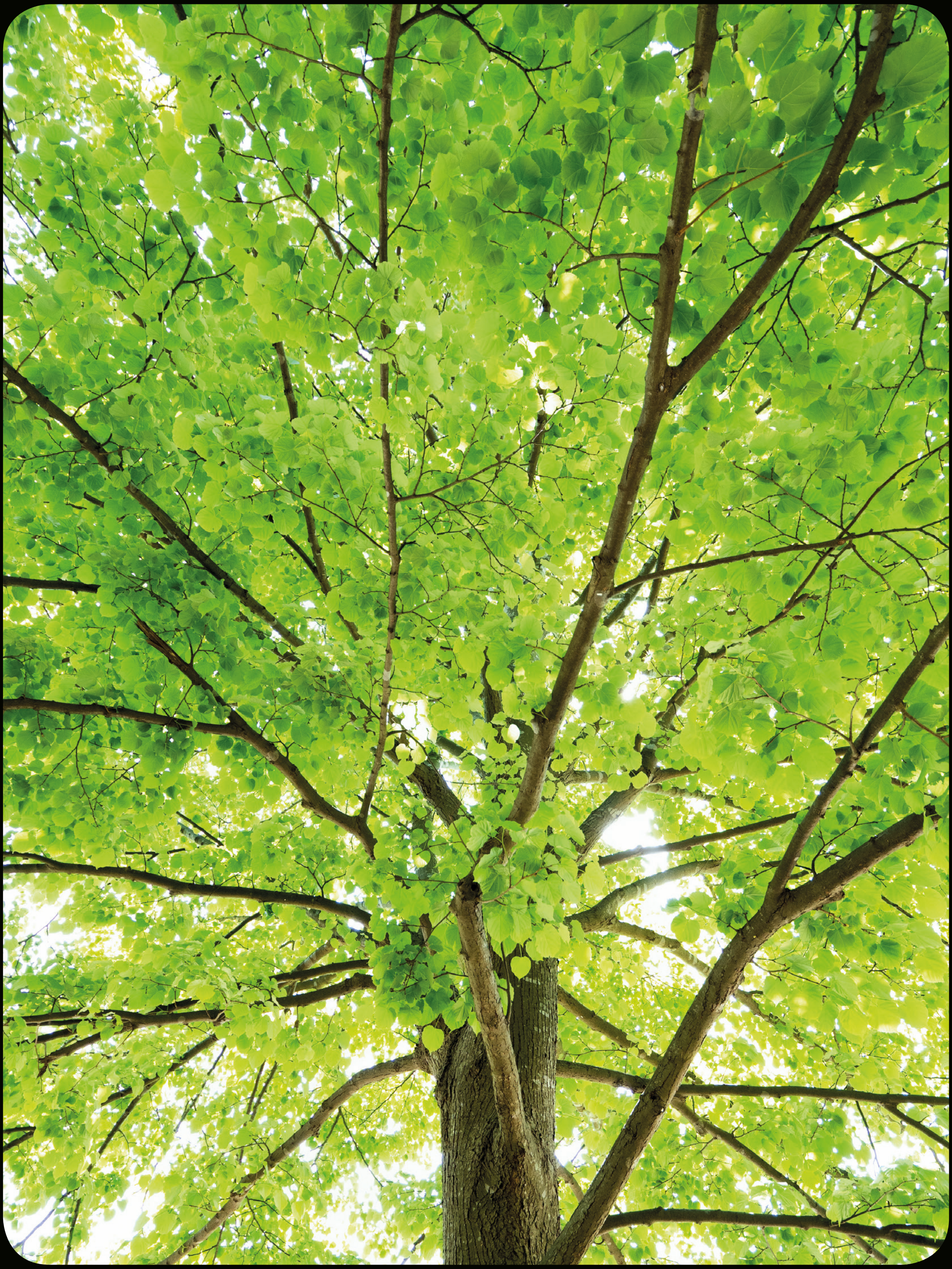
World Biomass

The International Review of the Biomass Industry



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Ash issues when firing alternate, engineered and opportunity fuels

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Alternate, engineered and opportunity fuels can offer a sustainable and renewable alternative to fossil fuels and traditional biomass fuels for industrial steam generation. Although these fuels can be lower in cost, they are often more difficult to utilize. There are a wide variety of options with each fuel source's impurities being unique in type and level. It is important to understand the inorganic chemical makeup of the fuel to avoid potential ash issues.

