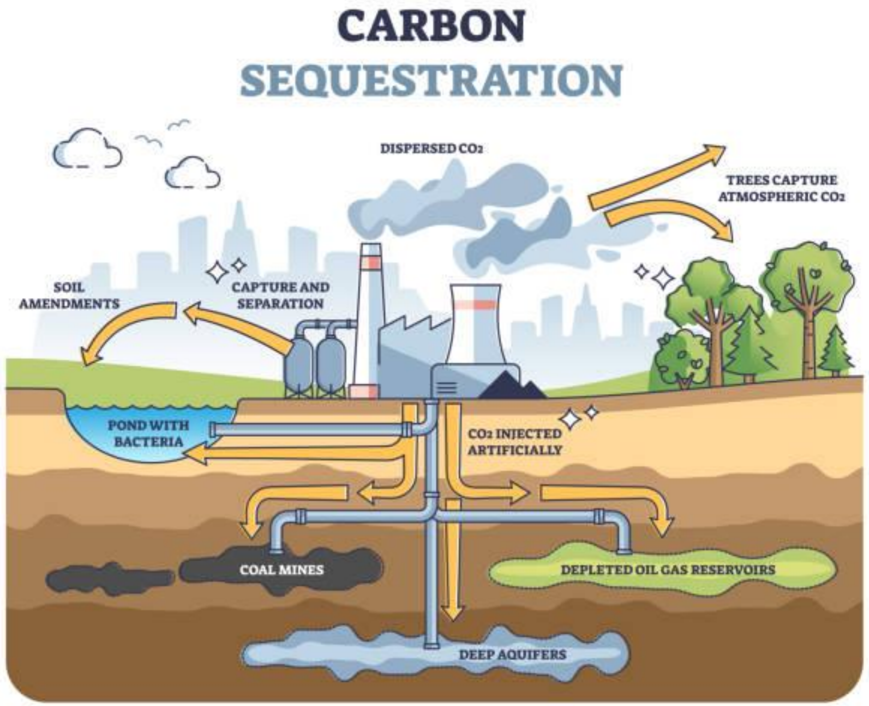
Technical WORKSHOPS

2022 ANH TECHNICAL TALKS

Reservoir characterization for CO2 capture

CARLOS MOLINARES, PHD

FRIDAY, SEPTEMBER 16TH 2022 8:00 a.m. – 9:00 a.m.



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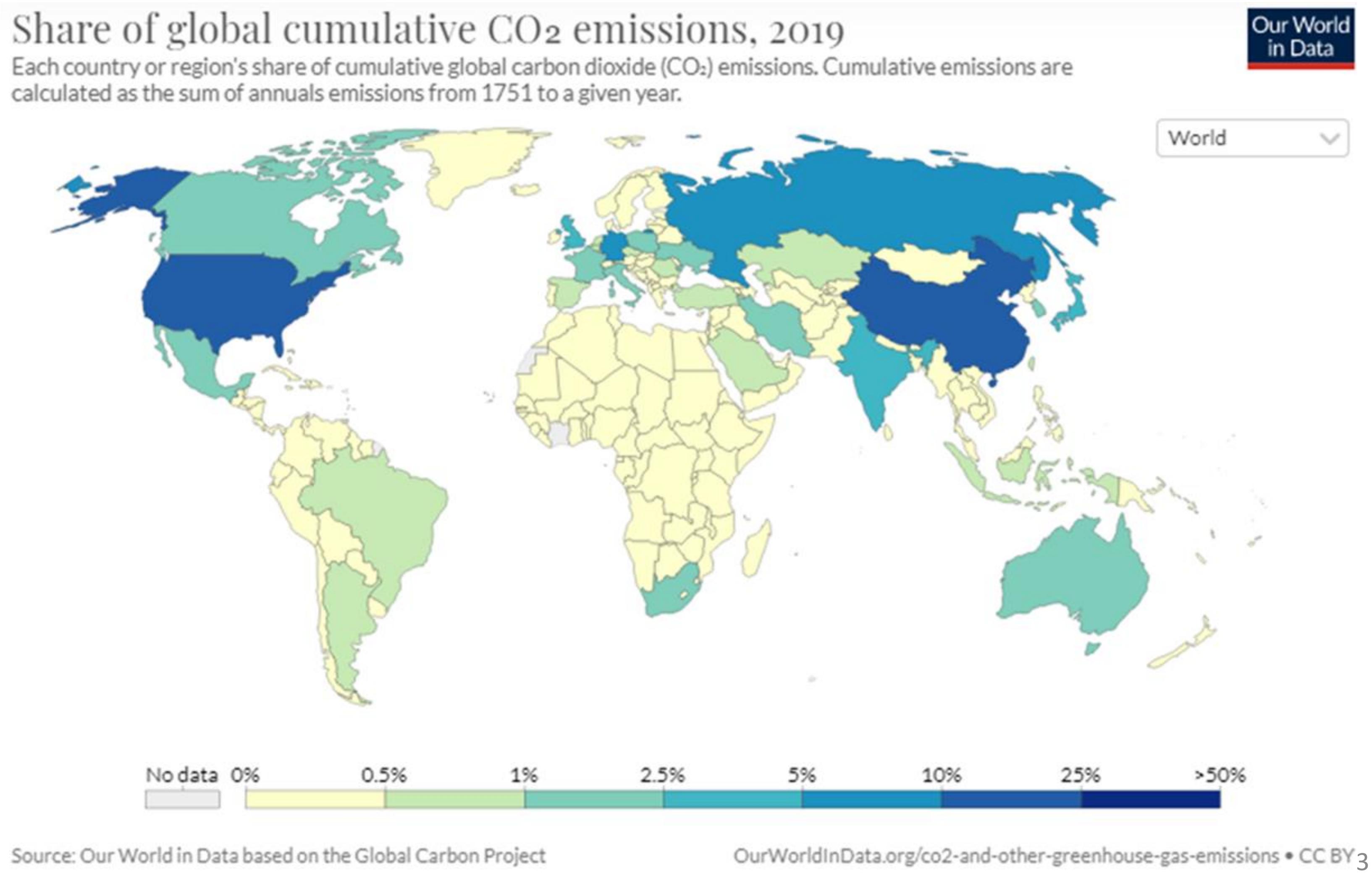
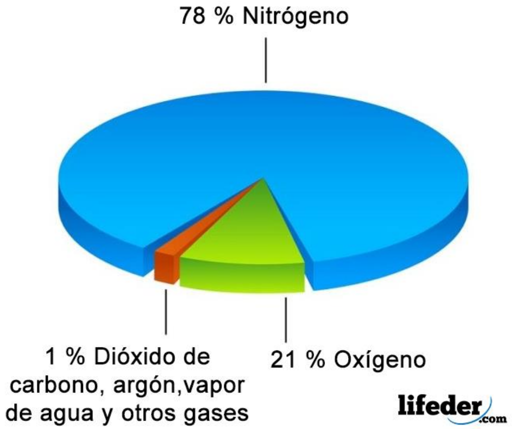
Outline

1. The CO2 Issue
2. Colombia GHG emissions
3. CCU is for U
4. Natural Gas
5. Remarks



The CO_2 Annual Balance



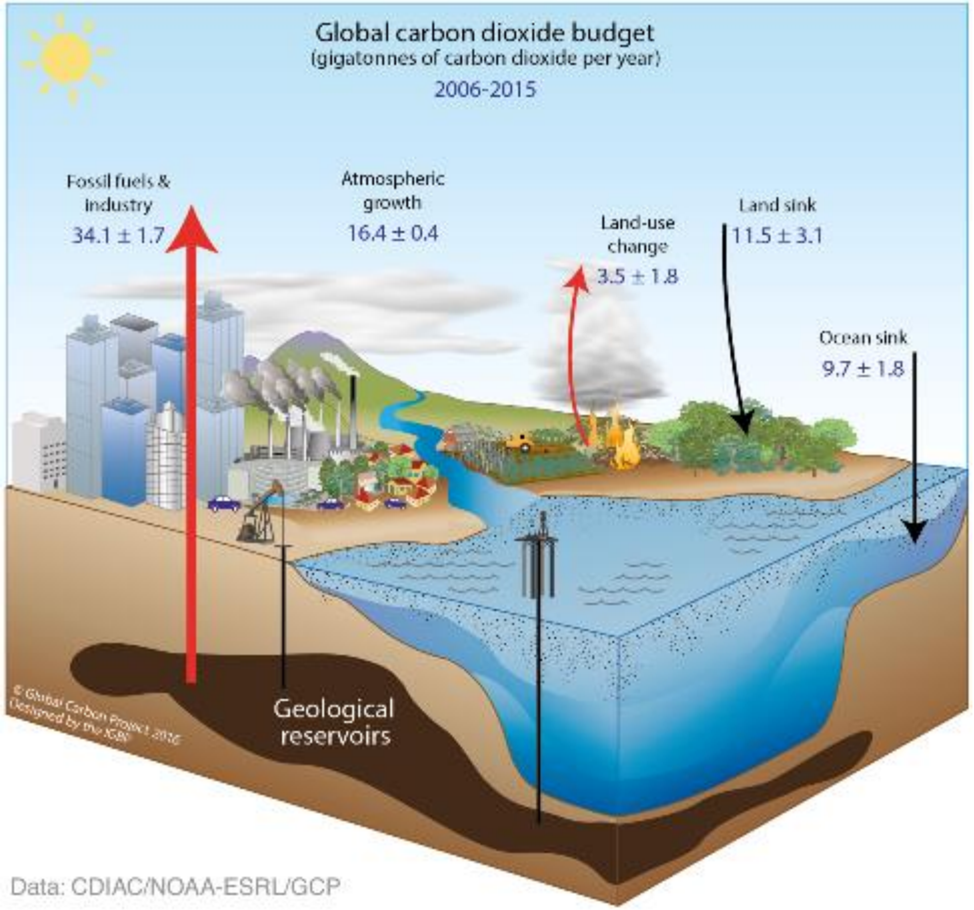
Average Values 2007-2015 (GtCO2/yr)

CO2 Sources Gt/yr:
Emissions: 34.1 ± 1.7
Land Use: 3.5 ± 1.8

CO2 Sinks Gt/yr:
Land: 11.5 ± 3.1
Ocean: 9.7 ± 1.8

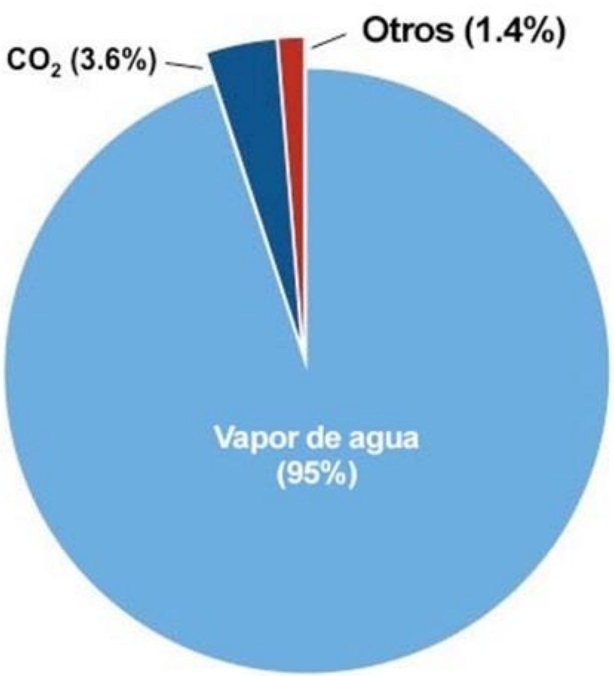
Total: 16.4 ± 0.4 Gt/year

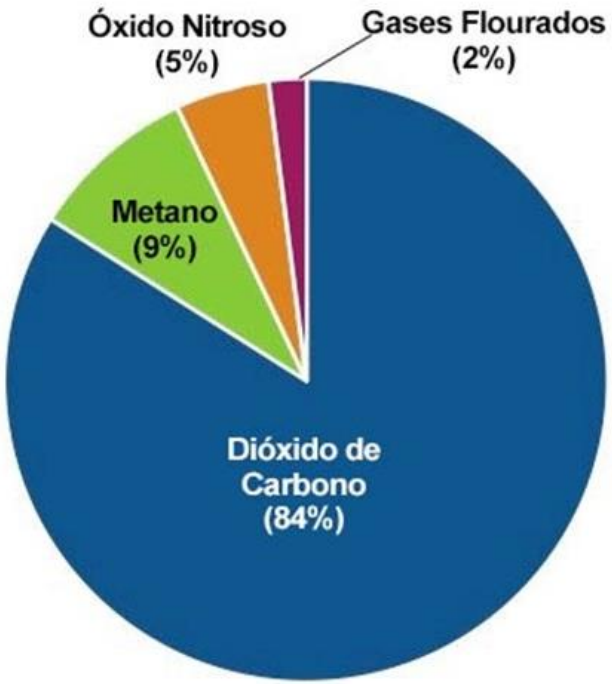
Aprox 50% of emissions
Remain in the atmosphere



Data: CDIAC/NOAA-ESRL/GCP

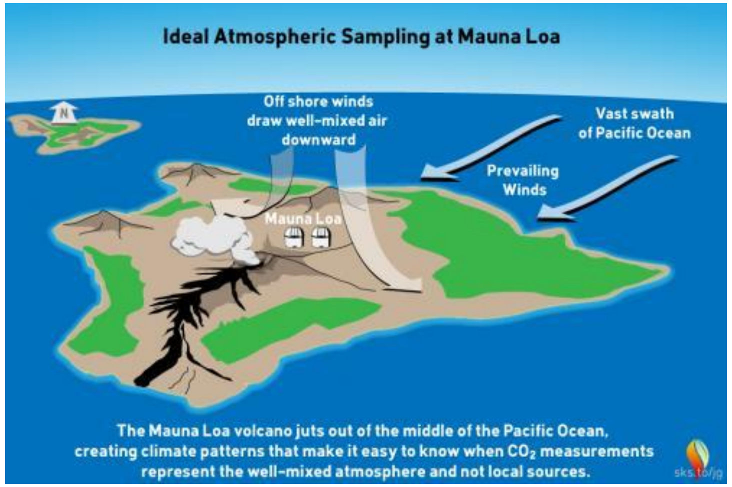
https://cdiac.ess-dive.lbl.gov/GCP/

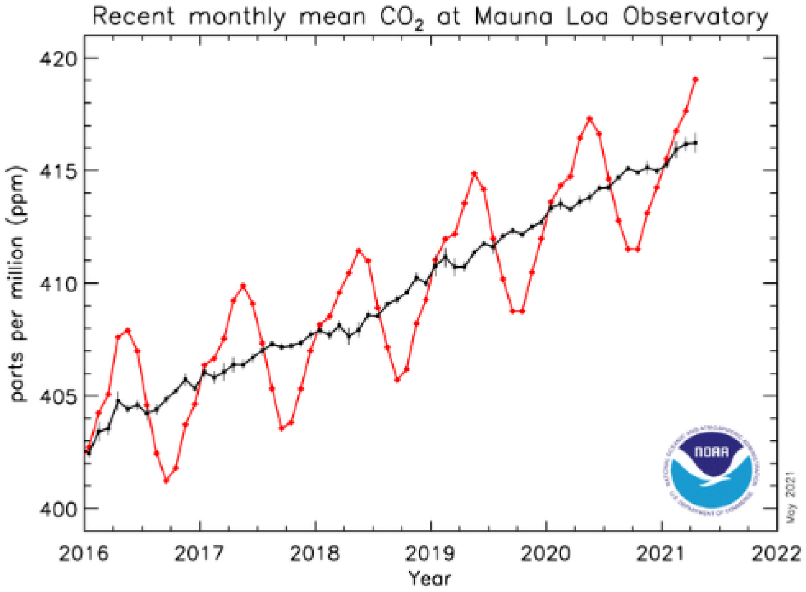


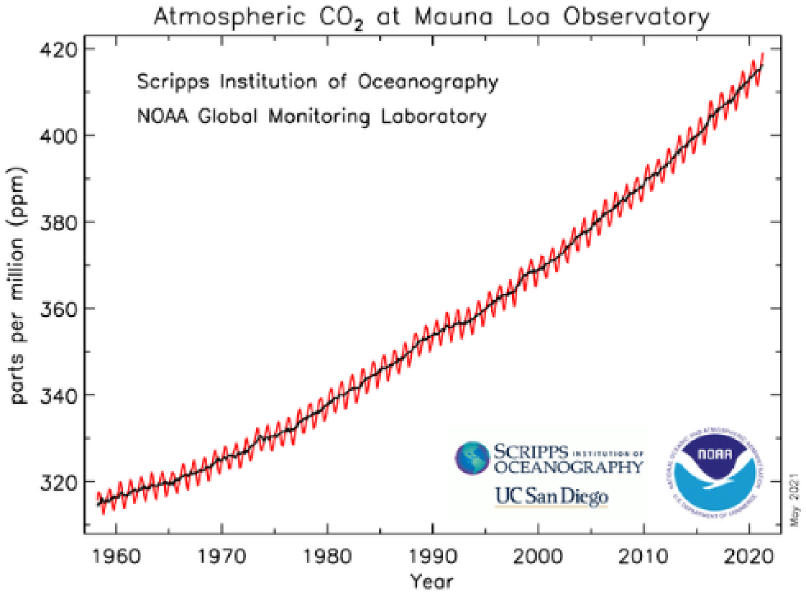


Greenhouse gas	Average lifetime in the atmosphere	Global warming potential of one molecule of the gas over 100 years (Relative to carbon dioxide=1)
Carbon dioxide	50-200 years*	1
Methane	12 years	21
Nitrous oxide	120 years	310
CFC-12	100 years	10,600
CFC-11	45 years	4,600
HFC-134a	14.6 years	1,300
Sulfur hexafluoride	3,200 years	23,900

The CO2 Issue !

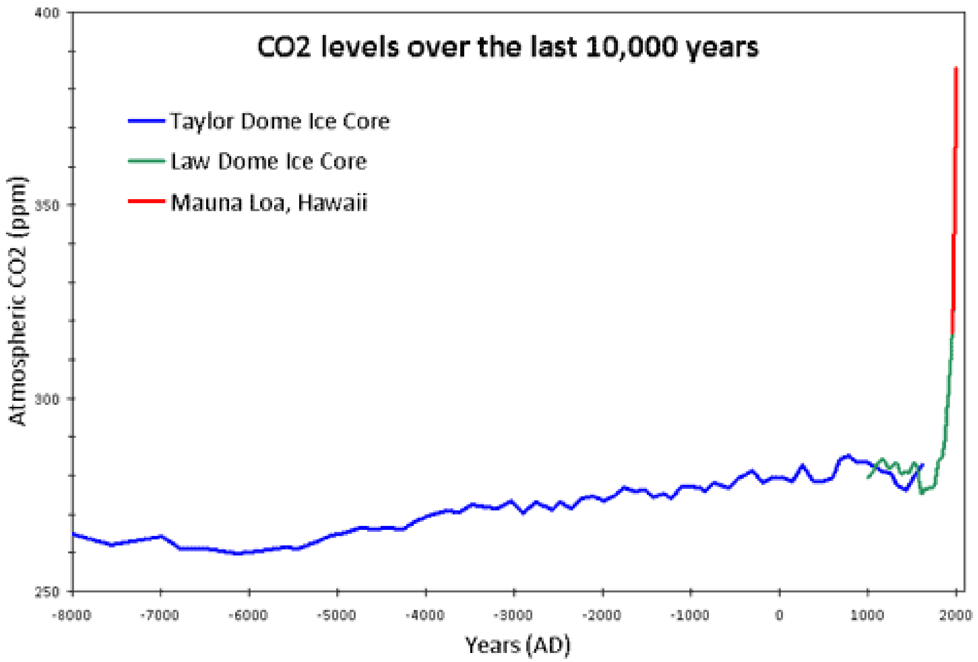






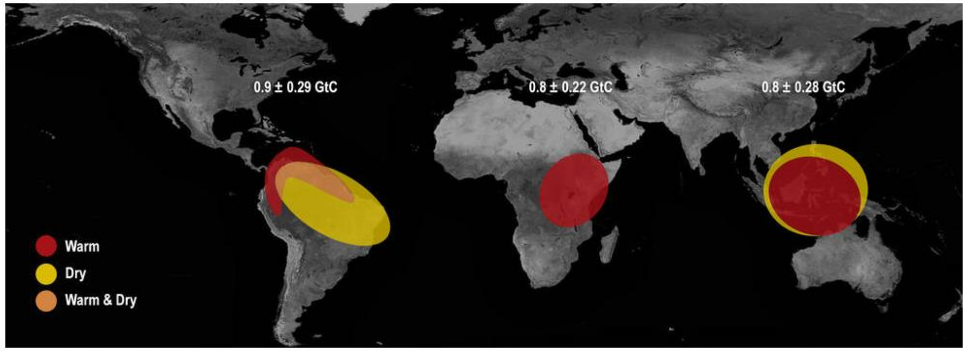
PNG Version PDF Version PNG Version PDF Version

The graphs show monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii. The carbon dioxide data on Mauna Loa constitute the longest record of direct measurements of CO_2 in the atmosphere. They were started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration *[Keeling, 1976]*. NOAA started its own CO_2 measurements in May of 1974, and they have run in parallel with those made by Scripps since then *[Thoning, 1989]*.

