

Current status of alternative fuel use in lime kilns

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ABSTRACT: Lime kilns consume large amounts of fossil fuels. Because of the steady rise in natural gas and fuel oil costs in recent years, mills need to find more economical fuel alternatives that have minimal impacts on lime kiln and chemical recovery operations. This paper examines the technical feasibility of various alternative fuels, including petroleum coke, directly fired or gasified wood residues, precipitated lignin, bio-oil, and olein biofuel. Because each fuel has a different composition, heating value, and burning characteristics, it is important to understand the pros and cons of burning each fuel before using it in the lime kiln.

Application: The process and operational impacts of various alternative fuels are unique to each mill. If kraft pulp mills can gain a better understanding of their own operations and economics, they can select the best type of alternative fuel for their situation.

In kraft pulp mills, lime kilns are used to convert lime mud (CaCO_3) to lime (CaO) for reuse in the causticizing plant. This process requires a large amount of heat, which is supplied to the kiln mainly by burning either natural gas or fuel oil. Depending on the kiln design and refractory type and whether it is equipped with product coolers or with a lime mud dryer, an average lime kiln may require 6 to 10 GJ of heat per tonne of CaO production. At the current natural gas price of 8 USD/GJ, the energy cost for a typical lime kiln is approximately 13.5 USD/ADMT, or approximately 4 to 7 million USD/year at a 1000 ADMT/d kraft mill.

Approximately two-thirds of the kilns in the United States and Canada burn natural gas, and one-third burn fuel oil. Along with these fossil fuels, many kilns also burn waste streams and by-products from various mill processes, such as concentrated non-condensable gases (CNCG), stripper off-gases (SOG), crude tall oil, and hydrogen. These auxiliary “fuels” typically provide 5% to 10% of the total heat requirement. High energy costs in recent years have created a need for alternative fuels that are more economical than traditional fuels and have minimal negative impacts on the operation of the lime kiln and the pulp mill. A number of alternative fuels have already been used in lime kilns, such as petroleum coke in the United States and syngas from gasified bark and sawdust in Sweden and Finland.

As part of the Energy and Chemical Recovery research program at the University of Toronto, information on alternative fuel usage has been gathered over the past two years through literature surveys, mill surveys, and discussions with fuel suppliers, research institutes, and pulp mills that burn alternative fuels in lime kilns. The information was systematically analyzed for each fuel type to assess the impacts of its use on lime kiln and mill operations. This paper discusses the major alternative fuels that are currently used in the industry and the pros and cons of their use.

ALTERNATIVE FUELS

Around the world, various alternative fuels are being used or proposed for use in lime kilns, including:

- Petroleum coke
- Wood biofuels
 - Directly fired wood residues (bark, sawdust)
 - Gasified wood residues (bark, sawdust)
 - Precipitated lignin
 - Pyrolysis oil (bio-oil)
- Olein biofuel

PETROLEUM COKE

Petroleum coke (or petcoke) is a by-product of the oil-refining process. It is a solid fuel that consists mainly of carbon (85 to 90 wt%) and an appreciable amount of sulfur (5 to 7 wt%), and has a higher heating value (HHV) of approximately 35 MJ/kg (15,000 Btu/lb).

Petcoke is supplied as solid lumps, which need to be finely pulverized before being fed into the lime-kiln burner. The two major capital equipment items required for pulverized petcoke burning are a petcoke storage and feed system and a multi-fuel-firing burner. Mills that opt to receive raw petcoke will also need to install a grinding mill, although most new installations are receiving pulverized petcoke because supplies of raw petcoke are generally not available. Currently, 20 mills are continuously firing petcoke in their lime kilns. These mills are located predominantly in the southeastern United States. Three of these mills have been burning petcoke for more than 20 years, and the remaining 17 mills have begun using petcoke since 2004. Petcoke typically replaces 25% to 85% of traditional fuel depending on permit and equipment limitations. In addition, there are two petcoke trials in progress and at least two more trials planned before the end of 2008.

