Clean Energy Systems, Inc.

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Date: August 20, 2007

To: Dr. Alan Loyd, Chair, ETAAC
Robert Epstein, Vice Chair, ETAAC

Subject: Carbon Capture and Storage (CCS) as a Game Changer

Dear Alan and Bob,

The attached paper describes the benefits that could be achieved with various carbon capture and storage (CCS) technologies. The Intergovernmental Panel on Climate Change identifies the GHG reductions that can be achieved with CCS to be of the same order of magnitude as conservation and energy efficiency; and renewable energy. CCS technologies should be identified as one of the committee's game-changers.

The paper provides an overview of carbon capture and storage technologies. In addition, it provides estimates of the potential CO_2 reductions by 2020 using various deployment schedules. These are representative quantities and can be scaled for other implementation schedules.

In discussing the specifics of the technology, I have focused on the oxy-fuel process used by Clean Energy Systems. The capabilities of our technology are similar to the other processes.

Finally, the most important message contained within the paper is that CCS technologies can be deployed today in the 50-150 MW size for commercial operation in 2010 if the proper regulatory incentives are provided to the investor owned utility companies. Encouraging California utilities to participate in the deployment of this technology will provide an appropriate signal to industry that there is a developing market for carbon capture and storage. Providing this market signal will facilitate the further development of the technology, lower its cost and bring the associated environmental benefits to California sooner than would otherwise occur.

Sincerely,

Leonard R. Devanna
Executive Vice President

cc: ETAAC committee members
Steven Church (ARB)

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Overview of Carbon Capture and Storage (CCS) Technologies As Potential "Game Changers"

Clean Energy Systems, Inc.

Carbon Capture Power Plant Technologies Overview

The substantial majority of power generated today in California and in the nation is produced by the combustion of fossil fuels. Because of availability and economics, dominance of electric power generation by fossil fuels will continue for decades, if not centuries. Traditional fossil fuels are burned in a "climate positive" environment whereby carbon, in the form of oil, gas and coal, is taken from the earth and discharged into the atmosphere as CO_2. As a result, the Federal and State governments have implemented various programs to encourage the use of "climate neutral" renewable fuels over fossil fuels.

Recognizing that fossil fuels will continue to be 40 percent or more of our power generation, the State should be advancing programs that will require that fossil fuels be used in a "climate neutral" manner. With "climate neutral" fossil fuel combustion, the environment would be indifferent as to the combustion of renewable or fossil fuels and greater CO_2 emission reductions could be realized. In addition, the combustion of renewable fuels, using the fossil fuels "climate neutral" technology, would result in a "climate negative" cycle that would actually be removing CO_2 from the atmosphere. This demonstrates the fact that the CO_2 levels in the atmosphere are not a result of the historic fuels used, but, instead, are a result of the historic combustion process used.

The historic combustion process has involved the mixing of fuels and air. Air is basically a mixture of oxygen and nitrogen. The oxygen, within the air, is necessary for the combustion while the nitrogen is tolerated since it is part of the air. However, the 79% nitrogen in the air is a detriment to the combustion process since it reduces cycle efficiencies; contributes to the formation of various pollutants, including NOx; and dilutes the CO_2 and other byproducts, making them increasingly difficult to remove from the resulting emissions stream.

There are three recognized processes for removing the CO_2 that are applicable to large scale power plants of several hundred megawatts. These processes capture the CO_2 in a manner whereby it can be permanently stored in existing oil/gas wells, coal seams and other geological formations. In addition, these processes have the potential to reduce or permanently eliminate the emissions of other pollutants into the atmosphere including NOx and particulate matter.

The three processes are post combustion, pre combustion and oxy-fuel. The post combustion process uses a chemical sorbent cycle to capture the CO_2 in the plant emissions stream. The CO_2 is then separated from the sorbent, processed into a high concentration gas/liquid and sequestered. The pre-combustion process involves reacting a fuel with oxygen or air and/or steam to create syngas composed of carbon monoxide and hydrogen. The gas is then reacted in a catalytic reactor resulting in a stream of CO_2, which is sequestered, and hydrogen-rich fuel gas that can be combusted. The oxy-fuel process combusts a fuel (i.e. natural gas, oil, bitumen, syngas, renewable fuels) in a pure oxygen environment. This results in an emissions stream of nearly pure CO_2 and steam. As this working fluid passes through a steam turbine/power generator, the steam condenses to water leaving a stream of concentrated CO_2 that can be efficiently processed and sequestered.

