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Using Coal to create Alternative Energy Resources

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Low-Rank Coal-Water Fuel Commercial Demonstration

Coal: America's Only Strategic Fuel

Of all the world's fossil energy reserves, coal is by far the most plentiful. The energy represented by the known reserves of oil are only a small fraction of its coal reserves. Few would disagree that the ascent of the United States to the world's most powerful and affluent nation was made possible to a large degree by inexpensive energy (especially electrical power.) Proven US coal reserves are greater than all of the world's gas or oil reserves. US coal reserves are capable of fueling America's growing economy for hundreds of years, whereas many experts predict America's oil and gas reserves will be exhausted in a few decades. Domestic production of petroleum accounts for only 40% of America's annual usage, requiring imports of a massive 60%, much of it from countries with unstable or unfriendly governments. Thus, in the 21 st century coal will remain a key energy resource, and must therefore be used in an environmentally and economically responsible manner. Although coal is the only US energy resource abundant enough to be a strategic fuel, to maximize its potential it must also be made available in a liquid form for advanced combustion applications. Nearly half the US coal reserves are either sub-bituminous or lignite. Unlocking the full energy potential of these inexpensive sub-bituminous and lignite coal reserves is one of the critical keys to solving America's developing energy crisis. This synopsis outlines the process whereby the US can utilize a new technology to unlock the full energy potential of half of its coal reserves.

Coal's Poor Public Image

It is no surprise that coal is generally viewed as a "dirty" fuel given decades of poor coal mining practices, dust generated during handling and shipping, large unsightly coal stockpiles, and coal burning and coke production without emission controls. Despite many improvements (such as extensive mine land reclamation programs, advances in emission controls, and development of clean coal technologies) public perception has changed little.

Why is oil not viewed as a dirty fuel? The answer is simple: oil is used sight unseen.

Coal spilled in water is non-toxic and non-hazardous. It will settle to the ocean floor and form a carbonaceous substrate for marine growth. So why is it that coal is considered dirty, even though coal spilled in water is non-toxic and non-hazardous? Unlike oil, usage of coal is a highly visible and unsightly process. Americans regularly see massive trucks hauling coal to stockpiles, hundred-car trains hauling coal to ports for distribution or to utilities, and enormous stockpiles at coal-fired utilities. If, however, coal could be used sight unseen in today's modern utilities, public perception of coal as a dirty fuel would change. The Low-Rank Coal-Water Fuel (LRCWF) Project is designed to demonstrate the economic feasibility and environmental superiority of LRCWF as a low-cost alternative to oil while creating a coal fuel that can be used sight unseen.

Comparison of High and Low-Rank Coals

Almost half of the world's estimated coal resources, including those of the US, are low-rank coals (LRC), which are sub-bituminous, lignitic, and brown coals. The mine-mouth price for Low Rank Coal is typically less than half that of bituminous steam coal. The price advantage in favor of LRC has been offset by higher transportation costs to distant markets due to LRC's high moisture content and consequently low energy content, which until now limited most LRC use to mine-mouth power generation.

When the US air emission standards (which drastically reduced sulfur emissions) were first promulgated in 1970, utilities were faced with the decision to switch to low-sulfur coals or to add sulfur capture devices. Even more stringent new standards enacted in 1987 and 1990 have led to widespread switching from high-sulfur eastern bituminous coals to low-sulfur LRC. For example, in 2004 the amount of LRC mined in Wyoming's Powder River Basin reached nearly 400 million metric tons.

In terms of utilization, LRC is non-agglomerating and has more volatiles, providing faster ignition and virtually complete carbon burnout. Thus, from a power generation perspective, LRC offers the potential for higher efficiencies in both conventional boilers and advanced combustion and gasification systems. Many LRCs also have low sulfur contents, ranging from less than 0.2% to 1%. Low mining costs, high reactivity, and low sulfur content would make these coals premium fuels were it not for their high moisture levels, which range from 25% for sub-bituminous coal to nearly 40% for some lignites. Many major coal users mistakenly perceive high-moisture coal to be of inferior quality and overlook the many positive features of LRC.