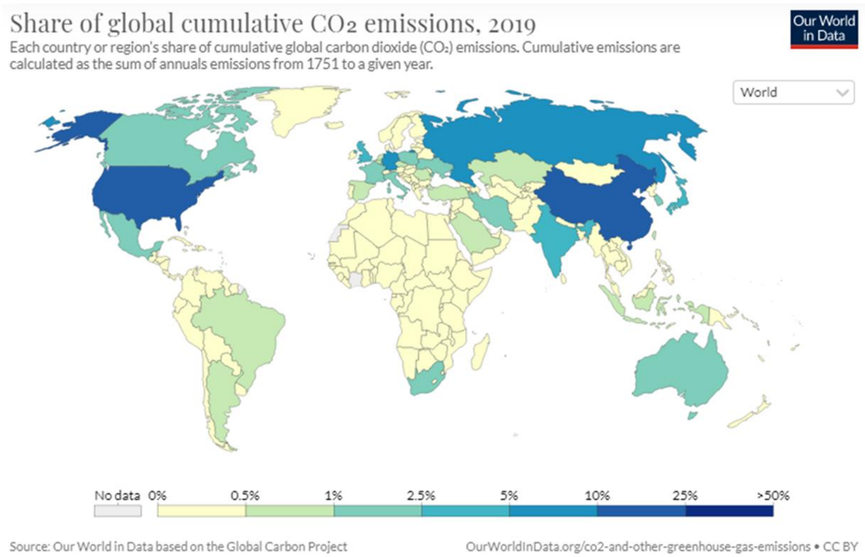


Oct. 12, 2017
RELEASE 17-082

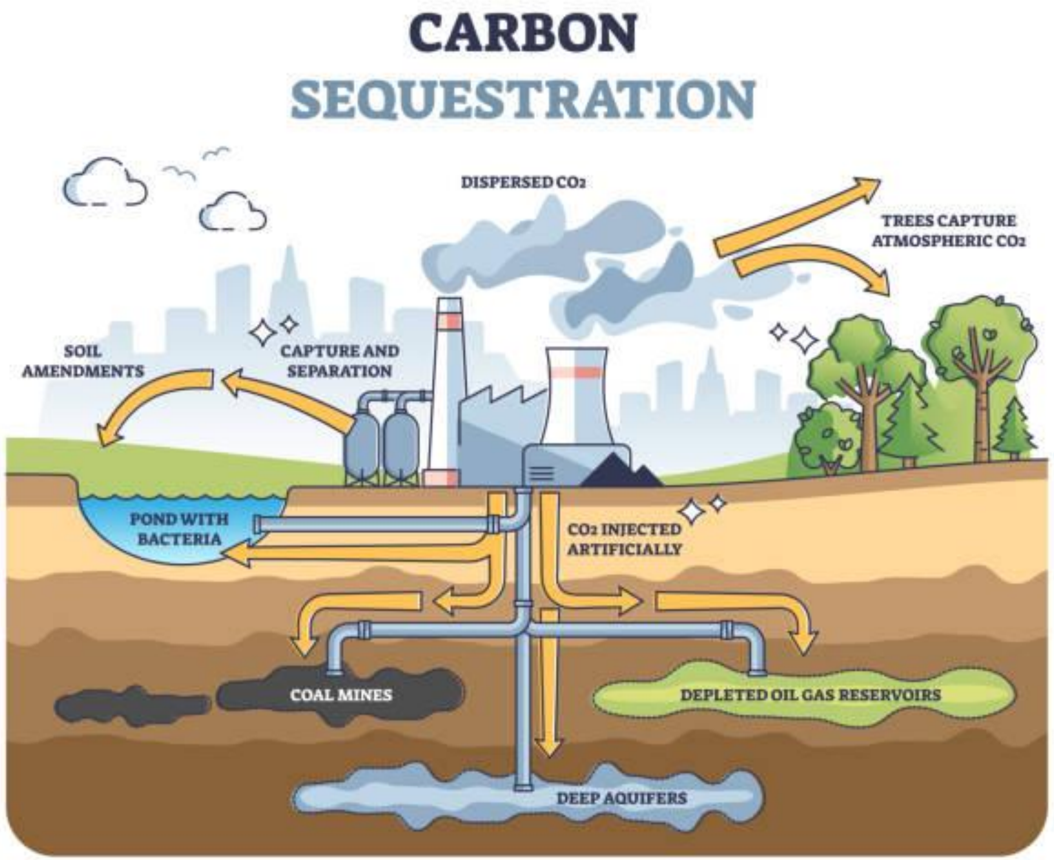
NASA Pinpoints Cause of Earth's Recent Record Carbon Dioxide Spike



The last El Nino in 2015-16 impacted the amount of carbon dioxide that Earth's tropical regions released into the atmosphere, leading to Earth's recent record spike in atmospheric carbon dioxide. The effects of the El Nino were different in each region
Credits: NASA/JPL-Caltech

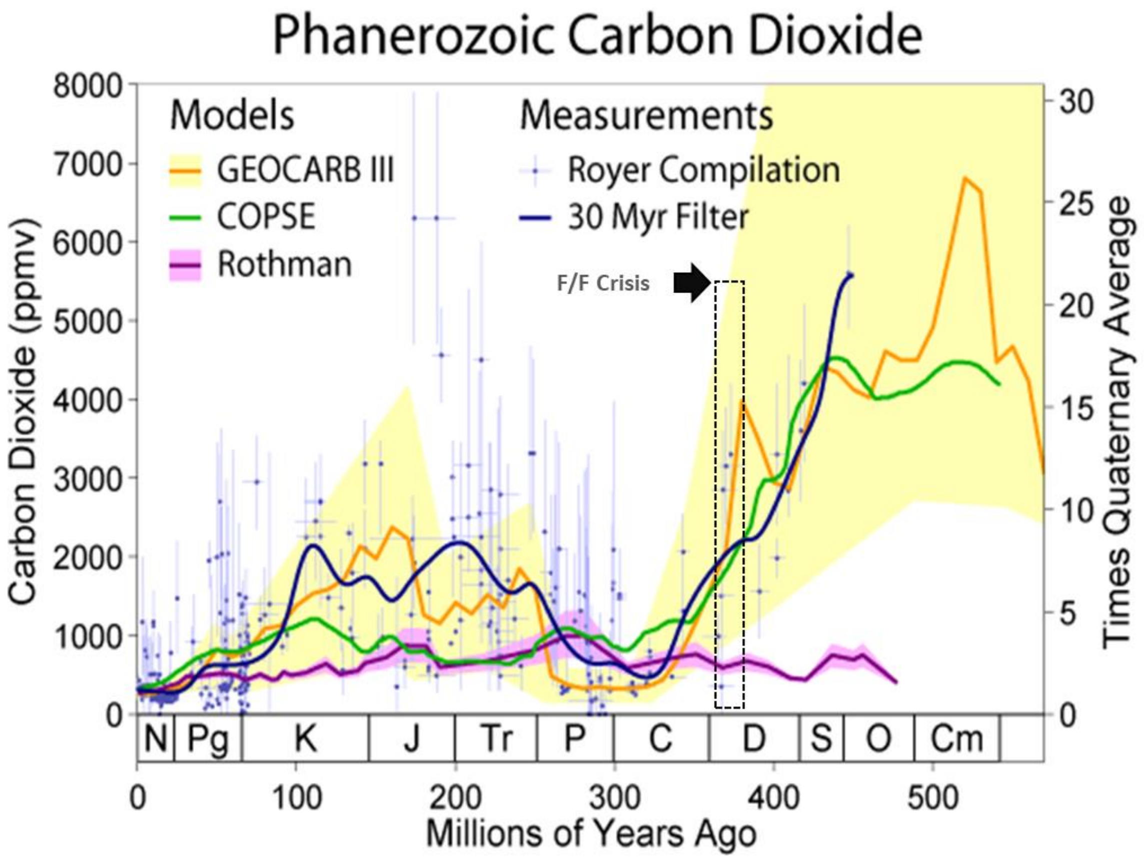


Artificial CCUS



By Getty Images

Natural CCS

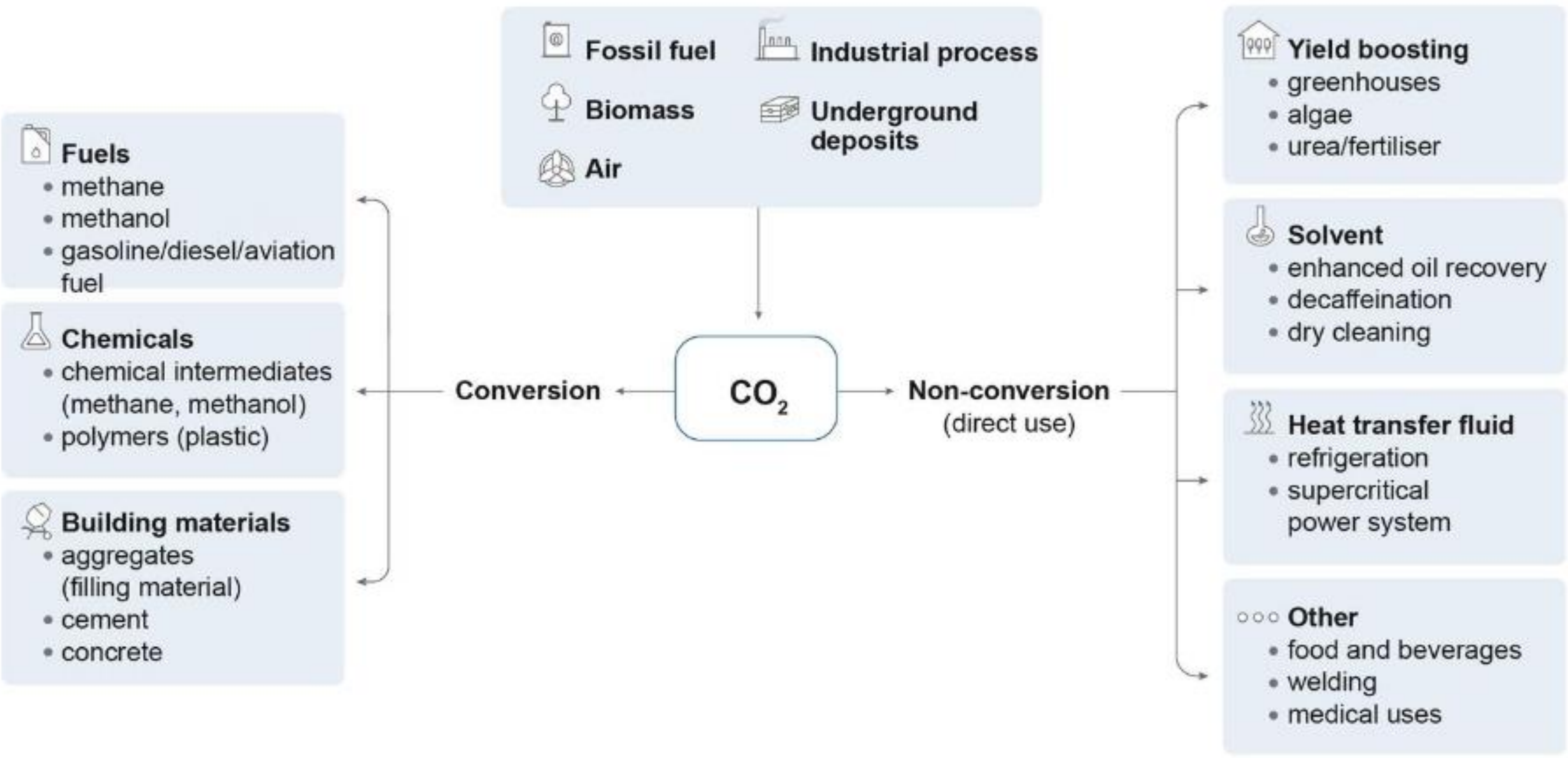


Phanerozoic_Carbon_Dioxide.png

Molinares et al., 2018

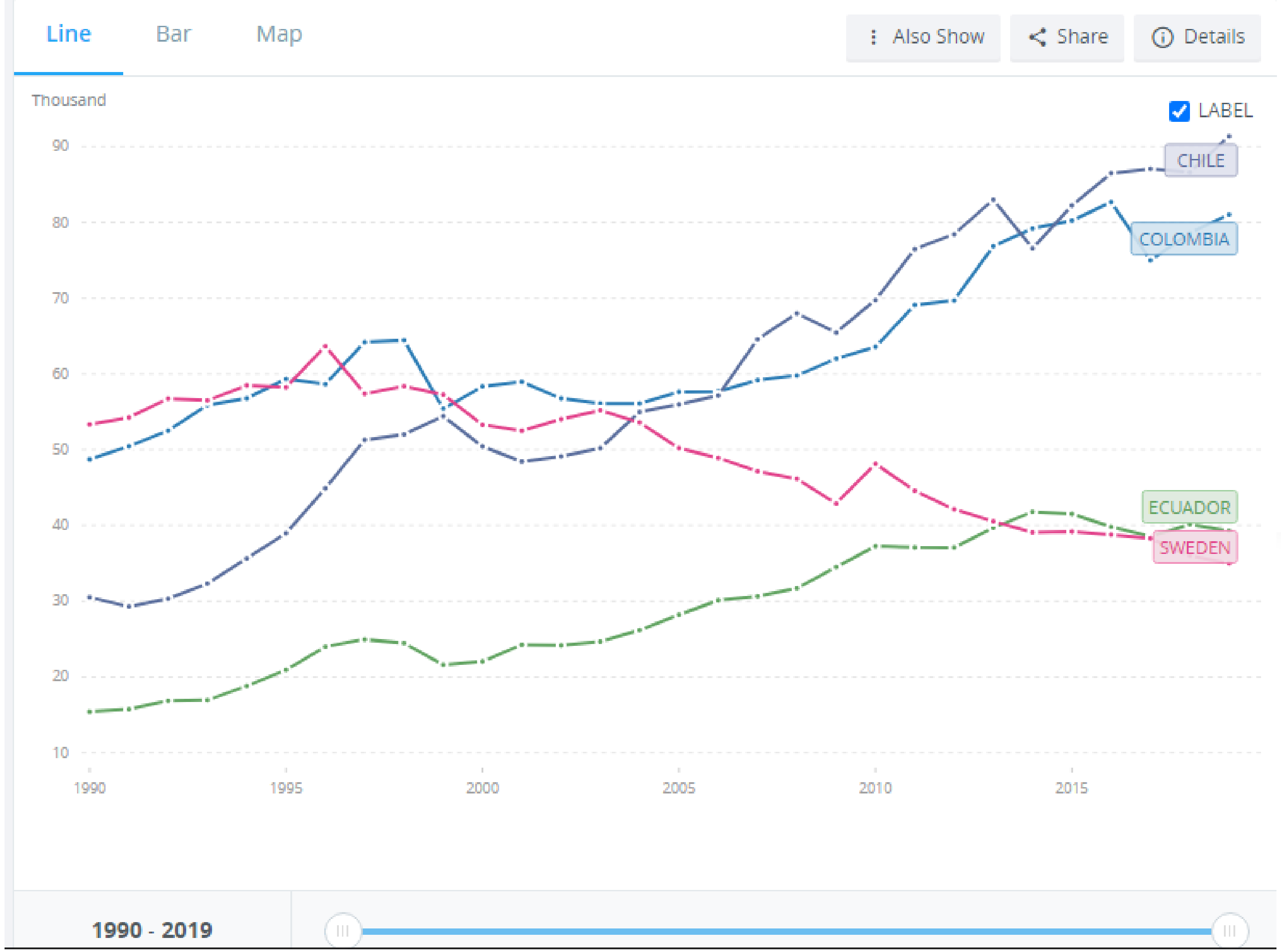
Carbon capture, utilisation and storage (CCUS) refers to a suite of technologies that can play an important and diverse role in meeting global energy and climate goals.

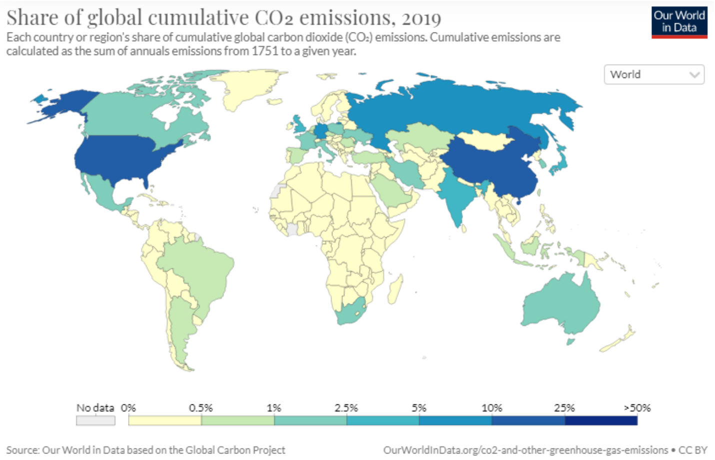
Simple classification of pathways for CO2 use



Further detail can be found in the IEA report "Putting CO_2 to Use".

Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. Available at: climatewatchdata.org/ghg-emissions.





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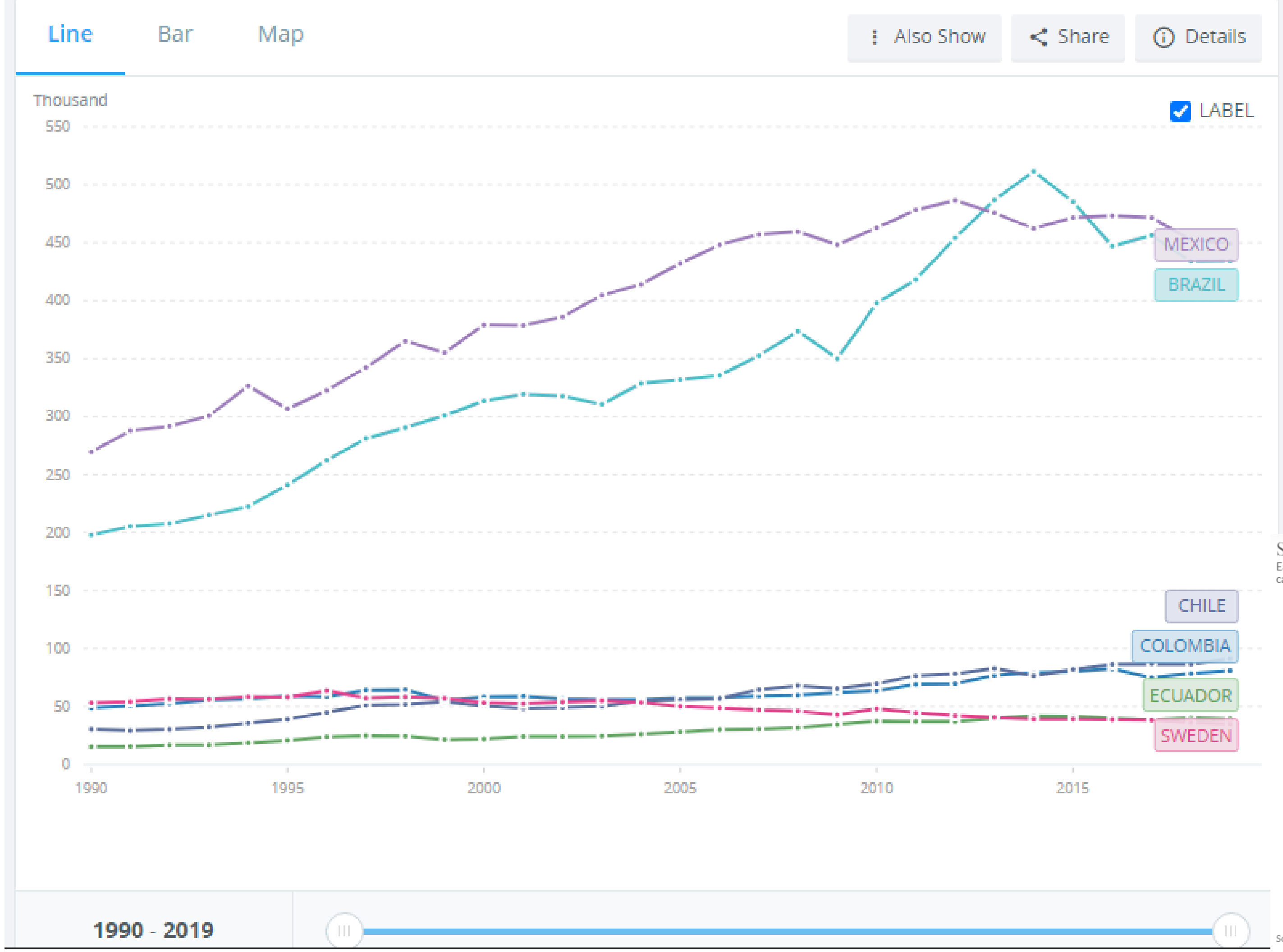

