



CORDIS Results Pack on algae innovation

A thematic collection of innovative EU-funded research results

March 2024

Sustainable alternatives emerging from European seas and waters



Research and
Innovation



Contents

3

Extracting protein from seaweed and legume by-products

5

Sustainable ingredients sourced from microalgae

7

Unlocking the secrets of seaweed to boost the aquaculture market

9

Turning microalgae into net zero, nature-positive food ingredients

11

The nitrogen-fixing microalgae that produce quality organic fertiliser, now with added benefits

13

Satellite data offers accurate marine algae surveillance

16

Brewing biofuels from scrap wood, with help from oil-rich algae

18

Tracing the global marine carbon cycle from the molecular level

20

A multi-product microalgae biorefinery for food, feed and fragrance

23

Algae-fed bacteria could make biodegradable yoghurt pots

25

Sewage-cleaning microalgae offer a green way to make blue

Editorial

Sustainable alternatives emerging from European seas and waters

Responding to global challenges of climate change, biodiversity loss, ecosystem degradation and increased demands from a growing population, Europe is set to transition to a sustainable, circular and carbon-neutral economy. Algae offer a sustainable means to deliver an almost endless number of valuable products including food, animal feed, nutritional supplements, pharmaceuticals, cosmetics, plastics, fertilisers, biofuels and more. This CORDIS Results Pack highlights 11 innovative EU-funded projects that showcase the potential and versatility of algae production and conversion.

Algae are an overlooked resource. Ranging from towering kelp to tiny microalgae, they can be cultivated in marine and freshwater habitats, ponds or photobioreactors.

Algae can be highly productive, and some can make use of atmospheric nitrogen for rapid growth. Microalgae in particular are amenable to a range of production methods, from open systems using sunlight, to closed bioreactors that run on a fermentation process. They can be produced in high quantities on land not suitable for arable production, and require a fraction of the water needed for terrestrial crops, and can even be reared on wastewater as part of a bioremediation process.

Macroalgae, also known as seaweed, absorb a range of excess inorganic nutrients from the ocean, including nitrogen and phosphorus as well as other compounds such as carbon, thereby reducing ocean acidification. They can be cultivated at sea (offshore) or onshore in ponds, greenhouses and raceway systems.

As demand for food and sustainable products increases, [algae offer a sustainable way to deliver these](#) while reducing impact on the environment. The [farm to fork strategy](#) supports the role of algae in the transition to plant proteins and its contribution to a sustainable food system. The use of algae could reduce the pressure on plant biomass derived from agriculture and forestry. Eaten as food, they are low in fat and rich in fibre, protein and micronutrients.

The farming of algae can also contribute to achieving the EU's objectives in terms of decarbonisation, zero pollution, circularity, the preservation and restoration of biodiversity, the protection of ecosystems and the development of environmental services. Strategic guidelines for a more sustainable and competitive EU aquaculture stress the need to promote the farming of algae as a way of contributing to the goals of the [European Green Deal](#).

In addition, the [European bioeconomy strategy](#) and the [blue economy strategy](#) stress the potential of algae, while the [recent communication](#) 'Towards a strong algae sector' aims to boost research, facilitate market access and increase consumer awareness and acceptance of algae products.

Research and investment, including the Horizon Europe programme, play a crucial role in delivering the innovations necessary to advance the production and valorisation of algae. The projects featured in this Pack cover a range of applications, including fundamental insights into the role of algae in the carbon cycle, the development of new and improved algae production systems, the use of algae in bioremediation, and the delivery of products such as animal feed, pharmaceuticals, cosmetics, yoghurt pots and more.

Support for algae innovation continues across Horizon Europe and other funding programmes, including the European Maritime and Fisheries Fund, which is supporting projects including [ALGAENAUTS](#), [KELP-EU](#), [ULVA FARM](#) and [Seafood Algae Alternative](#).

Extracting protein from seaweed and legume by-products

Pilot-scale biorefineries developed by the EU and industry-funded ALEHOOP project have successfully demonstrated the feasibility of sustainable plant-based protein.



An increasing population and a growing middle class have caused demand for protein to skyrocket. To meet current demand, Europe is already importing over 30 million tonnes of soya – a key source of protein – from the Americas every year. The majority of that soya is used to feed livestock, another main source of protein.

“Current protein sources are quickly becoming unsustainable, from both an economic and an environmental perspective, raising alarms about food security and creating an urgent need to find alternative proteins,” says Nuria Valdés Mediavilla, project manager at [Contactica Innovation](#) in Spain.



Current protein sources are quickly becoming unsustainable, from both an economic and an environmental perspective.

Two possible alternatives are macroalgae, better known as seaweed, and legume by-products – the seed coats, hulls, broken seeds and leaves that are generated during the drying, milling, dehulling and sorting processes of crops.

“Turning these by-products into alternative proteins and, thus, food and feed products, could help us meet the world’s increasing demand for proteins in a more sustainable way,” explains Valdés Mediavilla.

This is where the [ALEHOOP](#) project comes into play. The project is developing pilot-scale biorefineries for recovering low-cost dietary proteins from alga- and plant-based biomass. It aims to use the recovered proteins to produce high-value food and feed products, including snacks, smoothies, meat alternatives, animal feed and sports drinks. The project received funding from the [Circular Bio-based Europe Joint Undertaking](#), a public-private partnership.

Using innovation to overcome challenges

Like any research initiative, the ALEHOOP project has faced its fair share of hurdles. One was that the quality and quantity of seaweed available vary depending on the season and location. To overcome this challenge, the project had to optimise its biorefinery process and protein extraction methods to ensure consistently high-quality products, regardless of input.

The project also had to address the regulatory requirements and market barriers relating to the use of macroalgae and legume proteins in food and feed applications – a process that involved conducting numerous safety and quality tests.

