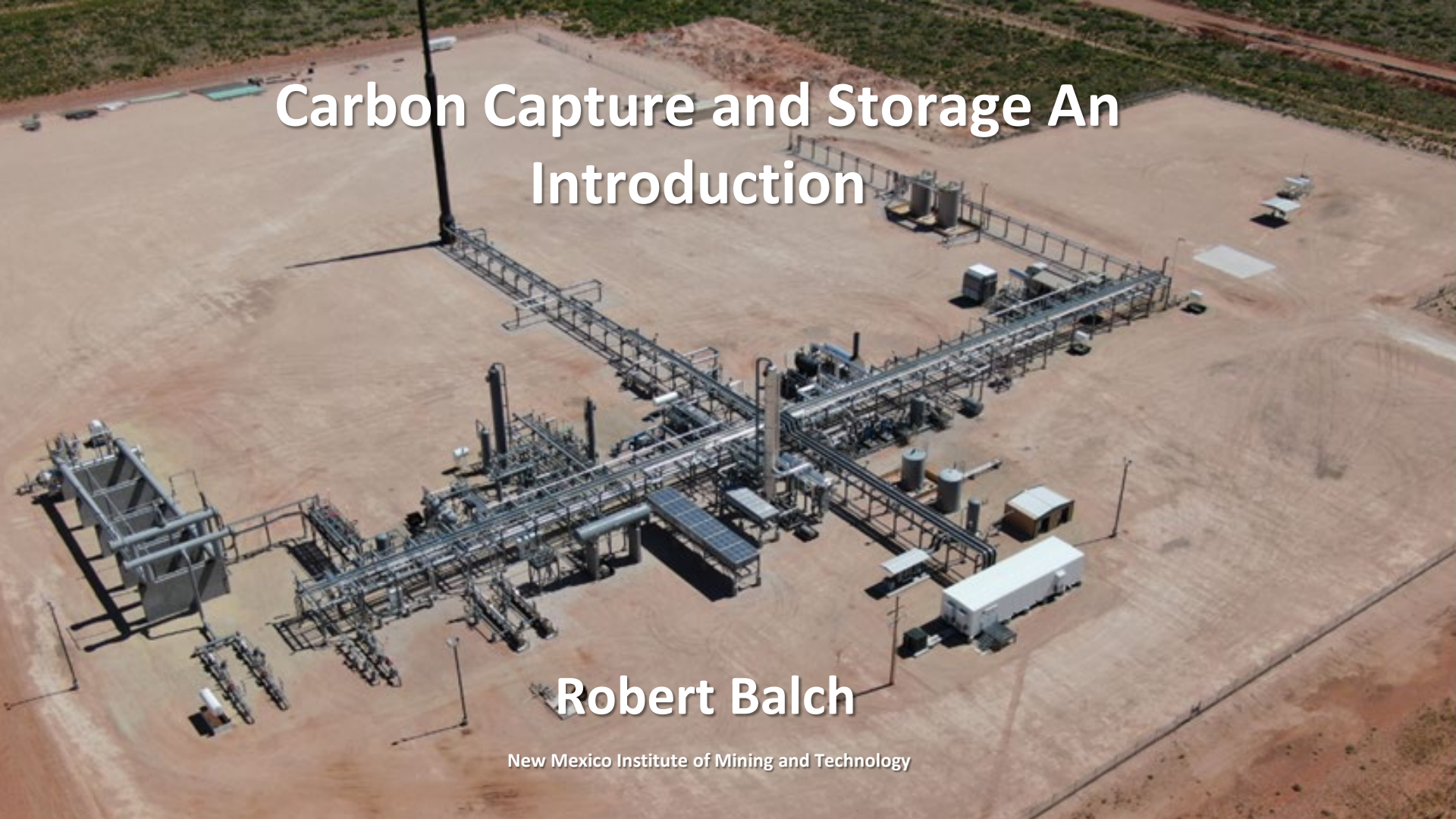

Carbon Capture and Storage An Introduction

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What Is an Energy Transition?

