Thursday, July 8, 2021

Watts Up With That?

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CARBON SEQUESTRATION

Energy Transition: Blue Oil Edition

1 week ago David Middleton 112 Comments

Guest “Responding to a reader request” by David Middleton

Hat tip to Mike Higton for requesting a deeper dive into “Blue Oil”

Mike was referring to this post of mine from May 18, 2021:

“Courts, customers and Wall Street delivered rebukes to Exxon Mobil, Chevron and Shell”… Oh my!

In that post, I quoted a statement from Denbury, one of the industry leaders in CO_2 enhanced oil recovery (EOR)…

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> *Chris Kendall, Denbury's President and CEO, commented, "We are thrilled to continue progress on our Cedar Creek Anticline EOR project in 2021. This will be one of the largest EOR projects ever undertaken in the United States, using 100% industrial-sourced CO_2 to recover over 400 million barrels of oil.* ***Additionally, the oil produced will be Scope 3 carbon negative, as the amount of industrial-sourced CO_2 that will be permanently injected to produce each barrel of oil will be greater than the combined emissions associated with the development and operation of the field, including the refining and combustion of the finished petroleum products. We believe that this carbon negative oil, which we have labeled "blue oil," will ultimately be a preferred commodity as it assists end users in reducing their own carbon footprint.*** *Today, approximately 20% of Denbury's production is blue oil, and we expect that proportion to increase to 25% once the Beaver Creek and Big Sand Draw acquisition closes in March. We are committed to increasing the proportion of industrial-sourced CO_2 used in our EOR operations, with the objective of reaching an overall Company Scope 3 carbon negative position by the end of this decade.*
>
> *"We are also extremely excited about the great potential we see for Denbury to lead in the emerging CCUS industry. Denbury's extensive, highly reliable, high-capacity CO_2 transmission infrastructure is perfectly located in the heart of the Gulf Coast industrial corridor, with significant available capacity and expansion potential. With the final rules on the IRS 45Q tax credit issued in mid-January, the stage is now set for a new era of carbon capture, and we believe that multiple new capture projects could be sanctioned beginning this year. Coupled with over twenty years of experience in designing, building, and operating CO_2 transportation, processing, and injection systems, we believe that Denbury is in a strong position to make a significant impact in this emerging and important industry.*
>
> *"Going forward, we will continue our fundamental focus on safety and operational excellence. As underscored by our decision to move forward with the [Cedar Creek Anticline] EOR development, we will continue to invest in EOR operations, while positioning the Company to be a leader in what we believe will be a high value, high growth CCUS business. We believe that Denbury's strategic focus and asset base uniquely position us for strong performance through the energy transition."*
>
> Denbury

- CCS: Carbon capture & storage
- CCUS: Carbon capture, utilization & storage
- EOR: Enhanced oil recovery.

Mike's specific question had to do with whether or not CO_2 EOR could actually make US crude oil production "carbon negative." I don't think CO_2 EOR on its own could accomplish this; however, if coupled with straight up geologic sequestration, I think the US could possibly go full "Blue Oil."

Before we get to numbers, let's look into the derivation of "Blue Oil."

The Colors of Crude Oil

Crude oil comes out of the ground in many colors, from amber to black and occasionally a little greenish.

Color variations of a crude oil column from a single connected reservoir. Courtesy D. McKinney, H. Elshahawi, Shell Oil Co. (ResearchGate)

Oil shows on mud logs usually exhibit a yellow or gold fluorescence.

> *Fluorescence can be an extremely sensitive indicator of the presence of hydrocarbons in drill cuttings. Sample fluorescence is evaluated in terms of color (ranging from brown to green, gold, blue, yellow or white), intensity and distribution. Fluorescence color may indicate oil gravity; dark colors are suggestive of low API gravity heavy oils, and light colors indicate high API gravity light oils. Following application of a solvent on the samples, hydrocarbon fluorescence will appear to flow and diffuse into the solvent as the oil dissolves. This diffusion is known as cut fluorescence, or more commonly just cut. Under UV light, hydrocarbons may be seen to stream from the rock pores into the surrounding solvent, turning the solvent cloudy.*
>
> Schlumberger

Blue fluorescence is generally due to the fluid being either oil-based drilling mud or gas condensate.

