Cap-and-Trade Auction Proceeds
Comments to Draft Second Investment Plan: Fiscal Year 2016-17 to 2018-19

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Investment Concepts: Clean Energy and Energy Efficiency

Negative carbon energy production

There is a real opportunity to couple carbon capture and storage technology with biomass electricity generation across California to literally produce power with *negative carbon emissions*. Electricity production from terrestrial biomass (non-fossil) fuels is considered to be carbon neutral because atmospheric CO_2 used to grow the biomass is released back to the atmosphere on a sustainable time scale. This contrasts electricity production from fossil fuels, which releases CO_2 that has been stored for geologic time periods. *Negative carbon emissions* are possible when biomass electricity generation is coupled with carbon capture and storage technology. That is short term CO_2 storage becomes permanent storage.

In the brief descriptions that follow, we highlight two carbon capture and storage technologies that are ready to implement with biomass power generation at the pilot or demonstration scale.

Biogas energy production and aqueous CO_2 capture and storage

Biogas energy production from the anaerobic digestion of bio-solids and other organic material at wastewater treatment facilities produces renewable energy and avoids production of methane that would otherwise be emitted to the atmosphere. There is the potential to combine the CO_2 emissions with wastewater treatment to achieve negative carbon energy. Wastewater treatment facilities that produce renewable biogas energy along the California Coast are ideal candidates for aqueous CO_2 capture and storage because the CO_2 source, treatment, and storage reside at one location.

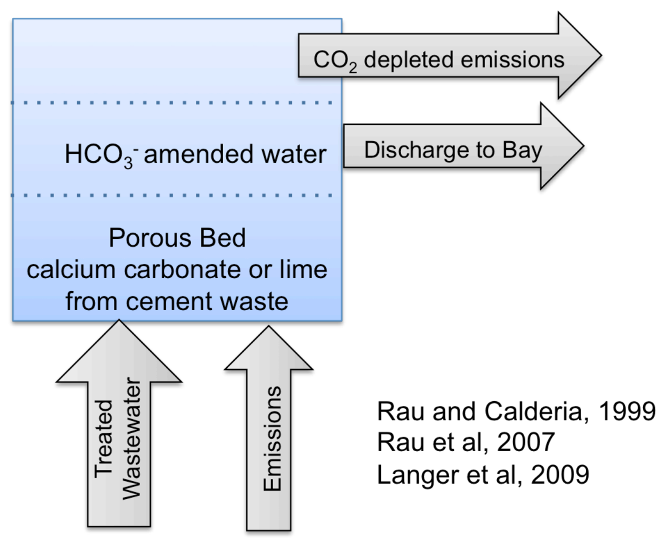


Figure 1. Process diagram showing the aqueous CO_2 capture and storage technology

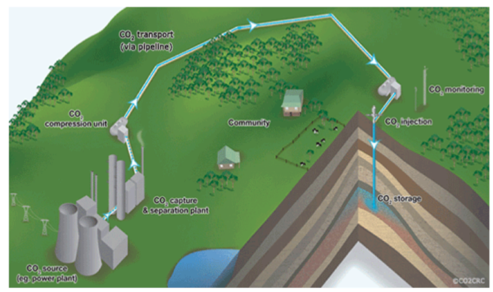
Aqueous CO_2 capture and storage could be achieved by flowing CO_2 emissions from the biogas combustion through a mixture of limestone and as part of the wastewater treatment practices (Figure 1). The chemical processes are straightforward and fully understood (Rau and Calderia, 1999; Rau et al., 2007; Langer et al., 2009). CO_2 emissions dissolve into the water as carbonic acid, which is then neutralized by dissolving limestone from cement waste. This process converts the CO_2 greenhouse gas to bicarbonate, a common compound that is suitable for discharge into the bay or ocean. Because the process adds alkalinity (bicarbonate) to the fluid discharge it also neutralizes acid and offsets ocean acidification resulting from greenhouse gasses as well.

Aqueous CO_2 capture and storage has been demonstrated in the laboratory and vetted by the scientific community and is ready to combine with CO_2 emissions for pilot scale demonstration. Planning would be required to optimize the pilot scale demonstration at a wastewater treatment facility.

We recommend that the *Cap-and-Trade Auction Proceeds Second Investment Plan: Fiscal Years 2016-17 to 2018-19* include technologies that combine renewable biogas energy production with aqueous CO_2 capture and storage to help mitigate climate change.

Terrestrial biomass energy production and geologic CO_2 capture and storage

A second technology combining geologic CO_2 capture and storage with biomass energy power plants takes advantage of global experience of mitigating CO_2 emissions from hydrocarbon production and power plant flue gas or syngas (Figure 2). The technology uses commercially available capture methods to separate and concentrate CO_2 for injection into deep saline and depleted oil and gas reservoirs for long term geologic storage. Geologic storage is happening across the United States and around the world. Large, commercial-scale projects, like the Sleipner CO_2 Storage Site in Norway, the Weyburn-Midale CO_2 Project in Canada, and the In Salah project in Algeria, have been injecting CO_2 for many years. Each of these projects stores more than 1 million metric tons of CO_2 per year. These commercial-scale projects are demonstrating that large volumes of CO_2 can be safely and permanently stored. The U.S. Department of Energy, Office of Fossil Energy, and the National Energy Technology Laboratory (NETL) are conducting several large-scale CO_2 tests (tests injecting at least 1 million metric tons of CO_2) in Mississippi, Alabama, Illinois, Montana, Texas, and Michigan (see Regional Carbon Sequestration Partnership (RCSP) Initiative).



Source: Global Carbon Capture and Storage Institute. 2012. "How CCS Works." http://www.globalccsinstitute.com/ccs/how-ccs-works

Figure 2. Process diagram showing the aqueous CO_2 capture and storage technology

The California Energy Commission and the U.S. Department of Energy have characterized multiple sites for geologic storage (www.westcarb.org) and are primed to take CO_2 from biomass power plants located along the Sierra Nevada foothills to generate carbon negative energy.

We recommend that the *Cap-and-Trade Auction Proceeds Second Investment Plan: Fiscal Years 2016-17 to 2018-19* include technologies that combine renewable biomass energy production with geologic CO_2 capture and storage to help mitigate climate change.

References

Rau GH, Caldeira K. (1999) Enhanced carbonate dissolution: a means of sequestering waste CO_2 as ocean bicarbonate. *Energy Conver Manage* 40, 1803–13

Rau GH, Knauss KG, Langer WH, Caldeira K (2007) Reducing energy-related CO_2 emissions using accelerated weathering of limestone. *Energy* 32, 1471–1477

Langer WH Carma SJA, Rau GH, Calderia K (2009) Accelerated weathering of limestone for CO_2 mitigation: opportunities for the stone and cement industries. Mining Engineering.