Figure 1: Cocoa Shells.

Coal has always been a relatively consistent fuel source with known impurities which have been studied and understood for centuries. Ash is formed during heating from the minerals in the coal. The tendency of this fuel to establish problematic formations depends on its elemental volatility as well as the viscosity of the produced ash. Volatility depends on the ratio of organically bonded elements along with the temperature. Viscosity is dependent on the chemical makeup of the ash, local conditions (oxidizing or reducing atmosphere) and temperature.

Furnace slagging and heat transfer fouling can be common problems when firing bituminous coals high in iron or sulfur content and with high levels of sodium and potassium (alkalis). Molten alkalis promote ash build up in upper furnace sections while molten iron can form large deposits in the lower furnace. Subbituminous coals (powder river basin) have high levels of silica, alumina and calcium which promote the formation of black glass deposits. Issues become more pronounced with low rank, high sulfur and higher ash content. Understanding these properties and the effects they will have on the combustion process allows for controls to be utilized to alleviate issues that may arise. Whether that be increasing the number of soot blowers, frequency of soot blows, adding flue gas recirculation to reduce the adiabatic flame temperatures or adding chemical additives and anti-fouling agents to the coal prior to combustion, there are numerous proven techniques that have allowed for the successful

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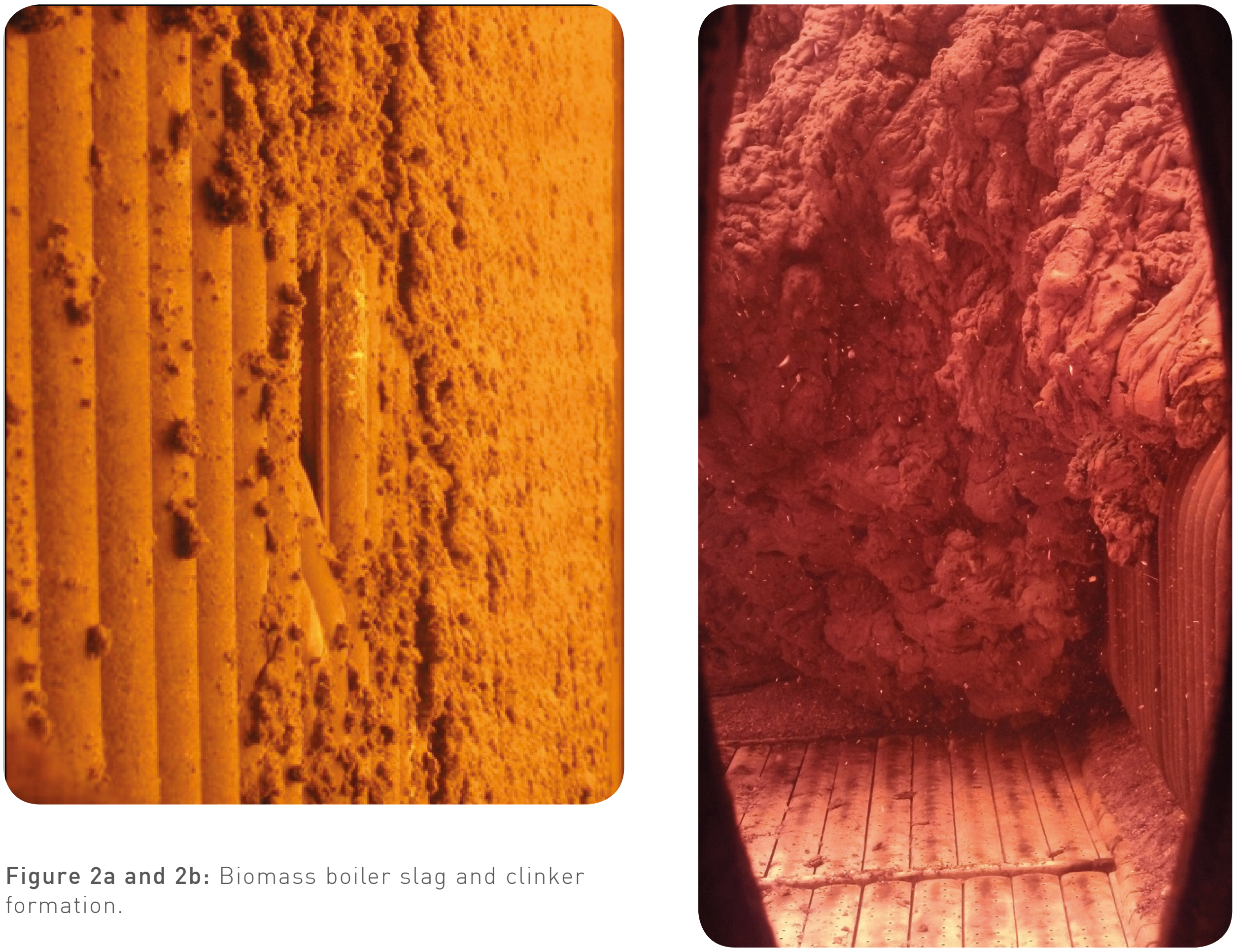