“By working with our project partners and industry stakeholders, and by applying innovative and sustainable solutions, we not only overcame these challenges, but did so in a way that ensured our work was aligned with the goals of such EU policy initiatives as the [Green Deal](#),” adds Valdés Mediavilla.

A growth industry

Although the project remains a work in progress, it has already achieved some significant milestones. At the top of that list is the successful demonstration of a pilot-scale extraction of proteins from residual macroalgae and legume by-products.

“This achievement represents a big step towards providing sustainable, low-cost dietary proteins that can help reduce the EU’s dependency on imported proteins while also increasing food security, contributing to the circular bioeconomy, and helping mitigate the effects of climate change,” remarks Valdés Mediavilla.

The project is now set to enter its final phase, during which the various alternative protein sources being produced within the ALEHOOP biorefineries will be validated for use in food and feed applications. “Underscoring the market readiness of these alternative protein sources will signal a transformative shift towards sustainable practices within the protein supply chain,” she concludes.

PROJECT

ALEHOOP – Biorefineries for the valorisation of macroalgal residual biomass and legume processing by-products to obtain new protein value chains for high-value food and feed applications

COORDINATED BY

Contactica in Spain

FUNDED UNDER

Horizon 2020-FOOD and Horizon 2020-LEIT-BIOTECH

CORDIS FACTSHEET

cordis.europa.eu/project/id/887259

PROJECT WEBSITE

alehoop.eu



Sustainable ingredients sourced from microalgae

Microalgae are an untapped source of valuable pharmaceutical and cosmetic compounds – and could help to feed a growing population.

[Microalgae](#), one of the most ancient life forms on Earth, are a diverse family of microscopic mono and multicellular organisms. Their biological and chemical diversity has long been a source of interest to the pharmaceutical, cosmetic and nutritional supplement sectors, because of the unique bioactive molecules they contain.

“Microalgae have unique adaptation abilities to various stress factors, such as light, salinity, pressure and temperature,” [AlgaeCeuticals](#) says project coordinator Madesis Panagiotis from the [Centre for Research and Technology Hellas](#) in Greece.

“To withstand such harsh conditions, they produce a variety of unique proteins, enzymes and metabolites. It is these molecules that are of interest to industry.”

In addition, there is growing interest in microalgae as a sustainable source of nutrition. Many species are excellent sources of protein, vitamins and minerals. Harvesting microalgae biomass at scale could provide a renewable source of food for a growing global population.



How microalgae produce valuable compounds

The AlgaeCeuticals project sought to identify and promote promising cultivation methods that could enable industry to more fully exploit the potential of microalgae. The project was supported by the [Marie Skłodowska-Curie Actions](#) programme.



Microalgae have unique adaptation abilities to various stress factors, such as light, salinity, pressure and temperature.

“To achieve our aims, we used new cultivation methods at both the lab and industrial scale,” adds Panagiotis. “These included various ‘omics’ approaches, such as [genomics](#), [transcriptomics](#), [metabolomics](#) and [proteomics](#), to understand the basic metabolic functions of microalgae.”

Using these methodologies, Panagiotis and his team were able to better understand how microalgae grow, how they produce valuable compounds, and how these compounds can be extracted for industrial use.

The team next attempted to produce higher yields of both biomass and valuable metabolites, specifically for sectors such as pharmaceuticals and cosmetics.

as well as skin repair enzymes. The project also succeeded in encouraging a great deal of knowledge exchange between academia and industry.

Identifying new high-value ingredients

Microalgae have long been recognised as an untapped source of useful compounds for a range of industrial uses – a challenge to date has been scaling up production efficiently. The AlgaeCeuticals project demonstrated that this is possible, and that microalgae can indeed be better exploited for high-value ingredients. In the immediate term, algae production businesses and the food and cosmetics industries stand to benefit from applying the processes pioneered in the AlgaeCeuticals project.

“We now need to capitalise on the results we have obtained so far,” says Panagiotis. “This will be achieved through further research. New funding will enable us to investigate in greater depth high-value metabolites produced by microalgae, and also optimal growth conditions for biomass.”

The continuation of this work could therefore lead to the discovery of new medicines and cosmetics, and further integrate microalgae into our food chain in a green and sustainable manner.

Industrial-scale algae-based production

The project achieved a number of breakthroughs, including a better understanding of how [mycosporine-like amino acids](#) are produced. These small, secondary metabolites are produced by microalgae that live in environments with high volumes of sunlight.

This has opened up the potential of growing and extracting mycosporine-like amino acids to produce natural UV sunscreens.

The project also identified ways of achieving large-scale microalgae production, for both biomass and specific metabolites.

This could open the door to the industrial production of algae-based nutraceuticals for functional foods and food supplements,

PROJECT

AlgaeCeuticals – Development of microalgae-based natural UV Sunscreens and Proteins as cosmeceuticals and nutraceuticals

COORDINATED BY

Centre for Research and Technology Hellas in Greece

FUNDED UNDER

Horizon 2020-MSCA-RISE

CORDIS FACTSHEET

cordis.europa.eu/project/id/778263

PROJECT WEBSITE

algaceuticals.gr



Unlocking the secrets of seaweed to boost the aquaculture market

By exploring new strains and cultivation practices for red dulse, the EU-funded ASPIRE project aims to deliver a sustainable, high-yield and quality seaweed for Europe.



Palmaria palmata, commonly known as dulse, is a leafy red seaweed that grows on the Atlantic coast, and has been eaten by Europeans for thousands of years. Its high-protein content and enjoyable taste make it an attractive crop for the aquaculture industry, but cultivation efforts have so far been met with only modest success.

The ASPIRE project, coordinated by Matthias Schmid and hosted by Ronan Sulpice from the [University of Galway](#) in Ireland, hopes to make significant strides with the development of new strains of dulse. “Current approaches to grow *P. palmata* in an aquaculture setting rely on randomly collected wild types,” Schmid explains “It means variation in biomass productivity and quality from one batch to another, and it still puts pressure on natural stocks of *P. palmata*.”