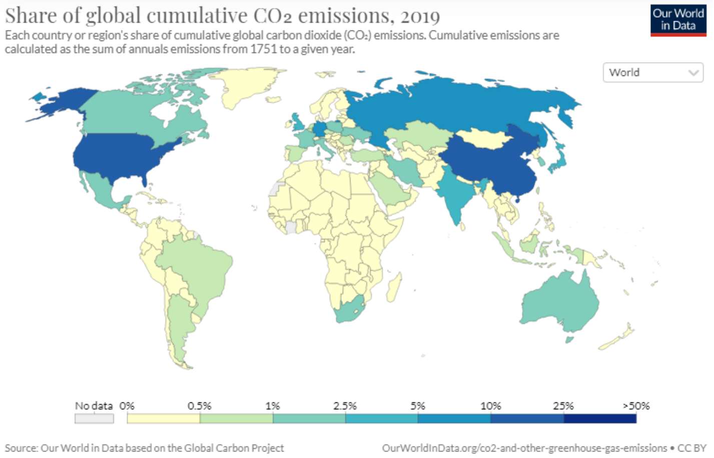

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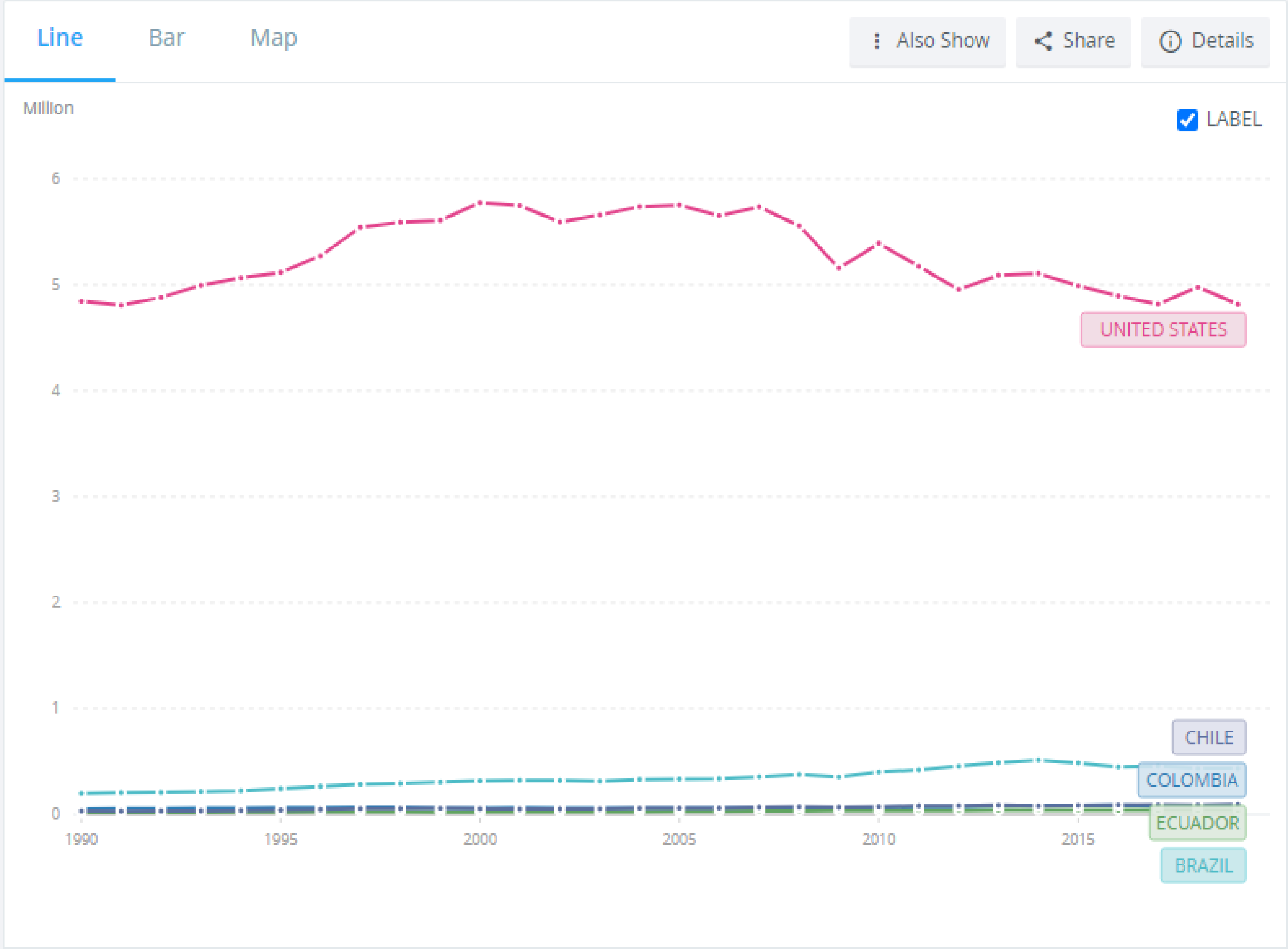
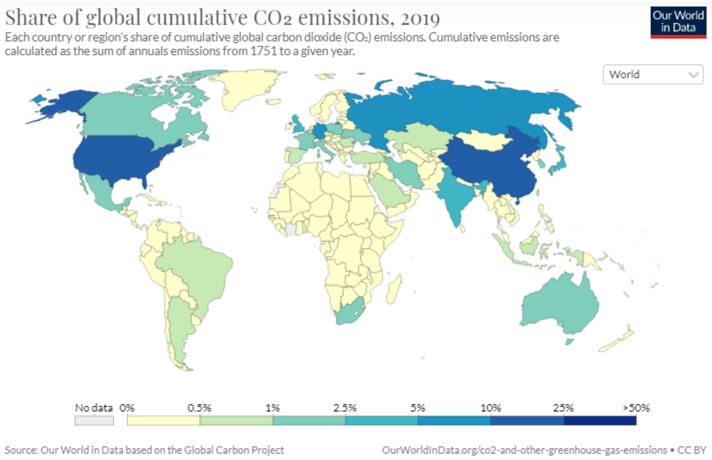
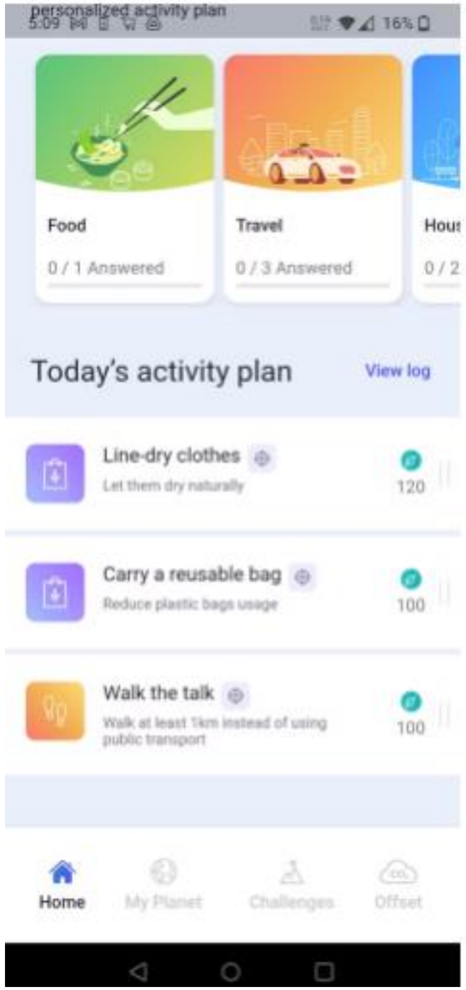




Do you know your personal CO_2 footprint?

MyEarth

Adva



Klima

JouleBug

Do you know your company CO_2 footprint?

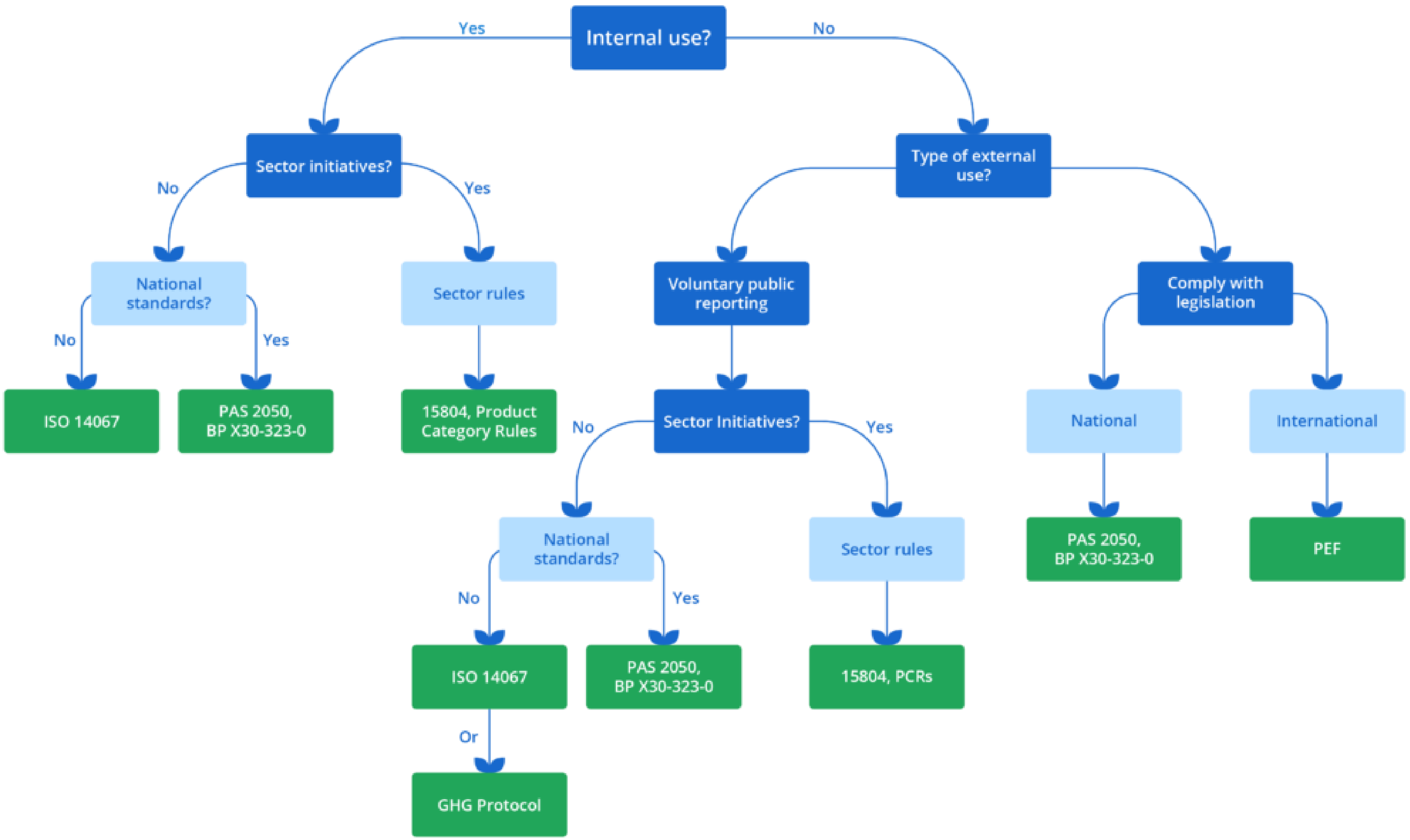
Current methodologies may be grouped into two families:

1) Single-issue methodologies, covering only emissions and impacts related to climate change

- The ISO 14067 standard
- PAS 2050
- GHG Protocol Product Standard

2) Methodologies used to determine the PEF*

- Product Environmental Footprint (PEF)
- BP X30-323-0
- EN 15804

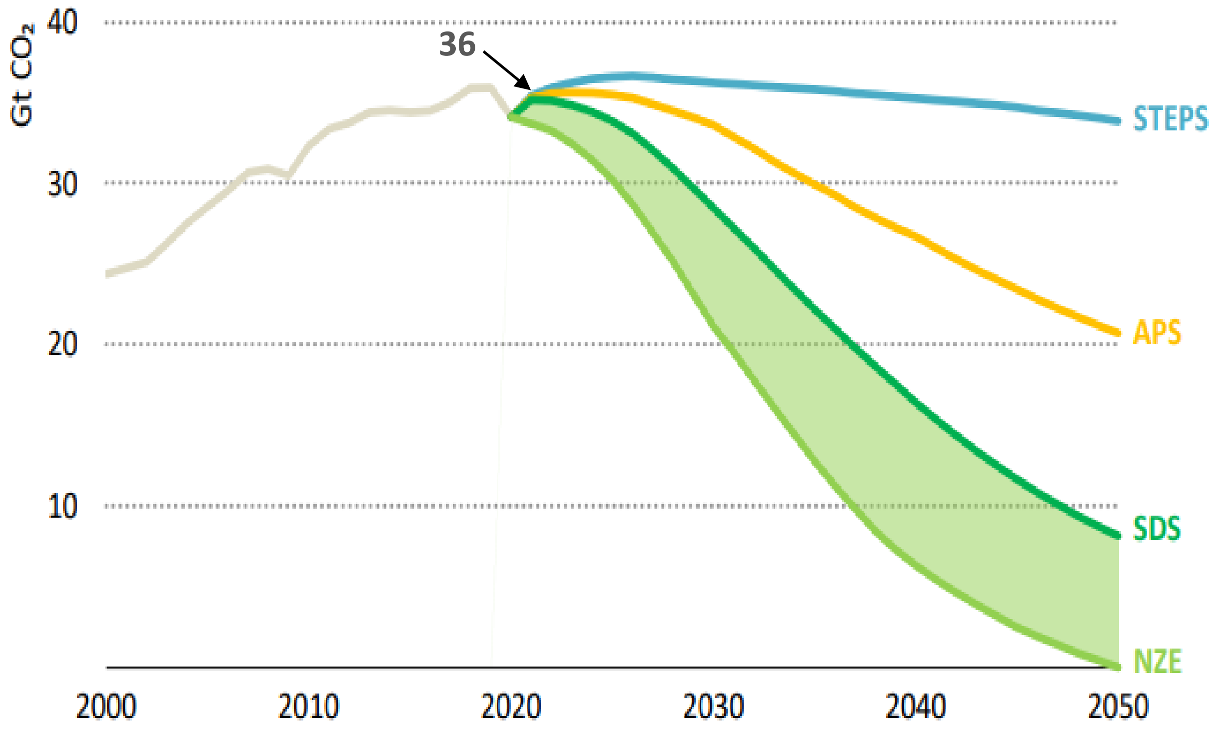


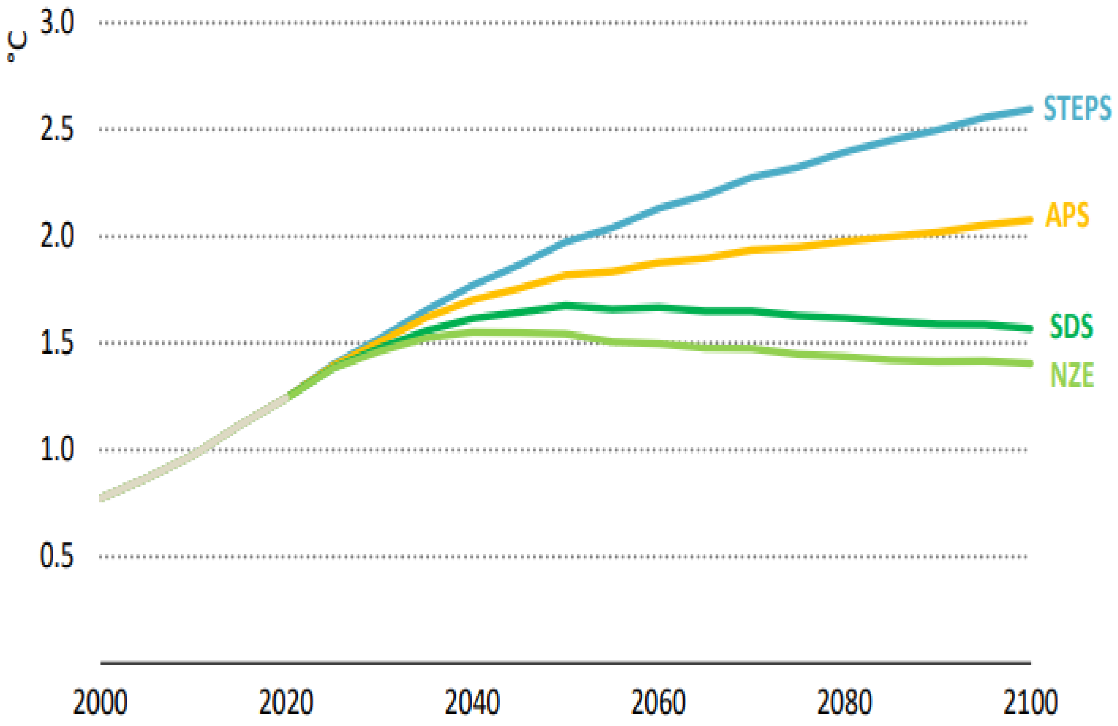
All standards mentioned above are built on the principles established in ISO 14040 and ISO 14044. They also seek alignment with the latest reports of the IPCC

*Product Enviromental Footprint (PCF)

Credits and thanks to my daughter ❤

IPCC Scenarios World Energy Outlook

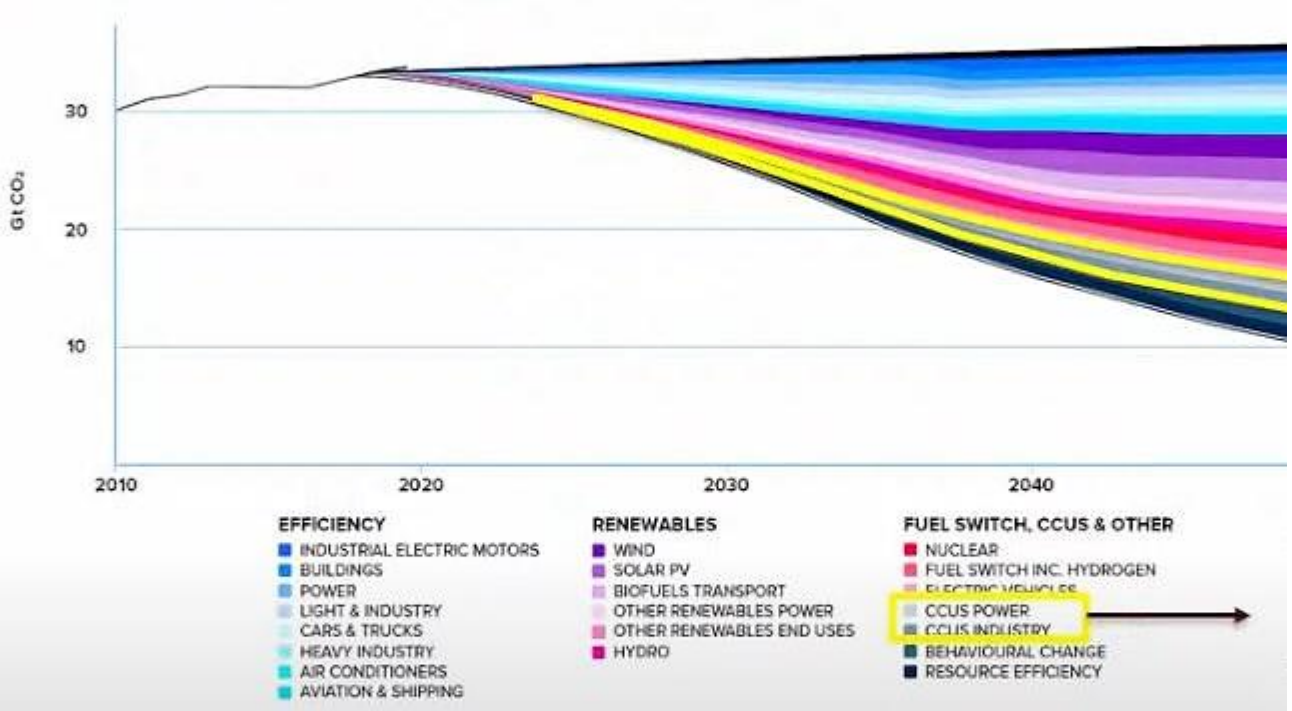




**STEPS= Stated Policies Scenarios; APS = Announced Pledges Scenario; SDS = Sustainable Development Scenario; NZE = Net Zero Emissions by 2050 Scenario*
Source: EIA https://safety4sea.com/wp-content/uploads/2021/10/IEA-WorldEnergyOutlook-2021_10.pdf

The APS sees a doubling of clean energy investment and financing over the next decade, but this acceleration is not sufficient to overcome the inertia of today's energy system and emissions.

Carbon Storage Under a SDS scenario



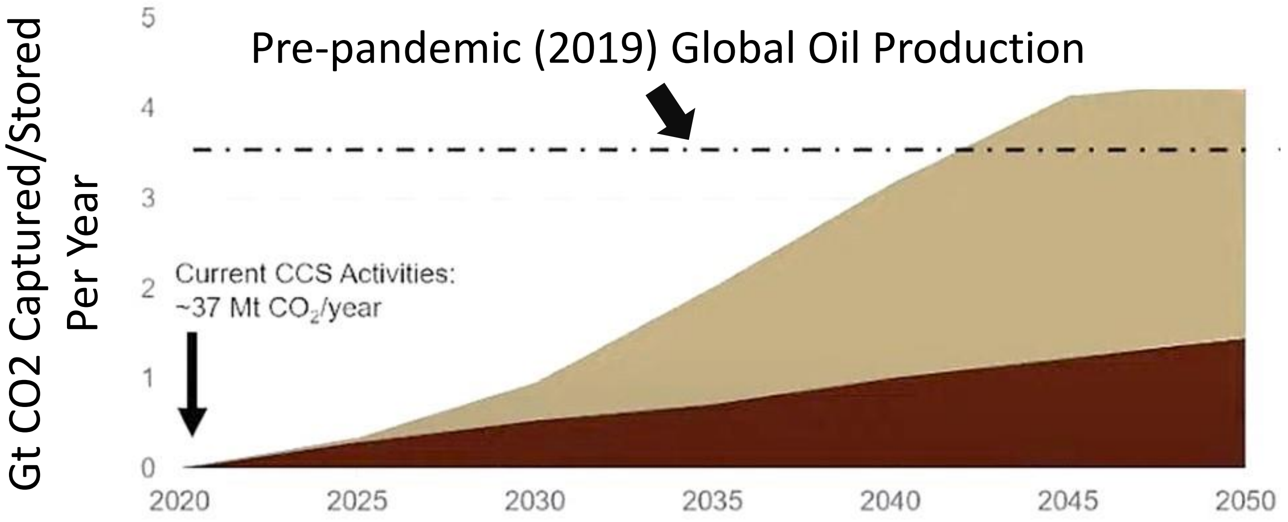
Source: IEA World Energy Outlook 2021 and the Stanford Center for Carbon Storage

1 Gt = 1 billion tons
1 Mt = 1 million tons

To get a 9% emissions reductions:

- Carbon capture with permanent storage (CCS) or utilization of the captured CO2 (CCU) are tools for reducing emissions
- 27 CCS Projects in Operation capturing 37 Mt CO2/ yr
- 3.5 GT /yr of CO_2 have to be captured and stored by 2050

The CCS GAP for the SDS Scenario



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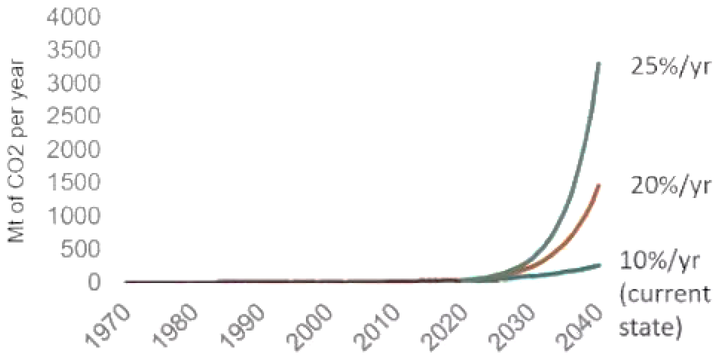
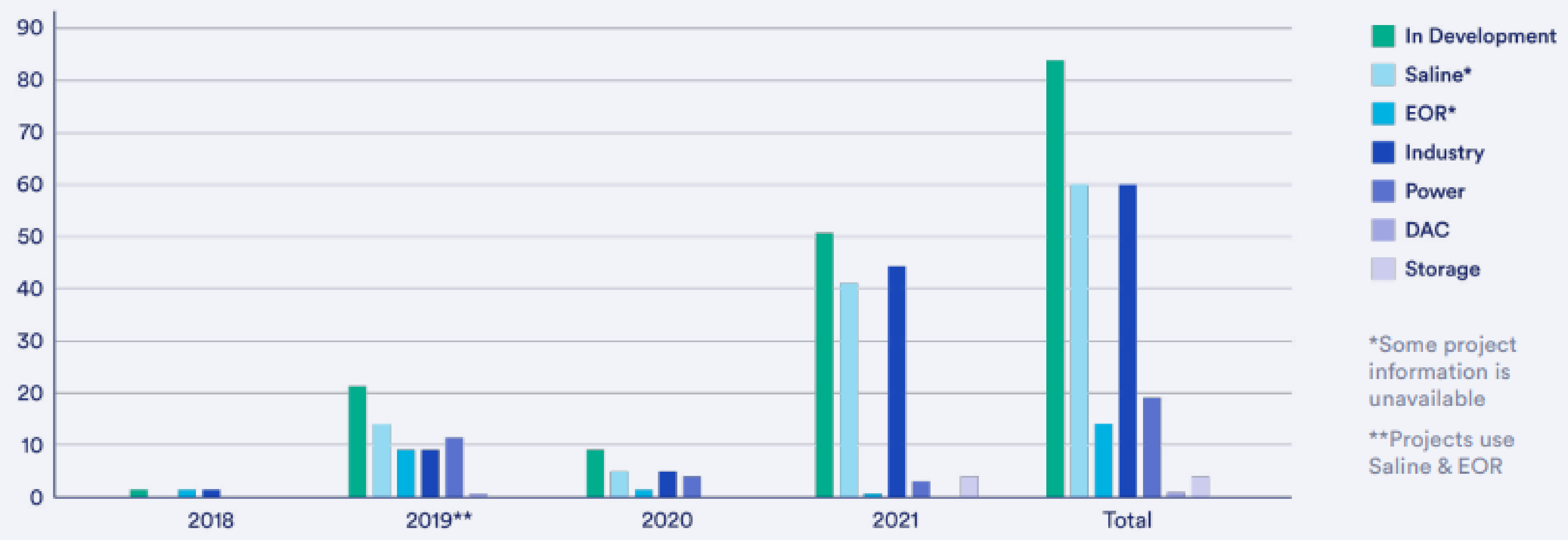


- 2020 25 CCS Projects in Operation capturing 37 Mt CO2/ yr
- by 2040 > 2000 CCS facilities operating are required (1.5 Mt/yr)
- Capex of USD$ 665-1280 Billons

U.S. Project Overview



Key Metrics and Trends

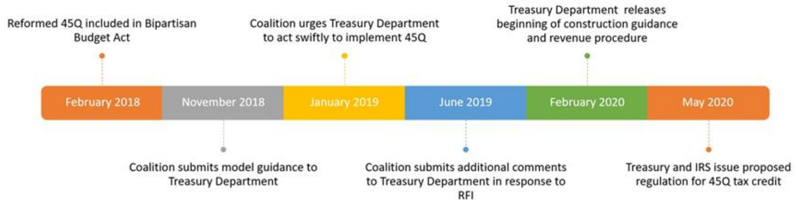
84

84 total U.S. projects have been announced since 45Q was reformed in 2018 with 51 announced in 2021 alone.

