Risk Issues with CCUS

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Carbon Capture, Utilization, and Storage

Capture

- Reasonably well understood for both pre-combustion and post combustion.
- Expensive for post-combustion (both natural gas and coal)
- Significant RD&D investment by DOE/FE

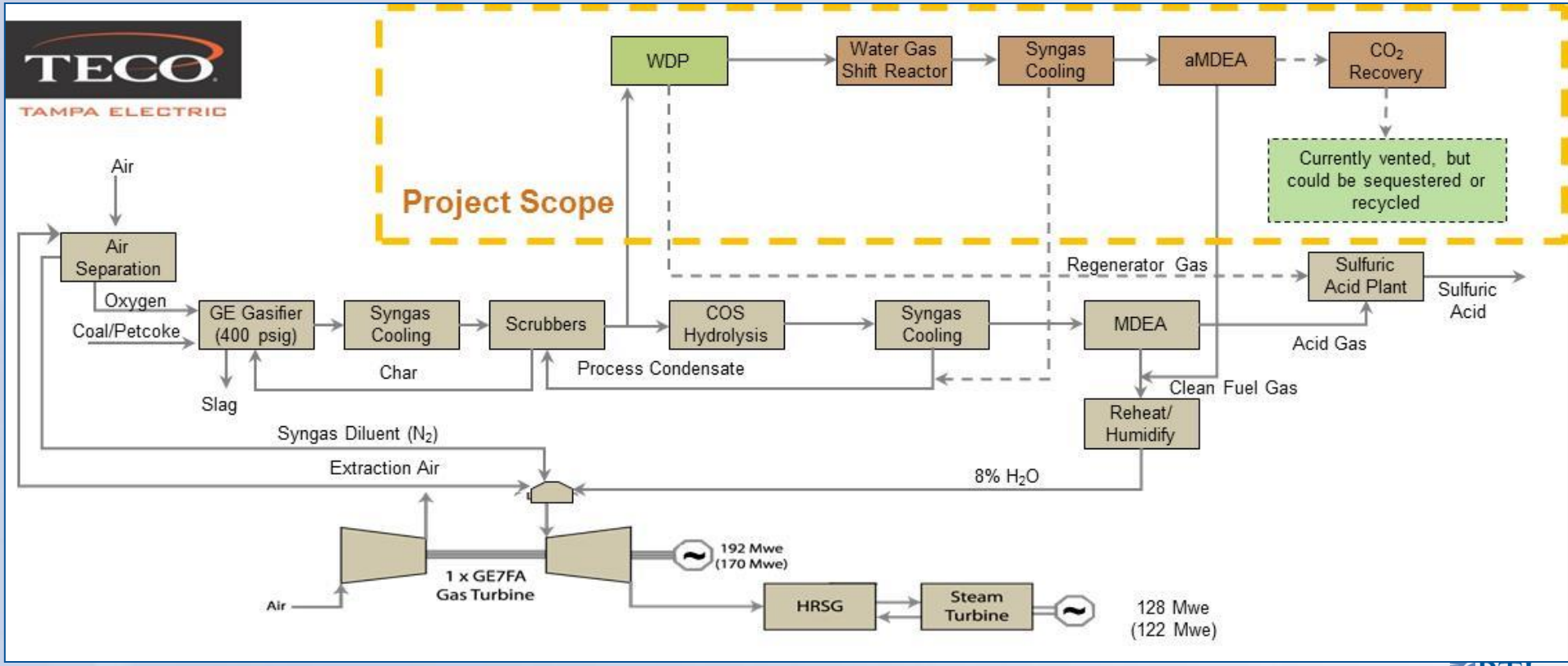
Utilization

- Enhanced Oil Recovery (EOR) is currently only viable option
- Production of fuels (may be chemicals) could be a future option