Each of these processes adds additional parasitic loads to the power plant that decrease the overall plant efficiencies. However, the plant emissions from each of these processes are zero or near-zero levels of CO_2 (i.e. ranging from 90 to 100% carbon capture). With the application of technologies used in related fields, one or more of these processes may result in the generation of zero emission power at the same price levels as that currently achieved with the most efficient power plants in use today. This is particularly true for the oxy-combustion carbon capture process.

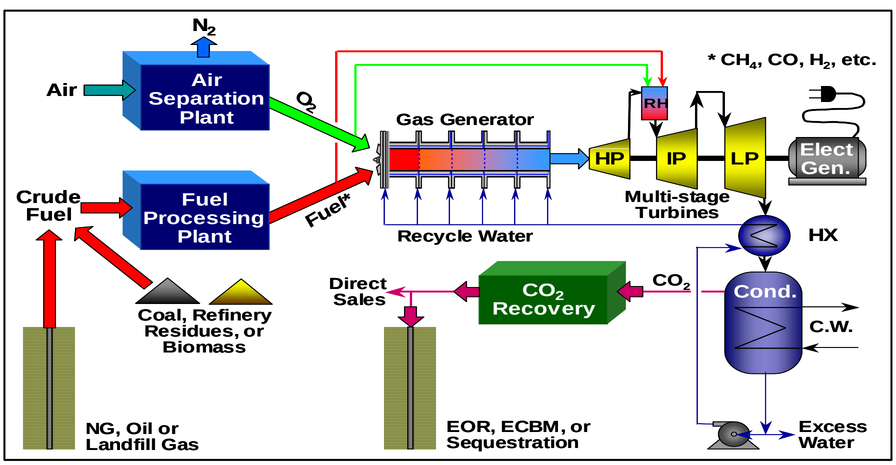
The CO_2 produced from these facilities can be sequestered in existing oil/gas wells and saline formations. In a large number of instances, the CO_2 can be sold to California producers to capture existing stranded oil quantities that are not economically recoverable with today's practices. In April 2005, the U.S. Department of Energy evaluated 90% of the State's oil resources to determine the potential increase in oil production that could be achieved if there were adequate quantities of CO_2 available to producers. Their study, Basin Oriented Strategies for CO_2 Enhanced Oil Recovery: California (http://www.fossil.energy.gov/programs/oilgas/publications/eor_co2/California_Document.pdf) concluded that "with the current high cost for CO_2 and uncertainties about future oil prices, only a very modest portion, 50 million barrels, of stranded oil would be economically recoverable, all from the San Joaquin Basin." However, with adequate supplies of CO_2, they estimated the potential recovery of 5.2 billion barrels. They further estimated that over 1 billion tons of CO_2 would be utilized. With California's current utility plant emissions of 56 million tons per year, this represents 18 years of emission storage. (Note that it is not economically feasible to gather the emissions from today's facilities and transport it by pipeline to the existing oil reservoirs. Instead, it is anticipated that a portion of the State's new generation will be located in the oil production areas and make use of the existing electric transmission system to deliver the power to the load areas.) In addition, existing saline formations within the State have the potential to sequester CO_2 in quantities one or more orders of magnitude above the storage volumes provided through enhanced oil recovery (EPR) opportunities. The West Coast Regional Carbon Sequestration Partnership (known as WestCarb), http://www.westcarb.org is a regional cooperative of the six Western states and one Canadian province that is evaluating the potential for storing captured CO_2 in secure geological formations.

The Intergovernmental Panel on Climate Change investigated the application of various carbon capture and storage (CCS) processes to determine their overall potential for reducing CO_2 emissions into the atmosphere. Their work can be found at: http://www.ipcc.ch/activity/srccs/index.htm . The overall conclusion from this study was that CCS alone could provide the same levels of emission reductions as that achieved by conservation and energy efficiency; and renewable energy.

