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Introduction

Chairman Dorgan and Members of the Subcommittee, first, I would like to thank this Subcommittee for their important work in advancing solutions to Climate Change. I would also like to thank you for inviting me to testify on a carbon-mitigation sector that I believe holds tremendous promise: the conversion of carbon dioxide (CO_2) to mineral form for beneficial reuse.

This hearing comes at a critical time: Congress is debating climate change legislation; the President has promised a green energy policy that helps not hurts our economy; and almost 200 countries are preparing for the Copenhagen international climate discussions. As these and other political decisions unfold against the backdrop of a global economic crisis, we must develop a broad array of cost-effective methods to mitigate the release of CO_2 into the atmosphere.

My name is Brent Constantz, and I am the CEO of Calera Corp., based in Los Gatos, Calif. Over the past 20 years, I have built three successful Silicon Valley companies based on innovative specialty-cement technologies, covered by approximately 70 issued U.S. patents I hold in this area. Additionally, I am a professor at Stanford University where my teaching and research are focused on carbonate mineral formation and oceanic carbon balance.

My goal today is to urge Congress to think broadly in terms of the carbon capture and sequestration (CCS) technologies it supports, and the current budget language that needs to be carefully crafted to take full advantage of the opportunities these technologies can offer. Additionally, my testimony will give you an overview of our CO_2-conversion technology; how it is possible to beneficially reuse CO_2 when it is converted to a mineral form; how our technology compares with other CO_2-capture options; and the commercial potential of beneficial CO_2 reuse.

Finally, I will conclude with recommendations that not only align with this Committee's demonstrated commitment to CCS, but also help move beneficial CO_2-reuse technologies such as Calera's from pilot-scale to global innovation, thereby fostering other technologies that may be alternative or complementary to CO_2 separation and geologic sequestration.

Calera has developed a transformational technology that converts CO_2 into green building materials. The process captures CO_2 emissions from power-plant flue gas and cement manufacturing, and chemically combines it with a variety of natural minerals, water and solid waste materials to produce cementitious materials, aggregate and other related building materials. Thus the process is more than CO_2 sequestration — it represents *permanent CO_2 conversion.*

Calera is backed by Khosla Ventures, a well-regarded venture capital firm specializing in "green" technology. With Mr. Vinod Khosla as a partner in this effort, Calera has been able to engage a formidable team of scientists and engineers to move beyond the laboratory and bench-scale research. We currently operate a pilot facility adjacent to a 1000 MW power plant in Moss Landing, Calif. that allows us to test our technology with a goal of scaling the process up to full production levels. In less than a year

Calera has grown from 12 to more than 70 employees, including 18 PhDs and senior executives with more than 200 years of combined experience in power, water and concrete.

But we have many milestones ahead to reach commercial scale, particularly in this difficult economic climate. Government support is necessary at this stage of development for demonstration facilities and early deployment in commercial plants. Government support, along with commercial partner investment will make the financial hurdle of financing these first scaled plants possible. Government policies that are directed toward mitigating carbon and stimulating the economy by the best available approaches will enable substantial progress for the profitable, beneficial reuse of CO_2.

Level the Playing Field for New Technologies

I would like to underscore that CO_2 mitigation technologies are evolving rapidly. Calera is one of several companies focused on CO_2 conversion technologies with the potential for beneficial reuse. Yet, despite the promise of these technologies, carbon mitigation funding has been narrowly focused on CO_2 separation and purification for geologic sequestration. This focus is proscriptive to one method, assuring that carbon reduction dollars will be directed only towards this method's narrowly defined pool of projects in hopes of making geologic CO_2-sequestration a viable option. This is especially vexing, considering that the Calera process and comparable CO_2-capture technologies largely avoid the economic burden, carbon balance, risk and permitting constraints that accompany geologic CO_2-sequestration.

We submit that taxpayer support and funding should be based on carbon reduction outcomes and seek to advance the most effective technologies. While CO_2 separation and purification for geologic sequestration is one important potential method in the carbon-capture toolbox, we need to consider all of the potential solutions to address the volume of CO_2 at issue. Broad statutory language is needed that encourages innovation and rewards breakthrough technologies consistent with our goals as a free-market nation. The methods we implement should be selected by how we best arrive at the desired outcome, and not constrained to any one particular method for CO_2 mitigation.

I will come back to the crucial point of how the federal government can level the playing field for other technologies after providing you with an overview of Calera's CO_2-conversion technology.

