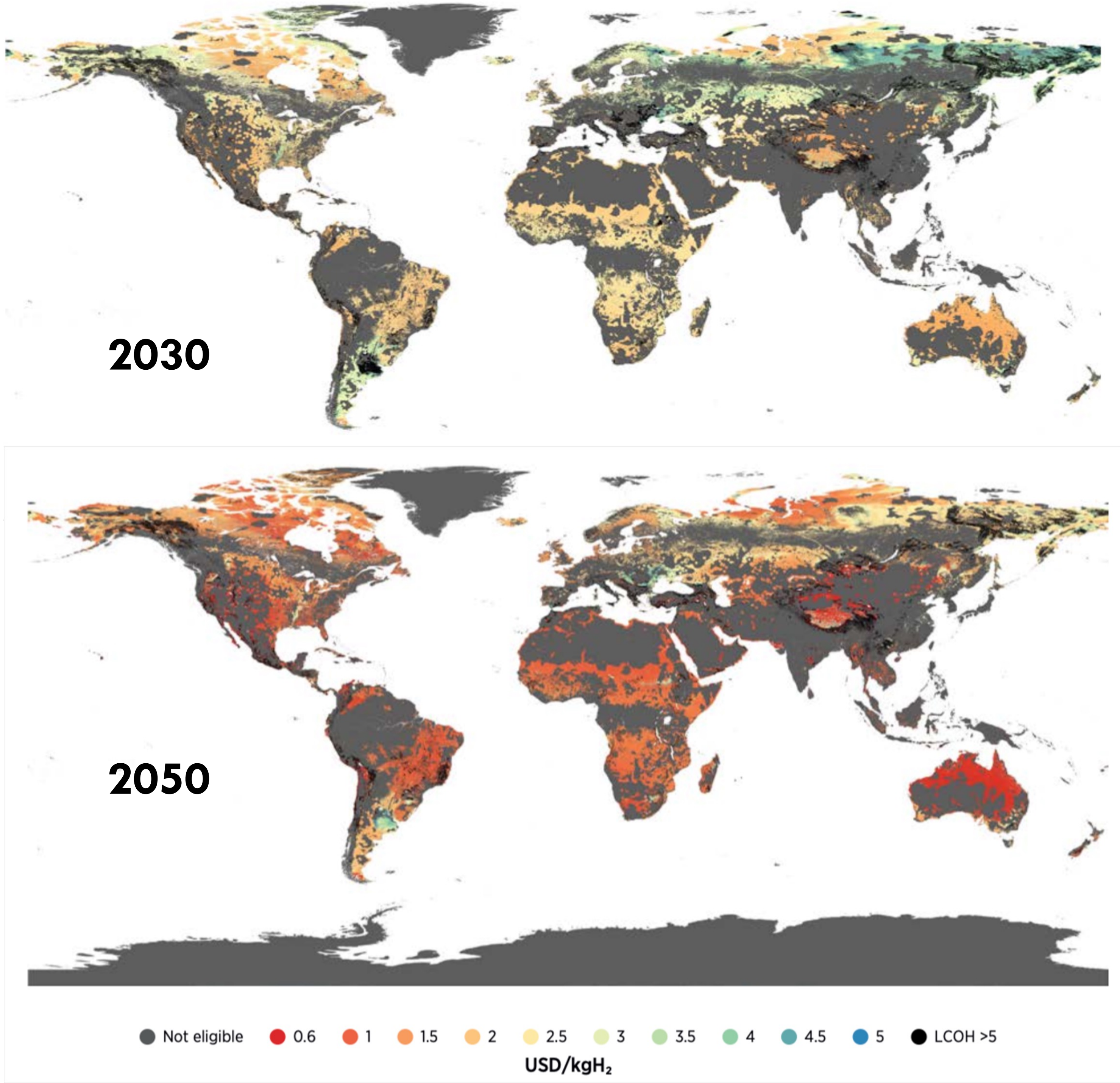
NOT ALL H_2 COST THE SAME



Hydrogen-based power generation versus natural gas. This cost comparison from the Hydrogen Council assumes the hydrogen cost from auto-thermal reforming with carbon capture and storage in **2030 in the U.S. will be $1.1/kg;** $.17/kg in Germany; and $1.8/kg in Japan and South Korea. Courtesy: Hydrogen Council

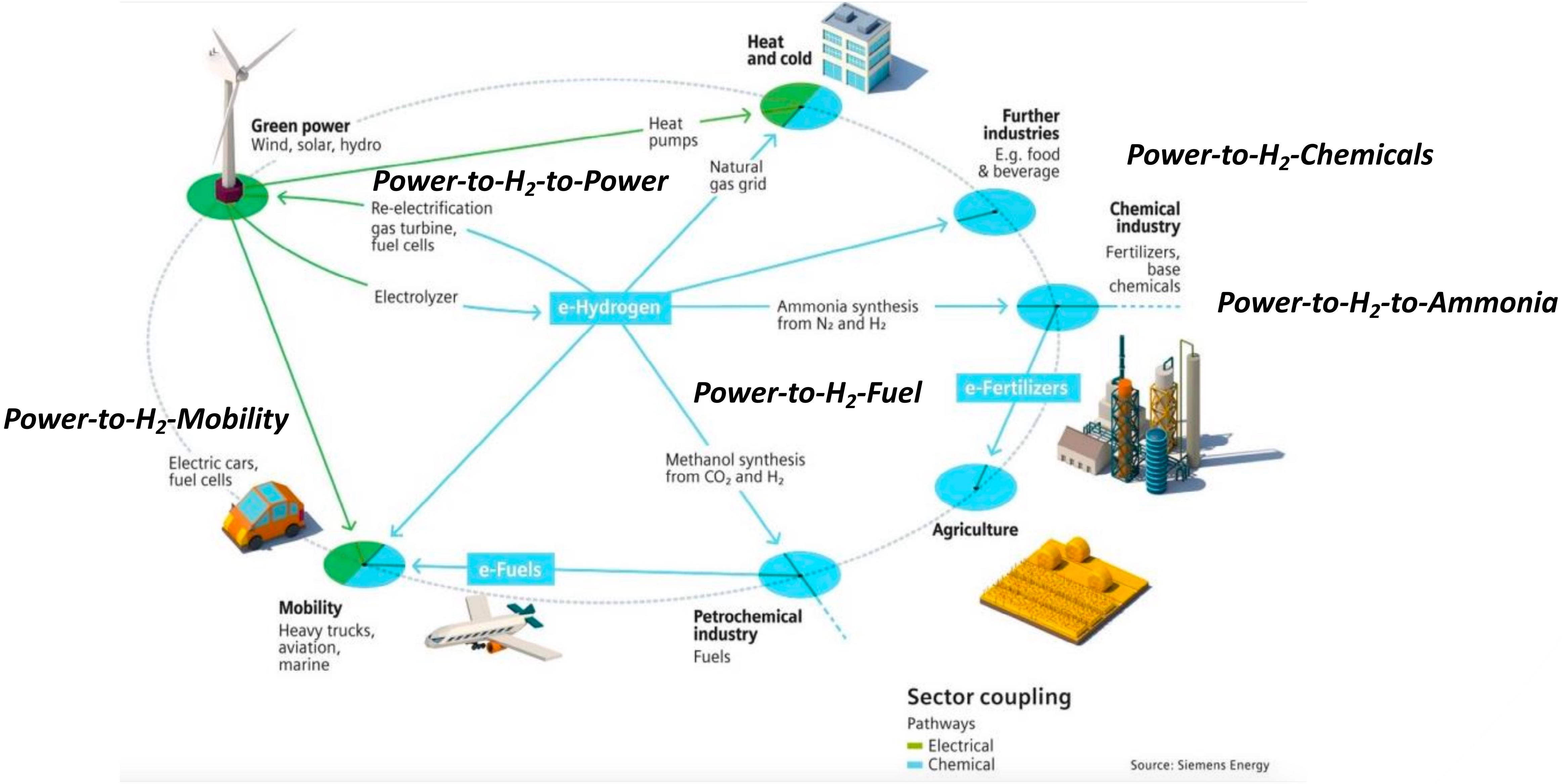
https://www.eco-business.com/news/explainer-the-many-shades-of-hydrogen/