The primary driver behind the use of petcoke in lime kilns

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is its lower cost, which for pulverized petcoke may vary from 3.8 to 4.7 USD/GJ (4 to 5 USD/MMBtu) depending on the transportation distance from the petcoke supplier to the mill. This price is not expected to change significantly because of the increased output of petcoke from oil refineries [1]. The payback period for a petcoke system is approximately two to three years when the cost of traditional fossil fuels exceeds that of petcoke by 2.8 USD/GJ (3 USD/MMBtu) [2]. One consideration for the long term, however, is the possibility that future carbon taxes imposed on pulp mills may reduce the energy cost savings available from petcoke. Consumer-based carbon taxes on fossil fuels are common in northern Europe and were implemented in British Columbia, Canada, on July 1, 2008.

A number of operational concerns must be taken into consideration when using petcoke in lime kilns. Petcoke is relatively difficult to burn because of its lack of volatiles and therefore is usually burned in combination with natural gas or fuel oil. Because combustion occurs at the surface of petcoke particles, a finer grind provides a larger surface area and makes possible higher levels of traditional-fuel substitution. It is important to ensure that petcoke is burned completely; otherwise residual carbon may end up in the lime mud, in white liquor suspended solids, and possibly in the pulp.

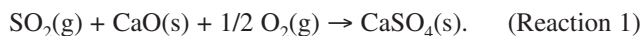
Petcoke also yields a higher flame temperature than fuel oil or natural gas. This may lead to increased front-end temperatures and consequently an increased risk of refractory damage. The high flame temperature and the relatively high fuel nitrogen (N) content in the petcoke may also result in higher NO_x emissions from the kiln stack. These problems, however, may be minimized by properly designed burners, improved front-end temperature control systems, or both.

Most of the non-process elements (NPEs) introduced with petcoke are not usually a concern. Thanks to the high alkalinity of the kraft liquor, heavy metals such as Pb, Zn, Cr, and Fe can be expected to form insoluble oxides or sulfides and be removed from the liquor system with grits and with lime dust disposal. Silica and alumina concentrations in the petcoke are usually low and are not usually expected to cause problems. Vanadium may, however, be problematic because of the high corrosivity and volatility of vanadium compounds and their possible contribution to superheater corrosion in the recovery boiler, although there is no evidence that this has occurred. A field study conducted in the early 1990s at a kraft mill where petcoke was burned in the lime kiln confirmed the presence of a high V concentration (250 ppm) in black liquor [3]. However, the study also concluded that the high V concentration was not the cause of the severe superheater corrosion experienced in the recovery boiler at the mill. In a recent laboratory study, no significant difference in corrosivity was found between deposits that contained no V and those containing 2 wt% V₂O₅ [4].

The biggest concern with petcoke burning in lime kilns is its high sulfur (S) content, which is typically approximately 6 wt%. Although the fate of S that enters the kiln with petcoke is not well understood, on the basis of mill experience and

current understanding of the process chemistry, one can reasonably speculate where S may end up and what impact it may have on the recovery operation.

In the kiln, S is oxidized to sulfur dioxide (SO₂), which reacts readily with calcium oxide (CaO) in the lime to form calcium sulfate (CaSO₄) in Reaction 1:

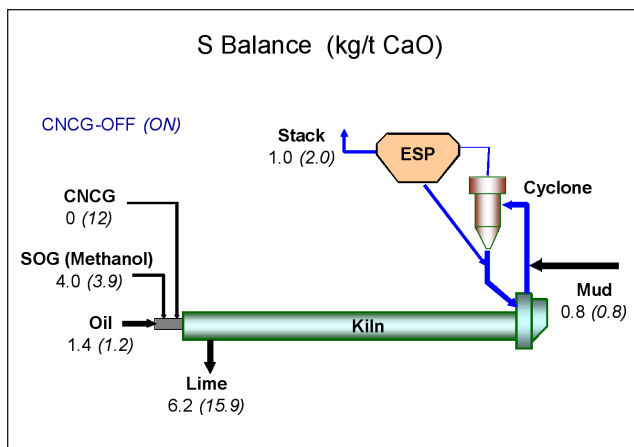


Despite the abundance of lime in the kiln, not all the SO₂ produced can react with lime because of poor gas-solid contact in the kiln and the low surface area of lime nodules. Depending on the fuel S content, kiln operating conditions, and lime mud characteristics, a portion of the SO₂ may pass through the kiln without reacting and contribute to increased SO₂ emissions. In a study of the effect of burning high-S-containing CNCG on the performance of an oil-fired lime kiln equipped with a lime mud dryer (LMD), the SO₂ emissions from the kiln stack were found to increase markedly from a base value of 20 to 30 ppm when the kiln was co-fired only with SOG (mostly methanol) without CNCG, to approximately 520 ppm when CNCG were also burned [5]. The S balance, expressed in kg/t CaO, for this kiln during the study is shown in **Fig. 1**.

