Executive Summary

The "VCCS™ Cycle" – A Patented Technology for:

Carbon Capture & Sequestration
+
Coal Ash Management/Remediation
+
Recovery of Rare Earth Elements & Other Minerals

Introduction

Coal-fired power plants provide the largest portion of electricity generation worldwide, including in the United States. They have been a long-standing contributor in providing affordable and reliable electricity that enables high standards-of-living and are an "engine" for economic competitiveness and growth. However, the combustion of coal (or other fuels) in thermal power plants raises significant environmental issues, among them the emission of the greenhouse gas carbon dioxide (CO_2) and the generation of fly ash and bottom ash (commonly referred to as "coal ash"), which contain potentially harmful components (e.g., heavy metals) that may present risks to the environment and to human health—a subject of recent increased scrutiny by policy-makers, regulators and the public at large.

Expansion Energy's **patented "VCCS™ Cycle" technology** is a solution that addresses both of these issues, improving the "environmental footprint" of combustion-based energy systems and helping to keep them economically and politically viable by:

- **Capturing CO_2 emissions** and *permanently* sequestering them through **"mineralization"**; and
- **Processing coal ash** (and other forms of fly ash and bottom ash) in such a way that potentially harmful and/or economically valuable components can be safely removed and further separated, **yielding marketable product streams ranging from high-value "rare earth minerals" to "bulk" agricultural, industrial and construction materials**

The VCCS Cycle can be used to capture/sequester CO_2 from virtually any industrial- or utility-scale CO_2-emitting source, including, but not limited to, coal-fired power plants, gas-fired power plants, biomass-fired power plants, municipal solid waste incinerators, industrial boilers, refineries, cement-making plants and other manufacturing/processing plants.

The **VCCS Cycle neutralizes CO_2** (an "acid" on the pH scale) **by combining it with an alkali** (a "base" on the pH scale), **such as coal ash or other alkaline industrial wastes**, to form a solid mineral material (i.e., mineralization) in a manner that requires virtually no additional energy input. (See "VCCS Cycle – Process Description" section below.) VCCS uses processes and inputs that achieve final products which are dry (i.e., not messy or cementitious), flowable and easy to handle, store and transport.

Importantly, **VCCS *permanently* sequesters CO_2**—i.e., there is no chance for the CO_2 to later escape into the atmosphere, which is a weakness of other carbon capture technologies, such as those which create supercritical CO_2 that is pumped underground. Instead, VCCS's outputs are marketable products that require no underground sequestration.

Adding to its positive environmental attributes, in many instances, a substantial portion of the energy required to run the VCCS Cycle can come from the recovery of waste heat from the existing power plant (or other type of thermal plant) that produces the CO_2 and, to a certain extent, from the heat produced by the chemical reaction of the VCCS Cycle process itself. Thus, there is significantly reduced impact on power plant efficiency (or other plants' efficiencies) compared to other CCS technologies. In other words, unlike other carbon capture technologies, **VCCS is a minimal "parasitic load."**

For its alkaline input material, the VCCS Cycle can utilize/process any calcium-oxide-containing ashes, which includes nearly all types of ashes from coal, biomass or waste combustion. Instead of using fly ash or bottom ash, the VCCS Cycle can also utilize other alkaline industrial waste materials such as caustic "red mud" (bauxite residue)—a waste byproduct of the aluminum-making process—or alkaline byproducts resulting from agricultural and food processing operations.

The VCCS Cycle technology is patented in the United States (Patents No. 7,947,240; 8,252,242 and 8,501,125), Japan (Patent No. 4880098), Canada (Patent No. 2,739,743) and Australia (Patent No. 2009302737), and is patent-pending in other international regions.

VCCS is available for license from Expansion Energy to qualified end-users and energy/environmental systems manufacturers and EPCs. **Interested parties are invited to contact Expansion Energy for further information.**

VCCS™ Cycle Overview

Economically, technologically and ecologically feasible solutions are necessary to mitigate the volumes of CO_2 emitted into the atmosphere, and to manage/remediate the substantial fly ash/coal ash streams that result from the combustion of coal and other materials. Technologies that can also safely and cost-effectively extract the valuable minerals and other materials contained in ash waste streams (or other alkaline industrial waste streams) answer even more market needs. **Expansion Energy's VCCS Cycle serves all three of these market needs**, as well as other market needs and opportunities identified in subsequent sections.