Figure 2a and 2b: Biomass boiler slag and clinker formation.

firing of a range of coal types. When this is compared to alternate, engineered and opportunity fuels where the physical characteristics can vary greatly, but even more so in the chemical makeup, the ash formation is not as straightforward and predictable as coal.

Detroit Stoker Company first developed a grate system specific for woodchip/bark firing in 1947. Since then, Detroit has provided over 400 systems for biomass combustion, which have been designed, installed and operated worldwide. This equipment utilizes the technology of spreader type firing with continuous ash discharge grates.

Traditional biomass fuels, mainly wood, consisting of wood chips, hogged wood, bark and sawdust that have dominated the forest products industry for the past century are not always cost-effective, unless they are a byproduct residue. In many cases, the most economical and available fuel source will be utilized. In some cases, that means replacing traditional biomass feedstocks with recycled wood products. Examples of this can include demolished buildings (urban waste), railroad ties, tree and bush trimmings and forest cuttings, often supplemented by local fuel streams generated by forest product manufacturers (sawdust/sander dust).

The majority of newer facilities are utilizing fuel feed stocks that include traditional wood chips, bark, poultry litter and agricultural residues such as olive and grape refuse. More traditional by-product fuels continue to be represented such as bagasse (refuse from cane sugar production), palm oil manufacture residues and the by-products from lignin ethanol productions. Table A represents the wide range of constituents in the fuels seen today.

Table A – Fuel Analysis Comparison						
Fuel Type	**Moisture %**	**HHV (MJ/kg)**	**Ash %**	**Chlorine %**	**Nitrogen %**	**Sulfur %**
Wood & Bark	40 - 55	9.3 - 11.6	1 - 3	<0.02	<0.2	<0.03
Bagasse	45 - 55	6.0 - 10.1	2 - 5	<0.02	<0.3	<0.03
Poultry Litter	30 - 55	6.6 - 19.5	8 - 20	0.5 - 1.0	2.5 - 6.0	0.4 - 1.0
Palm Residues	10 - 50	9.9 - 18.1	0.8 - 6.0	0.01 - 1.2	0.27 - 2.6	0.09 - 0.2
Cocoa Residues	18 - 25	13.9 - 15.0	2.3 - 6.4	<0.01	0.23 - 1.1	0.02 - 0.10
Olive Residues	5 - 60	5.5 - 20.4	2 - 8	0.1 - 0.8	0.4 - 5.0	0.2 - 1.0
C&D	25 - 35	15.1 - 19.2	4 - 12	0.1 - 1.0	0.4 - 1.0	>0.2

Table A: Analysis of Fuel Types.