An energy transition is a broad shift in technologies and behaviours that are needed to replace one source of energy with another (Jacard, 2020)

Has this happened before?: Sort of. Around 1750 the industrial revolution started in England, Biomass began to give way to coal. However... We still use biomass today, and in fact some coal power plants are being converted back to biomass, Arguably there has been only one Energy Transition which is still progress!

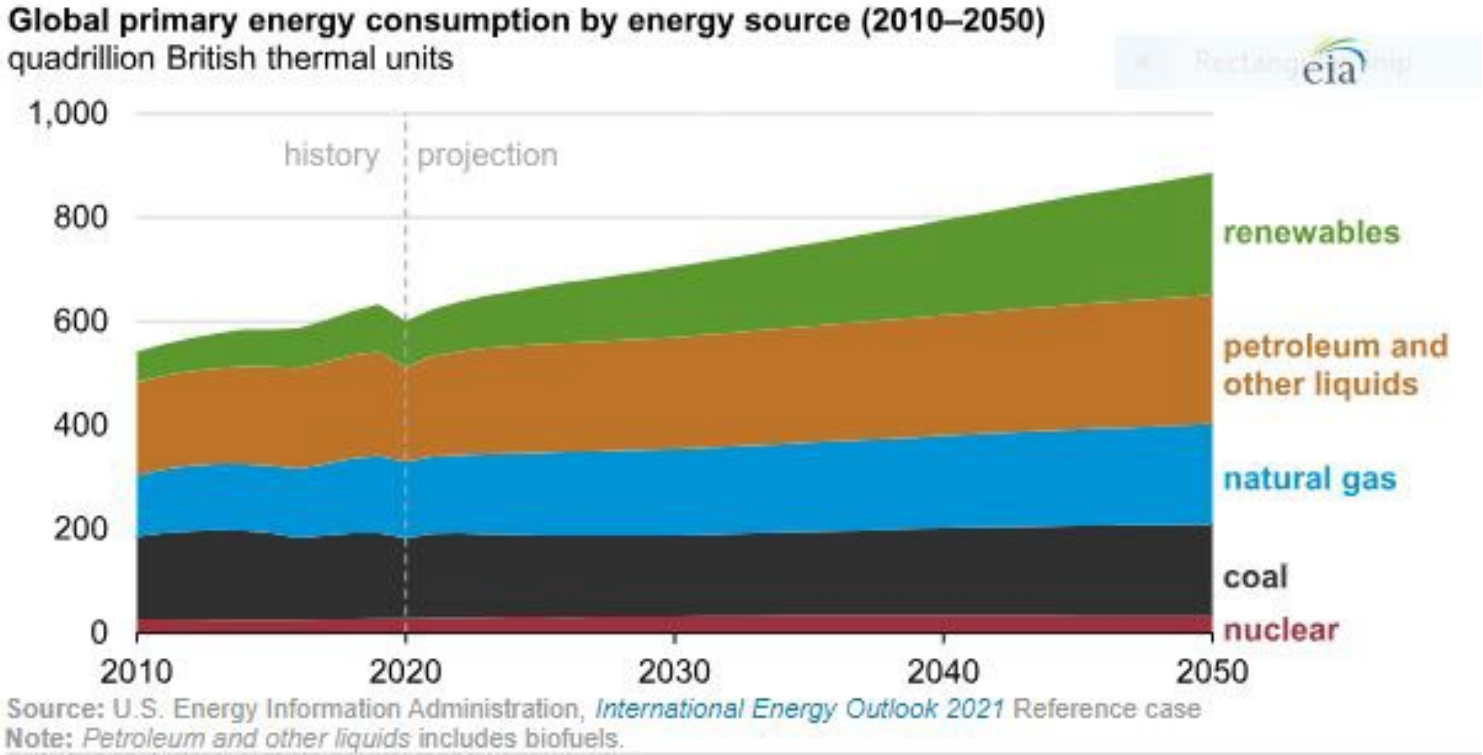
Biomass* > *Coal* > *Oil/Gas* > *Hydro* > *Wind* > *Nuclear* > *Solar PV* > *Modern Renewables