Based on the total amount of S entering the kiln with mud and fuel (oil, SOG, and CNCG) and the amount of S leaving the kiln with lime, the S capture efficiency (i.e., the ability of lime to absorb S in the kiln) can be calculated. This efficiency was 98.2% when the total S in the fuel was 5.4 kg/t CaO, but decreased to 88.7% when the total S in the fuel was 17.1 kg/t CaO.

For a hypothetical lime kiln that burns only petcoke (that is, with a 100% substitution rate) containing 6 wt% S, the total S input with petcoke would be approximately 10 kg/t CaO. If the above sulfur balance obtained from the CNCG-burning kiln is also applicable to the case of petcoke burning, there should be an insignificant increase in SO₂ emissions for kilns that burn petcoke at a substitution rate below 50%, which is the case for many kilns. For kilns equipped with flue gas scrubbers, SO₂ emissions are a non-issue because most of the remaining SO₂ in the flue gas will be absorbed in the scrubber solution. On the other hand, for kilns that burn petcoke at higher substitution rates, or petcoke together with CNCG and SOG, high SO₂ emissions are inevitable, particularly for kilns without scrubbers.

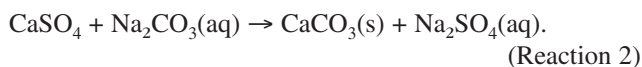
The high S capture rate of the lime implies that most of the S entering the kiln with petcoke will be converted into CaSO₄ and remain in the reburned lime and in the lime dust. This will lower the lime availability by approximately 0.16% per kg/t CaO of S input and increase the requirement for makeup lime by the same amount. The high S capture rate also causes the rapid formation of hard deposits on the kiln wall, which may lead to ringing problems in some lime kilns [6]. Furthermore, since CaSO₄ is formed mostly on the lime surface and is relatively insoluble in water, it hinders the contact between CaO in the lime, water,



1. Effect of CNCG burning on the sulfur balance of a lime kiln equipped with LMD [5].

and Na_2CO_3 in the liquor, making the reburned lime less reactive and more difficult to slake and making it settle more quickly in the slaker. As a result, CaSO_4 is enriched in grits and in lime dust and therefore is removed from the liquor system with grits and with lime dust disposal.

In the slaker and causticizers, the slaking and causticizing reactions cause lime nodules to break up into smaller particles and to release CaSO_4 into the liquor. The “released” CaSO_4 reacts rapidly with sodium carbonate (Na_2CO_3) in the liquor to form calcium carbonate (CaCO_3) and sodium sulfate (Na_2SO_4) according to Reaction 2:



The precipitated CaCO_3 is essentially lime mud. This increases the mud load to the causticizing plant and the lime kiln, thus offsetting the need for makeup lime. Na_2SO_4 , on the other hand, is water-soluble and ends up leaving the causticizing plant with the white liquor, becoming part of the sulfate dead load in the liquor cycle. Na_2SO_4 eventually enters the recovery boiler, where most of it is reduced to Na_2S . This process inevitably results in an increase in liquor sulfidity.

Note that the S/ Na_2 molar ratio of Na_2SO_4 is 1, whereas that of kraft liquor is much lower, 0.2 to 0.4, depending on the mill sulfidity. This means that mills will have two options when burning petcoke: i) operating at a higher sulfidity, or ii) keeping the same sulfidity and the same total titratable alkali (TTA) by purging lime dust (enriched in CaSO_4), recovery boiler precipitator dust (enriched in Na_2SO_4), or both, and by adding Na makeup at an amount equivalent to that lost with the dust purge. Although Option i) is simple, it changes the liquor characteristics and may not be feasible for some mills. Option ii) does not affect liquor characteristics, although its requirement for Na makeup may incur significant costs, and this must be taken into account when using petcoke. A combination of the two options is probably the best solution.

