PG&E GAS R&D AND INNOVATION

Uses for Captured Carbon Technical Analysis

7/27/2018

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BACKGROUND

Carbon, capture, and storage (CCS) has been one method to significantly reduce greenhouse gas (GHG) emissions by storing the carbon dioxide underground. However, CCS is an expensive process, so it is not prevalent today. The cost profile of captured carbon could be altered by finding an industrial or commercial use for the carbon dioxide resulting in revenue generation. It has been estimated that the top three reuse applications for carbon dioxide (fuel production, concrete enrichment, and power generation) could result in as much as one billion metric tons in 2030.

There is a $20 million challenge through XPrize called "Carbon XPrize" which is a global competition to develop breakthrough technologies that convert CO2 into valuable products that we use every day. (X-Prize, 2018)

CHALLENGES

In order for the use of captured carbon to be cost effective and to make an appreciable dent in global GHG emissions, a large amount of carbon dioxide is needed to reach the necessary economies of scale. Another challenge is that carbon dioxide is a highly inert molecule. For this reason, transforming carbon dioxide into industrial products requires a lot of energy.

Regarding the capture of carbon, the cost can be as much as $80 per metric ton. Firms working in this area expect to cut this number in half in the near future. Fossil fuels, which are the existing feedstock to most of the applications listed below are low cost, so the cost (including subsidies) will need to be improved in order to be competitive.

ALTERNATE USES FOR CAPTURED CARBON

Table 1 Comparison of the different uses of carbon (Global CCS Institute, 2018) (Sweet, 2918) (Williams, 2017) (Stockton, 2017)

Application	Description	Limitations	Who is working on this?
Fuel Production	Break down carbon dioxide to carbon monoxide. Hydrogen and carbon monoxide can be chemically reacted to create hydrocarbon chains that make up liquid fuels. Develop methanol using an artificial photosynthesis process.	Energy intensive (equivalent to combustion) Works best when using excess renewable electricity	- Carbon Engineering - Harvard University - California Institute of Technology - Breathe
Building Materials/Concrete Enrichment	CO_2 can be combined with waste products, such as fly ash, and produce an additive to concrete mixtures. The captured carbon would sequester the gas in the concrete, allowing the material to serve as a major carbon sink. A process called "Carbon Curing" allows for carbon dioxide to be injected into wet concrete, up to 4% by mass. This forms carbonate ions that turn into solid calcium carbonate. The process shortens curing time, increases water resistance, and overall strength.	Still in the early stages, so scaling of the technology needs to be improved.	- Carbon8 - Mineral Carbonation International - Carbon Upcycling Technologies

Power Generation	Use carbon dioxide to make turbines run more efficiently. Although not a reuse, this process will prevent large amounts of carbon dioxide from being released. In this process, carbon dioxide is heated and pressurized into a supercritical fluid. By taking less energy to compress compared to steam, this process is more energy efficient. Up to 49% efficiency to electricity generation.	Still in the early stages of the technology.	- Sandia National Lab - GE - Net Power
Oil and Gas Operations	**Enhanced Oil Recovery:** CO_2 is a common injection gas for enhanced oil recovery (EOR) to either increase pressure at the bottom of the reservoir or to reduce viscosity of heavy crude oil, which is prevalent in the Bakersfield area. When the reservoir is depleted of oil following the injection, the CO_2, will remain stored underground in the reservoir. **Fracking:** CO_2 can be added to fracking fluid to increase stimulation of the oil and gas fields.	The hydrocarbons produced using the CO_2 are likely to result in carbon emissions, which can negate the GHG advantages.	- NRG (Petra Nova Project) - Numerous oil and gas operators use this technique for EOR
Carbon Nanotubes/ Carbon Fiber	Convert carbon dioxide to carbon fibers or nanotubes using a molten electrolysis process. Use CO_2 and electricity to produce a strong, light-weight alternative to metal. This process costs less than traditional carbon nanotube manufacturing. Another method involves separating carbon from the CO_2 and reacting it with an iron catalyst to create carbon nanotubes.	The iron catalysts are not very stable and depending on how long it is in use, it can create irregularly sized carbon nanotubes.	- C2CNT - Vanderbilt University

OTHER APPLICATIONS (THAT DO NOT HAVE THE SAME VOLUME) (GLOBAL CCS INSTITUTE, 2018)

- **Wine Making** - CO_2 is used as a seal gas to prevent oxidation during the wine maturation process. However, it should be noted that CO_2 is produced during the fermentation stage, so this can be captured on-site and might not be needed from an external source.

- **Food Processing –** CO_2 can be used in cooling while grinding powders and in modified atmosphere packaging (MAP) to extend shelf life by inhibiting growth of bacteria that cause spoilage.
- **Paper Processing** – Used to reduce pH during pulp washing operations
- **Steel Manufacturing –** CO_2 is used in a minority of basic oxygen furnaces as a bottom stirring agent or for dust compression.
- **Refrigerant Gas** – CO_2 can be used as the working fluid in a refrigerant plant, specifically larger industrial air conditioning and refrigeration systems. The CO_2 would replace other toxic gases that have larger global warming potential.
- **Fire Suppression –** CO_2 provides a heavy blanket of gas that can suppress fire by reducing the oxygen level to a point where combustion does not occur. For this reason, CO_2 is found in fire extinguishers and industrial fire protection systems.
- **Pneumatics** – CO_2 can be used in portable power sources for pneumatic hand tools and equipment, as well as power sources for paintball guns and other recreation equipment.
- **Fertilizer –** CO_2 can be combined with waste straw and methane from landfill sites to create a crumbly soil enriching fertilizer.

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