AlgAria – Powering Nutrition.

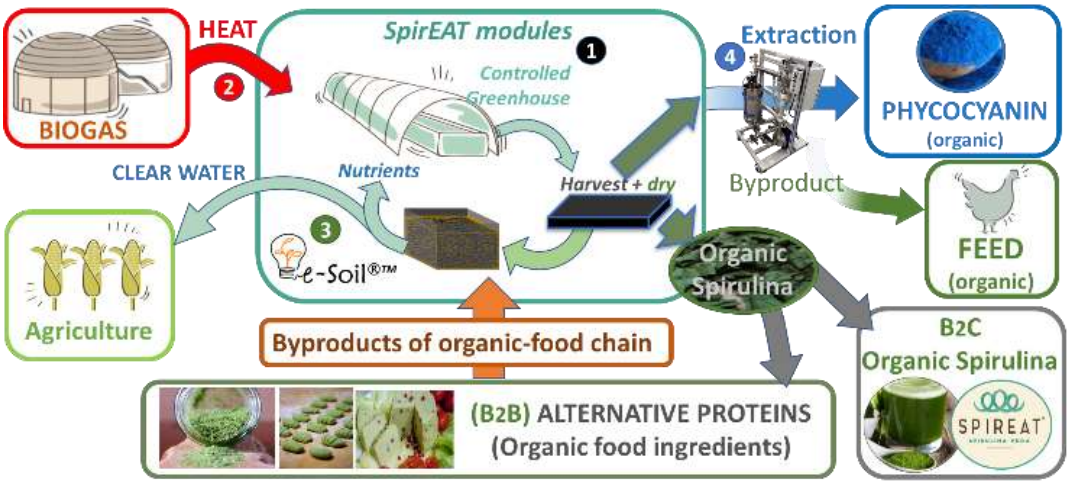
Towards a sustainable way to feed the increasing human population, we look for innovative solutions to produce highly-nutritional alternative food and ingredients, without impacting on ecosystems. AlgAria looks for solutions to drastically reduce ecosystems 'grabbing' for food production purposes.
Soil-less farming and microbial agriculture have the potential to simultaneously reduce land use, environmental and climate impacts by orders of magnitude, if compared to traditional crops. Cyanobacteria,microalgae and plants grown in vertical farming under controlled environments still use sunlight to do that, but with incomparably higher production efficiencies. Artificial lights powered by solar panels are another option to further concentrate cultivations. Lastly, microbial protein grown using directly electricity as source of energy for CO2 fixation (microbial electrosynthesis) is a more innovative option. Finally, the use of renewable sources of nutrients (N,P,K, etc...) and the recycling of water are the other keys for complete sustainability.
Algaria's project aims at tackling both technological and commercial constraints that still limit the success of such alternatives to food production.

AlgAria's Technological solutions (from TRL=9 down to TRL=3):
AlgAria proposes technological solutions in this field and develops innovative food products based on such alternative sources of nutrition.

1. AlgAria produces a cyanobacterium of the phylum *Arthrospira* at full-scale (TRL=9), using an innovative photobioreactor technology that recovers heat from biogas-fueled cogeneration units, able to optimize costs for B2B markets.
2. Based on such cultivation, AlgAria has developed, produces and sells on B2C markets several innovative highly-nutritional ingredients: phycocyanin blue dye (TRL=8), carotenoids-rich extracts (TRL=7), feed ingredients and food products: Spirulina chips (TRL=8), vegan mayonese with Spirulina (TRL=8), Italian Risotto (TRL=9), spirulina snack bar (TRL=9).
3. AlgAria has patented an innovative technological application based on microbial electrochemistry, called the 'electroactive Soil' or *e*-Soil. This artificial soil is thought for soil-less cultivation of plants or microorganisms and aimed at efficiently recycling nutrients from organic sources. *e*-Soil enables to obtain produce, within the 'Organic farming' framework. The e-Soil is already applied to Spirulina cultivation at TRL=7 (in the so-called e-Pond).
4. AlgAria develops innovative super-food products (rich in specific nutritional components) from a range of alternative microalgae strains, such as Chlorella, Phaeodactylum, Haematococcus, Botriococcus, etc.
5. AlgAria is driving a research program (TRL=3-5) on the production of microbial proteins from bioelectrosynthesis, i.e. using renewable electricity as unique source of energy/reducing equivalents for microbial CO_2 fixation, as well as for the fixation of atmospheric N_2. In few words: nutrition from air.

AlgAria's demo-scale facility (TRL=8) – Cremona (Italy)

Organic-rich **secondary products** of food industry and **wastewaters** are important sources of nutrients. We propose a technological alternative to recover these nutrients and grow microalgae cultures. The **e-Pond** assists **microalgae cultivations** by the introduction of a microbial electrochemical technology: **the electroactive soil (e-Soil**, see below**)**. The e-Soil is used as a separation between the microalgae culture and the organic byproduct. The pore dimensions of the e-Soil materials (<500 nm) is smaller than the microbial cells. This keeps the two environments separated in terms of **microbial contamination**.



High-**quality microalgae biomass** can be obtained from this system. **Animal feed supplements**, **plant biostimulants**, as well as **pigment extracts** can be obtained from different microalgae strains, with food-grade quality, depending on the inlet substrate.

