Why convert biomass to oil rather than just burning it directly?

Small scale success

By Phil Thane

Pyrolysis is the production of gases, liquids, and char (solid residue) by thermal decomposition of an organic compound in the absence of oxygen.

The liquid produced from pyrolysis of biomass used to be referred to as bio-oil or sometimes bio-crude but pyrolysis oil (PO) is now preferred and the properties of the oil are defined by ASTM D7544 - 09 Standard Specification for Pyrolysis Liquid Biofuel.

The standard contains specifications for solids, water content, flash point, pour point, gross heat of combustion, viscosity, density, sulphur and ash content.

Pyrolysis can be optimised in various ways to produce more or less of each of the three products. Where PO is desired it is normal to burn char for fuel to drive the process. Waste heat and gas are then available for biomass drying, power generation or area heating depending on local conditions. It is possible to engineer the system to burn the gas for fuel and output char which can be used as a soil improver.

Three of the leading projects looking at PO are BTG-BTL based in Enschede, the Netherlands, working with OPRA turbines and others; Envergent, a joint venture set up by UOP Honeywell and Ensyn, based in Des Plaines, Illinois, US; and a Finnish joint venture comprising Metso, UPM, Fortum and VTT.

Why pyrolyse?

Given that biomass can be burnt in specialist boilers, or co-fired with coal in conventional boilers people might wonder why companies would invest in a more complicated technology. There are two broad reasons, and a host of minor variations.

First, there is a very large installed base of oil-burning boilers and gas turbine CHP units. Burning pyrolysis in oil in those would go some way to meeting emission targets.

Secondly, biomass is not energy dense like coal or oil; a lot of it is needed to fire a boiler.

Transporting biomass is expensive and reduces the fuel's green credentials. Densification methods exist to make it easier to transport, such as chipping, pelleting and briquetting, but converting it to an oil that can be carried long distances using existing supply chains may turn out to be the ultimate densification technique.

Metso et al believe the forest regions of Scandinavia could export PO by ship or rail car to the more populous parts of Europe.

There is a third use for pyrolysis oil, as a feedstock for further processing to produce petroleum substitutes: this process faces significant competition from companies making syngas from the material instead of PO. Syngas can be reformed into renewable diesel and petrol, which are true drop-in replacements with the same chemical composition as petroleum products.

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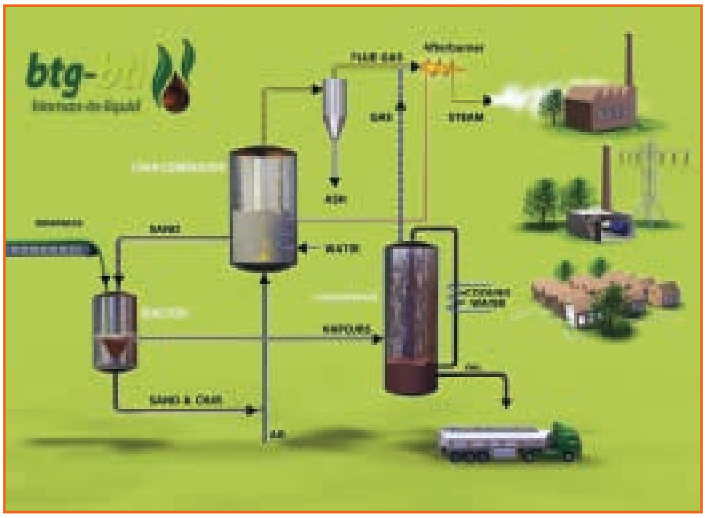
Pilot market

The market for PO at the moment is very small, consisting chiefly of pilot schemes. So far these are all looking positive and the potential is significant.

In the US Envergent has been working with the Orenda Turbine division of Magellan Aerospace studying the use of PO in combined cycle (CC) power generation. A conventional CC plant has a gas turbine driving a generator, followed by a boiler which extracts heat from the gas turbine exhaust to raise steam for a steam turbine. These systems are very efficient when run on petroleum fuels, but one cannot easily adapt a gas turbine to run on biomass. They can be run on pyrolysis PO though; adding a pyrolysis unit transforms a gas-fired power station to a biomass-fuelled power station. Envergent has also tested PO co-firing with coal in a conventional power station.

