Co-firing wood with coal

What is co-firing?

Co-firing refers to the combustion of biomass (process residues, forestry residues, purpose grown crops, other organic wastes) with coal. It therefore involves the use of two quite dissimilar fuels and may be considered essentially as a fuel management process to ensure the best blend is identified for each particular case. Co-firing may be used for strategic or economic reasons particularly when there is a shortage or high cost of one of the fuels. A blended fuel may also facilitate combustion.

[Note that cofiring can also be of a blend of different quality fuels such as wood pellets with bark to make a better combustible fuel. This Technical note[1] is only for the option of cofiring coal and biomass but many of the same principles apply to cofiring different quality biomass fuels.]

It is a particularly relevant energy option for New Zealand as we have large quantities of both resources. We are faced in the near future with the prospect of a 70 PJ per annum “wall of wood” from forest harvesting and have coal reserves sufficient to last for centuries.

Co-firing may refer to addition of biomass to predominantly coal fired plant or to the addition of coal to a predominantly biomass fired plant.

In an international context “co-firing” is generally taken to mean the addition of biomass to a coal-fired electricity generating power plant using a pulverised fuel (pf) combustion system, although there has been a good deal of smaller scale experimental testing carried out using other types of firing system. To allow for pneumatic injection of wood waste into the pf boiler it has to be ground down to a fineness similar to that of the pulverised coal. This is a costly operation. Typically the coal is about 100 µm, and the biomass in the form of sawdust is about 150 to 200 µm. To reduce the biomass particle size it can be added to the coal and passed through the pulveriser and then passed to the classifier. The sufficiently fine biomass is then fired into the boiler. (Previous tests at Huntly resulted in very little in the way of size reduction where much of the biomass was rejected.)

In the New Zealand context, “co-firing” refers more commonly to the addition of coarser hogged biomass which is fed into a coal fired grate boiler. The boiler may be part of a heat raising, or combined heat and power raising plant that uses very different fuel injection systems from those commonly found at electricity generating power stations.

Similarly coal can be fed into a biomass fired boiler.

The two approaches are quite different and are considered separately.

[1] Edited from the original produced by CRL Energy for the Bioenergy Association.

Adding biomass to coal-fired plant – the benefits:

The main advantage of adding biomass to coal fired plant comes from the fact that a coal fuelled facility can be made part renewable with minimal capital expenditure. This is attractive if the heat plant still has remaining economic life and/or the owner is capital constrained with regard to replacing the coal plant with biomass energy plant. The biomass may also be a cheaper fuel than coal and by blending can reduce heat production costs.

In addition biomass is considered a CO_2 neutral fuel in that when it is combusted it merely returns to the atmosphere the CO_2 that was removed during its formation. Biomass combustion does not therefore add to the greenhouse gas emission inventory.

For example, a 1 MWth coal fired boiler used to make process heat, operating 50% of the year consumes approximately 700 tonnes of "typical" sub-bituminous New Zealand coal. When combusted the coal emits approximately 1,500 tonnes of CO_2. Using biomass to provide 10% of the energy will reduce the CO_2 inventory by 150 tonnes per annum. Approximately 140 tonnes of (40% dry moisture content) wood will need to be added to replace the coal in order to provide the necessary heat.

Biomass also typically has a lower sulphur content and this results in reduced emission of SO_X gases. It typically has lower ash content and while this leads to reduced levels of ash formation, the difference in ash properties can occasionally lead to less desirable outcomes (see below).

The biomass may be in chip, hog or pellet form. Biomass pellets are particularly good for co-firing with coal because of their flowability, thus making blending attractive.

Adding biomass to coal fired plant – the issues:

In New Zealand CRL Energy have carried out an extensive series of co-firing evaluations on their combustion test rig in which a range of "typical" biomass materials (P. Radiata forest arisings and bark, and the stemwood from a commonly grown short rotation Eucalypt crop) were added to typical industrial New Zealand sub-bituminous coals. By "typical" is meant biomass materials with approximately 40% moisture content (dry basis) and a calorific value of 10 MJ/kg and coals of approximately 25% moisture content and calorific value of 23 MJ/kg.

Slagging

Slagging is the formation of hard ash deposits within the firebox. They can inhibit access of oxygen to the fuel and lower combustion efficiencies. Relative to coal, the lower ash content of biomass additives means reductions in amount of ash produced but not necessarily in the amount of slag. There is always the possibility of forming low melting materials that would not have formed when burning the coal (or biomass) alone.

One instance is formation of a low melting mixed sodium potassium sulphate slag. Coal alone produces low potassium ash, biomass alone produces low sulphur ash but when burned together in the "wrong" proportions, the low melting mixed sulphate material may form a slag. In the CRL tests it was seen only with bark addition but it is likely to also apply to other biomass additives. There are no totally foolproof, easy to use indicators, to forewarn of the potential for unexpected slag formation.

The nearest is an ash melting test but preliminary combustion testing is the best form of insurance. This is recommended if a blended mix is to be used.

