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
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 CO₂ into otherwise-unproductive wells, allowing new access to stranded oil

Key Aspects of CO₂-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.
EOR is a capture opportunity because natural CO₂ supplies cannot satisfy future growth potential

80% of CO₂ is from natural sources...

U.S. Sources of CO₂ (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 CO₂-EOR Market
- 123 EOR projects
- 350,000 barrels of oil / day
- 6% of production
- 62 million tons of CO₂

Long-term CO₂-EOR Market Potential
- 67 billion barrels of recoverable oil
- 40% of production
- 0.25 GT CO₂ per year

Note: Assumes natural sources under development will come online in 2020
EOR is possible only in stranded oil wells that have already completed traditional drilling and water injection.

- EOR can be used to extend the life of a depleted well (by more than 15 years in the example at left).
- CO₂ supplements but does not fully replace water injection techniques.
- Secondary water injection recovery is usually a prerequisite for CO₂ EOR (depends on price, availability, etc.).

Example: Shell field in west Texas.
Capture projects are price-takers, with EOR projects indexing their expected CO₂ prices to crude oil

Crude Oil Prices and Illustrative CO₂ Prices Based On Recent Trends, 2008-2012

**Illustrative: Not Historical**

- **WTI price, in $/bbl**
  - Capture projects must prepare for a market with significant price volatility
  - EOR contracts typically price CO₂ at ~35-45% of the WTI price, per ton (or 2-3% per Mcf)

- **$/tCO₂**

- **Potential CO₂ suppliers face a market where the price is indexed to oil.**
- **Developers need the cash to weather potential oil price volatility. CO₂ prices are nearly 4x higher than in 2002, but 30% lower than in 2008.**
- **While natural supplies may be constrained in the future, this has not yet affected CO₂ prices.**

*Note: CO₂ 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. Commodity. Future prices are generic monthly futures contracts to the end of Q4 2012, shown to the right of the dashed line; ticker: CLX1. Commodity.*
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