Clean Energy Systems Overview

Clean Energy Systems (CES) was incorporated in 1996 with a goal to develop a more efficient and environmentally acceptable combustion technology by integrating proven aerospace technology into conventional power systems. In 1999, the California Energy Commission (CEC) awarded CES an Energy Innovation Small Grant to help pay for the construction of a laboratory scale oxy-fuel combustor. CES successfully tested the laboratory scale unit at which time the U.S. DOE funded the design and testing of a 10 MW gas generator. The CEC subsequently awarded CES a $4 million grant to demonstrate a natural gas fired zero emission power plant. CES now operates that unit at its Kimberlina Power Plant in Bakersfield, CA. The 5.7 MW plant serves as a demonstration facility for the CES technology. Using the oxy-fuel combustion process, the facility has utilized a number of fuels including natural gas, syngas (as derived from coal and petcoke), emulsified bitumen and renewable fuels. Current investors in CES are Southern California Gas Co., AES Corp., Paxton Corporation and Quadrise America.

The core of the CES process is an oxy-fuel combustor adapted from rocket engine technology. The oxy-fuel combustion is performed at near-stoichiometric conditions in the presence of recycled water to produce a high temperature, high pressure stream of CO_2 and steam. Fuels include natural gas, syngas from coal, refinery residues, biomass gas; and biodigester gases. The oxy-fuel combustor's inherent ability to produce and control high temperature steam is the key to achieving high efficiency levels. The fact that no atmospheric nitrogen is involved in the oxy-fuel combustion process virtually eliminates the production of NOx. The combustion products power conventional or advanced steam turbines or modified aero derivative gas turbines operating at high-temperatures for expansion at intermediate-pressures. The steam is then condensed leaving, effectively, a 100 percent CO_2 stream. The CO_2 is then processed and delivered to an oil producer for EOR operations where it is finally sequestered. There will not be any atmosphere emissions from a CES power plant since all of the combustion products are either removed in the cleanup process or sequestered. The CES process is shown below:



The CES Process

A Power magazine article describing CES' technology and facilities is greater detail can be reviewed at http://www.cleanenergysystems.com/news/june_07.html .

CES is currently developing a 50 MW Zero Emission Power Plant (ZEPP) that will be located at the company's Kimberlina facility. The attributes of the CES technology that make this project attractive are:

- the production of power, on a utility scale with zero atmospheric emissions
- addressing the demand for major quantities of CO_2 to meet the needs of the EOR market
- the permanent sequestration of the CO_2 in existing oil wells
- the commercial introduction of a zero emission combustion technology that utilizes multiple low cost fuels (i.e. petcoke , bitumen, renewable, etc.) in an environmentally acceptable manner
- integrating zero-emissions technology with traditional power plant components, making utility adoption more likely; and producing cost effective power for the benefits achieved.

The 50 MW size plant is the next scale up step that will eventually lead to much larger (i.e. 500 MW) zero emission power plants providing pollution free power from multiple fuels, including coal.

The CAL ZEPP-1 power plant will be supported by Power Purchase Agreement(s) (PPA) from one or more utilities, and term sheet negotiations are currently underway. In addition, the CO_2 will be sold under contracts to existing oil producer(s) and WestCarb. As described earlier, WestCarb is the US DOE funded sequestration project for the six western states and one province that will sequester one-million tons of CO_2 in existing saline formations. It is expected that the facility will be readily permitted due to it having zero atmospheric emissions. The target commercial operation date is mid 2010.

CES is also developing a second project in Southern California that will produce 50 MW of power with zero emissions to the atmosphere. The CO_2 will be sold to an existing oil producer. Since the 300,000 tons/year of CO_2 produced from a 50 MW plant operating on natural gas is the minimum quantity for an EOR demonstration project, if successful, additional units may be added. CES also has projects underway in Norway and the Netherlands and proposals under consideration in the Middle East.

GHG Emission Reductions Achievable from CCS Technologies

As previously described, there are several CCS technologies that can reduce the CO_2 emissions from existing and new power plants. These technologies are applicable to the combustion of fossil and renewable fuels. Since the actual CO_2 emissions savings is dependent upon the schedule by which the various technologies are deployed, it is difficult for CES to estimate the total reductions that could be achieved by using CCS in those installations/applications where it makes economic sense. However, CES can estimate the benefits that its technology would achieve if implemented in a reasonable schedule.