VCCS provides a means for:

1. Capturing and *permanently* sequestering a substantial portion (or all) of the CO_2 emitted from a power plant or other type of CO_2-emitting plant.

2. Treating all fly ash produced at a coal-fired power plant, biomass-fired power plant, waste incineration plant or other type of thermal combustion plant to the point that its valuable and/or harmful components can be separated out, leaving an environmentally benign residual material that can be utilized for numerous "beneficial use" applications or safely landfilled.

3. "Harvesting" valuable minerals (such as rare earth elements, uranium, germanium, nickel, etc.) or other materials from the ash, which can generate substantial revenues via sale to the market.

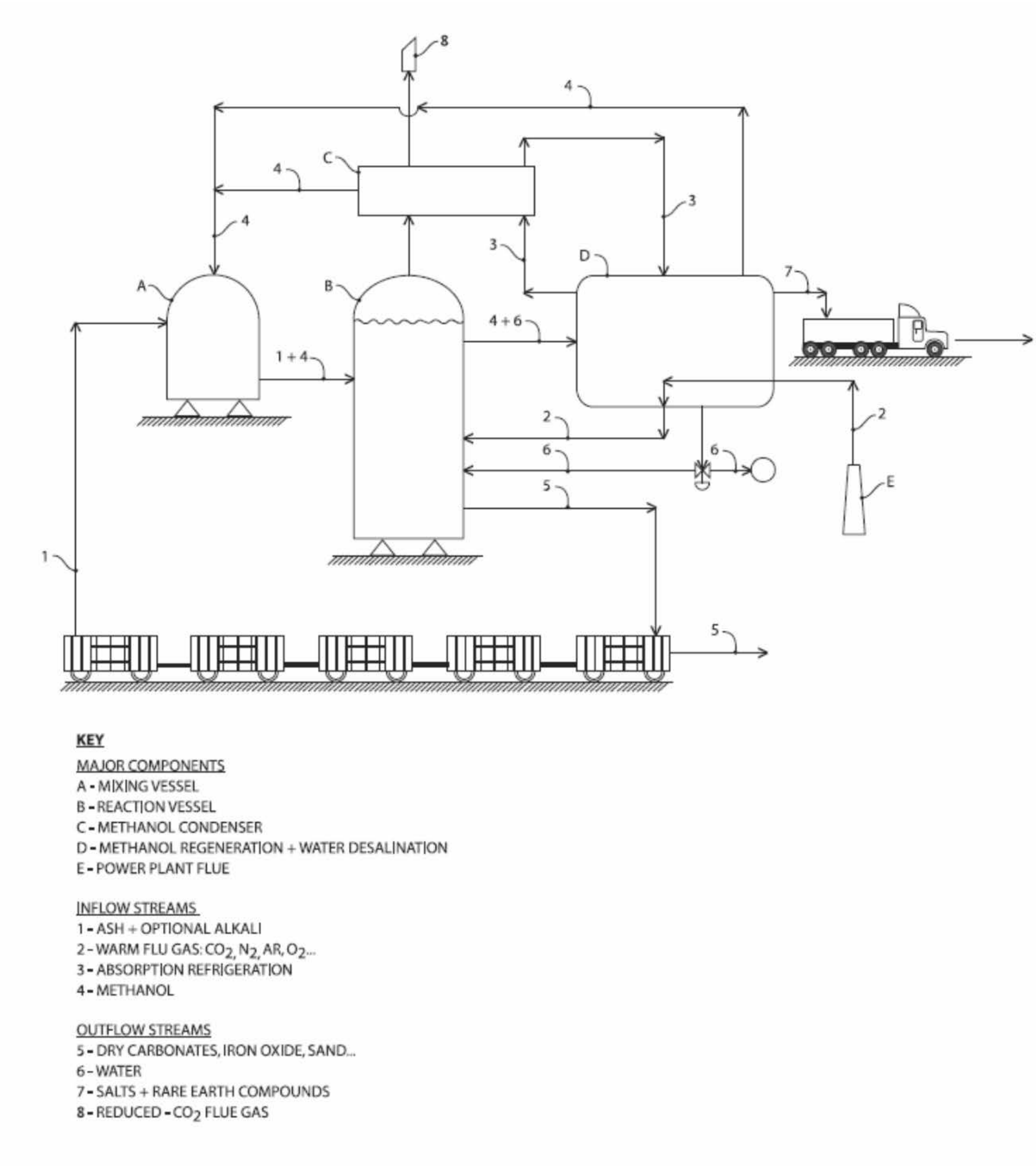
4. Producing safe (treated) bulk materials for numerous industrial and construction applications. Byproducts derived from the VCCS Cycle can also be utilized as agricultural (i.e., fertilizer) inputs and for the treatment of contaminated soils.

