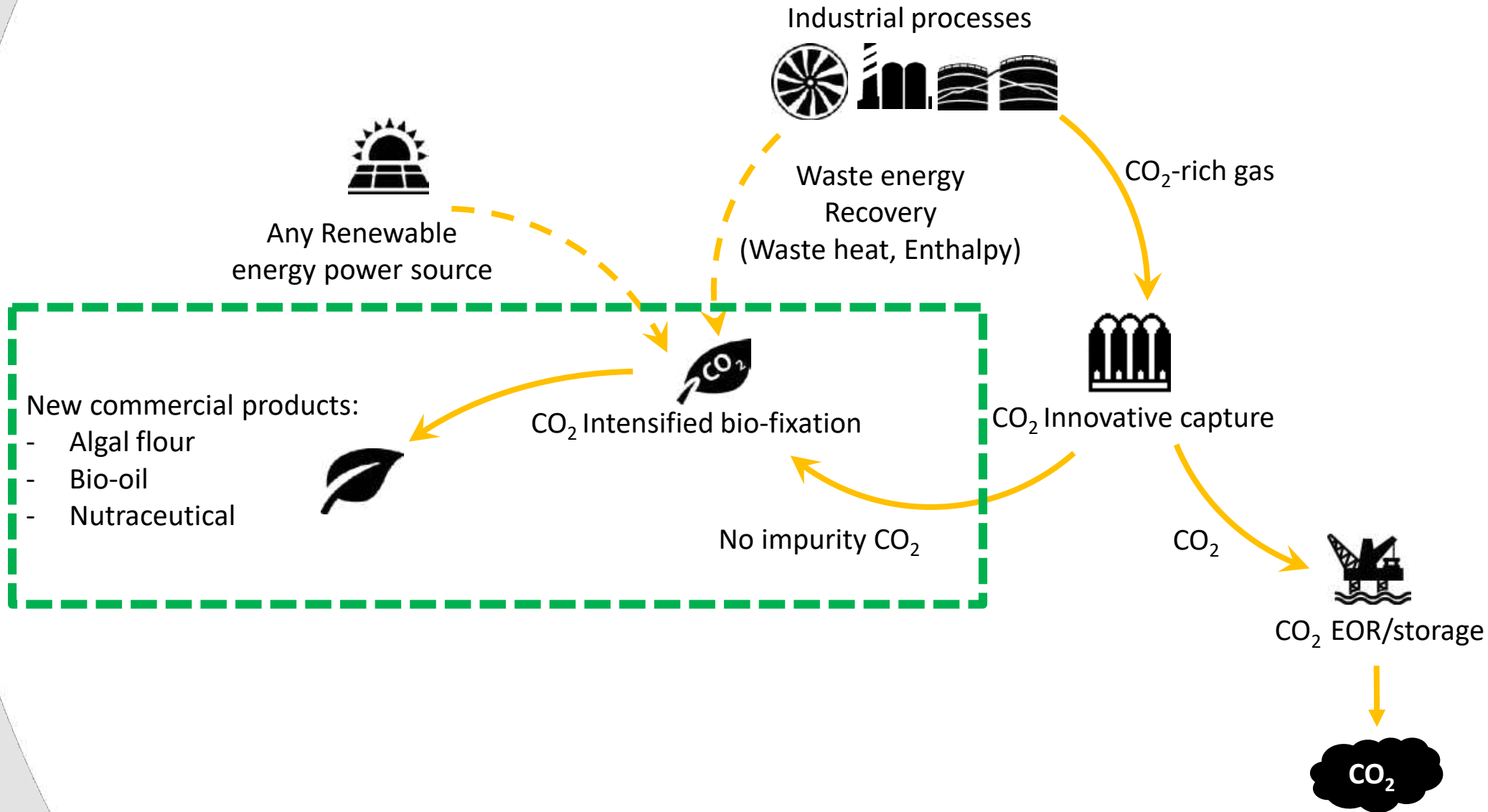

Introduction

Overall Integrated Decarbonisation Strategy – Focus on CO₂ Biofixation



Sustainable Development Goals - SDGS



CO₂ Biofixation - Sustainable Development Goals - SDGS



New low-impact food sources

An alternative source of high quality food, to supplement conventional food sources.



