A BRIEF LOOK INTO FUTURE ENERGY TRENDS FOR LOUISIANA: CCS & H2

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Energy Solutions
with a Cajun Accent

THANK YOU!

For being a great corporate neighbor and your support of this great forum

ASCENSION
CHAMBER OF COMMERCE

For the kind invitation to speak today and your successful growing of Louisiana's economy

ENERGY TECHNOLOGIES FOR LA IN ZAPPI'S OPINION/MIND:

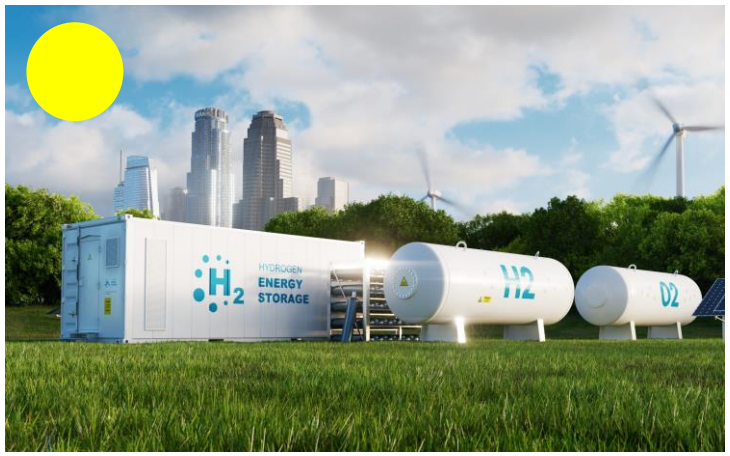
COMMERCIAL READY FOR LA

ALMOST COMMERCIAL READY FOR LA

HIGH POTENTIAL ALTERNATIVE ENERGY PROCESSES FOR LOUISIANA

PV Solar (Particularly Utility Scale)

Off-Shore Wind



Green Hydrogen

Blue Hydrogen

Lipids/FFAs to Renewable Diesel

Biomass to Power/Heat

HIGH POTENTIAL ALTERNATIVE ENERGY PROCESSES FOR LOUISIANA

Biomass to Alcohols (Methanol)

Carbon Capture & Storage (CCS)

Renewable Natural Gas (RNG)

CCU - CO2 Utilization into Algae

White & Black Biomass/Biocoal

GeoPower

OTHER HIGH POTENTIAL ENERGY PROCESSES FOR LOUISIANA

Biomass-To-Liquids (BTL) Diesel

Energy Storage - Batteries
(Industrial Scale Batteries)

Smart Micro/Macro Grids

OIL AND GAS WILL STILL BE BIG AND NEEDED

I THINK AT LEAST THROUGH 2075

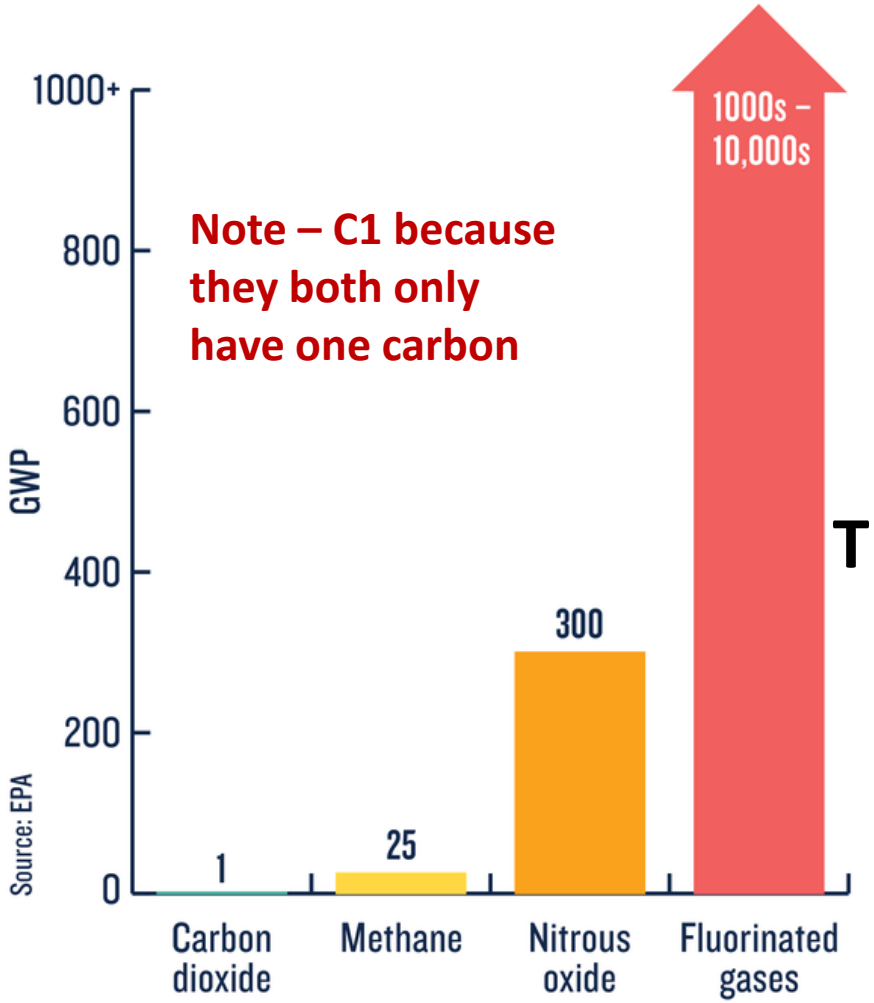
DECARBONIZATION

I do believe it's a "Not if – but When" scenario

But, the "When" should be based on technology readiness, economic reality, and ecological benefits

Don't forget Your Grandmaw – She Has to Pay Her Bills
(We can't out-price green – ready is not just that we technically can)

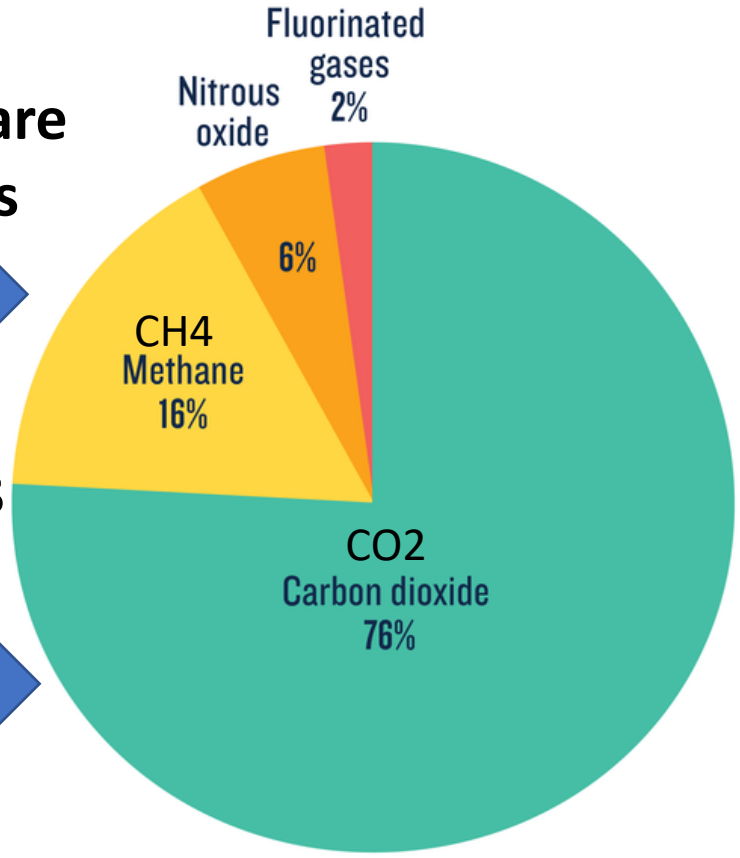
WHAT ARE THE KEY GREEN-HOUSE GASES OF CONCERN



The global warming potential (GWP) of human-generated greenhouse gases is a measure of how much heat each gas traps in the atmosphere, relative to carbon dioxide.

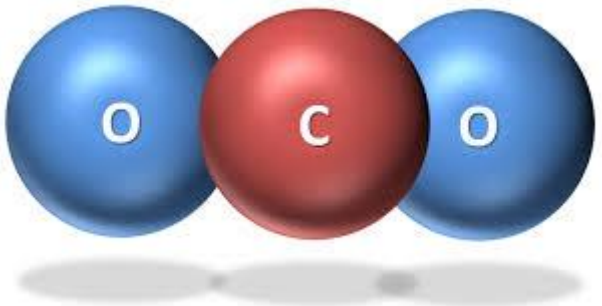
>90% are the C1s

The C1's



Source: IPCC (2014)

How much each human-caused greenhouse gas contributes to total emissions around the globe.



WHAT'S DAT?

CARBON DIOXIDE

CO_2

- COLORLESS GAS
- NON-FLAMMABLE
- NON-TOXIC
- CAN DISPLACE AIR/OXYGEN
- NON-REACTIVE
- FROZEN FORM IS KNOWN AS DRY ICE
- CARBON DIOXIDE IS THE FOURTH MOST ABUNDENT COMPONENT OF AIR (0.04%)
- BIGGEST NATURAL CO2 SINK IS PLANTS (PHOTOSYNTHESIS)

-BASIC AND SIMPLISTIC VIEW-

CARBON CAPTURE AND STORAGE (CCS)

CO_2 FROM PIPELINE

CO2 is captured at the plant and concentrated prior to transport

UPPER FORMATION

DRINKING WATER AQUIFER

SUBSURFACE FORMATION

CAPROCK/LOW PERMEABILITY ZONE

TARGETED FORMATION/RESERVOIR

Usually High Above Injection Zone

Usually Have More than One of These Layers

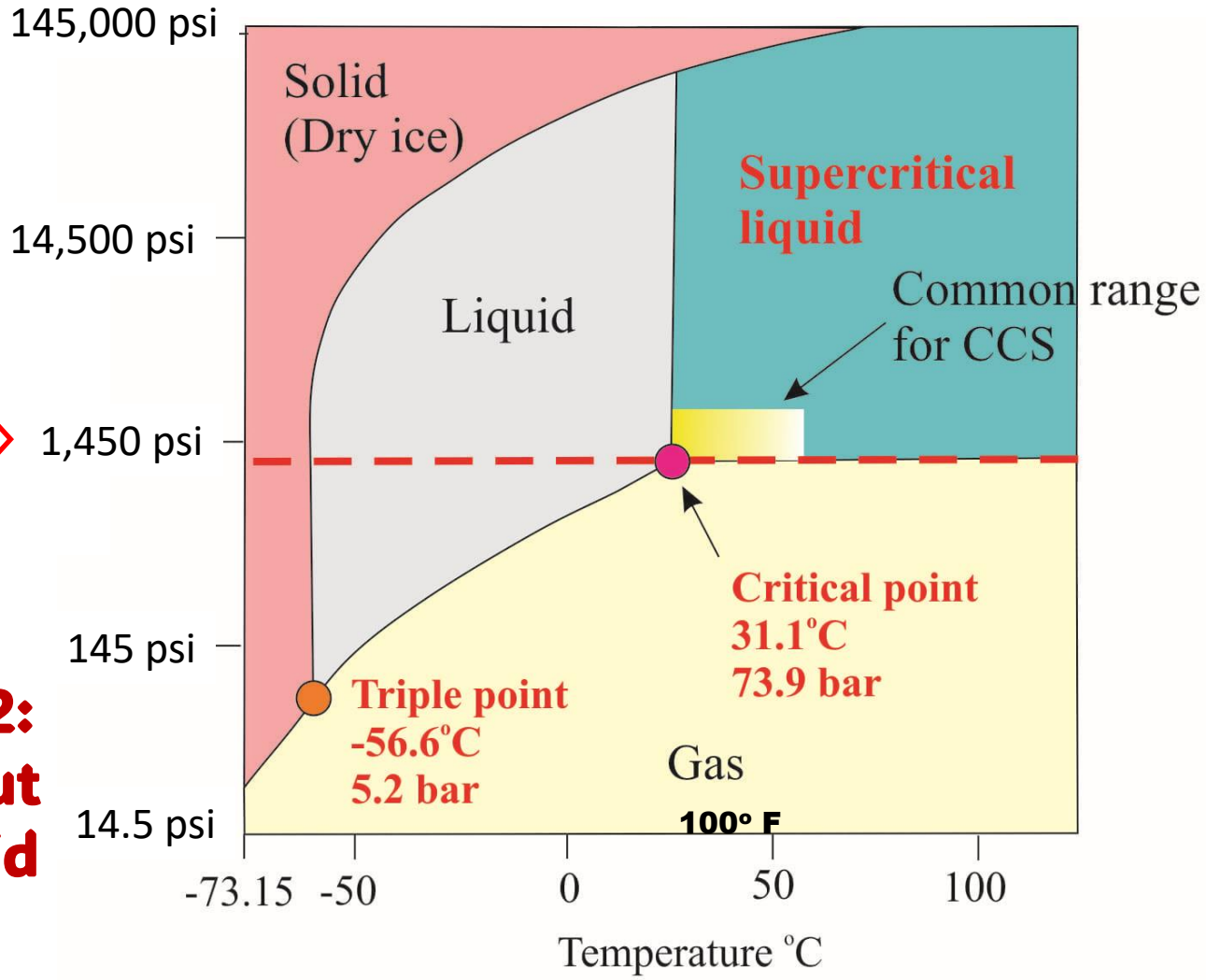
1,000's of feet

CCUS MAKES GREY HYDROGEN BECOME BLUE HYDROGEN – SAME HYDROGEN, JUST CO_2 GEO-INJECTION

Supercritical
CO2 (Semi-Liquid)