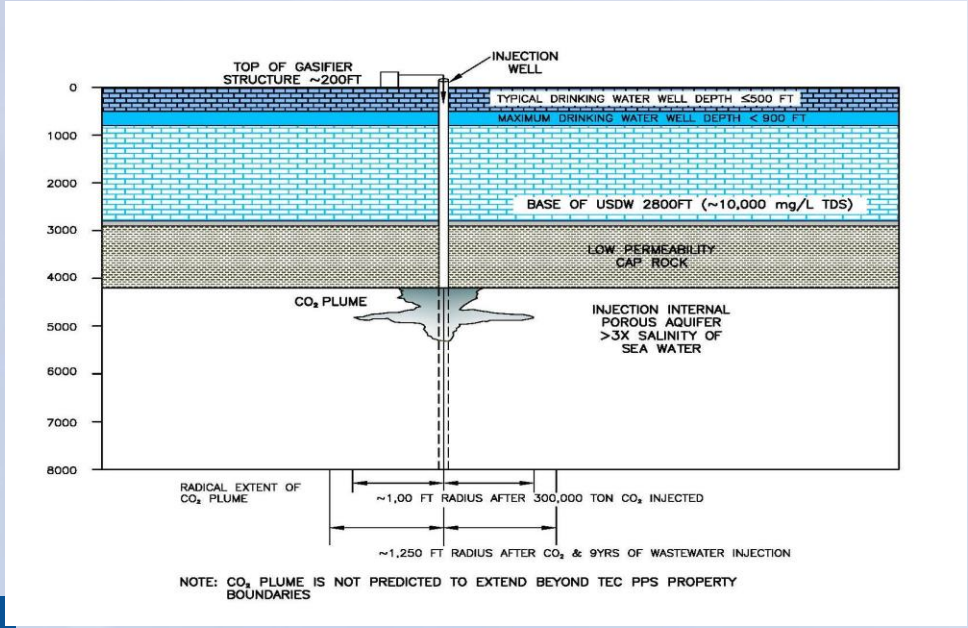
Storage

- Geological storage provides ample capacity
- Risk and regulatory regime is quite uncertain

RTI Warm Syngas Desulfurization Technology



Our experience with CCS at Tampa Electric



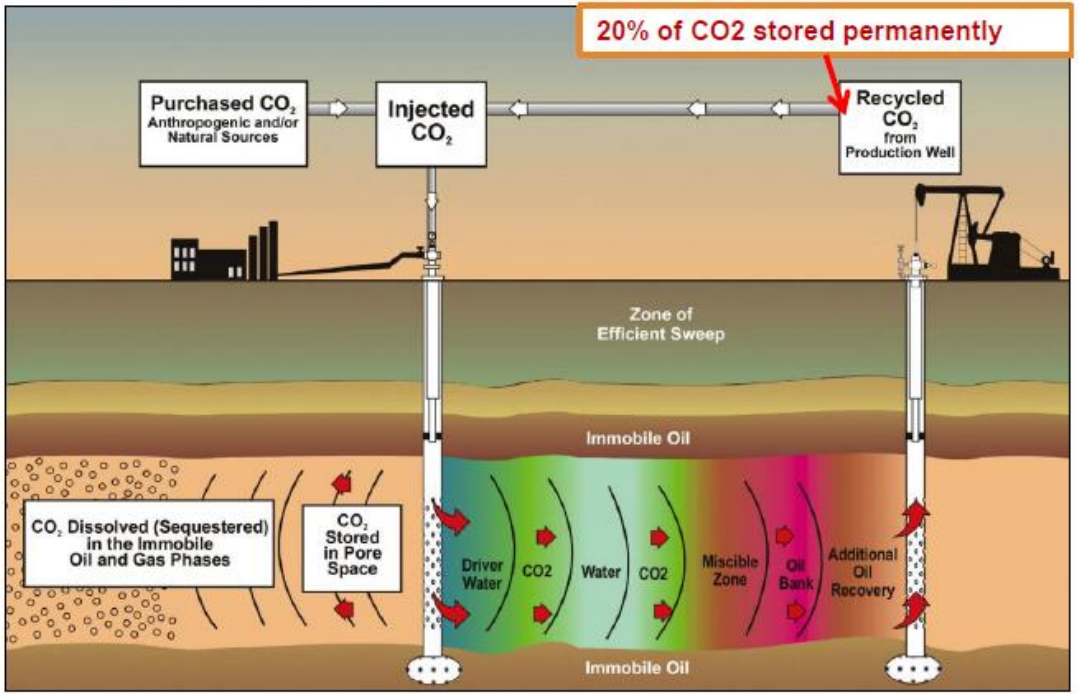
- Designed and built a carbon capture system for a 50 MW size
- Characterized the geology for on-site storage
- Found synergies with waste water injection
- Modelling indicated rapid mineralization of CO2
- EPA originally granted a Class V well permit, but later insisted on Class VI permit
- 50 year MVA requirements