Year	In Development	Saline*	EOR*	Industry	Power	DAC	Storage
2018	2		2	2			
2019**	22	14	9	9	12	1	
2020	9	5	2	5	4		
2021	51	41	1	44	3		4
Total	**84**	**60**	**14**	**60**	**19**	**1**	**4**

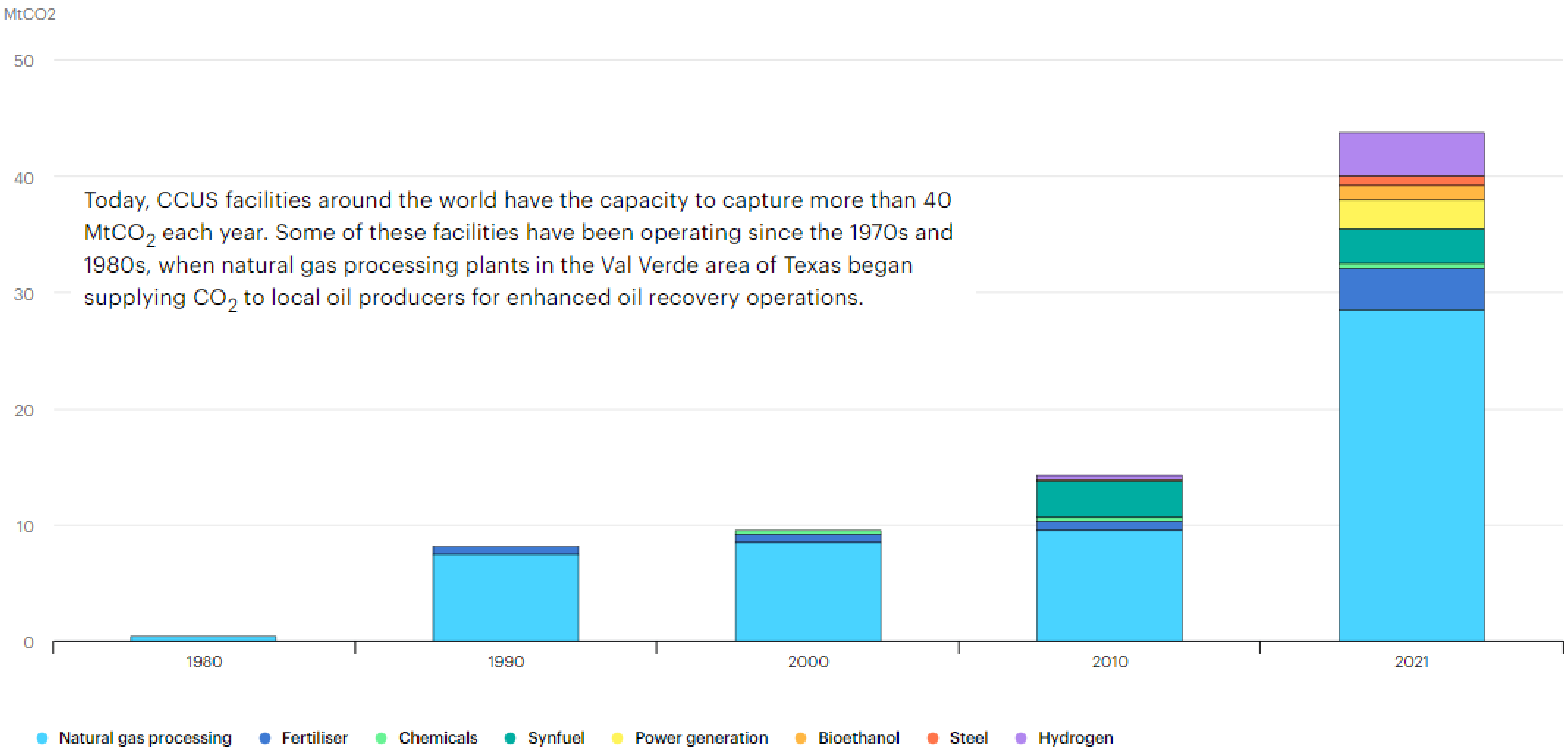
*Some project information is unavailable **Projects use Saline & EOR

45Q Tax Credit Timeline



https://cdn.catf.us/wp-content/uploads/2022/01/26092133/overview-carbon-management-projects.pdf

CCUS facilities in operation by application, 1980-2021



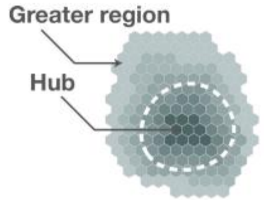
Today, CCUS facilities around the world have the capacity to capture more than 40 $MtCO_2$ each year. Some of these facilities have been operating since the 1970s and 1980s, when natural gas processing plants in the Val Verde area of Texas began supplying CO_2 to local oil producers for enhanced oil recovery operations.

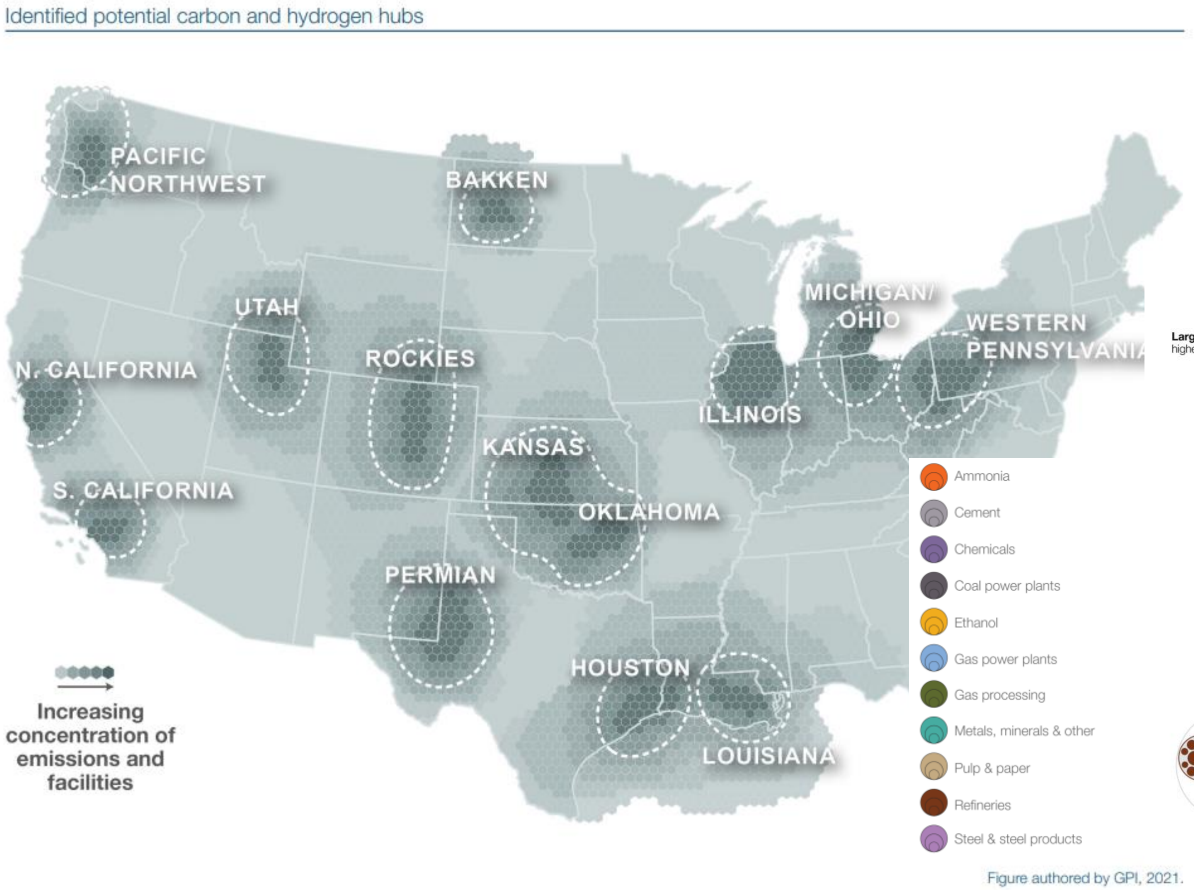
* First CCS facility 1971, Terrel Gas Plan TX

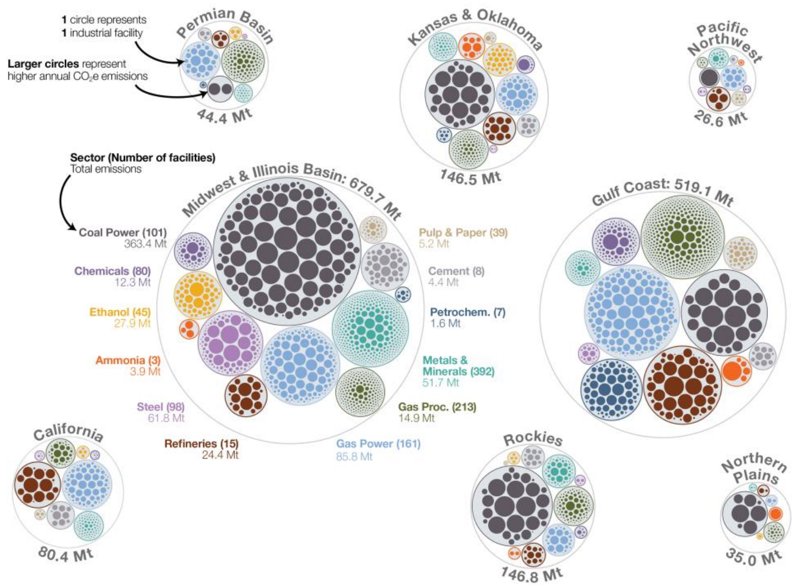
https://www.iea.org/reports/about-ccus

Potential Carbon Capture Hubs and Emissions by Regions and Industries

GPI has identified 14 hubs across eight regions of the United States. These are by no means exclusive, as industrial emissions occur throughout the country, and carbon removal or direct air capture will need to be deployed wherever beneficial. Three illustrative pages of components and opportunities are provided for each hub within this atlas.



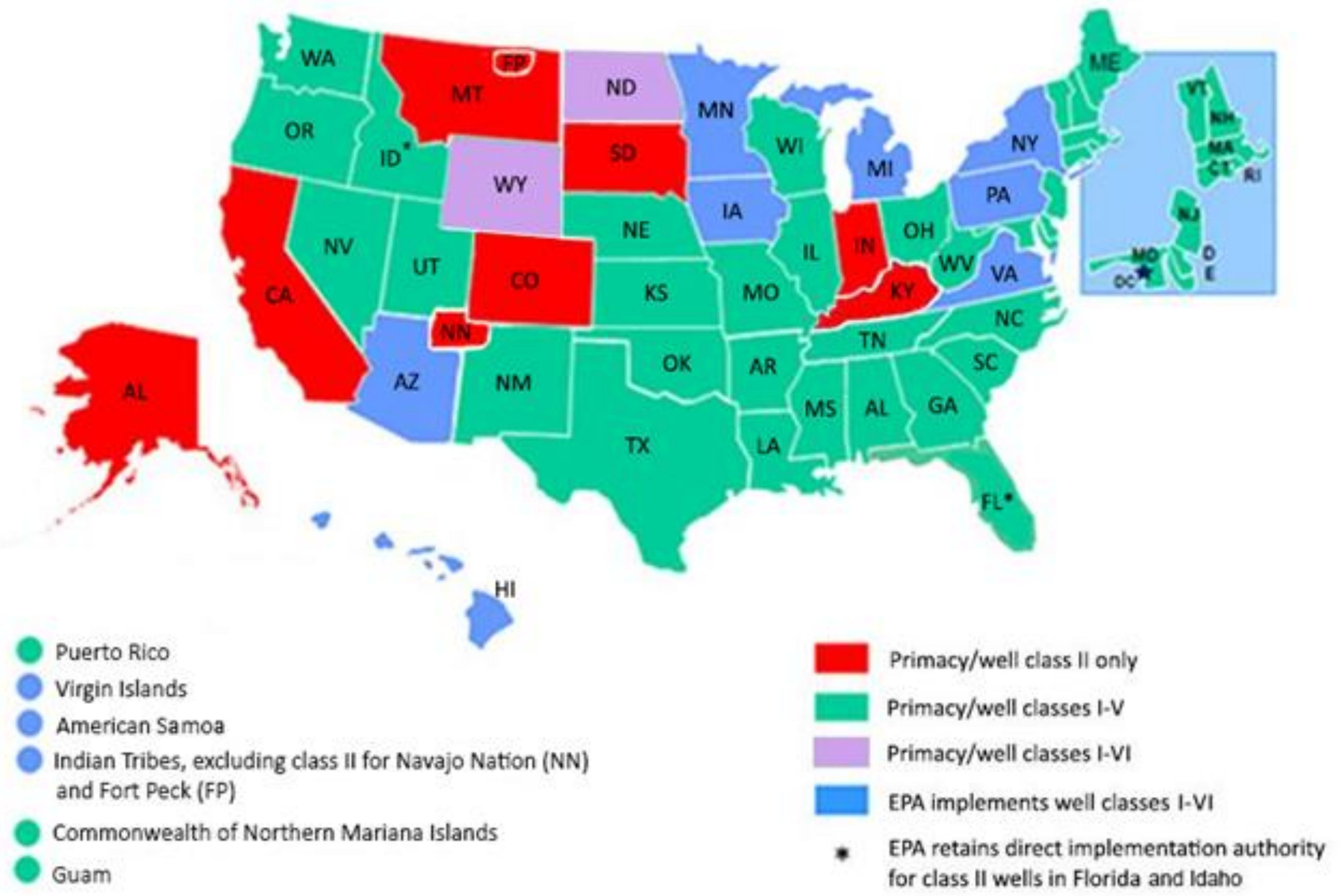




Source: GPI 2021

CO_2 is currently shipped in small quantities for use in the food and beverage industry Norway's Longship CCS project will be the first to transport large quantities of CO_2 to an offshore CO_2 storage site

There are two primary UIC well classes that cover CO2 injection projects, **Class II** and **Class VI**.



Class I
wells are used to inject hazardous and non-hazardous wastes into deep, confined rock formations.

Class II
wells are used to inject fluids (e.g., CO_2 and brine) associated with oil and natural gas production. Geologic storage of CO_2 in such operations can be incidental. 180,000 Class II wells are in US and over 2 billion gallons of fluid are injected underground each day.

Class VI wells are used to inject CO_2 into deep geologic formations solely for the purpose of permanently storing CO_2, which is often referred to as dedicated storage. EPA provide specific regulations for projects where the purpose is dedicated geologic storage. Wells must be sited, constructed, tested, monitored, funded, and closed once injection activities are completed

Environmental Protection Agency (EPA) regulates the Underground Injection Control (UIC)*
more than 740,000 injection wells

The 2020 Energy Act required a cross-cutting, inter-agency report on carbon capture, utilization, and storage to be submitted to the Congressional Committees on Environment and Public Works, Energy and Commerce, and Natural Resources and Transportation by the Chair of the Council on Environmental Quality (CEQ).

https://www.energy.senate.gov/services/files/32B4E9F4-F13A-44F6-A0CA-E10B3392D47A

The CEQ released its report in June 2021

https://www.whitehouse.gov/wp-content/uploads/2021/06/CEQ-CCUS-Permitting-Report.pdf

On November 15, 2021, President Biden signed the historic bipartisan Infrastructure Investment and Jobs Act (IIJA) into law. The IIJA includes $12 billion over five years for carbon management, storing CO_2 and lowering emissions (SCALE ACT)

https://carboncapturecoalition.org/wp-content/uploads/2021/03/SCALE-Act_Fact-Sheet-1.pdf

On February 15, 2022, the Biden administration released a fact sheet announcing a suite of actions to advance decarbonization efforts across multiple agencies

https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/15/fact-sheet-biden-harris-administration-advances-cleaner-industrial-sector-to-reduce-emissions-and-reinvigorate-american-manufacturing/

Table 1. Overview of types of permits and permissions needed for CCUS projects

Portion of the CCUS effort *	Authorization	Authorities that may require permits/permissions	Type of Agency**
	Land use	Local government, Federal Government (public lands)	City Council, Federal Land Manager (USFS, BLM, etc.)
	Discharges to surface water	State and/or Federal Government	State Department of Environmental Quality, U.S. Environmental Protection Agency
	Discharge of dredge or fill materials to waters of the U.S.	State and/or Federal Government	U.S. Army Corps of Engineers and or relevant State office (Florida, Michigan and New Jersey)
	Endangered species	State and/or Federal Government	State Environmental or Natural Resources Department, U.S. Fish and Wildlife Service, NOAA Fisheries
	Greenhouse gas reporting	State and/or Federal Government	State Environmental Department, U.S. Environmental Protection Agency
	Air permits	State and/or Federal Government	State Environmental Department, U.S. Environmental Protection Agency
	CO_2 pipeline safety	State and/or Federal Government	State and Federal Departments of Transportation
	Siting CO_2 pipelines	Local, State, and Federal Government	State Transportation Department or Utility Commission; Federal land management agencies
	Pore space ownership and mineral rights	Local, State, and Federal Government (if Federal lands)	Determined by State-specific law, Federal agency managing Federal Lands to be used
	CO_2 injection (and sequestration) permitting	State and/or Federal Government (some states have primacy for Class VI permitting)	State Environmental Department, U.S. Environmental Protection Agency

denotes utilization, denotes capture, denotes transportation, and denotes geologic sequestration

**Federal responsibility is listed together with exemplary state and local governments (which vary depending on local context). For Tribal lands/sovereign nations, the Tribal government will have oversight.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August 15, 2022
4:11 PM GMT-5
Last Updated 5 days ago

Commodities

Oil industry gears up to tap U.S. climate bill for carbon capture projects

By Liz Hampton

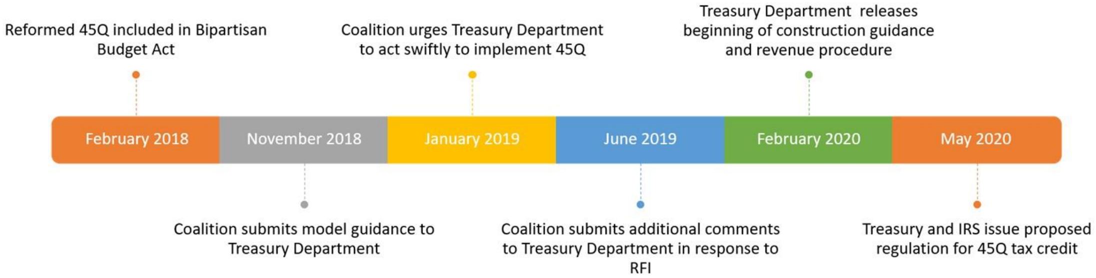
4 minute read

Aug 15 (Reuters) - Tax credits in the $430 billion U.S. climate and tax bill set to be signed into law this week will kickstart carbon sequestration projects, say oil and gas proponents, offsetting startup costs for some of the anti-pollution initiatives.

Carbon capture and storage hubs that take gases from chemical, power and gas producers and oil refineries have become the energy industry's preferred way to combat climate warming. But large-scale development has snagged over costs and lack of guaranteed revenue.

The Biden administration's Inflation Reduction Act, which was approved by lawmakers last week, provides a tax credit of up to $85 per ton for burying carbon dioxide produced by industrial activity, and up to $180 per ton for pulling carbon dioxide (CO2) from the air.