PHASE DIAGRAM FOR CARBON DIOXIDE
(Phase = Is it a solid, liquid, gas, or SC-Fluid)

>2,600 ft
Below
Ground

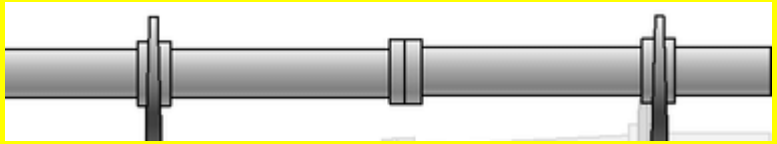


Supercritical CO2:
Flows like gas, but
Dense like a liquid

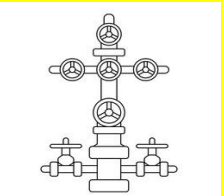
Oh No!
Not Science!

1 bar = 14.5 psi

Need Pressure to Send it Down the line!



Need Pressure to Send it Down the Hole!



EXAMPLE CCS PROCESS FLOW LINE

EMISSION FROM A FLUEGAS (STACK) AT PLANT

10% CO_2 (Carbon Dioxide)

GAS

CARBON REMOVEL FROM FLUEGAS USING AMINE ABSORPTION

95% CO_2

GAS

CAPTURED CARBON TRANSPORT TO INJECTION SITE USING PIPELINE ★

95% CO_2 2,000 PSI

SUPERCRITICAL FLUID

CARBON DIOXIDE INJECTION INTO DEEP GEOFORMATION PROVEN TO BE CAPABLE OF SAFE CO_2 STORAGE

95% CO_2 2,000 PSI 8,000 FT DEPTH

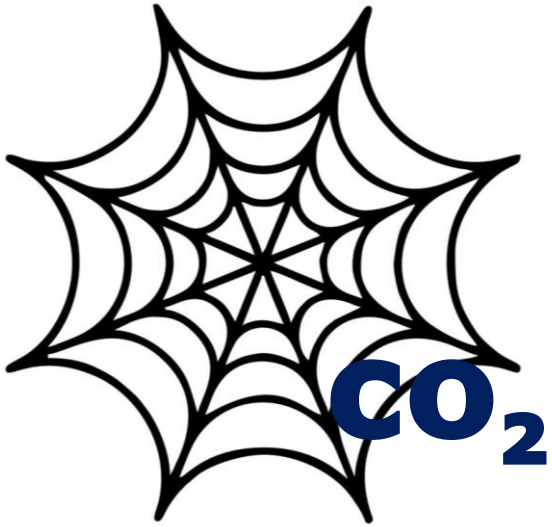
SUPERCRITICAL FLUID

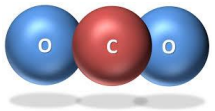
EXAMPLE: SUMMARIZED SCHEMATIC OF THE CCS PROCESS

CCS

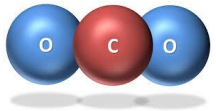
★ Some projects may transport the CO2 as a gas (lower pressure ~750 psi) for all or parts of the pipeline transport

KEY FACTORS WHEN DESIGNING A CSS SYSTEM

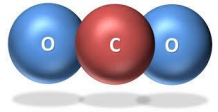




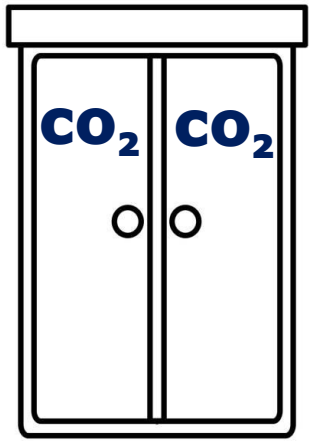
Carbon dioxide capture technology



Captured carbon dioxide transport



Captured carbon disposal/storage



TOTAL COST DISTRIBUTION:

CC – 50%

CT – 30%

CS – 20%

CO_2 CONCENTRATION TECHNOLOGIES

1. Chemical and physical absorption

- -Alkanolamine solutions - MonoEthanolAmine (MEA) or MethylDiethanolAmine (MDEA)
- -Ionic solutions
- -Base (Caustic) solutions
- -Dimethyl ethers of polyethylene glycols (Selexol)

Kinda like bubbling oxygen in water or mixing bourbon in water

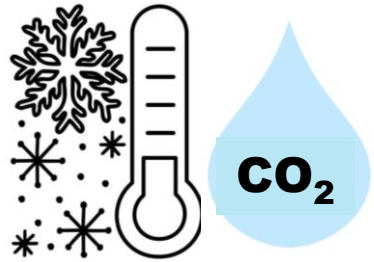
2. Membrane separation

- -Ceramic members
- -Polymeric membranes
- -Hollow fiber membranes

Kinda like a filter

3. Cyrogenic separation

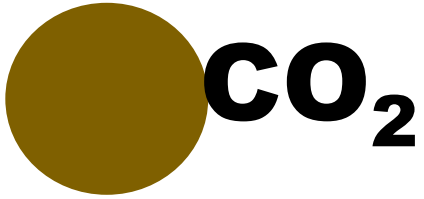
- -Vapor-Liquid (V-L) separation
- -Vapor–Solid (V–S) separation



Kinda like freezing out water from air

4. Physical adsorption on selective adsorbent materials

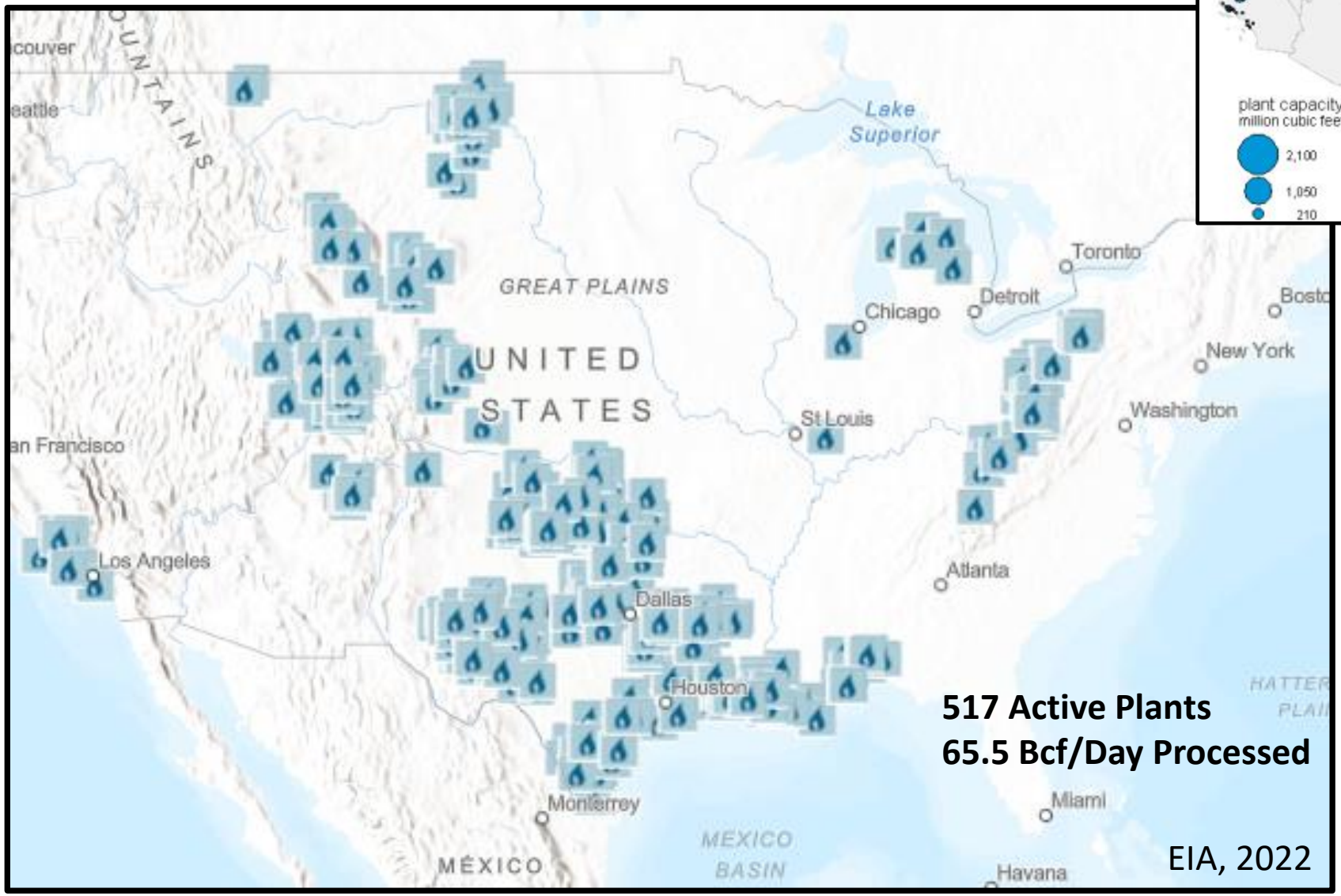
- -Polymeric & activated carbon adsorbents
- -Metals Organic Frameworks (MOFs)
- -Pressure Swing Adsorption (PSA)

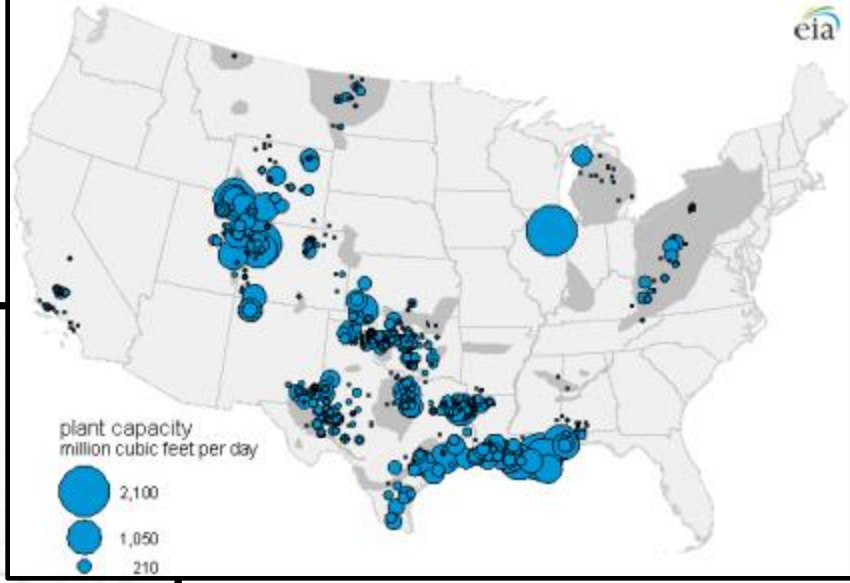


Kinda like activated carbon in your frig filter

LOCATION OF US NATURAL GAS PROCESSING PLANTS

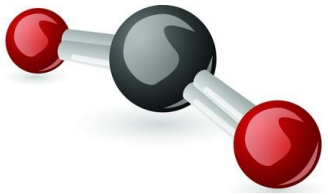
(Remove NGLs and often CO2, S, and H2O)



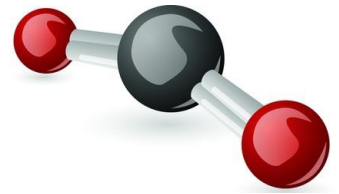


Processing plants are midstream facilities that separate natural gas liquids (NGL) from natural gas. Gas processing plants often perform several other functions, as well: dehydration, contaminant removal, and sometimes fractionation (separating an NGL stream into its component products).