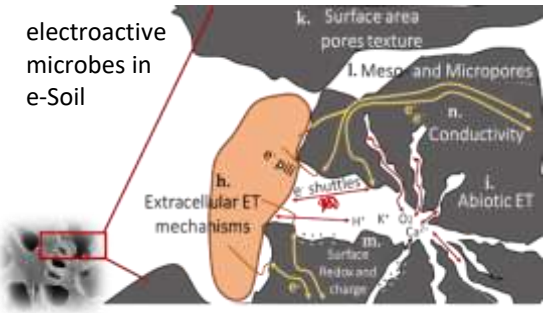
A **prototype scale e-Pond® system** (**TRL = 6**) is available at the facilities of **Algaria srl**, in Casalbuttano ed Uniti (CR, Italy). This project has already attracted funds by different grants: 1. **Neptune** – Blue growth accelerator - Voucher for SMEs - H2020 INNOSUP-1-2015 Cluster - 60k€; 2. **Vida** - European project (2018-2021) funded by the H2020 - INNOSUP Call - 60k€; 3. **TT-agrilab** voucher by Camera di Commercio Milano - 60k€.

The e-Soil® technology (TRL = 7)

https://www.e-soil.net/

Natural soils are actually the most efficient **circular-economy** actors: communities of microorganisms 'regenerate' organic residues by oxidizing organic compounds and releasing mineral forms of nutrients, turning them available for plants growth. A **biomimetic** approach is needed to reproduce this function in **soil-less farming** (e.g. microalgae cultivation or hydroponic/aeroponic/aquaponic farming), to limit their reliance on primary sources of mineral fertilizers.

The **e-Soil®** is a bioelectrochemically-enhanced artificial soil (***patent pending International deposit N. PCT/IB2019/060329 del 29 Novembre 2019, ITALY - N. 102018000010683 - 29/11/2018***) for soil-less agriculture and provides **recycled nutrients** in mineral forms from organic-rich streams. It is based on the bio-electrochemical oxidation performed by electroactive microbial communities, coupled to a special electro-conductive material, which enhances the exchange of electrons in biogeochemical reactions, towards the terminal electron acceptor. Different publications of single aspect of the proof of the concept are published[1–4].



The e-Soil® can be applied to recover nutrients from **food-grade secondary products** of the food industry to obtain food-grade products for humans and animal feeding; or from **organic waste or wastewater** to obtain non-food-grade products, e.g. natural dyes, active molecultes, biostimulants, fertilizers and biopesticides formulations.

Example: Brewery residues

The e-Soil can be coupled to

- microalgae cultivation (the application is called e-Pond)
- hydroponic/aeroponic cultivation applicable in vertical farming facilities (e-Hydroponics)
- aquaponic and integrated systems (e-aquaponics).

[1] L. Rago, S. Zecchin, S. Marzorati, A. Goglio, L. Cavalca, P. Cristiani, A. Schievano, A study of microbial communities on terracotta separator and on biocathode of air breathing microbial fuel cells, Bioelectrochemistry. 120 (2018) 18–26. doi:10.1016/j.bioelechem.2017.11.005.

[2] A. Goglio, M. Tucci, B. Rizzi, A. Colombo, P. Cristiani, A. Schievano, Microbial recycling cells (MRCs): A new platform of microbial electrochemical technologies based on biocompatible materials, aimed at cycling carbon and nutrients in agro-food systems, Sci. Total Environ. 649 (2019) 1349–1361. doi:10.1016/J.SCITOTENV.2018.08.324.

[3] A. Colombo, S. Marzorati, G. Lucchini, P. Cristiani, D. Pant, A. Schievano, Assisting cultivation of photosynthetic microorganisms by microbial fuel cells to enhance nutrients recovery from wastewater, Bioresour. Technol. 273 (2017) 240–248. doi:10.1016/j.biortech.2017.03.038.

[4] S. Marzorati, A. Goglio, S. Fest-Santini, D. Mombelli, F. Villa, P. Cristiani, A. Schievano, Air-breathing bio-cathodes based on electro-active biochar from pyrolysis of Giant Cane stalks, Int. J. Hydrogen Energy. 44 (2019) 4496–4507. doi:10.1016/j.ijhydene.2018.07.167.

Funded by: Neptune Blue Growth Accelerator; CAMERA DI COMMERCIO MILANO; VIDA value-added innovation in food chains

Phycocyanin extraction unit (TRL = 8)

Pilot-scale plant for membrane-based Phycocyanin extraction from spirulina biomass (TRL = 7): sequential membrane treatment (microfiltration + ultrafiltration). Located in a full-scale plant for spirulina production 300 m2 raceway Pond under greenhouse, ground-heat (TRL 8) by recovered heat from a full-scale biogas plant with co-generation unit.

Phycocyanin has massive commercial value as natural colorant in nutraceutical, cosmetic, and pharmaceutical industries, besides their health benefits. Demonstration of phycocyanin extraction technology, based on sequential membrane separation and concentration, using Spirulina biomass produced by e-Pond (recovering nutrients from dairy industry effluents). The pilot-scale plant (extraction capacity: 2 kg of dry Spirulina /day, PC production: 0.2-0.3 kg-PC/day), already existing at ALGARIA facilities will be improved (from TRL 6 to 7).

Phycocyanin extraction technology will be optimized, while testing the extraction method. The tests will be carried out on different extraction technology configurations:

a) sequential-freezing de-freezing enables cell-disruption.
b) A step of filtration at micromembranes (0.2-µm mesh) enables suspended solids separation after phycocyanin extraction.
c) phycocyanin concentration method (ultrafiltration at 50-100-kDa membrane).

Funded by:

Research projects

- BioFuelCellAPP project (ID: RBSI14JKU3, Sep 2015 – Sep 2019), SIR2014 GRANT by Italian Ministry of University and Research (MIUR) – 523 k
- e-Biochar project – June 2020 – June 2023 (Funded by Cariplo Foundation)
- Neptune Consortium – Blue growth accelerator - Voucher for SMEs - *H2020 INNOSUP-1-2015 Cluster* - 60k
- Vida - European project (2018-2021) funded by the *H2020 - INNOSUP Call* - 60k
- TT-agrilab voucher by Camera di Commercio Milano - 60k

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