

See the wood for the fuel

Countries are turning to their commercial forests as a source of non-agricultural biofuels. Elisabeth Jeffries reports

The biofuels tide has turned. Growing fuel was once presented as the cure for our petroleum addiction, and a key weapon in the fight against climate change. But many have now poured scorn on unrealistic hype.

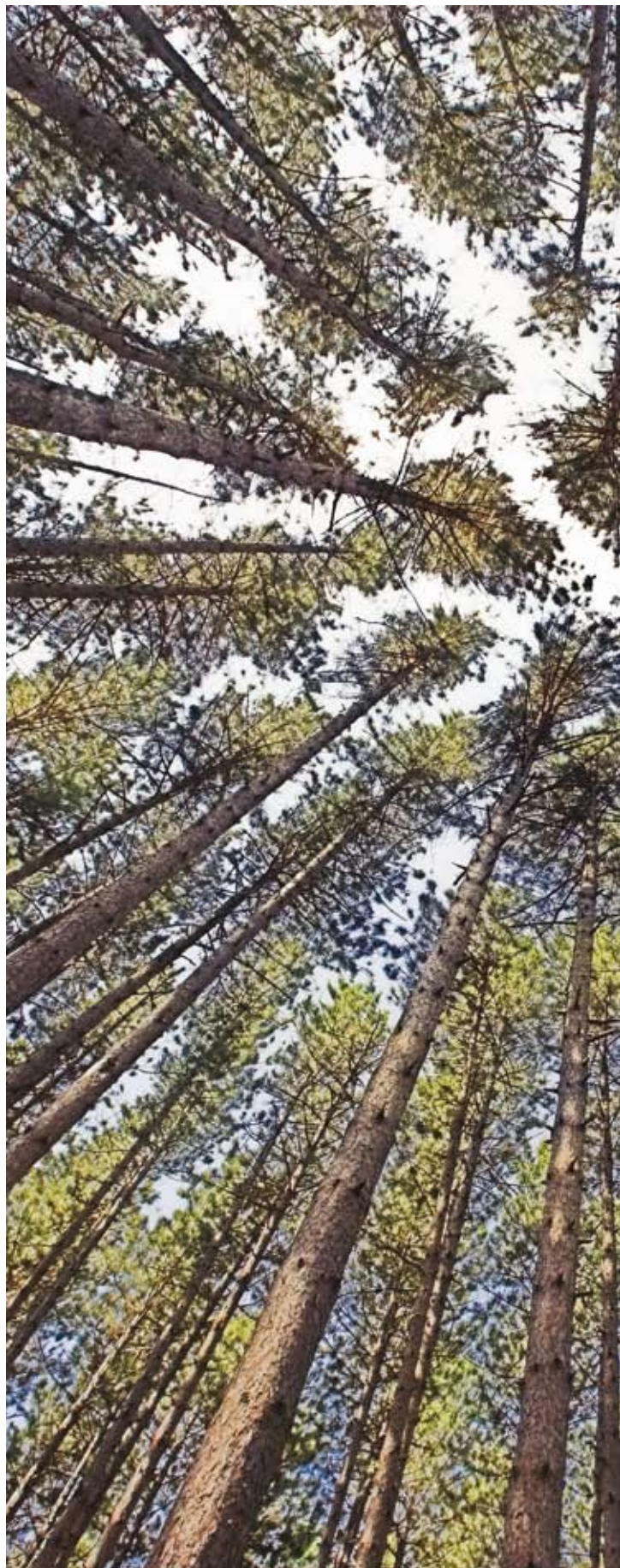
And the deforestation that provides the swathes of land needed to grow biofuel crops is a major factor in the debate. Renton Righelato, a scientist from the World Land Trust, a UK-based environmental organisation, has said that between two and nine times more carbon emissions are avoided by capturing carbon in trees and forest soil than by cultivating agricultural biofuels to replace fossil fuels. So waste biomass from forestry could provide an ideal solution: could biofuels created directly from these by-products and tree waste present the answer?

Black liquor, a by-product of the pulp and paper industry, is one of the sources of such new hope. The liquor already makes a significant contribution to the energy mix in the busy Scandinavian forestry sector. Finnish and Swedish government

data indicate that it makes up about 10 per cent of total primary energy consumption. Wood, pulp chip and sawdust in pulp mills are made of half cellulose and half lignin – a glue-like substance that holds wood fibre together. Black liquor is the watery solution left over once the cellulose has been extracted, and is made up of lignin remains and inorganic chemicals used in the pulping process. The mills burn the liquor to recover the caustic soda and sodium sulfide, while also generating steam, which means they are usually self-sufficient for energy.

