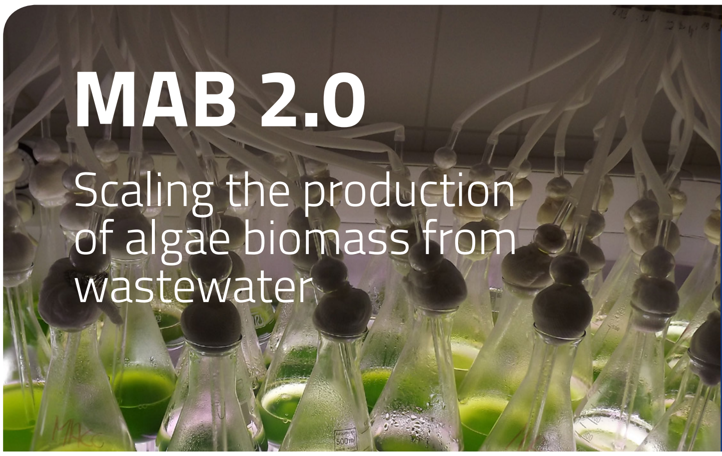

MAB 2.0

Scaling the production of algae biomass from wastewater

PROJECT DETAILS

Name: Microalgae Biorefinery 2.0 (MAB 2.0)

Website: algaerefinery.eu

Sector(s): Biomass / Chemicals

Project Partners: Pannon Pro Innovation Services Ltd., Budapest Sewage Works Pte Ltd, Utrecht University, Wageningen University, Wageningen Food and Biobased Research, INRA, the University of Valencia and the Polytechnic University of Valencia.

Project Duration: 2014-2017

Project Location: Budapest, Hungary

Key messages

- Microalgae Biorefinery 2.0 (MAB 2.0), an EIT Climate-KIC demonstrator project, worked on a proof of concept for large-scale algae biomass production using effluent from wastewater treatment plants.

- Transforming wastewater into algae biomass delivers energy savings, as it reduces the reprocessing required to clean the water; and the biomass produced is a CO2-neutral feedstock with multiple applications.

- Successfully scaling circular innovations which valorise contaminated waste requires consideration of wider system elements – particularly regulatory frameworks that seek to ensure that contaminants are not cycled.

Introduction

Wastewater treatment accounts for 1% of EU's total electricity consumption (1). The amount of wastewater produced in the European Union is steadily growing as an increasing number of households are connected each year to wastewater treatment facilities (2).

During the wastewater treatment process, a semi-solid residue is produced, called 'sewage sludge'. This sludge is dried out, or 'dewatered'. The resulting effluent (waste liquid) from this process contains contaminants such as heavy metals, and extremely high levels of nitrogen and phosphorus, which means that it cannot be safely returned to local water ecosystems (3), but is instead fed back into the primary stage of the treatment process. Eliminating the need to reprocess this effluent would reduce the energy usage of wastewater plants, as well as increase both their capacity and economic performance.

One potential circular economy solution to reduce the need to reprocess this waste effluent is to use it for growing algae biomass. Algae feeds on the nitrogen and phosphorus in the water, cleaning it during the process. The circular economy refers to a restorative economic model, which seeks to extend the life of products, components and materials by keeping these in use within the economy for as long as possible. Circular strategies include, but are not limited to: eco-design, reuse, repair, refurbishment, remanufacturing, product-service systems and recycling.

Microalgae Biorefinery 2.0 (MAB 2.0) was a three-year (2014-2017) demonstrator project supported by EIT Climate-KIC. Led by Pannon Pro (PPIS), a Hungarian environmental consultancy, it worked on connecting an algae bioreactor to an anaerobic digestor at a wastewater treatment plant (4). Algae bioreactors use microalgae to transform nutrient-rich water and CO2 into biomass and other valuable compounds. Well-managed algae production can deliver high biomass yields per area, which in turn has significant potential as an alternative feedstock for a variety of climate and land-intensive applications, such as animal feed, fertiliser, plastics and fuel.

