Engineered Coal Fuels ~ New Cost Effective Technologies are Available Today to Help Utility & Industrial Consumers Meet New Environmental Regulations

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Utilizing new Engineered Coal Fuels, opportunities exist today to generate economically viable and environmentally compliant electricity from coal. These new "prior-to-combustion" solutions substantially extend the scope of traditional coal preparation. Numerous processes are now in operation or under development to treat and enhance coal before combustion to better match power plant design specifications, increase efficiency and reduce emissions. Engineering coal's characteristics prior to combustion results in improved energy conversion efficiency and environmental performance and can mitigate the need for costly post-combustion environmental clean-up. Engineered Coal Fuels have been able to demonstrate lower SO_2, NO_x, CO, mercury, chlorine, dioxin and/or CO_2 emissions, in some cases sufficient to meet new US multi-pollutant regulations. In combination with other emission abatement technologies, Engineered Coal Fuels provide new opportunities for solving the emission puzzle.

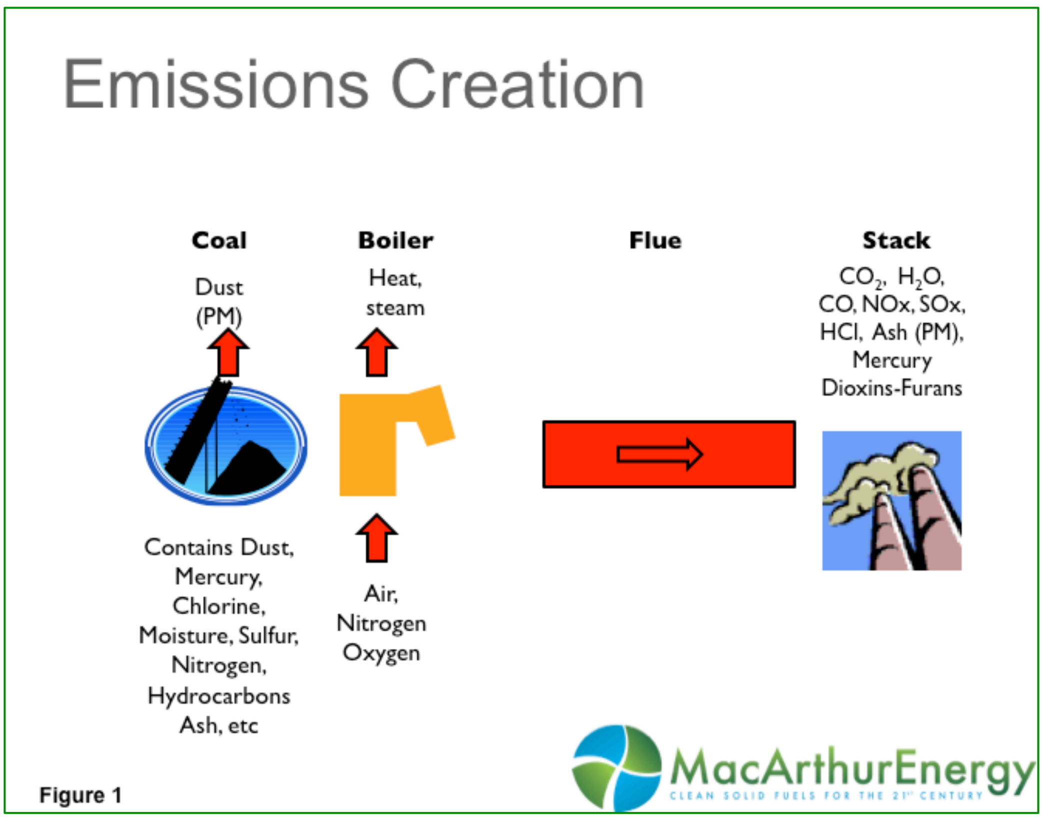

Figure 1

Coal is a mixture of biomass and mineral substances that has been subject to Mother Nature's conversion process involving heat and pressure over a long period of time. As seen in Figure 1, coal contains moisture, hydrocarbons, and ash consisting of various minerals including rock, sand, and wide range of other metals and materials.

In a typical combustion process, the moisture turns into water vapor, the hydrocarbons turn into water vapor and carbon dioxide and, while some of the ash falls to the bottom of the furnace, the rest is turned into various airborne emissions. This coal combustion process normally adds ten pounds of air to each pound of solid fuel, thus producing flue gases with more than ten times the volume and mass of the original fuel. Finally, the heat of combustion causes other chemical reactions, combining substances in the fuel with substances in the air, producing additional emissions of acid gases as well as dioxins and furans. Government authorities in various world jurisdictions regulate or are seeking to regulate many emissions including dust and ash particles, sulfur, nitrogen/oxygen compounds, mercury, dioxins and furans, hydro-chloric acid (as a surrogate for many acid gases), carbon monoxide (as a surrogate for organic compounds) and carbon dioxide.