The quantity and make up of ash in a fuel will have a direct impact on both the severity of deposition and slagging. The molten or partial melting pasty ash that deposits in the radiant heat transfer surface of a furnace is termed slagging. Furnace slagging occurs when the furnace temperature(s) exceed the ash softening temperature of the fuel. The sintered ash deposit in the convection region in the boiler is called fouling. Slagging, fouling and the corrosion that result can increase maintenance costs, safety risks and decrease boiler availability. When the larger particles of ash coalesce on the grate, they can form a low-melting glaze-like liquid and fuse with rock, dirt particles and sand into a clinker, growing to 5-6" deep on the grate.

If the ash is subjected to temperatures in 870-930°C (1600-1700°F) range, potassium meta silicates will dissolve the included silica pebbles and sand into an amorphous vesicular slag which resembles lava. Iron is particularly effective in aiding in the slagging process.

Concentrations of major elements vary greatly between biomass species. Ash composition can be affected by:

- Supply chain impact (rocks and soil)
- Biomass plant type and growing conditions
- Fertilizer
- Soil condition and composition
- Portions of the biomass plant being fired

European standards determine the two main groupings of ash sample elements:

- Minor elements measured according to EN 15297 include: As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V and Zn. Very small concentrations are typically found in fuels. These elements are typically expressed as (mg/kg) of fuel on a dry basis. Measurement relates mostly to environmental concerns whether the ash contains any toxic elements that may return to the environment upon its disposal.
- Major elements measured according to EN 15290 are the most abundant in the fuel ash: Al, Ca, Fe, Mg, P, K, Si, Cl, Na and Ti. Can be expressed as (mg/kg) of fuel on a dry basis or as weight percentages in the fuel ash. No significant environmental issues are associated with these elements, but they have a major impact on the ash melting behavior, slagging/fouling and corrosion. High concentrations of some elements may indicate fuel contamination with soil or sand.

The quantity and make up of ash in a fuel will have a direct impact on both the severity of deposition and slagging.

The elemental composition of the fuel along with the concentration of certain elements in the fuel is generally an indicator of tendency of fuels to slag.

The ash melting temperature for biomass fuels of 537°C (1000°F) is lower than the typical ashing temperature for coals 790°C (1450°F). High alkali content in coals can have a eutectic effect to the melting point with the minimum typically being around 621°C (1150°F). Therefore for boiler desgin consideration it is important to considered performance steam temperature and pressure

The elemental composition of the fuel along with the concentration of the following in the fuel is generally an indicator of tendency of fuels to slag: Alkali, chlorine, sulfur, and silica. Nevertheless, the majority of deposits occur post-combustion, so an analysis of the fuel composition cannot always fully predict slagging.

Sampling slag characteristics can help to understand formation of alkali metals and eutectic melting temperatures. Alkali content is the sum of potassium and sodium compounds (K_2O and Na_2O).

As with the coal industry, biomass fuels are being extensitively studied to help determine issues related to combution and ash formations. The alkali metals, total ash, and SiO2 contents all have effects on the eutectic ash melting temperatures. The following calculation provides for an inital index value if a potential biomass fuel could be problematic.

Clean wood chips and bark are generally below 0.17 kg/GJ (0.4 lb./MMBtu) and only produce loose deposits that can be controlled with regular soot blows. Bagasse is also generally low. It can slag, but most often limited and manageable.

General recommendation is to utilize fuels with alkali levels of 0.34 kg/GJ (0.8 lb./MMBtu) or less. If this cannot be avoided, it is recommended to blend fuels to this maximum level. It is important to understand blending to this level may not prevent slagging or deposits from fuels with high alkali concentrations like nuts and shells or straw. Tendency to form deposits or slag increases between 0.17 kg/GJ to 0.34 kg/GJ (0.4 lb./MMBtu to 0.8 lb./MMBtu) to definite fouling and possible slagging above 0.34 kg/GJ (0.8 lb./MMBtu).