At the well site, some upstream field processing may be done to remove condensate before gas is sent to a midstream processing plant for NGL extraction. In addition, gas producers may use dehydration units (to remove water) and amine treaters (to remove hydrogen sulfide and carbon dioxide).

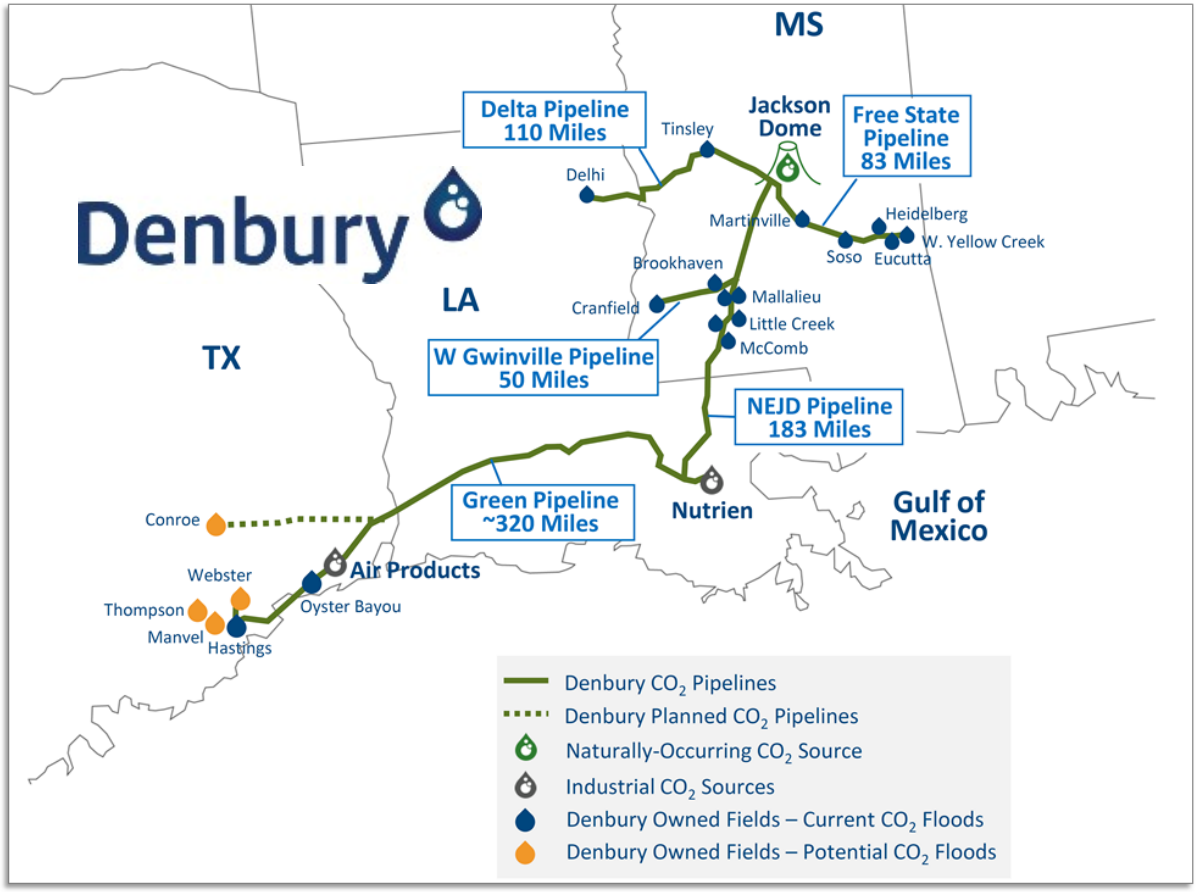


CO2 PIPELINES



- There are about 6,000 miles of CO2 pipelines in the US
- Fairly good safety record
- About 90% are used for EOR
- Pipelines offer CO2 movers about 1/10 the cost of trucking
- CO2 is dehydrated to avoid pipeline corrosion and/or the pipes are lined/protected
- Operating pressure in excess of 1,500 psi (to ~2,200 psi) within the pipelines keep the gas at a dense-phase (semi-liquid state) – BTW, NG pipelines are at ~900 psi

DENBURY CO2 PIPELINE



CO2 pipelines in our area is not new (over 20 years)

Nearly 925 miles of CO2 pipelines in Mississippi, Louisiana and Texas

NBC TV - Jackson, MS

The night a gas line rupture wreaked havoc in a small Mississippi town

By Patrice Clark
Published: Aug. 11, 2022 at 6:51 PM CDT

SATARTIA, Miss. (WLBT) - Imagine driving home from work or sitting and relaxing in your backyard with family or simply taking an evening stroll and, suddenly, you feel lightheaded, dizzy, and eventually collapse... sounds like a movie?

Residents of the small town of Satartia in Yazoo County say this is exactly what happened to them - and it is a nightmare they are still living every day.

“I thought we were going to die,” said Linda Garrett.

It was **February 2020**, around 7 o’clock Saturday night in Satartia. Yazoo County EMA Director Jack Willingham and Volunteer Fire Chief Durward Pettis were driving home when they got an alarming and strange alert on their phones.

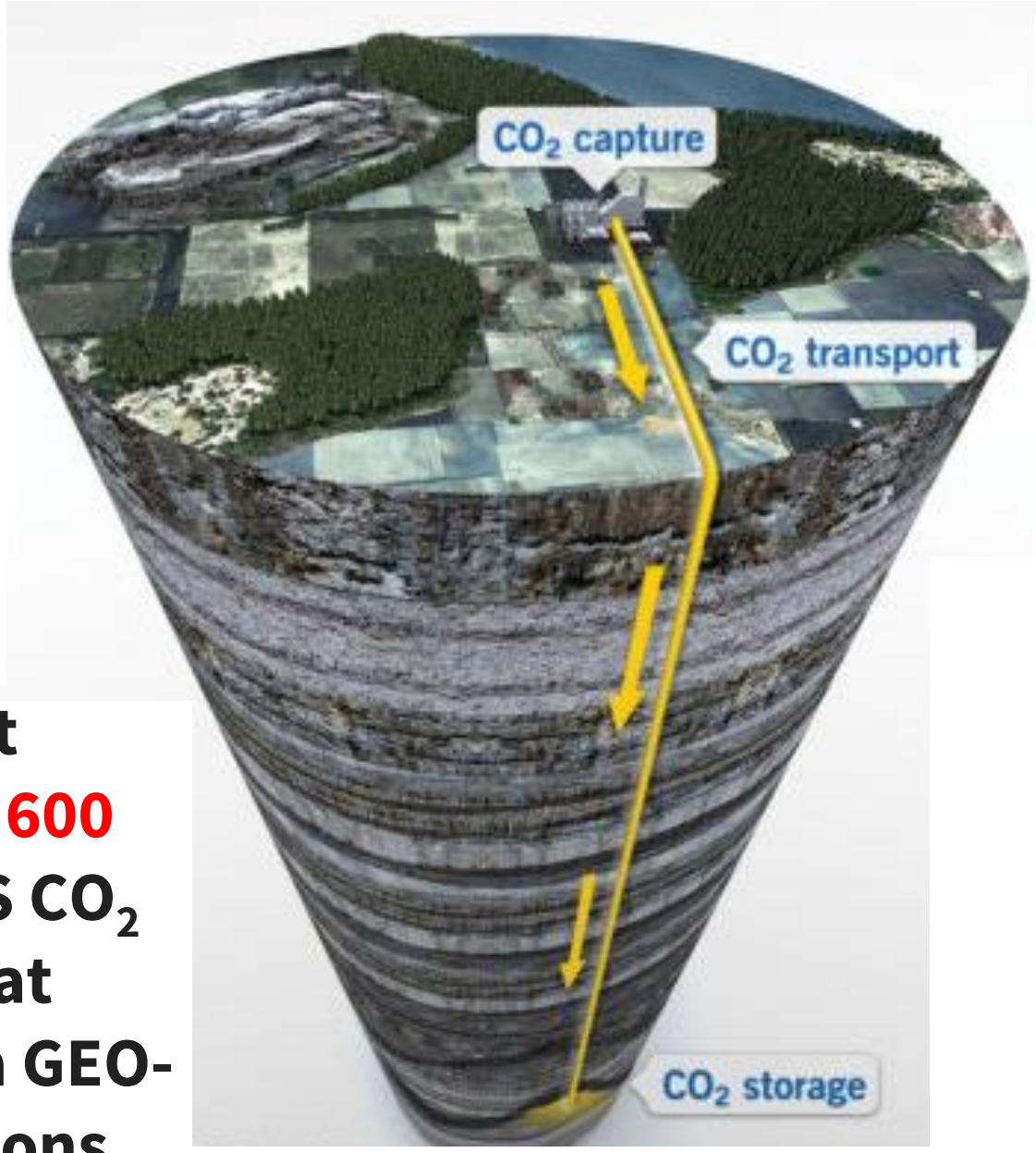
ACCIDENT END RESULT: About four dozen people went to the hospital with no deaths resulting.

SINCE THEN - PHMSA has announced new safety measures to protect Americans from carbon dioxide pipeline failures after the Satartia leak as well as the industry itself.