Pre 1750	1750	1850	1891	1895	1951	1951	1980

All of these power sources are still in use today

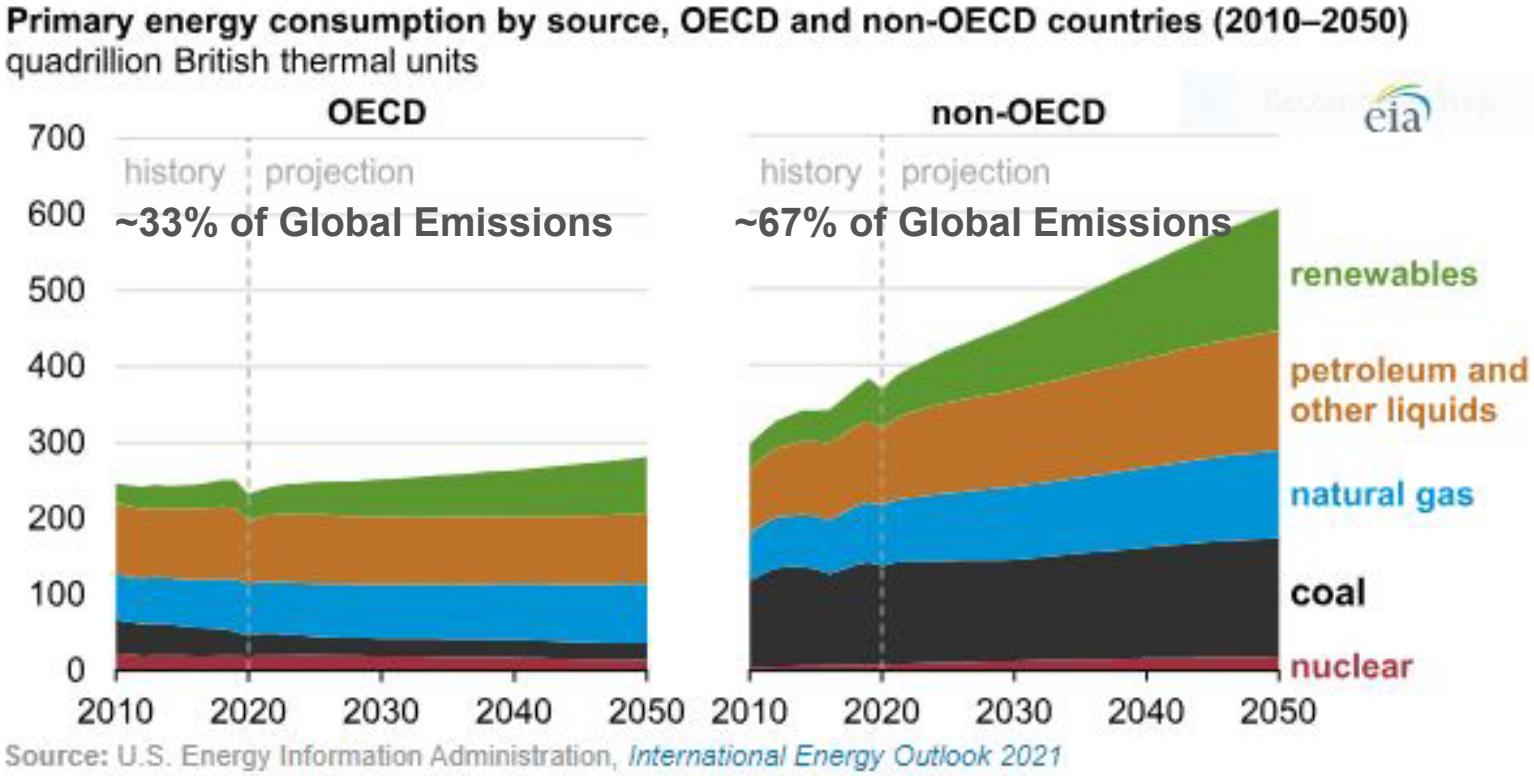
Energy Transitions are long-term processes, usually resulting from finding something better or cheaper: Early shifts in primary energy source driven by economics and capacity demand