Enhanced Oil Recovery injects CO_2 into otherwise-unproductive wells, allowing new access to stranded oil

Key Aspects of CO_2-EOR Process

- CO2 is transported to the wellhead, typically by pipeline, from either a capture facility or a natural deposit.
- 80% of the CO2 is recycled at the wellhead, with new CO2 replacing the 20% stored permanently
- The CO2 is injected into the wellhead, which is already flush with water.
- A typical well will inject more than 1150 tons of CO2 per day; roughly **0.25-0.4 tons** of CO2 needed per barrel of oil
- The CO2 lowers the viscosity of the stranded oil, making it easier to recover.

CO_2 Enhanced Oil Recovery Lifecycle



EOR is a capture opportunity because natural CO_2 supplies cannot satisfy future growth potential

80% of CO_2 is from natural sources…

U.S. Sources of CO_2 (2012)

Anthropogenic (Manmade sources) e.g. Gas processing, coal gasification
~12 Mt / yr (20%)

Naturally Occurring
e.g. Underground deposits
~50 Mt / yr (80%)

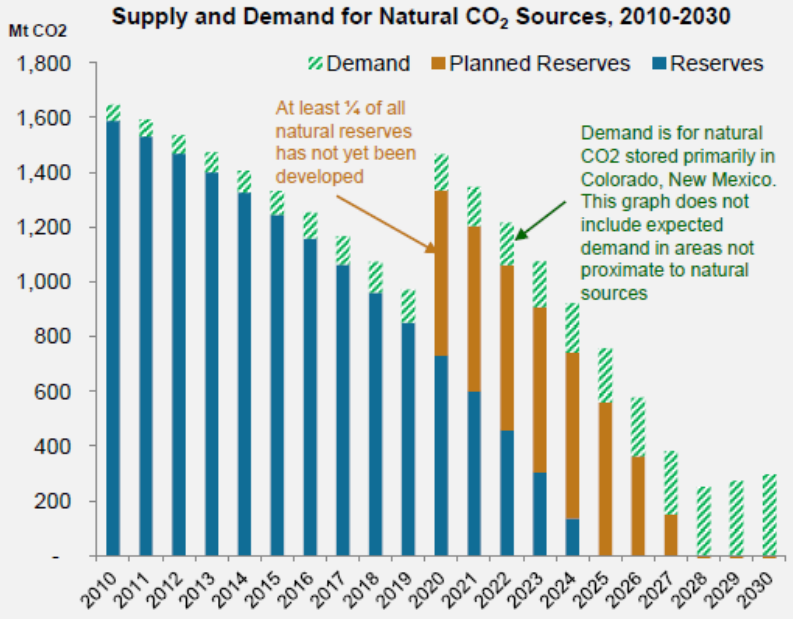
… But EOR is projected to grow to 40% of US oil production

2012 CO_2-EOR Market

- 123 EOR projects
- 350,000 barrels of oil / day
- 6% of production
- 62 million tons of CO_2

Long-term CO_2-EOR Market Potential

- 67 billion barrels of recoverable oil
- 40% of production
- 0.25 GT CO_2 per year

