DISCOVER — ENGAGE — IMPACT

FUELLING THE FUTURE

UQ researchers are harnessing the sun's energy through photosynthesis to find innovative replacements for finite fossil-fuels.

In the not-too-distant future, the fuel for your car, the medicine you take, and even the food you eat could be produced by tiny green algae powered by sunlight.

By 2050, the human population is forecast to expand towards 9.7 billion people, requiring 50 per cent more fuel, 70 per cent more food, and 50 per cent more fresh water than current levels. At the same time, the international community has committed to eliminating net carbon dioxide emissions as early as 2030–2050 to prevent dangerous climate change.

Professor Ben Hankamer, director of Brisbane's Centre for Solar Biotechnology (CSB) at UQ's Institute for Molecular Bioscience (IMB), has connected 30 leading teams across Europe, the United States, Asia and Australia. Together, they are dedicated to developing next-generation biotechnology solutions to meet this ever-growing demand for food, fuel and fresh water.

Their solution comes from a source you might not expect – algae.

Professor Hankamer and his teams are working to develop renewable, algae-based fuels. By harnessing photosynthesis and innovating, integrating and commercialising advanced technologies to develop solar-driven fuel production processes, they are part of a global effort to transition away from our current reliance on finite fossil-fuel resources.

However, the CSB team has its sights set on producing much more than renewable fuels alone.

The Centre is focused on developing solar-driven processes to produce high-value bioproducts such as protein therapeutics, aquaculture and livestock feeds, biofertilisers, green chemicals and water treatment eco-services. Algae systems can also be used to produce functional foods and bioplastics.

Microalgae – single-cell green algae – are microscopic, rapidly growing 'cell factories'. They have evolved intricate solar interfaces that contain photosynthetic nano-machinery, and, unlike traditional crop-based biofuel options, can be farmed on non-arable land, seawater, waste or agricultural run-off.

"Microalgae systems are already three times more productive than sugar cane and yields can be significantly improved beyond this," Professor Hankamer says.

"They're highly efficient at capturing and converting sunlight and carbon dioxide into energy stored for their own growth, and produce oxygen, clean water and biomass. Microalgae also reduce competition with food production for arable land and fresh water resources.

"The Centre for Solar Biotechnology was established to fast-track the development of solar-driven industries, including algae production systems. It provides us with the platform to scale up and optimise algae production."

Australia is internationally recognised as having near-ideal climatic conditions for microalgae production, with vast marginal and non-arable plains suitable for microalgae industries, large saline water resources along the coastline, and more than 55 times the solar energy needed to power the entire global economy every year.

"We test current systems at our pilot scale production facility and are focused on constantly refining next-generation technologies with our partners," Professor Hankamer says.

This work is supported by the analysis of the algae at the atomic level, to understand how they are constructed, and to detail how their intricate photosynthetic systems work.

The team analyses algae cell structure and membranes using optical microscopes before transitioning to electron microscopes, which provide higher-resolution greyscale images.

"We've been developing techniques called edge-detection algorithms, that can contour the cellular architecture to the molecular nanoscale. We aim to use this information to enable bio-inspired, structure-guided design," Professor Hankamer says.

Through these structural analyses, the team is working to improve the efficiency of various algae strains and production processes.

"We are exploring different algae strains for different processes, each with its own optimum conditions of production," he says.

"Using high throughput robotic screens, we define what these optima are and use this information to optimise the processes for our lead production strains."

But Professor Hankamer's progress hasn't been without challenges.

Aside from criticism from the fossil fuels industry – who have advocated that renewable fuel solutions won't be necessary for hundreds of years – the algae production processes must be economically viable to secure commercial buy-in and product development.

"While it is true that we have significant fossil fuel reserves, burning them will result in the global community exceeding the 1.5–2 degrees Celsius global warming 'safe level' limits, defined during the Paris Accord," Professor Hankamer says.

"There is no question that developing these technologies is tough, but it is also critically important. Internationally, approximately 70 per cent of voters want renewables, which indicates a ready market.

"While we are now making good progress on solar electricity generation, electricity only provides about 20 per cent of global energy demand. The other 80 per cent is provided by fuels. Much progress has been made on electric car technology. However fuel is, and will likely remain essential for the foreseeable future, for long distance travel and heavy vehicles (aviation, shipping trucks), as batteries remain heavy and expensive and have a much lower energy density than fuels."