It is this product which Lignoboost, the Swedish subsidiary of research company STFI-Packforsk, wants to exploit alongside pulp mill partners Stora Enso – with whom it has been running a 4000 tonne demonstration plant since late 2006 – and US-based Weyerhaeuser, with whom it hopes to build an 80 000 tonne commercial installation. Using an evaporation and filtration process, the company has been separating the lignin from

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In short

- Wood-based biofuels make good use of forestry waste while avoiding the use of farm land, and the damaging nitrous oxide emissions from agricultural biofuels
- The manufacture of these fuels has been pioneered in densely-forested regions, such as Scandinavia, and widespread use of wood-based transport fuels in such regions is likely by 2018
- By adopting lignin, a wood component, as a fuel, the Scandinavian pulp and paper sector could become fossil-fuel free

Could forestry provide the ultimate biofuel solution?

the black liquor, and refining it to produce a more intense fuel than the black liquor itself (*see box p46*). 'We think we'll have high value fuels marketed from these waste materials within a few years,' says Peter Axegard, a director of STFI-Packforsk. Throughout the last century, pulp mills tried without success to create a workable fuel from lignin. Axegard says this time it is different: 'We've made a breakthrough and use less energy, water and equipment, producing a drier and cleaner fuel,' he says.

Run of the mill

There are good financial reasons to use lignin rather than the black liquor itself, because it can help the mills to increase production without investing in new recovery boilers. At the same time, Axegard says, they gain a new source of income by selling the fuel (initially to pulp mills not producing it), while becoming fossil fuel free in the process. But he also has high hopes for further developments. 'We are working on it as a feedstock for carbon fibres, for which it has enormous potential. It could also be used in the production of phenols and benzene, via the biological route,' he says. Although transport is not a likely application for the fuel.

Lars Vallander, of the Swedish Energy Agency, is positive about lignin. He estimates that Swedish mills 'could get to produce half a million tonnes of lignin within five to ten years. There are a lot of combined heat and power (CHP) stations in Sweden so this fuel could be used to replace other [fossil] fuels they use.' This would have an impact on carbon emissions, by, for example, replacing the oil used to heat lime kilns, he adds. Mikael Hannus, business manager at pulp and paper company Stora Enso, is also optimistic. 'This technical step has been made in a remarkably short time, compared to what is usual in this field. Other lignin processes are not at all as effective as this,' he says.

Wasted resources

Lignoboost's work is only a part of a much bigger picture emerging of a whole industry dedicated to producing wood-based biofuels, using lignocellulose rather than sugar cane as its base. Wood-based fuel in liquid form is more versatile than solid pellets already used for thermal applications, which produce ash. Solid fuel is not used for transport, which also lacks the

range of sustainable fuel alternatives enjoyed in heat and power applications. So the need to find sustainable transport fuels is urgent.

The enormous resource for wood-based biofuel could play a major role in this regard, and would be derived not only from the paper and pulp industry, but from forestry thinnings and waste, sawmills, short rotation coppices of willow and poplar, and even used commercial and household wood. Statistics from a Royal Society report published this year point to the existence of 125 million hectares (ha) of industrial forestry plantations across the globe, which is only 3.5 per cent of the total forest area.¹ And the report was unequivocal in its view of the potential for wood-based biofuels, stating that 'in the future, biofuels will be produced from more complex sources [than farm crops], particularly lignocellulose'.

Paul Jarvis, emeritus professor of forestry and natural resources at Edinburgh University, goes further: 'forestry is more promising than biofuels from crops,' he says. As well as the competition for land between food and fuel, Jarvis points out that the amount of the greenhouse gas N_2O in the atmosphere caused by nitrogen-based fertilisers 'will neutralise the benefits of using crops as biofuels'.²

Mindful of the controversies surrounding agricultural (first generation) biofuels, companies across the world are developing alternative fuel solutions. Choren, a German biofuels company in which Anglo-Dutch energy giant Shell has taken a stake, has developed a fuel that can be made from wood waste, using gasification and the Fischer-



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Tropsch process, that can also be used to synthesise liquid fuels from coal and gas.