It is difficult to estimate how high the liquor sulfidity

may become and how much Na makeup may be required as a result of burning petcoke in the lime kiln. These figures depend on many factors, including the S capture efficiency of the kiln, the kinetics of Reaction 2, the quantities of grits and lime dust going to disposal, and the amount of S loss through SO_2 and particulate emissions from recovery boiler and lime kiln stacks.

Petcoke does offer operational advantages in addition to significant fuel cost savings. Kilns fired with a 75% petcoke-25% natural gas mix have a similar temperature profile to kilns fired with 100% fuel oil. They are also more responsive to control actions than kilns fired with 100% natural gas, produce higher concentrations and flow rates of CO_2 for downstream precipitated calcium carbonate (PCC) plants, and tend to be less dusty, probably due to better sintering of lime nodules [1] and the formation of CaSO_4 on the lime surface in the burning zone.

WOOD-BASED BIOFUELS

Gasified wood residues

Gasification is a thermal process that converts carbon (C)- and hydrogen (H)-containing solid fuels into gases, which can displace natural gas or fuel oil in boilers, dryers, and lime kilns. In an oxygen-lean atmosphere at high temperatures, C and H in solid fuels can be gasified into combustible gases (H_2 , CO, and hydrocarbons). The resulting gases (syngas) also contain CO_2 and H_2O , and N_2 as well if air is used for gasification.

Syngas produced from wood residues has been proposed for use as a lime kiln fuel because it offers the benefits of a renewable non-fossil fuel that reduces CO_2 emissions and has proven in some cases to have economic benefits. One of the major concerns with syngas from wood residues, however, has been its low heating value compared to natural gas or fuel oil. Depending on gasifier operating conditions, wood residue type, moisture content, and whether O_2 or air is used, the higher heating value of syngas may vary widely, from 3 to 12 MJ/kg (1500 to 5000 Btu/lb), compared with 53.2 MJ/kg (22,300 Btu/lb) for natural gas and 43.1 MJ/kg (18,400 Btu/lb) for fuel oil. The low heating value means that more fuel is required to achieve the same heating rate, leading to greater amounts of exit gases going to the flue-gas handling system and the possibility of exceeding the system capacity. In addition, a higher gas flow rate through the kiln can also lead to increased gas velocities, which may cause more dusting to occur and put an additional strain on the flue-gas handling system. Other challenges include lower flame temperatures, temperature profiles that differ from those of natural gas and fuel oil, and introduction of NPEs into the kiln, particularly when the cyclones are ineffective, allowing ash and particulates to enter the kiln along with the syngas. The economics of this alternative fuel option vary greatly depending on oil and natural-gas prices, but also on transportation costs. Mills that gasify sawdust, for example, are typically located close to the sawmill that is the source of the fuel.

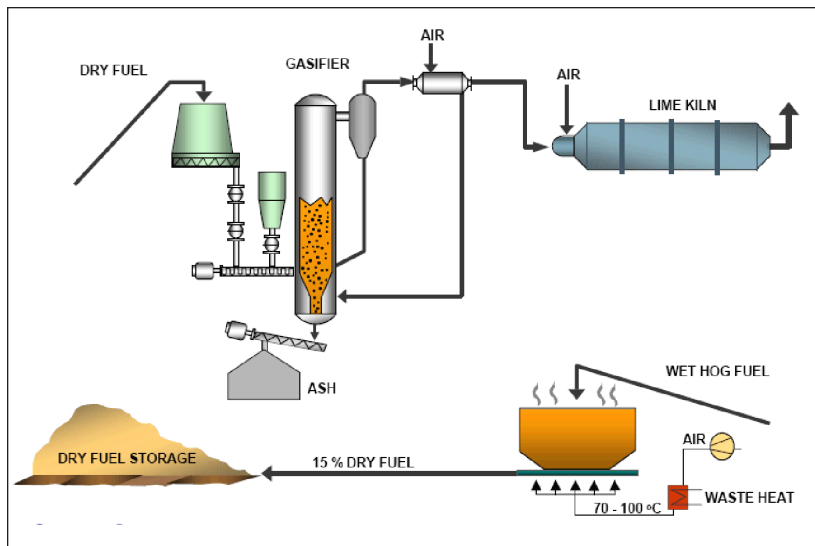
Commercial wood-residue gasifiers for use in lime kilns