On maps, well logs and cross-sections, oil is usually colored green, gas is colored red and water is colored blue.

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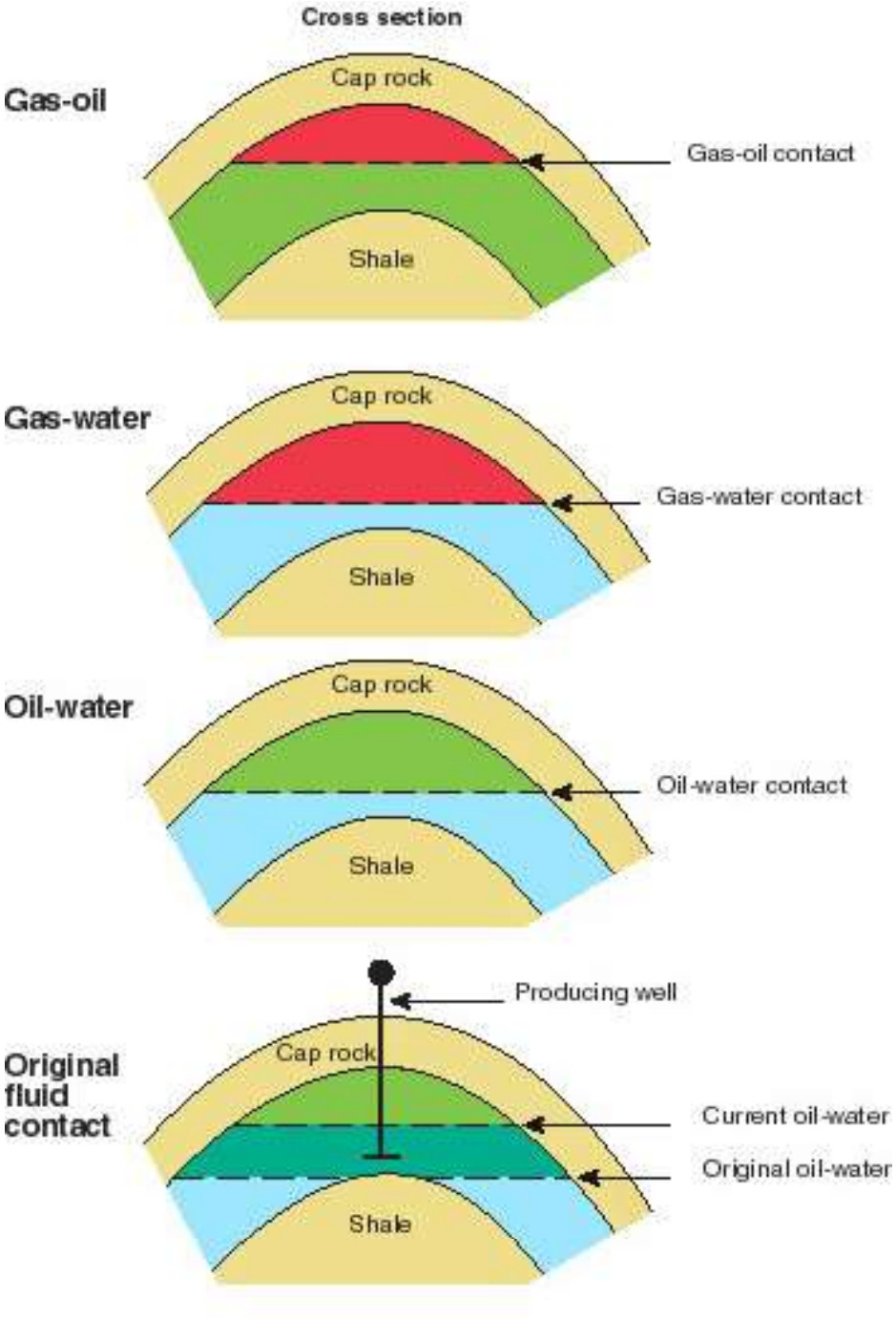

Fluid contacts. Schlumberger Oilfield Glossary

To the best of my knowledge, Denbury is the only company currently using the phrase “blue oil”… But I think I know how it was derived.