Global Energy Mix in 2050



- Renewables are the fastest growing category (45%)
- However, world energy demand is expected to grow by 50% in the same time period.
- Renewables are displacing, in part, new hydrocarbon demands, but all energy sources are increasing by 2050

Geopolitics Plays a Large Role…
Unmitigated Future Emissions



OECD Countries: Primarily Europe, North America, Far East Asia are expected to slightly reduce Hydrocarbon use by 2050, and have modest growth in demand covered by renewables

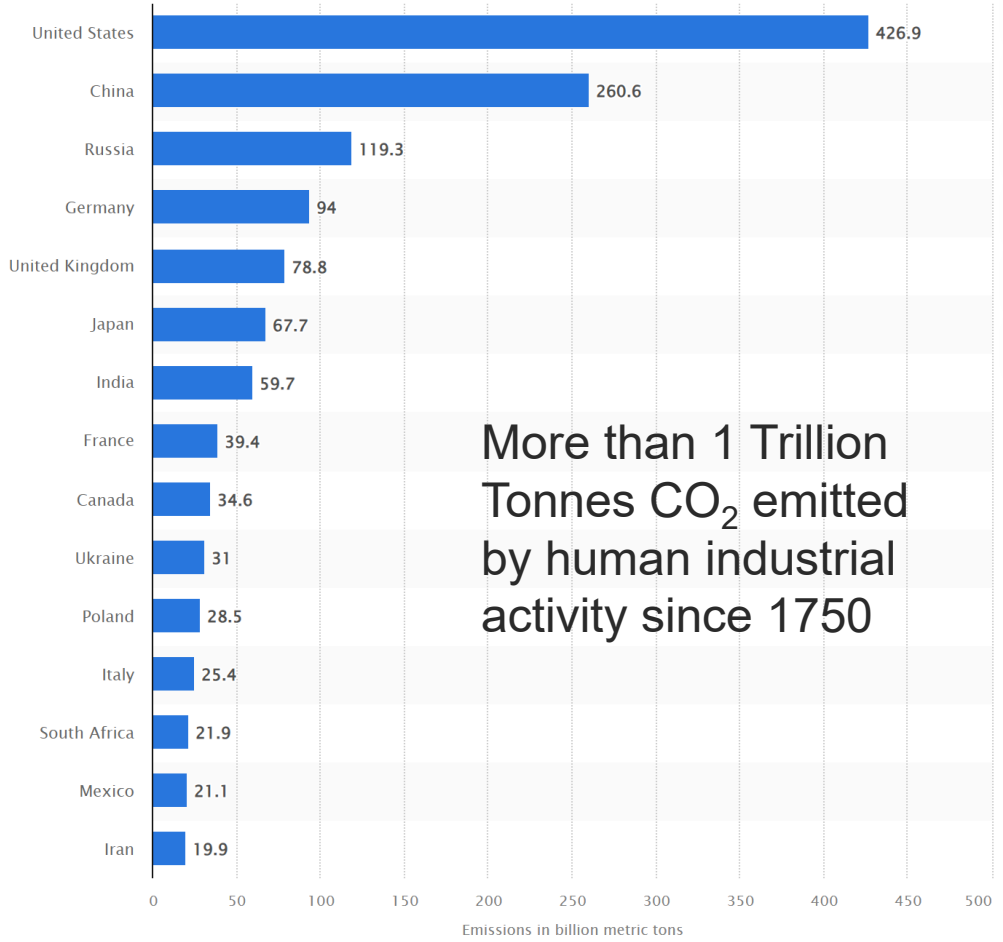
Non-OECD Countries: See rapid growth in every energy category, leading to a net increase in hydrocarbon use world-wide in 2050

6. Legacy Emissions

The problem is not just current emissions…

While China and ultimately India will surpass US total emissions, at present OECD Countries represent over 75% of all the CO_2 that has been emitted by human activities since the beginning of the industrial revolution (1750 to present)

CO_2 molecules resides in the atmosphere for an average of 990 years



How Do We Manage These Emissions?