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were built in the 1980s by Ahlström at mills in Sweden, Finland, and Portugal. These gasification systems included a wood-residue feeding system and a drum or pneumatic dryer with an accompanying hot-gas generator, gasifier, and cyclone separator. The designs strove for 100% fuel substitution and therefore required biomass dryers to ensure that the gasifier-produced syngas had a sufficiently high heating value. Many of these gasifiers have suffered from low availability, often due to problems in the dryers and feed systems rather than in the gasifiers themselves. A number of these mills have since ceased to use gasifiers, particularly after oil prices decreased in the late 1980's and 1990's.

Wood-residue gasifiers today are offered by a number of suppliers and come in different types. Fluidized-bed gasifiers have been used for lime kiln, boiler, power plant, and district heating applications. These gasifiers are usually either of the bubbling fluidized bed (BFB) or circulating fluidized bed (CFB) type. They can be operated at low or high pressure and with oxygen or air. Low-pressure CFB gasifiers fed with air are typically used in lime kiln applications. An example of how a CFB gasifier might be integrated with a lime kiln is shown in **Fig. 2**.

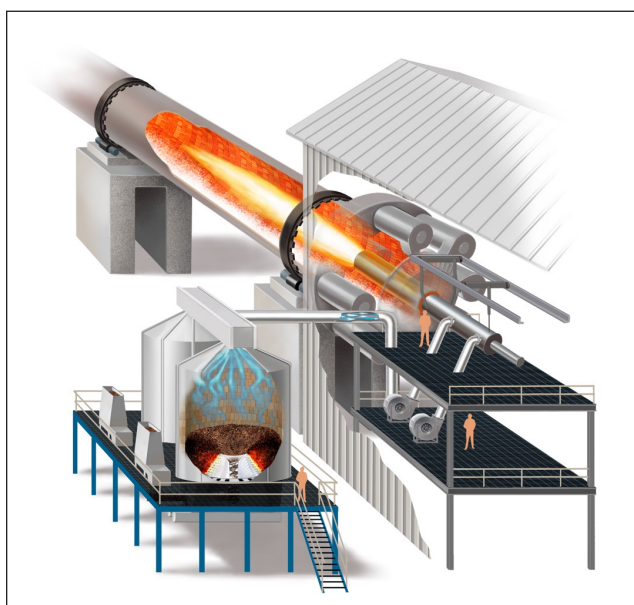
Another type of gasifier being offered for thermal heating, cogeneration, boiler, and lime kiln applications is the fixed-bed updraft type (**Fig. 3**). Design simplicity, low capital and operating cost, clean syngas (low particulate and NO_x emissions), and fuel flexibility (up to 55% moisture) are among the advantages cited for this technology.



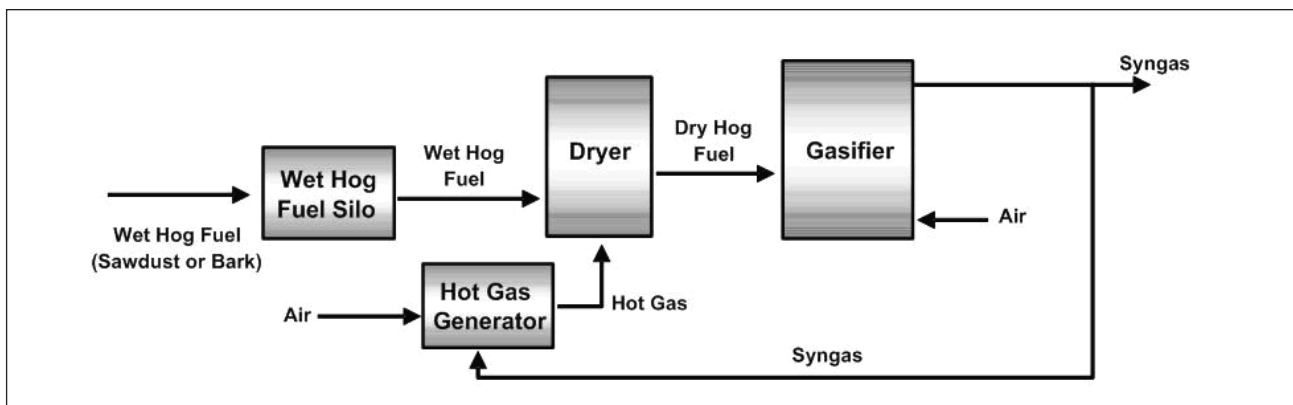
2. Schematic of a CFB gasifier integrated with a lime kiln (courtesy of Carbona Inc.).