Low carbon footprint bio-fuels and synergies with low carbon energy sources

Bio-oil production as well as integration with low carbon intensity energy sources may lead to increased penetration of RES in the current energy framework



CO₂ utilization and oxygen production

Direct CO₂ reutilization as well as avoided CO₂ by displacing some carbon intensive products

Water preservation by recycling of the culture media

Water is highly preserved in comparison with existing agricultural technologies and recycled within the system



New business opportunities in all areas where Eni is working

New business opportunities and new profits in all geographical areas where Eni is present



Reduced land use and possibility of minimal ILUC

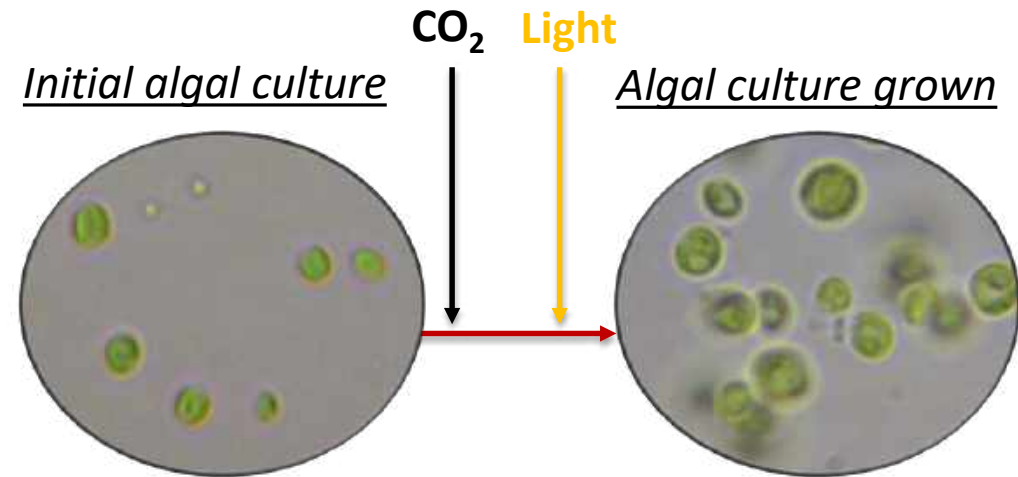
Capability to use non-fertile areas reducing habitat exploitation or agriculturally relevant areas



CO₂ Biofixation Technology

Introduction to CO₂ biofixation through photosynthesis

CO₂ is fixed by the algae through photosynthesis $6 \text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$



This reaction takes place in two steps:

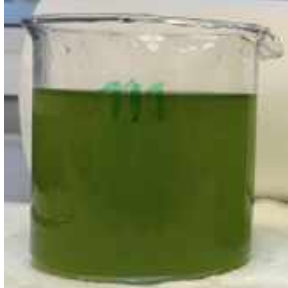
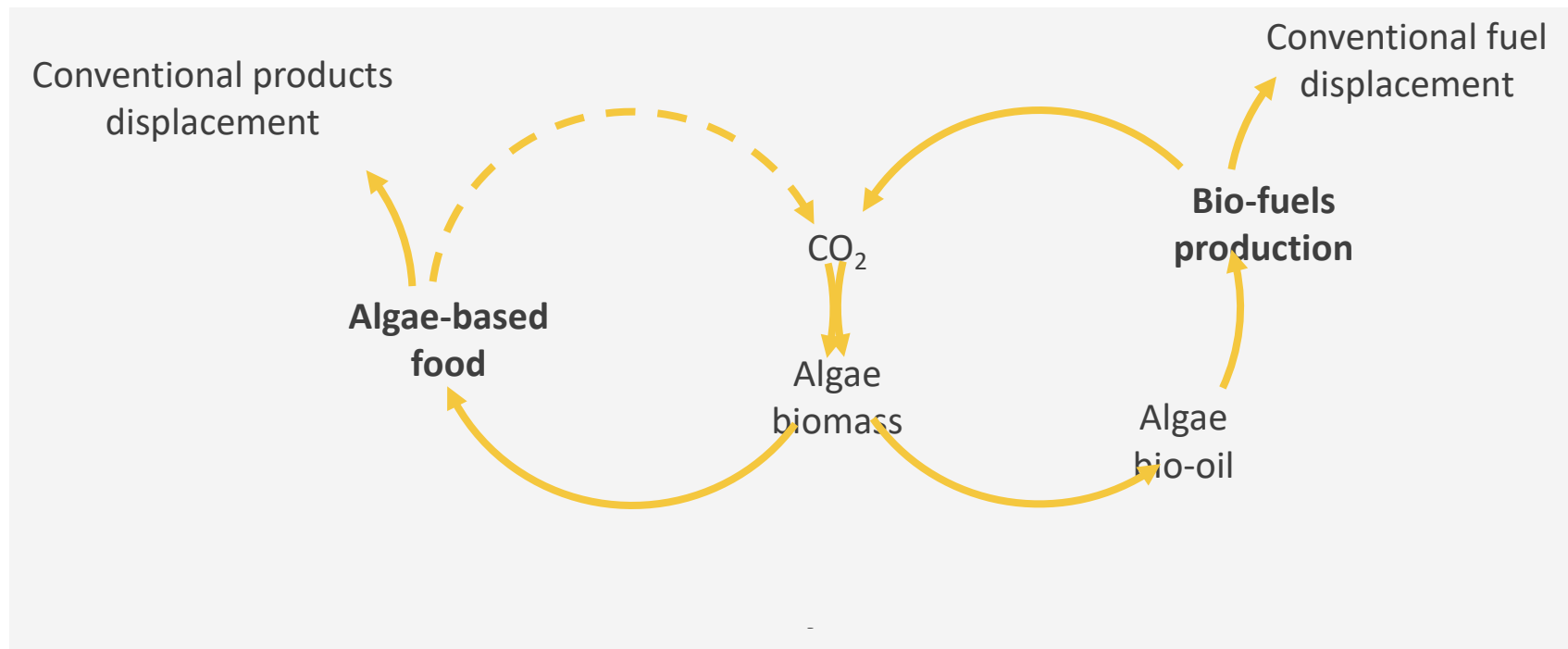
- “light” step in which chlorophyll gets “charged”
- “dark” step in which energy is used to fix the CO₂

Need of nutrients (NO₃⁻, PO₄³⁻, ...) according to protocols

- Complex interaction between the different parameters, influenced by reactor’s design

Biofixation Technology description

- *Innovative technology for CO₂ management, as an alternative to conventional solutions such as the reinjection and the chemical conversion. Based on the photosynthesis operated by microalgae, with sunlight or artificial light, into special PhotoBioReactors*
- **Advantages:**
 - *CO₂ fixation and valorization into marketable products, such as algae meal, nutraceutical compounds, and algal oil*
 - *The produced algal bio-oil can be a possible feedstock to be upgradable to **advanced** bio-fuel in Green Refinery*
 - *Application of a complete green process to the O&G business; valorization of natural gas reserves with high CO₂ content*



Microalgae sample



Algal biomass



Algal Bio-Oil



Two different Bio-fixation Technologies

- *First R&D application in Eni: Open Pond in Gela Refinery*
- *Subsequent application in Eni: based on Photobioreactors*



Sunlight CO₂ Biofixation



Technology provider: BioSyntex Srl (BSX)

