guardian.co.uk

Craig Venter turns from DNA to saving the environment

Biologist and entrepreneur Craig Venter is developing genetically engineered biofuels which he claims will provide a greener alternative to oil. But some environmentalists are far from convinced, writes Carl Zimmer from Yale Environment 360, part of the Guardian Environment Network

From **Yale Environment 360**, part of the **Guardian Environment Network**
guardian.co.uk, Tuesday 6 January 2009 14.35 GMT

A larger | smaller

Craig Venter is ready for his next incarnation.

In the 1990s, Venter became familiar to the world as a maverick who would sequence the human genome faster and cheaper than a huge team of government scientists. Six years ago he made headlines by announcing his plan to synthesize an entire genome from scratch, insert it into a cell, and manufacture a new species. In both cases, Venter has followed up his promises with some hard results. He published the first gold-standard sequence of an individual's complete genome (his own). And while he hasn't made an artificial life form yet, he and his colleagues at the J. Craig Venter Institute have achieved a series of landmarks, from synthesizing large chunks of DNA to performing the world's first "genome transplant" on a microbe.

Now Venter says he wants to help save the environment. For some time, he has speculated that genetically engineered microbes could help wean the world off oil and reduce greenhouse gases at the same time. In 2005 Venter set up a company, Synthetic Genomics, to pursue that goal. And now, according to Venter, the company is seeking the capital to move forward. "We're ready to build a pilot plant right now," he says.

Venter is not a lone voice in the wilderness. A number of other companies have spent the past few years tinkering with microbes in the hopes of producing gasoline, diesel, and other fuels. Some of them are so far along in development that they'll have microbe-produced fuels on the market in a few years. And their backers say fuels from microbes will be exactly the kind of clean alternatives to oil that the Obama administration will be pushing for.

Yet environmental experts are adopting a wait-and-see attitude. Details on how these fuels will actually be produced are fairly sketchy at this point. A new industry of microbial fuels might indeed prove to be green. Or it might lead to more greenhouse gases and create extra pressure to convert land to farm fields to feed these hungry microbes. "The devil is in the details," says William Laurance, a senior scientist at the Smithsonian Tropical Research Institute who studies the environmental effects of biofuels.

The microbe-made fuels Venter and others are developing represent a new stage in the history of genetic engineering. In the 1970s, scientists figured out how to insert a gene from one species into another, launching the $80 billion biotechnology industry. In the past few years, however,

read genes cheaply and store their sequence in online databases. Venter and his colleagues, for example, have trawled the oceans for new genes and have identified over six million new ones.

It's now relatively cheap for a scientist to send the sequence of one of these genes to a DNA-synthesis company and get copies of the gene delivered by FedEx in a matter of days. By inserting several different genes into a single microbe, scientists can engineer it to carry out complex chemical reactions to make new molecules.

This new version of genetic engineering goes by the name of synthetic biology. One of the epicenters of synthetic biology research today is Lawrence Berkeley Laboratory, which is directed by Obama's nominee for Energy Secretary, Steven Chu. Jay Keasling a chemical engineer at Lawrence Berkeley, has had one of the lab's biggest successes — engineering microbes to produce a powerful but expensive drug for malaria, called artemesinin. A San Francisco company called Amyris is now working on scaling up Keasling's system for large-scale production of the drug. If they succeed, the cost of the drug may drop by 90 percent.

Along with new medicines, synthetic biologists now see another potential in their modified microbes: a source of energy. Today, a number of small companies, including Amyris, are developing new microbes that can turn their food — which might be anything from sugar to sewage — into hydrocarbons that can be used as fuel.

The companies are using different creatures, feeding them different foods, and hoping to make different fuels. Amyris, for example, has engineered yeast that can eat sugar cane juice and secrete diesel. In November, Amyris opened its first pilot plant in Emeryville, California. It expects its microbes to be churning 200 million gallons of diesel a year by 2011. Another company called LS9, has altered a different metabolic pathway in E. coli so that it can turn sugar into a hydrocarbon that's similar to petroleum. A third company, Solazyme, feeds sugar to algae, which is raised in sealed steel tanks.

Synthetic biology, its backers claim, will change the rules of the energy game. There's no need for building expensive rigs for drilling deep into the earth, or lopping off the tops of mountains to get coal. Every microbe is its own miniature refinery, carrying out complex chemical reactions that would be expensive to carry out in a man-made factory. Synthetic biology fuels promise to be competitive with ordinary fuels when they hit the market in a few years.

Advocates for these fuels promise that they won't just be profitable. They'll also be good for the environment. A car running on diesel will spew carbon dioxide into the atmosphere regardless of whether the diesel came out of the ground or out of a fermenter. But it takes a lot of energy to get diesel out of the ground, refined, and delivered to a car. Synthetic biology promises to eliminate a lot of the emissions created by producing this energy. Amryis claims that its biodiesel will produce 80 percent less greenhouse gases than conventional diesel.

Steven Aldrich, president of Bio Economic Research Associates, thinks synthetic biology fuels could indeed turn out to be good for the climate — at least compared to the fuels they'd be replacing. "Compared to conventional oil, sugar-to-fuel could have profoundly positive overall

environmental consequences," says Aldrich.