VCCS™ Cycle – Process Description

At its core, the VCCS Cycle process is **an acid + base (alkali) reaction** that primarily produces a carbonate, heat, and water, plus some residual materials such as iron oxide and sand. The "acid" source is moist CO_2 found in flue gas (e.g., a power plant's emission stream) and also in natural gas, landfill gas, and anaerobic digester gas. (See "Additional Applications for VCCS: Gas Clean-Up" section below.) The alkali (for example, calcium oxide (CaO)) can be found in fly ash (and bottom ash) from coal-fired power plants or other combustion plants, or from other alkaline industrial wastes (e.g., "red mud" from alumina plants or certain agricultural and food processing wastes). If desired, the CaO can instead be purchased from the market as a commodity. For most large-scale flue gas treatment applications, fly ash (including coal ash) is the preferred alkali source. For small-scale natural gas clean-up or "sweetening" applications of VCCS, purchased (essentially pure) CaO is usually preferred.

One of the innovative features of VCCS is **that the acid + base reaction is *not* induced in the presence of water**, which would create a "saltwater" reclamation problem and a difficult-to-handle (e.g., cementitious) material. Instead, the reaction is "hosted" in methanol. The water produced by the reaction is constantly removed by "methanol regeneration," allowing the continuous process to maintain its mostly non-aqueous (non-water) state, thus allowing the carbonates formed by the reaction to fall to the bottom of the reaction vessel with virtually no water absorbed by the carbonate. Because the recovered carbonate and residual material is dry (i.e., contains no water), it is powdery and "non-sticky," and requires no further processing in order to handle and store it.

Figure 1: VCCS Cycle – Process Schematic



Key steps of the VCCS Cycle process are as follows, referencing Figure 1 above:

1. Methanol is laced with the alkali in a mixing vessel (A), producing a methoxide solution, and sent to a reaction vessel (B).

2. The CO_2-carrying flue gas (and some moisture) from (E) is bubbled through the methoxide in reaction vessel (B), allowing for the acid + base reaction. Specifically, the acid CO_2 contained in the power plant's flue gas reacts with the alkaline calcium oxide and other basic metal ions in the fly ash (or other alkaline material), **resulting in inert materials such as calcium carbonate (limestone), iron oxide and sand**. Keeping the methoxide cold improves the efficiency of the process and counteracts the heat formed by the VCCS reaction. The pressure at which the CO_2-carrying gas enters the reaction vessel is also important. Higher pressure improves efficiency.

3. The wet (aqueous) methanol is continuously regenerated in (D), such that the water content in the reaction vessel is under certain limits. There are several well-understood methods for regenerating wet methanol, any of which can be utilized in VCCS. The patented VCCS system also includes a novel methanol regeneration step that uses refrigeration, which occurs in (D) before being sent back to (A) for further use. The recovered water from (D) can be used for industrial or agricultural purposes (after additional filtration).

4. The solid, dry carbonates that result from the acid + base reaction plus the residual sand and iron oxide are continuously removed from the reaction vessel (B), and are ready for use in the variety of industrial, construction and agricultural applications discussed in subsequent sections. Similarly, **recoverable metals are extracted from the ash stream** in (D), resulting in stream (7).