The Calera Process: CMAP Technology and Low-Voltage Base Production

Calera's technology is called *Carbonate Mineralization by Aqueous Precipitation (CMAP).* The Calera process is unique in how it essentially mimics the natural carbonate mineralization of corals when making their external skeleton. This technology captures CO_2 emissions by converting CO_2 to CO_3 (carbonate) and effectively storing it in a stable mineral form. This mineral can then be used to replace or supplement traditional portland cement, offsetting emissions that would otherwise result from the CO_2-intensive manufacture of conventional cement.

The biggest hurdle to the mineralization concepts studied has been high-energy demand or extremely slow rates of reaction occurring over geologic timeframes. Calera's CMAP bypasses the limitations of previous mineralization approaches, but it has not been broadly pursued in the past due to the requirement for sustainable, unlimited chemical-base sources. Amongst the many technologies now possible are novel base-production methods that are low in cost, energy, and carbon footprint. These Calera innovations — fully described in USPTO patent applications — revolutionize the technical feasibility, carbon-mass balance and economics of carbonate mineralization for CO_2 capture and conversion via aqueous mineralization.

Calera's mineralization process utilizes break-through, low-voltage chemical base-production technology that makes the conversion from CO2 to carbonate cost-effective and sustainable. Using approximately one-fifth the voltage of conventional base-production processes, Calera's base production has a very low carbon-footprint and is an alternative to natural or waste sources of chemical base. Therefore, the process can occur irrespective of any specific site location.

The technology uses aqueous minerals and CO_2 from power plant flue gas. The CO_2 in the flue gas is dissolved in a reactor, where it becomes carbonic acid converted to carbonate ions that forms a slurry containing the suspended mineral carbonates. A solid-liquid separation and dewatering step results in a pumpable suspension. Calera employs spray dryers that utilize the heat in the flue gas to dry the pumpable suspension. Once dried, the Calera cement looks like white chalk and can be blended with rock and other material to make concrete. A graphic illustration of this process is attached.

Once it is hydrated, Calera's carbonate mineral cement behaves like traditional portland cement, and it can be used as a supplementary cementitious material to replace portland cement at various levels. A 20%-50% replacement has been tested extensively against ASTM C 1157 concrete specifications. Based on worldwide production estimates, approximately 1.5 billion tons of portland cement could be substituted with carbonate cement, and another 30 billion tons of aggregate used in concrete, asphalt, and road base could be substituted — each ton of carbonate aggregate and cement containing one half-ton of CO_2. Thus, some16 billion tons of CO_2 could be permanently converted to CO_3 per year on an ongoing basis at a profit. This product would be stable for centuries.

The Department of Energy, the National Energy Technology Labs, and several academic institutions in the U.S. and other countries have evaluated several methods for accelerating the natural chemical weathering of minerals to produce carbonate minerals. Research has focused both on aboveground conversion of CO_2 to carbonate minerals, and the potential for carbonate conversion belowground in brine reservoirs, or at geologic sequestration injection sites. These investigations began in the mid-1980s with Reddy's investigation of techniques to accelerate the natural mineral carbonation process.

Since then, there have been many well known scientists working in this study area: Herzog at MIT, Halevy and Schrag at Harvard, O'Connor, researchers at the National Energy Technology Laboratory in Albany, and others, active in mineralization research. The focus of this research was testing of various base materials, reducing the massive energy consumption in the processing of these materials, and acceleration of the reaction rates. Current research has moved toward carbonation of coal-combustion fly ash and accelerated dissolution techniques of magnesium- and iron-rich silicates (so-called mafic minerals) used in carbonation processes.

Cost-efficiency

Every carbon-capture technology struggles with the issue of cost. The economic viability of our carbonate mineralization business model is significantly enhanced by the ability to sell captured-and-converted-CO_2 building materials into large end-markets. For each ton of CO_2 captured, about two tons of building material can be produced. This process provides the opportunity to transform an environmental liability into a profit center. The market for these newly created materials can be significant. Based on USGS data showing worldwide annual cement consumption of 2.9 billion tons, approximately 12.5 billion tons of concrete are used yearly. Additional aggregate usage for asphalt and road base almost triples the potential for storing this captured CO_2.