Applications where ash chemistry includes high silica and high levels of alkali can lead to formation of alkali rich silica slags. These slags can be corrosive to standard boiler refractories. In some applications, alternative refractory materials are required.

Newer biomass fuels along with opportunity and engineered fuels can have higher percentages of ash, sometimes greater than 25%, extreme ranges of as fired moisture (5-60%), higher percentages of Cl and N, and higher percentages of alkali metals. Fuel characteristics need to be evaluated and then monitored for major changes away from design scenarios. Variations in as fired

$$\frac{lb\ Alkali}{MMBtu} = \frac{1 \times 10^6 Btu}{Btu/lb\ (dry)} \times \%Ash\ \times \%Alkali\ of\ Ash$$

$$\frac{kg\ Alkali}{GJ} = \frac{1 \times 10^6 kj}{kj/kg\ (dry)} \times \%Ash\ \times \%Alkali\ of\ Ash$$

Figure 3: LB alkali/MMBTU Calculation.

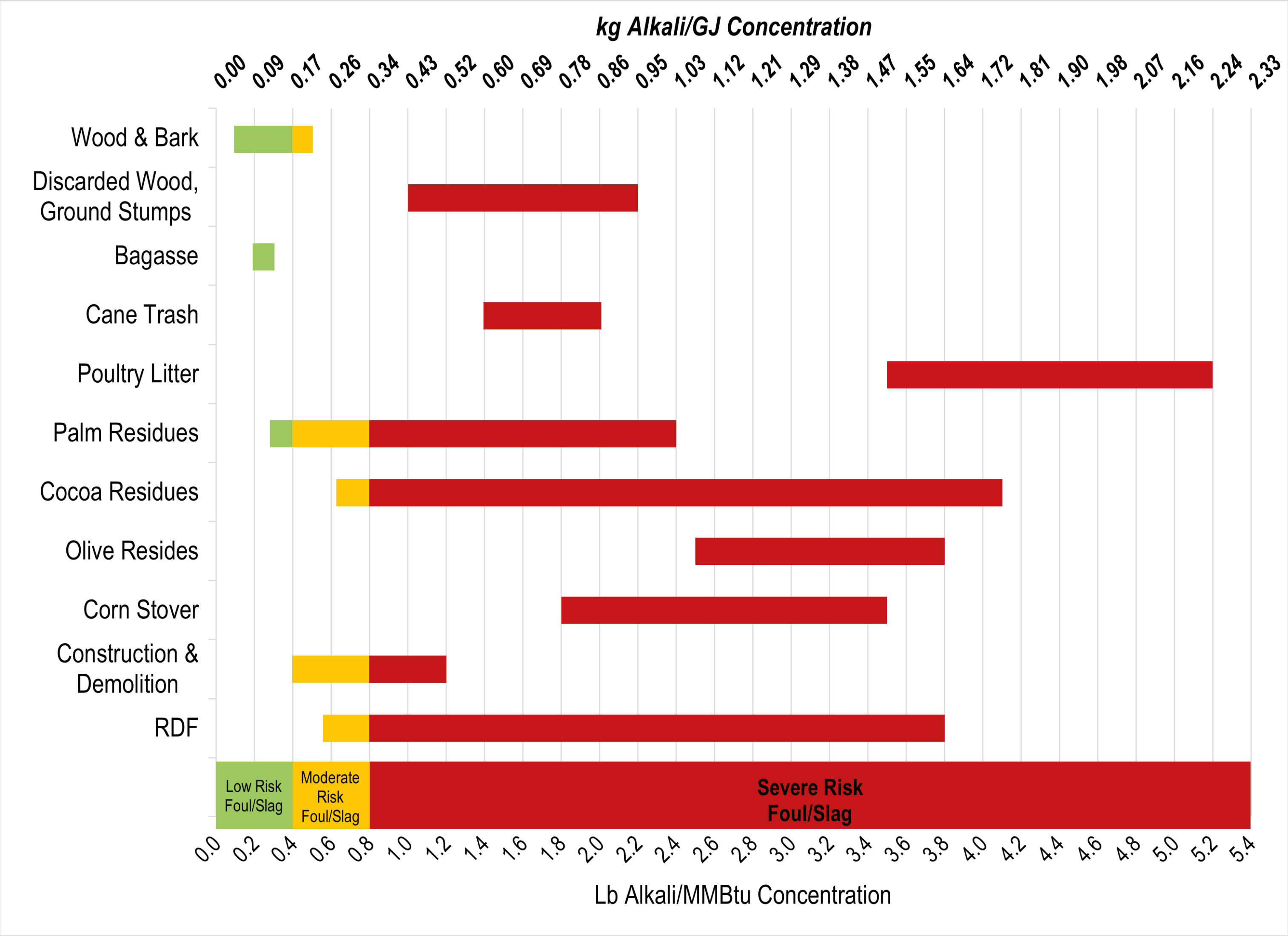

Figure 4: Comparison of renewable fuels fouling and slagging indexes.

moisture (5-60%) can have significant effects on ash.

Two important factors that are considered during the design of new systems are emissions and fuels. New systems further attempting to reduce CO and unburned carbon loss requires operating with less excess air and addition of lower furnace refractory when fuel moistures exceed 40%. The expectation for future fuels includes increased use of higher alkali fuels (Ag, engineered fuels, process dusts). Variable pre-heated combustion temperatures are important when design fuel is expected to have a wide range of moisture.

Lower furnace refractory and/or tiles offer significant reduction in CO with fuel moisture above 40%. This promotes a consistent "heat sink" to dry and volatize biomass fuels quicker. Also offers added protection in lower furnace with fuels having elevated Cl and S contents.