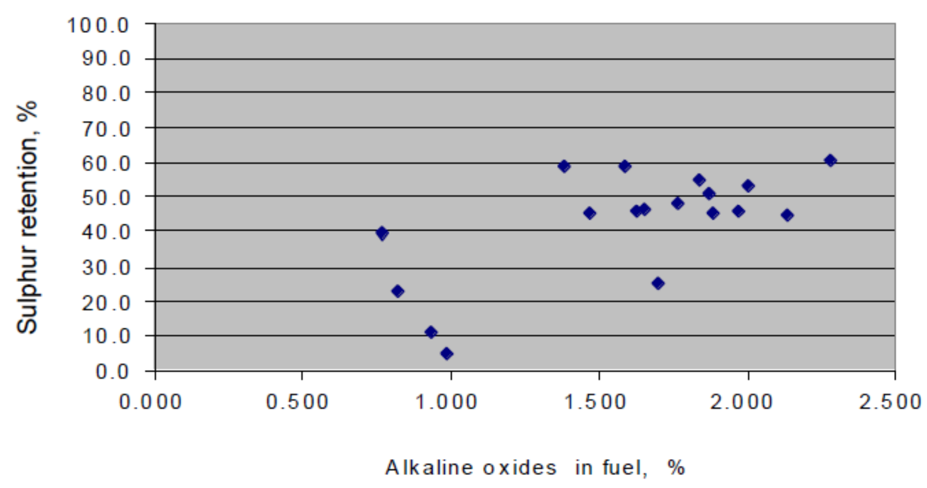
Emissions

The higher moisture content of biomass may lead to reduced combustion efficiencies and increased emissions of carbon monoxide and methane. In the case of the CRL Energy combustion tests no significant problems were seen for up to 25% addition of any of the biomass additives to coal.

One means of checking whether problems may arise is to calculate the maximum theoretical firebox temperature for the mixed fuel. Although this temperature is never reached in practice, it does provide a good indicator of likely burnout of carbon monoxide and methane. A potential maximum firebox temperature in excess of 1000 to 1100°C is generally considered desirable in order to ensure good burn out of these gases. There is less likelihood for significant changes in combustion behaviour if the difference in maximum theoretical combustion temperature for coal and the coal/biomass blend remains less than 100°C.

The expected decreases in SOx emissions are seen to occur when burning mixed fuel. On occasion the SOx emission reductions are greater than expected because the biomass may assist with retaining some of the sulphur within bottom ash. *Refer Figure 1*. Greater than 1.5% alkaline oxide in ash suggests better than 40% sulphur retention in ash. NOx emission levels may also decrease as a result of lowered firebox temperatures from a mixed fuel. *Refer Figure 2*.

Figure 1: Sulphur retention in ash



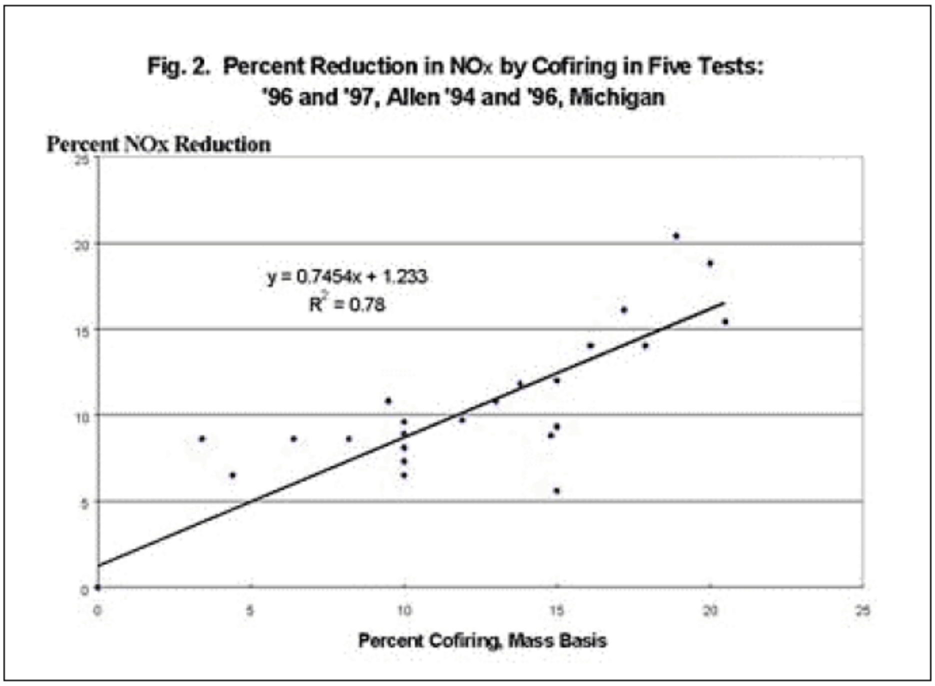


Fig. 2. Percent Reduction in NOx by Cofiring in Five Tests: '96 and '97, Allen '94 and '96, Michigan

Particulate emissions may increase because of lower density of the biomass ash. This places greater demands on the grit arrestor equipment and if this happens to be an inertial cyclone specifically designed for coal ash particulates, as is often the case in industrial coal fired boiler plant in New Zealand, its capture ability may be compromised. This becomes more noticeable above approximately 15% biomass addition and may require changes in the set-up of the particulate capture system. In extreme cases it may require the installation of more effective grit arresting equipment – a baghouse for example.

