

BUSINESS

Algae bloom again

A handful of pioneers are trying to bring algae-based biofuels back from a near-death experience. **Amanda Leigh Haag** reports.

On a spring afternoon in Fort Collins, Colorado, a bath of lime-green algae is glinting in the sunshine. Filling an 18-metre-long tank that sits in the parking lot of a disused power station, the bubbling liquid consists of millions of microscopic single-celled photosynthetic organisms. But for local company Solix Biofuels, this is more than a warm bowl of slime: it's a photobioreactor, which could soon serve as a viable energy source — and as a carbon sink, to boot.

Surging oil prices and a shortage of biofuel feedstocks are reviving interest in making fuel from algae. A barrage of tax credits and subsidies has already spawned a boom in facilities to make biofuels from corn (maize), rapeseed (canola), soya and oil palms — and hiked up the prices of these commodities. But advocates of algae say they have attributes that should make them strong contenders in the long run.

According to figures compiled by the Global Petroleum Club, a business community for leaders in the oil, gas and energy industries, soya typically produces 450 litres of biodiesel per hectare per year; canola 1,200 litres; and oil palm 6,000 litres. Researchers predict that a hectare of algae could produce 90,000 litres of biodiesel, and have the potential to go even higher. They can also be grown on land that is agriculturally barren. "Algae offer orders of magnitude greater resource potential for natural oils than any terrestrial crop," says John Sheehan, an energy analyst with the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

In addition, algae consume carbon dioxide as they grow, so they could be used to capture CO₂ from power stations and other industrial plant that would otherwise go into the atmosphere.

In the short term, Solix and the handful of other companies working on algae want to produce oils for biodiesel, replacing a significant proportion of the diesel fuel that currently serves about one-third of transport needs in the United States. Eventually, they plan to produce

ethanol from the starchy residues as well.

Progress on getting energy from algae pretty well ground to a halt in the United States in 1996 when the NREL abandoned an 18-year-old programme on it. NREL researchers sifting through thousands of algal species had identified 300 that promised the highest oil yields. But they also pinpointed major roadblocks to the technology — such as the difficulty in reliably replicating laboratory growth conditions for algae on a larger scale in the field.

Algae garner energy from sunlight, water and CO₂ through photosynthesis. They reproduce quickly and can be harvested day after day. Each species produces different ratios of oils, carbohydrates and proteins. Oils squeezed from algae can be turned into biodiesel, and the rest of the biomass can be converted into ethanol and animal feed, say advocates. Whereas oil palms — currently the leading producer of oil for biodiesel — typically yield 20% of their weight in oil, some algae yield more than 50%.

Doing all this on a commercial scale isn't straightforward, however. Shaine Tyson, chief executive of Rocky Mountain Biodiesel Consulting in Glenwood Springs, Colorado, is a veteran of NREL's algae programme. "When we actually tried to increase the oil content, we would reduce the total mass yield," Tyson recalls. Some published projections for algae's potential are based on the false assumption that algae will have equally high production rates all year round, she adds.

Algae can also be picky: too much direct sunlight can kill them; temperature must be held steady; overcrowding will inhibit their growth; and the 'waste' oxygen they produce must be continually removed from the water.

Even the bubbles of CO₂ can rupture algal cells. Open algal ponds are subject to evaporation and rainfall, which cause salinity and pH imbalances. And local species of algae often overgrow the desired strain — a problem that the NREL never solved.

To address some of these challenges, Solix



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grows algae in enclosed chambers made from plastic sheeting. But some companies, such as LiveFuels in Menlo Park, California, see open-pond systems as the only hope for keeping capital costs low enough to be commercially viable.

Solix has partnered with the New Belgium Brewery and Colorado State University, both in Fort Collins, and plans to start operating a small-scale commercial plant this autumn that will siphon off the CO₂ generated by fermentation in the brewery. Eventually, Solix would like to link up with the power industry: it calculates that a 1-gigawatt coal-fired power plant, which produces some 6 million tonnes of CO₂ annually, would need 16,500 hectares of algal greenhouses to soak up 90% of its CO₂ emissions.

But for now, the algae companies see biodiesel as their main objective, with carbon capture as a bonus. "It's a huge benefit, but it happens not to be much of an economic driver," says Bryan Willson, chief technology officer at Solix. "Currently, the economics of fuel production far outweigh those of carbon capture," he says. "That could change dramatically if there are structural changes made to the carbon regulations in the United States."

LiveFuels has raised \$10 million so far and would like to raise another \$35 million to set it on its way to its target of making biocrude — the precursor of biodiesel — from algae for \$1 per gallon by 2010. "We don't know whether



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— Doug Henston



Green gold: algae could produce biodiesel much more efficiently than conventional crops.

that's achievable, but it is our goal," says Lissa Morgenthaler-Jones, its chief executive. Green-Fuel of Cambridge, Massachusetts, has so far raised \$20 million from venture-capital groups that support early-stage companies and 'disruptive' technologies.