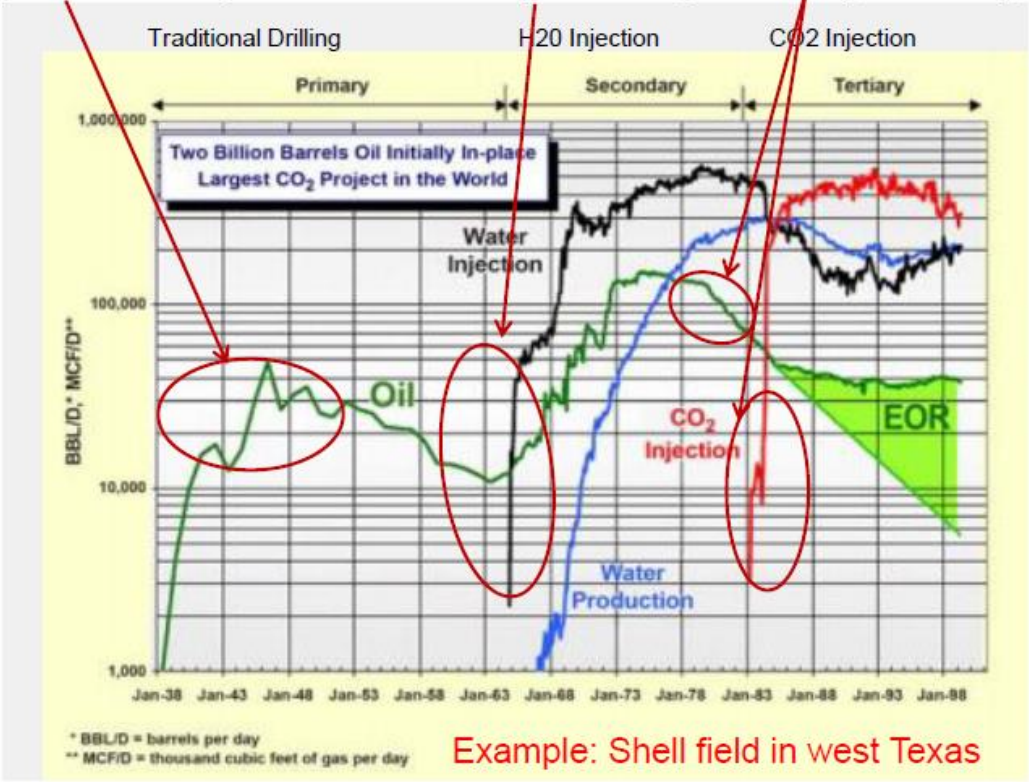


Note: Assumes natural sources under development will come online in 2020

- Several large EOR projects are approaching CO_2 utilization rates of 3-4 Mt per year (similar to amount of CO_2 produced by a 500 MW coal-fired power plant)