The CO_2 binding and minerals extraction **reactions occur on a short timescale (measured in seconds)**, making the Cycle suitable for large-scale fly ash producers, including virtually any coal-fired power plant or other type of combustion plant in operation today.

The flue gas (or other CO_2-carrying gas) that entered the system leaves without any CO_2. Thus, VCCS **thoroughly *captures* CO_2**. Just as importantly, the CO_2 is "mineralized" into a stable carbonate, which **permanently achieves the *sequestration* goal.**

VCCS Characteristics – Scalability & Flexibility

VCCS can be applied at any existing or new CO_2-emitting plant. VCCS deployments can be designed to work at almost any scale, and using a wide range of ashes or other alkaline materials. Whether VCCS captures 100% of the CO_2 emitted from any particular plant or only a portion of such CO_2 is merely a matter of scale and material balance, which can be selected according to the user's needs or preferences. Moreover, VCCS can be deployed as either a continuous process or as a batch process.

VCCS uses primarily basic process equipment which is in abundant supply at low capital cost and does not require long lead times—e.g., reaction vessels, blending equipment and augers, basic PLCs, standard piping, etc. No "exotic" equipment or materials are required.

Market Needs & VCCS Solutions

Carbon Capture & Sequestration ("CCS"). CO_2 is currently produced on a scale that affects global atmospheric chemistry and also acidifies all major bodies of water. Across the globe, nations and private enterprises are undertaking significant efforts to curtail emissions of CO_2 (a greenhouse gas), and are in search of cost-effective breakthrough technologies to achieve this without dramatically impacting standards-of-living or costs to industry. Efforts are underway globally to regulate/restrict emissions of CO_2 due to its greenhouse gas characteristics. This includes the U.S. Environmental Protection Agency's (EPA) new Clean Power Plan, which will restrict the amount of CO_2 that can be emitted by new (and potentially by existing) fossil fuel-fired power plants.

While many approaches to capturing CO_2 from flue gases (post-combustion) are being considered (and a few of them actually being deployed on a pilot scale), most of these approaches emphasize "capture" and offer little in terms of reliable and permanent "sequestration." Moreover, most other CCS systems (such amine-based and CO_2 compression approaches) consume large quantities of energy themselves, resulting in large "parasitic loads." Thus, there remains a substantial market need for CCS technologies that can efficiently and cost-effectively both capture *and* sequester substantial volumes of CO_2.

> ***VCCS Solution:*** *Expansion Energy's VCCS Cycle cost-effectively captures up to 100% of the CO_2 emitted by power plants and other industrial facilities, and permanently sequesters the CO_2 through a mineralization process. VCCS's energy input comes substantially from waste heat from the power plant (or other type of plant) where it is deployed and from the heat produced by the VCCS chemical reaction, so VCCS is not a significant parasitic load.*

Coal Ash Management/Remediation & Beneficial Use. In addition to post-combustion CO_2 released from coal, residual coal ash (and other forms of fly ash) presents its own environmental and waste disposal challenges, primarily stemming from potentially harmful components—such as mercury, arsenic, lead and heavy metals—that are typically found in coal ash. This material can leach into groundwater or surface waters, contaminating them and/or affecting pH levels, and can affect air quality.

Traditional approaches to dealing with fly ash waste (and other types of alkaline industrial waste) have mostly been rudimentary practices such as landfill disposal or long-term (essentially permanent) storage in wet ponds. In both of these approaches, it is almost always raw, untreated coal ash (or other alkaline industrial wastes) that is disposed of, which contains substantial amounts of potentially harmful materials. In the case of liquid coal ash storage ponds, if these ponds are breached, the coal ash slurry itself can present acute human and animal health risks and risks to property. The most glaring example of the risks associated with the traditional approaches to dealing with coal ash is the breaching of coal ash ponds at the Tennessee Valley Authority's Kingston Fossil power plant in December 2008. That spill caused acute and ongoing environmental damage and health risks as well as substantial property damage. It is estimated that the Kingston spill will ultimately cost $1.2 billion for clean-up and other liabilities. Over the past decade, smaller coal ash pond spills have occurred in Georgia, Pennsylvania and Wisconsin.