GLOBAL COST OF H_2 CONSIDERING WATER SCARCITY

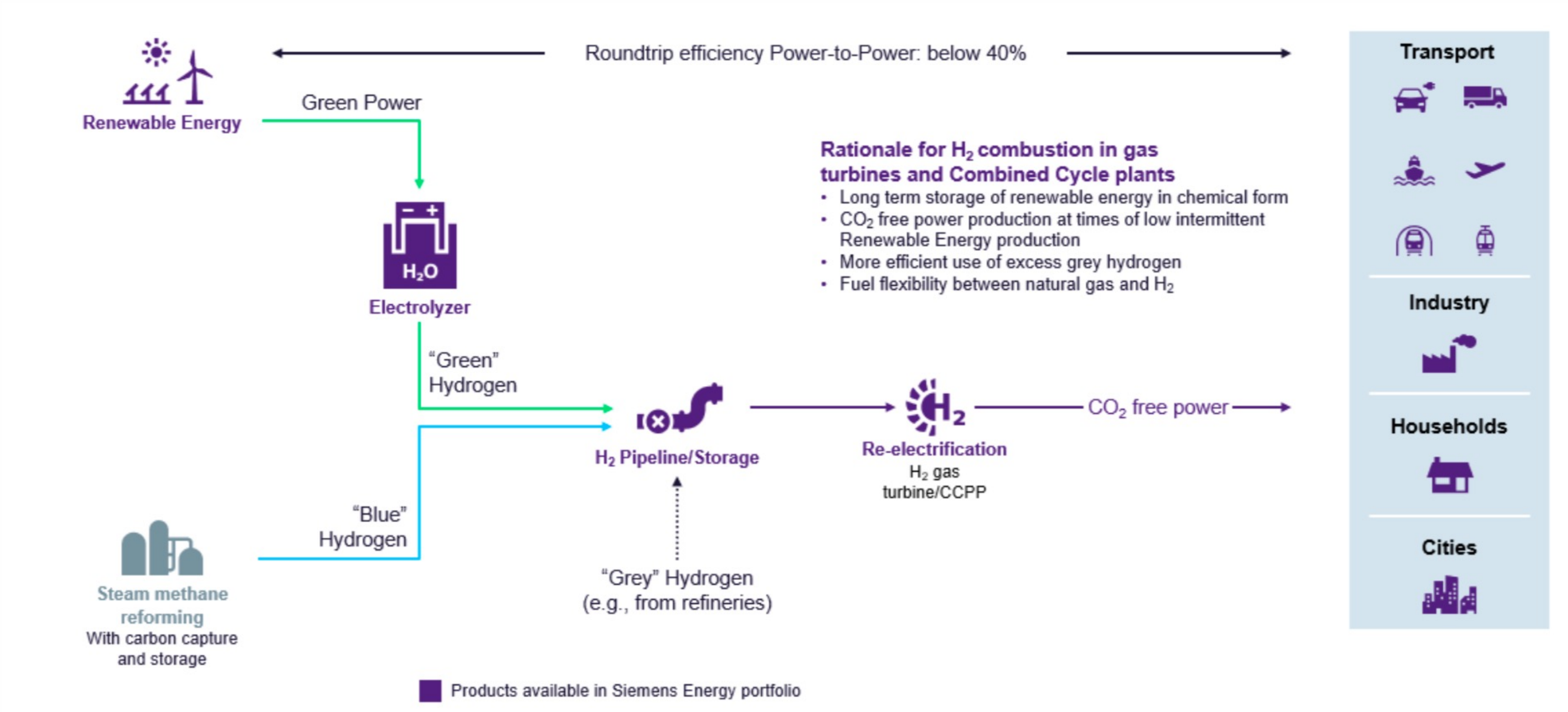


https://www.irena.org/publications/2022/May/Global-hydrogen-trade-Cost

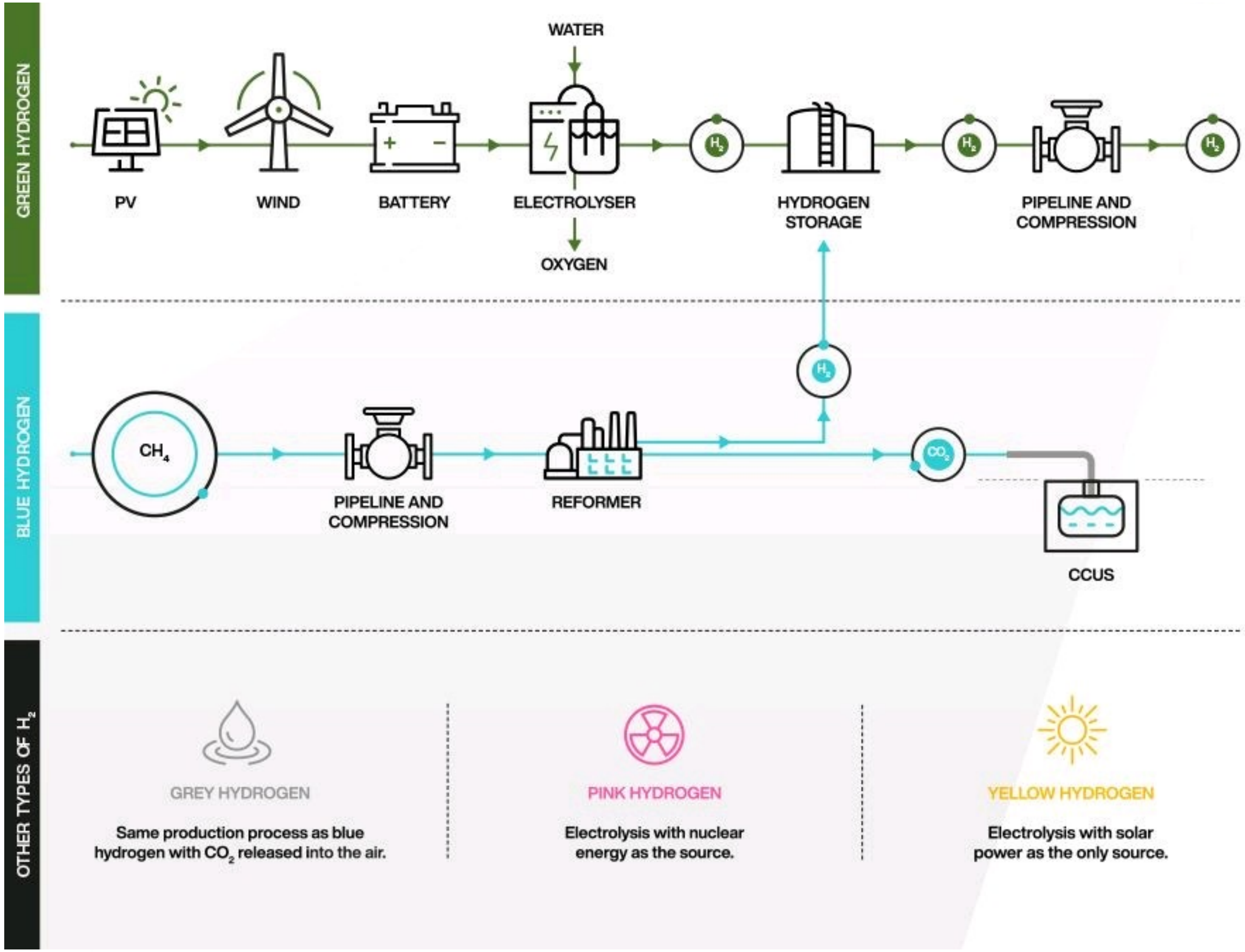
ENERGY CARRIER: POWER-TO-H_2-TO-X



HYDROGEN RE-ELETRIFICATION (POWER)

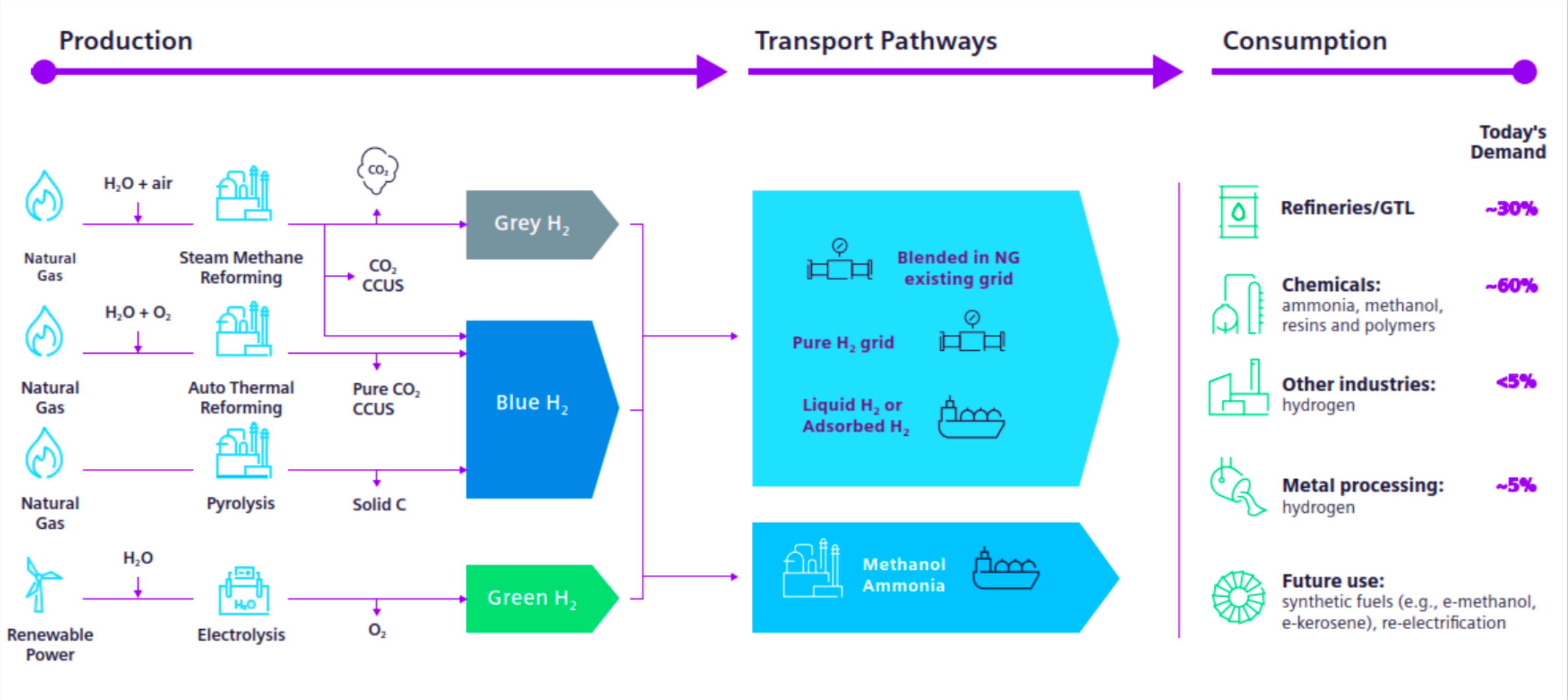


HYDROGEN-READY POWER PLANT (SIEMENS)



https://www.siemens-energy.com/global/en/offerings/technical-papers/download-hydrogen-gas-turbine-readiness-white-paper.html

HYDROGEN SUPPLY CHAIN



https://www.siemens-energy.com/global/en/offerings/technical-papers/download-hydrogen-gas-turbine-readiness-white-paper.html