Simply stated this is an immense challenge

- **Hydrocarbon Energy:** Is pervasive and impacts every aspect of modern life
  - Coal-fired power (~30% of world CO_2 emissions)
  - Natural gas (~22%)
  - Vehicle Fuel (~9%)
- **Critical Building Materials:** Drive economic development
  - Cement (~8% world emissions)
  - Steel (~9%)
  - Glass (~2.5%)
- **Strategic Minerals are Scarce:** Relative to new demands we lack sufficient supplies to meet demand for renewables, *renewable power storage*, and 0 emissions vehicles

- **In the next two decades we need to mitigate (store) emissions while new technologies catch up both technology and infrastructure**
- **CCS/CCUS needed at scale of 6-8 Gt/year… Starting last year (EIA, IEA, IEAGHG, etc.)**
- **Also need to manage legacy CO_2 that has already been emitted (Direct Air Capture)**

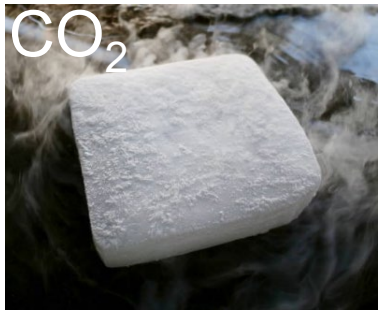
So… What does CCS Look Like?