Due to potential environmental and human health risks, both of these traditional approaches to disposing/storing fly ash (particularly coal ash) are currently facing an increasing threat of regulatory and/or legislative action that would require more stringent regulation and processing of this material. The U.S. EPA and other regulatory entities have recently tightened coal ash disposal and storage regulations, and have even considered reclassifying coal ash as hazardous waste. These more stringent coal ash regulations increase the need for more advanced methods for its disposal and treatment.

While coal ash can (for now) be utilized in such "beneficial use" applications as road construction and cement-making, much of it continues to go to landfills (on-site or off-site) or to storage ponds. Moreover, more stringent regulations on fly ash could eventually restrict its utilization in the beneficial use applications for which it is used today.

> ***VCCS Solution:*** *The VCCS Cycle utilizes coal ash and other fly ashes as the alkaline material in its core chemical reaction. In the process, valuable minerals and/or harmful substances are extracted from the ash and can be separated for further processing/remediation and/or sale into the market. Thus, in addition to providing an additional revenue stream from the sale of minerals into the market, VCCS can eliminate the need for landfilling coal ash or storing it in liquid ash ponds, thereby reducing overall costs.*

Caustic Industrial Waste Management/Remediation. Like coal ash, caustic (alkaline) "red mud" and agricultural wastes can also be harmful to human health and the environment, when not properly managed/remediated. One example of this is the massive 2010 red mud disaster in Akja, Hungary, where a red mud storage reservoir adjacent to an alumina manufacturing plant ruptured and flooded about 40 square kilometers, killing nine people and injuring more than a hundred others. In addition to the acute effects on human safety and health, the spill also caused significant damage to waterways and soil quality in the area.

> ***VCCS Solution:*** *Similar to coal ash, the VCCS Cycle can utilize other alkaline industrial wastes (such as red mud or agricultural and food processing waste) as the alkaline material in its core chemical reaction. In the process, valuable and/or harmful substances can be extracted and separated for further processing/remediation and/or sale into the market. Thus, in addition to providing a potential additional revenue stream from the sale of extracted materials into the market, VCCS can eliminate the need for red mud storage ponds or storage/management costs related to other types of industrial alkaline wastes.*

Rare Earth Minerals & Other Valuable Minerals. So-called "rare earth minerals" (also known as "rare earth elements") are a group of 17 valuable minerals that have become an important topic in the past several years. These minerals are critical raw materials for advanced energy-saving, energy storage and energy generation technologies, such as hybrid cars, solar panels, wind turbine components/electronics and advanced batteries, as well as for many ubiquitous communications devices (e.g., smart phones and

PDAs), for medical applications (e.g., MRI and X-ray machines) and for critical military applications such as advanced weapons systems and "smart bombs." Global demand for rare earth minerals continues to rise substantially year over year.

Table 1: 17 Rare Earth Elements

Scandium	Promethium	Holmium
Yttrium	Samarium	Erbium
Lanthanum	Europium	Thulium
Cerium	Gadolinium	Ytterbium
Praseodymium	Terbium	Lutetium
Neodymium	Dysprosium	

Today, China is the world's dominant supplier of rare earth minerals—with a global market share of approximately 95%. This has begun to raise serious national security concerns related to over-reliance on China for critical raw materials used in military applications, in addition to major commercial and economic concerns regarding the reliance on China for strategic U.S. industries such as Energy, Communications and Manufacturing. For example, in April 2010, the U.S. General Accountability Office warned of "vulnerabilities" for the U.S. military due to a lack of domestic rare earth minerals supplies. Already China has begun to restrict the export of rare earth minerals to other countries, preferring instead to insist that those raw materials be used to manufacture value-added products within China itself.

In addition to rare earth elements, numerous other valuable minerals, including uranium, germanium, nickel, iron and lead, are also resident in coal ash. However, at present, these minerals are generally not extracted from coal ash, leaving the value of these materials "untapped."

