Oil from algae
a long way to go

Oil-from-algae could be a promising alternative to biofuels from land-based crops. But there are many hurdles still to overcome. Commercial production is at least ten years away.

by Leen Preesman

'Nobody can tell yet whether oil from algae is going to provide the ultimate alternative to mineral oil. As matters now stand, we expect it will take ten years before the product can be available on a large scale and at competing prices. It will very much depend on how society and industry respond to the phenomenon. And of course, oil prices are going to play a crucial role in this.'
This is the sober assessment of René Wijffels, a professor at the Dutch agricultural university Wageningen, on the potential to extract oil from algae on a significant scale. As a scientist, Wijffels prefers caution. After a year and half of research as head of the Bioprocess Engineering Group in Wageningen, he is very much aware there are still many hurdles to cross.
'At the moment, the main challenge is to turn the energy balance of growing and harvesting algae into a positive one,' Wijffels explains. 'We need to get the amount of water in the mixture down, because the process of keeping it in motion, adding CO_2, draining O_2 and harvesting the raw product still uses far too much energy. The production costs of algae paste from a 100-hectare algae farm would be €4 a kilo based on our present knowledge. We need to drive this down by a factor of ten before it is competitive with oil at a price of €70 per barrel.'

> *'Algae have great potential as a sustainable feedstock for the production of diesel-type fuels'*

Wijffels has been working on algae for eight years. Initially, he focused on extracting its useful ingredients, such as sugars and proteins. 'The algae we are studying contain a great deal of soluble proteins that are of interest to the food-processing industry. It is the entire potential of algae that makes growing it interesting,' he points out.
In early 2007, Wageningen's Bioprocess Engineering Group began researching how to extract oil from algae. Fifteen researchers work on the program. They are backed by 14 companies from all

Algae growing in plastic bags at algae production facilities of Valcent Products in El Paso, Texas. Photo: Valcent Products

over the world, including large Dutch energy providers – such as Eneco, Nuon and Essent – Dow Chemical, Finland's Neste Oil and the Hong Kong-based biofuel company, Hadnesford. The Dutch government sponsors three-quarters of the €7 million project.

After first making an inventory of costs and bottlenecks, Wijffels' team set itself a timetable in which to produce concrete results. 'Within two years we expect to have a pilot project running,' Wijffels says. 'And within four to five years we must reach a break-even level at a demonstration project on a one-hectare algae farm.'

One of the aims of the present research is getting the balance right within the bioreactor. 'In addition,' says Wijffels, 'we believe there is a potential to double the amount of solar energy that can be used for conversion into biomass.'

But the scientists have more issues to tackle. 'We are also looking at how to improve harvesting. We need to find a way to make the tiny algae cling together spontaneously, so we can filter them out in a more energy-efficient way. And for a better result from the extracting process, we actually need an alga species with a thin cell wall,' Wijffels explains.

This is one of the reasons why the Wageningen researchers are still looking for the perfect alga. 'We need a large species, which reproduces quickly, takes in CO_2 easily, is saltwater-resistant and produces a large amount of fat. We will hunt for wild species, because they are likely to be more stable than genetically-modified ones since they have come out on top in the struggle for the survival of the fittest.' Wijffels is confident that he will be able to find the right alga within a year.

It's not only that algae can thrive in salt water and don't need arable land. Wijffels points out they have another important advantage over traditional plants. 'Their yield is at least five times greater than what traditional plant crops can produce. A hectare of algae can produce between 20 and 60 m^3 of oil a year. A palm oil plantation produces six m3 on average, while rapeseed merely yields 2.5 m^3. Therefore an algae farm would make the most economic use of space.'

At the same time, space requirements appear to be the downside of growing algae for fuel. 'At the moment, we don't have a clear idea of the scale needed, as well as how to set up such a system and organize the logistics,' Wijffels concedes. 'For example, to provide 20% of the required transport fuel in the Netherlands, we need roughly 50,000 hectares of algae farms, about nine times the surface area of Manhattan. However, it is clear that Mediterranean regions offer a better growing environment than northern countries.'

'I think we must have a closer look at the practicalities of utilizing algae fuel as we continue developing the process,' Wijffels adds. 'The ultimate alternative for fossil oil will probably be a combination of technologies, such as biofuels, energy from wind, sun and sea, as well as cogeneration (combined heat and power).'

KLM

His view is shared by Peter van den Dorpel, chief operating officer of Algaelink, a Dutch company that bills itself as a manufacturer of 'commercial-scale cultivation equipment and algae-to-fuel technology'. Says van den Dorpel: 'We think there will be many solutions for liquid fuel in the future.' Earlier this year, Algaelink concluded an agreement with Dutch airline KLM to develop an alternative fuel for the aviation industry. It claims to have already reached the break-even point in its algae growing system, which works with closed tubes. 'So far, we have secured patents for a system that cleans the inside of the tubes of the algae that grows on the inner surface and blocks the sun, as well as for a fully integrated computer system to optimize the growth process,' Van den Dorpel says.