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> *Cracking the hydrogen colour code*
>
> *Although there is no universal naming convention for hydrogen, almost everyone can agree on the fact that the majority of today's H_2 production is either green, blue or grey. Let's start with the most beautiful part of the hydrogen rainbow:*
>
> *Green hydrogen, simply put, is hydrogen made with renewable electricity via electrolysis. We believe it's the oil of the 21st century and the only way to decarbonise society's liquid and gaseous fuel needs. Electrolysers use an electrochemical reaction to split water into its components of hydrogen and oxygen, emitting zero carbon dioxide in the process. Water electrolysis has been widely used since the 1920s, first with alkaline technology (TA) hydrolysers, followed in the 1960s by proton exchange membrane (PEM) systems, and now, our highly-efficient anion exchange membrane (AEM) electrolysers. Green hydrogen currently makes up less than 1% of overall hydrogen production, but we're planning to help change that very soon with scaled-up production of our game-changing AEM technology.*
>
> ***Blue hydrogen is produced mainly from natural gas using a process called steam reforming, which brings together natural gas and heated water in the form of steam. The output is hydrogen and carbon dioxide, with the latter then caught through industrial Carbon Capture, Utilisation and Storage (CCUS) projects. CCUS projects seek to make blue hydrogen production climate-neutral by moving the captured CO_2 to underground cavities like spent gas and oil reservoirs or finding industrial uses for the captured gas. However, blue hydrogen can perhaps be better described as 'low-CO_2 hydrogen' as the steam reforming process doesn't actually avoid the creation of greenhouse gases.***
>
> *Grey hydrogen is essentially any hydrogen created from fossil fuels without capturing the greenhouse gases made in the process. This is where things start to get a bit more complicated — depending on the hydrocarbon used and how much carbon dioxide it releases, it can also be known as brown hydrogen or black hydrogen. If it's made from lignite (brown coal), it's most likely brown hydrogen, and black hydrogen if it comes from black coal, although some people call any hydrogen made from fossil fuels either black or brown hydrogen. Hydrogen has been made from coal through the process of 'gasification' for more than 200 years. Grey hydrogen from steam reformed natural gas without CCUS accounts for around 71% of all hydrogen production today, while coal gasification makes up the majority of the rest.*
>
> Enapter

"Blue Oil" is what is referred to as "carbon-negative" oil, an apparent oxymoron. Crude oil is loaded with carbon compounds… It's a mixture of complex hydrocarbons. However, Denbury's niche in the oil industry is CO_2 enhanced oil recovery (EOR) and it appears that when the CO_2 comes from industrial sources, the total volume of CO_2 injected can exceed "the combined emissions associated with the development and operation of the field, including the refining and combustion of the finished petroleum products." Since the net CO_2 emissions are negative, it is referred to as "carbon-negative," hence the sobriquet "blue oil."