> ***VCCS Solution:*** *Expansion Energy's laboratory testing has shown that coal ash produced in the United States contains significant quantities of most rare earth minerals as well as uranium, germanium, nickel, iron and lead. While no one harvests these minerals from coal ash today, Expansion Energy's VCCS Cycle technology lends itself to the cost-effective extraction of these minerals, which can subsequently be sold to the market. Thus, VCCS has the potential to turn coal ash from a "cost center" into a "profit center."*

Bulk Industrial & Construction Materials. "Bulk" raw materials for industrial uses and for use as construction and building materials are constantly in demand in high volumes. In addition to the rare, high-value minerals cited in the previous section, coal ash (or other alkaline waste sources) also contains significant amounts of bulk material that can be utilized for industrial and construction applications. Already today, coal ash is utilized for such "beneficial use" applications in some areas. However, untreated (raw) coal ash is coming under increasing scrutiny regarding its safety for such applications, and may become a more stringently regulated material in the future (possibly as a hazardous material), which would restrict its use for many application, unless it undergoes a remediation process.

"Artificial" limestone is one bulk material that can be derived from coal ash if it undergoes further processing, though this is rarely done today. Artificial limestone can be used as a substitute for virtually any application where "natural" limestone is used, including the following:

- Cement, mortar, aggregate, road fill and other building materials
- Fertilizer input
- Soil treatment/remediation (a conditioner to neutralize acidic soils)
- Reagent for flue gas desulfurization (reacts with sulfur dioxide for air pollution control)
- Glass making
- Blast furnaces (for steelmaking, etc.)
- Additive for paper, plastics, paint and tiles—both for white pigment and as a filler
- Re-mineralizing and increasing the alkalinity of purified water to prevent pipe corrosion and to restore essential nutrient levels

> ***VCCS Solution:*** *VCCS converts coal ash (or other alkaline industrial waste) into clean, non-toxic calcium carbonate—i.e., "artificial" limestone. Thus, VCCS produces bulk limestone that can be utilized as a raw material for any of the limestone applications cited above. Similarly, other bulk materials derived from VCCS's core chemical reaction, such as iron oxide and sand, can be used for their own industrial and construction applications.*

Fertilizer Inputs. Agricultural is ever-more reliant on advanced fertilizers to increase crop yields to feed a growing global population. The application of fertilizers requires high volumes of bulk fertilizer inputs blended into multi-ingredient formulations. Chemical reactions inherent in the VCCS Cycle process result in the production of fertilizer input materials—particularly calcium carbonate/limestone —which can be sold into large, ubiquitous and growing markets worldwide.

> ***VCCS Solution:*** *The "artificial" limestone (calcium carbonate) produced by VCCS can be used as a bulk ingredient for numerous fertilizer formulations.*

De-Acidification of Oceans & Other Bodies of Water. In addition to changing atmospheric chemistry, CO_2 emissions (an acid on the pH scale) from power plants and other man-made or natural sources have the effect of "acidifying" all major bodies of water, including the oceans, which absorb CO_2 emitted into the atmosphere. As much as 40% of man-made CO_2 is eventually absorbed by oceans, rivers and lakes. This negatively impacts aquatic organisms (fish, plants, shellfish, plankton, coral, etc.) and ecosystems, making habitat more acidic than many of these organisms can tolerate, leading to thinning populations and "dead zones."

To counter-act the effects of ocean acidification, safe/benign alkaline materials may be introduced into these bodies of water. Calcium carbonate—a non-toxic substance—is viewed by many marine scientists as the preferred material to introduce into select areas of the oceans and other bodies of water to de-acidify them. The alkaline calcium carbonate reacts with the acidic CO_2, thus neutralizing the water and providing a more normal and hospitable habitat.

Moreover, calcium carbonate minerals are "the building block for the skeletons and shells of many marine organisms." (U.S. National Oceanic and Atmospheric Administration, 2013) In areas where most marine life exists, elevated levels of calcium carbonate are present and necessary. In fact, calcium carbonate is a frequently used material for constructing man-made or re-constructed reefs that support aquatic life. The fact that increasing ocean acidification reduces the amount of calcium carbonate available to marine organisms further amplifies the need for new sources of calcium carbonate in oceans and other bodies of water.