LETS GET DOWN!: THE CARBON CAPTURE AND STORAGE (CCS) PROCESS

Uses USEPA Classified Class VI Wells

LA NOW HAS PRIMACY

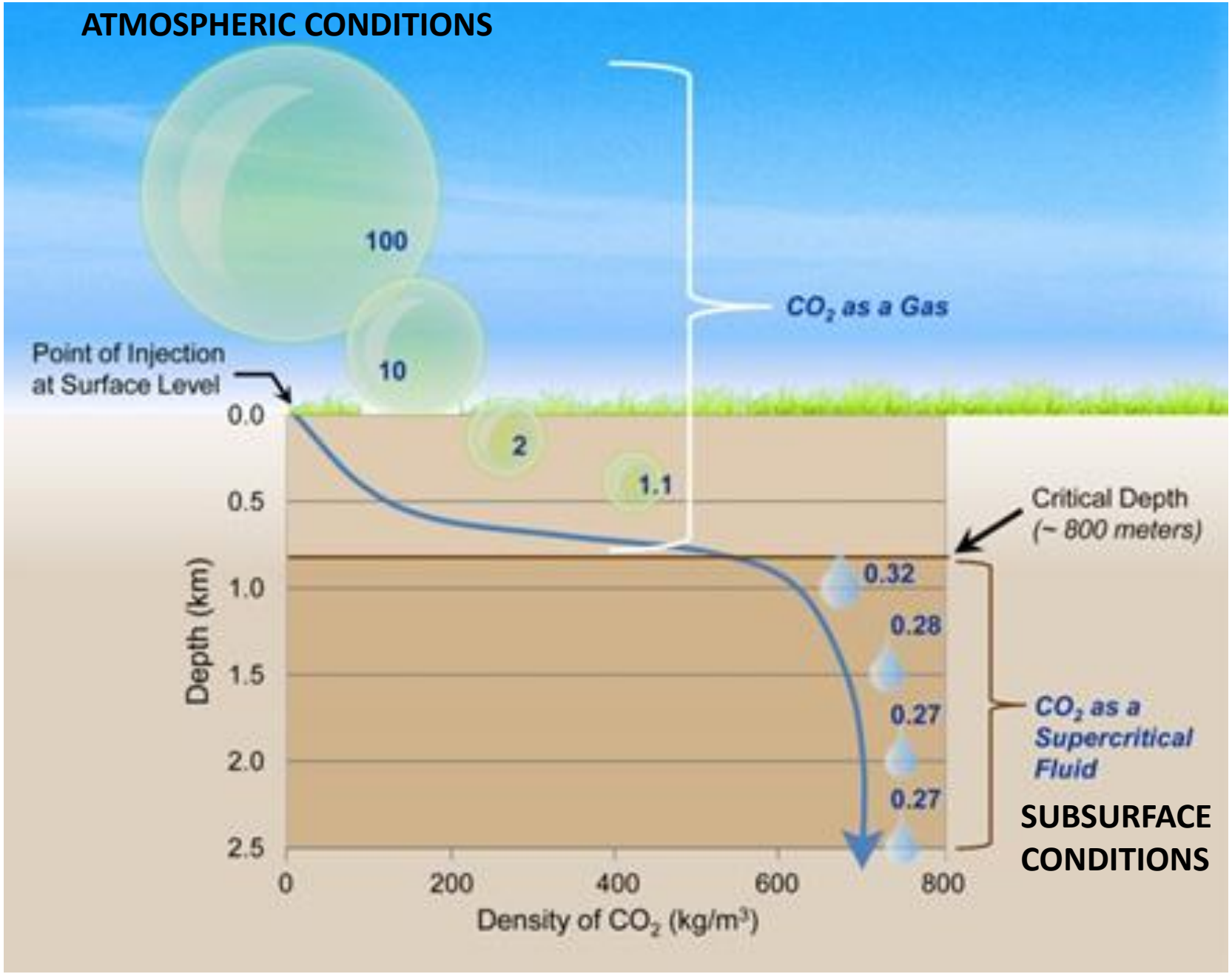


Geologic formations suitable for sequestration include:

1. Depleted oil and gas fields
2. Deep coal seams
3. Enhanced oil recovery (EOR)
4. Oil shale
5. Saline formations

DOE estimates that there is more than 600 years of current US CO_2 plant emissions that could be stored via GEO-CCS in our formations.

Often Getting Down to Depths in the 4,000 ft to 10,000 ft range



NOTE: Figure and info from the US DOE, 2023

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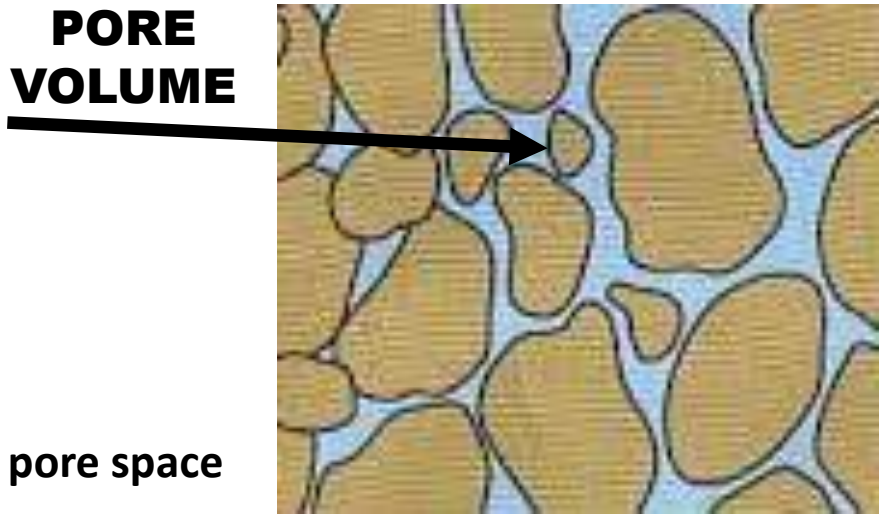
The CO2 is volume-reduced by 99.23% (100 cf goes to 0.23 cf) when going from surface conditions to the injection point conditions.

As a supercritical fluid: The CO2 is dense like a liquid but flows like a gas – making it easier to transport and manage injection pressures). This the results is a dense semi-liquid fluid that moves through porous media like a gas but dense like a liquid.

One ton of supercritical CO2 occupies about 60 cf of volume.

PORE SPACE RIGHTS – TWO MODELS

(Note: Pore Volume = Pore Space)



AMERICAN RULE (Louisiana generally follows this policy):

- **Mineral Servitude (Rights) Holder – Owns the extracted minerals but not the pore space**
- **Surface Owner - Owns the geologic pore space and thus has storage rights.**

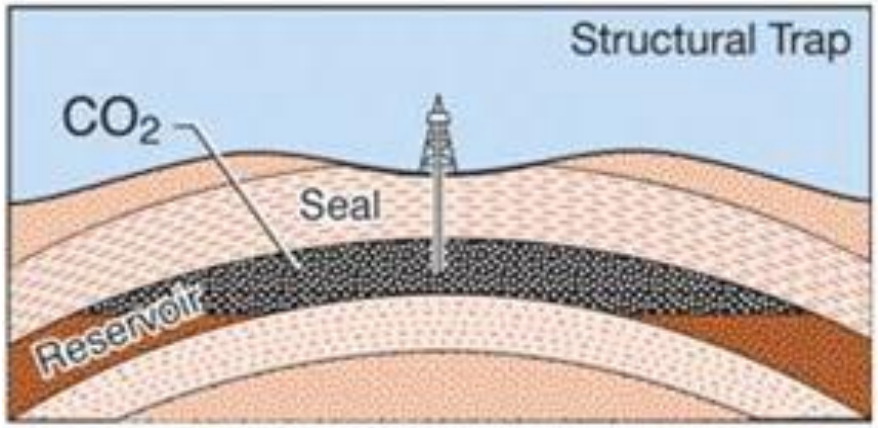
BUT, the pore space rights holder must allow the mineral rights holder access to the minerals/product within the pore spaces (not been challenged in LA).

- **Hence, the pore volume is owned vertically downward following the surface ownership property lines (2D ownership of the bounded 3D pore volume).**

ENGLISH RULE:

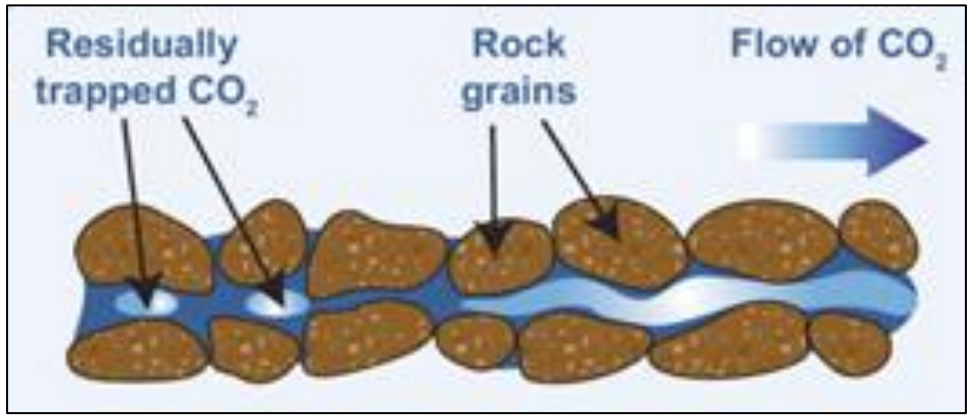
- **The mineral estate (rights) owner owns the natural resources and the pore space (3D).**

PRIMARY CARBON DIOXIDE TRAPPING/SEQUESTRATION MECHANISMS



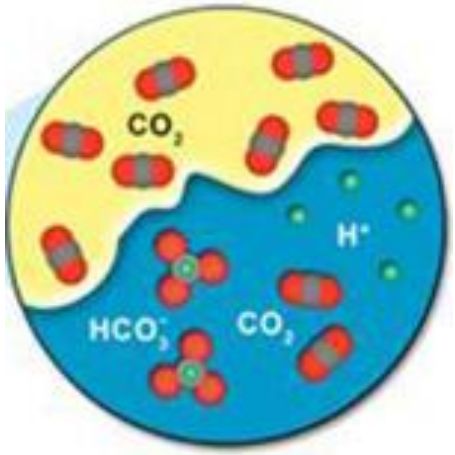
Timing: Instant

Structural Trapping
(MACRO-PHYSICAL MECHANISM)



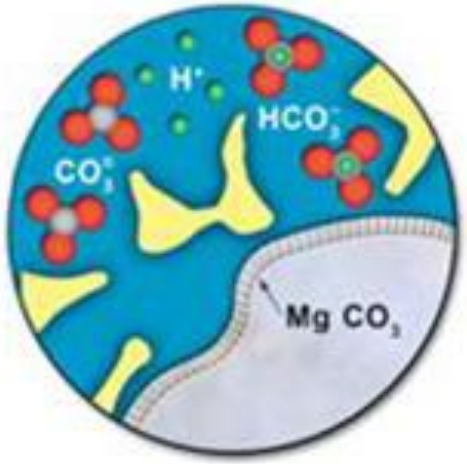
Residual Trapping
(MICRO-PHYSICAL MECHANISM)

Timing: Few Years



Timing: Few Years

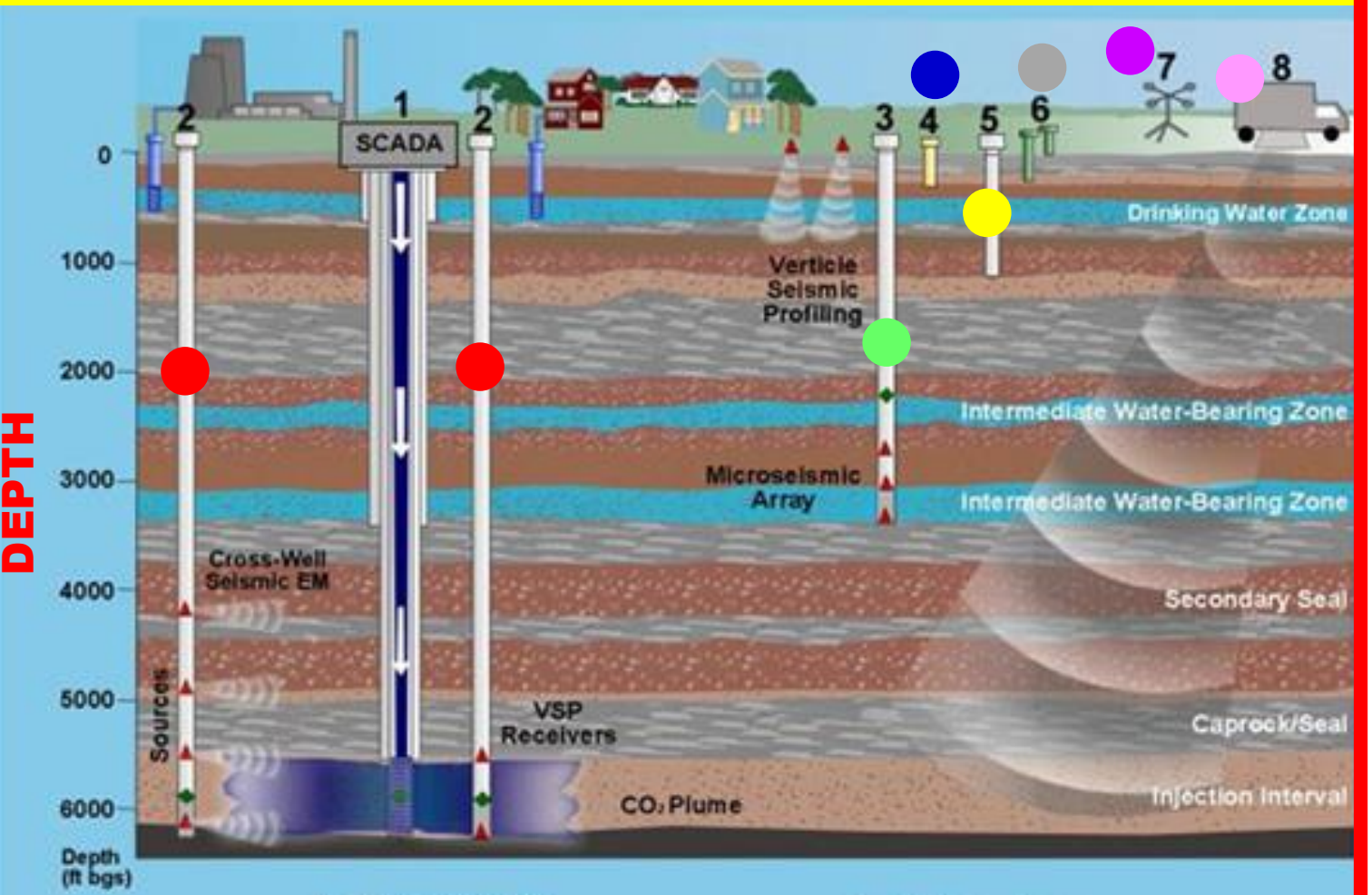
Solubility Trapping
(PHYSICAL/CHEMICAL MECHANISM)