Coal-Water Fuels

Coal-water fuels were developed in response to the oil crises of the 1970s and early 1980s and led to a new industry that produced a low-cost alternative to imported oil. Today's coal-water fuel (CWF) industry uses expensive bituminous coals that are formulated with water, using costly proprietary additives, to produce dense CWF. Due to its low inherent moisture, bituminous coal can be used directly without moisture reduction to prepare Coal Water Fuel; however, since bituminous coal is hydrophobic, it tends to settle rapidly. Because of its settling tendencies and high viscosity in water, bituminous CWF requires costly additives to reduce viscosity and provide stability. The high cost of bituminous coal and required additives coupled with the oil glut in the 1990s led to decreased interest in CWF in North America. Canada, the world leader in CWF technology in the 1980s, has no CWF producers today; however, Japan, which must import all its oil and is concerned about the security of oil suppliers, has developed a commercial bituminous CWF industry.

Burning Coal-Water Fuel (CWF) is essentially burningbituminous coal with its inherent strengths and weaknesses. Most work on bituminous CWF production in North America focused on increasing the solids content and improving viscosity; little attention was paid to the combustion characteristics. Consequently, the initial tests with CWF were plagued by poor atomization, particle agglomeration, and incomplete combustion. Because most bituminous coals swell and go through a plastic state when heated, they tend to agglomerate, producing particles many times larger than the initial feed. Ash coatings form around the unburned carbon and the agglomerated particles burn slower and not as well as single particles. Agglomerates also lead to erosion problems in the convective sections of boilers and to a significant **'boiler derating'; however, after the Department of Energy and Japanese CWF developers spent millions of dollars developing new atomizers for bituminous CWF, tests in large oil-fired boilers that employed relatively long residence times achieved acceptable carbon burnout and launched the CWF industry.

(**Boiler derating is a value that quantifies how well a replacement fuel performs in providing the same energy as the original fuel. For example, if the maximum amount of replacement fuel that can be used in an oil-fired boiler provides 75% of the energy that the original oil does, then the replacement fuel has a 25% derating. Obviously, low derating numbers indicate better substitute fuels. Derating is based on combustion-related characteristics such as the speed of ignition, completeness of carbon burnout, particle size and agglomeration, etc.)

The Search for a Low-Rank Coal Utilization Technology

High moisture content has been the major obstacle to the wide-spread use of Low Rank Coals. Over the last 40 years LRC researchers around the world have investigated virtually every low-rank coal drying technology conceived. The driving force behind this research was the desire to develop an economical drying method that would produce a dry and stable LRC that could withstand the rigors of shipping and compete with bituminous steam coal. Any LRC can be dried to virtually 0% moisture using hot flue gases to evaporate the coal moisture. These processes cost the least due to the low temperatures used, and are preferred if the dried product is for immediate use; however, evaporative drying temperatures are too low to cause permanent changes in the coal structure. As a result, evaporative-dried LRC behaves like a sponge, reabsorbing lost moisture when exposed to humidity or water. Another drawback to evaporative-dried LRC is that it is more friable than raw LRC, rapidly degrading into dust, and thus making it more susceptible to spontaneous combustion and

even explosion.

The Breakthrough: Hydrothermal Treatment

Of all the low-rank coal drying technologies assessed, Hydrothermal Treatment (HT) is the most promising. All other low-rank coal-drying processes are designed to produce a dried low-rank coal. In contrast, the HT process produces a liquid fuel with inherent benefits of liquid handling, transportation, and storage and also eliminates the stability problems that have plagued the traditional use of dry LRC. Hydrothermal Treatment is an advanced technology that features a process of moderate temperature and pressure non-evaporative drying that irreversibly removes much of the moisture from Low Rank Coal. The HT process is particularly effective for producing a concentrated low-rank coal-water fuel suitable for many liquid fuel applications. Hydrothermal Treatment allows LRCWF to be produced that has a solids content rivaling those obtained with bituminous coal-water fuels. Unlike bituminous CWF, which requires the use of costly additives, LRC characteristics retained during HT make additives unnecessary. LRCWF is a non-hazardous, easily transportable liquid fuel that avoids the dust-generation and spontaneous combustion problems associated with LRC handling, storage, and transportation.

In comparison to bituminous coals, LRC has clearly superior combustion characteristics B ituminous coal agglomerates into larger and slower burning particles when heated. In contrast, LRC has more volatile matter and when heated blows apart into smaller fragments, exposing tremendous surface areas, which leads to superior combustion. These LRC properties lead to rapid ignition and nearly complete carbon burnout. In addition, much of the mineral matter (ash) in LRC is inherent. It is molecular in size and bonded to the organic structure of LRC or exists as minute grains of minerals finely dispersed throughout the coal. This mineral matter is so fine that it easily follows the hydrodynamic flow and does not impinge on the heated surfaces, thereby greatly reducing erosion and fouling. LRC’s high reactivity, rapid carbon burnout, and small-sized ash ensure superior LRCWF combustion. In all reported combustion tests, LRCWF always burned substantially better than bituminous CWF.