The new generation of gasification systems for lime kiln applications has been fitted with improved feed systems to avoid the availability problems that have plagued the installations from the 1980s. A number of other improvements are being implemented in the area of wood-residue drying. In most designs, wood-residue dryers are installed before the gasifier to lower the feed moisture, making possible higher syngas exit temperature and heating value. Tar in the syngas is also an important consideration. The amount and composition of tar varies with wood-residue composition, gasifier type, and operating parameters. In general, entrained-flow gasifiers produce tar-free gas because of their high temperatures; fixed-bed downdraft gasifiers produce gas with a low tar content; fixed-bed updraft gasifiers produce relatively high tar concentrations in the outlet gas; and fluidized-bed gasifiers produce significant, but variable, amounts of tar [7]. As the gas cools down, the main challenge is to ensure that the tar stays in the gaseous phase in the pipelines that connect the gasifier to the kiln burner. Condensed tars can clog up the equipment and are difficult to remove. The key to preventing tar condensation is to minimize heat losses through the piping and to ensure that the syngas exits the gasifier at a sufficiently high temperature, which is one of the reasons for drying the wood-residue feed before gasification.

New drying options are now available to overcome the mechanical-component failures and fire-safety availability issues experienced in older dryers. One example is low-temperature belt dryers. These systems use mill waste heat sources to heat air, which in turn contacts the biomass on conveyor belts in a cross-current fashion. The low-temperature operation (relative to that of pneumatic and drum dryers) has the advantage of reducing fire and explosion risks and minimizing the generation of VOCs from the biomass. Other dryer options include rotary dryers heated indirectly by mill waste-heat sources. If waste heat is not available, hot-gas generators fuelled by syngas



3. Schematic of a fixed-bed updraft gasifier integrated with a lime kiln (courtesy of Nexterra Energy Corp.).



4. Typical gasifier system schematic.

or fossil fuels may be used as a heat source for the dryer. It is important to note that the most suitable dryer type will depend on the availability of waste-heat sources at the mill.

Two mills in Sweden are still running their biomass gasifiers from the 1980s. Mill A has two lime kilns, one burning oil and the other burning syngas from a biomass gasifier, which provides an excellent opportunity for comparison. Their sawdust-fed CFB gasifier has been in operation since 1985. Mill B has operated its bark-fed CFB gasifier since 1987. The mill has one lime kiln that typically burns approximately 95% syngas and the remainder fuel oil. The gasification plant at each mill consists of a biomass storage and feed system, a biomass dryer and related equipment, and a CFB gasifier, as shown schematically in **Fig. 4**. In both cases, the dryer is fuelled by the syngas produced, and usually approximately 25% of the syngas is used for this purpose.

Similarly to most other biomass gasifier installations from the 1980s, the gasification plants at these mills have struggled with poor availability and long downtimes over the years, mostly due to problems in their feed systems and dryers. Despite the consistent availability problems, the mills have still saved money on lime-kiln fuel costs.

A number of operational observations have been made over the years at Mill A. The smaller kiln that fires oil has a hotter flame than the larger kiln, with the syngas flame being almost 200°C cooler than the oil flame. The flame is longer and more stable with syngas than with oil. The operation is smoother with syngas, but it is harder to control the temperature because the response time of the syngas flame is slower than that of the oil flame.

Mill B reports a difference in lime quality between burning oil and syngas: the lime availability is lower with syngas because of the magnesium and phosphorus that come in with the bark. This is mainly because the cyclone is inefficient and allows ash and particulates to enter the kiln with the syngas.