> ***VCCS Solution:*** *Calcium carbonate is one of the main outputs of the VCCS Cycle. Thus, VCCS can "pay double" in mitigating the effects of CO_2 emissions—not just by capturing CO_2 at the emissions source itself (e.g., power plants), but also by converting that CO_2 into calcium carbonate which can be used to reverse the effects of CO_2 acidification in oceans and other bodies of water (whether nearby or far away from the CO_2 emissions source).*

Gas Clean-Up – An Additional Application for VCCS

The processing of natural gas and industrial gases often requires the feed gas to first be cleaned up by removing of CO_2, water, nitrogen, H_2S, and other impurities. Such impurities can affect the processing of the gas and/or the quality of the final products that result from such processing. Examples of where gas clean-up systems are needed include natural gas processing plants, LNG liquefaction plants, anaerobic digester gas (ADG) facilities, landfill gas (LFG) facilities, and plants that produce industrial gases. Thousands of such facilities exist worldwide.

Traditionally, molecular sieves or membrane systems have been utilized for gas clean-up in the above facilities. However, such systems are usually very expensive and are often not robust enough to handle feed gas that is particularly "dirty," such as field gas, ADG and LFG. If volumes are high enough, even relatively clean pipeline-quality feed gas can require further clean-up systems, which are complex and expensive, before such gas can be used for certain applications (e.g., for LNG production).

In addition to its applications for CO_2 capture & sequestration and for fly ash processing/remediation, Expansion Energy's VCCS Cycle is ideally suited for demanding gas clean-up applications such as those listed above. For such gas clean-up applications, the core VCCS process functions nearly exactly the same as it does for CCS and fly ash processing applications. Each VCCS unit can easily be sized appropriately for any particular volume of feed gas or for virtually any quality (i.e., level of impurity) of the feed gas.

Technology Validation

Laboratory testing and demonstrations of the VCCS Cycle using coal ash from US coal-fired power plants have validated the viability and efficacy of the Cycle. (Results of such laboratory testing are available on Expansion Energy's website.) These tests have also confirmed that methanol is a superior "host" material for the CO_2 + alkaline chemical reaction. Utilizing methanol as the host material yields a dry, powdery (i.e., flowable and non-sticky) slate of resulting products (carbonates, iron oxide, sand, etc.), and the methanol is easily recovered for reuse in the Cycle.

In addition, methanol has been shown to be an effective solvent for extracting a range of valuable minerals from the fly ash (or other alkaline industrial wastes), thereby making such separated minerals marketable, and substantially reducing (or virtually eliminating) the heavy metals load of the carbonates and other byproducts produced by VCCS.

Field demonstrations of the VCCS Cycle are planned for the near future, likely involving one or more potential users/licensees of the VCCS Cycle (e.g., coal-fired power generators, energy systems manufacturers, industrial recycling companies, gas processing companies, etc.).

Competitive Analysis: VCCS vs. Other Carbon Capture Technologies

Other pre- and post-combustion CCS technologies have been proposed—and a few actually deployed—for the large-scale capture and sequestration of CO_2. However, few such systems have been shown to be viable, either technologically or economically. A handful of projects are having economic success where the captured CO_2 can be transported by pipeline to nearby oil fields, where it can be sent underground for enhanced oil recovery (EOR). However, most large CO_2 emitters are not located near enough to oil fields for this approach to be viable for them. Thus, absent a nearby oil field suitable for EOR and absent an existing public policy framework that penalizes the release of CO_2 into the atmosphere, other proposed CCS systems generally do not appear to be able to stand on their own economically.

In contrast, VCCS yields multiple marketable products—each serving different applications and industries—which can be sold to generate multiple revenue streams. This helps make VCCS economically viable even in the absence of substantial revenues derived from the capture & sequestration of CO_2. Moreover, the marketable products produced by VCCS can be transported easily by truck or rail, and do not need an expensive, fixed pipeline system, which EOR requires. In addition, VCCS has the potential to derive revenues from the management/remediation of coal ash and other industrial alkaline wastes—a benefit and revenue stream that no other CCS technology offers.

In addition to advantages related to revenue generation, VCCS offers numerous other competitive advantages. The matrix comprising Table 2 below compares VCCS to the other main CCS technologies being promoted in the market today, using numerous criteria.