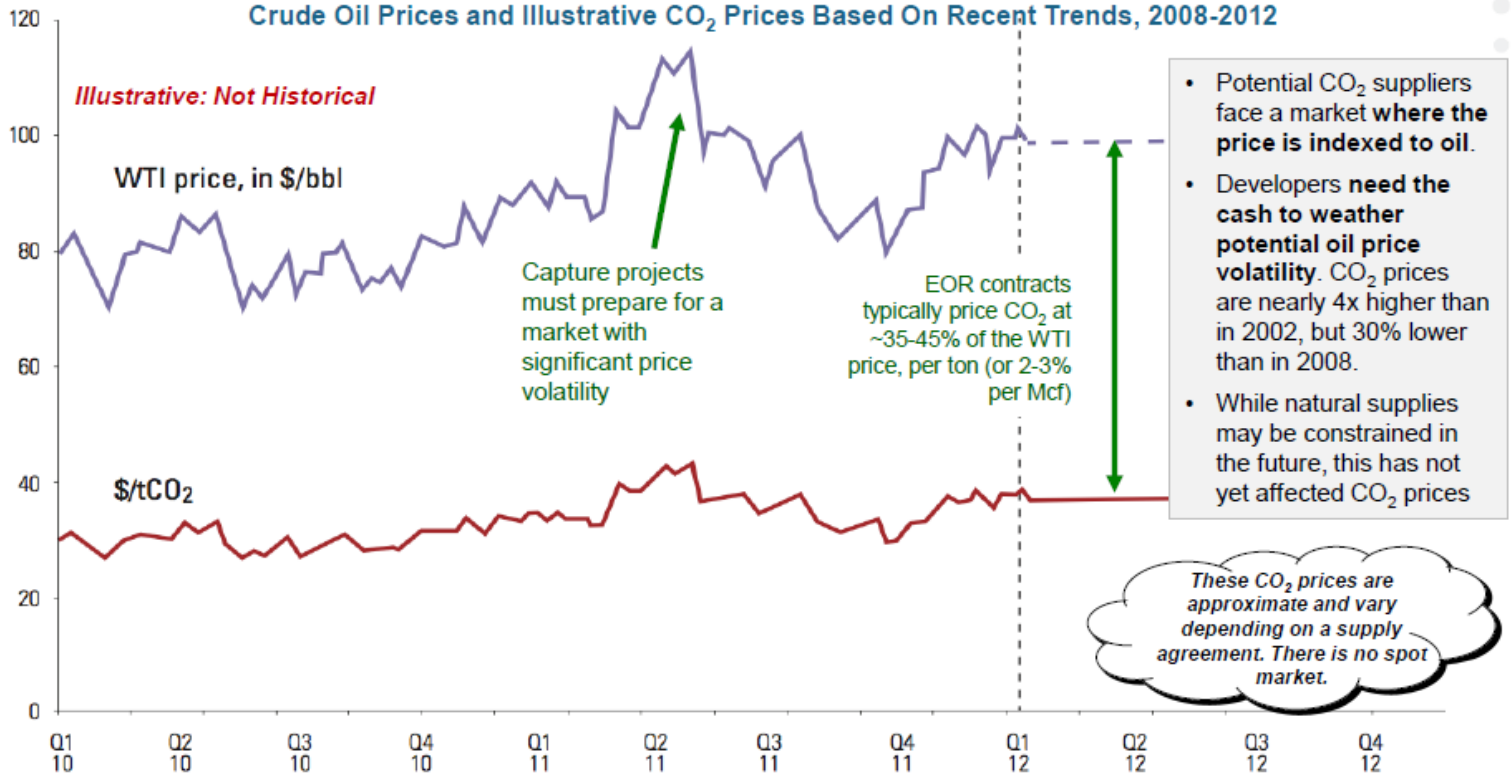
EOR is possible only in stranded oil wells that have already completed traditional drilling and water injection

Field is at high pressure, high yield when initially drilled > H_20 is injected as the field's pressure drops > CO_2 is injected once field is H_20 flooded but yield has begun to drop



- EOR can be used to extend the life of a depleted well (by more than 15 years in the example at left)
- CO_2 supplements but does not fully replace water injection techniques
- Secondary water injection recovery is usually a prerequisite for CO_2 EOR (depends on price, availability, etc.)

Capture projects are price-takers, with EOR projects indexing their expected CO_2 prices to crude oil



Note: CO_2 prices are based on a relationship to oil prices: for WTI oil prices, historical prices are an aggregate of first-month future contracts, ticker: CL1 Comdty. Future prices are generic monthly futures contracts to the end of Q4 2012, shown to the right of the dashed line, ticker: CLX1 Comdty

Summary

- EPA's proposed rule of 1000 lbs CO2/MWh for all new plants (>25MW) will likely stop any new coal capacity
- For geological storage, the risk and regulatory regime has be to streamlined for industry to understand long-term risks and liabilities associated with CO2 storage
- EOR is a niche application. Without extensive CO2 pipelines, matching sources and sinks for CO2 will be a major challenge