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This additional refractory can become an issue when there are multiple fuel sources being fired that have a large range in fuel moisture, or even if the fuel moisture deviates from design. If the fuel moisture decreases, lower furnace temperatures increase, Utilization of alternative fuels is increasingly relied upon to stay competitive and compliant in the marketplace.

quickly surpassing the eutectic melting temperature. Slagging, fouling and piling of fuel on the grate surface will follow.

Fuel quality needs to be monitored closely. In a case where fuel source changes and the moisture drops significantly, either undergrate air temperature would be decreased or flue gas recirculation introduced. In both cases, the end goal would be to reduce and maintain adiabatic flame temperature to stay below the eutectic melting temperature. Flue gas recirculation, which has traditionally been a NOx control strategy, can assist combustion by reducing the total oxygen concentration especially at the grate level. Additionally, when used at fuel delivery points, FGR can provide a level of reduction in both NOx and CO by having lower excess oxygen in localized areas than traditionally oxygen rich zones.

Consideration is also given to both grate and boiler performance. Increased metal content can cause decreased availability of equipment. High alkali content can greatly increase slagging or fouling occurrences while higher fuel nitrogen contents can lead to greater variability in Oxides of Nitrogen (NOx) emissions. These considerations along with low carbon monoxide (CO) permit requirements, require more conservative combustor designs. These and other considerations influence both the furnace construction and grate selection.

Figure 5: Palm refuse - empty fruit bunches.