In a joint research project (supported by the US Department of Energy and the Alaska Science and Technology Foundation) test quantities of LRCWF were produced from Alaska's Beluga coal in a pilot plant and burned in a test boiler. The Beluga LRCWF proved to be an excellent fuel, having less than 4% ash and only 0.07% sulfur. Carbon burnout rated “excellent” at over 99.8%. Gaseous emissions monitored during the test registered extremely low levels of SO_2 in the flue gas and reduced NO_x (Nitrogen Oxides) compared to burning the coal in its raw form. Likewise, substantially less LRCWF ash deposition was created compared to burning the parent coal. Further, the LRCWF ash deposit was softer, which permits easy removal by normal soot-blowing operations. Other Low Rank Coals from around the United States have been shown by bench-scale testing to be good candidates for processing into LRCWF.

The technical feasibility of HT has been demonstrated in small pilot plants in Australia, Japan, and the US. Over a dozen LRCs from the major deposits around the world have been processed. They all responded favorably to HT and produced LRCWF that could be burned without the addition of any supplemental fuel. As a general rule, the increase in energy density for LRCWF versus coal water slurries prepared from untreated coals are 30% for sub-bituminous coals, about 50% for lignites, and well over 100% for brown coals, peat, and biomass.

Low-Rank Coal-Water Fuel’s Environmental Premium

For a product to compete successfully with petroleum-derived fuels, it is not enough merely to be priced lower. Other advantages must be offered for users to consider switching to a new fuel. LRCWF has many important environmental advantages associated with its production and use. One of LRCWF’s most important environmental attributes is its non-hazardous nature in the event of spills. This property alone will be a significant factor in the acceptance of LRCWF as a replacement for fuel oil. Another advantageous attribute of LRCWF made from sub-bituminous coal and lignite is its relatively low-sulfur content. As US utility companies strive to comply with new clean air regulations, they are faced with the decision of either adding expensive sulfur emission clean up equipment or switching to lower sulfur fuels. Finally, when LRCWF is burned, its inherent water moderates combustion temperatures and eliminates hot spots, thereby reducing thermal NO_x.

In comparison to using raw LRC, LRCWF provides the opportunity to economically recover CO_2 (carbon dioxide) and reduce greenhouse gas emissions. CO_2 emitted during combustion is only a fraction of the flue gas, due to N_2 dilution from combustion air. Carbon in the coal that exists as oxygenated species contributes little or nothing to coal’s energy content but adds to the amount of CO_2 released during combustion. During Hydrothermal Treatment much of the oxygenated carbon species are released as CO_2. Since this off-gas stream typically consists of over 95% CO_2, it can be recovered far more easily and inexpensively at this phase of the HT process than as CO_2 from exhaust flue gas streams, which have been greatly diluted by N_2 in the combustion air. Since many likely LRCWF production sites are near oil fields, the recovered CO_2 may well have a value for use in enhanced oil recovery.

Unprocessed LRC has a water content of approximately 25% to 40%. All water that is initially separated from the LRC during the Hydrothermal Treatment will be captured and recycled to formulate the liquid LRCWF. Thus, all LRCWF production plants will be zero aqueous discharge facilities.

Estimated Commercial Low-Rank Coal-Water Fuel Costs

The pro forma calculations for a commercial production LRCWF plant located near a mine are based on a 10 million BOE per year of LRCWF. This number was the chosen basis in order to take advantage of economies of scale and to be large enough to obtain a favorable long-term LRC purchase price agreement. This size would service the (oil-fired) electrical industry in a meaningful manner while still providing enough LRCWF to feed a Texaco Gasifier for the production of jet fuel and a myriad of other exotic fuels and products.

