Basics of Calera Process

Calera Corporation captures carbon dioxide (CO_2) from the burning of fossil fuel and converts it into carbon-negative building materials, enabling the production of green power, cement, fresh water and other products to promote sustainable growth. The process can capture other emissions, including sulfur dioxide, particulate matter, mercury, and other metals. In capturing CO_2 and other emissions from flue gas, Calera's carbonate mineralization technology utilizes solid and liquid sources of alkalinity, such as fly ash, wastewaters, and brines. The outputs of the process are clean air, fresher water, and solid materials that can be sold as an aggregate or supplementary cementitious material (SCM). Calera's carbon-negative aggregate can be used to make concrete, asphalt, and other building applications, and its SCM can enhance the strength of concrete and supplant a portion of the cement in concrete blends. Calera, based in Los Gatos, Calif., operates a pilot plant next to a 1000 MW power plant at nearby Moss Landing that can operate continuously and currently can produce an average of five ton of SCM per day. A demonstration plant is under construction to capture and mineralize flue gas from the power plant at a rate equivalent to 10 MWe from the natural gas power plant.

Inputs and Outputs of the Calera Process

The Permanence and Stability of Calera's Conversion of CO_2 to CO_3

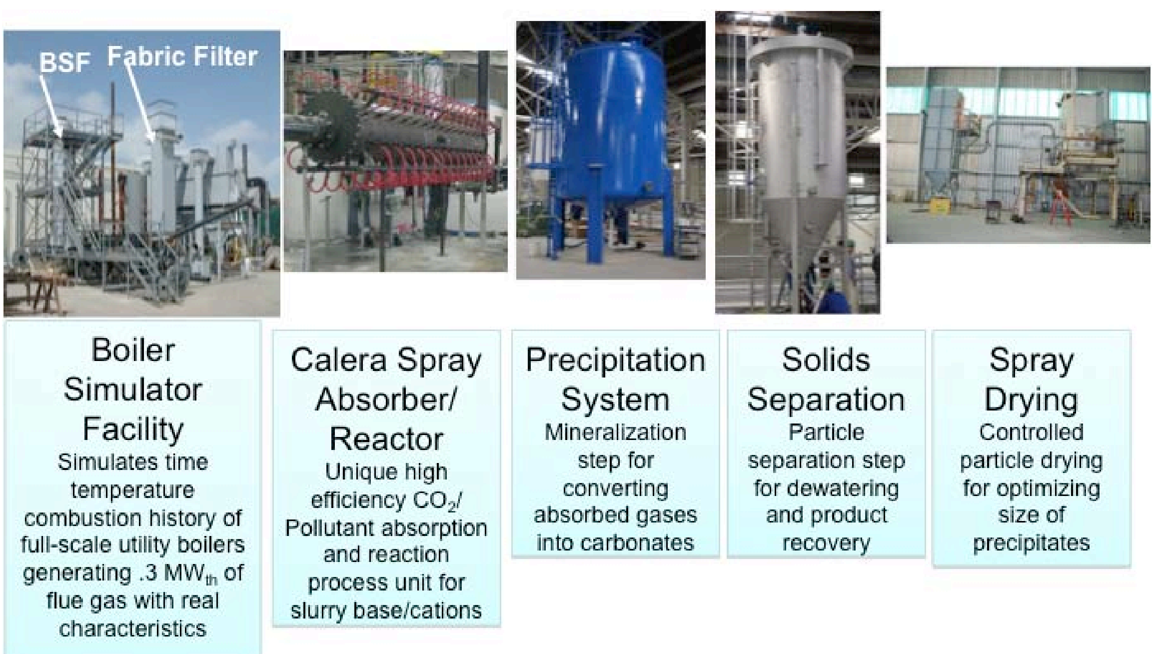
A key step in the Calera Carbonate Mineralization by Aqueous Precipitation (CMAP) process is the conversion of carbon dioxide (CO_2) to carbonate (CO_3) and binding it to minerals such as calcium and magnesium. The output is a material composed of carbonate minerals that are stable across geological timeframes. Since the minerals are no longer in the form of carbon dioxide, long-term storage does not require monitoring, as does separated CO_2 geological storage. Calera continuously assesses the carbon dioxide captured using continuous emissions monitoring of the flue gas and confirms the carbon content and sources of carbon in the products by state-of-the-art carbon isotopic marking methods.