Schmid highlights the drawbacks of existing cultivation practices: “The absence of a systematic breeding programme limits the industry’s ability to cultivate strains that exhibit desirable traits, such as high growth rates, stress resistance, etc. Without targeted selection, the aquaculture sector may miss out on opportunities to enhance productivity.”

Speeding up growth

The solution, according to the researchers, lies in a better understanding of growth performance and biochemical profile variability. Insights here could allow the selection of fast-growing local strains of dulse.

The project’s key innovation was the use of a high throughput phenotyping platform that allows the rapid screening of high numbers of seaweed strains. This will provide the base for the deployment of modern breeding methods. The parallel development of the comprehensive database PalMap will make growth performance, biochemical and genetic information accessible to all.

ASPIRE was undertaken with the support of the [Marie Skłodowska-Curie Actions](#) programme, and drew upon collaborators from across Europe. “As part of the ASPIRE project, we are actively working with various representatives of the seaweed aquaculture community in Europe,” says Sulpice. “This includes working with the likes of [Mungo Murphy](#) – a small seaweed and abalone farm

in Ireland facilitating farm-level trials – and collaboration with international seaweed companies and laboratories across Europe.”

New standards

The project has already achieved significant milestones. “The initial trials showed a huge potential for optimising *P. palmata* aquaculture,” adds Sulpice. “Growth rates were tenfold higher in the fastest-growing strains compared to slow-growing ones.” These promising results pave the way for more extensive testing and farm-level trials, set to commence in early 2024.

Looking ahead, Schmid underlines the need for further laboratory screens as well as the beginning of the farm-level trials. He also mentions the potential expansion of the PalMap database to other algae species, which could revolutionise data management and accessibility in the field.

The project aims to provide new solutions to stakeholders by late 2024, offering the means to identify productive and stress-resistant dulse strains. “The project will provide the required platform for an urgently needed modernisation of seaweed breeding programmes across Europe, setting a new standard for the seaweed aquaculture industry,” he concludes.



Growth rates were tenfold higher in the fastest-growing strains.

PROJECT

ASPIRE – Accelerated Seaweed Production for Innovative and Robust seaweed aquaculture in Europe

COORDINATED BY

University of Galway in Ireland

FUNDED UNDER

Horizon Europe-MSCA

CORDIS FACTSHEET

cordis.europa.eu/project/id/101066815



Turning microalgae into net zero, nature-positive food ingredients

The EU-funded Biosolar Leaf project helped develop an innovative solution for efficiently and sustainably producing food ingredients from microalgae at scale.

The global population continues to rise and is expected to hit 10 billion around the middle of the century. More people means more mouths to feed, with demand for food forecast to reach 3 billion tons per year by 2050. That's a 43 % increase on 2009.

How does one provide this many people with secure, high-quality food, in a way that doesn't harm the environment? For [Arborea](#), the answer is algae.

With the support of Horizon 2020 funding, the company developed an innovative system to grow microalgae and turn this into net zero, nature-positive food ingredients. "Our Biosolar Leaf cultivation system produces the only carbon-neutral plant biomass on the market and, from it, extracts natural proteins and other functional ingredients," explains Julian Melchiorri, CEO of Arborea."



From microalgae to macronutrients

According to Melchiorri, microalgae are a superfood with huge potential. "These microscopic plants offer unlimited potential to produce the diverse range of natural, nutritious, clean label ingredients needed to ensure that everyone can eat well," he says.

To leverage this potential, Arborea drew inspiration from the natural photosynthetic process. "Just like photosynthesis in nature, Biosolar Leaf sequesters CO₂ and uses sunlight as unlimited feedstock," Melchiorri adds. "This boosts the cultivation of microalgae while releasing breathable oxygen – resulting in a carbon-neutral plant biomass from which we can extract high-quality proteins and ingredients."



Our Biosolar Leaf cultivation system produces the only carbon-neutral plant biomass on the market.

Because Biosolar Leaf is a soil-free system, it can be sited on any surface, even barren land and rooftops. "Our system's ability to produce more protein in a given area than any other type of food production, combined with the fact that it doesn't require agricultural land use, means we could enable food production to give land back to nature," notes Melchiorri.

Validated technology

With the system fully developed, the next step was to validate the technology and move it towards commercialisation. For that, the company once again turned to EU funding.

Under the new Horizon Europe programme, Arborea sized the market and established go-to-market and supply chain strategies. Then, working in collaboration with industry partners, the company demonstrated the effectiveness of its technology.

"Thanks to this additional EU funding, we were able to enlarge our team and develop our technology to a point where we could validate it via a fully functional facility," says Melchiorri.

From this facility, Arborea succeeded in gaining important data and insights, which it is now using as it works to build its first commercial facility for mass-producing protein and other functional ingredients out of microalgae.

How the EU and its citizens stand to benefit too

It's not just Arborea that has benefited from the EU's financial support. Europe and its citizens stand to benefit too. "The EU needs sustainable, carbon-neutral, scalable solutions for producing food within Europe, thus reducing its dependency on foreign imports while also supporting its [Green Deal](#) objectives," notes Melchiorri.

Here, microalgae in general and the Biosolar Leaf system in particular deliver. "Our work is an excellent example of how, by supporting European start-ups, the EU can deliver on its own initiatives," concludes Melchiorri.

Work continues at Arborea as it collaborates with industry partners to create sustainable, nutritious and tasty new products, sequester CO₂ and sever the link between food production and biodiversity loss.