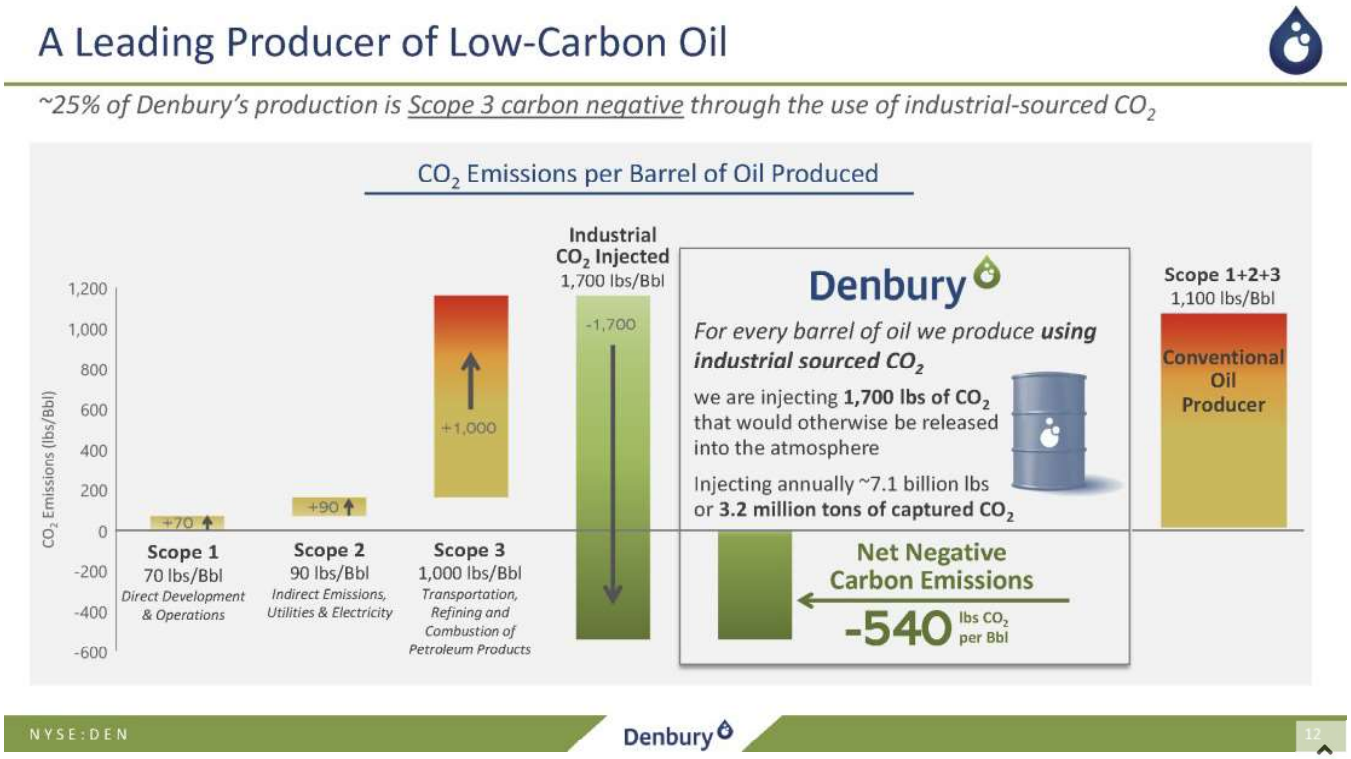

Figure 1. "Carbon-negative" oil. (Denbury)

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If Denbury's numbers are accurate, about 25% of their production is "blue oil."

CO_2 and other "greenhouse gas" emissions are categorized into three scopes:

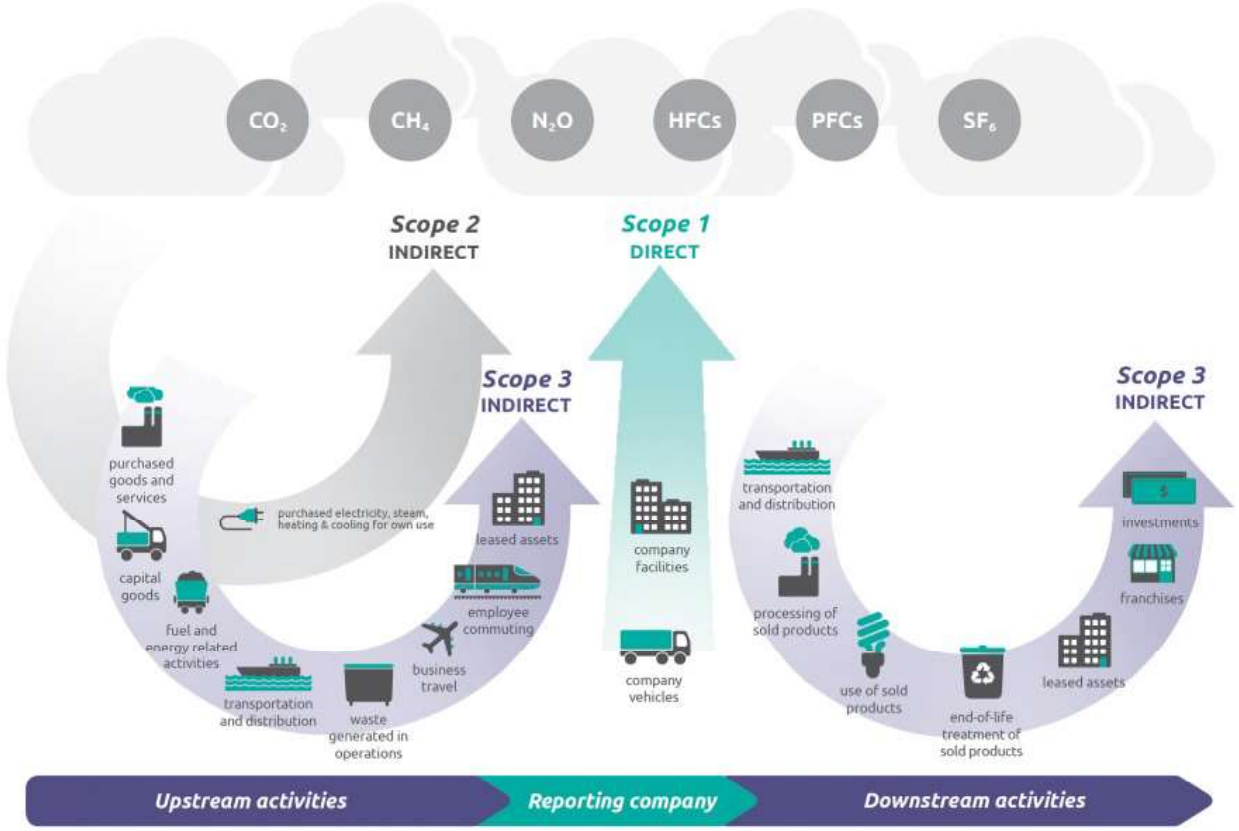

Figure 2. GHG emissions scopes. (EPA)

In the case of oil production, Scopes 1 & 2 are the direct and indirect emissions from exploration and production (E&P) operations. Scope 3 includes the emissions from refining, transportation and ultimate consumption of the finished product. Needless to say, Scope 3 emissions are very difficult to estimate. Denbury's estimate of 1,100 lbs/bbl is not unreasonable; however the plus/minus is probably very large.

1,100 lbs/bbl ~ 0.5 tonnes of CO_2 per barrel of oil. US oil production is currently around 12 million bbl/d. For US crude oil production to be "carbon-neutral," the US would have to sequester about 6 million tonnes of CO_2 per day. It would be awesome if that could all be done through enhanced oil recovery (EOR). Unfortunately, there probably aren't enough economically viable EOR candidates, even with the $35/tonne 45Q tax credit. About 350,000 bbl/d of current US crude oil production employs CO_2 EOR. Even if this was tripled, it would only amount to a little over 1/12 of US production. However, there is a lot more pore space in the subsurface than there is in producing and/or depleted oil & gas reservoirs.

Saline aquifers

> *Saline aquifer formations: Saline aquifer formations represent the best salted sink for storage of CO_2 among all geological options due to their enormous storage capacity (Grobe et al. 2009). Recently, estimates of the order of 103 Gt CO_2 have been made for the Alberta deep saline basin by accounting for the solubility trapping mechanism (Bachu and Adams 2003). Another example is the injection of the produced CO_2 into the Utsira aquifer in the North Sea (Korbøl and Kaddour 1995; Torp and Gale 2004). It is required that the aquifer be saline because this already makes it unsuitable for industrial, agricultural and human purposes (Aydin et al. 2010; Metz et al. 2005).*
>
> Ajayi et al., 2019