The CSB have developed sophisticated models to detail and evaluate the entire solar fuel production process for a given algae strain. This allows them to evaluate triple bottom line performance proactively – to ensure economic, social and environmental benefit.

"Our Techno-Economic and Life Cycle Analysis (TELCA) model shows that current best practice solar-driven, algae-based renewable diesel is 2–3 times the price of commercial diesel. So our task is to bring down the production costs to assist commercialisation," Professor Hankamer says.

He thinks this is technically possible.

"We measure social benefit through the energy-return ratio (energy into the system versus energy out of the system), as energy is needed to drive society. Reducing greenhouse gas emissions is the environmental benefit," he says.

Now, to unlock the economic benefit, he sees political support and industry engagement as the catalyst to move forward and bring certainty to the market.

To further develop these technologies, the team are increasingly engaging with industry around their various bioproduct streams, which could contribute to profitability and significantly help to create regional jobs and sustainable economies for the future.

"The global energy market is valued at about $6 trillion annually. Australia should evaluate whether it wants this industry to establish here," says Professor Hankamer.

"We're always interested in exploring new opportunities for industry and governments to solve these challenges.

"This requires political leadership."

Professor Hankamer wants politicians to take a stand on climate change, based on the facts.

"The climate change debate is a political football. I'd like to see politicians taking a bipartisan position and develop fact-based policy, so that people understand the importance of policy in this debate and don't just accept simple slogans as fact," he says.

"Fast-tracking the scale up of renewable fuel systems is critical in order to stay within the global warming 'safe zone'."

"I think people should expect Government leadership on this issue. Leaving this problem for the next generation is not acceptable. We need to act now."

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Greener visions

Professor Hankamer and his team are working on a number of green project initiatives for the future, which could fast-track the development of valuable microalgae bio-products.

'Integrated Bioeconomy Project'

The Centre for Solar Biotechnology team are also working to develop the Integrated Bioeconomy Project (IBP) – a controlled biosphere and protected cropping system. The IBP would produce ten times more high-quality food with ten times less water than conventional field production, and enable the expansion of food production onto traditionally unusable land.

Tapping into the growing horticulture and clean foods markets, the IBP would bring together a range of advanced technologies to optimise capital investment and operating costs, as well as production conditions, including temperature, humidity, carbon dioxide, light, nutrients, pest and disease control.

"Our strategy will allow the conversion of abundant natural resources – sunlight, carbon dioxide, degraded land and low quality water – into high value products such as fresh nutritious food, algal products, clean energy and clean water," Professor Hankamer says.

'Growing Roads' and 'GreenSmart Cities'

Imagine drab freeway noise barriers, roads and railways revived with greenery, melding with our natural environment.

'Growing Roads' is another initiative led by UQ's Centre for Solar Biotechnology (CSB). The concept involves 're-greening' our roadscapes and transport infrastructure with aesthetically pleasing, functioning microalgae production systems. Not only visually striking, the microscopic plant cells would filter the air and reduce carbon dioxide emissions, while producing algae-derived bioproducts, such as pigments, biofertilisers, biofuels and bioplastics.

The project, which was launched in 2017, will be guided by analysis to optimise systems and to ensure that that they are economic, durable and sustainable.

"This vision is to open up new economic opportunities and sustainable services, offset infrastructure and vegetation management costs, and visually innovate our cities," Professor Hankamer says.

Similarly, the CSB seeks to integrate microalgae production systems into buildings and urban living spaces, while making our cities more functional and liveable.

Progress so far:

2013: Pilot scale production facility launched by Queensland Premier

2013: High throughput algae purification platform established

2014: Development of high efficiency cell lines

2015–2016: High throughput nutrient and light optimisation of selected strains

2016: Pilot scale tests of high efficiency production strains and systems

2016: Modelled global fuel supply and carbon dioxide emissions trajectories

2017: Scale up of advanced harvesting process

2017: Molecular resolution 3D imaging of algae cells

2017: Advanced systems modelling to fast track process optimisation

2017: Production of therapeutic protein leads in algae

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