PROJECT

Biosolar Leaf – Disrupting the food ingredient and protein markets: a breakthrough technology for large-scale microalgae cultivation

COORDINATED BY

Arborea in Portugal

FUNDED UNDER

Horizon Europe-EIC

CORDIS FACTSHEET

cordis.europa.eu/project/id/190186816

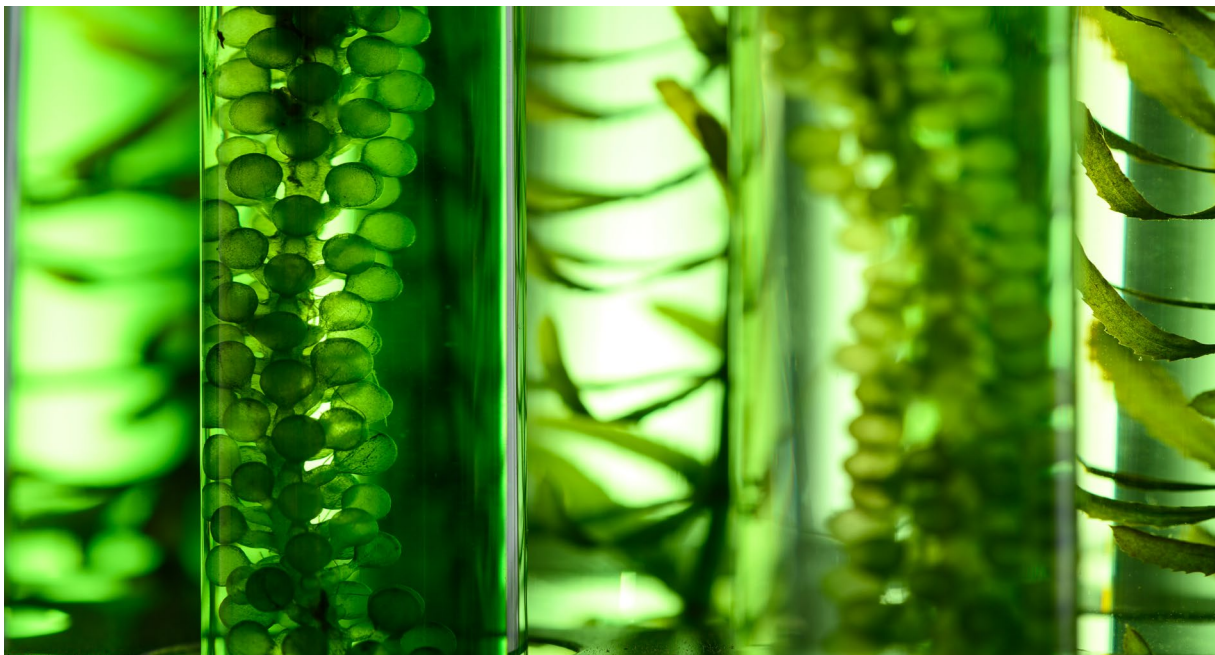
PROJECT WEBSITE

arborea.io



The nitrogen-fixing microalgae that produce quality organic fertiliser, now with added benefits

The EU-funded Cyanobacteria project's circular biotechnology – integrated into their AlgaeNite management system – produces high-quality, clean, liquid biofertiliser, maintaining crop yields with zero emissions.



Currently, fertilisers are presenting a barrier to more sustainable agriculture and European food security. Significant amounts of energy are required to produce ammonia fertilisers typically generated by climate-damaging fossil fuels.

The 150 million tons of ammonia produced globally in 2010 accounted for over [450 million tons of CO₂](#) – about 1 % of CO₂ emissions. Ammonia fertilisers can also compromise soil fertility over time. Added to that, the European supply of mineral fertilisers has been severely impacted by the war in Ukraine, with much previously imported from Russia.

However, more eco-friendly organic products frequently prove inadequate. “More expensive than chemical fertilisers but with less yield, organics simply aren't offering a commercial alternative for the rapidly developing precision agriculture sector,” says Lior Hessel, coordinator of the Cyanobacteria project.

The project developed a biotechnology driven by [blue-green algae](#) and powered by the sun, to provide high-quality liquid fertiliser. The process is managed through the project's monitoring technology, dubbed AlgaeNite.

"As well as being effective for plant growth, our fertiliser production generates almost no pollution, and with our reduced electricity needs sourced from renewables, is virtually greenhouse gas neutral," adds Hessel from project host, Go Green FoodTech (known as [Growponics](#) globally).

The microalgae technology

Using sunlight, the cyanobacteria fix nitrogen from the air, which is then extracted and oxidised by bacteria to produce nitrate for fertiliser. Water needed for microalgae growth is recycled, and the CO₂ emitted from the oxidation process is further used for microalgae growth.

"The process also produced more 'available nitrogen' – the type necessary for plant growth – than conventional organic fertilisers," notes Hessel. "Our biofertiliser-grown crops did as well as those grown with top-quality chemical fertilisers."

Monitoring for optimisation

To test the technology, the team built a 3 000 litre photobioreactor facility at the Growponics facility in Kfar Bialik, Israel. This facility produced enough fertiliser to continuously feed a hydroponic unit of about 800 square metres.

The project also developed a management system, AlgaeNite, which uses sensors and cameras to gather data about the status of the bioreactors. This is then analysed by artificial intelligence, with the results presented to end users to help decision-making.

Heralding third-generation farming

Since the project's completion last year, Growponics has pivoted to a solution that offers greenhouses standalone bioreactors for growing plant protein. These reactors don't require in-house expertise, additional equipment or infrastructure. The AlgaeNite system is already being supplied to greenhouses in several locations.

"We've also developed a way to encase [inoculum](#) starters into a product similar to Nespresso capsules which can be couriered to customers – a totally new concept," adds Hessel.

Hessel believes that this paradigm shift could herald third-generation farming, as the microalgae contain over 50 % protein, with net zero emissions and at low cost, using half the water and less than 10 % of the land needed by other methods.

While the team explores practical options for protein-producing photobioreactors located in sun-drenched locations such as deserts, three hydroponic pilots are under way.