German Chancellor Angela Merkel visited Choren's plant in the state of Saxony in April to acknowledge the completion of the building phase of its plant. This is the world's first commercial synthetic biofuel production plant – using wood from forests and commercial waste such as wooden fruit crates. The company hopes to have it fully operational by 2013.

Lignin produced by the Lignoboost process

Neste Oil in Finland (see p48) is developing a similar plant in partnership with Stora Enso and plans to start commercial sales by 2014–15. Henrik Erämetsä, vice president of renewable fuels development at Neste, estimates that Finland could eventually benefit from five to ten plants supplying one million cubic metres of fuel each.

Randal Goodfellow, vice-president at Ensyn, a Canadian wood biofuels company, is engaged in the production of a liquid described as a

The big breakthrough

Scientists have tried for years to develop lignin as a fuel, but have repeatedly come across a major stumbling block. The established technique to obtain the lignin is to evaporate the black liquor, precipitate it, filtrate it out and then wash it.

But researchers found that, when they precipitated it, the filter cake clogged up and would not dissolve easily. The problems typically occurred because a high alkalinity during the washing process combined with a low ionic strength of the solution to affect the properties of the lignin. So the aim was to eliminate the extremes of pH.

The Lignoboost process controls the pH by evaporating the black liquor to about 30 per cent and separating out the soap, but

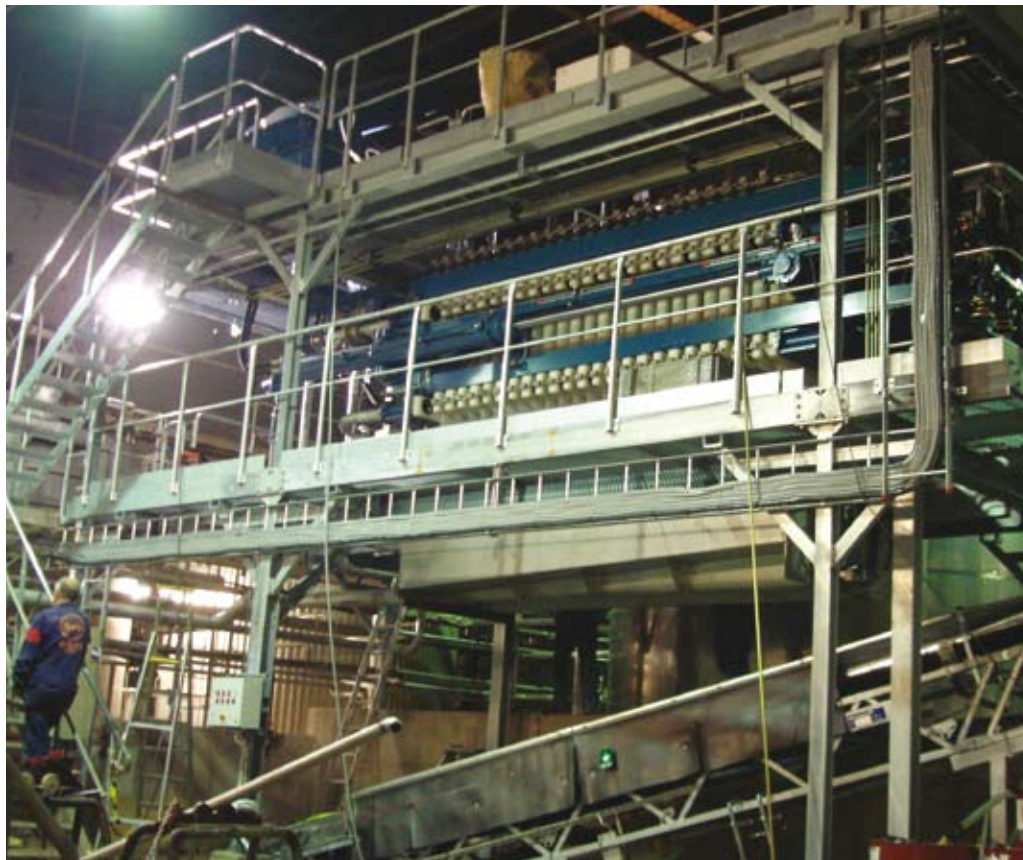


delaying the washing process. Instead, it disperses the filter cake in the liquor, under conditions where the pH is controlled by

introducing pure CO_2 , which brings the pH to about 10 – which is similar to the pH of the final wash liquor. This means that the extremes of alkalinity and ionic strength do not occur during the washing stage, which in turn means that the solubility problems are solved.