Directly fired wood residues

In response to high oil prices in the 1980s, some Scandinavian mills began to fire powdered wood residues (sawdust or bark) directly into their lime kilns as a simpler alternative to biomass

gasification. The heating value of the wood residues is typically 19 to 22 MJ/kg (8200 to 9500 Btu/lb) on a dry basis. The basic requirements for this fuel option are low-moisture residues and the use of more purchased lime to control the NPEs that come in with the residues. The drying system usually consists of wood silos, a grinder, a hot-gas generator, and a dryer. Design issues and considerations for the dryers in directly fired wood systems are similar to those for gasified-wood dryer systems. The major disadvantages of this option are low reburned lime availability, high power consumption, and mechanical wear in the grinder.

The first system was installed at the Smurfit Kappa Mill (formerly Lövhölmén) in Piteå, Sweden, in 1979. Another system was also installed in Sweden at Södra Cell's Mönsterås Mill in Mönsterås in 1985. Both installations are still in use today.

Precipitated lignin

Separating lignin from black liquor and burning it in lime kilns has been advocated since the late 1980s by researchers at Paprican and the University of British Columbia in Canada. This body of work included computer-based simulations and subsequent pilot-scale kiln trials for replacing fossil fuels with precipitated lignin in lime kilns [8,9,10].

More recently, the LignoBoost Process, developed jointly by STFI and Chalmers University in Sweden, has been commercialized. In this process, lignin is separated from black liquor using acid precipitation and ultrafiltration. The precipitated lignin consists mostly of carbon, oxygen, sulfur, and hydrogen. It is usually dried to 70% dry solids and has a lower heating value of 25.4 MJ/kg (10,920 Btu/lb) on a dry basis.

Lignin precipitation has an added advantage for mills where the recovery boiler is thermally limited and is the bottleneck for mill production capacity. The heat load of the recovery boiler is roughly proportional to the amount of lignin entering with the black liquor, and therefore reducing the amount of lignin sent to the recovery boiler by means of lignin precipitation can help debottleneck the system [11]. One of the challenges in firing lignin in the kiln, however, is to ensure that the lignin is washed thoroughly to reduce the sodium content to an acceptable level. This is important, not only for minimizing

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chemical losses [11], but also for avoiding possible problems with ring and ball formation in the kiln [8].

Precipitated lignin has not yet been used commercially in lime kilns, but is well on its way. A pilot-scale study on precipitated-lignin combustion has already been conducted, and a full-scale trial in a lime kiln is scheduled for later this year at a mill in Sweden.

Pyrolysis oil (bio-oil)

Wood-pyrolysis oil (or bio-oil) is produced by thermally degrading (or pyrolyzing) the organic components in wood residues in the absence of oxygen at temperatures of approximately 400°C to 500°C. The initial products of this pyrolysis process are char and volatiles, which are condensed to form bio-oil. In contrast to the traditional way of producing charcoal, the process parameters for the modern fast pyrolysis process are designed to give high yields of pyrolysis oil rather than char. Bio-oil is a dark brown or reddish-brown liquid with a smoky odor.

Bio-oil may be used as a fossil fuel substitute for heat and power, lime kiln, and boiler applications. It has a higher heating value of 16 to 19 MJ/kg (6900 to 8200 Btu/lb) and a water content of approximately 20 wt%. Bio-oil consists of more than 100 compounds, but ultimately contains mainly C, H, and O and is essentially sulfur-free.

Tests conducted using the pilot lime kiln at the University of British Columbia, Canada, have shown that bio-oil atomizes and burns well, yielding a flame comparable to that of natural gas. The results also showed that the temperature and calcination profiles were similar to those of natural gas and that the lime reactivity was not affected. Tests performed by bio-oil supplier Dynamotive in a BFB pyrolyzer pilot facility in West Lorne, Ontario, Canada show that the levels of CO, SO₂, and NO_x in off-gases are comparable to those of natural gas.

Ideally, a bio-oil production facility would be located in an area with a large supply of biomass available, on the order of 200 moisture-free t/d. The resulting bio-oil can be used at the facility or easily shipped by tanker trucks because the reduced volume of pyrolysis oil relative to raw biomass (a 12:1 volume ratio) enables economical short-term storage and transport and the possible sale of excess oil to other users. Therefore, pulp mills would have the option of shipping in bio-oil or producing it on site.