Commercial installations are being tested for meeting agri-food business demand for organic produce at both Growponics and local government-supported farms in Connecticut and Florida, United States. Initial results are anticipated by the end of 2024.

The team also plans to build a full-sized commercial installation, containing both a semi-commercial biofertiliser production site and a research and development campus in Shaar Efraim, Israel.



In 2010, global ammonia production accounted for over 450 million tons of CO₂ – about 1 % of annual emissions.

PROJECT

Cyanobacteria – Developing an organic fertilizer production system using nitrogen fixing Cyanobacteria

COORDINATED BY

Go Green FoodTech in Israel

FUNDED UNDER

Horizon 2020-LEIT, Horizon 2020-Societal Challenges and Horizon 2020-SME

CORDIS FACTSHEET

cordis.europa.eu/project/id/961930

PROJECT WEBSITE

growponics.co.uk



Satellite data offers accurate marine algae surveillance

The EU-funded e-shape project uses Earth observation imagery to protect coastal environments from invasive algae blooms, and help businesses turn the nuisance algae into profit.



Since 2011, massive landings of [Sargassum](#) have been reported in the Caribbean. These invasive blooms of algae can make marine navigation difficult, impact wildlife and foul offshore turbines. The algae also piles up on pristine tropical beaches, rotting with a bad stench.

"Before 2011, there were no reported massive landings," explains [e-shape](#) project pilot leader Marion Sutton from [CLS](#) in France. "One theory is that an anomaly in ocean circulation enabled *Sargassum* to escape from a region in the Atlantic called the *Sargassum* sea during the winter 2009-2010. The algae has since been oscillating with the currents between the Caribbean and West Africa."

Seasonal forecasts of *Sargassum*

CLS has been working on the *Sargassum* algae issue since 2018, using satellite data to inform Caribbean marine coastal services and governments and help them to better monitor the situation. To this end, a [dedicated tool](#) has been developed, providing end users with a 5-day forecast.

"Our role in the e-shape project was to build on this," says Sutton. "We wanted to go beyond the 5-day forecast, and provide tools that can facilitate seasonal planning."

To achieve this, the project team looked at historical data, and developed algorithms to interpret current satellite information. This work represented an important element of the overall e-shape project, which sought to improve user uptake of Earth observation data across a number of fields.

"We used high-resolution data sourced from [Copernicus Sentinel-3](#) satellites," adds Sutton. "This data provided a resolution of 300 m, far better than current resolutions of 1 km."

The pilot project team also used data from [Sentinel-2](#) satellites, which provided a resolution of just 20 m. This enabled the team to go into far more detail about the density and extent of the algae rafts.

Long-term forecasts enabling effective action

Throughout the project, Sutton and her team worked closely with end users in the Caribbean, including national marine parks. Satellite data was used to produce bulletins warning about possible algae influxes over the following six months. This enabled preparatory actions to be taken, and government support to be requested.

The positive results have enabled CLS to refine their forecasting tools. A number of entities in the Caribbean are currently using these services, to better prepare for the arrival of *Sargassum* algae.

"We are also [sharing our data](#) with researchers," notes Sutton. "There is a real need for operational data from the scientific community."

Identifying commercial opportunities using *Sargassum*

Sutton and her team regard the e-shape project as an important milestone in using satellite data to protect the marine environment. Timely action means that pristine Caribbean mangroves and beaches, for example, can be better protected.

There are also potential opportunities to valorise collected *Sargassum*, and turn it into products such as fertiliser, biomaterials, cosmetics and even animal feed. Sutton notes that a number of pilot projects in the Caribbean region are currently under way, to see if collected *Sargassum* could be used as a biofuel.

"Many of these start-ups are at prototype level, and need information about seasonal



Many of these start-ups are at prototype level, and need information about seasonal influxes to prepare their business plans.

influxes to prepare their business plans,” she explains. “This is where satellite information can help.”

CLS is currently involved in a follow-up EU-funded project, called [SODA](#). A key aim of this initiative is to develop new algorithms, and find ways of better sharing satellite data for marine purposes. Another project, called [SeSaM](#), aims to strengthen seasonal forecasting. “These projects represent the next step forward,” says Sutton.

PROJECT

**e-shape – EuroGEO Showcases: Applications
Powered by Europe**

COORDINATED BY

ARMINES in France

FUNDED UNDER

Horizon 2020-ENVIRONMENT

CORDIS FACTSHEET

cordis.europa.eu/project/id/820852

PROJECT WEBSITE

e-shape.eu



Brewing biofuels from scrap wood, with help from oil-rich algae

Using a type of microalgae that grows using sugar as well as sunlight, the EU-funded FLEXI-GREEN FUELS project was able to turn woody waste into sustainable biofuel – with a stream of nutraceuticals as a side benefit.



© Yellow Boat/stock.adobe.com

The EU has set ambitious targets for reducing fossil fuel use, with EU Member States [obliged](#) to ensure that the share of renewables in transport is at least 14 % by 2030. This includes a minimum share of 3.5 % of advanced biofuels.

Advanced biofuels are liquid fuels that are generally derived from non-food-based feedstocks, and can deliver significant life-cycle reductions in greenhouse gas emissions. The investigation into new feedstocks is an area of intense research, and includes work on the commercial and technical viability of microalgae.

Ensuring sustainability of biofuels

The aim of the [FLEXI-GREEN FUELS](#) project was to create a highly flexible integrated biofuels process, capable of treating multiple types of viable waste biomass. This would make available a range of marketable drop-in biofuel products for shipping and aviation, as well as value-added side streams.

"A major concern with liquid biofuels is their sustainability," notes FLEXI-GREEN FUELS project member Alok Kumar Patel from [Luleå University of Technology](#) in Sweden. "We need to be able to define the actual greenhouse gas reduction potential of the feedstock, identify any land-use change issues, and assess biomass availability."