Mineral Trapping
(CHEMICAL MECHANISM)

Timing: Likely Several Years

EXAMPLE CCS INJECTION SITE MONITORING PLAN LAYOUT



PENN STATE U

STORAGE DEPTH EQUALING **6** EMPIRE STATE BUILDINGS

8,724 ft

MONITORING COMPONENTS

- Monitoring Wells (Injection Zone)
- Intermediate Wells (Sentinels)
- Shallow Wells (Drinking Water)
- Contingency Wells (Second Sentinels)
- Soil Gas Sensors
- Surface Air Sensors
- Surface Seismic (3D Subsurface)

Seven Monitoring Strategies Integrated to Ensure Containment and Ecological Protection

US TAX CREDITS TO STIMULATE CCS

STATES THAT CREDIT GOES TO "OWNER" OF CCS SYSTEM

Section 45Q of the U.S. tax code of 2008 and expanded in 2018 & 2022 (IRA) [aka. 45Q Tax Credit]

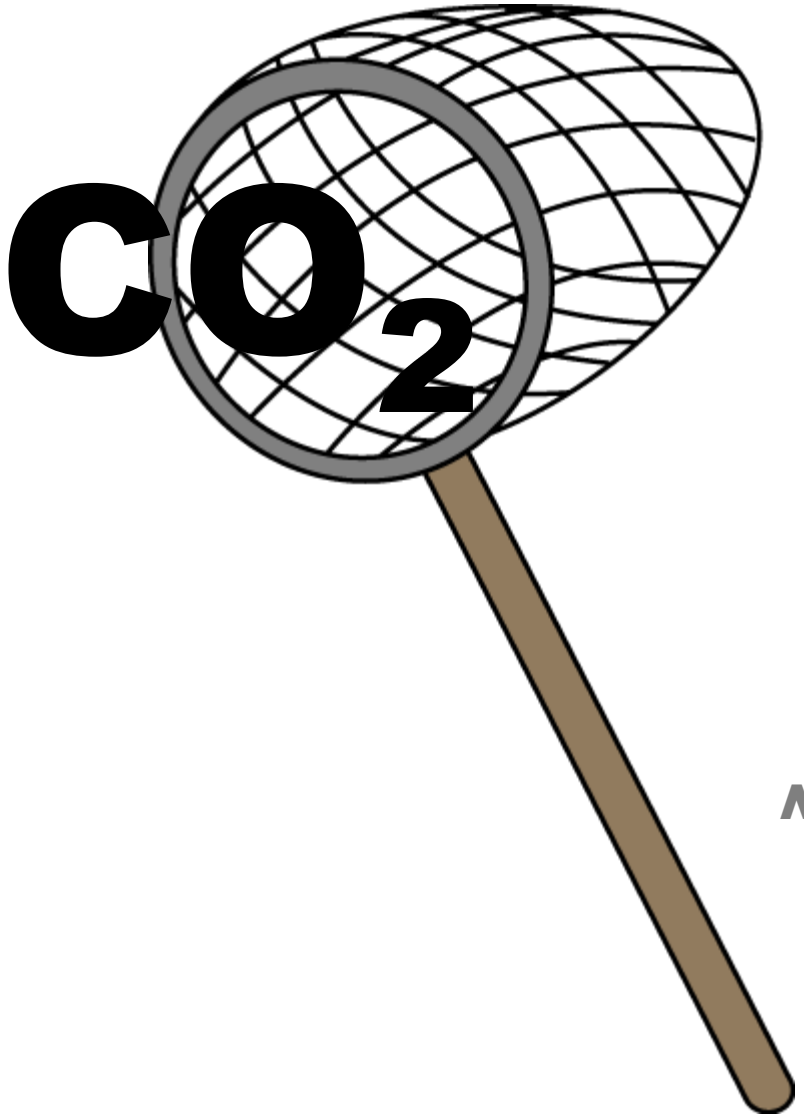
$85/mton CO_2-eq

($160* - $180/mton for Direct Air Capture [DAC])**
($60/mton for Enhanced Oil Recovery [EOR] use)

45Q IS A 12-YEAR TAX CREDIT
MUST START CONSTRUCTION PRIOR TO 2033

ANNUAL MASS LIMITATIONS & SCHEDULING: Power plants must emit more than 18,750 tons per year; industrial facilities must emit more than 12,000 tons per year; and DAC facilities must capture at least 1,000 tons per year.

*Permanently stored **Used carbon



Reported CO2 Capture (CC) Costs:

~30% to ~80% CO_2

Concentrated Stack Gases:

NG Processing Plants, Some Steel Plants, Cement Plants, & Corn Ethanol Plants

$15 to $25/ton

~$20/TON

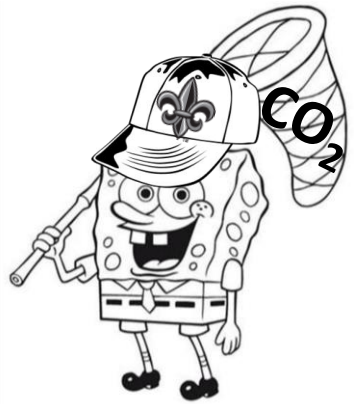
~2% to ~15% CO_2

Dilute Stack Gases:

NG Fired Power Plants, Oil Fired Power Plants, & AI Plants

$40 to $120/ton

~$90/TON



1 + 2 + 3 = CCS TODAY

Individually – Each Step has Over 50 Years of Good Reputation Usage Without Much Public Concern/Issues

1. Carbon Capture: First applied in 1970s (CRS, 2013)

2. Carbon Dioxide Pipeline: First US large-scale was Canyon Reef Line in the 1970s (NETL, 2015)

3. Carbon Dioxide Injection: First US EOR was applied at the Kelly -Snyder field in West Texas in the 1970s (Parker, et al., 2009) – over 13,000 EOR wells & >800 million tons of CO2 injected to date (Global Energy Institute & US Chamber of Commerce)

All Engineered Systems Tend to have Risk

Zappi general assessment of risk for occurrence:

L = Low; M = Medium; & H = High

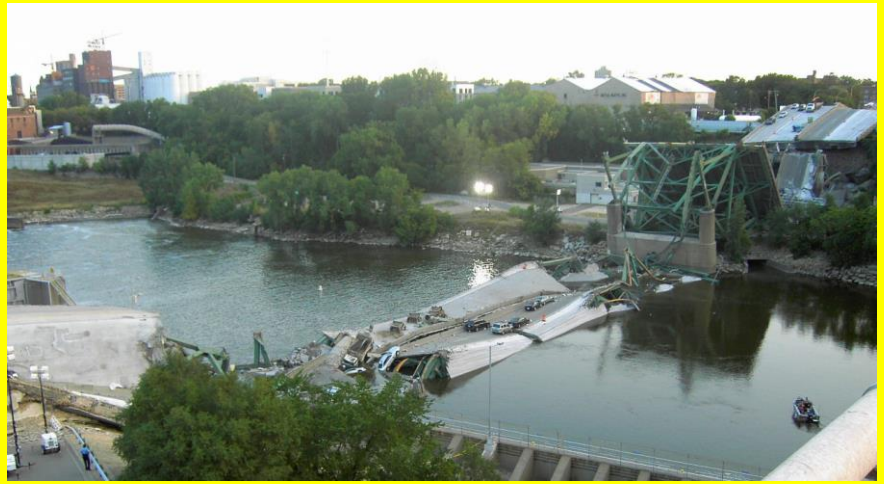
KEY POTENTIAL CCS RISKS:

- **Elevated Costs (L/M)**
- **Pipeline Rupture (L)**
- **Slow Escape of Injected CO_2 (L)**
- **Reservoir Intake Flow or Storage Capacity Reduction (L/M)**
- **Increased Seismic Activity (L)**
- **Rapid loss of Injected CO_2 (L)**
- **Groundwater Contamination (L)**
- **Leaks along well borings (~L)**

Note: All with the assumption that the projects are done correctly

ENGINEERED SYSTEMS HAVE AND WILL FAIL (THANKFULLY – NOT MANY AND NOT OFTEN)
IF NOT PROPERLY DESIGNED, CONSTRUCTED, AND MAINTAINED
-If we do this? No - we must do it right-

New Orleans Hotel Construction Collapse, 2019



Minnesota I-35 Bridge Collapse, 2007

Japan Fukushima Daiichi Nuclear Power Plant Tsunumi Hit, 2011

Lithium Battery Burned Laptop

FOR CCS TO BE EFFECTIVE

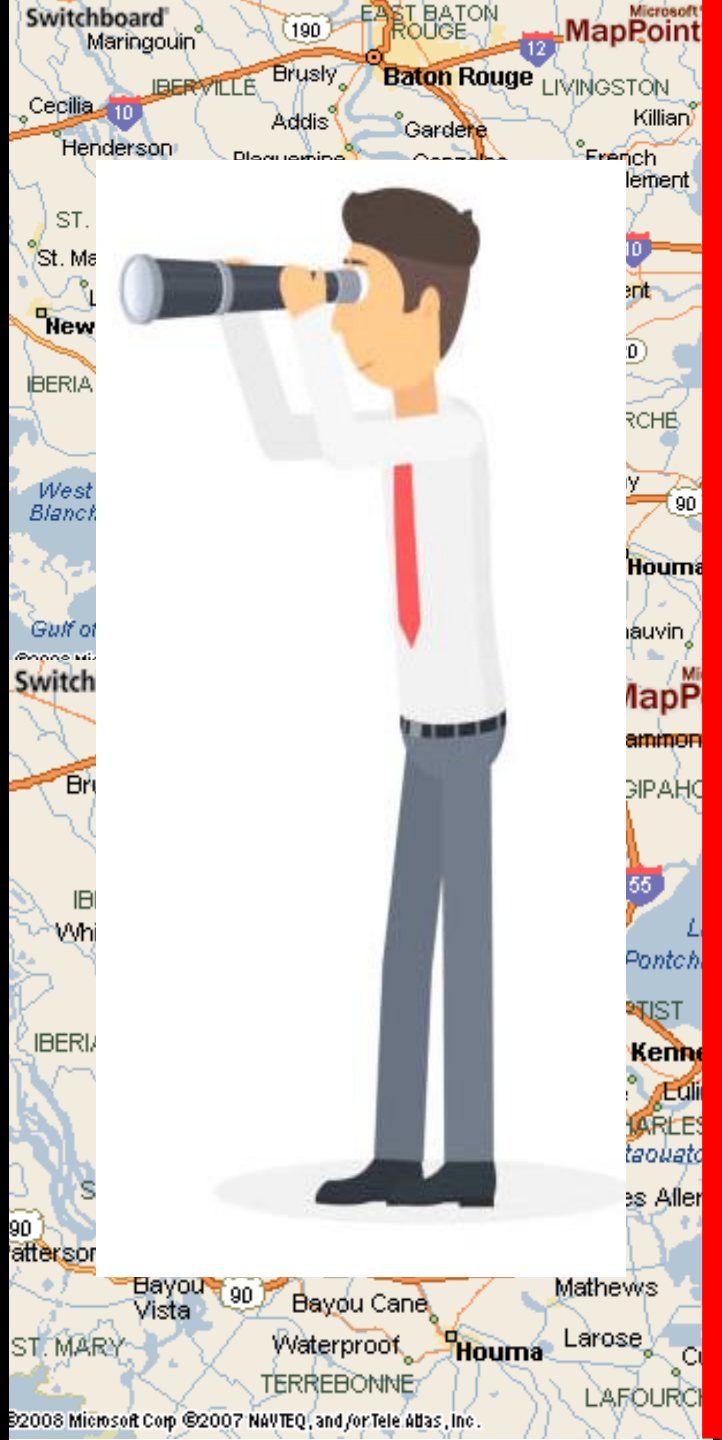
Storage Sites must be:

Well-Selected,

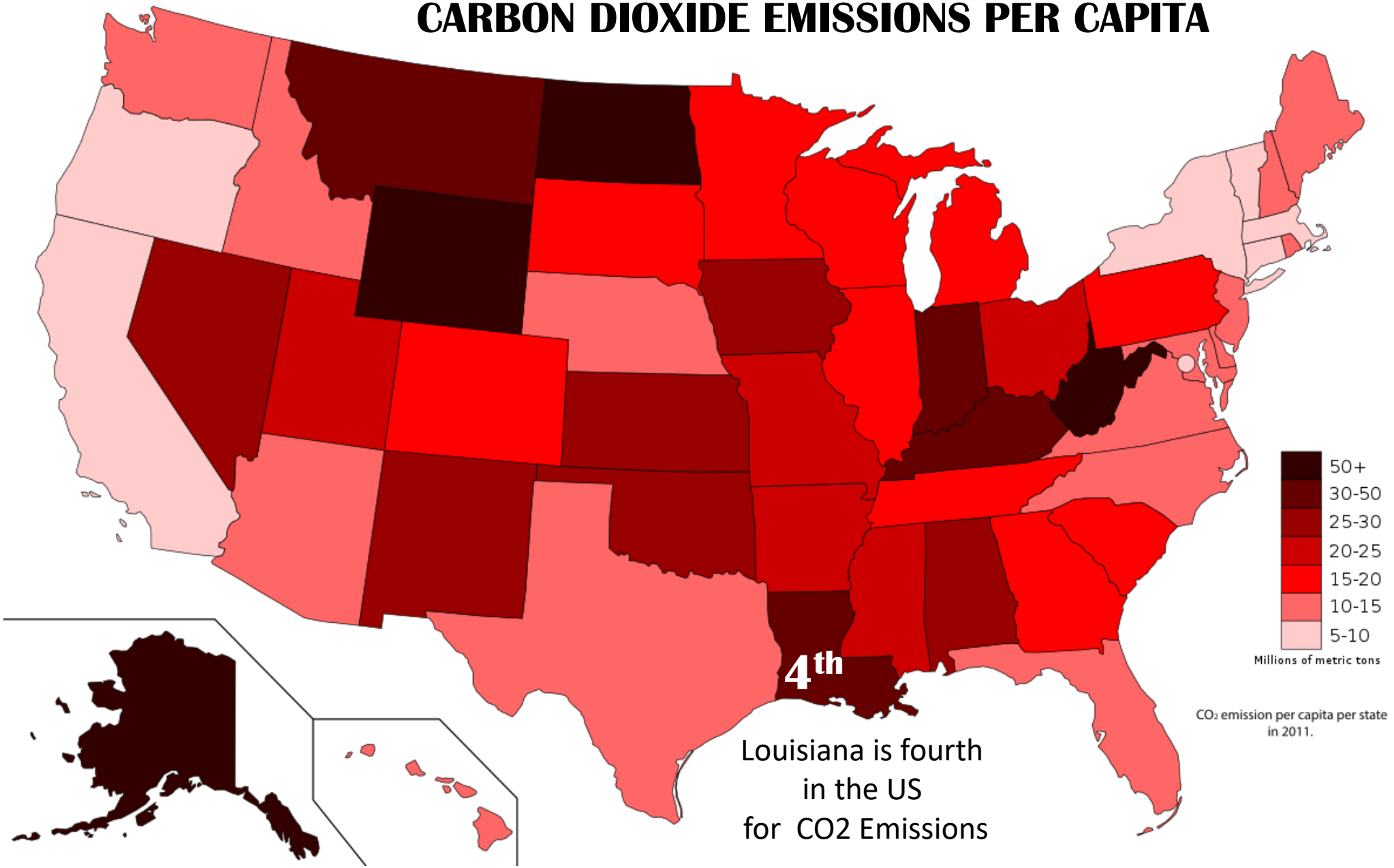
Well-Designed, and

Operated Appropriately.