Assuming that the Scope 1, 2 & 3 CO_2 emissions for US oil production are 1,100 lbs/bbl, the annual emissions would be:

Scope 1, 2 & 3 Emissions		
1,100	lbs/bbl	
0.50	tonnes/bbl	

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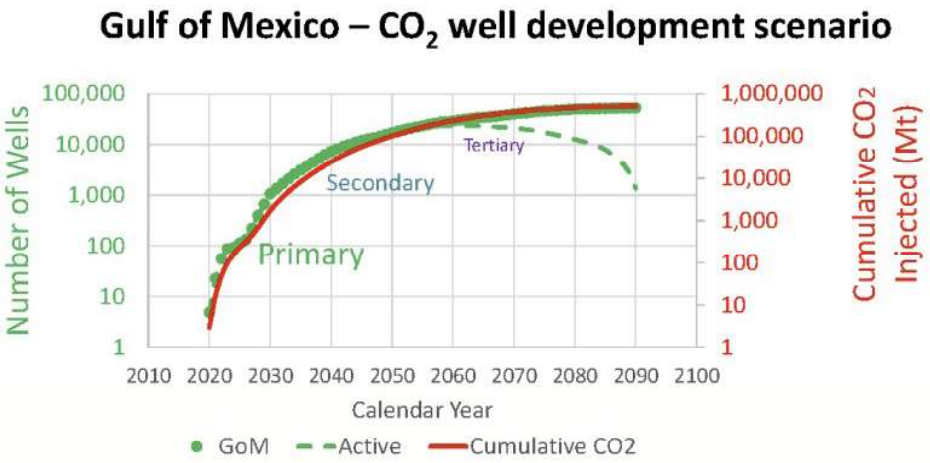
5.99	Mt/d	Megatonnes per day
2,185	Mta	Megatonnes per anum

Could the US oil industry reach the point where we were injecting 2,185 Mta of CO_2 into saline aquifers? If industry drilled CO_2 injection wells in the Gulf of Mexico at a comparable rate to how we drilled oil & gas wells in the first place, within 30 years, we could be injecting 7,000 to 10,305 Mta.



2020+ SCENARIO	Avg. Well Inj. Rate Mt/yr	Number of active wells in 2050	Incremental Rate in 2050 Mt/yr	Cumulative Mass in 2050 Mt CO2	Comment
GoM	0.6	17,175	10,305	99,946	Unlikely one region will develop this aggressively; Incremental goal exceeded; Close to cumulative goal
GoM	0.41	17,175	7,000	67,891	Injection rate low, not cost effective; Cumulative goal not met

15

Figure 3. Gulf of Mexico CO_2 development scenario. (Meckel, Treviño & Hovorka, 2019)

That's 31-46 years worth of current Scope 1, 2 & 3 emissions… just in the Gulf of Mexico… Under a development scenario that has already been accomplished. The CO_2 storage capacity in the Gulf of Mexico is fracking YUGE. The Bureau of Economic Geology at the University of Texas estimates that the storage capacity just in Texas state offshore waters is 172 Gt (172,000 Mt).