Cost-competitiveness with current fossil fuels also remains a major barrier for the deployment of such biofuels. "The environmental and economic sustainability of producing liquid biofuels is largely dependent on the feedstock used for the process," adds Patel.

Sustainable feedstocks

The project, coordinated by [Bremerhaven University of Applied Sciences](#) in Germany, set about identifying low-impact feedstocks that do not compete with food production.

For this purpose, inedible [woody waste](#) from the forest industry was selected as a feedstock for growing oleaginous microorganisms – microalgae that accumulate oils and fats (lipids) as part of their natural life cycle. These lipids can then be harvested and purified into a sustainable biodiesel.

Wood waste from Norway spruce and silver birch was separated into cellulose, hemicellulose and lignin. The cellulose fraction was then treated with enzymes to reduce it to simple sugar. This glucose was then fed to *Auxenochlorella protothecoides*, a microalgae that is able to use sugar as an energy source.

The team optimised conditions within the prototype bioreactor to maximise lipid production. "A major advantage of this method is that it is cost-effective and comparatively easy to operate, with quite low daily maintenance," says Patel. "Cultivation can be performed without illumination, hence, there is no photobioreactor requirement."

The lipids produced by this algae fermentation process were further converted via advanced hydrotreatment processes into

fuel, optimised for aviation or shipping fuels. Patel notes this is the first time that biofuels have been produced using microalgae fed on a diet of wood waste: "Microalgae are the best source for the production of intracellular lipids that can be transformed into biodiesel."

Lucrative side streams

The algae fermentation was also found to contain high numbers of nutraceutical compounds, such as squalene and long-chain omega-3 polyunsaturated fatty acid, offering an additional revenue stream for anyone using the process to generate biofuel.

The methods pioneered by the FLEXI-GREEN FUELS project represent an important step toward biofuels that do not compete with food crops or other land uses. By making use of biowaste, and creating value in the process, the process could be a boon for forestry, agricultural and municipality waste industries.



Microalgae are the best source for the production of intracellular lipids that can be transformed into biodiesel.

PROJECT

FLEXI-GREEN FUELS – Flexible and resilient integrated biofuel processes for competitive production of green renewable jet and shipping fuels

COORDINATED BY

Bremerhaven University of Applied Sciences in Germany

FUNDED UNDER

Horizon 2020-ENERGY

CORDIS FACTSHEET

cordis.europa.eu/project/id/101007130

PROJECT WEBSITE

flexigreenfuels.eu

Tracing the global marine carbon cycle from the molecular level

Through better knowledge of the molecular products of microalgae, researchers on the EU-funded MARINEGLYCAN project are advancing our understanding of the ocean's ability to sequester carbon dioxide.



The ocean harbours a vast reservoir of dissolved organic [carbon](#), much of which is composed of glycans – sugar-based molecules created by photosynthetic organisms. These glycans are highly diverse molecules, and emerging evidence suggests certain types of glycans can sequester carbon for hundreds of years.

“In order to get a better understanding of marine carbon glycan flows at the molecular level, we need precision chemical tools,” explains [Conor Crawford](#), a postdoctoral researcher at the Max Planck Institute of Colloids and Interfaces. “These tools will allow us to scientifically approach questions in marine carbon cycle research with the same technical rigour that is required in medical research,” he adds.

In the MARINEGLYCAN project, undertaken with the support of the [Marie Skłodowska-Curie Actions](#) programme, Crawford and his colleagues sought to bridge this technological gap by developing a set of biochemical tools to study how marine glycans flow in ecosystems. This transdisciplinary endeavour integrated chemistry, microbiology, biochemistry and ecology.

The primary objectives of the project included creating small molecule inhibitors to regulate microbial carbon cycling, developing tools to sense and quantify glycan degradation in complex communities, and advancing automated glycan synthesis.

Honing in on marine microalgae

Marine microalgae play a crucial role in capturing and storing CO₂ as glycans. A better understanding of this process could unlock new pathways for carbon sequestration, impacting atmospheric CO₂ levels significantly.

"To put it in perspective, a 1 % increase in the carbohydrate or glycan carbon pool would have a larger effect on atmospheric CO₂ levels than the immediate stop of all fossil fuel burning by humans," says Crawford.

During the project, the researchers developed automated methods to synthesise different types of marine glycans and tools, such as [Förster resonance energy transfer](#) (FRET) probes. These molecular sensors can be used to detect, quantify and isolate microbes with rare carbon-degradation activities in an activity-based fashion, something not possible with current technology.

The team used these innovations with collaborators to explore, define and expand our understanding of how microbes and microalgae interact.

"Each tool allowed us to study how algal glycans and microbial proteins interact at the molecular level," notes Crawford. "This

biomolecular understanding is crucial for understanding how and what types of glycans are rapidly digested, released into the atmosphere as CO₂; and identifying those capable of storing carbon for hundreds or even thousands of years."

Enhancing our understanding of algal glycans, microbial degradation mechanisms and the overall carbon cycle lays the foundation for innovation, which is key to addressing the climate and biodiversity emergency, says Crawford. Tools developed in the project could also be used to discover the bioactive epitopes of sulfated marine glycans – known to have antiviral, anticancer and neuroprotective properties.

"The team remains committed to delving deeper into algae's molecular intricacies, although the future trajectory of this research relies significantly on obtaining funding," he says.



A 1 % increase in the glycan carbon pool would have a larger effect on atmospheric CO₂ levels than the immediate stop of all fossil fuel burning by humans.

PROJECT

MARINEGLYCAN – Marine chemical glycobiology: a molecular understanding of the carbon cycle and bioactive sulfated marine glycans

COORDINATED BY

Max Planck Society for the Advancement of Science in Germany

FUNDED UNDER

Horizon 2020-MSCA IF

CORDIS FACTSHEET

cordis.europa.eu/project/id/101029842



A multi-product microalgae biorefinery for food, feed and fragrance

An abandoned industrial site turned into an algae factory by the EU and industry-funded MULTI-STR3AM project can deliver sustainable high-value products for a range of industries.