The long-term stability of carbonate minerals is well known (the White Cliffs of Dover are carbonate minerals).The results of a review of published literature showed that storage of captured CO_2 as carbonate minerals provides a secure storage over geologic time frames, even in acidic environments.

Calera Testing Labs

Calera's CO_2 absorption and mineralization technology has been executed and tested at both the lab and pilot scales to produce a variety of magnesium and calcium carbonate minerals. At the pilot level CO_2 capture rates of greater than 50% are routinely observed and absorption rates above 90% have been achieved. One unique advantage of the CMAP process is the ability to capture and stabilize a number of pollutants in addition to CO_2. For example, capture of SO_2 at the pilot plant routinely approaches 100%.

Equipment at the Calera Moss Landing Pilot Facility



Environmental Benefits of the Calera CMAP Process

Carbon Capture, Handling, and Storage

The Calera process has a number of advantages compared to the other carbon capture and storage methods that are currently being researched and tested. The capture method provides a post-combustion capture process that will not require large changes to current power generation infrastructure. The mineralogical sequestration converts the gas into a stable solid that will reliably store the carbon as CO_3 in a mineral form for millions of years. This process is designed to utilize flue gas from a wide variety of industrial CO_2 emission sources and can operate with flue gasses containing a wide range of CO_2 concentrations, from less than 2% to essentially pure CO_2.

Other carbon capture and storage (CCS) technologies generally take one of two forms – geological sequestration or terrestrial sequestration. Cost projections for these CCS technologies are very high. Calera's process offers a safe economical alternative that converts carbon dioxide into a useful byproduct without disruption to power generation activities. The reliability and safety of Calera's form of sequestration provides advantages over geological sequestration. Calera believes that capture and mineralization with beneficial re-use will prove to be the most competitive option from a cost perspective.

The Calera process eliminates the need to transport gaseous carbon dioxide, locate feasible storage sites, and address the ownership and liability issues associated with injection operations and long-term storage. With the known stability of the carbonate mineral forms, coupled with their beneficial use in the built environment, ownership is clear and liability is limited to the normal liability for any building material. Of particular benefit is the elimination of risk of CO_2 leaking from pipeline or geologic storage sites, as well as the environmental issues associated with building the pipelines to transport CO_2 to geologic storage sites.

SO_x Control

The CMAP process functions as a highly efficient sulfur scrubbing system, with SO_2 removal efficiencies of greater than 95% routinely demonstrated at the pilot plant. The CMAP process also has the promise of incorporating calcium sulfate compounds into the solid, predominately carbonate product, which can then be used for various applications in the built environment.