BioSyntex

Artificial Light CO₂ Biofixation



Technology provider: Everbloom et al. (LED system developed by MEG)

everbloom

meg



Two different Bio-fixation Technologies

Sunlight CO₂ Biofixation

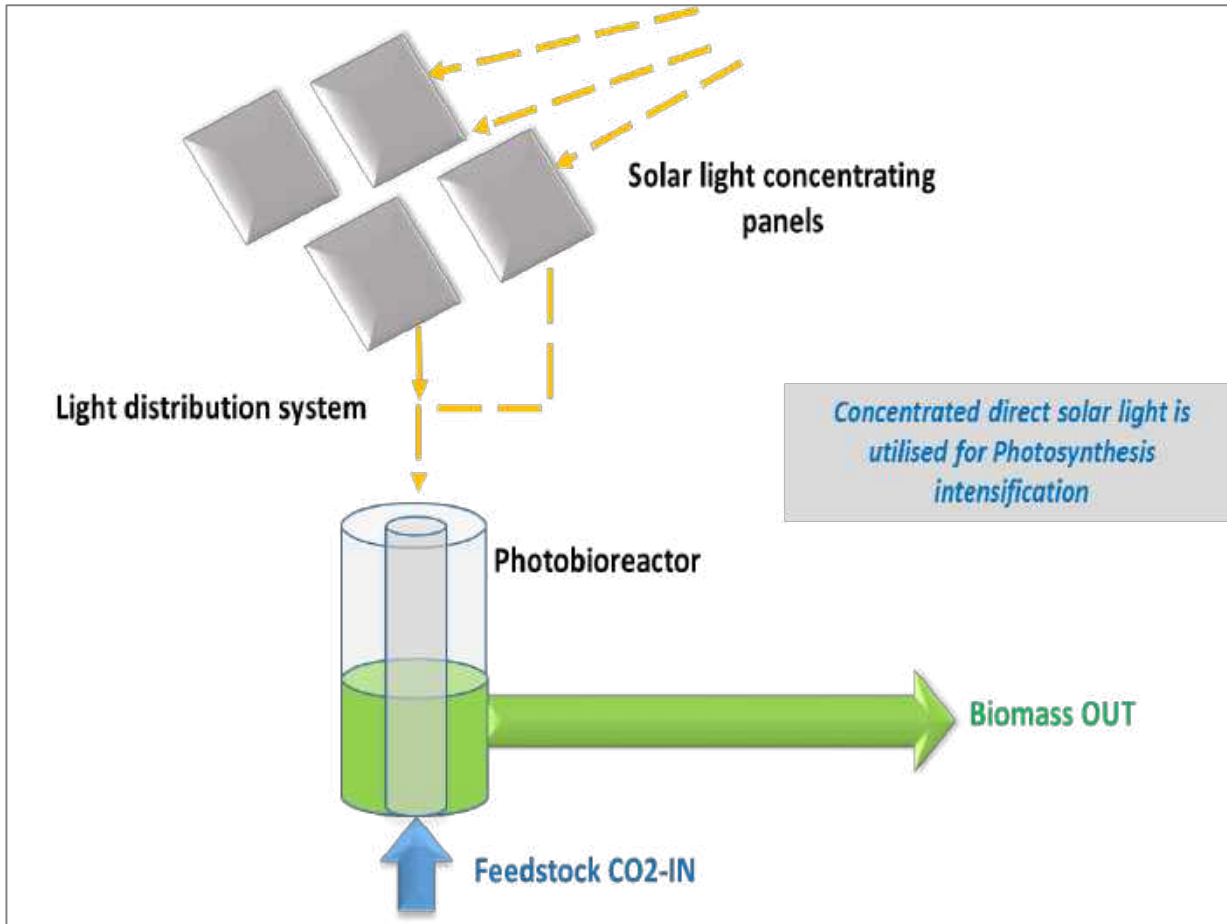


Technology provider: BioSyntex Srl (BSX)

BioSyntex



Sunlight CO₂ Bio-fixation



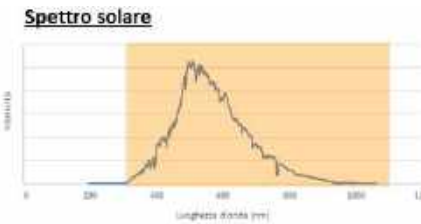
HIGHLIGHTS

- ✓ CO₂ capture and valorization
- ✓ Production of high value products and advanced Bio-oil
- ✓ Sunlight-based system (very low energy consumption) *
- ✓ Complete water recycle
- ✓ No additional waste