Both the Metso group and BTG-BTL have been experimenting with PO in a combined heat and power (CHP) plant. Metso has so far produced about 80 tonnes of PO at its plant in Tampere, 20 tonnes of which partner Fortum has burnt in a modified district heating plant at Masala near Helsinki. Jani Lehto, pyrolysis project manager at Metso, reported that the trials showed that PO can be used as a replacement for heating oil



The BTG-BTL process

with only minor modifications to the burner system.

Fortum's head of R&D Jukka Heiskanen explains that the company has numerous oil-fired district heat and industrial steam boilers in service and the cost of converting those to burn PO is much less than renewing the boilers completely to burn solid biofuels. On the larger power plant scale the competitiveness of pyrolysis oil is reduced and at the moment solid biomass is more economic.

Meanwhile in the Netherlands BTG-BTL's turbine partner OPRA is testing a CHP unit that will supply 1.8 MW of electric current to the grid and 4.5MW of heat to 1500 homes via a district heating system. The turbine combustion chambers were modified slightly and a dual fuel system arranged so that the system starts on ethanol or natural gas then switches to PO once it reaches operating temperature. The turbine can run at full load on 100% PO and no ill-effects were observed.

BTG-BTL's marketing manager Dagmar Zwebe does not see PO replacing coal or natural gas on a large scale due to economic reasons, but believes there is a place for it on a smaller scale where, for example, there is no access to natural gas.

Predicting future markets is notoriously difficult but Jani Lehto for one believes that the price of crude oil will rise significantly in the future making PO more competitive:

'With carbon taxes and/or renewable fuel incentives in many countries PO will become a very intriguing option in the future. But at the moment, it's case-by-case as markets are still developing.'

Metso's product burning in a CHP plant in Masala, Finland

OPRA's CFO Colin Bartell makes a similar point:

'Biofuel applications are a new and exciting segment for us but the market still largely needs to be developed. We do however see lots of potential and are actively pursuing a number of opportunities.'

Competing technologies

In the BTG-BTL process chopped, dried biomass and hot sand are dropped onto a spinning cone inside a reactor. The biomass is pyrolysed in a couple of seconds. Gases leave the top of the reactor, sand and char fall to the bottom and are carried to a char combustor chamber. Sufficient air is admitted to burn the char, re-heating the sand which returns to the reactor. Gases from the reactor are cooled, most condense to PO; the non-condensing fraction is burnt, together with flue gas from the char combustor to raise steam for power generation or area heating. Some heat may also be diverted to biomass drying if necessary. The system is energy self sufficient; no external heat or fuel is needed.

BTG believes its process, developed even before the company was spun out of the Chemical Engineering faculty at the University of Twente, is more compact and less complex than rival systems due to the fact that no inert gases are used. This also results in cleaner oil with less particles, BTL can reach an ash content of less than 0.05% (weight) within the PO.

The Envergent Rapid Thermal Processing (RTP) system is based on work on thermal conversion technologies begun by Robert Graham in 1978 at Forintek Canada. In 1984 he founded Ensyn and is currently chairman. RTP uses a circulating fluidised bed, and has some similarities with the Fluid Catalytic Cracking system used by UOP to crack petroleum. Scaling a fluid bed system from small pilot to demonstration production scale and on up to full size is tricky, but UOP's experience with FCC systems and software modelling from Particulate Solid Research Inc. has enabled Envergent to overcome these issues.

Biomass is fed into fluidised hot sand and pyrolysed in seconds. Gas, char and sand are carried up and out of the reactor to a cyclone which drops the solids into a reheat vessel. Air is admitted causing the char to burn and reheat the sand which is fed back to the reactor. Gases from the pyrolysis are condensed and non-condensible gases are available for other uses.

Mark Reno, Envergent's general manager, says the advantages are that RTP is easy to control to maximise liquid yield and reduce gas generation and like FCC is 'heat balanced'; there is no external heat needed.