Fuel handling

Coal is typically fed into the combustion unit through a hopper system but biomass fuels have a tendency to bridge if fed through coal hoppers. They may require a hopper assembly with a different geometry or may need to be fed in separately on a conveyor system. Usually it is possible to add fuel with up to 25% biomass additive through an appropriately designed hopper system.

A mixed fuel requires two separate storage and handling systems which increases the capital cost of a heat raising system.

General comment

It may also be noted that because the biomass additive often has a higher moisture content than the coal on which the firebox normally operates, extra heat may be required to ensure the fuel ignites at the correct position within the boiler and levels of unburnt carbon are kept to a minimum. This may require modifications to operation conditions or, in more extreme cases, changes to firebox geometry. The CRL Energy trials showed that with up to 25% biomass additive, there were no significant issues in this regard.

Adding coal to biomass fired plant – the benefits:

The main advantage of adding coal to wood is to act as a reliable, regular quality auxiliary fuel at those times when biomass supply is limited or biomass fuel quality is variable. Typically, the addition of coal also adds extra calorific value to the fuel and while this has advantages it can lead to less desirable outcomes (see below). It is likely to lead to increased sulphur emissions and ash formation.

Adding coal to biomass fired plant – the issues:

CRL Energy has also carried out tests on the addition of typical industrial New Zealand sub-bituminous coals to the biomass materials (P. Radiata forest arisings and bark, and short rotation Eucalypt) used in the previous combustion assessments.

Slagging

The addition of coal, with its lower moisture content and higher calorific value can lead to increased thermal intensity within the firebox and this, in turn, can translate into increased slag formation.

Bark and forest arisings often contain high levels of quartz and a silicon containing albite feldspar. This is not surprising given the dominance of silicaceous rock types in the volcanic plateau area where many of the bark and arisings samples were grown. The albite feldspar material typically melts at or near the temperatures (1,000 to 1,050°C) found in biomass combustion systems. The addition of coal and the corresponding increase in thermal intensity can easily translate into melting of the feldspar and the onset of slag formation. For biomass samples that may have been dragged across the plateau soil and picked up significant deposits of the albite feldspar, the danger is especially high. On occasion, the addition of as little as 10 to 15% coal by calorific value was sufficient to bring about the formation of significant quantities of slag.

Emissions

The CRL Energy combustion test rig was set for biomass combustion and the addition of up to 25% coal (by weight) with its lower moisture content and higher calorific value had no adverse affects in terms of increased emissions of carbon monoxide or methane – indicators of reduced combustion efficiency. This has been confirmed in practice where 15 to 20% by weight of coal has been added to bioenergy plant fuel supply and resource consent conditions have not been exceeded.

In the tests, SOx emissions increased although the rise was seldom as large as that expected. Many of the Waikato sub-bituminous coals generate alkaline ashes and, under stoker type combustion conditions, are able to assist with sulphur retention in bottom ash.

Particulate emission levels were not significantly altered with the addition of up to 25% coal. In this case, the grit arrestor (an inertial cyclone) was specifically designed originally for higher density coal ash material and it experienced no difficulty in capturing them

Fuel handling and operation conditions

Comments made above relating to fuel handling and modifications to operation conditions and firebox geometry are also relevant in the case of addition of coal to biomass plant.

NZ experience

CHH Whakatane

Carter Holt Harvey Packaging (Whakatane Mill) co-fires coal and hog fuel in their number 3 John Thompson chain grate boiler. The boiler was initially designed as a coal fired boiler but was modified so as to utilise as much as possible of the hog fuel generated from on site product processing. This included retro-fitting of a hog fuel feeding system. Originally natural gas was used to help establish steady combustion of the hog fuel, but increases in natural gas prices have seen the plant turn to coal for providing auxiliary heat. Currently the plant co-fires approximately 80:20 by calorific value of biomass to coal. It typically raises 18 tonnes of steam per hour and consumes approximately 6 tonnes of biomass and 1 tonne of sub-bituminous Waikato coal per hour.

The boiler is running very well with steady combustion, high levels of carbon burn-out, and no signs of any slag formation on the grate.

Dunedin Hospital

Dunedin Hospital heat is supplied by Pioneer Energy from the old coal fueled boilers. At times of the year they are supplemented by use of wood fuel.

JNL Kaitaia

JNL at kaitaia have often had shortages of wood fuel supply and so have supplemented the fuel with coal.

Windstone Cement Works

The cement kilns at Portland, Northland are duel fueled with wood waste and coal. Because of the high temperatures in the kilns the wood waste used as fuel can contain some contaminants.