45Q Tax Credit Timeline



FINANCIAL POST

Oil & Gas / FP Energy / Commodities

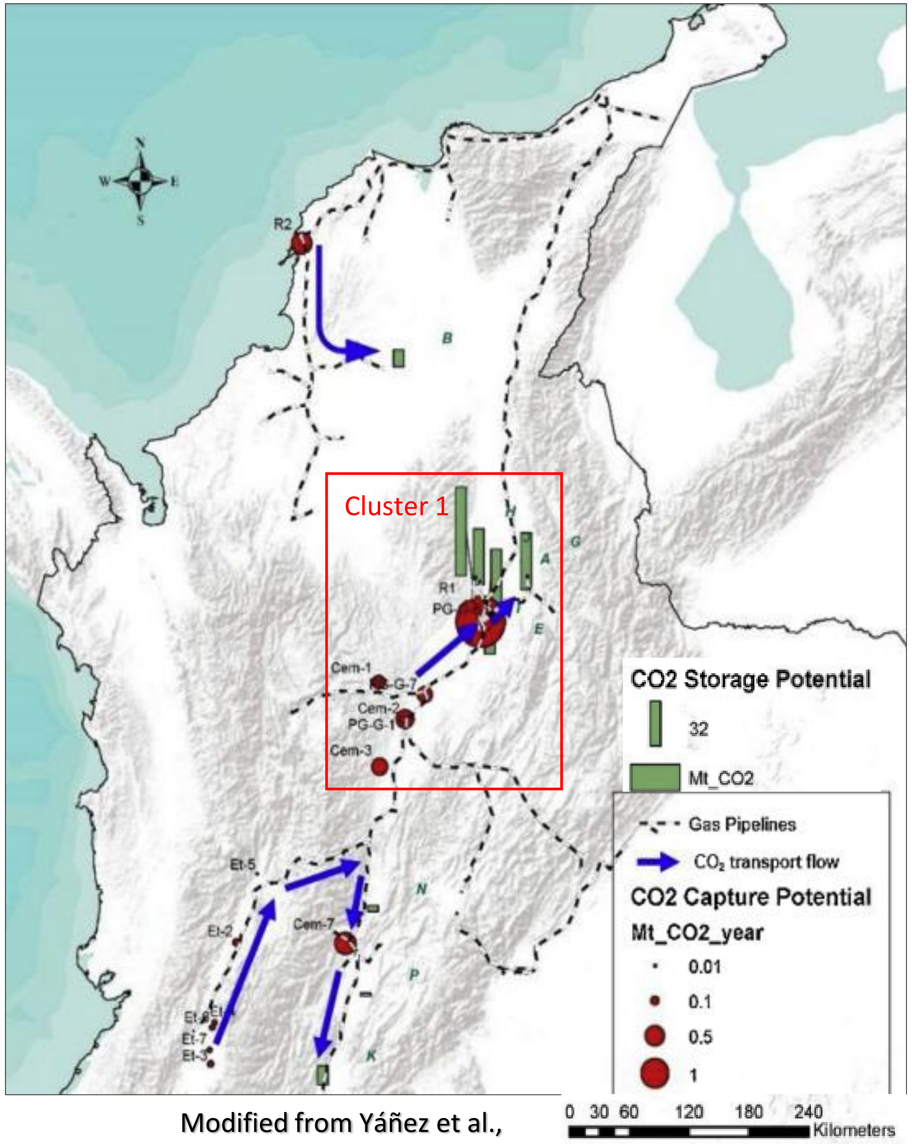
Trudeau proposes tax credit to cover 50% of carbon capture technology cost

The credit would reduce the large, upfront capital costs involved in constructing carbon capture, utilization and storage

Meghan Potkins
Apr 07, 2022 • April 7, 2022 • 4 minute read • 6 Comments

Conventional oil producers in particular were disappointed with the federal government's decision to opt against extending the credit to projects that capture carbon dioxide for use in enhanced oil recovery (EOR), a process that involves injecting CO2 into existing oil fields to push trapped oil out of the ground. Industry proponents have argued Canada's policy should aim to be competitive with a tax credit in the United States, known as 45Q, which allows companies to earn money for carbon capture projects that include EOR.

"We are, in the main, disappointed that CCUS-enhanced oil recovery is not included," Goodman said. "We think that's a missed opportunity to actually reduce GHG emissions. The oil is actually going to be produced anyway, so I don't know why we wouldn't want to make it economic to produce it at a lower GHG rate."



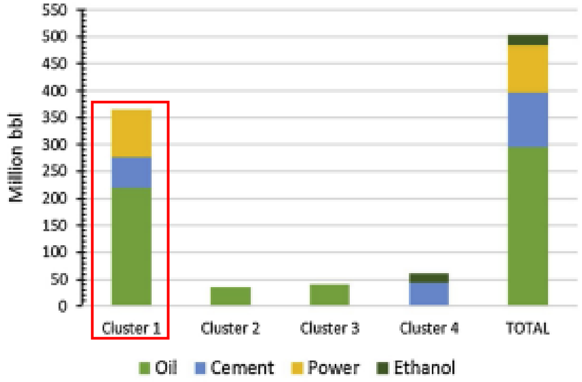
Modified from Yáñez et al., 2020

ECOPETROL REFINERY BARRANCABERMEJA (2018)

	Unit	Value
Crude oil throughput	Mt/year	12.13
Annual CO_2 emissions	Mt $CO_{2\text{-eq}}$/year	3.7
Electricity production	PJ_e/year	2402
Steam production	PJt_h/year	24 843
Hydrogen production	kt/year	29.11
Total conversion yield	%	84.62
Distillation throughput	kt/year	12 131
FCC throughput	kt/year	5065
HDT throughput	kt/year	4814

FCC: Fluid catalytic cracking unit.
HDT: Hydro-treatment processing unit. The low capacity of this unit is related to a mild hydrotreating process which results in high-sulfur diesel production. So, there is a relatively low hydrogen consumption of 5.5 kg H_2 per t of input load.

Yáñez et al., 2018; Ecopetrol; IDEAM 2016

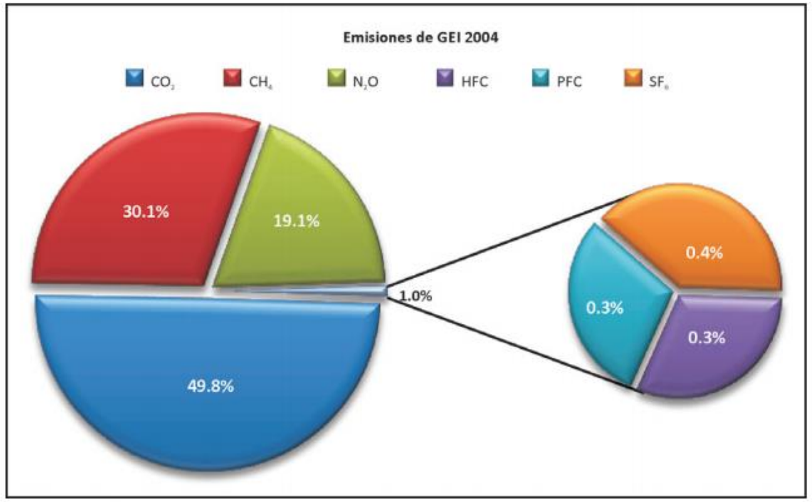


Incremental oil recovery potential based on the CO2 supplied by sector and clusters for CCS-EOR in Colombia.

3 Key data about Colombia:

- **The most needed reductions are associated with transport and land use**
- **1.5-1.6 times Natural Gas Production**
- **4 o 5 times electricity capacity need it**

Cuba is the only country with less emission per capita than Colombia



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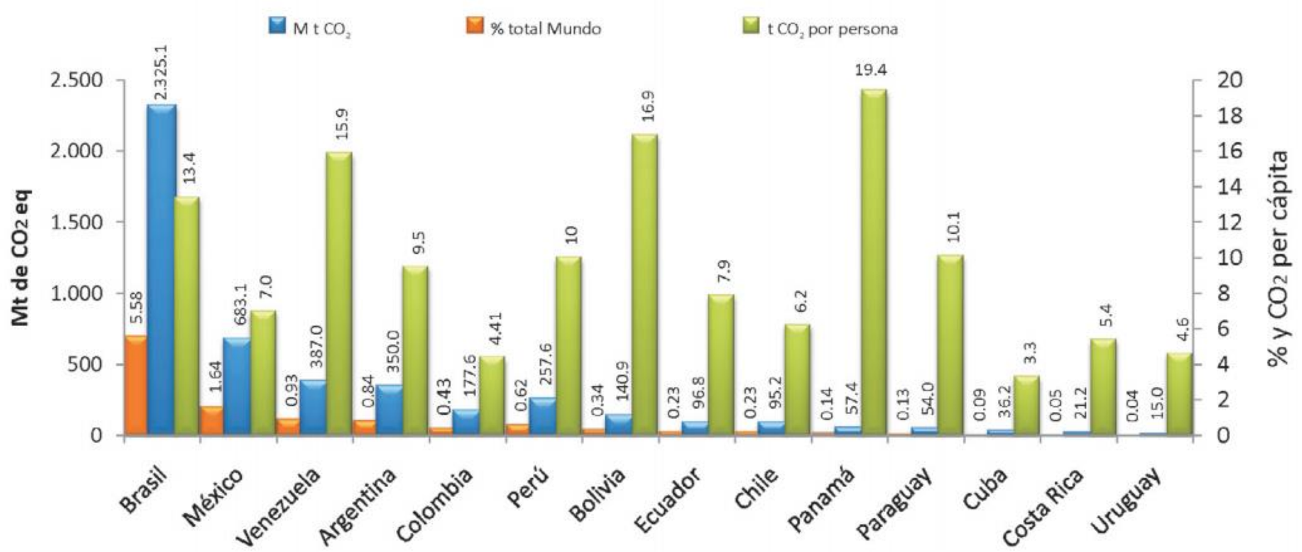

Fuente: IDEAM 2004, 2020

Outline

1 The CO2 Issue

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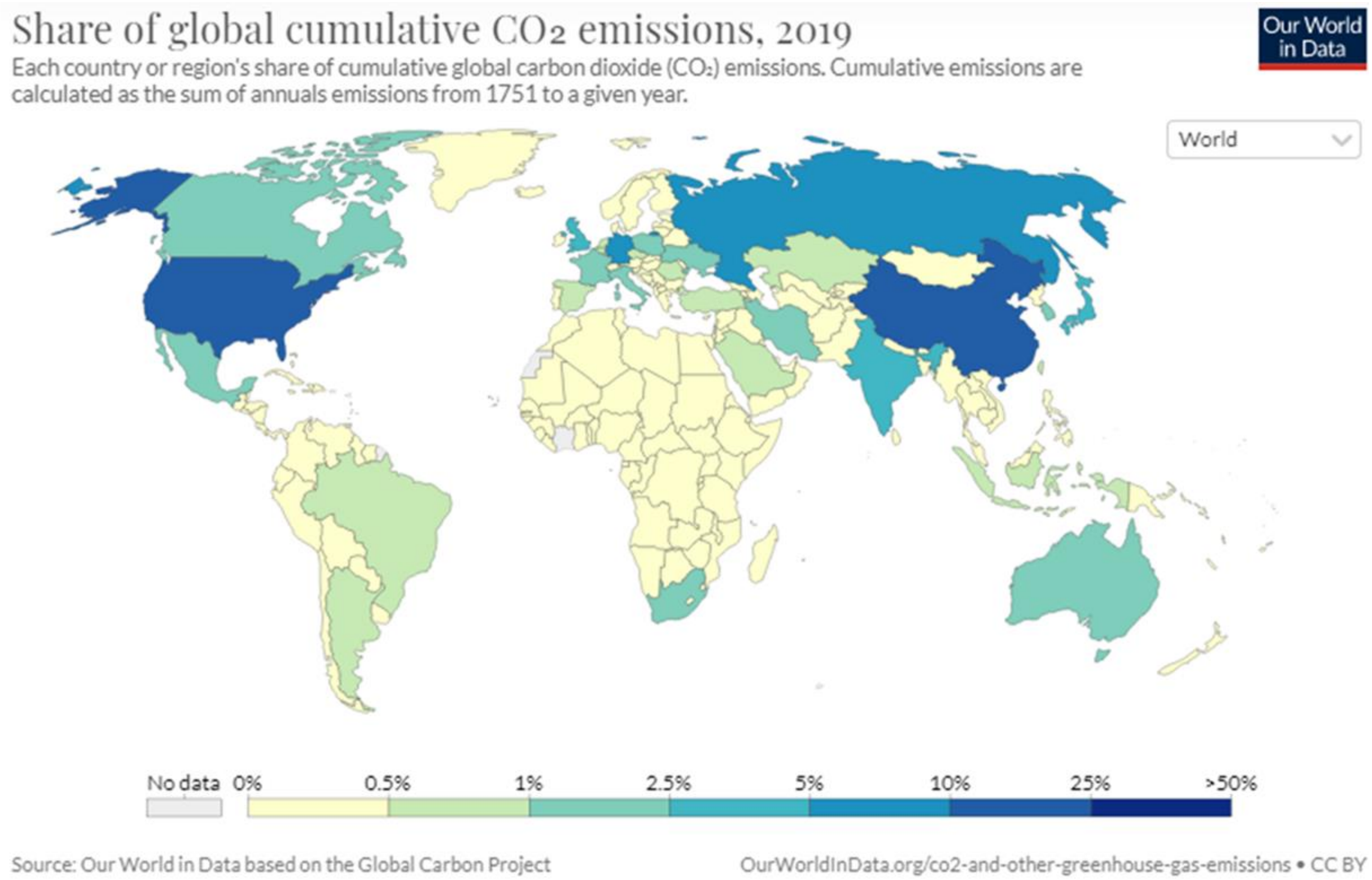
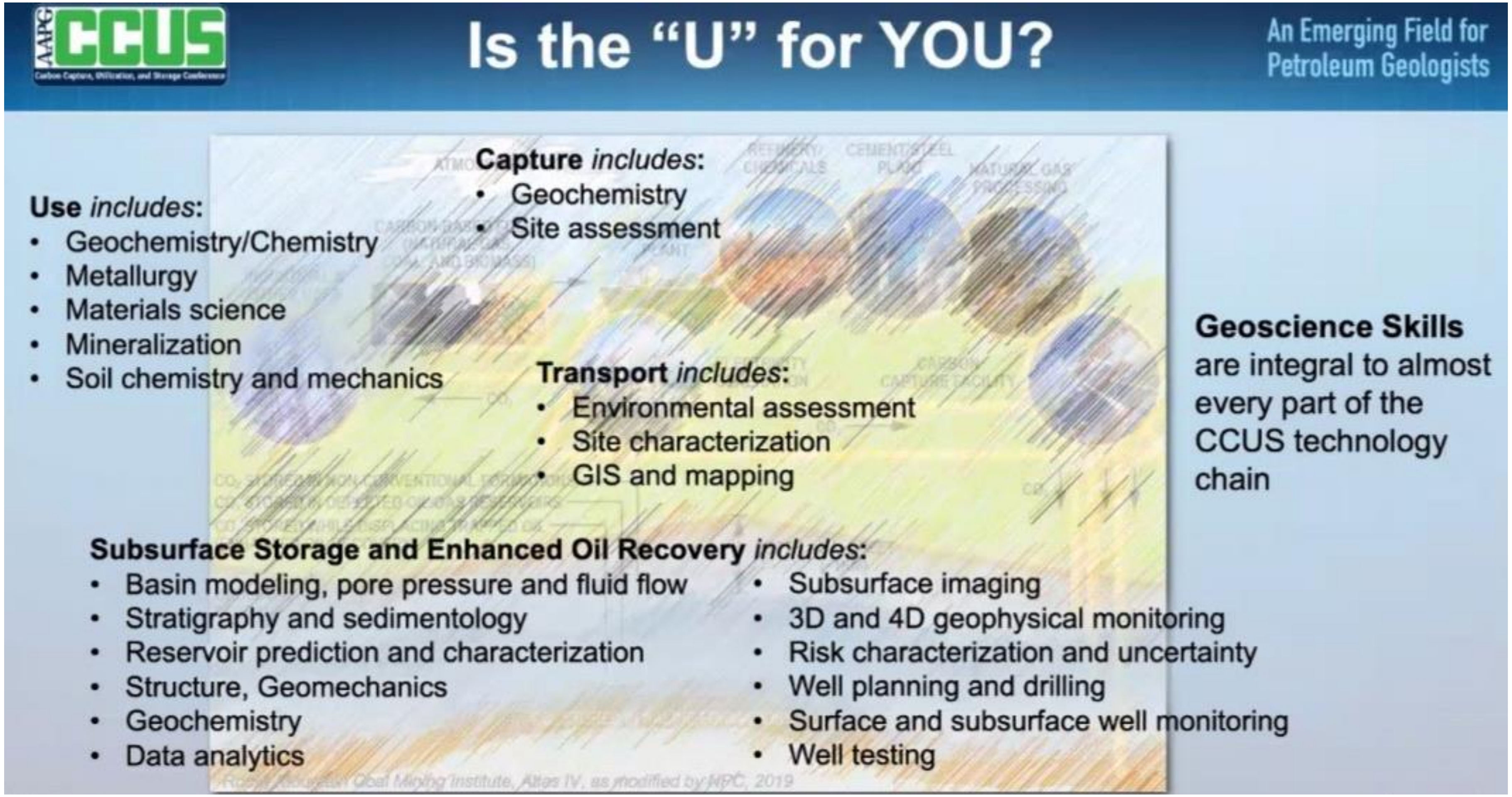
4 Natural Gas

5 Remarks

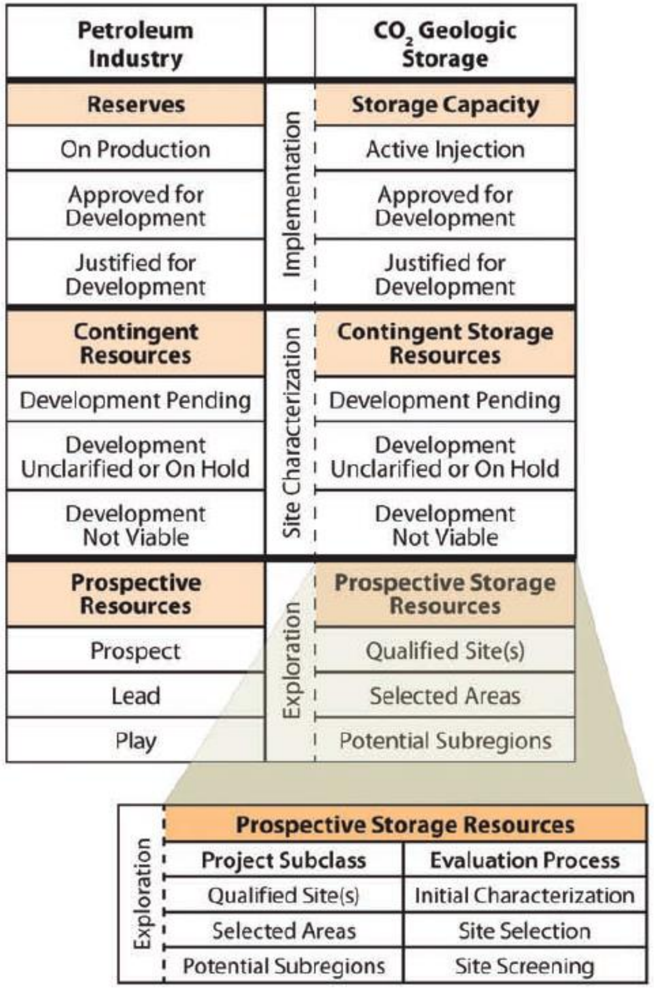




By Cindy Yeilding – BP America

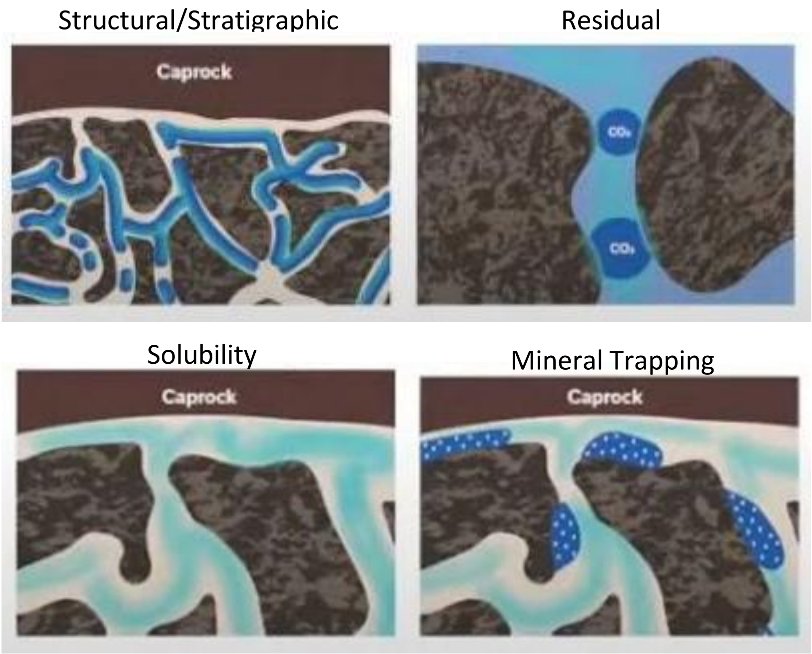
“clean energy jobs transition”

