

Low cost 'waste' feedstocks will also be helpful in bringing down costs; however, they can't be relied upon forever, warns Gerson Santos, director R&D corporate at Abengoa Bioenergy. 'We cannot count on using a low cost waste because it's going to be a commodity at some point.' Ultimately, Santos says that biofuels producers 'are going to enter into a carbon-constrained environment and will be rewarded for reducing carbon. If that doesn't happen, if you don't have an incentive to reduce carbon in the transport sector then you are going to be merely competing on price.'

Further in the future, meanwhile, biofuels experts point out that most facilities will also operate as biorefineries that produce a whole range of other renewable chemicals besides fuel. Some of these biofuel side-streams could be more valuable than the fuels themselves. 'We see biorefineries evolving just like oil refineries did,' says Brent Erickson, executive vp of BIO. 'So when they first made gasoline for the Model T, now they make a whole range of products. We see that happening with biorefineries as well.'

For now though, the real challenge is not technology integration, it is supply chain development, says Jack Huttner, vp commercial and public affairs at DuPont Danisco. 'The requirement of biorefineries for biomass is significant and organising the farmer producers to deliver the kinds of volumes we're going to need is a big challenge.'

'Building a biorefinery is going to cost north of \$250m. We can't move it once it's built if all of

a sudden farmers decide they are going to grow asparagus or something.'

Making sure that the correct infrastructure is in place is another challenge. Ethanol cannot be distributed in the existing petroleum gasoline pipeline system which poses a significant problem for suppliers. Alternative biofuels such as biobutanol have the advantage of having hydrocarbon-like properties that mean they can be sold directly to refiners and use the existing infrastructure, says Patrick Gruber, ceo of Gevo, which is aiming to commercialise its biobutanol technology by 2011. 'The more interesting part of the story actually is that if you take the isobutanol, do a little chemistry to it, then you can make renewable gasoline. This is exactly gasoline, it meets the ATSM spec,' he continues.

Car manufacturers could also help by making all new models flex-fuel vehicles, able to run on gasoline or blends of up to 85% ethanol, adds McKinsey's Caesar. 'I don't know why every vehicle today isn't a flex fuel vehicle. It costs just \$200 extra to make them.'

Ultimately, Caesar continues, the real sustainability of biofuels will be judged on a complete 'well to wheel' analysis that takes in all their inputs and emissions – including fertilisers, water, power consumption power and the impact on land and biodiversity – compared with conventional gasoline. 'Biofuels can contribute to reducing environmental impact but only if you produce them in the right way with the right feedstocks in a truly carbon reducing

manner. I believe biofuels are going to be important but biofuels done wrong can create problems. Not every biofuel will pass the test.'

Biofuels manufacturers, meanwhile, argue that there is plenty of land available to grow all the energy and food crops needed. Biotechnology is already bringing big increases in crop yields, as well as developing plants capable of thriving on land that would otherwise have been left idle, they point out.

In the US, to produce the huge quantities of biofuels needed, 'every region of the country will have a different model and a different feedstock. It could be wood, it could be dedicated energy crops, it could be sweet sorghum. In the Midwest it'll probably be corn residue,' Erickson says. 'All of these choices will have to be made in the context of an overall set of criteria of sustainability, Gruber adds. 'There is no one general rule and answer.'

'If you start talking internationally, then the best place to grow biomass is in the tropics because there biomass is growing 365 days a year,' adds Abengoa's Santos, pointing in particular to Brazil as an area where he believes even more biofuels could be sustainably produced.

The 40-45m ha of land needed globally to produce biofuels, meanwhile, would account for only 3% of all arable land, Caesar reflects, adding that 'we are at 1.5% today... With increased crop yields, this is not the sort of change that would result in a meaningful impact on crop production – but it is a lot of land!'

Fuel from steel mill emissions

New Zealand firm LanzaTech is able to pull off a trick that no other ethanol producers have been able to achieve, according to the firm's ceo Sean Simpson. Its proprietary technology is able to convert the waste carbon monoxide emissions from energy intensive facilities such as steel mills and convert them to make fuel ethanol. Within five years, Simpson says, the plan is to start up a commercial facility to make ethanol from the emissions from energy-intensive industries like steel and oil refining – by retrofitting them with its proprietary fermentation process.

The world's steel mills alone generate enough carbon monoxide emissions to make 50bn gallons of ethanol every year, Simpson says. Half a tonne of carbon monoxide is emitted for every tonne of steel produced, all of which is currently expelled to the atmosphere where it reacts to form the greenhouse gas carbon dioxide.

'We looked essentially for the lowest cost source of carbon that was out there,' Simpson told the *New Zealand Herald* in a recent interview. 'You quickly realise that waste

resources are the lowest cost.'

The bacterium that LanzaTech uses in its fermentation is special in being able to convert the CO-rich emissions from industry into ethanol. However, the technology is essentially a thermochemical process that can also be used with virtually any carbon-based feedstock, including MSW, waste wood and even other industrial waste such as tyres, Simpson elaborates. While Simpson won't reveal how much the firm's ethanol will cost, he believes it is on track to produce the world's lowest cost ethanol.

'The economics are certainly compelling in certain geographies



where there are currently very high MSW disposal charges in place. However, a major cost factor here will be the cost of the conversion technology to produce a syngas.'

While ethanol made from steel mills wastes has exactly the same composition as bioethanol produced from cellulose, however, it may not be considered as a biofuel everywhere. 'Different countries have very different legislative definitions of what can and can't be considered a biofuel,' Simpson elaborates, pointing out that the LanzaTech technology was not considered possible at the time the legislation was created. 'Our understanding is that in, for example, major steel producing nations such as in China and India, waste-derived ethanol is a viable biofuel.'

LanzaTech is already putting its technology to the test at a pilot plant just outside Auckland where the carbon monoxide emissions from a local steel mill are fed into a bacterial fermenter that converts around 70% of the gas into liquid ethanol. 'Going forward we hope to convert 90% or more,' Simpson says.