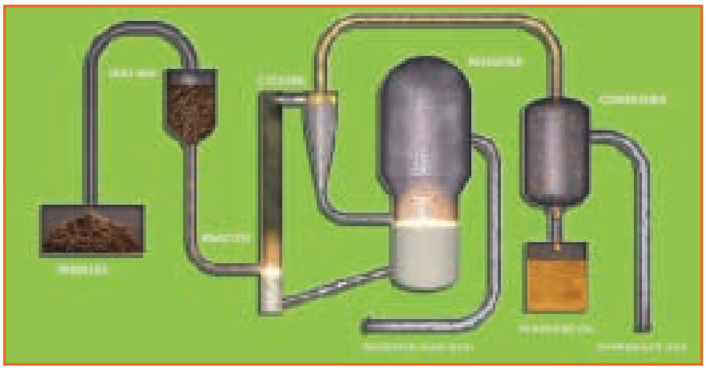
Finland has a lot of forests, and a lot of experience using fluid bed biomass fired boilers for industrial process heat, especially in the pulp and paper industry. Finland's Technical Research Centre, VTT, saw the potential to use existing fluid bed boilers as the reheat stage in a pyrolysis system.

In the Metso process two holes are made in the fluid bed boiler to remove hot sand and return it somewhat cooler together with char from the pyrolysis unit. According to Metso's Jani Lehto this has little effect on the boiler function. The pyrolysis unit (shown inside the green dashed line) resembles Envergent's system except that here the non-condensible gases are supplied to the heat and power boiler. This gas, together with the char, reduces fuel consumption in the boiler.

Feedstocks

Feedstock costs are a significant factor and its availability and reliability must be factored in when planning a pyrolysis plant.

UPM is among the most important users of wood-based raw materials in Finland, and feedstocks for PO are side products of UPM's current business – forest residues and sawdust. By integrating the pyrolysis plant into an existing boiler in operation at a timber mill, transport costs are minimal, and waste heat from the boiler can be used to dry the feedstock.

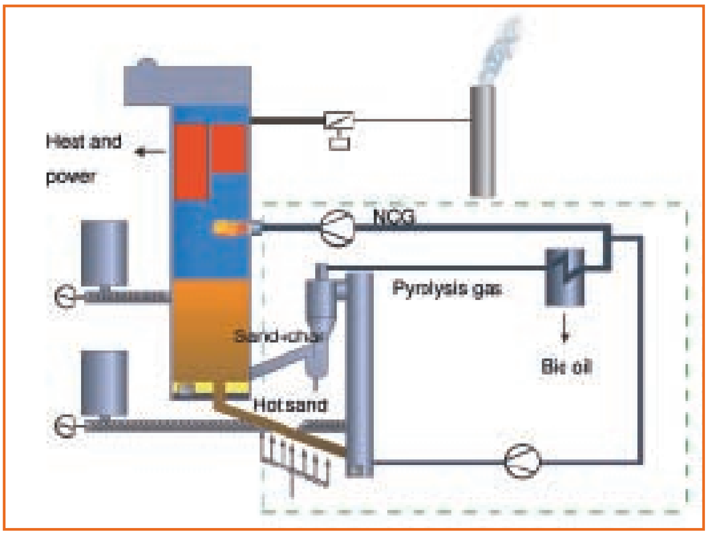


The Envergent Rapid Thermal Processing (RTP) system

Envergent has tested about 70 different feedstocks including corn stover, bagasse, algal residues from algal oil production and many different kinds of wood. Mark Reno says they all work, but finds that using any kind of wood the resulting PO has a low pH value. This is not a huge problem when the PO is is destined for use as fuel, though it does have handling implications. In Finland Metso says that it simply transports its oil in lined tanks used for chemicals, rather than conventional oil tanks.When pyrolysing algal residue or softer energy crops such as Penny-cress Envergent reports that the PO is only moderately acidic or even neutral. This is more important when the PO is intended for upgrading for transport use, and Envergent is continuing to research the processes that create the acidity.

It is essential that PO units are built close to the source of biomass. BTG's plant Empyro will be used to demonstrate commercial use with a wide range of feedstocks and it is licensing its technology in other countries where substantial amounts of biomass and residues are available. Back home in the Netherlands there is not a lot of (woody) biomass, but BTG-BTL has been working with switchgrass that grows wild alongside highways and dried sewage sludge for example. Pyrolysis is an ideal method of dealing with problem feedstocks that do not perform well in other processes.

The final word on feedstocks goes to independent feedstock supply specialist Michael Keller of Santa Cruz, California. 'If a plant requires 10 years to pay off the debt issued to construct it, the feedstock supply must be contracted for 10 years and backed by a solid balance sheet. The reason being if the feedstock doesn't get delivered, real damages are incurred. The feedstock provider must provide bankable guarantees to ensure financing, and this is almost tougher to do than anything.' ●



A Metso fluid bed boiler used in a heat and power plant integrated with a pyrolysis system