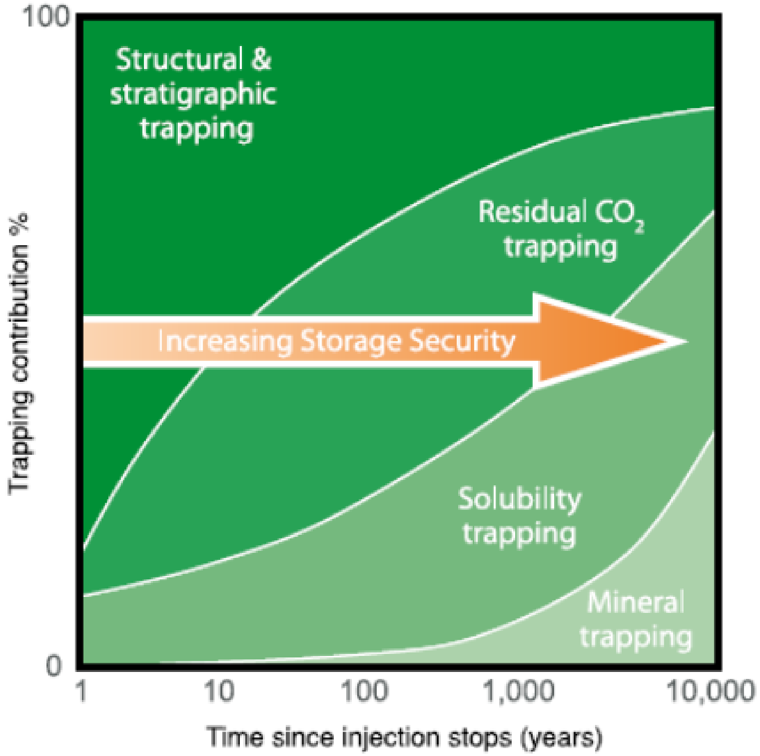
Oil and Gas	CCS
Reservoir	Confining Zone
Lowest Known Oil	Plume
EUR	Fate
Seal	Cap rock
Production	Injection
Surveillance	Monitoring
Basement	Basal zone
Retention	Containment
Disposal	Storage
Imbibition*	Drainage
Recovery Factor	Storage Efficiency Factor
Reserves	Storage Capacity



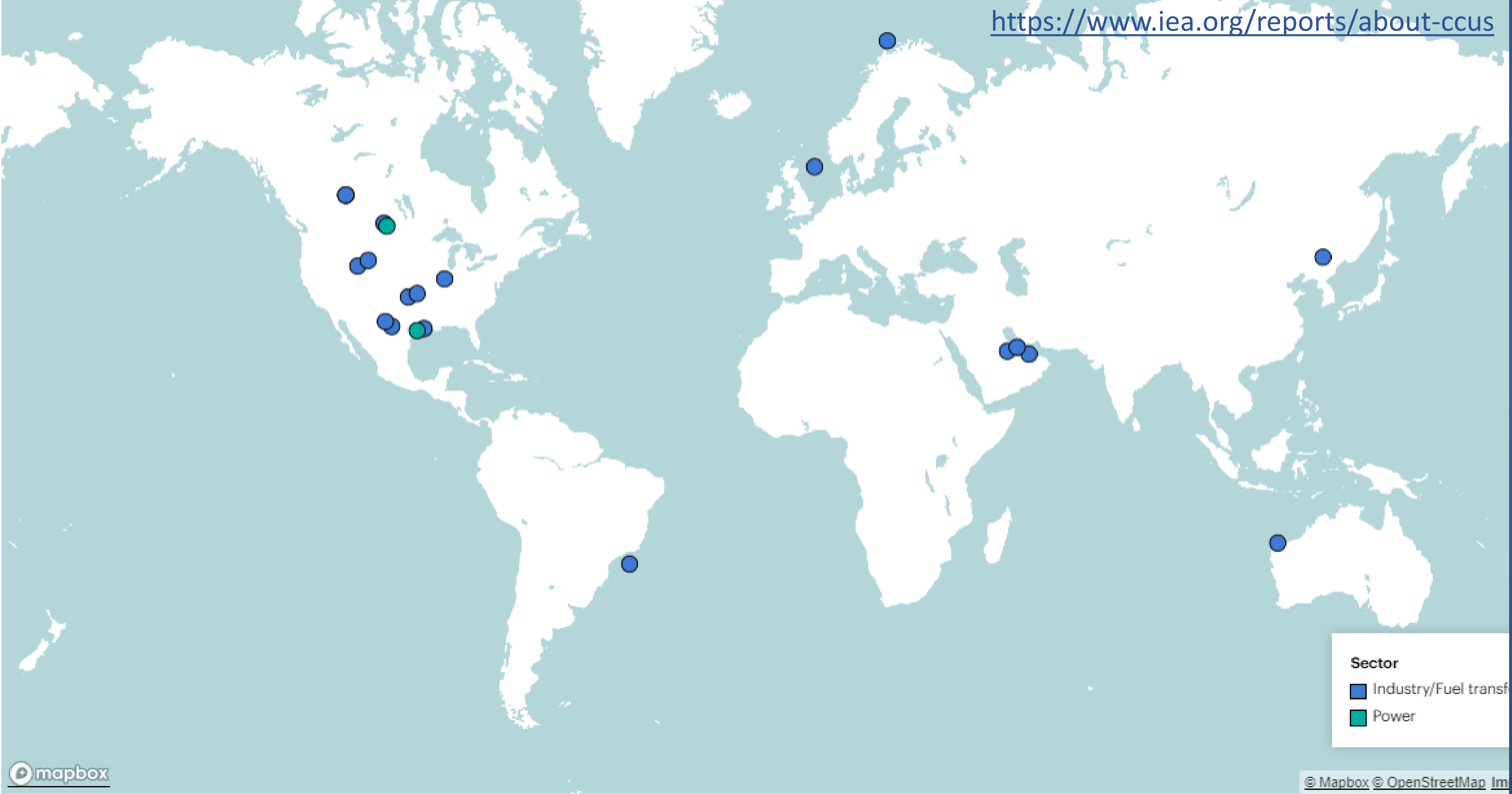
Sources: SPE 2017 SRMS, DOE CCS Atlas.

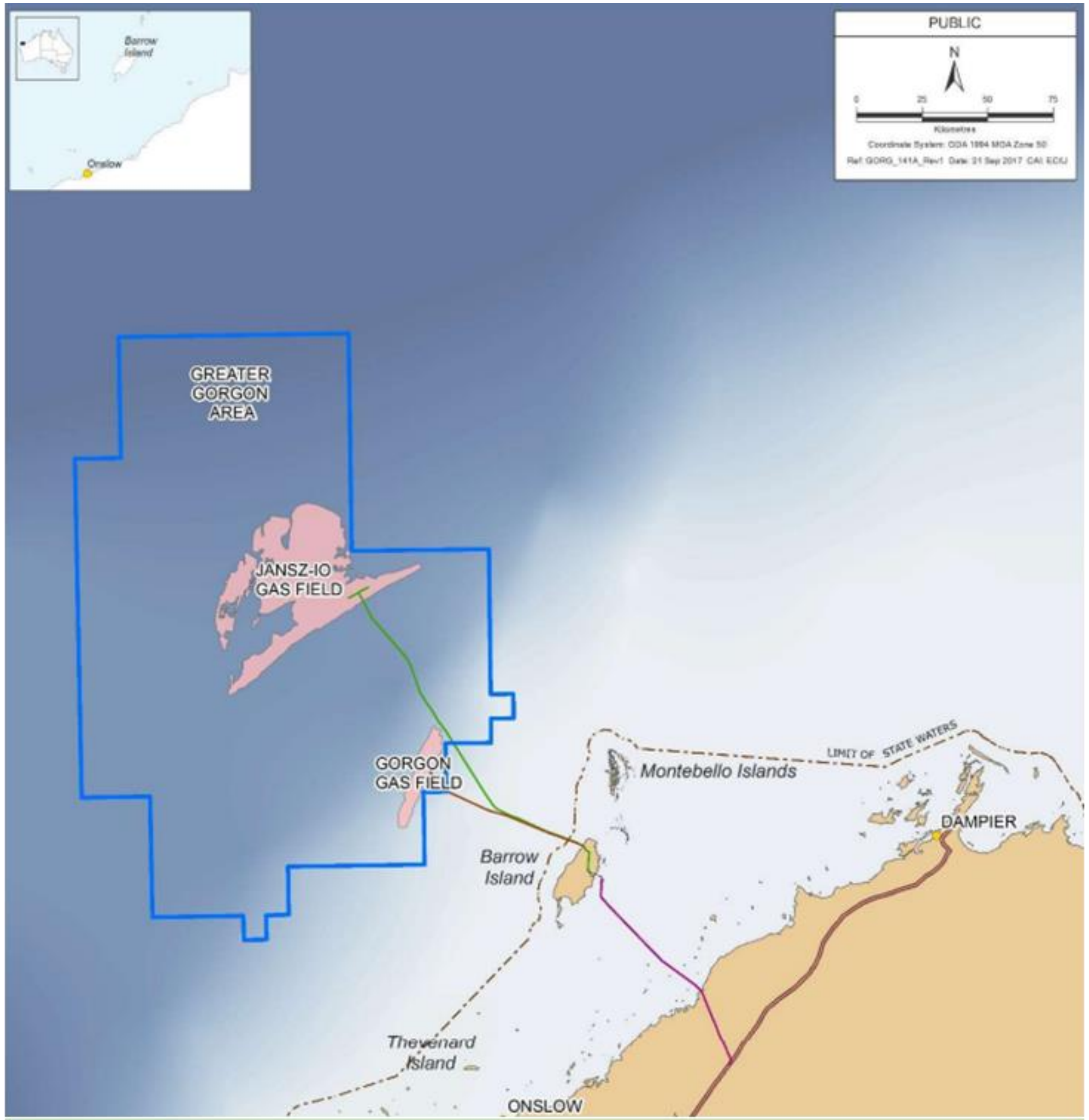
Geological Trapping Mechanisms for CO_2





Source: Hermanrud et al., 2009 and the Stanford Center for Carbon Storage https://www.iea.org/reports/about-ccus





Gorgon LNG - CCS Project

Chevron 47.3%, ExxonMobil 25%, Shell 25%, Others 2.7%

CCS / CCUS is for YOU (Petroleum Geo)!

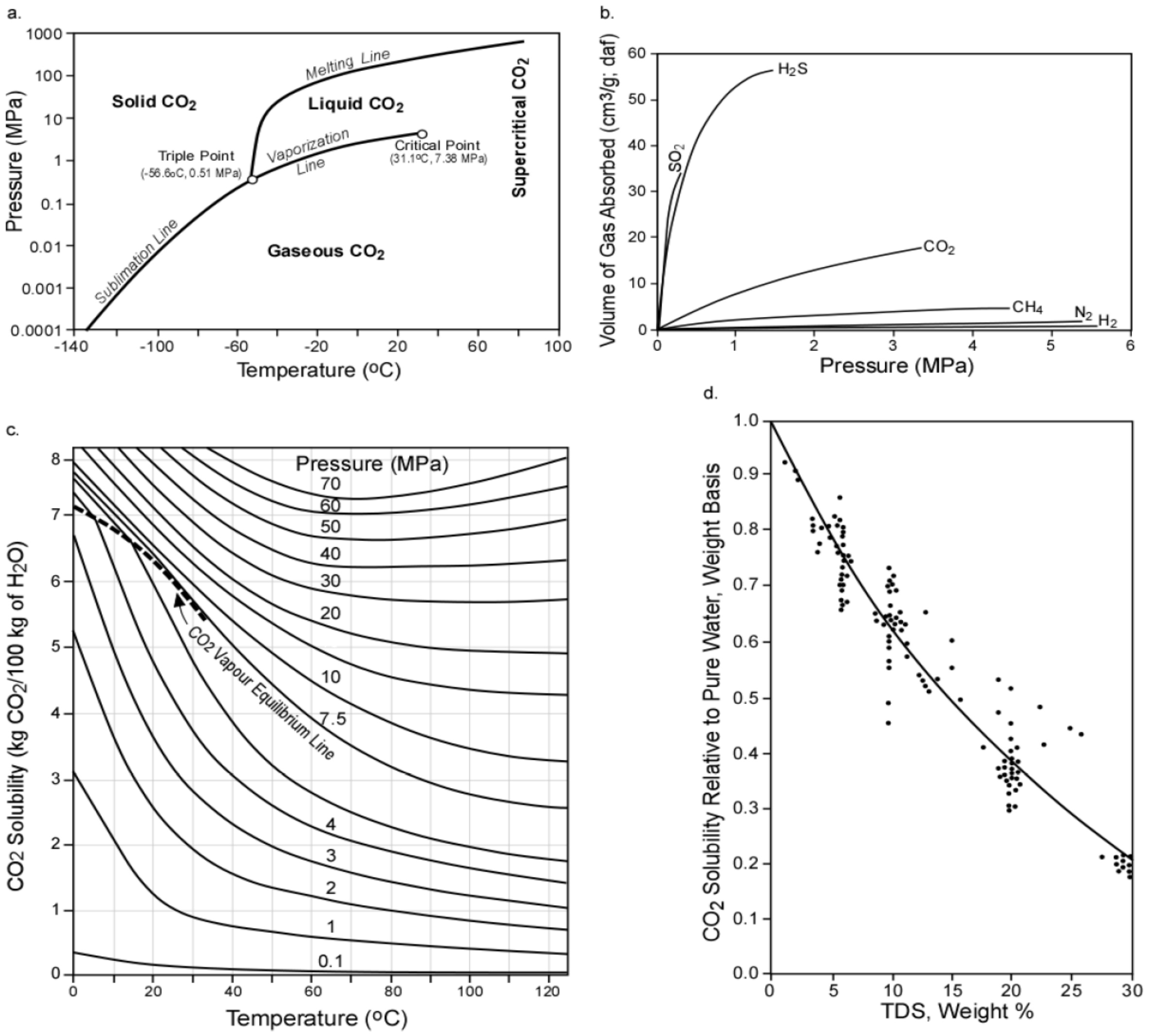
- Gorgon is by far the largest CCS project with approx.. 40% of all CCS projects operating around the world

- Gorgon presented a series of technical difficulties which could be typical in CCS projects.

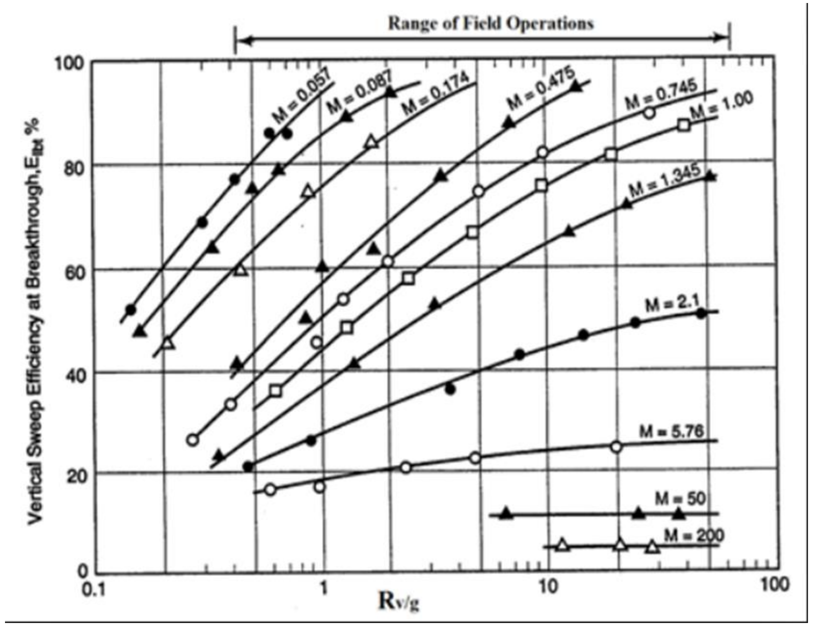
- Injecting is underperforming by 13% Pressure management and water injectivity issues with the Barrow Group (*Reservoir Characterization !)*

- Offsetting its CO_2 shortfall may cost Gorgon *US$100 – US$184 millions*

“clean energy jobs transition”



CO2 Properties. Bachu 2021



N. Gupta 2019

Courtesy: Carlos Bahamon Oxy

“clean energy jobs transition”

Engineering Skills needed for CCS/CCU

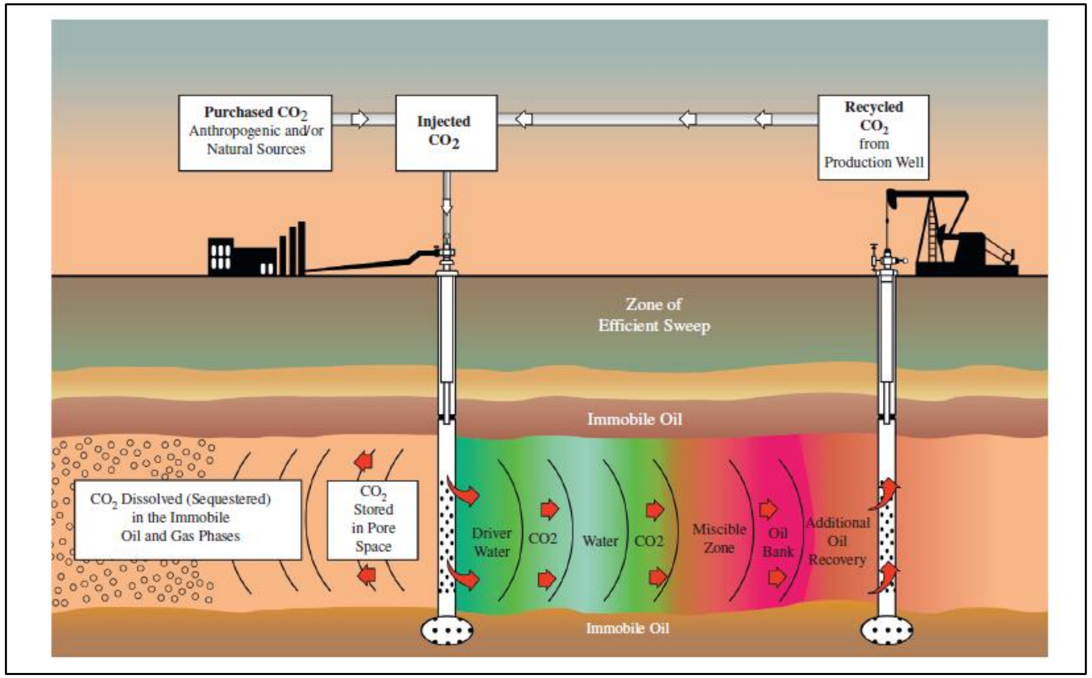
(1) **Sweep efficiency** during EOR floods, and methods for improving it

(2) large **injection** rates are possible without exceeding original **reservoir pressure**, but only when correspondingly large fluid-production rates are maintained, **capillarity issues**

(3) **Detecting injected fluid** movement in a reservoir remains a challenge (wellbore and reservoir)

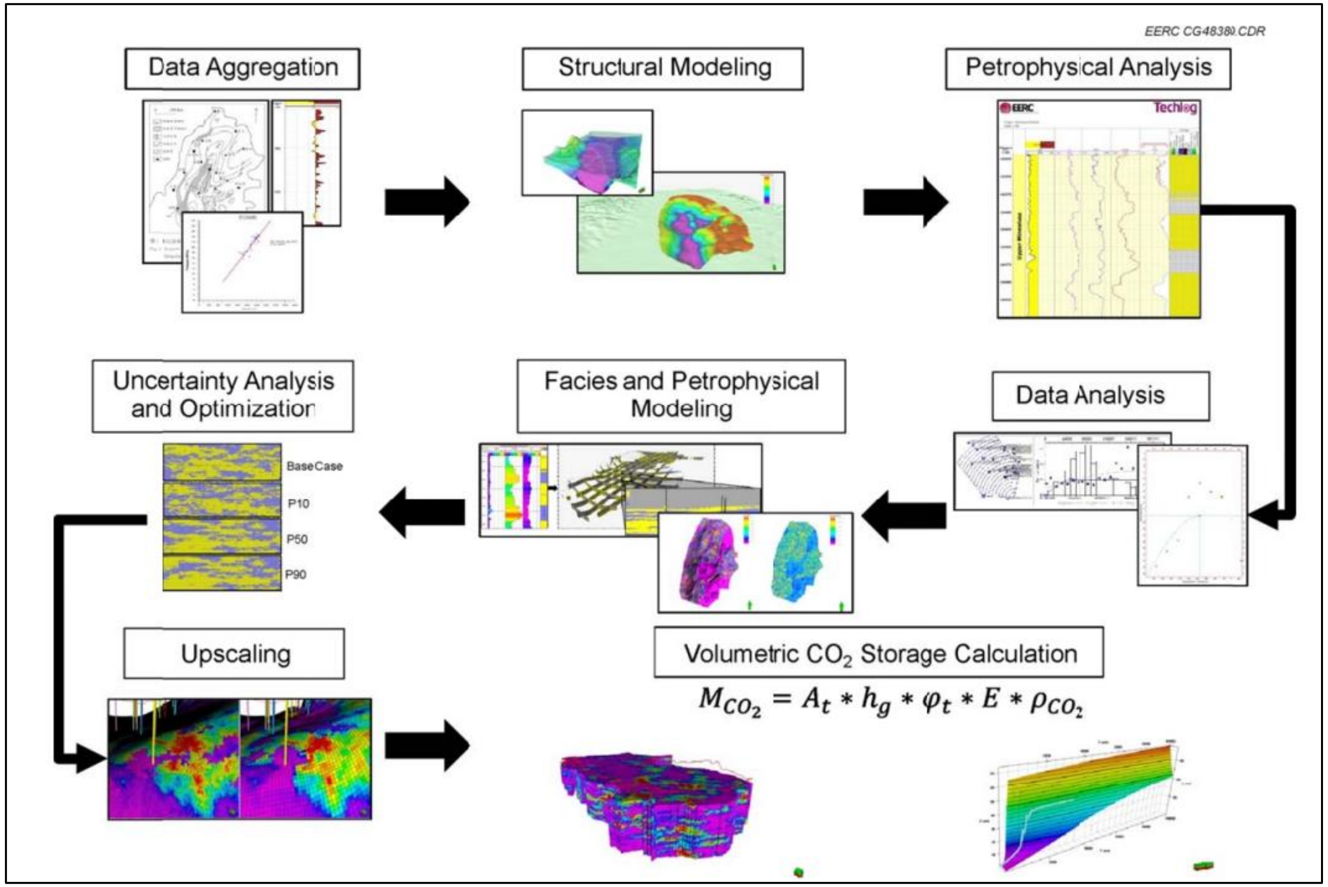
(4) **surface CO_2 leaks detection** and no caprock breaches during EOR or storage

Courtesy: Carlos Bahamon Oxy



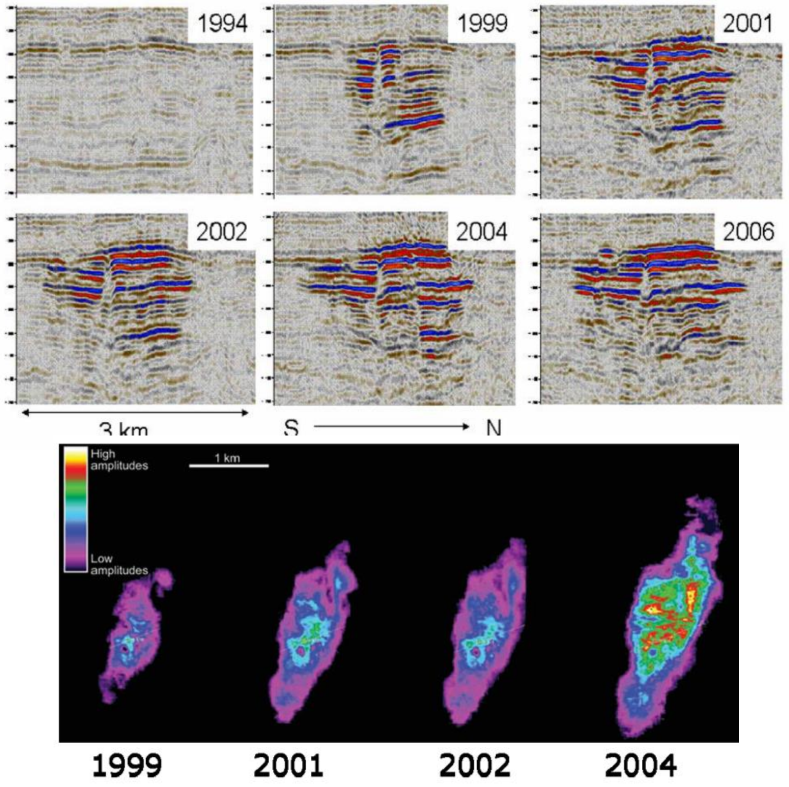
Science of Carbon storage in deep Saline Formations., 2018.