MAKE ENERGY TRANSITION SUSTAINABLE

MODIFIED KAYA IDENTITIES: ECONOMY X ENERGY X OTHER IMPACTS

$$X = P*(G/P)*(E/G)*(X/E)$$

X intensity
(units of X /kWh)

energy intensity
(kWh/$)

per capita economic activity

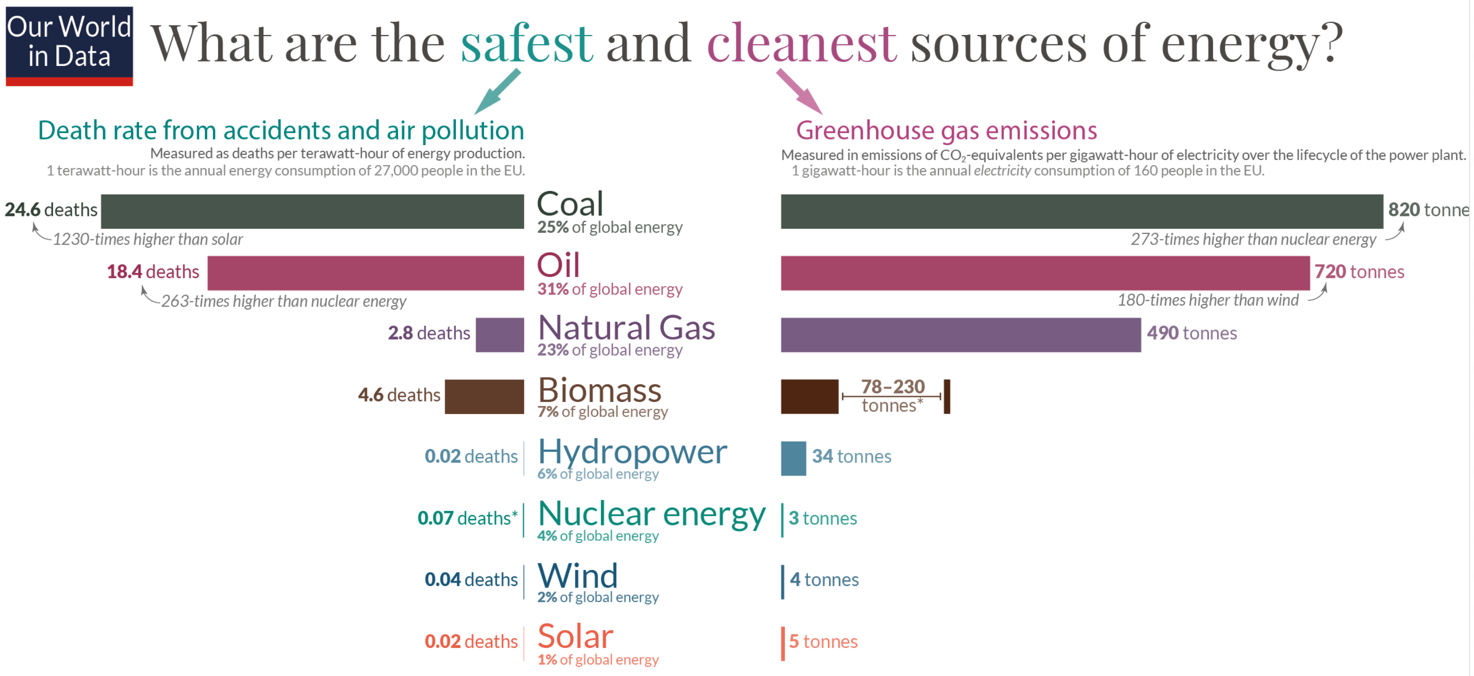
TECHNOLOGY

Reduce X Intensity of Fossil Energy

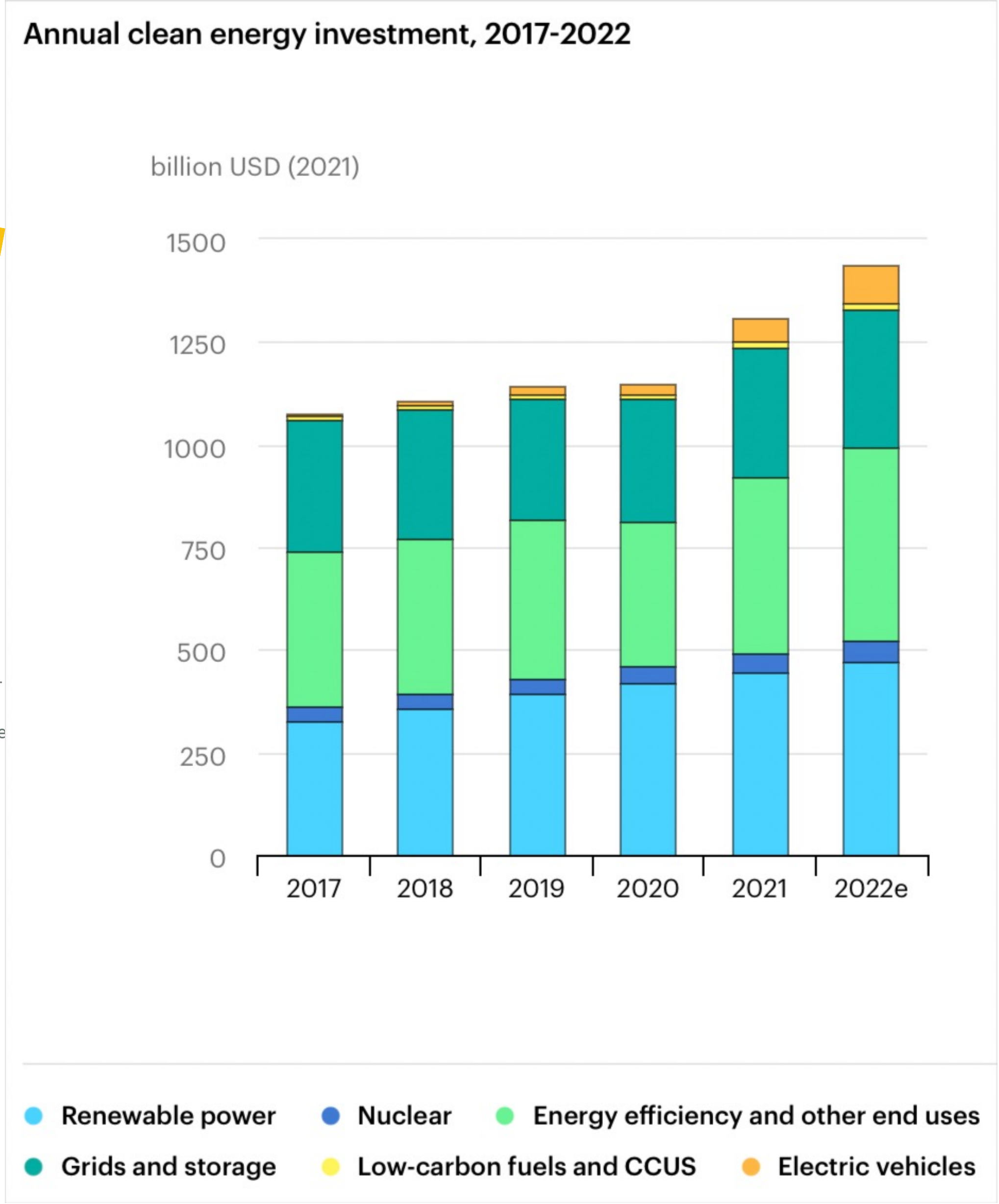
Identify optimal Share in Energy for minimizing X

X = **global impact X**;
P = global population growth;
G = global GDP;
E = global energy consumption.