**Seasonal dependent*

Sunlight CO₂ Bio-fixation: CO₂ Bio-fixation Incubator Plant in Ragusa

Pilot plant fed by fossil CO₂ (from Eni associated gas), properly purified



Sunlight CO₂ Bio-fixation: Main Results (operating time: 13.500 h *)

- *Plant Start-up in April 20th , 2017; First algal biomass (“flour”) production in July 20th , 2017*
- *Test campaigns:*
 - *2017: troubleshooting and improvement/optimization activities*
 - *2018 and 2019 (conclusion of the experimental campaigns)*
 - *Confirmed the effectiveness of 2017 intervention*
 - *Growths protocol improved setup (air, CO₂, pH)*
 - *NPT reduction to zero*
 - *Operational improvements*
 - *Reactors temperature control fully operative*
 - *The technology needs additional optimizations, since it is not ready – AS IS - for possible industrial application. In addition, the technology is intrinsically function of the weather conditions of the plant site*



Sunlight CO₂ Bio-fixation: Impact on SDGs

- *In Ragusa, full production chain from CO₂ to final product*



- *Water is fully recycled in the pilot plant*



- *Bio-oil extracted from biomass produced in Ragusa shall be suitable for Ecofining™*



- *Impact on local content*



- *CO₂ usage*



- *Valorization of soils not usable for agriculture*



Two different Bio-fixation Technologies

Artificial Light CO₂ Biofixation

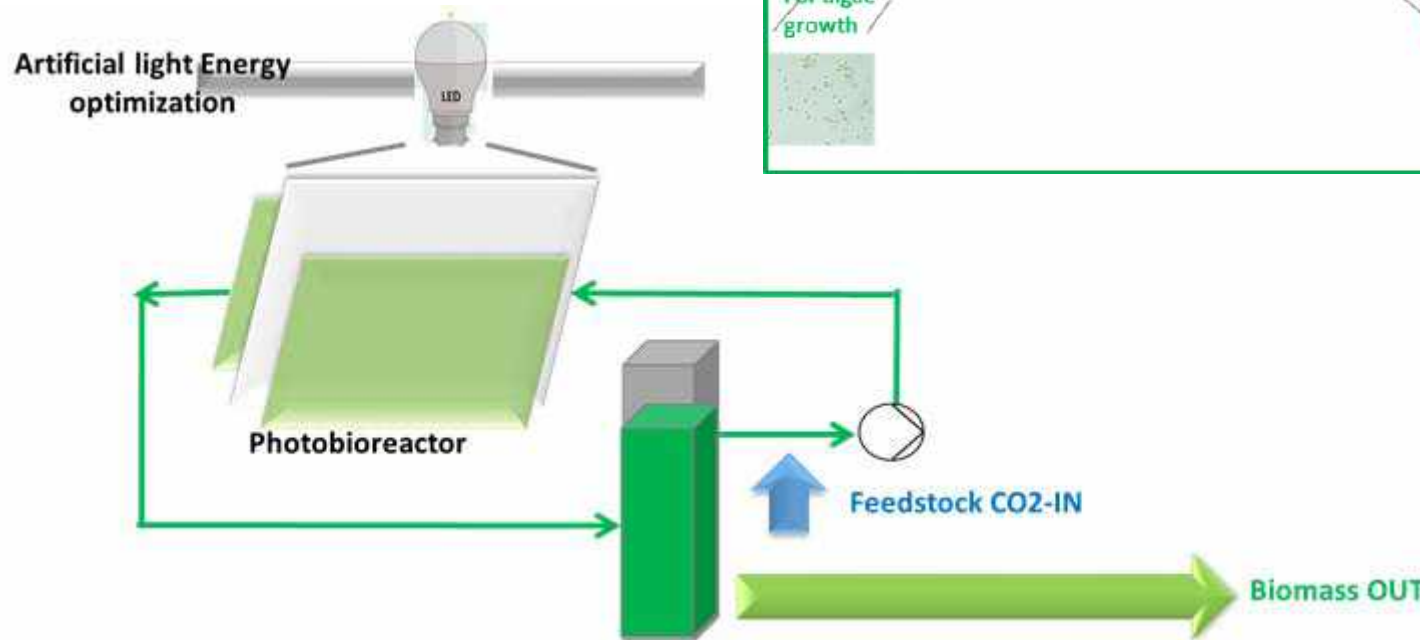
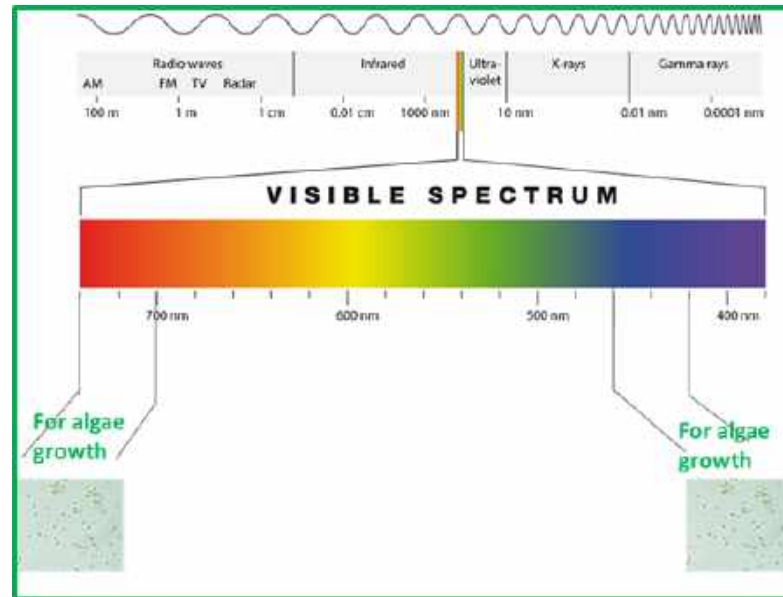


Technology provider: Everbloom et al. (*LED system developed by MEG*)