Image 1: Location of pilots, the algae glasshouse at the North Budapest wastewater treatment plant operated by Budapest Sewage Works

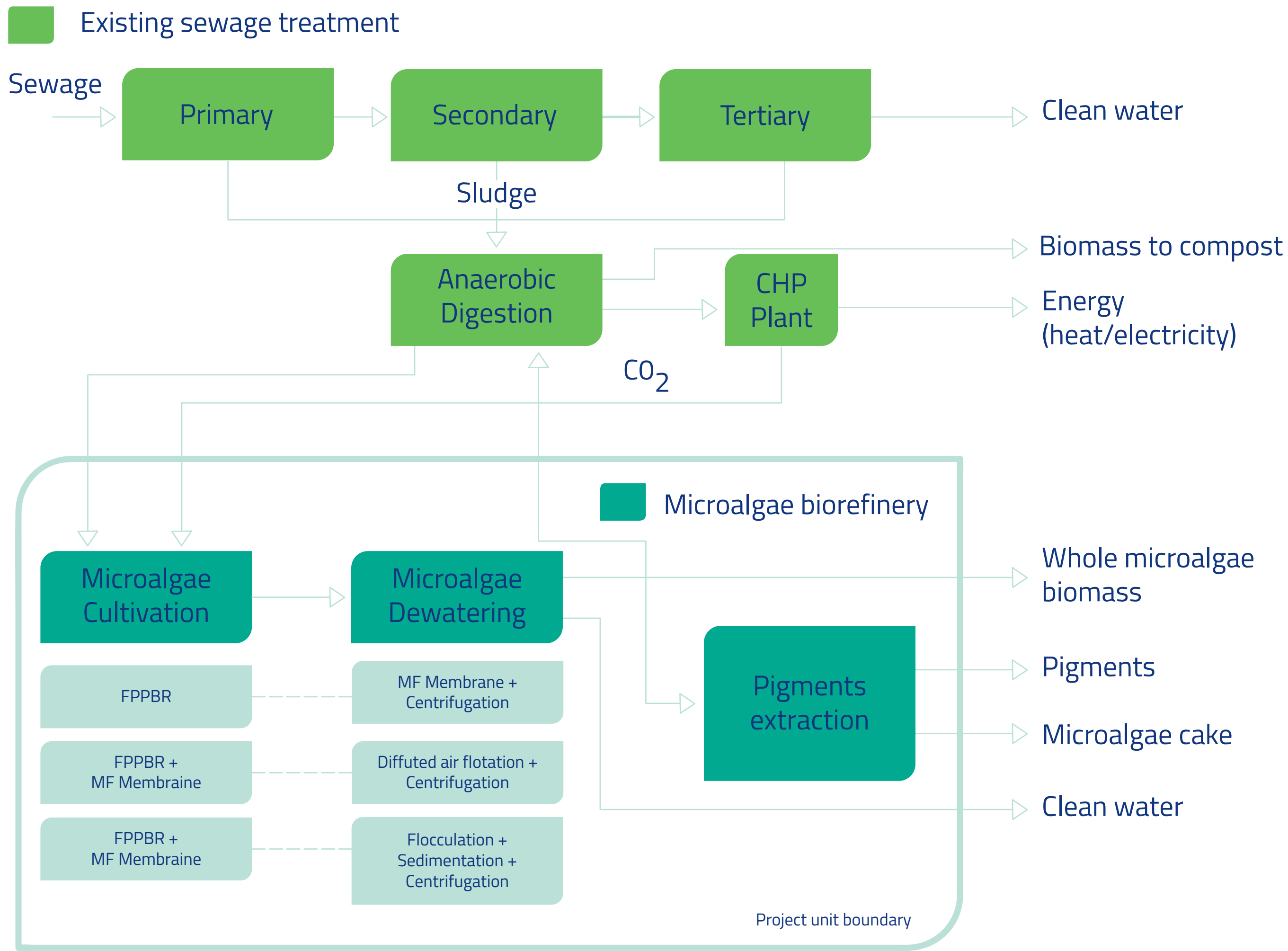

Figure 1: Overview of the MAB 2.0

MAB 2.0's business model

During the project a microalgae biorefinery was installed at the North Budapest wastewater treatment plant, operated by Budapest Sewage Works Pte Ltd. (a MAB 2.0 consortium member). The microalgae biorefinery runs in three steps: pre-treatment, algae bioreactor, centrifugation (see Figure 1). The algae grows exponentially – feeding on the excess nutrients in the wastewater effluent (nitrogen, phosphorus), sunlight and the CO2 produced by the treatment plant's onsite anaerobic digestor – and in the process captures all contaminants in the water. It is then harvested and dried, leaving behind the effluent in a state clean-enough for it to be discharged back into nature.