By the 1940's and 50's, many industrial cities burning significant volumes of wood and coal for combined heat and power were inundated with noxious smog. This was notoriously true in London and Pittsburgh, but many other cities as well. This smog was largely ash in the form of fine particulate matter that was produced in the combustion process. Since the smog was generated in the combustion process, there was no way to remove it through pre-combustion treatment of the fuel. Filters, bag houses, and electrostatic precipitators were thus designed to remove the ash of particulate matter from the flue gases on a post-combustion basis and proved to be very effective at reducing smog and cleaning up our air.

Later, when acid gases of sulfur, nitric oxides, and various forms of mercury were deemed to be pollutants, industry again turned to post-combustion treatments to reduce these emissions. Because of the 10-to-1 ratio of added air, post-combustion technologies must treat 10 times the volume of material to remove effluent, than if the fuel could treated before combustion.

As regulations have tightened over the years, it has become more and more costly to scrub flue gas for smaller and smaller concentrations. In some cases, scrubbing for a series of emissions such as particulate, SOx, NOx, and mercury has created conflicts between various flue gas scrubber technologies that degrade their efficiency. These effects have also impacted public policy efforts to promulgate new air regulations.

Engineered Coal Fuels include:

- Coal Preparation ~ This most widely used form of pre-combustion treatment involves cleaning coal via a wet, dry or chemical process to lower ash and reduce certain chemical elements that generate post-combustion emissions.

- Coal Upgrading/Drying ~ Coal upgrading technologies primarily remove moisture from lower-ranked coals, thus increasing the energy density (Btu/lb) of the enhanced product and reducing regulated and CO_2 emissions.

- Coal Treatment ~ These technologies use additives to alter the coal's combustion characteristics, resulting in beneficial emissions reductions.

- Biomass-Coal Blends ~ Combining coal and biomass into a homogeneous product results in a higher heat content, improved efficiency and a renewable component (biomass) that enhances environmental performance without costly plant modifications or down-rating from loss of mill power.

Prior to combustion technologies afford us the opportunity to more closely align the combustion characteristics of a specific fuel with the boiler in which it is to be fired. This improves efficiency, saving both cost and fuel, and helps reduce criteria and greenhouse gas emissions. See Figure 2 for a comparison of pre-combustion, during combustion, and post-combustion technologies. To be efficient and practical, the new clean coal paradigm must include pre-combustion technologies to remove non-fuel substances from the fuel, mid-combustion technologies to mitigate unwanted emissions that are created in combustion, and post-combustion treatment for emissions that can be efficiently removed at the late stage.

Clean Coal Technologies

Existing coal generating plants

Pre- Combustion	Inside Boiler	Post Combustion
Moisture	Carbon Monoxide	Ash and dust
Chlorine	Nitrous Oxides	*Chemical injection*
Mercury		Mercury
Heavy metals	*Chemical injection*	Acid Gasses
Sulfur		Sulfur Oxides
Nitrogen		Nitrous Oxides
Increases efficiency	**May impact efficiency**	**Reduces efficiency**
Reduces CO_2		Increases CO_2

Increasing costs →

Figure 2

Engineered Coal Fuel Solutions

Our coal energy industry has been hampered by the blinders of two historical activities: first, we generally accept coal as-mined and second, we try to manage consequences post combustion. However, engineers know that optimum results are obtained by evaluating an entire process from raw material to the delivery of value added products. In nearly all cases, cleaning the raw material improves the efficiency of the process and reduces the amount and cost of by-product waste. The coal energy objective is to efficiently produce heat and power from the hydrocarbons in the coal. The specific conversion process such as combustion, fluidized bed, oxy-combustion, liquefaction, gasification, or chemical looping combustion is largely irrelevant to the evaluation of inputs and outputs to seek greater efficiency. There follows a review of by-product issues where Engineered Coal Fuel solutions may pertain.

Particulate – this comes from 2 sources: coal or ash dust pre-combustion; and fly ash or unburned carbon as a result of combustion. The pre-combustion PM will never be addressed by fabric filters or ESP, but must be addressed by controlling fines in raw fuel, washing, screening, and the enclosure of crushing, conveying, and pulverization. As to the second source, tuning the combustion, and the addition of combustion catalyst can reduce fly ash, UBC, and lower the operating costs for PM removal from flue gas and disposal.

Ash - is the non-combustible part coal that makes up most of the bottom ash in the furnace. A cement producer may want to maximize ash as a part of his raw material for making cement, but most energy producers improve efficiency with lower ash. Ash specs on raw fuel purchasing are important, but one can also use flotation or fluidized bed gravity separation as prior-to-combustion technologies to reduce ash in the fuel as fired.