Carbon Dioxide Basics

Water

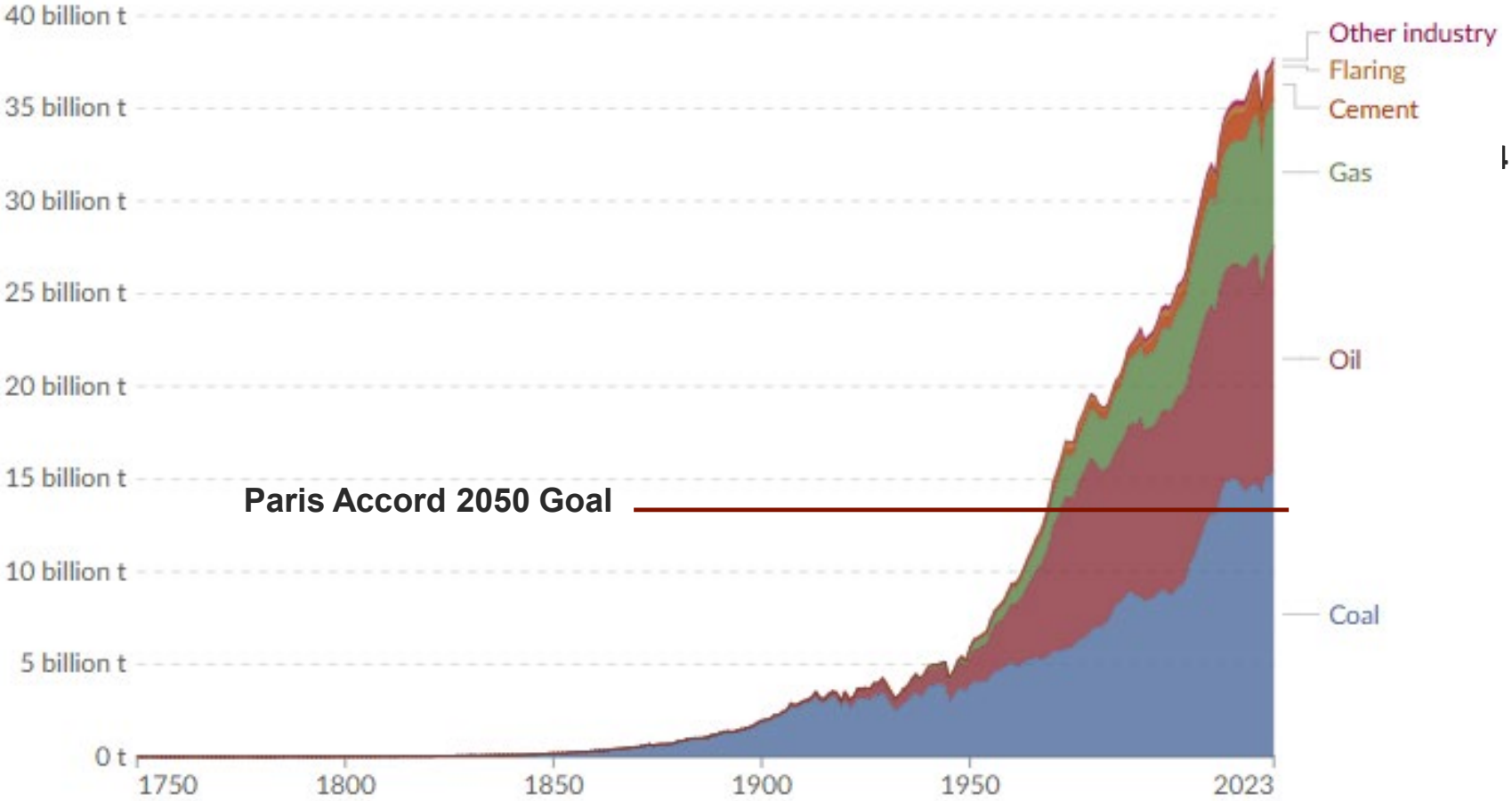
Lower ← Temperature → Higher

CO_2



Higher ← Pressure → Lower

- **Most things have 3 basic forms that have different properties**
  - Solid
  - Liquid
  - Gas
- **As you change pressure and temperature you change the form of the material and its density**



Ourworldindata.org

Understanding the scale of emissions (and storage)

25 Tonnes Liquid CO_2

- **World emissions 2024 37.4 billion tonnes**
  - **1186 trucks every second**
- **US emissions 2024 4.8 billion tonnes**
  - **152 trucks every second**
- **NM emissions 2022 46.5 million tonnes**
  - **1.5 trucks per second**