Solix has solid backing from a local private investor, and says it plans to develop its technology as far as it can on its own before seeking venture capital. Solix believes it can build a system that's competitive on a small commercial scale with between \$5 million and \$15 million, and says it has sufficient backing to do this.

Solix chief executive Doug Henston warns, however, that it's important not to overstate the case for the technology. He prefers to take a low-key approach: "Biofuels are in a great position to fall on their face," he says, noting President George Bush's pledge to replace 35 billion gallons of petroleum with ethanol and biodiesel by 2017. "What happens now if people are all geared up for biofuels, but the market's not there?"

And all agree that the key to algae's success will be getting costs down. "The challenge is coming up with economical systems," says Al Darzins of the bioenergy centre at the NREL, which is now collaborating with LiveFuels. "When it comes down to it, you're producing a commodity that has to be dirt cheap." ■

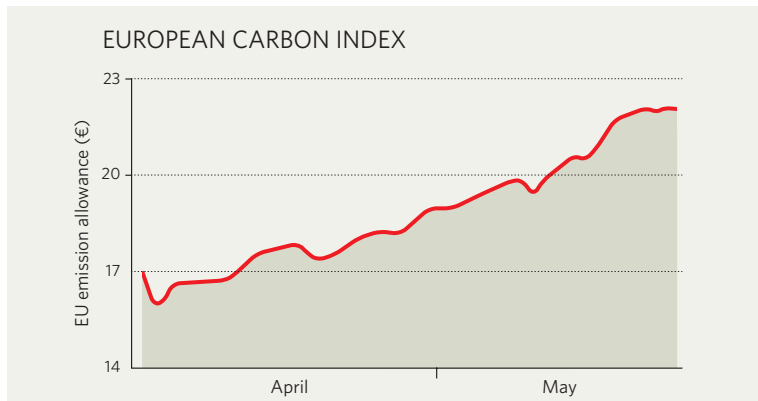
IN BRIEF

ENVIRONMENTAL UPTURN US engineering firm General Electric (GE) says it has doubled sales of environmentally friendly products, to \$12 billion annually, in the two years since it announced that it was 'going green' (see *Nature* 435, 410-411; 2005). At an event in Los Angeles with California governor Arnold Schwarzenegger, GE chief executive Jeffrey Immelt said that the company was on track to meet its target of \$20 billion in sales of such products by 2010. The goods in question range from energy-efficient light bulbs to railway locomotives — GE also introduced what it says is the world's first diesel-electric hybrid locomotive at the event.

COPYCAT CATCH Sun Pharmaceuticals, India's biggest drug maker, has confirmed that it will purchase Israeli generics maker Taro for US\$454 million. The purchase, which reflects an increasingly acquisitive streak among Indian drug makers, will help the Mumbai-based company make inroads in the United States, where Taro has most of its sales. The Israeli company has been in financial difficulties, but Sun's shares rose by about 5% when the deal was announced on 21 May.

GROUNDING NASA Computer company Hewlett-Packard has won a mammoth contract, worth up to \$5.6 billion, from NASA, to supply computers and other equipment to parts of the federal government. The unusual contract enables any government agency to buy the kit within a framework agreed between the space agency and the computer maker, which is based in Palo Alto, California. It's a follow-on from two far smaller contracts that have run since 1992.

MARKET WATCH



As the European Commission implements more stringent national caps on carbon dioxide emissions this spring, demand is rising on the emissions markets for the allowances that let companies emit more CO₂.

Several million allowances are traded daily at five European carbon exchanges, including the European Energy Exchange (EEX) in Leipzig, Germany (above).

Many energy-supply companies in the European Union (EU) are snapping up allowances now, in the expectation that they will cost more by next year. The price of an allowance to emit one extra tonne of CO₂ in the second phase of the European emissions-trading system, from 2008 to 2012, has almost doubled since February, reaching a year high of €22 (US\$30) on 22 May.

EU emissions trading, introduced in 2005, seems to have got over an early phase of pronounced, and at times

worrying, turbulence, analysts say (see *Nature* 441, 405; 2006). Thanks to the reduced caps for the second trading period, the market is now unlikely to collapse, according to one senior market-watcher based in Amsterdam.

"There is a lot more clarity now," agrees Milo Sjardin, who watches carbon markets for New Carbon Finance in London. "Uncertainty hasn't gone away entirely, but the market is definitely more robust than it was."

There is not yet enough liquidity on the market to prevent single, large transactions from moving the price up or down. But brokers are confident that the price will continue to rise moderately through the summer, perhaps levelling off towards the end of the year when power companies have signed their contracts for selling electricity in 2008.

Quirin Schiermeier ■

SOURCE: EEX