However, Van den Dorpel declines to provide European Energy Review with details of the company's progress towards producing algae oil on a commercial scale – 'in order to protect our customers,' he says He confirms that only recently, an Algaelink pilot project made clear that 36 meters of tubing can produce between two and four kilos of dry biomass a day, adding that the company's main focus now is on increasing the scale of its growing facilities.

Algaelink is convinced that the scale required is large. The company has calculated that an algae farm needs a surface of almost 54 hectares in order to produce 100 tons of dry biomass a day. These 100 tons can in theory produce 50 tons (about 350 barrels) of oil. 'But this is still 20 to 50 times less space than conventional fuel crops,' says Van den Dorpel.

KLM cannot yet indicate when jet fuel from algae will be available for testing. 'As far as we are concerned, we still must find out whether the right oil can be produced, from which kerosene can subsequently be distilled,' KLM spokeswoman Nanke Kramer says. 'At the moment, we cannot estimate any timescale, and it is even unclear whether kerosene from algae is feasible at all.'

Recently, KLM joined a global taskforce – established by Boeing – to accelerate the development and commercialization of new sustainable aviation fuels. The group announced two initial research programmes: a comprehensive sustainability assessment of algae and a study of the potential of the jatropha plant. 'Both species may potentially become part of a portfolio of biomass-based renewable fuel solutions that can help aviation to diversify its fuel supply,' said a taskforce statement. Members of the nine-strong group include the European carriers Air France, Virgin Atlantic Airways and SAS.

Green crude

US company Sapphire Energy aims to produce 'green crude' from algae on a commercial scale – 10,000 barrels a day - within three to five years. The firm announced that its funding for improving production facilities to full commercial feasibility has recently been increased to over $100 million.

Sapphire claims its product is similar to light sweet crude and can be refined through the same industrial process into chemically identical fuel products, such as petrol, jet fuel and diesel products. 'This

How it works

The algae studied in Wageningen are tiny single-cell plants, which convert CO_2 and sunlight into biomass containing sugars and proteins. Some algae also produce oily fats. Because they don't have leaves or flowers, their efficiency is greater than traditional field-grown plant crops.

They are grown in bioreactors, which can be closed systems – in the form of vertical transparent tubes or plates – or open basins equipped with paddle wheels to keep their contents moving. According to the Wageningen scientists, open ponds are cheaper to construct and slightly more efficient than closed systems, but more prone to pollution and infection. In addition, keeping the CO_2 level, temperature and light intensity in the basins in check is more complicated. They also take up four times as much space as closed bioreactors.

Wageningen University uses one-meter high plates with a thickness of a couple of centimetres. The plates are positioned vertically, since this allows them to catch more sunlight.

Algae don't require potable water. Some species grow in fresh water, and others live in salt water. As for nutrients, they need nitrogen and phosphorus, which are normally the main ingredients of waste water or even sewage. The CO_2 supply should ideally come from industrial processes, in which CO_2 has a negative value. This contributes to the cost-effectiveness of oil-from-algae. Growing algae does not have to take up any arable land.

Oil from algae is almost identical to mineral oil. It contains mainly light fractions, with many short carbon chains that prevent it from coagulating.

René Wijffels in his test lab in Wageningen. Photo: Leen Preesman

is entirely compatible with the current energy infrastructure, from pipelines and refineries, to cars and airplanes,' according to a company statement.
Sapphire claims to have already developed the world's first renewable 91-octane petrol that conforms to the criteria of American Standards for Testing and Materials.

Sapphire says it uses both open-air basins and closed systems to grow algae. The company is still in the process of calculating how much surface is needed for these processes. 'However, we can assume that our process will require only a fraction of the land required for traditional bio-fuel crops, since algae can be harvested year round. Our main challenge at present is scaling up. We expect to bring the growing process to perfection along the way,' a spokeswoman for the company says. Sapphire is considering 'a number of options' for the algae to be grown, including genetically modified organisms.
According to the company, its scientific supporters include the Scripps Research Institute, the University of California in San Diego, the University of Tulsa and the Department of Energy's Genome Project.

'The ultimate alternative for fossil fuel will probably be a combination of technologies'

'Algae have great potential as a sustainable feedstock for the production of diesel-type fuels, with a very small CO_2 footprint,' Graeme Sweeney, Shell's vice ceo of future fuels and CO_2 said in the British newspaper The Independent. However, he acknowledges that the commercial potential of the scheme still has to be proven. Sweeney says that Cellana will only grow non-genetically modified algae.

The growth system of Cellana is based on open-air ponds. In order to check whether algae are economical when scaled up to a commercial level, Cellana has also planned the construction of a 1,000-hectare site, to be followed by a full-scale 20,000-hectare algae-growing facility within 10 years. Shell hasn't disclosed how much this project will cost. And a spokeswoman declined to say at what oil price Shell thinks the production of oil-from-algae will be competitive. ■