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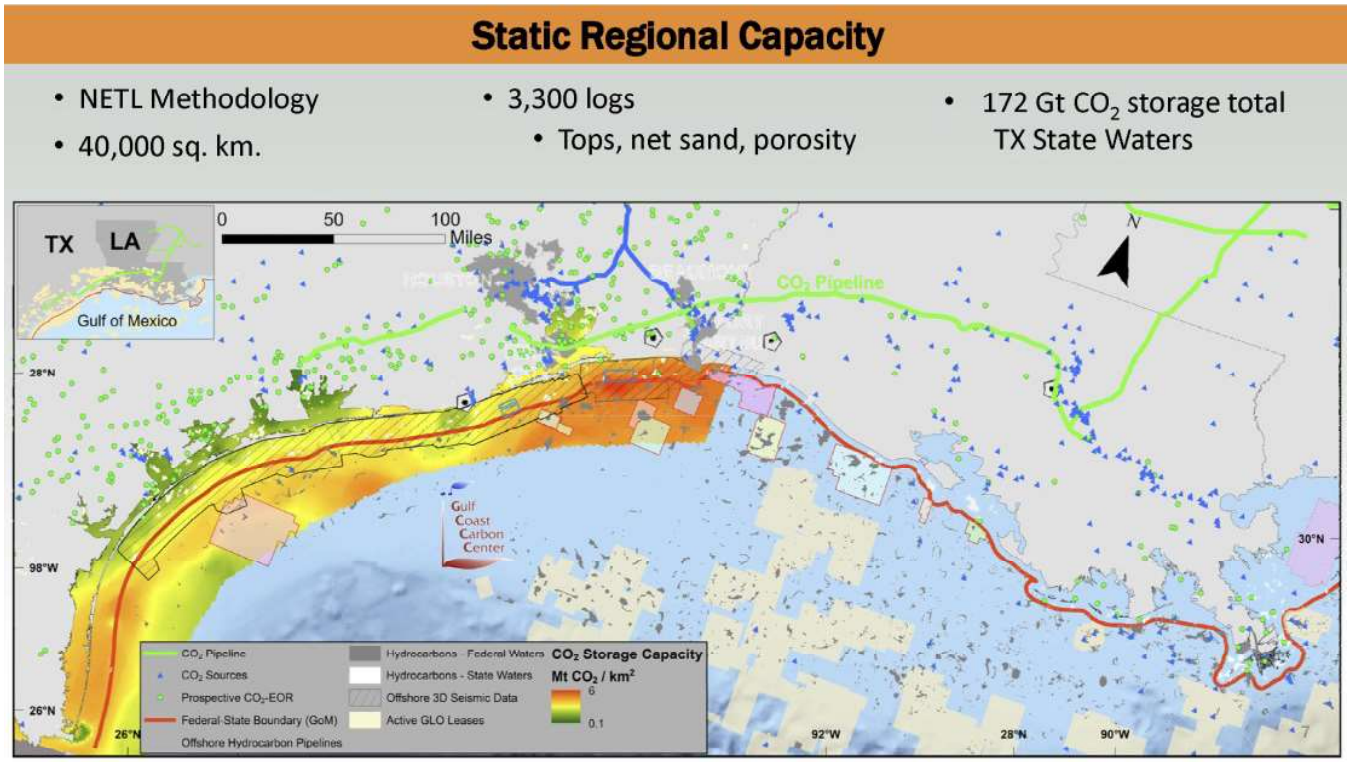

Figure 4. Texas state waters CO_2 storage capacity. (Meckel, Treviño & Hovorka, 2019)

As mentioned in the previous post, the States of Louisiana and Texas are already seeking bids for CO_2 sequestration (CCS) projects in State waters and onshore State leases.

> *In September 2020, the Texas GLO received approval to begin the lease development process for CO_2 storage projects off Jefferson County (southeastern Texas). In April 2021, the GLO formally opened a RFP process for applications for lease development16 . These recent developments have initiated CO_2 storage hub development in the Port Arthur region (Fig. 4). In addition, large corporations have made significant announcements intending to develop the greater Houston area into a low-carbon hub, with perhaps as much as 100 Mta CCS anticipated in the future. Other regions now considering similar hub development include Lake Charles, LA, Corpus Christi, TX, and Brownsville, TX.*
>
> Meckel, Bump, Hovorka & Trevino, 2021

Texas Governor Greg Abbott recently signed into law bipartisan legislation giving the Texas Railroad Commission "sole jurisdiction over Class VI Injection Wells and carbon capture, use, and sequestration ("CCUS") activities in Texas" (regulatory primacy). Louisiana did the same about a year before Texas. By the time industry is ready to start drilling CO_2 injection wells, the EPA will be cut out of the regulatory loop, with the Texas Railroad Commission and Louisiana Department of Natural Resources having UIC Class VI primacy.

Whether you like it or not, this is already happening.

On the notion of an "Energy Transition"

This is how S&P Global defines "energy transition":

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