DEATH RATE, GHG EMISSIONS & INVESTMENT PER ENERGY SOURCES

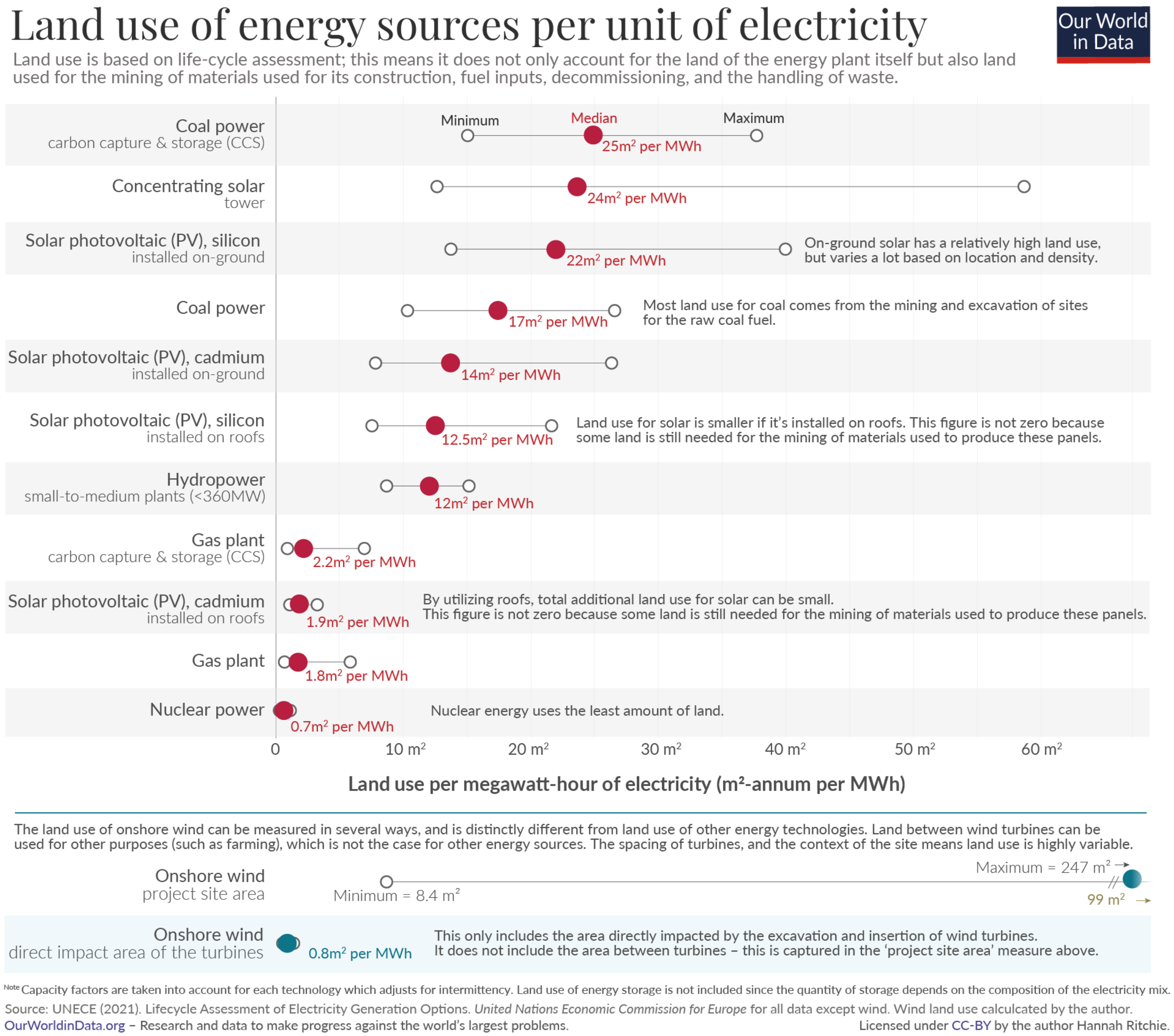


https://ourworldindata.org/safest-sources-of-energy

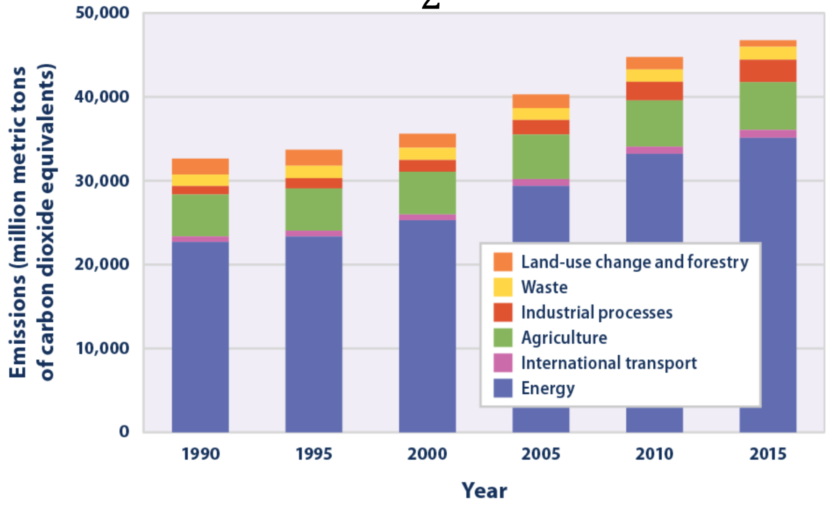


https://www.iea.org/data-and-statistics/charts/share-of-variable-renewables-in-the-global-electricity-mix-2015-2024

(LIFECYCLE) LAND USE

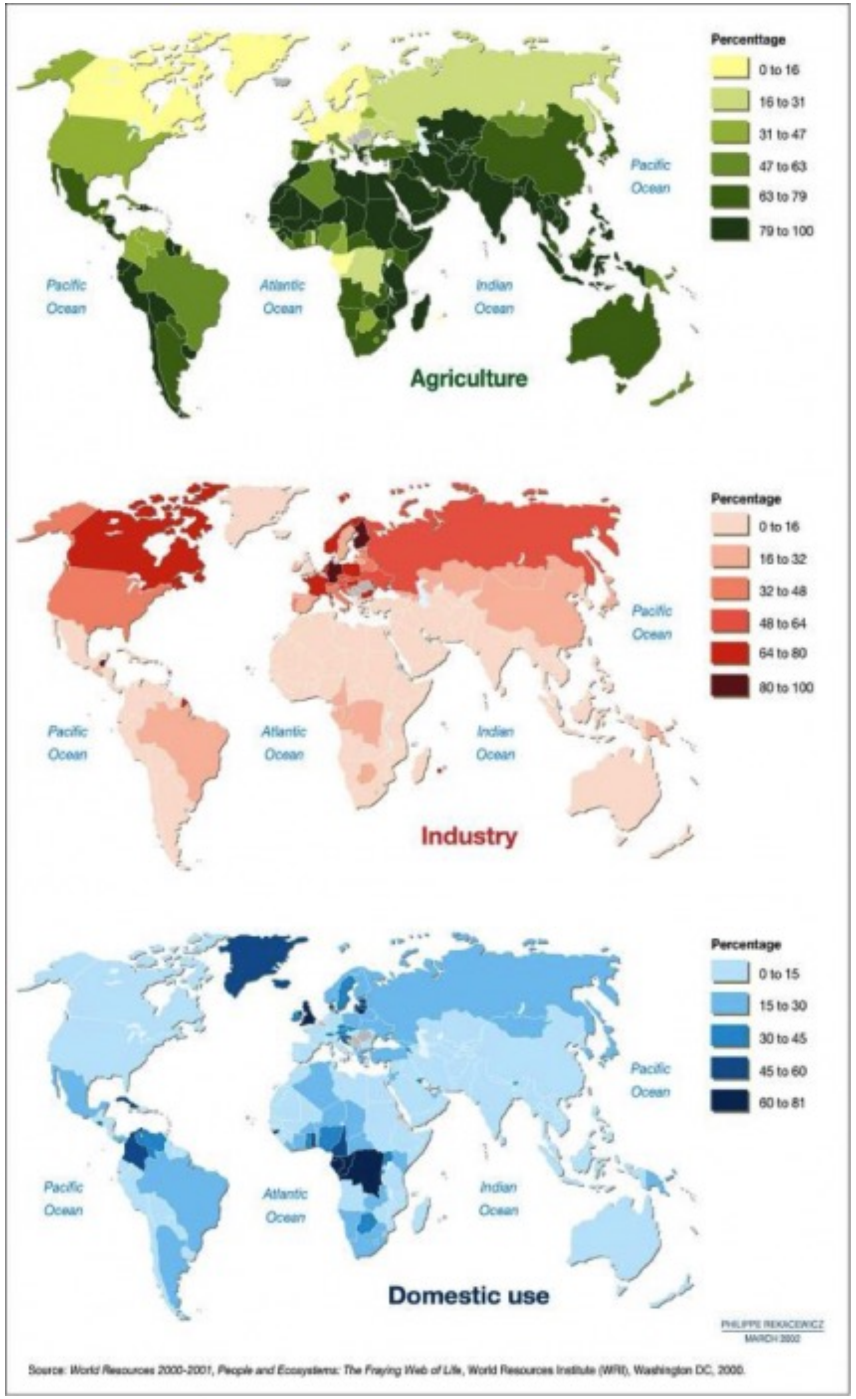


$LUC \rightarrow CO_2$ EMISSIONS

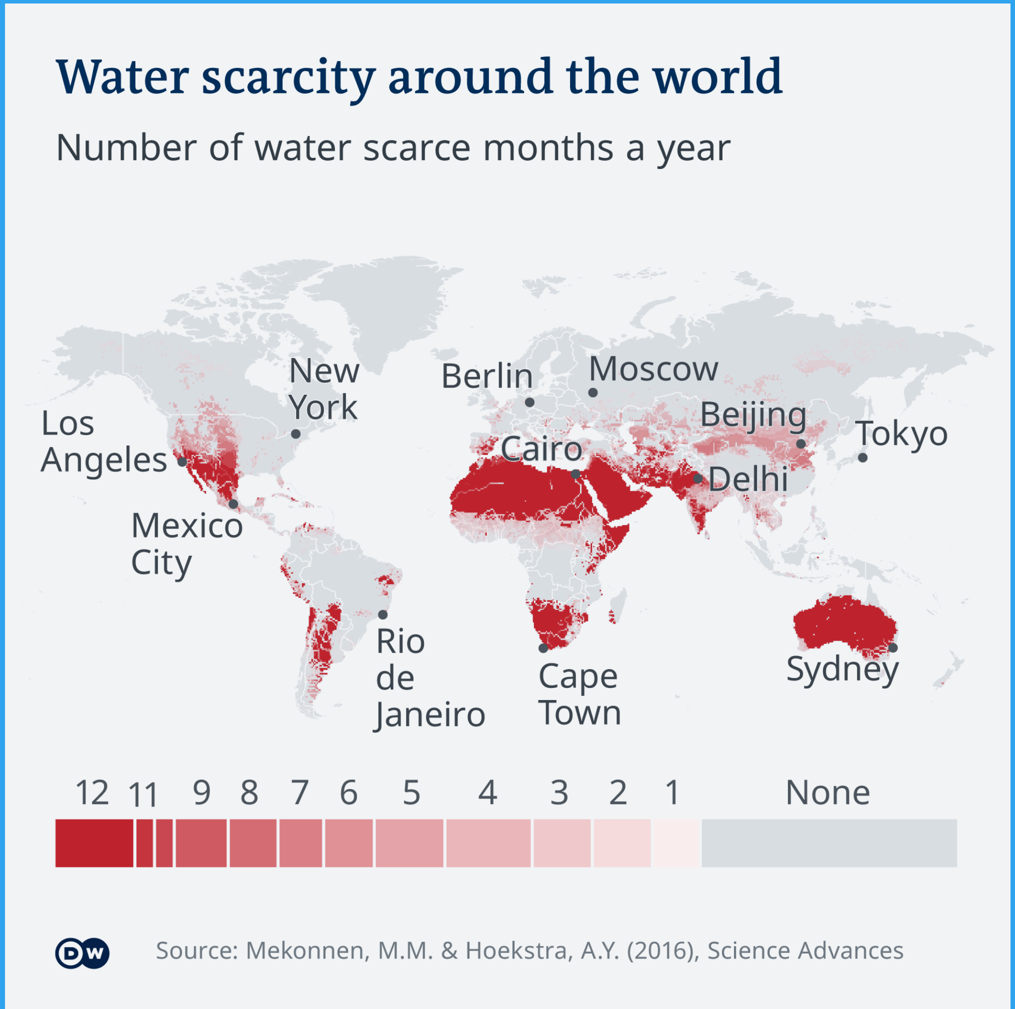


https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions

WATER USE



https://www.e-education.psu.edu/earth111/node/849



https://www.dw.com/en/how-big-is-your-water-footprint/a-61171792

GEOREFERENCING THE TRANSITION

7 AFFORDABLE AND CLEAN ENERGY

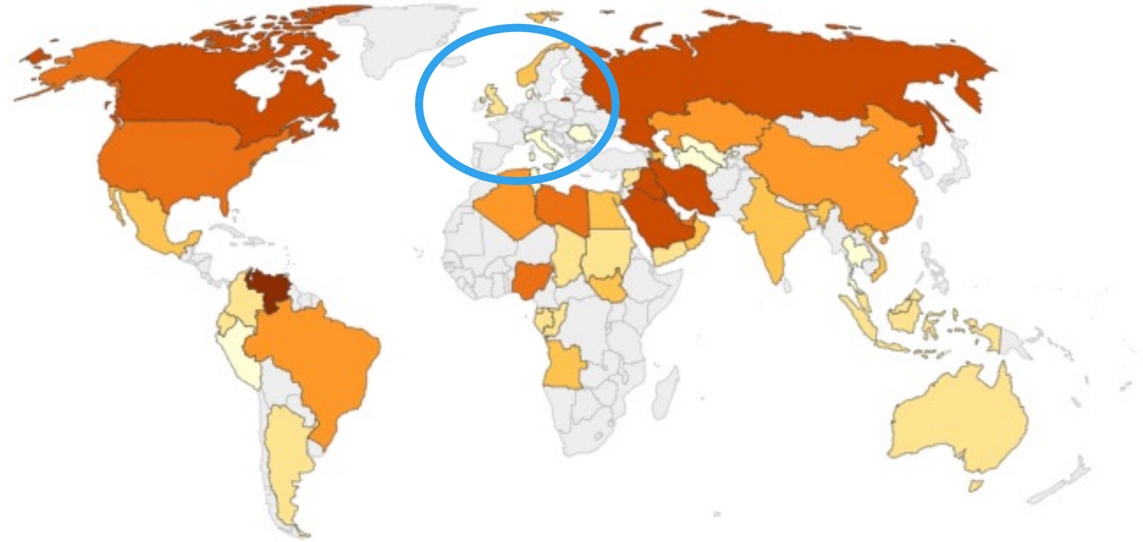
13 CLIMATE ACTION

Oil reserves, 2020

Our World in Data

Shown is the total proven reserves of oil. This is oil that we know with reasonable certainty can be recovered in the future under existing economic and operating conditions. Proven reserves decrease when we extract oil, and increase as new resources are discovered or become economically viable to extract.