Moisture – is not a regulated emission, but is a significant impediment to efficient energy production. For our purposes, there are two issues: one, water does not burn, and two, it takes a huge amount of energy to evaporate water. The energy leak of a moist fuel uses extra fuel and puts more emissions into the atmosphere per unit of energy production. Coal upgrading and drying removes moisture before combustion. It can also recover the moisture and convert it into a valuable resource in arid regions. Water recovery is far more costly when trying to condense the water vapor out of flue gas, than removing it from the raw fuel.

Mercury – is present in coal in varying amounts, but the emission of mercury is restricted in many jurisdictions. Gravity separation has been shown to remove ash containing higher levels of mercury, thus reducing the amount in the combustion flue gas. Coal upgrading/drying can also remove mercury through thermal treatment and recover it as a valuable by-product before combustion. Once coal with mercury is combusted, the emissions vary significantly depending on the level of chlorine in the coal, thus making post combustion removal more variable. Post combustion mercury control can also make fly ash unsalable as a by-product.

Chlorine – in coal and biomass is present in either organic or inorganic varieties. Inorganic salts of sodium chloride, calcium chloride, etc. can often be removed or reduced with pre-combustion washing. Inorganic chlorine is removed via thermal coal upgrading/drying. If left in the coal for combustion, salts can reduce ash fusion temperatures and lead to boiler slagging. This result can often be mitigated with combustion catalyst additions. Combustion in the presence of chlorine also generates dioxins and furans, complex chlorine compounds that are now the subject of new regulations. When dioxins and furans are in parts per billion of flue gas, the detection and removal becomes very expensive and makes prior-to-combustion removal more attractive. Higher levels of chlorine in the presence of water vapor can generate hydrochloric acid and cause extensive boiler corrosion. High maintenance is such situations often demand prior-to-combustion removal of chlorine from coal. On the post combustion side, wet scrubbing for oxides of sulfur can also remove hydrochloric acid.

Sulfur – is present in most coals in widely varying concentrations. The most cost effective prior-to-combustion removal method is gravity separation. When separation is done on a fluidized bed with hot flue gas for agitation, the fuel is also dried, while mercury and sulfur are both reduced. Such combined, low energy, coal upgrading has been very successful with North Dakota lignites. Sulfur can be removed by more extensive thermal treatment, but high energy use may make it more expensive than post combustion treatment. Certain chemical additives to the raw coal are said to reduce emissions of SOx, mercury and chlorine. These additives end up binding with some of the emission precursors and end up in the ash and may be useful in tweaking nearly compliant levels of such emissions.

Nitrogen – is generally friendly as it is 78% of the air we breathe. However in nitric-oxide form, it is strictly regulated. NOx are formed in the combustion process from the nitrogen present in coal and also from the nitrogen in the air that is blow into the furnace to oxygenate the combustion. Back end nitrogen scrubbing can be expensive, thus, there is demand for reducing the nitrogen in coal, and for using excess oxygen in the combustion air. Interestingly, in chemical looping combustion, oxygen for combustion is delivered from a metal oxide, and NOx is not produced at all.

Carbon Monoxide – is sometimes produced in the burning of hydrocarbons. As one wants the carbon for combustion and energy production, boiler tuning and the addition of catalysts to aid combustion is often the best way to convert carbon monoxide into carbon dioxide. Pre-combustion carbon removal is counter-productive.

Carbon Dioxide – is regulated in some jurisdictions but not in others. It is produced in the combustion of ALL hydrocarbons as it fundamental to the exothermic reaction of combining carbon with oxygen. The recovery of CO_2 as a valuable by product is scientifically complex and expensive. In addition, the most economic value as a by-product at this time is in enhanced oil and gas recovery. However, any system for the recovery of CO_2 whether from normal air combustion, oxy-combustion, gasification, or chemical looping will likely require a purification of the raw hydrocarbon fuel to remove moisture, ash, mercury, chlorine, sulfur or other elements that will contaminate catalysts or other highly complex chemical reactions.

Renewables – are required in 35-40 states as part of the energy portfolio. In many cases this may mean the combustion of biomass. We note above some of the issues with chlorine in biomass. In addition, when burned in a traditional coal boiler, there can be significant down rating issues due to the moisture and lower calorific value. Certain thermal prior-to-combustion technologies can produce a homogeneous mixture of biomass and coal of high heat value that can run seamlessly in existing coal infrastructure. Such fuel may be the most economic method of meeting renewable portfolio requirements without government subsidies for other alternative energy sources.

As the world seeks more elegant energy production solutions, we need to begin to include more prior-to-combustion technologies in our mix of strategies to achieve our goals.

The American Coal Council's Coal 2.0 Alliance members represent the leading developers of these various Engineered Coal Fuel technologies. The members use technologies ranging from traditional coal preparation and washing, to various forms of separation, drying, and thermal upgrading, to chemical combustion additives and biomass additions. These companies are on the cutting edge of the solid fuel improvements that must be of interest to operators of old and new plant alike. Coal 2.0 Alliance Fact Sheet:
http://americancoalcouncil.org/associations/10586/files/ECF_factsheet_Mar2012.pdf

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