The Sleipner CCS project (offshore Norway) was the world's first commercial CO2 storage project (1996)
The West field contains up to 9% CO2 which is injected into Utsira saline formation 800m below the seabed.



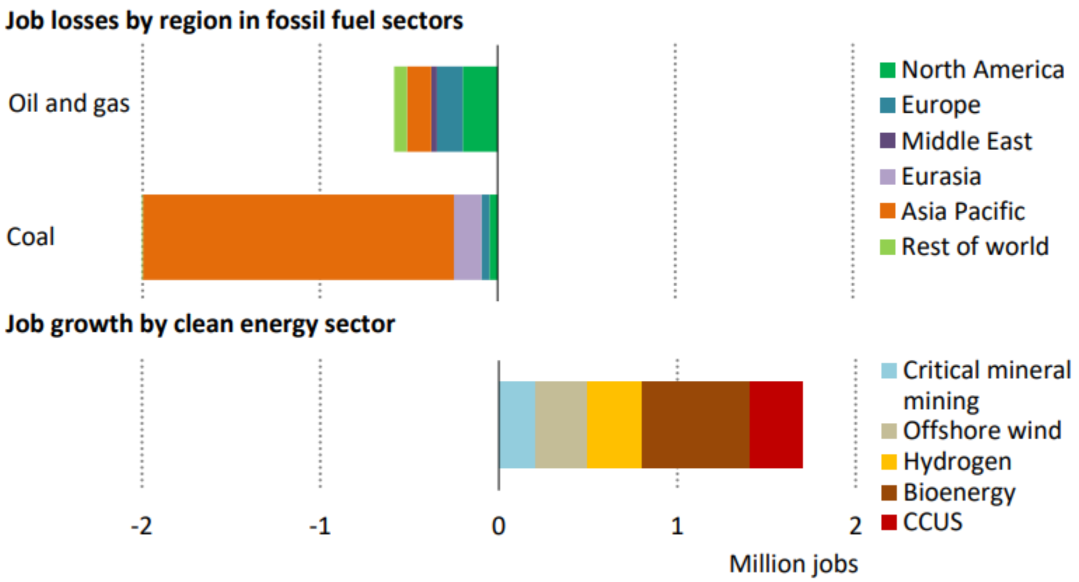
Source: Stanford Center for Carbon Storage

Time lapse seismic data in the Utsira Formation



Hermanrud et al., 2009

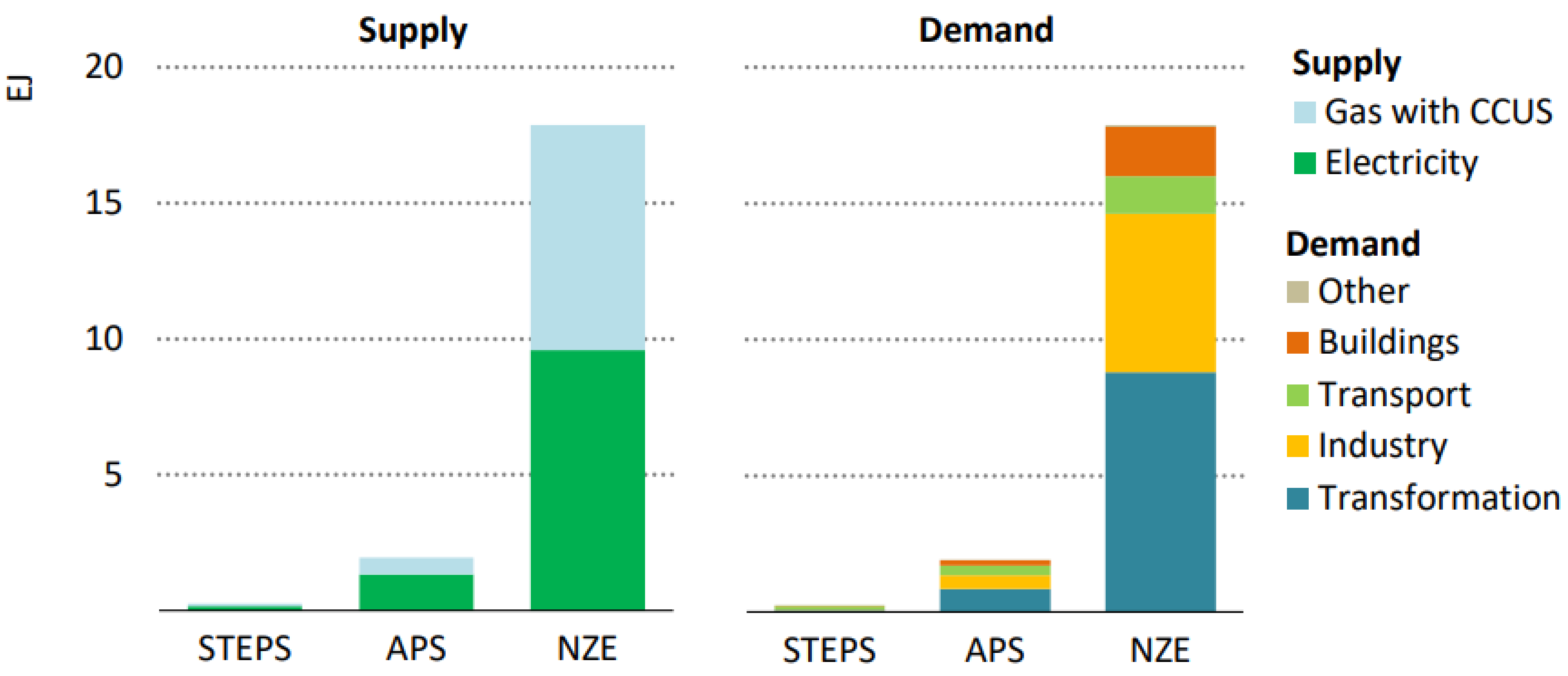
Employment growth to 2030



***APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario*

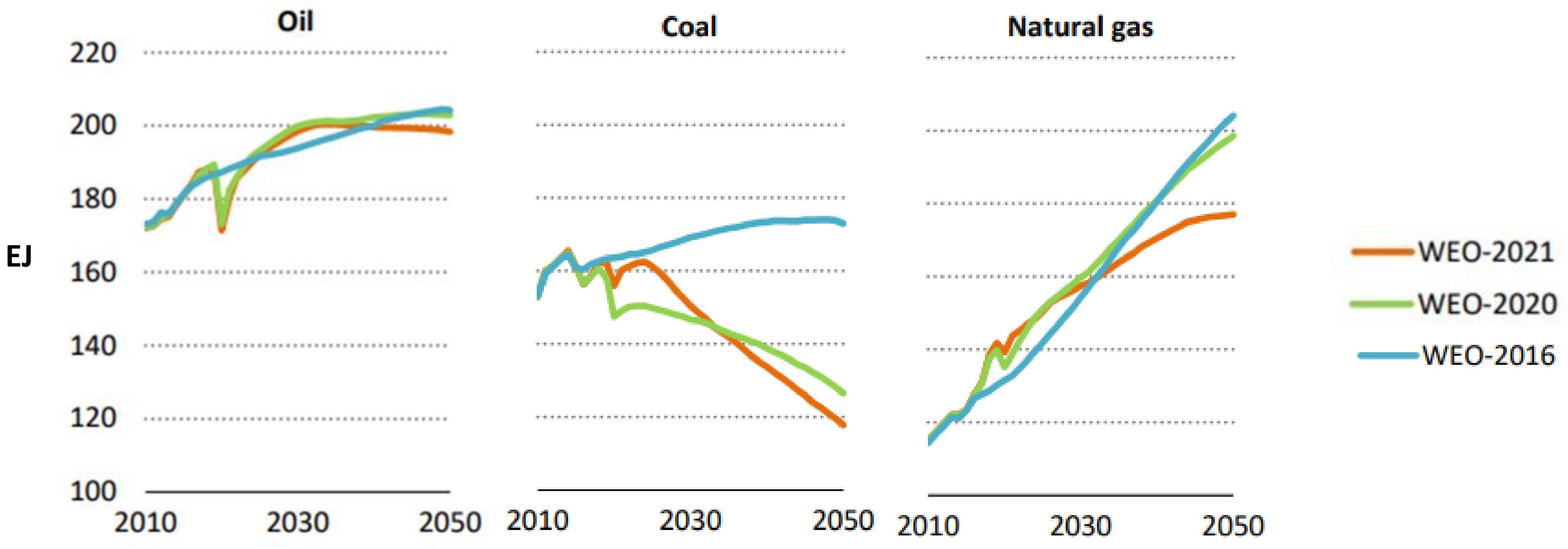
Source: IEA World Energy Outlook 2021

Natural Gas will power the energy transition



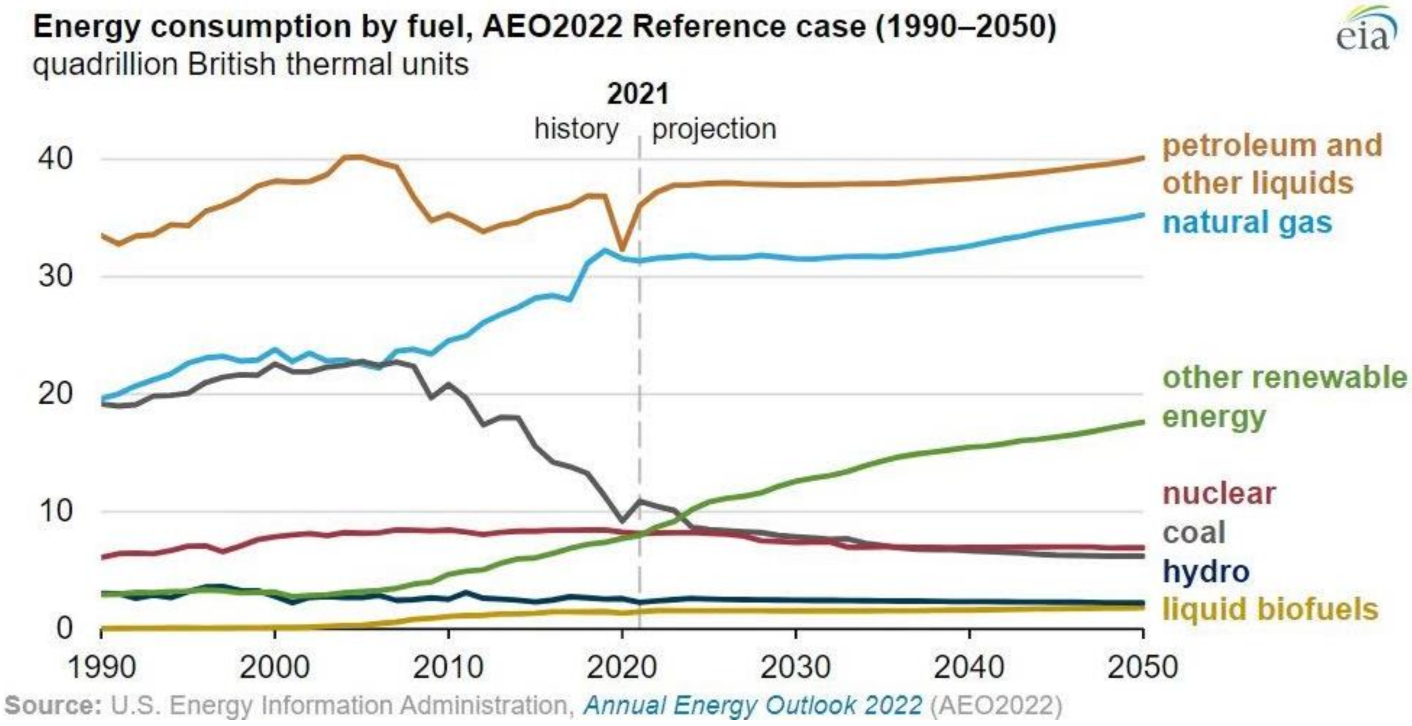
Source: IEA World Energy Outlook 2021

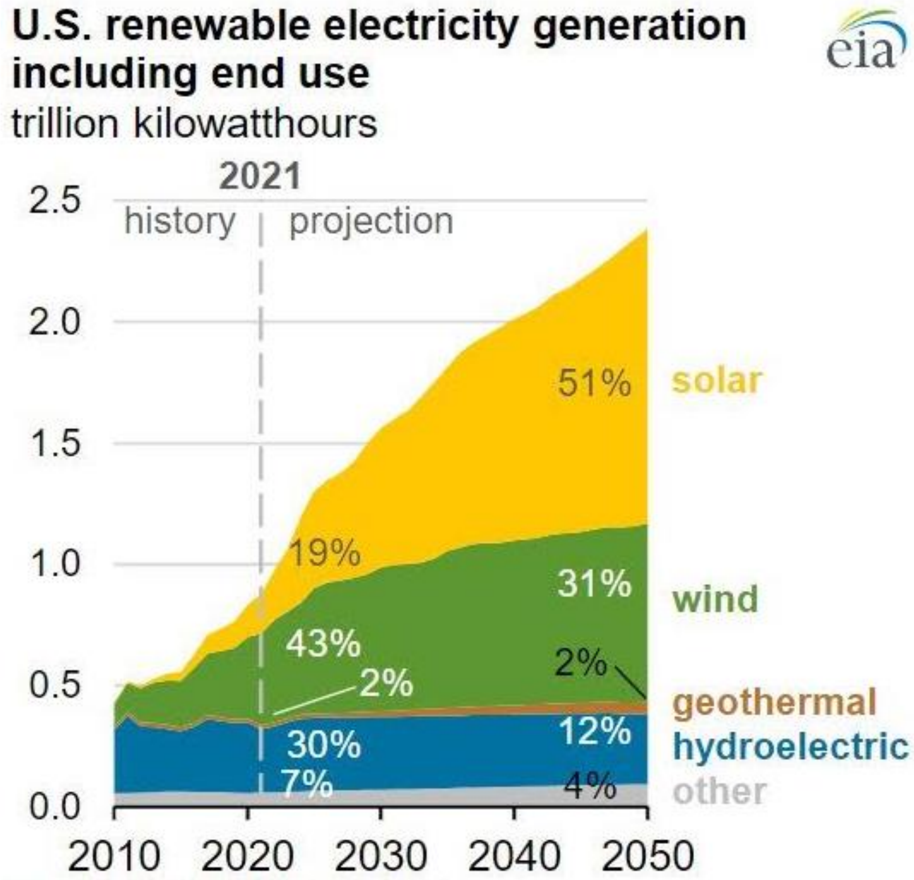
Natural Gas will power the energy transition



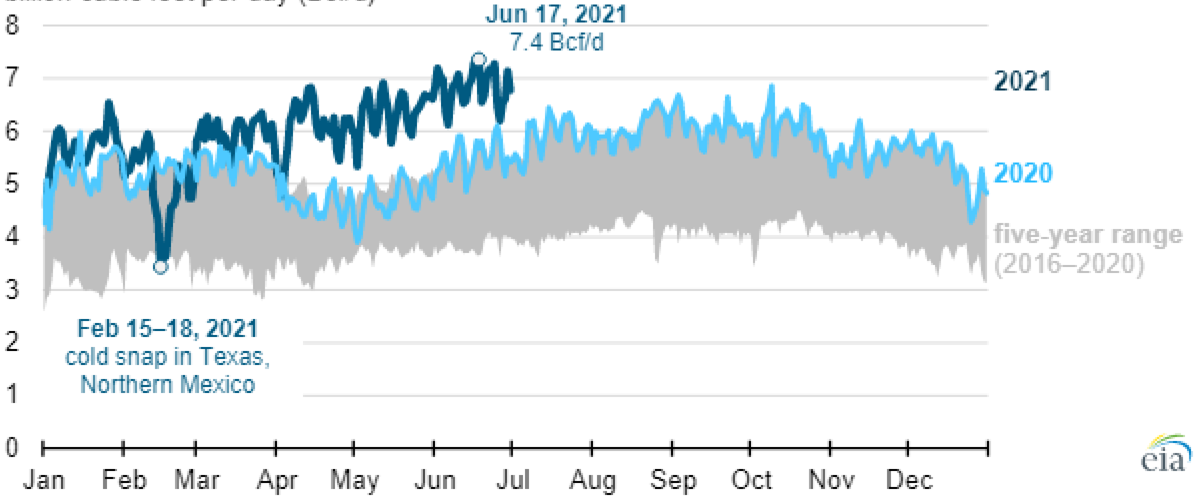
**EJ is exajoules = 23.88 Mtoe Source IEA 2021*

Natural Gas will power the energy transition

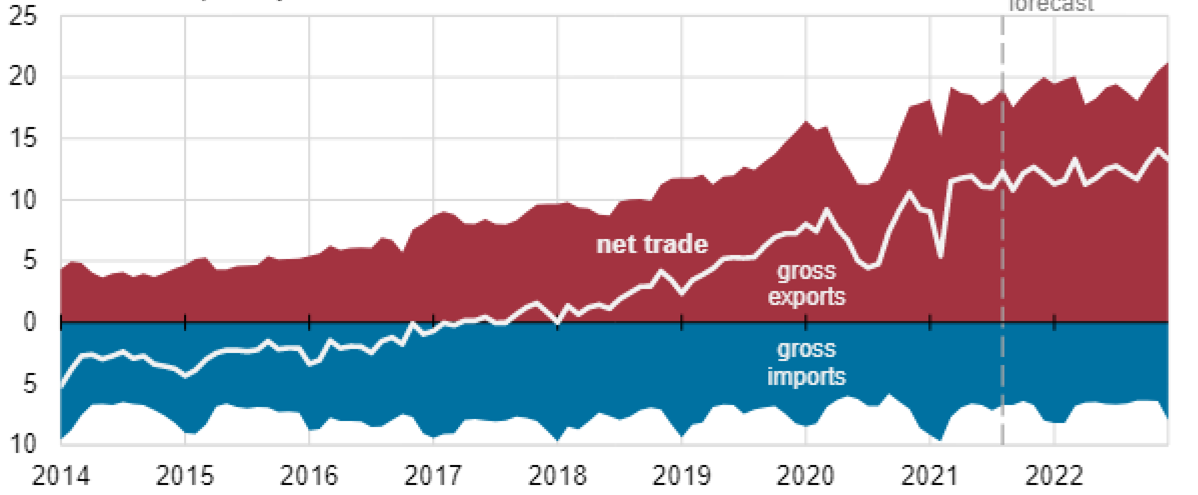




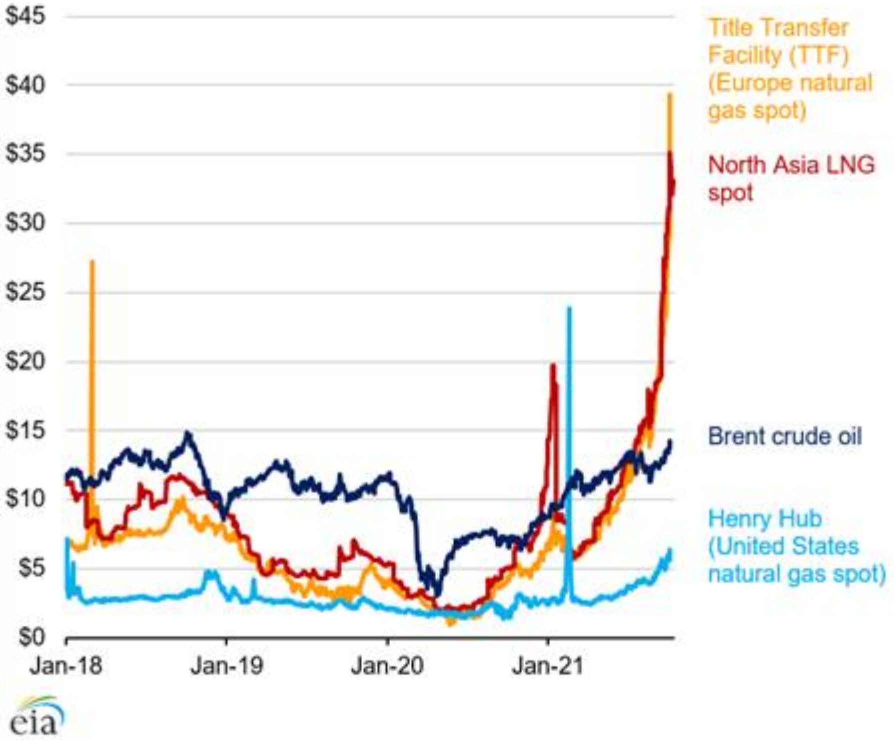
U.S. daily natural gas pipeline exports to Mexico (Jan 1, 2016–Jun 30, 2021)
billion cubic feet per day (Bcf/d)



Monthly U.S. natural gas net trade (Jan 2014–Dec 2022)
billion cubic feet per day