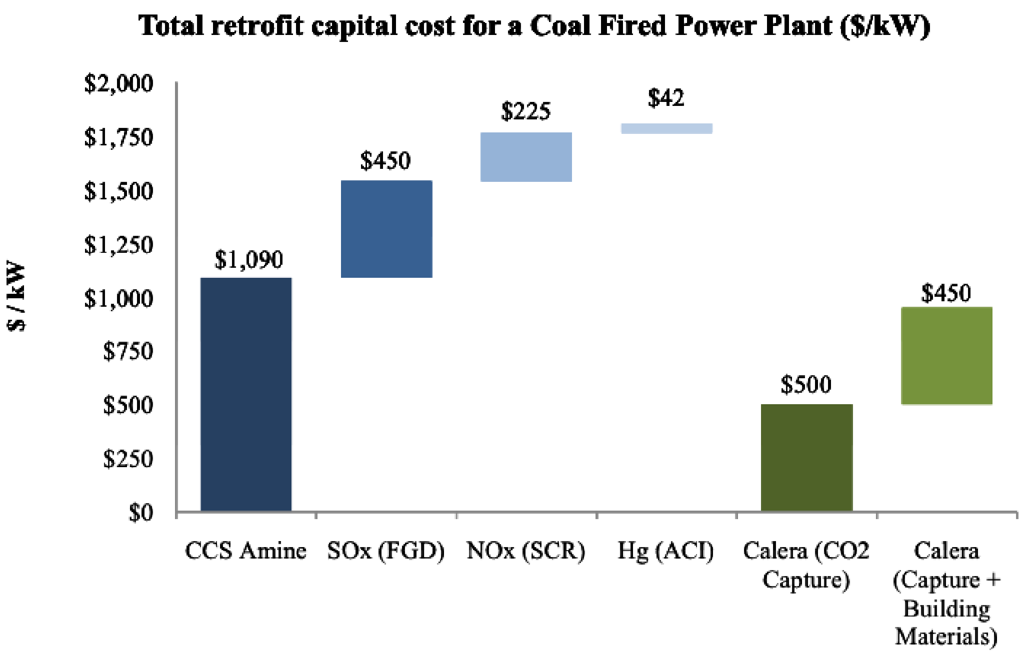
Mercury Control

Coal-fired power plants represent the largest source of mercury emission in the United States, but most operate with minimal controls designed to capture particulate matter that remove less than 35% of the mercury from their flue gas. This removal percentage can increase to greater than 50% when a sulfur scrubber is added, but capture levels are dependent upon coal type. With new federal and state regulations emerging, many power plants are contemplating the use of activated carbon injection (ACI) or other additional controls to remove more mercury from flue gas. The Calera CMAP process has the potential to not only capture mercury that would otherwise be emitted, but to bind it into the mineral output in a way that will prevent leaching to the environment.

Trace Metals and Other Pollutants

As with mercury, other trace metals can be captured by the CMAP process, including lead, chromium, cadmium, selenium, zinc, and others. Another candidate for capture is downstream ammonia (NH_3) slip in a plant with a previously installed SCR system. Verifying this capability would demonstrate added value even in situations where NO_x control was already installed. In fact, Calera's planned 10 MWe demonstration plant, at the gas-fired Dynegy power plant in Moss Landing, CA, is a situation where this case will be tested.

The graph below illustrates how the combined benefits of Calera's multi-pollutant reduction enhance the cost effectiveness of the CMAP process. The total cost of capturing carbon dioxide, sulfur dioxide, nitrogen oxides (NOx), and mercury (Hg) using traditional single pollutant technologies is $1807 per kilowatt. The Calera process can reduce these emissions are various competitive capture rates and create marketable building materials for around half of that cost.



<u>Solid Waste Remediation</u>

The Calera process can use solid wastes such as fly ash, cement kiln dust, and other materials to supply the necessary minerals and alkalinity to capture carbon in a mineral form. This provides an opportunity to utilize these wastes and capture their constituents in chemically stable building materials. After stockpiled solid wastes have been fully remediated, the waste can still be used on an as-produced basis, and Calera can supply the additional mineral and alkalinity requirements from other available or manufactured sources.

<u>Wastewater Remediation</u>

As with solid wastes, Calera can draw its input needs from mineralized liquid sources such as brines and industrial wastewater. The very nature of the process is to harvest the minerals from the water, making them more readily treated and desalinated. The Calera process effectively removes the hardness (calcium and magnesium) from water.

<u>Fresh Water Production</u>

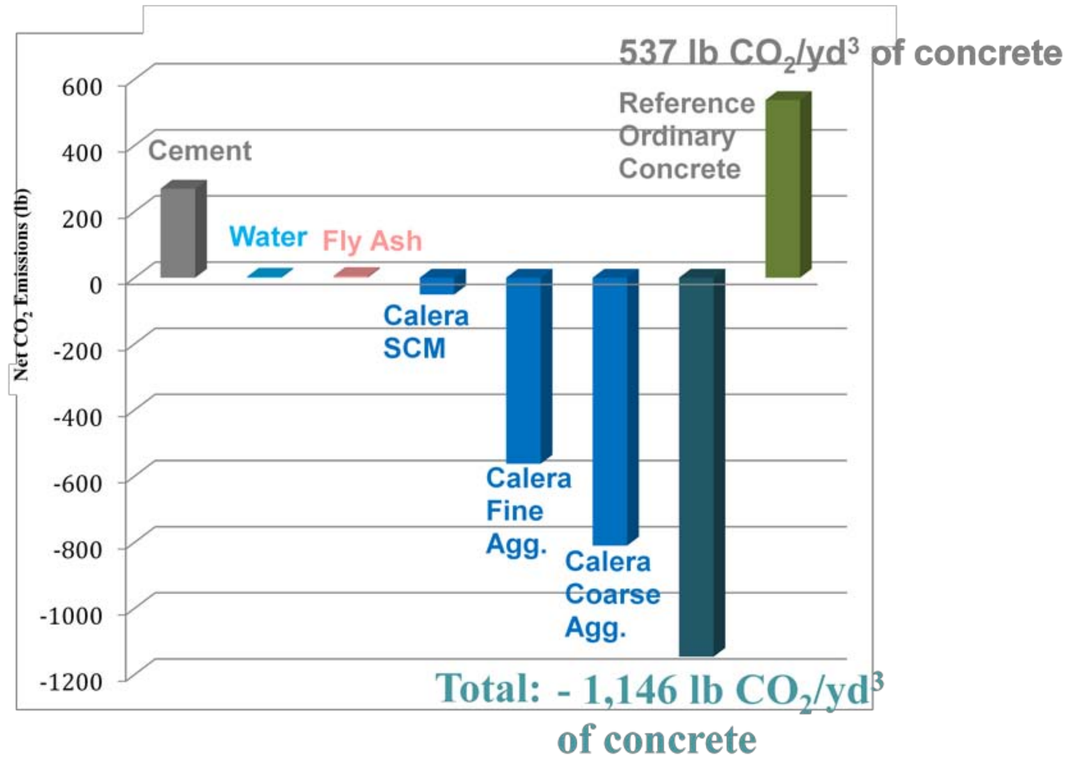
Since the water used in the CMAP process is demineralized, Calera can enhance the production of fresh water. This is particularly appealing in areas with abundant brines or seawater, but scarce fresh water. The water exiting the CMAP process can then be suitable for agricultural purposes with little or no additional treatment, or for conversion to potable water with far less treatment—and thus less energy expended—than the water entering the process. In areas with little water availability, even in a mineralized form, Calera can recycle a limited supply of water by remineralizing it with each introduction.