Test data has shown that we can capture and convert CO_2 at 70% to 90%+ efficiency with our current absorption configuration on flue gas typical of coal fired utility boilers (about 10%-15% CO_2). We have higher capture efficiencies for other industrial combustion sources, with higher concentrations of CO_2 such as cement kilns (about 20%-40% CO_2) and refinery operations (about 95%-100% CO_2). In addition to our high-capture efficiencies, we produce materials that offset other products that have large carbon emissions such as cement. When we include the "avoided" CO_2 of our capture and conversion into materials, this results in CO_2 efficiency greater than 100%.

We believe our CMAP technology can be cost-competitive. Particularly advantageous as compared to traditional CCS methods, our conversion technology does not require CO_2 separation, which can be more energy, cost and carbon-intensive as the CO_2 gas becomes more dilute or compressed. Separating CO_2 emission from dilute streams, such as a coal-fired plant or a cement plant, is far more difficult than from a refinery that is almost pure CO_2. In addition, our process does not require transportation, injection, storage or monitoring. Finally, it is important to keep in mind that as our plants grow and scale, we believe our costs will be lower than revenues, enabling a more rapid and extensive scale-up to address large-scale CO_2 mitigation.

Pollutant Removal

Unlike other carbon-mitigation technologies, CMAP removes sulfur compounds and other pollutants. We are developing a multi-pollutant control option using the same basic absorption and conversion techniques we are using for CO_2. The basis of our process for SO_2 (sulphur dioxide) control is similar to seawater scrubbers that have been used in the world's largest power plants. We are still in the process of generating data, but our initial analysis indicates that we will be able to readily achieve SO_2 capture efficiencies greater than 90%.

We are also working on new systems that will control NOx compounds by converting NO (nitrogen monoxide) to NO_2 (nitrous oxide), serious greenhouse gases that are water-soluble and can be stabilized in our mineral product. A significant advantage of our carbonate mineralization technology is that scrubbing SO_2, NOx, particulate matter and other regulated air pollutants is not required in order for the process to capture CO_2. This robust feature is in sharp contrast to other CO_2-capture technologies such as those based on amine (MEA) and chilled ammonia, which require stringent control of SO_2 because it interferes with the absorption process. Therefore, to adequately compare carbonate mineral-CO_2 reduction to conventional CO_2-reduction methods would require that the cost and energy consumption of the additional SO_2 control be included with the conventional method for comparison sake.

Demonstration Plants

Calera's business model is focused on the global potential of our technology with a milestone-driven plan to demonstrate capture rate and scalability. Our plan calls for building one or more demonstration plants that capture and convert flue gas CO_2. These projects will benefit the socioeconomic status of the local communities by creating new jobs and business opportunities. Each plant will create 200-300 construction jobs over a 2-year construction phase. Job types required include pipe fitters, electricians, operators, carpenters, laborers, steel workers, ironworkers, mechanics, bookkeepers, and bookkeepers, clerical staff, among others. The completed facility will also provide new permanent jobs.

We have completed a substantial amount of laboratory and scaled batch-process development and have recently commissioned a continuous pilot plant at Moss Landing, Calif., producing an average of one ton of material per day (a photo of this site is attached at the end of this document). From there we can quickly scale up the process to 20-80 MW for demonstration at coal-fired, electricity-generating units and cement manufacturing plants. Though the capital expenditures on these demonstration facilities are lower than many other CO_2 mitigation technologies, they require investments in the tens to hundreds of millions of dollars — hence, my testimony today in support of a more balanced legislative language to foster the commercial development and scale-up of innovative technologies such as ours.

Our process converts CO_2 into carbonate minerals, thus permanently converting CO_2 into a stable mineral form. When compared to traditional CCS methods, this conversion technology does not require costly CO_2 separation or compression. Like any other manufacturer, energy is required to produce this product. Unlike other processes, our technology has the flexibility to capture CO_2 and produce products continuously, while shifting a large fraction of the electrical power consumption to off-peak hours. The shifting of power consumption is accomplished through energy storage in chemical intermediates specific to the mineral sequestration chemistry. By producing and storing these intermediates during periods of low power demand, this process not only avoids straining the grid, but also better utilizes off-peak sources of power such as solar and wind.

Calera's technology also reduces energy consumption and carbon footprint by utilizing power plant waste-heat for product processing. The use of waste heat is enabled by the process chemistry, which requires only low temperatures — in contrast to the very high temperature processes employed in the manufacture of other building materials. As a further means of reducing environmental impact, advanced versions of the process employ recirculation of process water. Although recirculation of process water may be desirable in arid regions, other process options under development may exploit synergies between the mineralization process and desalination technologies, resulting in improved economics for freshwater production.