World



https://ourworldindata.org/fossil-fuels

No data | 0 barrels | 1 billion barrels | 3 billion barrels | 10 billion barrels | 30 billion barrels | 100 billion barrels | 300 billion barrels | 1 trillion barrels

Source: Statistical Review of World Energy - BP (2021)

Our World in Data

Per capita CO_2 emissions, 2020

Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.

World

https://ourworldindata.org/co2/country/brazil?country=~BRA

No data | 0 t | 0.1 t | 0.2 t | 0.5 t | 1 t | 2 t | 5 t | 10 t | 20 t

Source: Our World in Data based on the Global Carbon Project

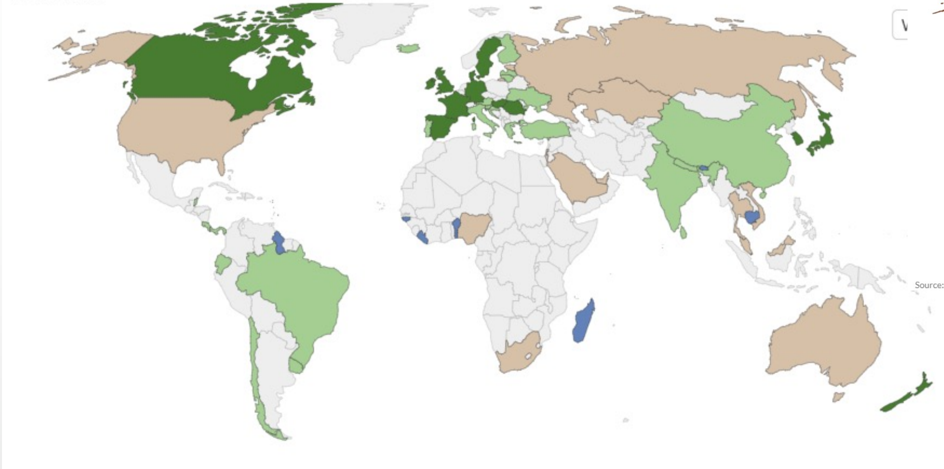
OurWorldInData.org/co2-and-other-greenhouse-gas-emiss

GEOREFERENCES & NEXUS

Status of net-zero carbon emissions targets

The inclusion criteria for net-zero commitments may vary from country to country. For example, the inclusion of international aviation emissions; or the acceptance of carbon offsets.

To see the year for which countries have pledged to achieve net-zero, hover over the country in the interactive version of this chart.



Achieved | In law | In policy document | Pledge | No data

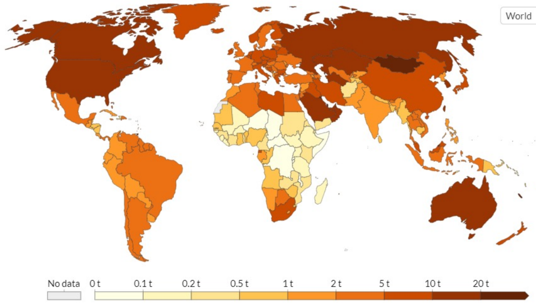
https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Source: Net Zero Tracker. Energy and Climate Intelligence Unit, Data-Driven EnviroLab, NewClimate Institute, Oxford Net Zero. Last updated: 2nd November 2021.

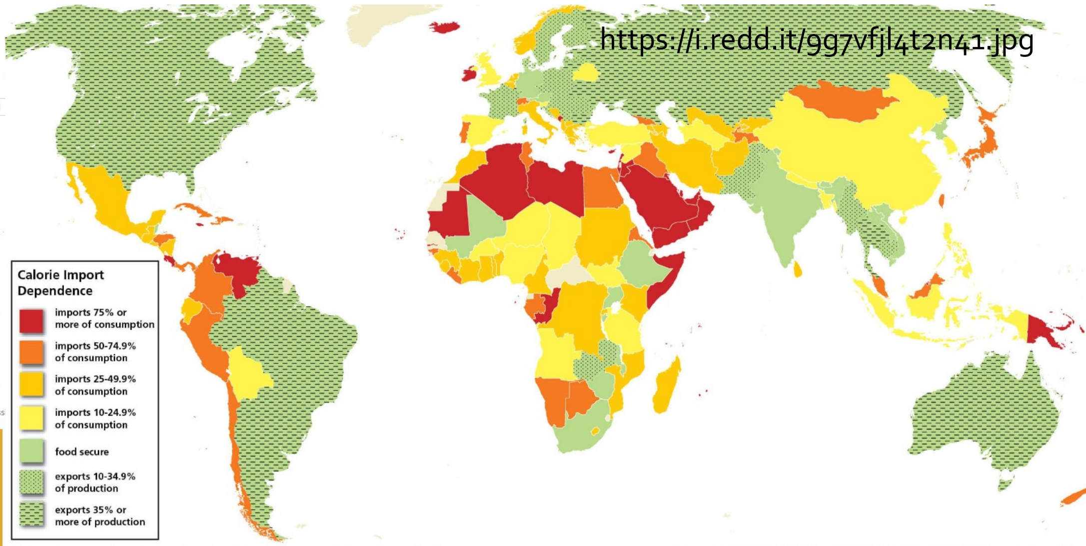
Our World in Data

Per capita CO_2 emissions, 2020

Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.

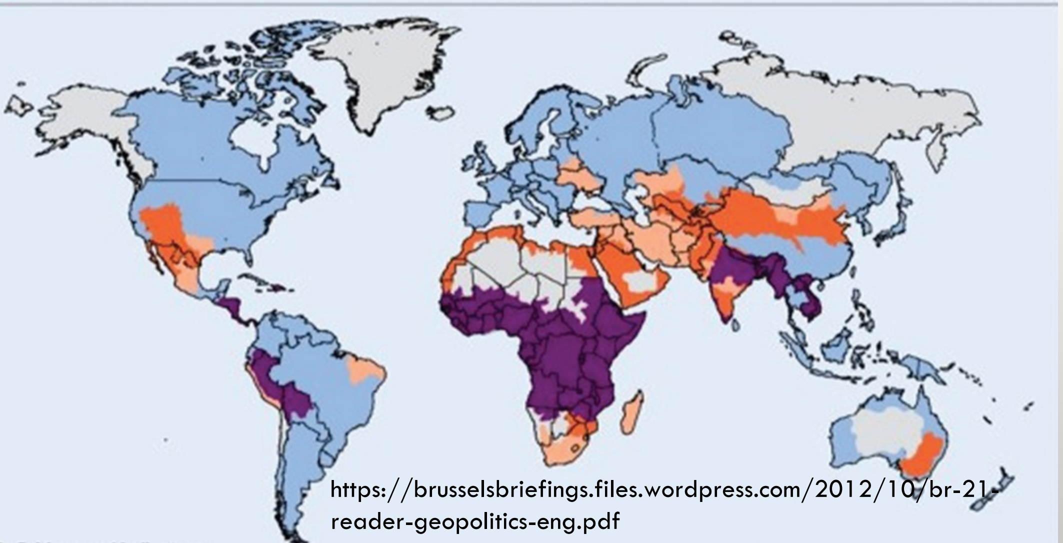


Source: Our World in Data based on the Global Carbon Project   OurWorldInData.org/co2-and-other-greenhouse-gas-emiss



Trade and consumption of raw maize, wheat, rice, soybeans, and other minor grains for any purpose.   Sources: USDA FAS, UN FAO, and UNCOMTRADE   © 2020 Zeihan on Geopolitics

Little or no water scarcity | Approaching physical water scarcity | Not estimated
Physical water scarcity | Economic water scarcity

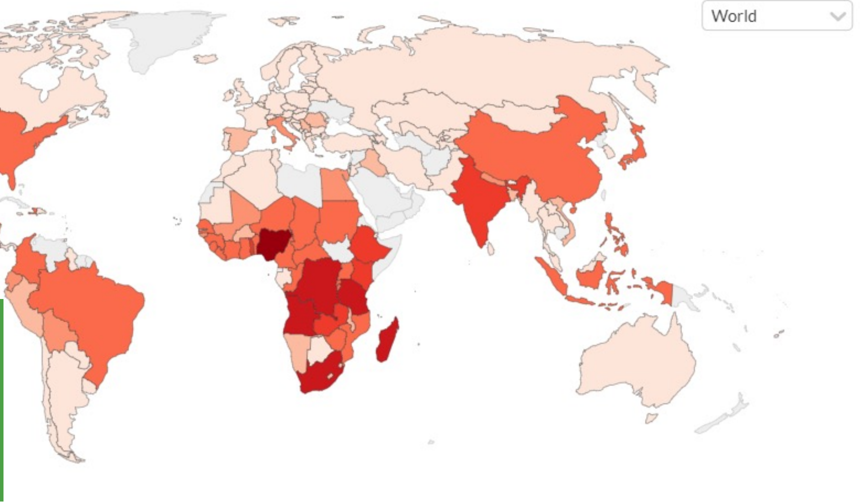


https://brusselsbriefings.files.wordpress.com/2012/10/br-21-reader-geopolitics-eng.pdf