But a number of environmentalists aren't convinced. "We can't afford to say no to this research, but we really need to be ramping up our understanding of the risks," says Nathanael Greene, director of renewable energy policy at the Natural Resources Defense Council.

Where, for example, would these microbes get their sugar? The most obvious source of sugar is sugarcane plantations, and some companies already are arranging a steady supply of the stuff to feed their microbes. Earlier this year, Amyris formed a partnership with Crystalev, one of the largest sugarcane growing companies in Brazil. The partnership was natural, not only because Brazil makes a lot of sugar, but also because they already use it to make fuel — specifically, ethanol.

That experience worries some scientists who study the environmental effects of biofuels. David Pimentel of Cornell University and Tad Patzek of the University of California at Berkeley have tallied up the environmental impact of ethanol production in Brazil, and they argue it's not a pretty picture. It takes 393 kilograms of oil or its equivalent to produce a hectare of sugarcane, and it takes 12 to 14 kilograms of fresh sugarcane to produce a single liter of ethanol. Erosion is very high on sugar plantations, because farmers harvest almost the entire plant, leaving little behind to anchor the soil. According to Pimentel and Ptazek, Brazil sugarcane plantations lose 31 tons of soil from every hectare — 30 to 60 times more than the land can regenerate.

Sugar plantations are also very thirsty. To produce a single liter of ethanol in Brazil requires 7,000 liters of water. And as the water runs off sugar plantations, it carries with it some of the herbicides, pesticides, and fertilizers that are applied at high levels on the plants. Even after the cane is harvested, there's still more wastewater to deal with: ethanol plants produce 10 liters of wastewater for every liter of ethanol they make.

The more fuel we get from sugar-fed microbes, the more land will need to be used to grow it. "As with any conversion technology, there is concern that land will be cleared to provide feedstocks," says Jason Hill, economist at the University of Minnesota.

Aldrich thinks that water would be the environmental wild card in a synthetic-biology boom. "The impact of the large-scale conversion of land not currently under the plow into sugarcane fields has a potentially significant environmental cost with respect to freshwater resources," says Aldrich.

Synthetic biology's defenders argue that the effects of microbial fuels depend on how carefully the process is carried out. According Neil Renninger of Amyris, plenty of depleted pastureland in Brazil could be converted to sugar plantations without pushing into pristine habitats. "Sugarcane is grown nowhere near the Amazon," he points out.

What's more, fuel-making microbes might be able to feed on many other plants. Energy Secretary-designate Chu has long been a champion of a project to engineer microbes that can make ethanol from the cell walls in corn stalks and leaves. This so-called cellulosic ethanol is widely expected to be a major improvement on the corn-based ethanol backed in recent years by

the U.S. government. Chu and a number of other researchers are agreed that the production of corn-based ethanol is, on balance, a source of additional greenhouse gases. Engineered microbes may be able to make ethanol more efficiently. They might also make ethanol from other plant matter, such as prairie grasses, wood chips, or grass clippings. Even sewage might be a palatable feast for the microbes.

Craig Venter thinks these plant-to-microbe-to-fuel projects are the right advances to be making now. "These are smart guys, and I have great respect for them," he says. But in the long term he doesn't think these projects will be sustainable. "These are the first baby steps."

Instead of waiting for plants to make hydrocarbons, Venter wants to cut out the middleman and head straight for their original source of carbon: the air. Researchers at Synthetic Genomics have been experimenting with photosynthetic bacteria, which (like plants) use the energy in sunlight to combine water and carbon dioxide. Using some of the genes Venter's team has discovered, the researchers have altered the bacteria. Now the microbes can rapidly build molecules known as lipids. Lipids come in a range of forms and serve many functions in cells, storing energy, for example, and forming membranes. But instead of using lipids for such purposes, Venter's bacteria secrete them. Researchers at Synthetic Genomics have drawn up plans for gathering those lipids.

"They can go right into an existing refinery," says Venter. Not only would these microbes not create any extra pressure to cultivate more land, but they would actually take greenhouse gases out of the air.

Greene is concerned that these microbes might cause harm if they escape into the environment. "I don't have a Michael Crichton attitude that they're going to destroy the world," he says, "but we really need to understand them."

Venter thinks Greene has a legitimate worry. "We should be totally aligned with the environmentalists on this," he says. Researchers at Synthetic Genomics have been developing ways of addicting bacteria to certain nutrients they would not be able to find outside their tanks. If engineered bacteria escaped into a nearby pond, they would die.

But Greene wonders if genes could escape from the dying microbes and be passed on to other microbes in the environment. Genetically modified crops have also been engineered not to produce seeds to protect against contamination. "And yet we've seen that happen anyway," Greene notes.

Synthetic Genomics is in the process of raising capital for a pilot plant. It's not a great time to look for investors for any kind of biotechnology, especially one that's still so young. And with gas prices less than half of what they were just a few months ago, it may be hard to get people to think about moving beyond oil.

"People have trouble seeing beyond the current week," says Venter. But he warns that oil reserves will continue to dwindle and the Earth will continue to warm. Venter believes that synthetic biology must be part of the solution to both problems, because of its huge potential.

"It's infinitely scalable," says Venter. "We think the future will be very bright."

• This article was shared by our content partner Yale Environment 360, part of the Guardian Environment Network

guardian.co.uk © Guardian News and Media Limited 2009