Another key breakthrough of our technology is the capacity to incorporate solid waste normally bound for landfills into useful products. Waste (such as fly ash) or aluminum smelter by-products (such as red mud and other waste products) can be incorporated into this process.

Beyond Cement

Calera will be important and valuable to states producing and/or consuming coal as they attempt to meet future carbon capture and trading requirements. Calera projects will bring long-term benefits to the coal industry by allowing existing coal plants to continue their operations under new air compliance regulations and avoid shutting down plants producing electricity at the lowest cost. This will save jobs at coal plants, mining sites and in transportation. The low cost of implementing Calera's technology compared to other CCS technologies reduces the impact of new CO_2 regulations on the cost of energy and avoids leakage of U.S. operations oversees to countries that don't have CO_2 regulations.

By shifting the treatment of CO_2 from a pollutant that needs to be disposed at a high price, to a potential raw material for clean manufacturing, our process enables a sustainable and cost-effective capture of a significant portion of the anthropogenic CO_2. In fact, when factoring the long-term potential revenues, revenues from building materials, carbon incentives and water treatment using a carbonate mineral process will be offset by the cost of capturing a ton of CO_2.

Based on our current estimates for construction and operating costs, and our forecasts for the building material markets, we expect a payback period of less than 10 years. Furthermore, based on our experience we believe our costs will go down as we learn to build and operate our plants, to the extent that our payback period could be reduced to 7 years. In our two years of operation we have made significant progress in understanding the scientific and engineering tasks of building a full-scale plant. From a small one-liter batch process to a 1-ton per day continuous pilot plant, we have learned how to optimize our capture rates and reduce our footprint and costs. Our progress is supported enthusiastically by the scientific community, environmental groups, potential business partners and the public. However, as for any industrial large-scale process, the next step requires a large investment to build a full-scale plant confirming our commercial scalability. Furthermore, the urgency of the climate challenge calls for an accelerated development path that demands special investments and support.

Recommendations

Congress is working hard to address CCS and to rethink product manufacturing. We commend the Committee for acknowledging the importance of CCS and funding innovations in this area. However, current legislative language and government funding consistently targets geological sequestration, which disadvantages other CCS options. While we acknowledge the potential value of geologic CO_2 sequestration, we recommend placing other viable CO_2-sequestering technologies on an equal playing field with geological sequestration.

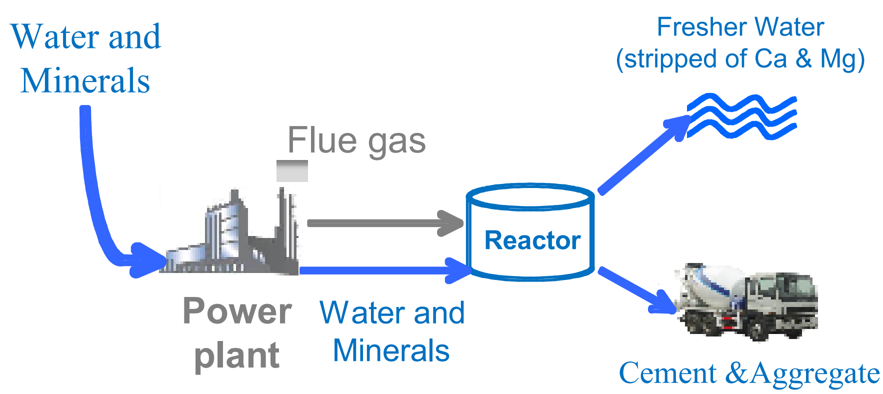
It is our hope that your committee will also consider supporting an independent assessment by the National Academy of Sciences that reviews the opportunities and challenges of beneficial reuse and carbon conversion as part of the larger national CO_2-reduction strategy.