Number of people that cannot afford a calorie sufficient diet, 2017

Our World in Data

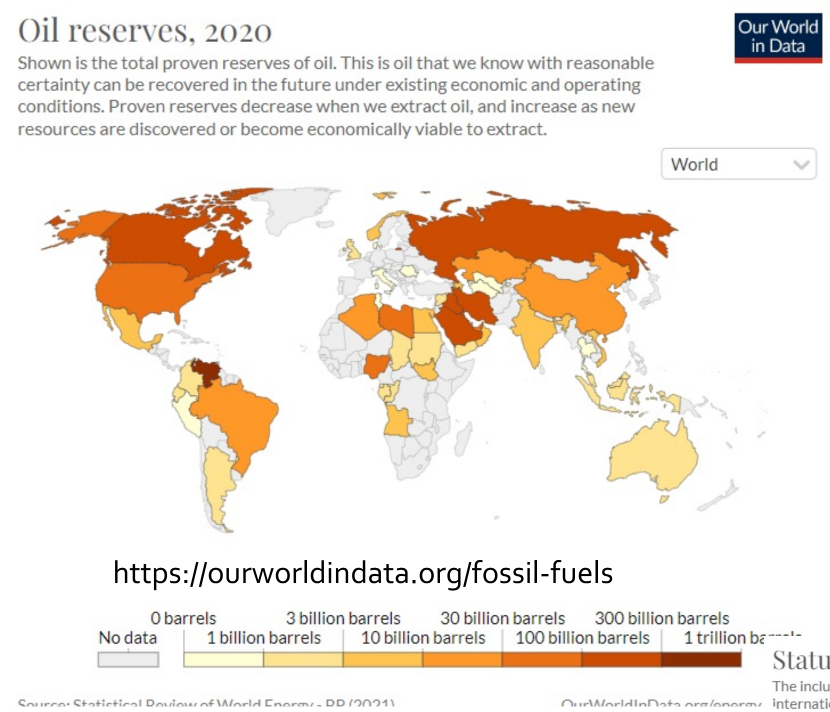
A diet is deemed unaffordable if it costs more than 63% of a household's income. The cost of an energy sufficient diet is defined as the minimum cost to meet energy requirements using the least-cost available starchy staple food in each country.



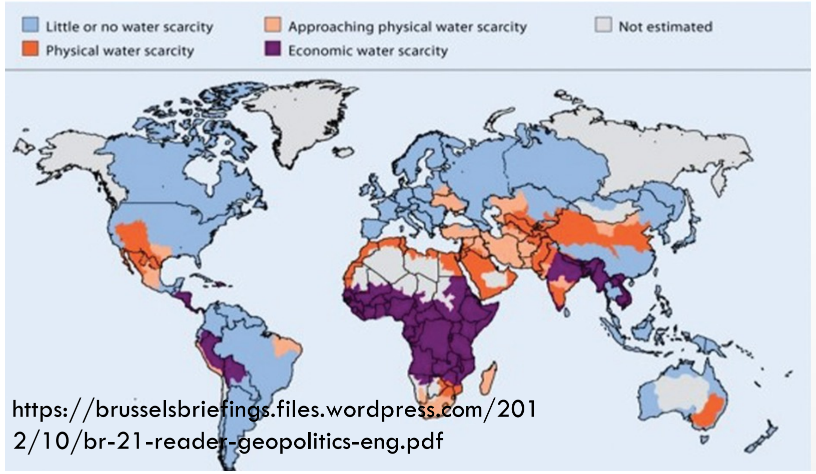
Source: Herforth, Bai, Venkat, Mahrt, Ebel & Masters (2020); and World Bank International Comparison Program (ICP).
OurWorldInData.org/food-prices • CC BY

GEOPOLITICS, NEXUS & ENERGY TRANSITION

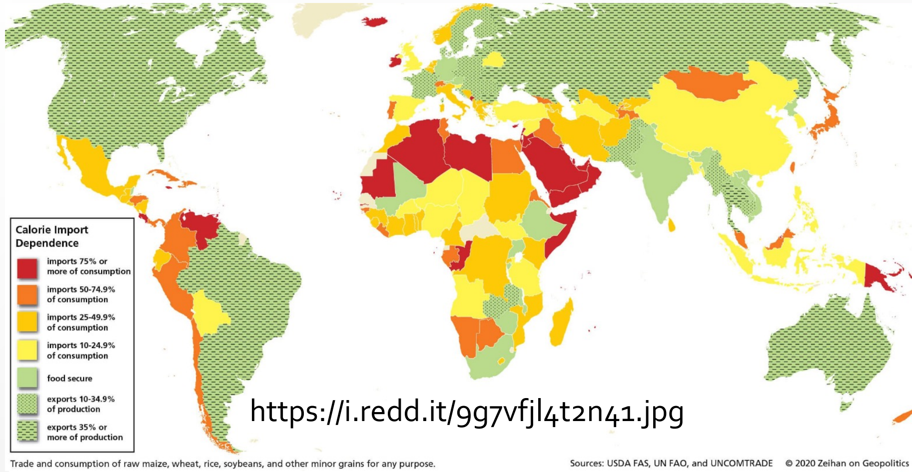
"THAT LATIN AMERICA IS ABOUT TO BOOM IS RELATIVELY CERTAIN. (...) LATIN AMERICA IS RICH WITH THE RESOURCES THE REST OF THE WORLD NEEDS"
https://www.thelykeion.com/the-investment-case-for-latin-america/



https://ourworldindata.org/fossil-fuels



https://brusselsbriefings.files.wordpress.com/2012/10/br-21-reader-geopolitics-eng.pdf



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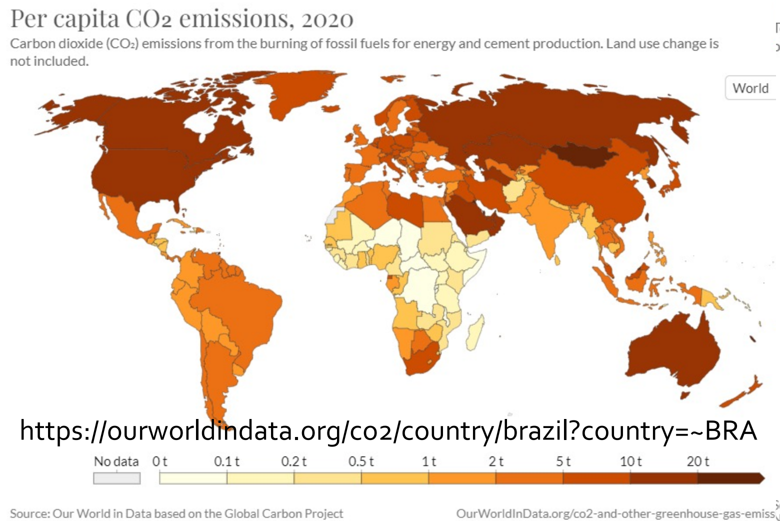
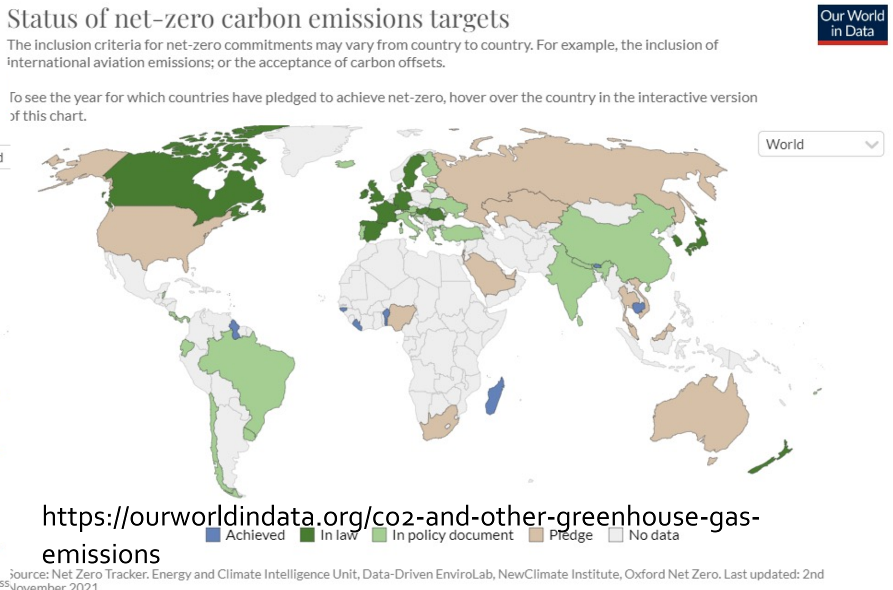
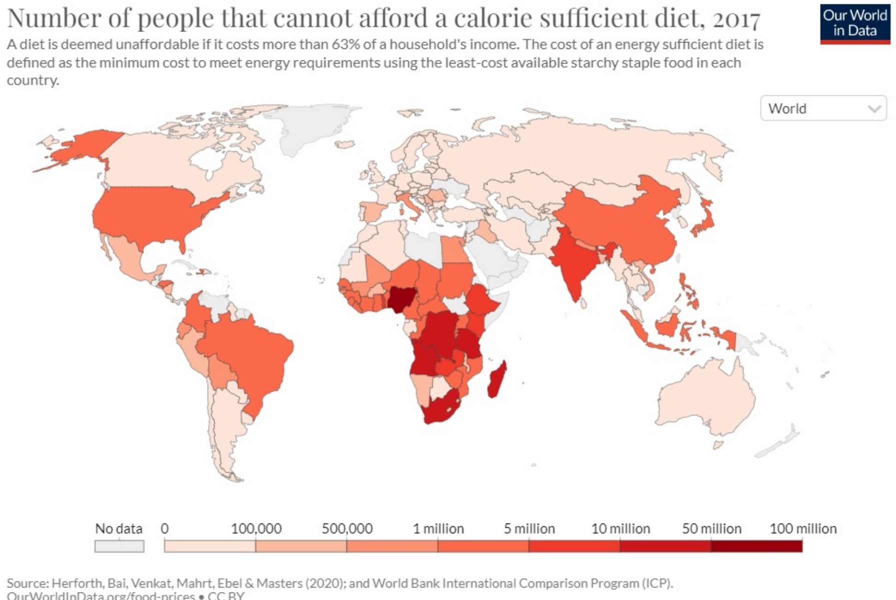