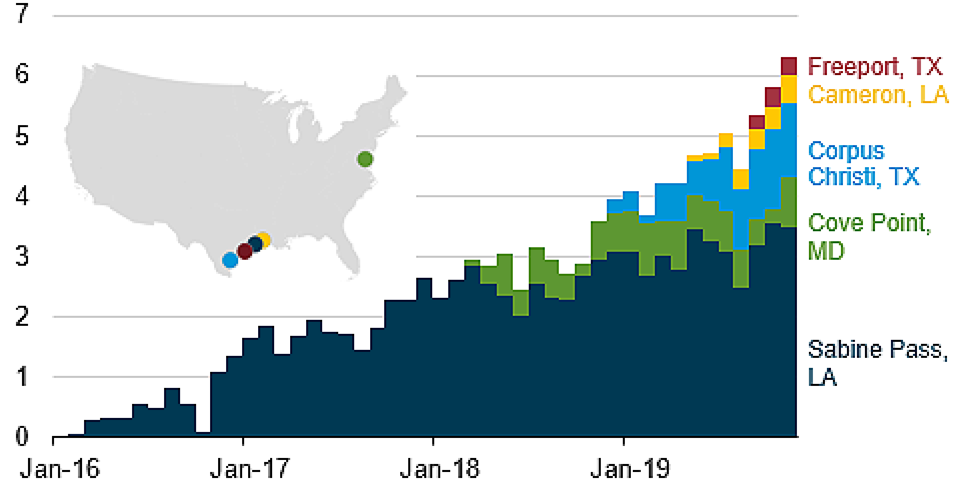


Daily crude oil, natural gas, and LNG spot prices (Jan 2018–Oct 2021)
dollars per million British thermal units



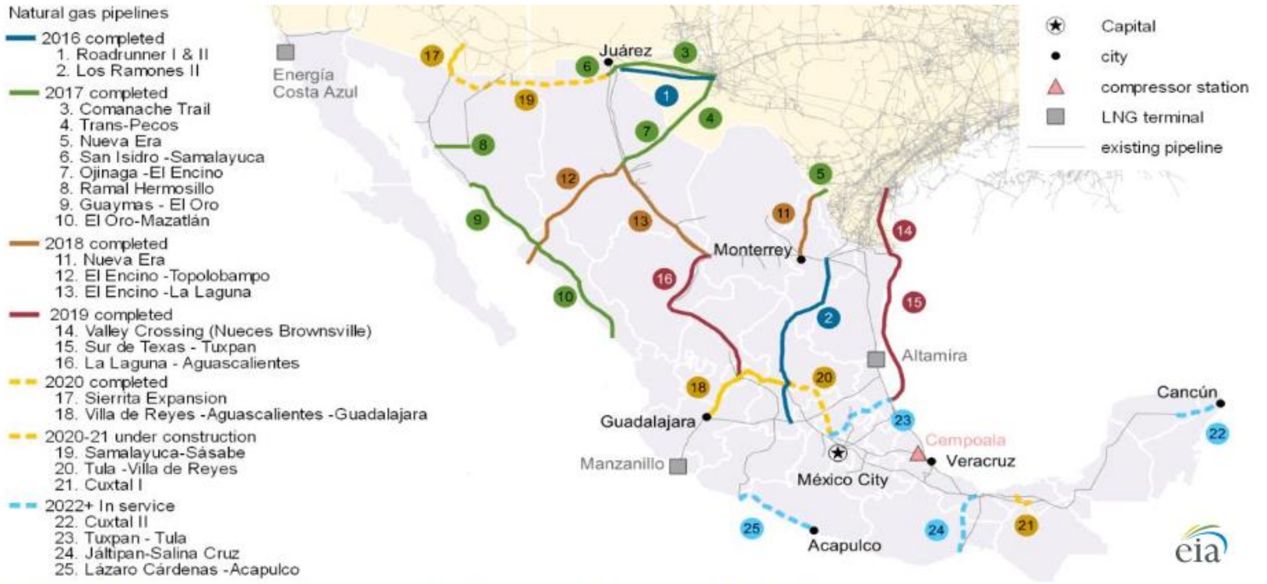
U.S. LNG exports by liquefaction terminal (Feb 2016 – Nov 2019)

billion cubic feet per day

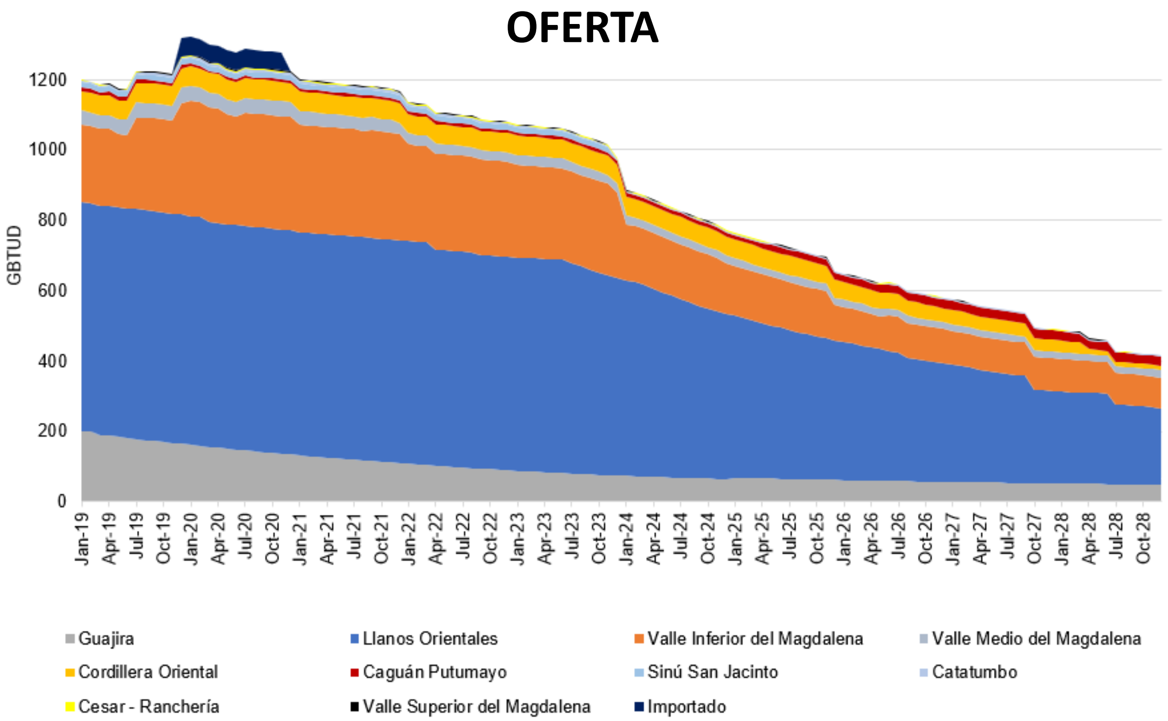


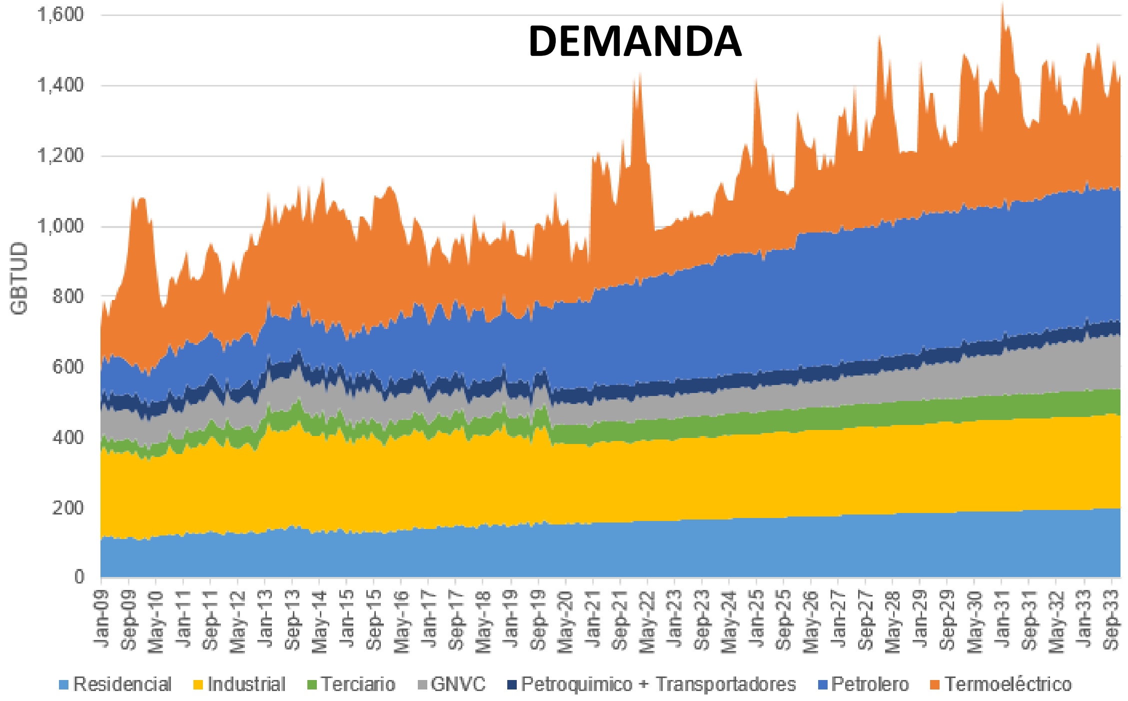
Sources: U.S. Energy Information Administration; U.S. Department of Energy, Office of Fossil Energy; and Bloomberg Finance, L.P.
Note: Export volumes for November and December 2019 are EIA estimates based on vessel shipping data provided by Bloomberg Finance, L.P. Estimates are based on LNG vessels that departed U.S. export terminals in November and December, filled at 95% of LNG-carrying capacity.

U.S. natural gas exports to Mexico set to rise with completion of the Wahalajara system



Source: U.S. Energy Information Administration, Comisión National de Hidrocarburos, Mexico





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Remarks

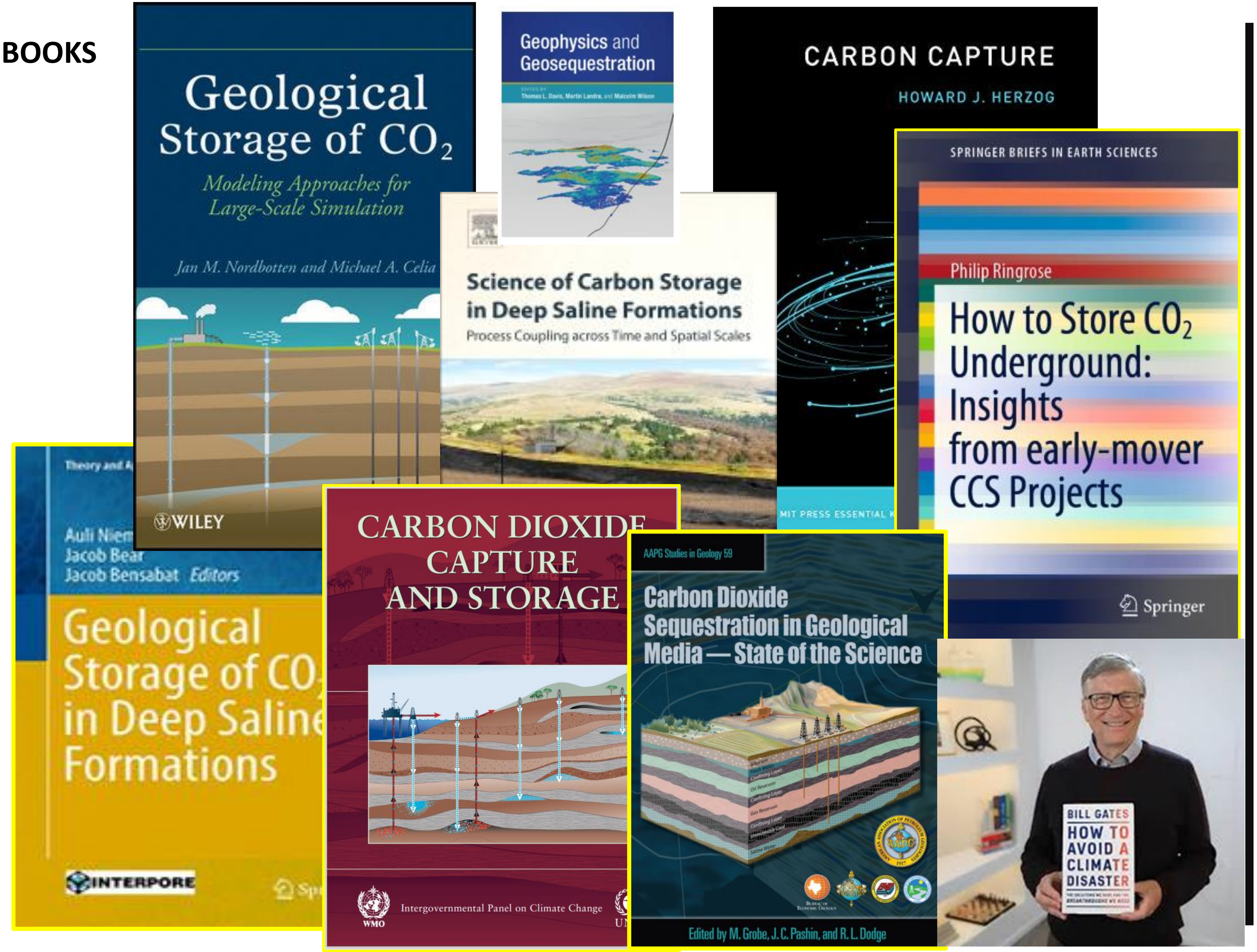
- CCS/CCU is an emerging topic with great employment opportunities in near and long future

- > 2,000 CCS facilities need be operating by 2040 to meet 9% emissions contribution associated with CO_2 storage and the Oil and Gas fields provide an ideal repository for CO_2

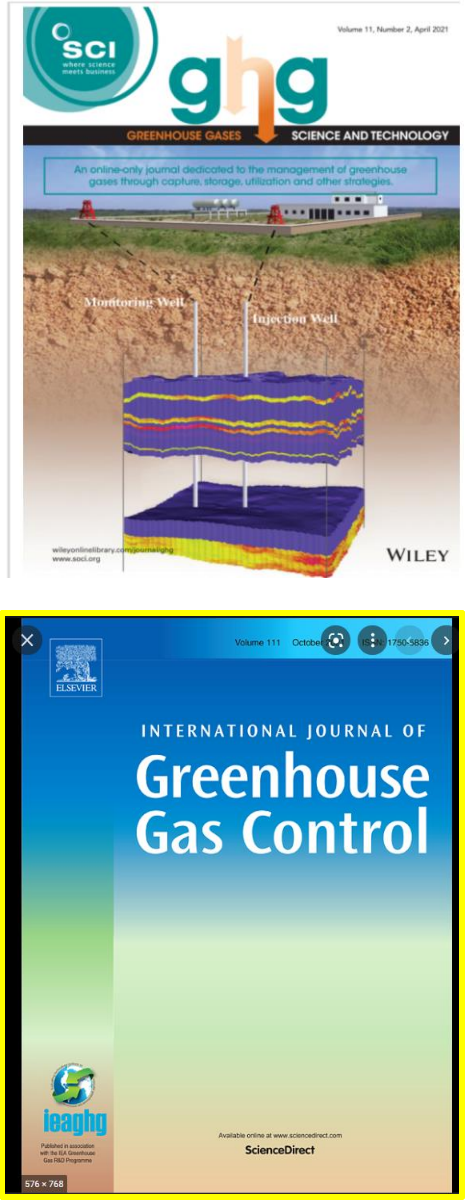
- The technical skill associated with EOR/Reservoir characterization gained in school by O/G workers (students) will also be applied in CO2 storage projects (Back to the basics)

- ***Where to learn about CCU/CCS?***

BOOKS



JOURNALS



Courtesy: Carlos Bahamon Oxy

Where to Study

Stanford School of Earth, Energy & Environmental Resources – Stanford Center For Carbon Storage

University of Houston

Colorado School of Mines – Earth • Energy • Environment

EGI Energy & Geoscience Institute at the University of Utah – Since 1972

TEXAS Geosciences – The University of Texas at Austin, Jackson School of Geosciences

Mewbourne College of Earth and Energy – Mewbourne School of Petroleum and Geological Engineering – The University of Oklahoma

NTNU

Norway

The University of Edinburgh

Scotland. (Msc Carbon Mngt'

University of Stavanger

The University of Adelaide

Australia

Heriot Watt University

United Kingdom

IFP School

University of Regina

Canada

ieaghg

Worldwide

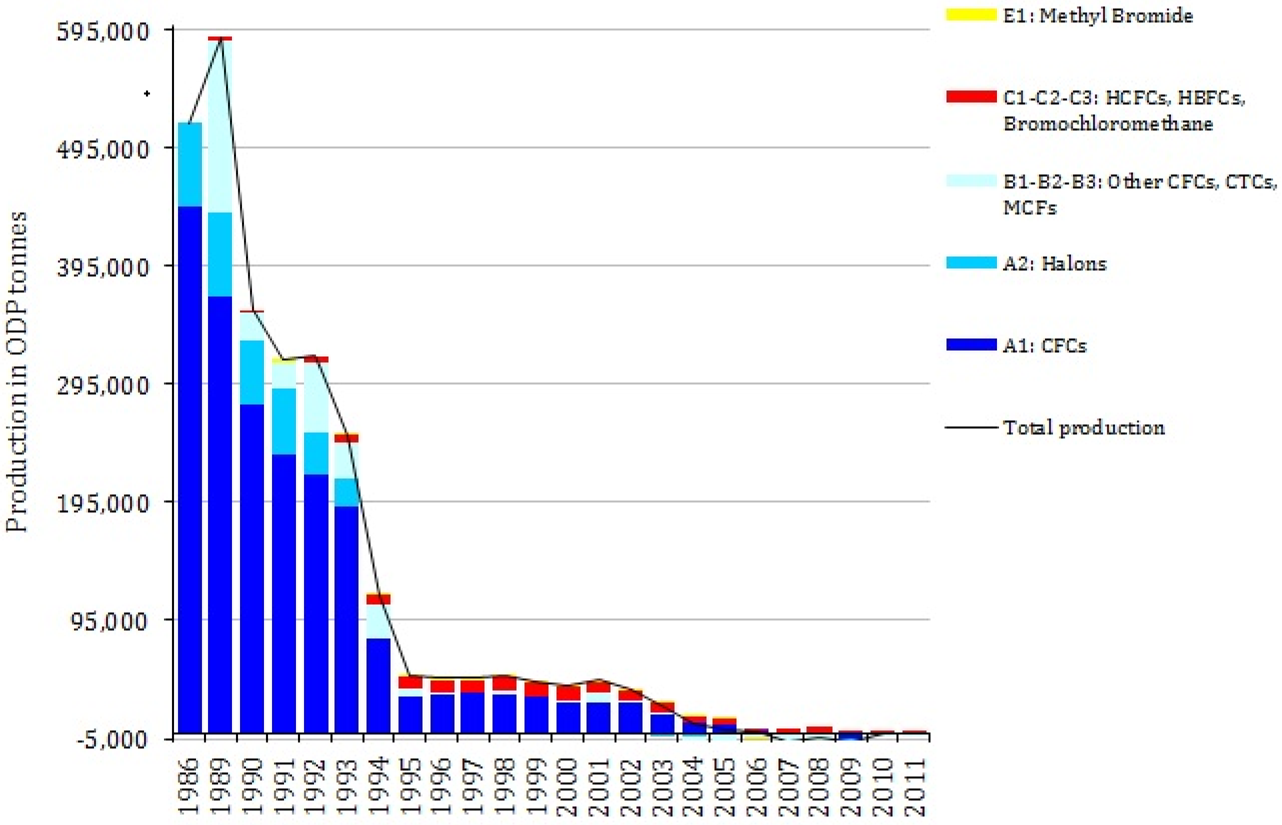
Research Centre for Greenhouse Gas Innovation

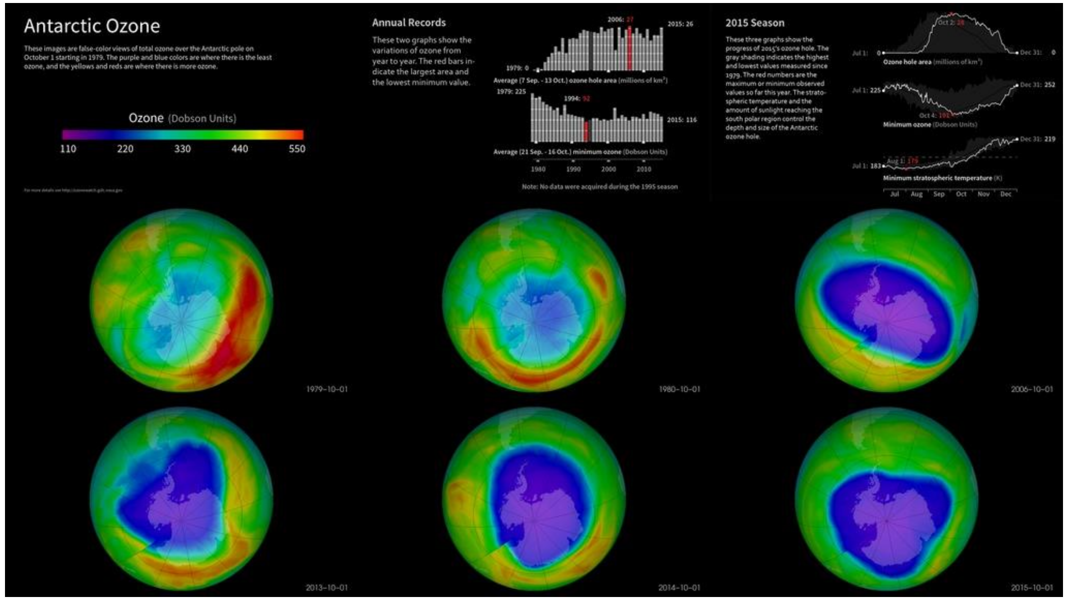
Univ. Of Sao Paulo, Brazil

Events

GLOBAL CCS INSTITUTE

The CFC, HCFCs and other Ozone killers





https://svs.gsfc.nasa.gov/30731

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