Algae bioreactors are not new technology, nor is the use of wastewater as a feedstock (5). The innovative aspect of the MAB 2.0 project was the business model developed, based on consultancy and technical services for two client segments.

The first client segment comprises the wastewater treatment plants, to whom consultancy services would be offered to assist in managing the integration of algae bioreactors into their process. Within this activity, project partners would perform various roles, from selecting the optimal strain of algae for a particular plant and carrying out an environmental impact assessment, to designing the biorefinery and integrating it into each plant's existing infrastructure.

The second client segment would comprise the companies purchasing the algae biomass produced, with MAB2.0 acting as an intermediary between treatment plants and buyers (algae processors). Three possible types of application (and corresponding buyers) for the algae biomass were identified, ranging from simple, well-regulated applications like fertilisers to more complex uses such as bioplastics and animal feed.

The algae processing sector is not yet mature, which poses a significant constraint for MAB2.0's operations and limits their opportunities for finding viable high-value markets for the algae biomass. For example, one of the nearest companies identified, which uses algae for producing bioplastics, was a start-up based in the Netherlands – a prohibitively expensive distance from Budapest.

System Conditions

With climate change requiring urgent and concerted action, there is a need to reconfigure and transform our economies and societies. Innovative technologies and business models alone will not live up to the mark as they are not guaranteed access to market; it is often the surrounding environment that proves decisive on whether an innovation will flourish or perish. This is because the innovation is a part of a wider system and influenced by key system elements, such as: Policy, Skills, Behaviour, Market Structures, Information Flows, Organisational Governance and Finance. Innovation needs to happen on all these fronts ('systems innovation') in order to achieve substantial system transformation.

MAB 2.0: Enablers

Policy

Wastewater effluent – and its disposal – are highly regulated, both at EU and national levels, due to the presence of contaminants such as heavy metals, hormones and pharmaceuticals. The most relevant piece of European legislation is a 1991 Council Directive concerning urban wastewater treatment (6), which was drawn up to protect the environment from the adverse effects of urban wastewater discharges as well as those from certain industrial sectors. This directive sets strict rules surrounding the transportation of wastewater effluent.

The MAB2.0 consortium concluded that space constraints in many wastewater treatment plants would require that the algae biorefineries are built on land adjacent to the site. But the regulation of wastewater effluent, as specified by the above-mentioned directive, becomes prohibitively complex once the wastewater leaves the treatment site – even if it is being fed directly into an algae production facility next door.

A shift in the legislative approach could help remove this barrier – related to end of waste status – which is recognised by the EU (7). Miklós Gyalai-Korpos, the MAB 2.0 project lead and Innovation Manager at PPIS Ltd., remains optimistic that the increasing focus on circular economy strategies at the EU and national levels will bring about this change.

Market Structures

Taking into account insights from visiting wastewater treatment plants in several Eastern European countries – including Romania, Slovakia and Slovenia – as well as their experiences in Budapest, the MAB 2.0 consortium concluded that the bureaucratic nature of the public sector, including its procurement policies, was a barrier to the adoption of its technology.

Although wastewater treatment plants would generally respond positively to the adoption of the technology proposed by MAB2.0, the bureaucratic nature of municipally run facilities meant that the approval for investing in new technologies would take a long time. On top of this, plant managers were often uncomfortable with the prospect of managing operations outside their core areas of expertise (e.g. running the algae biorefinery). Gyalai-Korpos pointed out that in order to overcome this barrier the sector "needs not just a shift in technology but in organisational culture".

Market structures also posed a challenge further along the value chain. While algae biomass has several potential applications, the fact that MAB 2.0's biomass is derived from municipal wastewater means that its composition is not exactly the same every time. This poses challenges to the buyers, as they have to comply with strict regulations.