LOOKING AT OPPORTUITIES FOR LOUISIANA AND CCCS

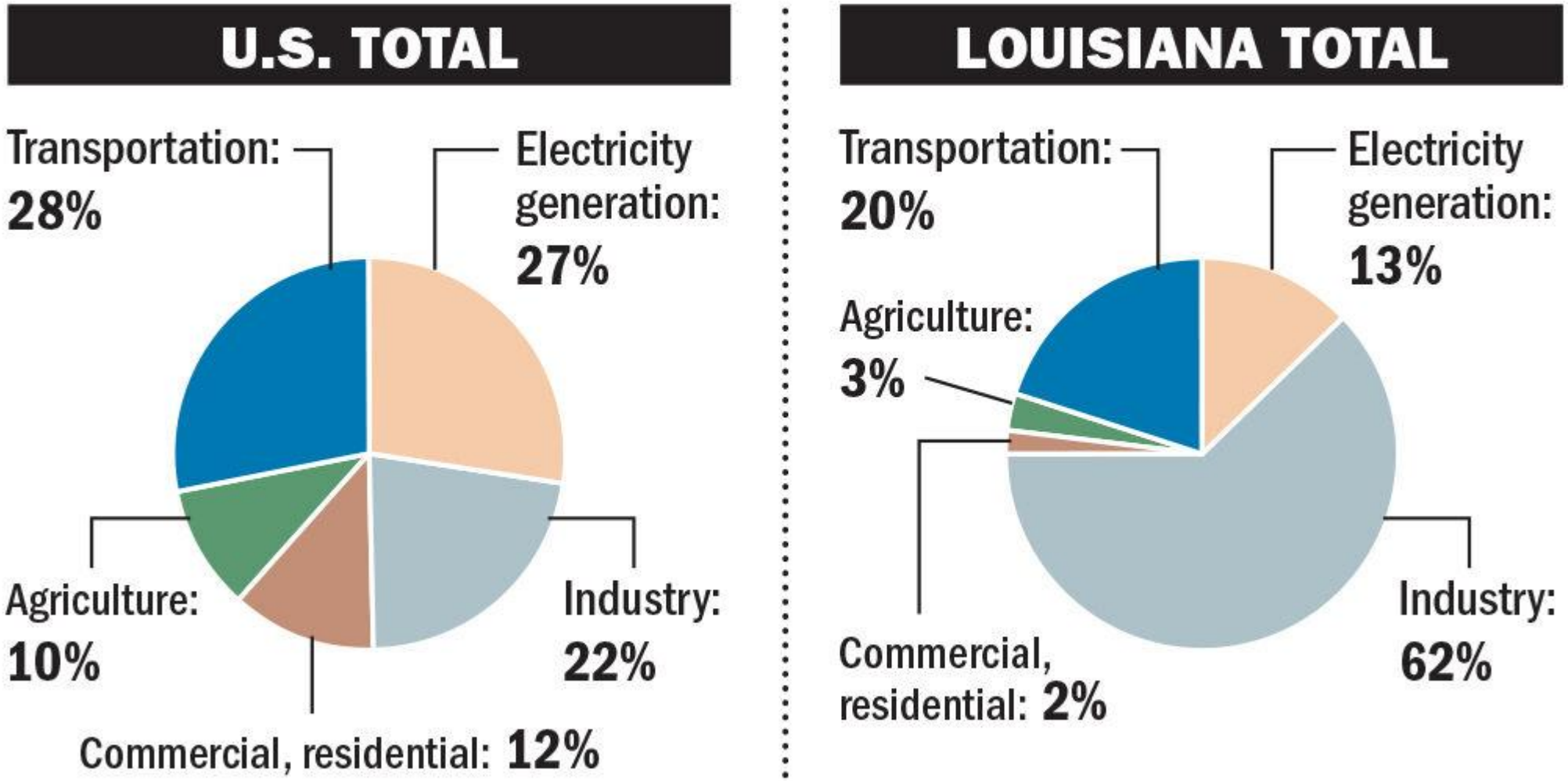


CARBON DIOXIDE EMISSIONS PER CAPITA



Louisiana is fourth
in the US
for CO2 Emissions

Source of greenhouse gas emissions, 2018

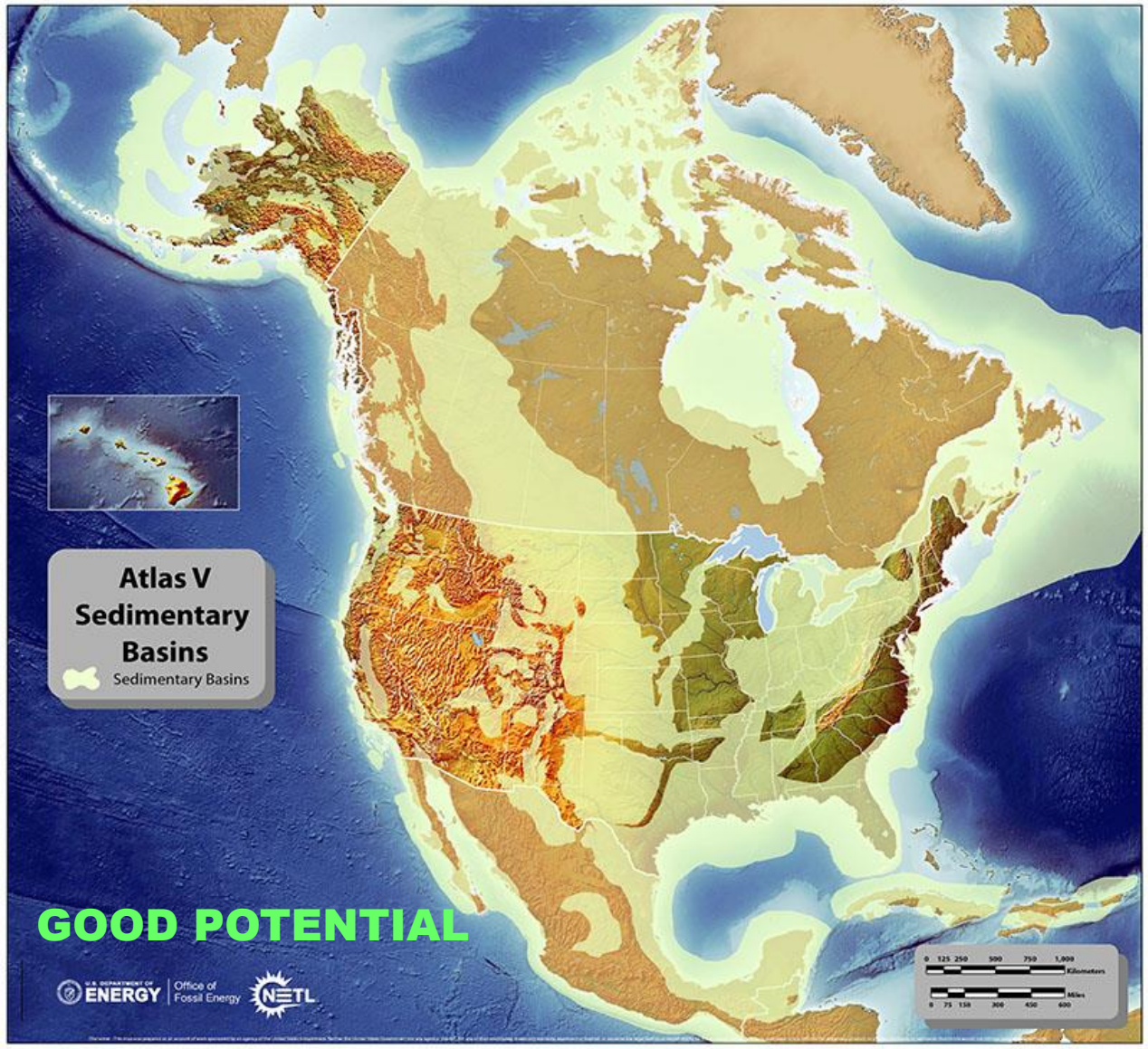


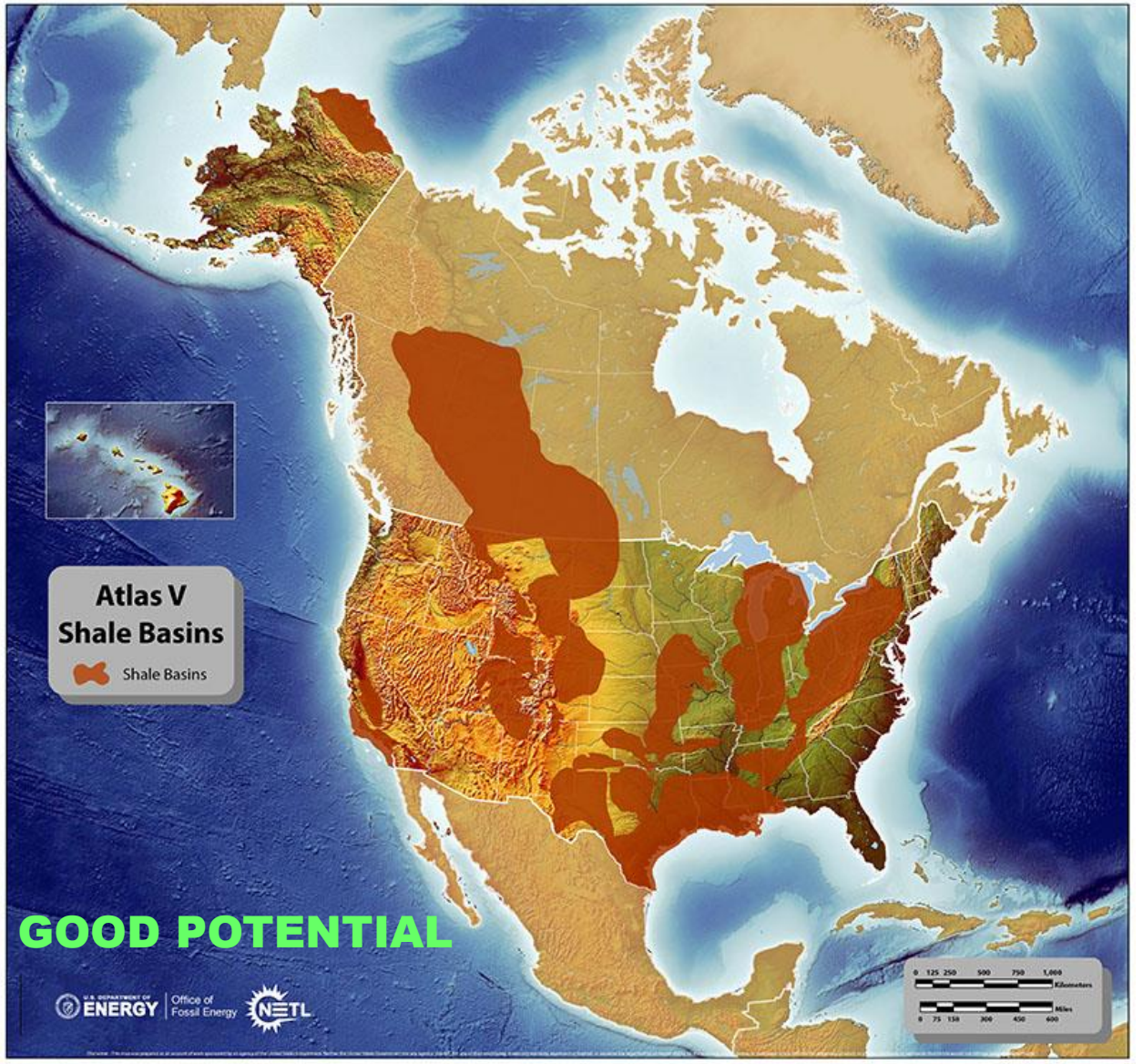
Source: LSU Center for Energy Studies

ACTUALLY FAIRLY CONDUCIVE TO CCS APPLICATIONS

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

US NATIONAL CO2 STORAGE VOLUME ASSESSMENT





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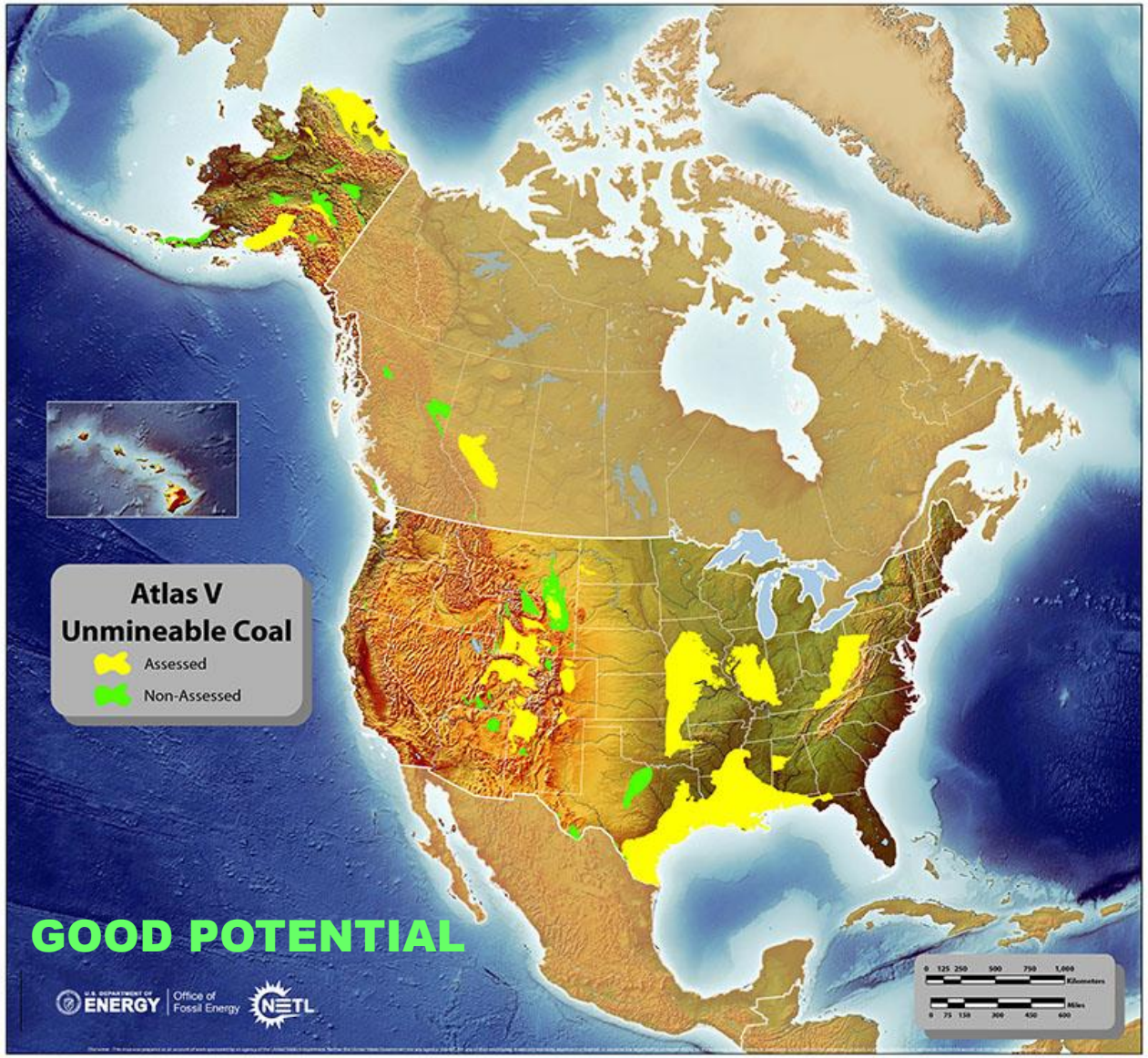
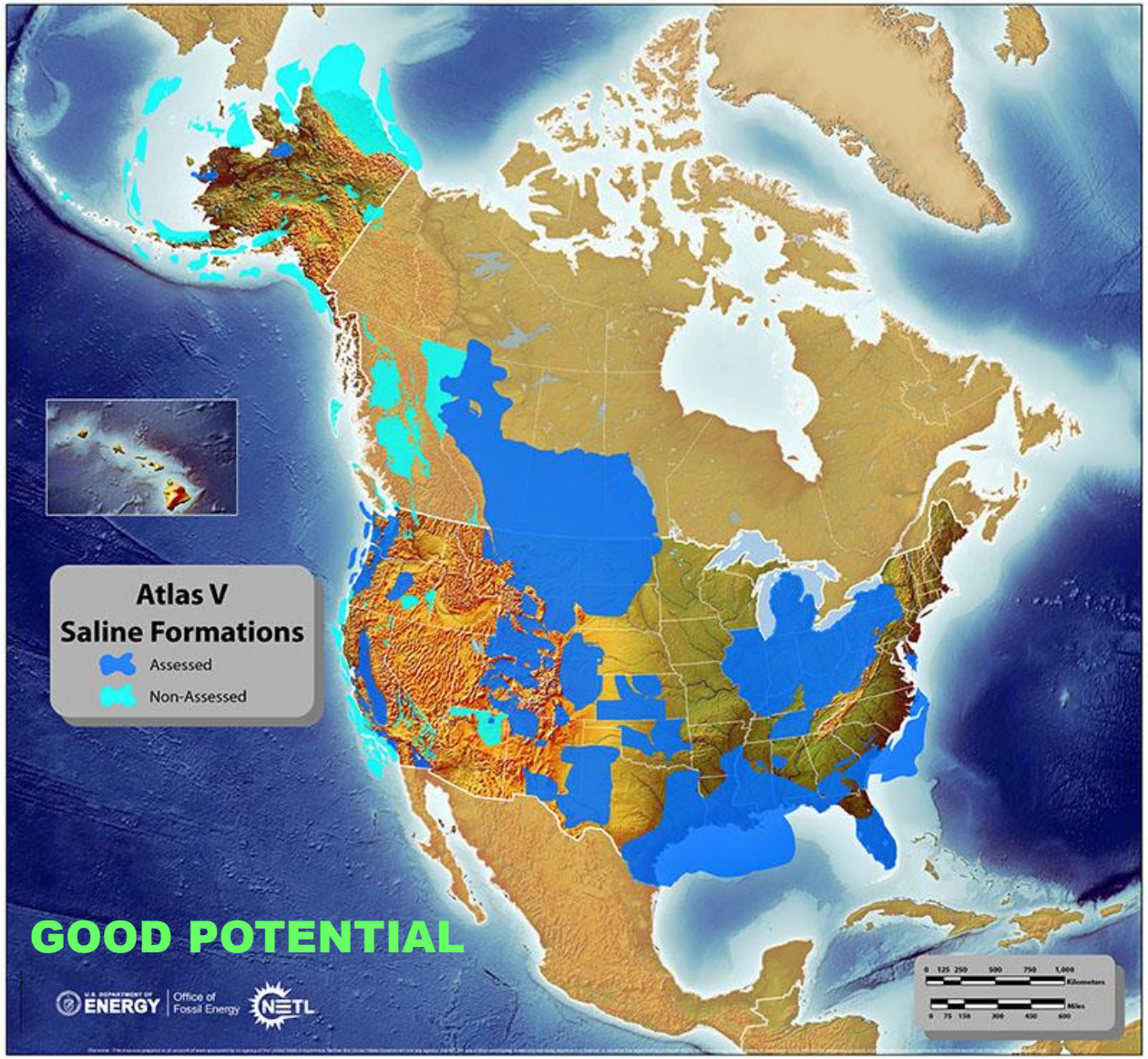
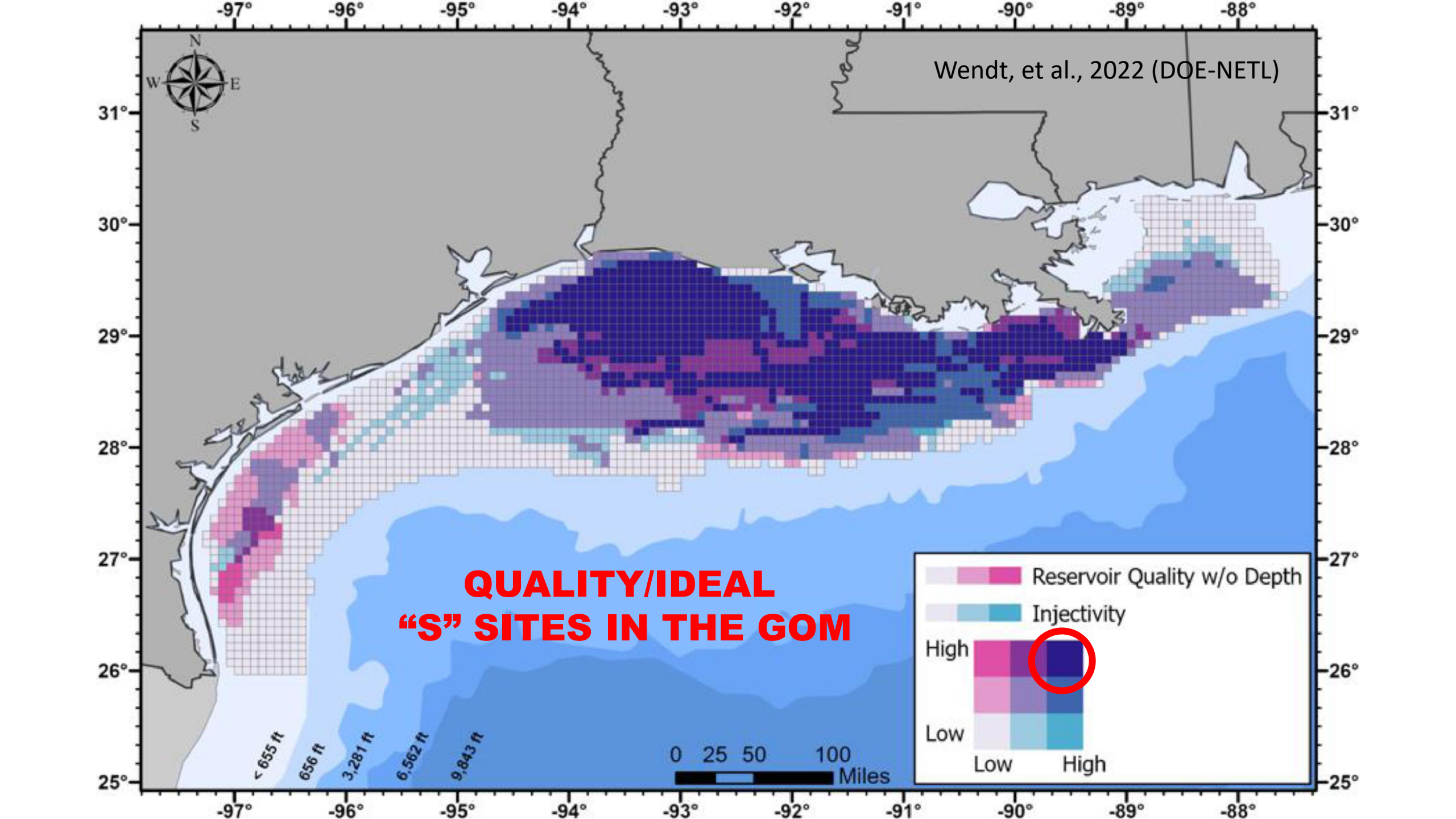
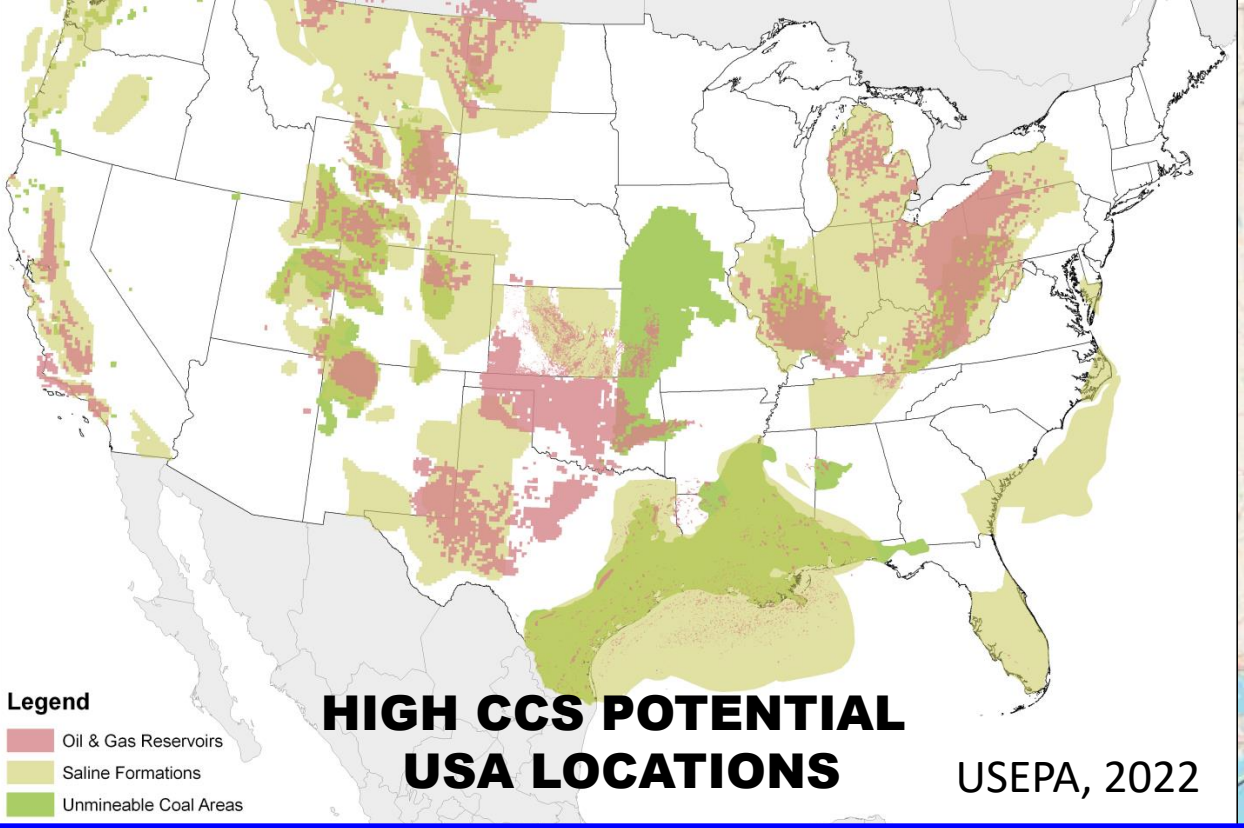