As an example, if California added 100 MW per year, starting in 2007 with the first commercial operations in 2010, the reduction in CO_2 and PM 10 emissions by 2020 would be 3.7 $MMTCO_2E$/yr and 121 tons/yr respectively. If a more aggressive schedule of 100 MW/yr for the first 5 years and 200 MW/yr for the following 6 years was followed, the 2020 reductions would be 5.7 $MMTCO_2E$/yr of CO_2 and 187 tons/yr of PM 10. Finally, if the State achieved zero emissions for 100 MW/yr in years 2010-2012, 200 MW/yr in years 2013-2015 and 500 MW/yr in 2016-2020; the annual reduction by 2020 would be 10.5 $MMTCO_2E$/yr of CO_2 and 374 tons/yr of PM 10. The above numbers assume natural gas is used as the power generating fuel. If petcoke or a similar fuel were utilized, the CO2 reductions would approximately double. Relative to the strategies identified as underway or to be initiated by ARB in the 2007-2009 periods, these are major reductions and have a high probably of being achieved.

Each of these schedules is technically and economically achievable. The level of GHG and PM 10 savings will be most likely dependent upon the time and effort that is dedicated to achieving “climate neutral” combustion process of fossil fuels as compared to only looking at the fuel source (i.e. renewable fuels) and accepting the traditional “climate positive” processes even when more beneficial climate alternatives are available.

The above implementation proposals are for only a fraction of the new power plants that need to be installed between now and 2020. While the logistics of power plant siting preclude all of the State’s generation from being located where EOR opportunities exist, a portion of the new plants can be located in these areas to achieve the significant environmental benefits that CCS offers.

Legislative and Regulatory Issues That Must Be addressed to Facilitate the Introduction of CCS Technologies

After the first oil price shock in the mid 70s, this country recognized the need to make energy efficiency, conservation and renewable energy cornerstones of future energy policies, legislation and regulation. At the time, products, services and technologies were generally not available to support the new energy policy initiatives. As a result, various energy programs were implemented that mandated the achievement of certain goals. The critical value that these programs provided is that they created a market for the development of new technologies. Without the mandated programs, the achievements that we have now realized in these areas would not have been realized as rapidly.

Today, CCS technologies are at the same place as the energy efficiency, conservation and renewable energy programs were over 30 years ago with two major exceptions. First, much of the technology to achieve CCS is available today. Second, the speed at which technology can be implemented today is much greater than it was 30 years ago. As a result, CCS technologies can begin providing significant environmental benefits within the next three years if appropriate investor owned utility incentives are put in place today.

The three basic actions that would accelerate the introduction of this technology are as follows:

1. The California legislature has identified two major policies for addressing the growing demand for energy. These policies are to promote energy efficiency/conservation and renewable energy as the primary means to address future demands. Each of these policies provides significant environmental benefits and should continue to be the first and second priorities in the electricity loading order. However, these policies do not address the GHG emissions from the combustion of fossil and renewable fuels. As a result, the State should implement the necessary policies to incentivize the development of CCS technologies in the same manner as energy conservation/efficiency was earlier accelerated. This can be achieved by providing "climate neutral" combustion a third legislated priority immediately after energy conservation/efficiency and renewable energy in the loading order.

2. California's investor owned utilities purchase the vast majority of power within the State. As a result, the California utilities, in cooperation with the CPUC, effectively control the technologies that will be developed since, without ownership by the utility or a Power Purchase Agreement (PPA), a power plant with its unique game-changing technology does not get financed or built. Currently, the California utilities are mandated to purchase renewable energy to meet 20% of their electric load by 2010. As a result, utilities have little incentive to consider zero emission fossil fuel power projects. This is a significant barrier since a project, such as a zero emissions power plant, if not owned by the utility must have a PPA to secure the necessary financing and demonstrate the technology. CES has found the California utilities to be open to new technologies, but concerned as to how to fit potential game-changing technologies within their portfolio when the technologies are not renewable. The CPUC should implement the necessary policies and programs to incentivize public utilities to assist in the development of new game-changing technologies.

3. The cost to produce power and sequester the CO_2 will, initially, be greater than the cost of power production only. To allow for the early introduction of this technology, regulators must provide further assurance to the investor owned utilities that these costs can be passed through to their customers. Otherwise, utilities will not accept the risk of the new technology knowing that it can be detrimental to their bottom line. With regard to CES' technology, there is a clear technology migration strategy that will lead to the cost of power from a zero emission facility to be equal to the cost of power from a non-sequestering facility. However, the migration to a lower cost of power is only achieved if a market for CCS technologies is created. Without energy regulators incentivizing the market for CCS technologies, the necessary technological advances will not occur in a timely manner and the public will be denied the resulting economic and environmental benefits.