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Our current agricultural and manufacturing systems come with negative environmental and ecological impacts such as pollution, habitat destruction and emissions from fossil fuel burning. To meet the goals of the [European Green Deal](#) and limit these impacts, new processes need to be found.

Algae present an environmentally friendly solution, with a wide range of potential uses as a fuel, food source and material for manufacturing. However, microalgae products currently struggle to achieve the same economies of scale as conventional products, making them currently underexploited as a crop.

In the [MULTI-STR3AM](#) project, researchers are developing a biorefinery for microalgae products, integrating several technologies to bring down costs of production and boosting scale and sustainability. The project received funding from the [Circular Bio-based Europe Joint Undertaking](#), a public-private partnership.

“To scale up and lower the costs of microalgae production, the MULTI-STR3AM project aims to demonstrate the integration of different technologies within a centralised biorefinery, in a production model that is both sustainable and economically viable,” says Mariana Doria, innovation manager at [A4F-Algafuel](#) in Portugal and MULTI-STR3AM project coordinator.

Developing new microalgae products

The MULTI-STR3AM project is currently processing 10 different microalgae strains to produce 27 ‘biorefinery fractions’, or ingredients. In this project, A4F produces microalgae [autotrophically](#) (using photosynthesis), while [Phycom](#) is scaling up production by [fermentation](#).

Industry partners [Upfield](#), [ForFarmers](#) and [IFF](#) are testing and evaluating these fractions to find the best candidates for pilot and demo scales, and in vivo trials.

They will then be integrated into formulations of edible spreads, animal feed ingredients for poultry, pigs and ruminants, and other organic compounds for use in the fragrance industry.

“Microalgae have a vast biosynthetic potential and are a rich source of lipids, protein and high-value compounds such as pigments,” notes Doria.

Creating a microalgae biorefinery

To create these products, the team successfully achieved a scaling up of microalgae production from 1 m³ to almost 100 m³. This led to a biorefinery with a capacity to process 10 tonnes of biomass per year.

“This biorefinery was designed to process multiple microalgae species using different technologies and providing different products,” adds Doria. “The construction of the MULTI-STR3AM biorefinery involved the retrofitting of an abandoned industrial site, revitalising old installations into a sustainable biorefinery for the future.”

The MULTI-STR3AM biorefinery was designed to use diverse species of microalgae for the generation of several high-value ingredients. By using different biomass feedstocks and integrating industrial waste streams provided by the production units, the biorefinery offers a zero-waste approach to operations.

Positive feedback

The project has already achieved several important results. This includes the integration of industrial side streams – such as nitrogen-rich effluent and industrial brine effluent – as feedstock for microalgae cultivation.

The biorefinery has produced 26 microalgal samples for testing in food, feed and fragrance applications, from *Spirulina*, *Dunaliella*, *Nannochloropsis* and *Chlorella*.

Some products are already being tested by end users, whose feedback is informing the ongoing development of the biorefinery. During the final year of the project, which ends April 2025, partners will expand their trials, scale up their prototypes for further testing and evaluate the formulation of products.



Microalgae have a vast biosynthetic potential and are a rich source of lipids, protein and high-value compounds.

To boost microalgae productivity, optimise biorefining processes and support industrial partners, the project also involves [IMIC](#), [iBET](#) and [LNEG](#).

“As the biorefinery expands and more equipment is commissioned, process optimisation is an ongoing process to reach the best conditions for microalgae fractioning and purification and refining,” concludes Doria.

PROJECT

MULTI-STR3AM – A sustainable multi-strain, multi-method, multi-product microalgae biorefinery integrating industrial side streams to create high-value products for food, feed and fragrance

COORDINATED BY

A4F-Algafuel in Portugal

FUNDED UNDER

Horizon 2020-FOOD and Horizon 2020-LEIT-BIOTECH

CORDIS FACTSHEET

cordis.europa.eu/project/id/887227

PROJECT WEBSITE

multi-str3am.com/en



Algae-fed bacteria could make biodegradable yoghurt pots

An alternative to fossil fuel-based plastics, the EU and industry-funded NENU2PHAR project has developed biodegradable products derived from microalgae, offering a new bioplastic value chain.



© CEA (French Alternative Energies and Atomic Energy Commission)

Thanks to their mechanical, thermal and protective properties, plastics are indispensable in high-volume manufacturing of consumer products and packaging. Yet most of these plastics are produced using fossil fuels, can be hard to recycle and can lead to environmental hazards such as microplastic pollution.

While various efforts are under way to recover, reuse and recycle these plastics, an alternative approach gaining traction is to find biodegradable source materials.

The [NENU2PHAR](#) project has successfully demonstrated a value chain that delivers a family of polymers called

polyhydroxyalkanoates (PHAs), using bacteria grown on sugars produced by microalgae.

"Despite being widely recognised as a viable replacement for fossil fuel-based plastics, no sustainable PHA value chain exists yet in Europe," explains Pablo Alvarez Diaz from the [French Alternative Energies and Atomic Energy Commission](#), coordinator of the NENU2PHAR project.

Funded through the [Circular Bio-based Europe Joint Undertaking](#), the project comprised 17 research and industry partners.

Fuel that doesn't compete with food

PHAs are a class of renewable, biodegradable and bio-based polyesters considered members of the 'green polymer group'. These have appealing physicochemical, thermal and mechanical properties, similar to polypropylene (PP) and low-density polyethylene (LDPE), which constitute the majority of plastic packaging used today.

"PHAs are particularly attractive because they are environmentally friendly at end-of-life, degrading in soil, aquatic media as well as home and industrial compost," says Jean-François Sassi, co-coordinator of NENU2PHAR.