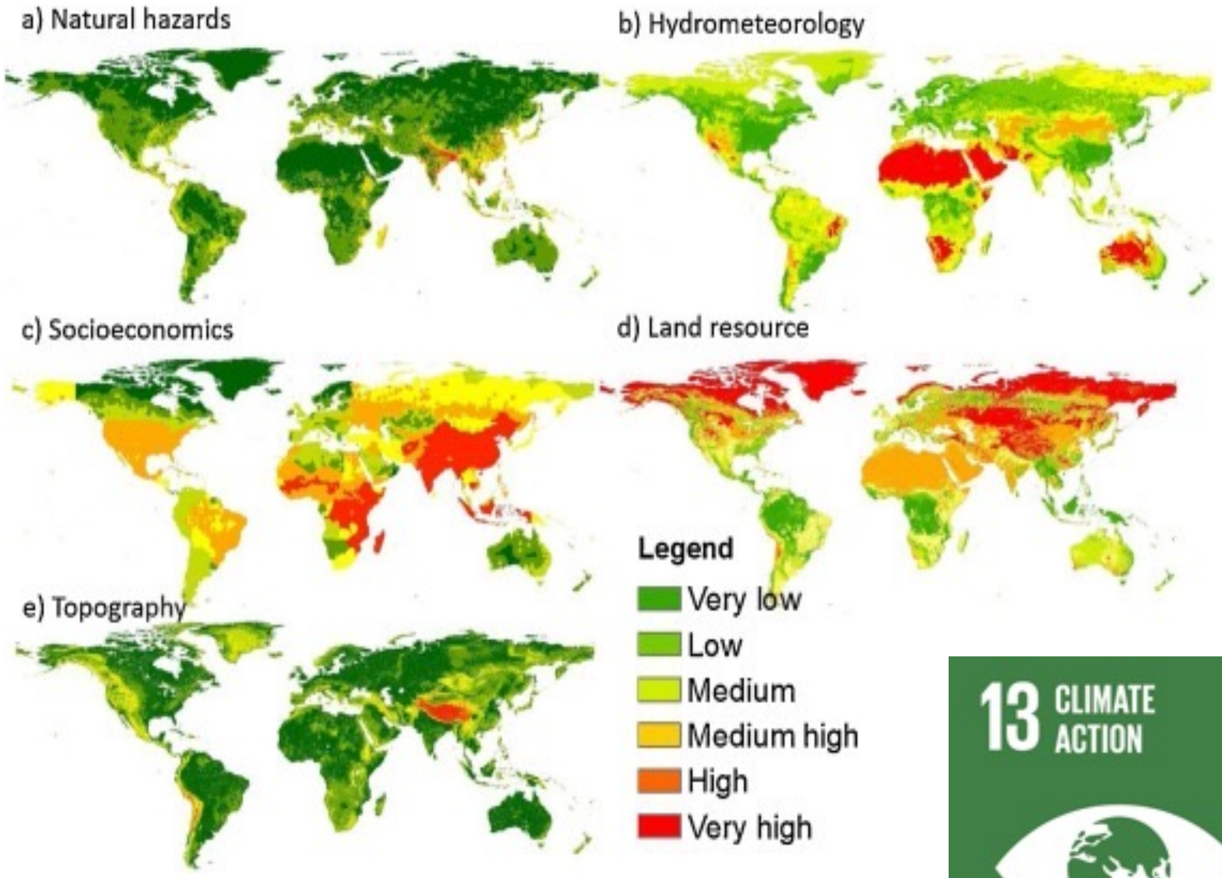
https://ourworldindata.org/co2/country/brazil?country=~BRA