Low-Rank Coal-Water Fuel Market Potential

Low-Rank Coal-Water Fuel offers the potential to reverse the trend of declining US coal exports while increasing employment opportunities by creating a value-added product from coal, the US's most abundant natural resource. LRCWF will permit LRC to compete in the more valuable oil marketplace, rather than the thermal or steam coal market. LRCWF could be transported by pipeline, semi-tractor trailer, or rail to barges for delivery to oil-burning utilities in Florida, other Gulf Coast states, and the Northeastern United States, or to maritime tankers for export. LRCWF would create new market opportunities without the environmental hazards associated with oil or bulk coal handling and transportation.

The huge market potential for LRCWF in the Gulf Coast region alone can be appreciated by examining the magnitude of petroleum-derived fuel use in utility and industrial boilers. Florida utilities are by far the largest consumer of oil for power generation in the US. In 2001 Florida utilities consumed over 65 million barrels of petroleum-derived fuels. Industrial oil use is much larger, but more difficult to quantify since most of it is used in the petrochemical industry. Nevertheless, although only 25% of the industrial oil use in Texas and Louisiana is for process heating and power in industry, it amounted to over 196 million barrels of oil in 2001.

Another unique property of LRCWF is that it will not burn in open air. It is non-flammable except when injected into a preheated boiler, gasifier, or heat engine. Thus a tank farm of LRCWF cannot be set ablaze. This safety feature may be a consideration for LRCWF use in other applications. For example, military bases at home or abroad can be provided with an environmentally friendly and less expensive energy source for installation heating and electricity, as well as a non-explosive fuel at base locations that might potentially be subject to terrorist attacks.

Another advantage to LRCWF is that it can be transported via any of the thousands of miles of existing fuel-carrying pipelines throughout the US. Further, if a pipeline carrying LRCWF is ruptured, whether by a natural disaster or a terrorist act, it will not result in a fiery explosion.

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The next step in commercializing the promising Low-Rank Coal-Water Fuel technology is the construction and operation of a commercial demonstration-scale LRCWF production facility. The first nation to build the world's first and probably only LRCWF demo plant will be the industry leader and have the opportunity to test LRC from around the world. Silverado has formed a team of the best LRCWF experts in the world and has developed a design for a 120-ton per day LRCWF production plant that can be operated 24/7 for weeks at a time. Construction of the facility and conducting the entire LRCWF commercial demonstration project will cost approximately $26 million and require less than 36 months to complete.

The primary objectives of the LRCWF production and utilization demonstration are to:

- Validate the process on a commercial scale and develop scale-up parameters;
- Determine the derating when switching from oil to LRCWF in commercial oil-boilers;
- Accurately establish process and commercial production costs; and
- Produce thousands of tons of LRCWF for independent end-user testing.

Project Expectations

The technical feasibility of producing and utilizing a premium Low-Rank Coal-Water Fuel made from ultra-low-sulfur Alaskan sub-bituminous coal following hydrothermal treatment has already been successfully demonstrated on a pilot plant scale. In follow-on combustion tests, this LRCWF produced excellent results. Fouling was minimal, carbon burnout was exceptional,

and SO x emissions (sulfurous oxides) were below even the most stringent requirements. Process economics suggest that Low-Rank Coal-Water Fuel can be commercially produced from Mississippi (or other Gulf Coast states') Lignite for about $11 per BOE, from Alaskan Low-Rank Coal for approximately $13 per BOE, and from Montana/Wyoming Low-Rank Coal for approximately $10 per BOE.

This demonstration project is the culmination of years of extensive planning and research, and the work of a world-class team of scientists and experts, headed by Dr. Warrack Willson, a world-renowned leader in the field of Low Rank Coal processing; Silverado Green Fuel, Inc. is absolutely confident of the success of this LRCWF Commercial Demonstration Project. Silverado Green Fuel, Inc. believes that this successful demonstration will lead to the creation of a new industry that produces millions of tons of Low-Rank Coal-Water Fuel from sites across the United States. This will provide the United States a secure supply of a non-hazardous, low-cost substitute for petroleum fuels used in industrial and utility boilers. Such a secure domestic supply will preclude the price volatility inherent in the oil market controlled by OPEC. LRCWF technology will also be available to assist developing nations in using their indigenous LRC in an environmentally sound manner.

The Low-Rank Coal-Water Fuel Commercial Demonstration Project will establish the United States as the world leader in this exciting new industry, and provide the means to inexpensively create a high-demand, value-added product from America's most abundant fossil energy resource. The LRCWF Commercial Demonstration Project will also pave the way for the United States to once again become a major exporter of coal products and decrease our nation's dependence on imported oil.