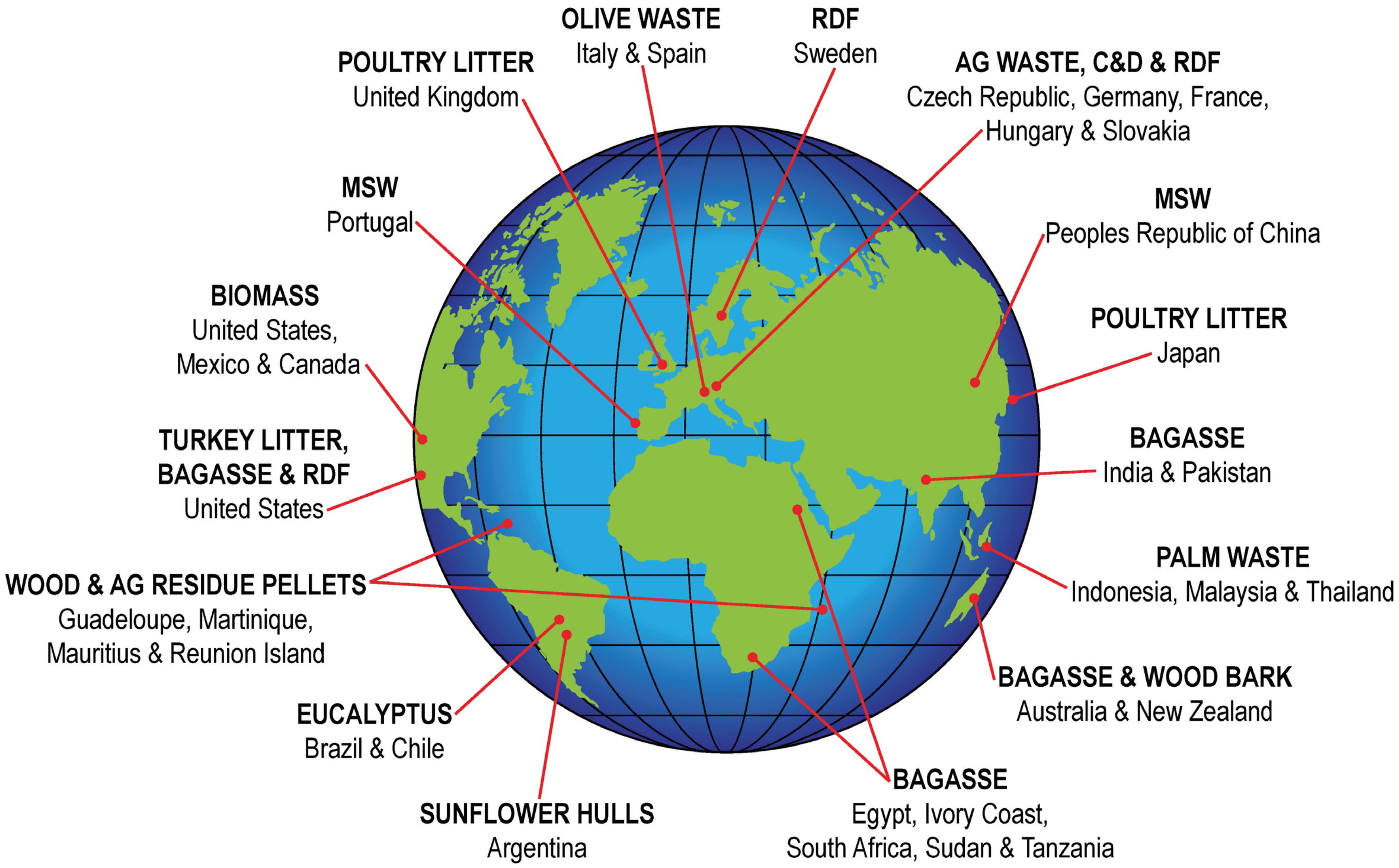

Figure 6: World Map showing alternative fuel locations.

Special considerations are required for burning fuel with high alkali concentrations. Conventionally designed boilers are not suitable for these fuels. Boilers designed with low furnace exist gas temperatures, generally less than 815°C (1500°F), are ideal for crops and residues, including straws and grasses. Designs should include grates with the ability to remove large amounts of ash, soot blowers to clean strong deposits, sufficient waterwall surface area and combustion air control to control flue gas temperatures.

Detroit Stoker Company is not a boiler or steam generator provider. Rather we are a provider of combustion equipment, having integral combustion air systems and fuel distribution equipment. We work with a wide variety of boiler designers and providers throughout the world. By working with both international and regionally based boiler companies, we provide over 125 years of combustion experience for a wide range of fuels.

Owners and operators of solid fuel boilers continue to look for alternative opportunities to compete with fluctuating business conditions and increasing environmental demands to provide the most reliable and consistent energy production possible.Utilization of alternative fuels is increasingly relied upon to stay competitive and compliant in the marketplace.

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