New Mexico Emissions

Second	Minute	Hour	Day
	88.5	5,308	127,397

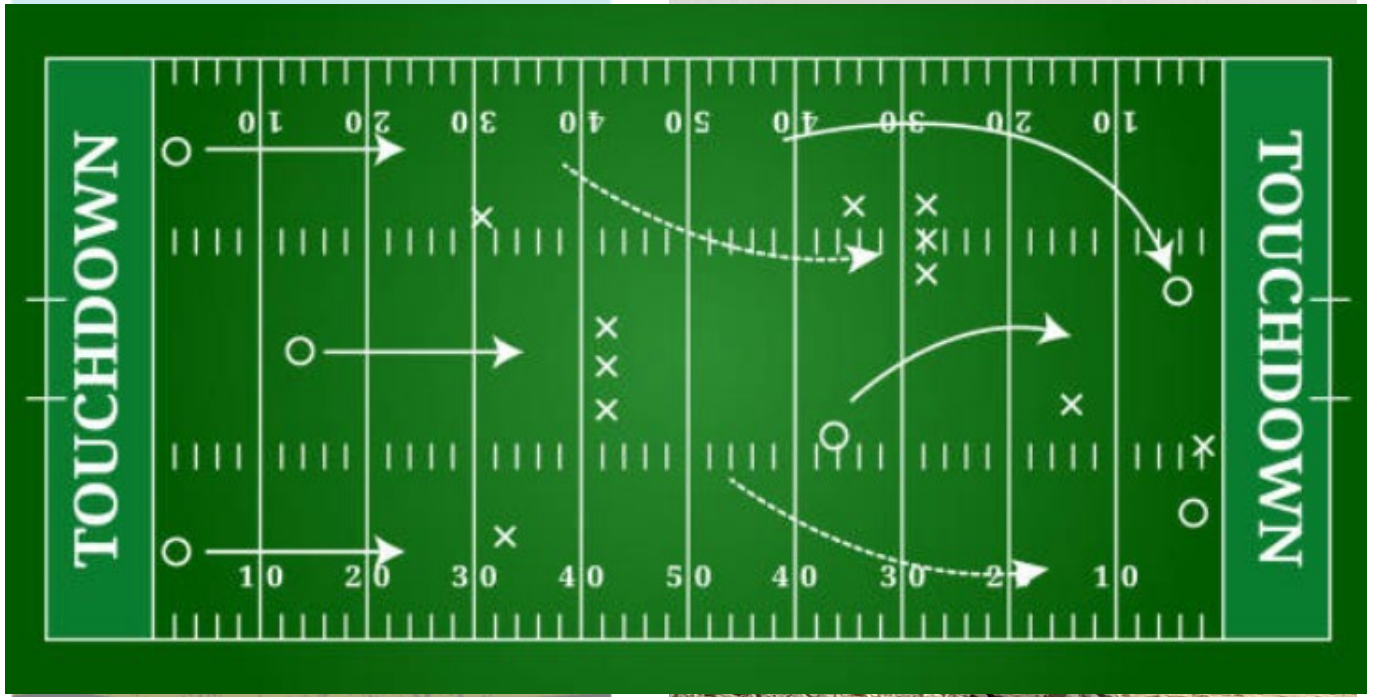
Carbone Dioxide: Where from? Where to?

Where does CO2 come from?

- Fossil Fuel Power Plants
- Refineries
- Gas Plants
- Cement & Steel Plants
- Hydrogen Production
- Ethanol

How do you capture CO2?

- Pre combustion
- Post combustion
- Direct Air Capture (DAC)

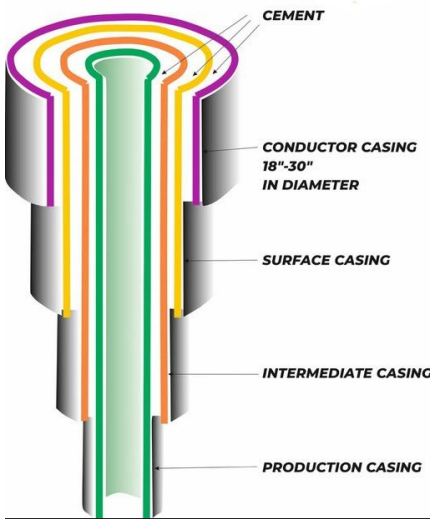


(EPA.gov)

How Does the CO2 Stay Where You Put It?

UIC Program - Groundwater Protection Council (GWPC)

- UIC Class VI wells are very stringently controlled by through EPA rules with oversight from GWPC



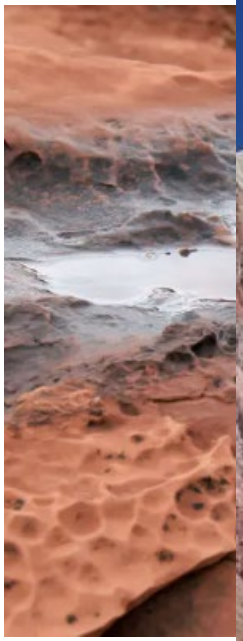
Multiple layers of pipe and cement

Stainless steel pipe

CO_2 resistant cement

How Does the CO2 Stay Where You Put It?

Use G iers



Reservoir ly allow fluid flow

How Does the CO2 Stay Where You Put It?

Extensive Monitoring and Modeling

- Track regularly groundwater, air quality, seismicity
- Constantly update predictive models using all information available