To date, pyrolysis oil has not been used commercially in a lime kiln, although a short-term field test has been performed at a pulp mill in British Columbia, Canada, and reportedly has shown the thermal performance and lime quality to be comparable to those obtained with natural gas. There are some possible concerns with bio-oil pH and viscosity [12], which likely will be addressed as trials continue.

OLEIN BIOFUELS

A kraft pulp mill in Brazil is currently burning filtered, liquefied animal fat from a nearby meat-processing plant in their

lime kiln. The fuel is an oil derived from an animal fat called olein. Olein is made up of a variety of fatty acids, but ultimately it consists mostly of carbon, hydrogen, and oxygen and contains virtually zero NPEs. Olein biofuel has a higher heating value of 39.3 MJ/kg (16,900 Btu/lb).

The mill has conducted tests to characterize the biofuel before burning to achieve the correct tuning of their burner system and to avoid plugging or overheating in the fuel piping. They have not had to replace their pumps or burner because through proper temperature control they have managed to lower the viscosity of the olein biofuel to the same value as that of the heavy oil they were previously using. They also report that the use of olein biofuel has reduced deposition in pipes and pumps and in the burner because it is more similar to light oil than to heavy oil. The kiln temperature profile, flame length, lime reactivity, and lime availability are comparable to those achieved with heavy oil, and the mill is achieving significant reductions in fuel costs.

ECONOMIC ANALYSIS

The choice of the optimal alternative fuel is essentially mill-specific. Although the cost and availability of an alternative fuel are often the main considerations for selection, the potential impacts of its use on lime kiln performance, the chemical recovery operation, and the environment are also important factors to consider. This, along with ever-changing fossil fuel prices in recent months and wide variations in transportation costs and regulations (such as carbon taxes) from mill to mill, makes it difficult to evaluate properly the overall economics for each of the six main alternative fuels mentioned in this paper.

The challenge for kraft pulp mill personnel is therefore to gain a better understanding of the unique process and operational impacts of each alternative fuel, so that they can efficiently and effectively select the best type for their particular situation.

SUMMARY

Various alternative fuels are being used or proposed for use in lime kilns, each of which has different process impacts on the lime kiln and the chemical recovery cycle that must be examined before the fuel is used. Petcoke is the most common alternative fuel in the United States because of its high heating value and low cost, but it has several disadvantages, in particular associated with high sulfur input to the mill recovery system. Gasified wood residues, directly fired wood residues, bio-oil, and precipitated lignin all offer the benefit of being renewable non-fossil fuels that reduce CO₂ emissions, yet all have the disadvantage of lower heating values relative to fossil fuels, with resulting impacts on kiln production and performance. **TJ**

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INSIGHTS FROM THE AUTHORS

The original motivation for this research was to understand how deposits are removed by a sootblower in an effort to optimize recovery boiler operation. This quickly led into investigations of the impacts of various alternative lime-kiln fuels on the operation and economics of both recovery boilers and lime kilns. This research project is one of five major tasks in the authors’ research program, “Alternative Fuels for Lime Kilns.”

The most difficult aspect of this research was finding information on past experience with alternative fuels in lime kilns, particularly for installations that are no longer in use. This difficulty was addressed through a rigorous review of older journal issues and through conversations with experienced individuals from industry. It was very interesting to discover that many of today’s ideas and issues surrounding alternative fuels for lime kilns were already being discussed in the 1980’s and that some still-active installations date from that time.

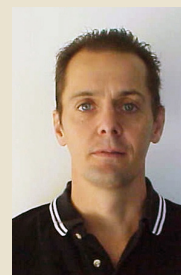
It was found, not surprisingly, that the process and operational impacts of the various alternative fuels are unique to each mill. The challenge for kraft pulp mills is to gain a better understanding of their own operations and economics so that they can select the best



Francey



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type of alternative fuel for their particular situation.

Given the increasing use of alternative fuels with high sulfur contents in lime kilns, the next step is to look more closely at the effects of sulfur absorption by lime and how this impacts lime kiln and chemical recovery operations.

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