In that sense, industrial wastewater could be a better source of raw material as, unlike municipal wastewater, it can be strictly controlled. "In industrial wastewater, they know what is inside," Gyalai-Korpos says. "If you produce something from controlled-origin waste water, you can probably go for a higher market value." While still an assumption that needs to be tested, industrial wastewater-derived algae biomass could potentially facilitate easier entry into highly regulated markets like the food industry, for example.

Image 2: The open-pond system tested in the project was provided by Zöldségcentrum Ltd and it was developed in Vegaalga project under grant agreement No. 673023

Conclusion and lessons learnt

Within the circular economy, projects such as MAB 2.0 can be the missing link between the producers of waste streams and the industries that can make use of them. However, the market for algae biomass is not yet mature enough.

MAB 2.0 encountered significant challenges trying to implement their technology in the municipal wastewater treatment sector – particularly related to space constraints for locating this technology and regulations around transporting waste water effluent relating to the risk of contamination.

The key lessons learnt from their commercialisation experience thus far are:

▪ **Circular ventures seeking to valorise contaminated waste need to understand the complexities of relevant regulatory frameworks.** Due to the risk of contamination, both wastewater and products derived from its treatment – such as algae biomass – are highly regulated, restricting their valorisation.

▪ **Circular innovations should consider business models built on both public and private sector waste sources.** Building on the MAB 2.0 consortium experience, one potential way to overcome the inherent challenges associated with municipal wastewater (e.g. variable wastewater composition and long procurement processes) is to redesign the business model on the private sector. Unlike municipal wastewater, the composition of industrial wastewater is not variable, resulting in algae biomass that is more suitable for high-value applications.

▪ **Commercialising circular solutions in strict regulatory environments requires continuous consideration of alternative routes to financial viability to ensure cash flows.** PPIS Ltd. are exploring new ways to make the business model viable under the current regulatory circumstances. For example, they are exploring developing countries as a market, where physical space – and sunshine – are more readily available.

Incorporating existing technologies into innovative settings can provide unlimited circular solutions. In the case of MAB 2.0, the combination of algae production and wastewater treatment under a new business model has the potential to: deliver energy savings for wastewater treatment plants, reduce contaminants in wastewater effluent and produce a CO2-neutral substitute for many land-intensive products, such as animal feed, fertiliser, plastics and fuel.

About

EIT Climate-KIC is Europe's largest public-private partnership addressing climate change through innovation to build a net zero carbon economy. The Climate Innovation Insights are one of the most knowledge sharing prominent formats of EIT Climate-KIC since 2016. Building on innovation endeavours of EIT Climate-KIC start-ups and partner institutions, the Insights are intended to share learnings and provide a platform for reflection and discussion.

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Endnotes:

(1) Horizon2020 ENERWATER project website: http://www.enerwater.eu/enerwater-project-waste-water-treatment-plants/ and https://ec.europa.eu/easme/en/news/watering-down-energy-consumption-wastewater-treatment-plants

(2) Eurostat Statistics, (2017) Water Statistics – Wastewater Treatment, https://ec.europa.eu/eurostat/statistics-explained/index.php/Water_statistics#Wastewater_treatment

(3) European Commission (2016) Sewage Sludge. http://ec.europa.eu/environment/waste/sludge/index.htm

(4) Nagy et al. (2018) MAB2.0 project: Integrating algae production into wastewater treatment. The EuroBiotech Journal, Vol. 2, Issue 1., pp.10-23. https://content.sciendo.com/view/journals/ebtj/2/1/article-p10.xml

(5) Dalrimple et al. (2013) Wastewater use in algae production for generation of renewable resources: a review and preliminary results. Aquat Biosyst, Jan 5, 9, (1) 2. https://www.ncbi.nlm.nih.gov/pubmed/23289706

(6) European Council (1991) Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31991L0271&-from=EN

(7) European Commission (2018) Communication on the implementation of the circular economy package: options to address the interface between chemical, product and waste legislation. COM (2018) 32. https://ec.europa.eu/docsroom/documents/27321