Displacement of Carbon-Intense Building Materials

The U.S. market for mineral building materials totals well over 3.5 billion tons per year, and concrete is the most widely used man-made material in the world. Concrete is made of roughly 80% aggregate (sand and gravel), 10-15% cement, and the remainder air, water, and additives. The CMAP process is capable of permanently mineralizing carbon in the form of either fine or coarse aggregates or a supplementary cementitious material that can be utilized in the built environment and meet the growing green product market as a carbon-negative material. The standard process for manufacturing Portland cement generates large amounts of CO_2 both from the fuel used to heat the raw materials ($CaCO_3$, clays, etc.) as well as from the calcination process itself (the conversion of $CaCO_3$ to CaO, releasing CO_2). Therefore, concrete made from portland cement carries a CO_2 footprint of approximately 0.8-1.5 ton CO_2/ton cement, translating to roughly 537 pounds of CO_2/cubic yard of concrete. This CO_2 footprint can be reduced somewhat through the use of supplementary cementitious materials (SCM) such as fly ash that displace portions of the portland cement used in a concrete mix.

Since Calera's SCMs do not undergo the combustion or calcination processes of portland cement, their production does not release any CO_2. Calera SCM both captures carbon from one source and avoids carbon emissions from another. Concrete made with Calera fine and coarse aggregate, 20% cement replacement with Calera SCM, and 20% cement replacement with fly ash would have carbon footprint of negative 1146 pounds of CO_2/cubic yard of concrete. This is a carbon savings of 1683 pounds of CO_2/cubic yard of concrete compared to standard concrete. With projected U.S. portland cement consumption at nearly 200 million metric tons by 2020, a 20% market penetration with a SCM replacement level of 50% would reduce CO_2 emissions by 30 million metric tons.

Production of Carbon-Negative Concrete



Source: Calera analysis

Cement companies already have distribution channels for their products, so this industry makes an ideal partner for Calera. The Calera process can capture emissions of carbon dioxide, sulfur oxides, mercury and other metals, binding them in a marketable mineral building materials. Such partnerships are also suitable for Calera's carbon-capture operations at power plants or other emission sources, with the cement or concrete company distributing the carbon-negative products.

Low-Energy Electrochemistry

As mentioned above, Calera can—if necessary or financially preferable—manufacture the alkalinity inputs necessary to capture carbon from industrial flue gas. Production of sodium hydroxide has traditionally required significant energy use. Calera has developed, patented, and proven a revolutionary Low Voltage Base (LVB) process that reduces these energy demands by as much as 80%. The caustic that is produced by the LVB process can be reacted with carbon dioxide and minerals to form a stable carbonate species. One potential opportunity presented by this process is the ability to use off-peak renewable energy to create this alkalinity, thus effectively storing carbon-free energy to utilize in the production of low- or zero-carbon fossil fuel energy.

DOE Endorsement

On September 23, 2009 the U.S. Department of Energy announced that Calera was to be awarded a grant for the expansion of the Moss Landing facility to a demonstration scale. At this site, Calera will treat a 50-megawatt coal equivalent slipstream from the adjacent Dynegy plant, removing the carbon and other emissions to produce a carbonate mineral product. The award is in the category of "innovative concepts for beneficial carbon dioxide use."