https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions



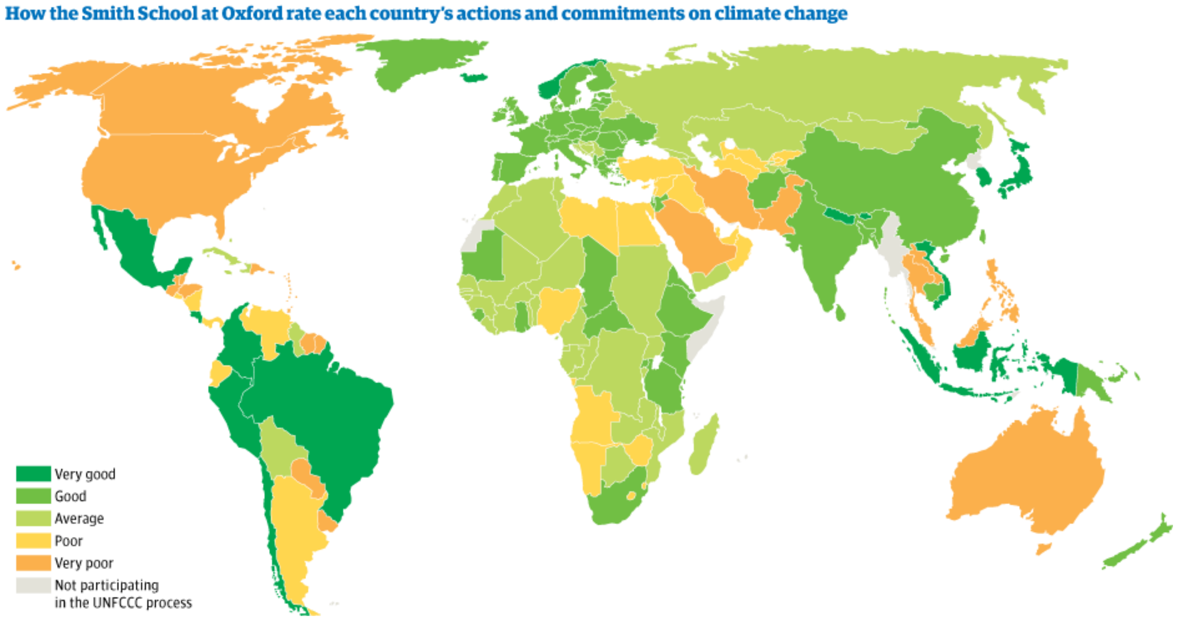
VULNERABILITIES



https://doi.org/10.1016/j.mex.2019.03.023

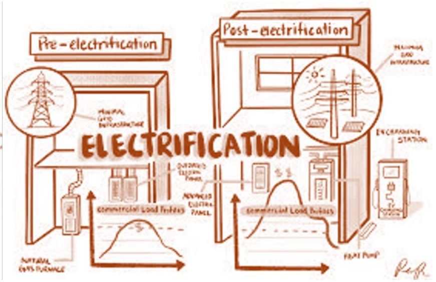
13 CLIMATE ACTION

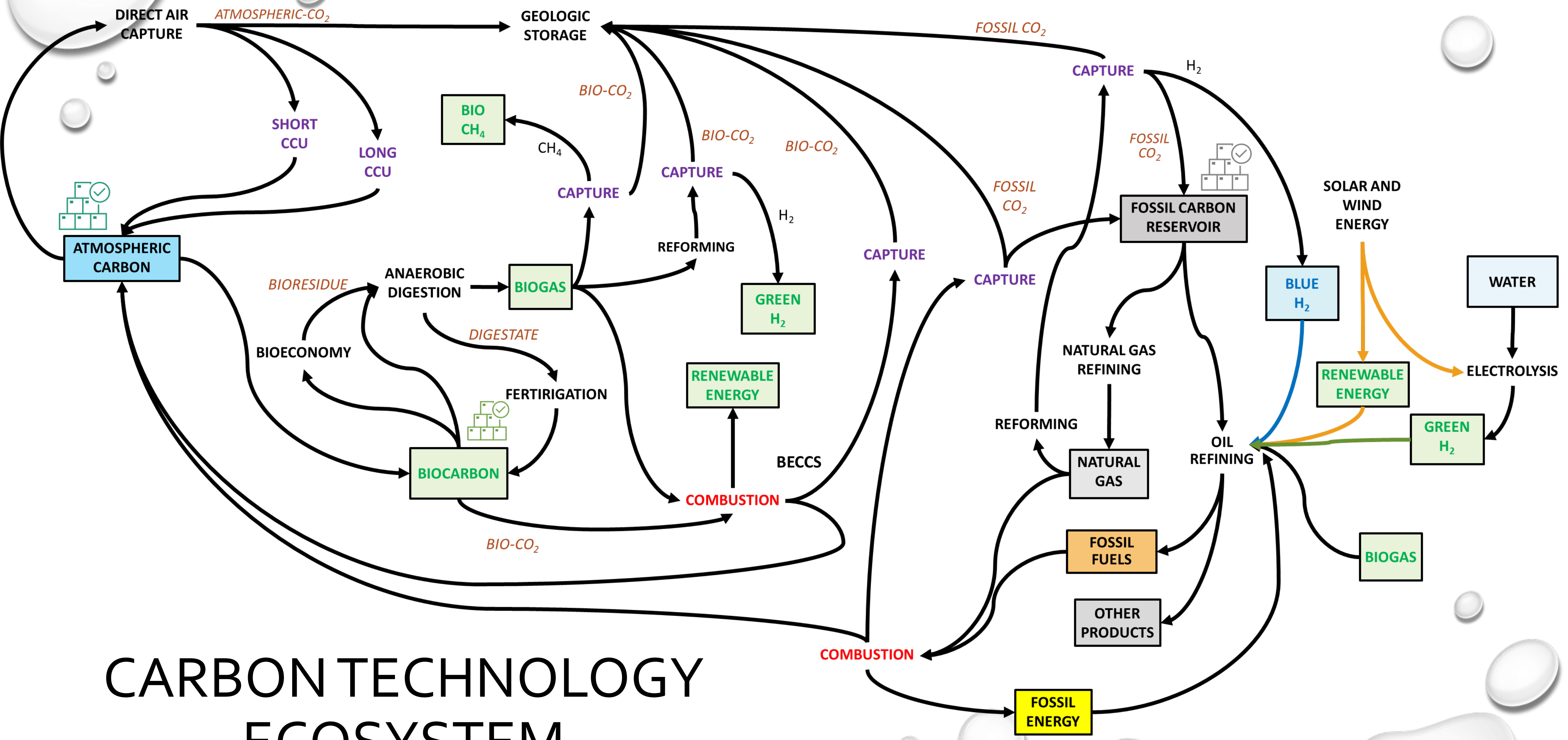
COMITMENTS ON CLIMATE CHANGE



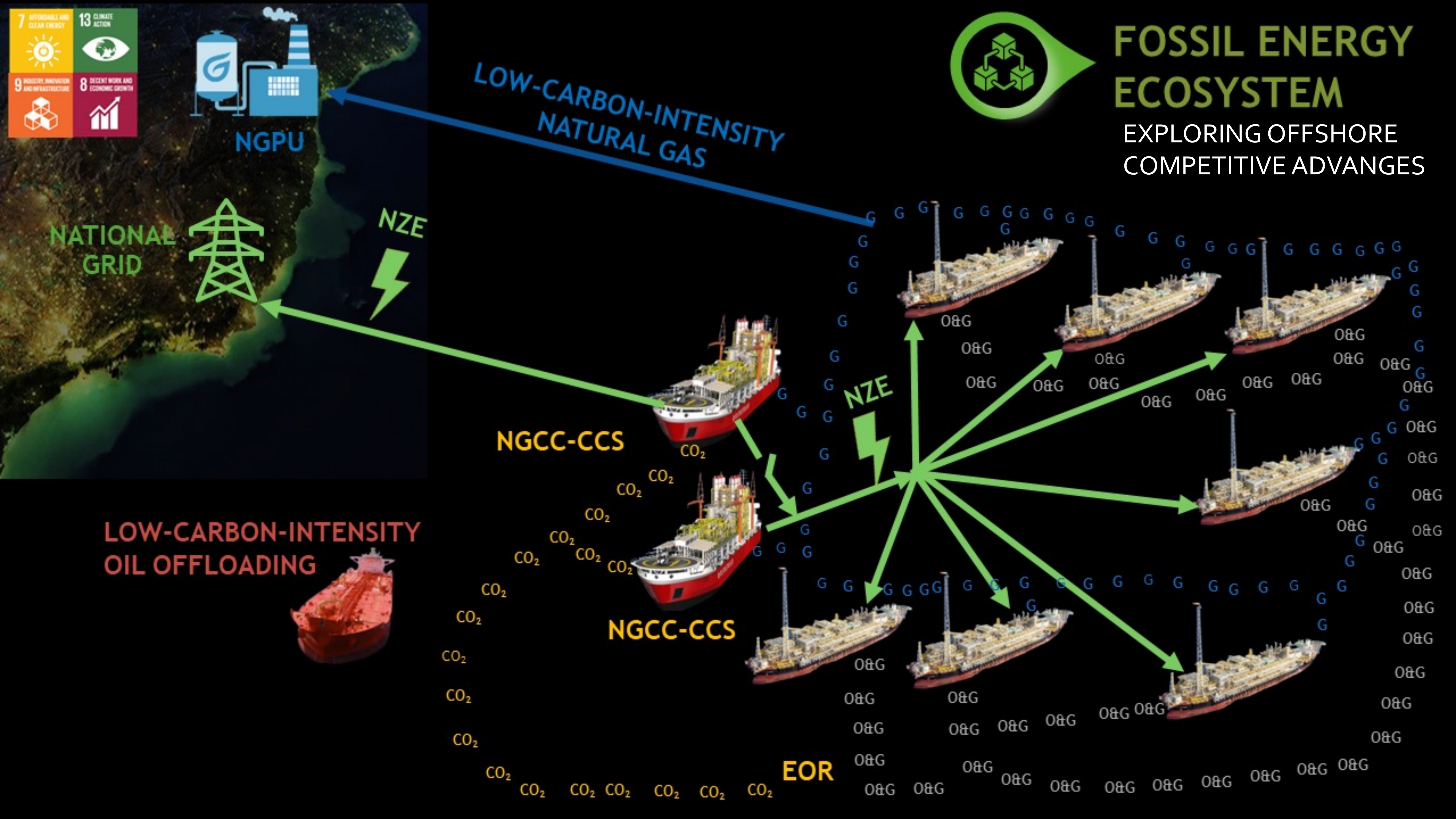
https://www.theguardian.com/environment/graphic/2011/jul/15/smith-school-action-climate-change

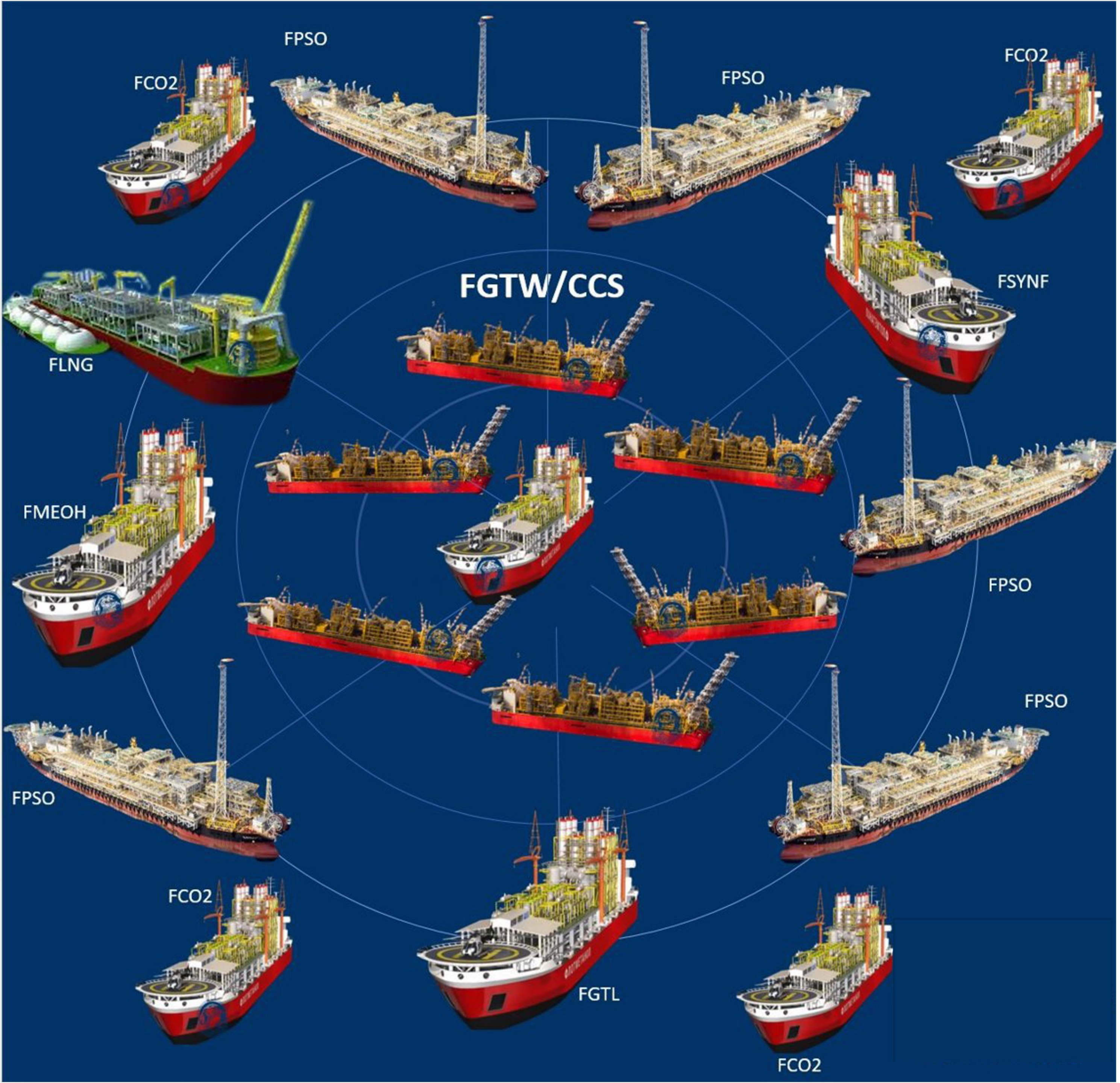
FINAL REMARKS





CARBON TECHNOLOGY ECOSYSTEM


FOSSIL ENERGY ECOSYSTEM
EXPLORING OFFSHORE COMPETITIVE ADVANGES
7 AFFORDABLE AND CLEAN ENERGY
13 CLIMATE ACTION
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
8 DECENT WORK AND ECONOMIC GROWTH
NGPU
LOW-CARBON-INTENSITY NATURAL GAS
NATIONAL GRID
NZE
NGCC-CCS
NGCC-CCS
LOW-CARBON-INTENSITY OIL OFFLOADING
NZE
EOR
CO_2
G
O&G



Offshore Hub for Natural Gas Monetization

ENERGY TRANSITION

MULTICRITERIA

"ENERGY INFLATION"

Climateflation, fossilflation and greenflation

https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220317_2~dbb3582f0a.en.html

Minimize the risk of the energy transition creating spiraling price pressures across the economy

ESGWASHING

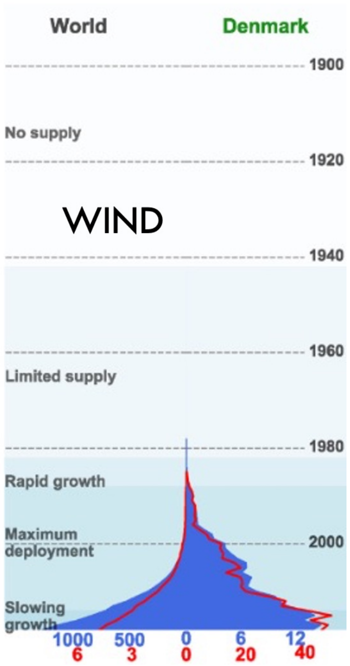
The favored energy-transition technologies — solar, wind and batteries — require a lot more to be mined, refined, fabricated and constructed to replace the fossil-based energy supply.

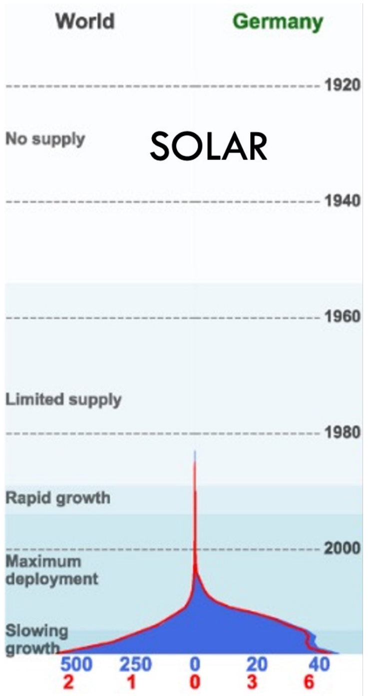
Technology transitions take time.

COVID and Russia-Ukraine war supply-pushed inflation AND exponentially increased awareness of energy safety.

How fast can the world bring online any new sources of energy on the scale needed?

Policymakers answer with legislations, posing upward pressure on energy prices.





ofelia@eq.ufrj.br

THANK YOU FOR YOUR ATTENTION AND

STAY SUSTAINABLE