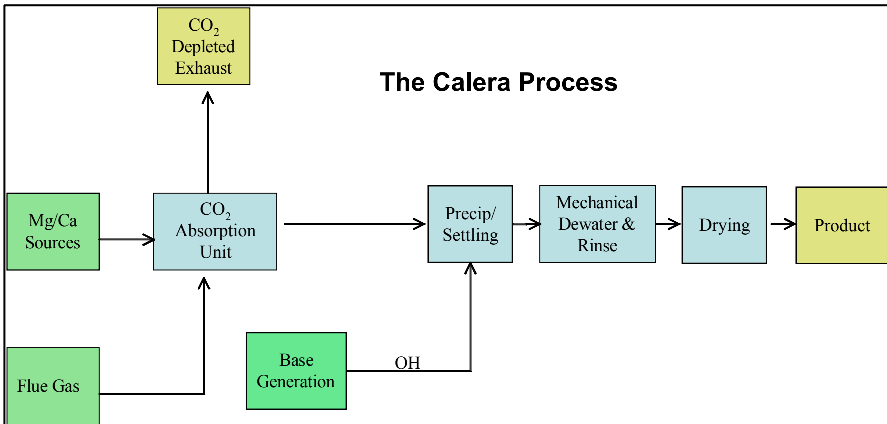
Calera is one of many breakthrough clean technologies that are evolving rapidly. Companies like ours need government funding to help move this process towards commercialization. It is in the best economic interest of our country to advance the most effective technologies over time by providing grants, loan guarantees, tax incentives and other sources of financial support. For this reason, I urge Congress to preserve our ability to move beyond existing carbon-sequestration technologies through broad statutory language that encourages innovation and rewards breakthrough technologies that are not yet, but may soon be, household names.

Finally, we seek federal government support because — despite the promise of technologies such as ours, the capital requirements are high in an extremely challenging macroeconomic environment and the risk of any new business venture is significant. The market for CO_2-reduction solutions such as ours is tremendous, but our product will take time and considerable capital to develop sufficiently in order to offset our development costs. Thus we need to scale up rapidly.

On behalf of Calera Corp. and our stakeholders, I respectfully thank Chairman Dorgan, Ranking Member Bennett, and Subcommittee Members for your time and consideration. We see an important new option with the recovery funding, and we thank the Energy and Water Subcommittee for providing us with this opportunity to explore with you the beneficial reuse of CO_2. The funding we seek could be both stimulating and transformative to energy policy, climate change, and the future of our economy. We look forward to working with the U.S. Congress and the appropriate committees of jurisdiction (i.e., Senate Energy, Senate Finance, and others) to ensure equitable policies are in place that provide federal support of CO_2-beneficial reuse technology.

The Calera Process: Mineral Carbonation





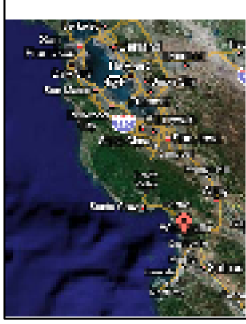
Basic Chemistry of the Calera Process

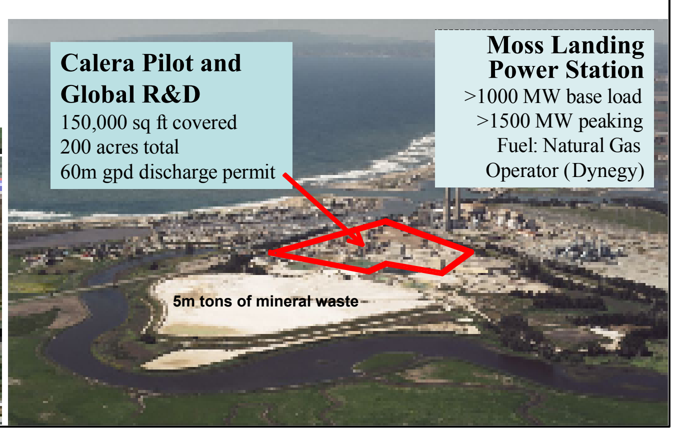
$$Ca^{+2} + 2OH^- + CO_2 \rightarrow CaCO_3 + H_2O$$

$$Mg^{+2} + 2OH^- + CO_2 \rightarrow MgCO_3 + H_2O$$

CA Pilots Validate Process, Product and Environmental Feasibility

- Pilot plants running large-scale batch and continuous processes
- Flue gas simulator ĞAbility to test any type of coal and flue gas composition
- Producing material for product development and testing
- Demonstration of waste mineral utilization
- Monterey Bay Marine Sanctuary requires highest level of environmental performance





Carbon Footprint Basic Calculation

Embodied CO_2 of Ingredient x Pounds of Ingredient (per cubic yard) → **Sum All Ingredients** → **Concrete Carbon Footprint**

First Carbonate Mineral concrete ĞJuly 2008

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decompressor
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