Table 2: VCCS Cycle vs. Competing CCS Technologies

	Amine-Based (Post-Combustion)	IGCC (Pre-Combustion)	Oxy Combustion	VCCS™ Cycle (Post-Combustion)
Can be retrofitted to existing CO_2-emitting plants	Yes	No	No	Yes
Stand-alone system; can be implemented incrementally	Yes	No	No	Yes
Applicable for CO_2-emitting plants other than power plants	Yes	No	No	Yes
Commercially viable at small scales (not just large scales)	No	No	No	Yes
Yields multiple marketable byproducts	No	No	No	Yes
Requires fixed pipelines to deliver marketable byproducts	Yes	Yes	Yes	No
Parasitic load (energy required from power plant or grid)	++++	+++	+++	+ or None
Delivers *permanent* CO_2 sequestration	No	No	No	Yes
Requires CO_2 to be stored underground	Yes	Yes	Yes	No
Requires compression/dehydration of CO_2 before storage	Yes	Yes	Yes	No
Requires sorbents, catalysts or other expensive materials	Yes	Yes	No	No
Requires steam for sorbent regeneration, etc.	Yes	No	No	No
Requires separation of CO_2 from O_2, N_2, SO_2, NO_2 in flue gas	Yes	Yes	No	No
Requires purification of CO_2 separated from flue gas	Yes	Yes	Yes	No
Requires production of syngas or air separation (ASU's)	No	Yes	Yes	No
Water consumption	+++	++	++	None
Water production	None	None	None	Yes
Size of "footprint"	+++	+++	+++	++
Specialized equipment required (few or single vendors)	Yes	Yes	Yes	No
Capital costs	$$$	$$$$	$$$$	$
Operating costs	$$$	$$$	$$	$

Future Goals & Near-Term Objectives

VCCS is available for license from Expansion Energy to qualified end-users and energy/environmental systems manufacturers and EPCs.

Expansion Energy is currently seeking opportunities to further demonstrate the core concepts of the VCCS Cycle, including additional technical analysis, economic feasibility studies, and demonstration/deployment opportunities. The company welcomes the opportunity to establish partnerships or alliances (including licensing of the VCCS technology) with organizations that have a strategic interest in the VCCS technology or in any of the challenges and opportunities it addresses.

Expansion Energy also seeks to establish alliances with coal-fired power producers, biomass generators and waste incinerators (which have fly ash needing to be managed/treated) as well as natural-gas-fired power producers and other combustion-based industrial plants whose plants can substantially reduce or eliminate CO_2 emissions utilizing the VCCS Cycle.

Similarly, Expansion Energy also seeks opportunities/alliances for demonstrating VCCS for gas clean-up applications. These may include gas processing plants, gas pipeline/midstream companies, LNG facilities, or LFG and ADG facilities.

A major goal of Expansion Energy is to dramatically improve the "environmental footprint" of fossil fuel energy systems such that they can cost-effectively meet or exceed any pending or future regulations restricting CO_2 emissions, and thus remain economically and politically viable. Expansion Energy envisions ultimately deploying the VCCS technology across the U.S. and globally at combustion power plants and waste incineration facilities (where substantial volumes of CO_2 and fly ash are produced), and at other types of power plants and industrial facilities where high levels of CO_2 are emitted. Early deployments may occur where environmental regulations related to coal ash or other alkaline industrial wastes are becoming more stringent.

A second main goal of Expansion Energy is to provide a sustainable and economic means for managing coal ash and other alkaline industrial wastes, while extracting valuable minerals from these waste streams. The company also envisions that VCCS will eventually enable a new and reliable source/supply chain for critical raw materials such as rare earth minerals, uranium, germanium, industrial and construction materials, and agricultural inputs.

Expansion Energy also anticipates that VCCS may become a widely used process for demanding gas clean-up applications, where traditional clean-up systems such as molecular sieves and membranes are too expensive or not robust enough to perform effectively.

Contact Information

Interested parties are invited to contact Expansion Energy by visiting the "Contact Us" page of our website (www.expansion-energy.com) or by emailing us at **info@expansion-energy.com**.