Artificial Light CO₂ Biofixation

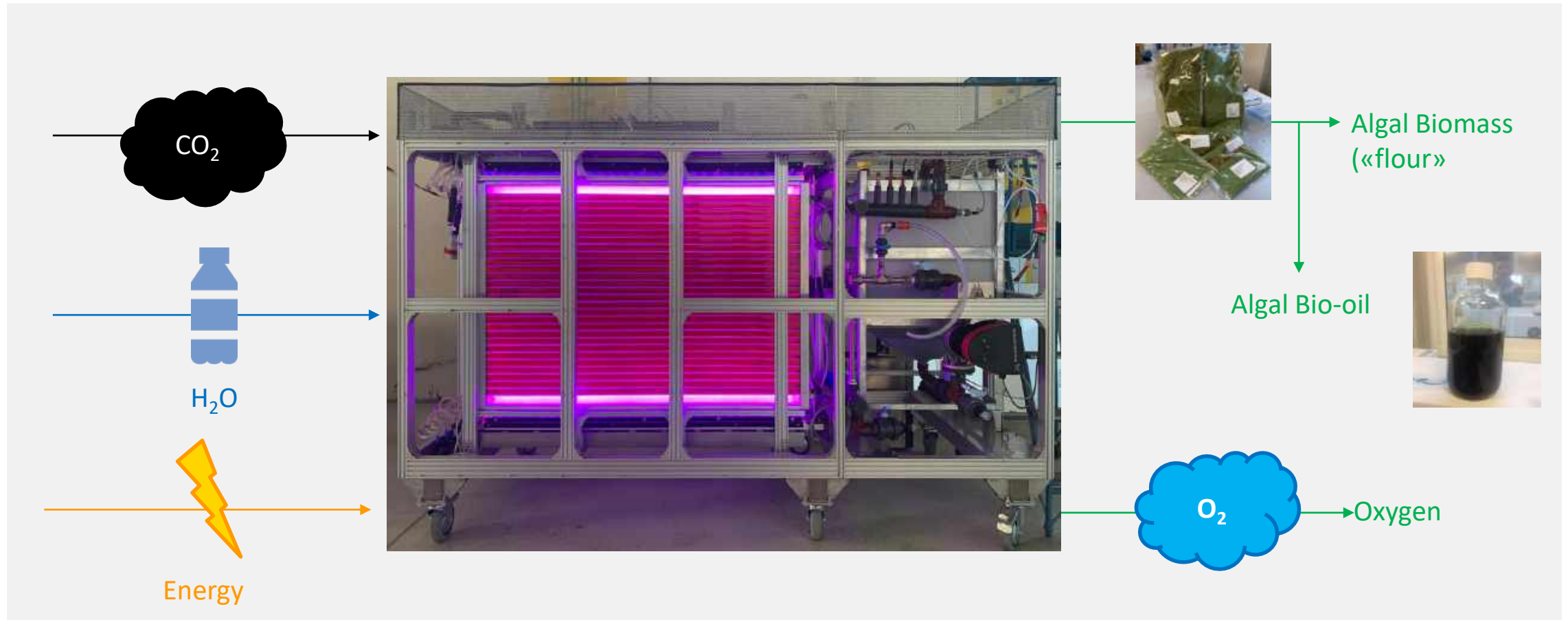
Qualitative picture



HIGHLIGHTS

- ✓ CO₂ capture and valorization
- ✓ Production of high value products and advanced Bio-oil
- ✓ Artificial light-based
 - ✓ Optimization of the energy consumption
- ✓ Versatility and flexibility and h24/7 continuity

Biofissazione CO₂ con luce artificiale: schema semplificato



Circuito chiuso, senza possibilità di contaminazione del ceppo algale

Artificial Light CO₂ Biofixation (almost 5000 h running *)

**Operation of PBR 1 (Full scale fotobioreactor)
since 30/9/2019, 5 runs in total**



Image at beginning of growth run, with minimum algae concentration



Image at END of growth run, with algae in «black body» condition

**Operation of SKID 1 since
18/2/2020, 2 run performed**



*

**from 4Q 2019 to 1Q 2020, without discontinuity*



Artificial CO₂ Bio-fixation: Impact on SDGs

- *High quality biomass (proteins and lipid content) suitable for commercialization*
- *Water can be fully recycled in the pilot plant*
- *Bio-oil extracted from biomass is suitable for Ecofining™*
- *Strong impact on local content: modular industrial application*
- *CO₂ usage (high decarbonization percentage)*
- *Future perspective: valorization of soils not usable for agriculture*



Eni bio-fixation products



Eni algal biomass

- *Eni products from R&D activities are suitable for commercialization*
- *Some samples have high proteins content (more than commercial microalgae)*
- *Toxicity results from experimental reactor are encouraging*
- *Some samples have high lipid content (both saturated and unsaturated fatty acids)
Compatible with Ecofining™*

Conclusions

CO₂ Bio-fixation: Expected benefits

- *Despite the specific kind of technology (reactor design lighting system), the technology is very promising in terms of:*
 - *CO₂ fixation and usage → decarbonization*
 - *Optimization of the CO₂ management/utilization/valorization, with associated revenues if compared with conventional solutions (e.g. reinjection, venting,...) which only includes additional CAPEX*
 - *Optimization of the natural gas production (e.g. debottlenecking, additional gas sale,...)*
 - *GHG emission reduction*
 - *CO₂ saving*
 - *Side markets opportunities*
 - *Succeeding in having a closed loop, by recovery CO₂ and re-including it in Eni productive cycle (through alga bio-oil, and the synergy with Eni Refineries)*