There are still some problems, though: CO_2 costs are high, and the company wants to find ways to reduce its use. One possibility that the company is considering is the use of CO_2 extracted from lime kiln gases. In trials, Lignoboost found that the lignin came out as a solid brown cake which produces relatively little ash, an advantage when used in intensive incineration processes.

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'bio-oil'. Ensyn's process is known as Rapid Thermal Processing (RTP) and can use sawmill residuals and construction and demolition wood waste as well as fast-growing wood species such as willow and poplar, liquefying 75 per cent of the original in a fast pyrolysis process.

Bio-oil can be used directly as a fuel, but it also contains natural chemicals, resins and fuels, which can be refined for use in stationary boilers and other thermal applications, and which could compete with petroleum-based chemicals in the resin and polymer industries. Originally developed in the 1980s, it has already found an application as a feedstock in the food flavouring industry.

In addition to these synthetic biofuels, organisations in many countries around the world – including Japan and the US – are developing ethanol using lignocellulosic sources (a term which includes plant waste such as cereal stalks as well as wood). These include Iogen in Canada – which Shell is also partnering – and Sekab in Northern Sweden, which uses a hydrolysis process followed by fermentation and then distillation. Engineering company JGC started up a similar pilot biorefinery in 2002 at Izumi on the South Western tip

of Japan. It uses furniture and paper industry waste.

But there are hurdles between the laboratory bench and commercial-scale production. A good deal can go wrong even in the shorter step up to demonstration scale. 'On a demonstration project, you could get several months worth of unwanted materials building up,' explains Neste's Erämetsä. 'Gasifying the raw material is not a problem. It's cleaning it so it's clean enough to go through the synthesis that we need to deal with.' Sekab, for its part, needs to develop new enzymes to break down the cellulose in plant material into sugar and new types of yeast that convert the different types of sugars in the biomass into ethanol. 'Lignocellulose is not as easy to handle as sucrose,' says Jarvis. It is a complex matrix consisting of polysaccharides, phenolic polymers and proteins. And although cellulose stores lots of energy, its accessibility to biochemical hydrolysis and sugar release is restricted by the cell wall structure and lignin – an inert polymer. This is a big stumbling block in the quest for an energy-efficient process – energy-intensive chemical and physical pre-treatments, or thermochemical routes are used to open up the walls for enzymic hydrolysis. Plant oils

STFI-Packforsk's Bäckhammar demonstration plant in Sweden

'Biofuel could be made from forestry thinnings, sawmill waste and even used household wood'

and sugars, on the other hand, are readily accessible for converting to biofuels.

So huge production efficiencies will need to be gained before these plants can compete with agricultural biofuels plants, let alone fossil fuel plants. But companies are also trying to produce butanol, rather than ethanol from these sources, which has a higher energy density and is easier to blend with conventional fuels. If they succeed they will have a fuel that is much more efficient than any of its competitors.

Lost in the forest

But which trees will produce the most reliable and renewable feedstock? Jarvis argues against short rotation coppices – a feedstock that Ensyn, like many others, is considering. 'They can have high yields. But after the first few cycles they require fertiliser while the leaves – which contain important resources – blow away. After about 20 years, disease sets in, in particular for poplars, which are very susceptible to rust,' he says. 'I don't think they will take off, plus they need to use agricultural land.' By contrast, he argues that resources in coniferous forests stay put and are more stable: 'they are ideal as a source, and are grown anyway for timber,' he says.

It will be a long hard road to make all of these technologies competitive, but Jarvis is very optimistic about the future for forestry biofuels, although he predicts that their impact will be specific to countries with intense forestry industries, including his home country, Scotland – which plans to increase its forestry cover to 25 per cent. 'Bio-petrol using a blend with alcohol, butanol or other chemicals is available in Brazil and other countries from sucrose or other chemically simple crop wastes; and will be available widely from lignocellulose within 10 years,' he says. 'Developments will continue predominantly in countries with large forest areas and production, such as Sweden, Finland, Austria ...and will be used widely [there] to reduce dependence on fossil fuel.'

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References

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- 2 P J Crutzen et al, *Atmos. Chem. Phys.*, 2007, 7, 1191