However, because the bacteria need sugar to grow, producing large amounts of plastic in this way faces a serious challenge. "Currently the carbon feedstocks used as fermentation substrates come from starch produced from crops like wheat and potatoes, so they compete with traditional agri-food supply systems, and increase food prices," Alvarez Diaz adds.

NENU2PHAR demonstrated that microalgae could be an ideal source of fuel for the bacteria. Growing algae in bioreactors captures large amounts of CO₂ from the atmosphere and turns it into the starch needed by the hungry biopolymer-producing bacteria.

"Producing pure white starch from green sludgy microalgae was a highlight, and important, as the industry needs colourless, transparent plastics at the start of the production process," notes Sassi.

The team also developed a process to extract PHAs from the bacteria that uses more environmentally friendly solvents than

conventional chlorinated varieties. The PHAs are then formulated into raw bioplastic production materials.

Encouragingly, there may already be a ready supply of the feedstock: microalgal biomass is routinely produced by European sewage facilities during the wastewater treatment processes. NENU2PHAR's value chain could turn a waste stream into a revenue stream.

The catwalk to a more circular economy

As a demonstration of the versatility and suitability of PHAs, the team has unveiled a collection of microalgae-derived bioplastic products. This includes sliced cheese trays, film lids, pots and pouches for wet food such as yoghurts, roll-on bottles for deodorants, filament used in 3D printing, medical meshes and agro-textiles.

"We got such positive feedback at various events, with people typically saying: 'Wow, you've really done it'. You can't argue about the feasibility of these bioplastics while you are holding one of our yoghurt pots," says Alvarez Diaz.

PROJECT

NENU2PHAR – For a sustainable and European value chain of PHA-based materials for high-volume consumer products

COORDINATED BY

French Alternative Energies and Atomic Energy Commission in France

FUNDED UNDER

Horizon 2020-FOOD and Horizon 2020-LEIT-BIOTECH

CORDIS FACTSHEET

cordis.europa.eu/project/id/887474

PROJECT WEBSITE

nenu2phar.eu



Sewage-cleaning microalgae offer a green way to make blue

The EU-funded Waste Water To Blue Pigment-by-Microalgae project is advancing our capacity to use microalgae such as *Spirulina* to clean wastewater, generating alternative fuels and high-value compounds in the process.



© Elena Schweitzer/stock.adobe.com

The EU contains around 3.2 million km of sewer pipes – [enough to stretch to the Moon and back four times over](#). Most of these pipes end at a treatment plant, where wastewater is made safe before it is released back into the environment.

Microalgae can play a key role in this process, removing harmful pollutants from the wastewater before being harvested for use as fuel or fertiliser, or processed to extract valuable compounds.

“*Spirulina* can process and remove a wide array of nutrients and pollutants from wastewater, including nitrate, phosphate and even heavy metals,” explains project coordinator Stijn Van Hulle, from the [Laboratory for Industrial Water Treatment and Ecotechnology](#) at the University of Ghent. “It does so while producing high-value products such as phycocyanine, a blue pigment.”

However, the harvesting and drying of microalgal biomass are costly, limiting the practice. The WWTBP-by-Microalgae project, undertaken with the support of the [Marie Skłodowska-Curie Actions](#) (MSCA) programme, aimed to valorise the process of and develop improved harvesting techniques.

Innovative harvesting methods

MSCA fellow Bahram Barati focused on optimising growth conditions for the microalgae, while enhancing their pollutant absorption and phycocyanin production. To address technical challenges related to microalgae harvesting, he introduced a two-step treatment process.



Our process could capture CO₂, treat water and return high-value products.

“Harvesting is a high-energy demand process and one of the key challenges to overcome if we are to achieve a cultivation system that’s both energy-efficient and environmentally friendly,” he says.

Working with Van Hulle, he devised a new encapsulation process for *Synechococcus*, a photosynthetic bacteria found widely in the marine environment. The pair also devised an innovative low-energy method to harvest *Spirulina* based on electrocoagulation filtration. This significantly eases the harvesting process, making it more efficient and less energy-consuming compared to traditional methods.

Red light, green tech

The way forward is not without challenges. Europe’s cold winters can adversely affect the growth of selected microalgae strains, consequently the project team is currently testing other strains for efficiency in low temperatures.

Other potential limitations relate to scalability, with factors such as cost, public perception and regulations on the use of microalgae products from wastewater treatment in sectors such as pharmaceuticals, cosmetics, food and nutritional supplements.

Nonetheless, Barati emphasises real-life applications for industries such as breweries and food processing. “In these sectors, our process could capture CO₂, treat water and return high-value products.”

The project has yielded promising results so far, particularly in optimising *Spirulina* growth. “Our findings indicate that red light yields the highest biomass and pigment productivity,” remarks Barati. Additionally, the project demonstrates effectiveness in treating brewery wastewater.

Looking ahead, the team intends to focus on developing an advanced sensory system to optimise CO₂ concentration during the process, which in turn would maximise biomass productivity. They are also testing out thermochemical conversion methods such as hydrothermal carbonisation and hydrothermal liquefaction to facilitate digestate transformation into high-value products such as biochar and bio-crude oil.

Scheduled to complete in September 2024, WWTBP-by-Microalgae will explore options for introducing their process and product to the market. “We intend to develop a thorough and well-thought-out business plan,” Barati adds. “This includes conducting market research, obtaining legal protections, ensuring regulatory compliance, developing a business model, securing funding and crafting a marketing plan.”

PROJECT

WWTBP-by-Microalgae – A circular economy platform for treatment of wastewater by blue green microalgae

COORDINATED BY

University of Ghent in Belgium

FUNDED UNDER

Horizon Europe-MSCA

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The ocean contains nearly 80 % of all life on Earth. As a source of oxygen, food, and employment, it supports billions of people, and also forms the planet's largest carbon sink. This Results Pack highlights 13 EU-funded research projects focusing on ocean observing and essential actions for its sustainable management.



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