US NATIONAL CO2 STORAGE VOLUME ASSESSMENT



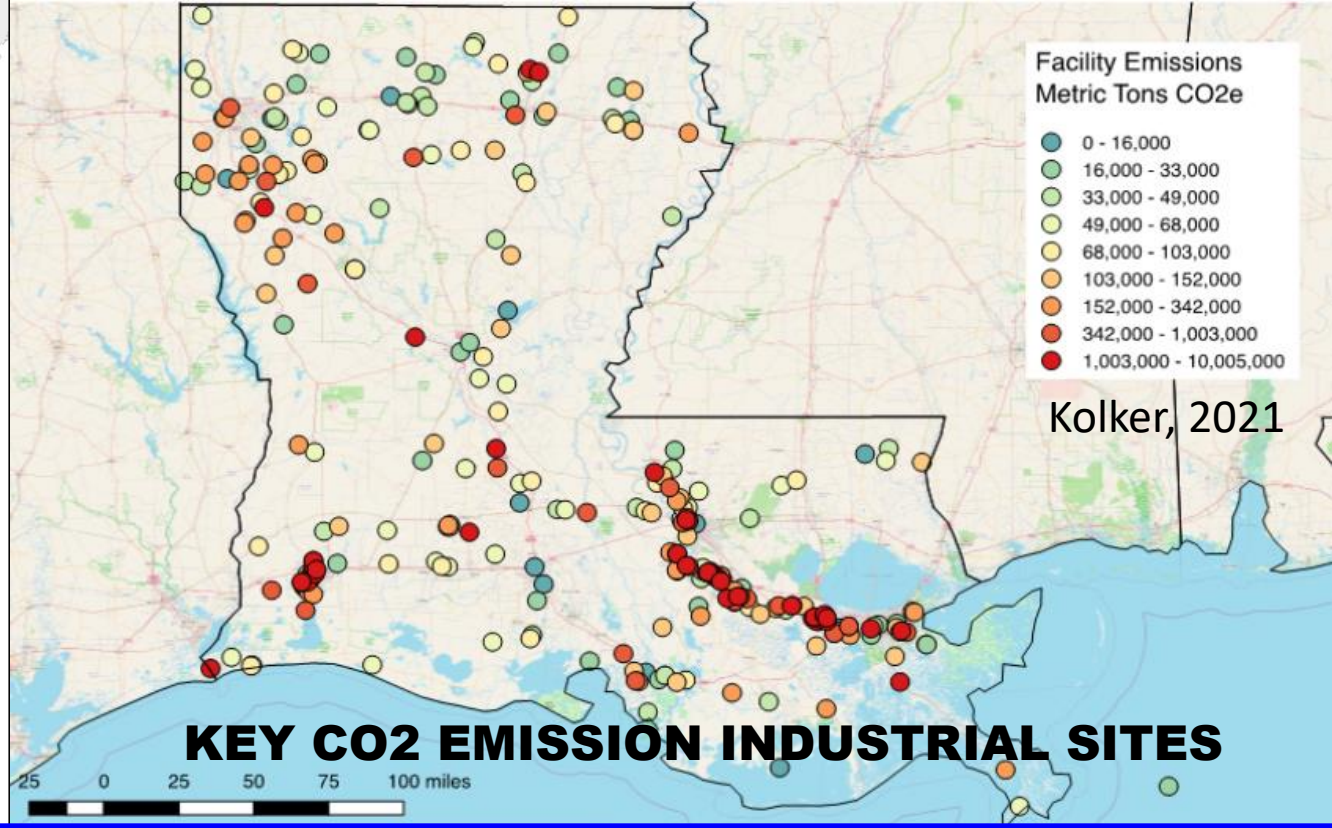



Wendt, et al., 2022 (DOE-NETL)
QUALITY/IDEAL
"S" SITES IN THE GOM
Reservoir Quality w/o Depth
Injectivity
High
Low
Low
High
< 655 ft
656 ft
3,281 ft
6,562 ft
9,843 ft
0 25 50 100
Miles
-97°
-96°
-95°
-94°
-93°
-92°
-91°
-90°
-89°
-88°
31°
30°
29°
28°
27°
26°
25°



HIGH CCS POTENTIAL USA LOCATIONS

USEPA, 2022



KEY CO2 EMISSION INDUSTRIAL SITES

Kolker, 2021

A NEW DECISIONAL FACTOR FOR ECONOMIC DEVELOPMENT CONSIDERATIONS?

Plant locations reasonably near high-capacity geological CO2 storage zones

QUESTIONS?
COMMENTS?

ENERGY INSTITUTE
OF LOUISIANA
UNIVERSITY OF LOUISIANA AT LAFAYETTE