Open Workshop on Microalgae Market

ABG AlgaeBioGas

Robert Reinhardt
AlgEn, algal technology centre, Slovenia
robert@algen.si

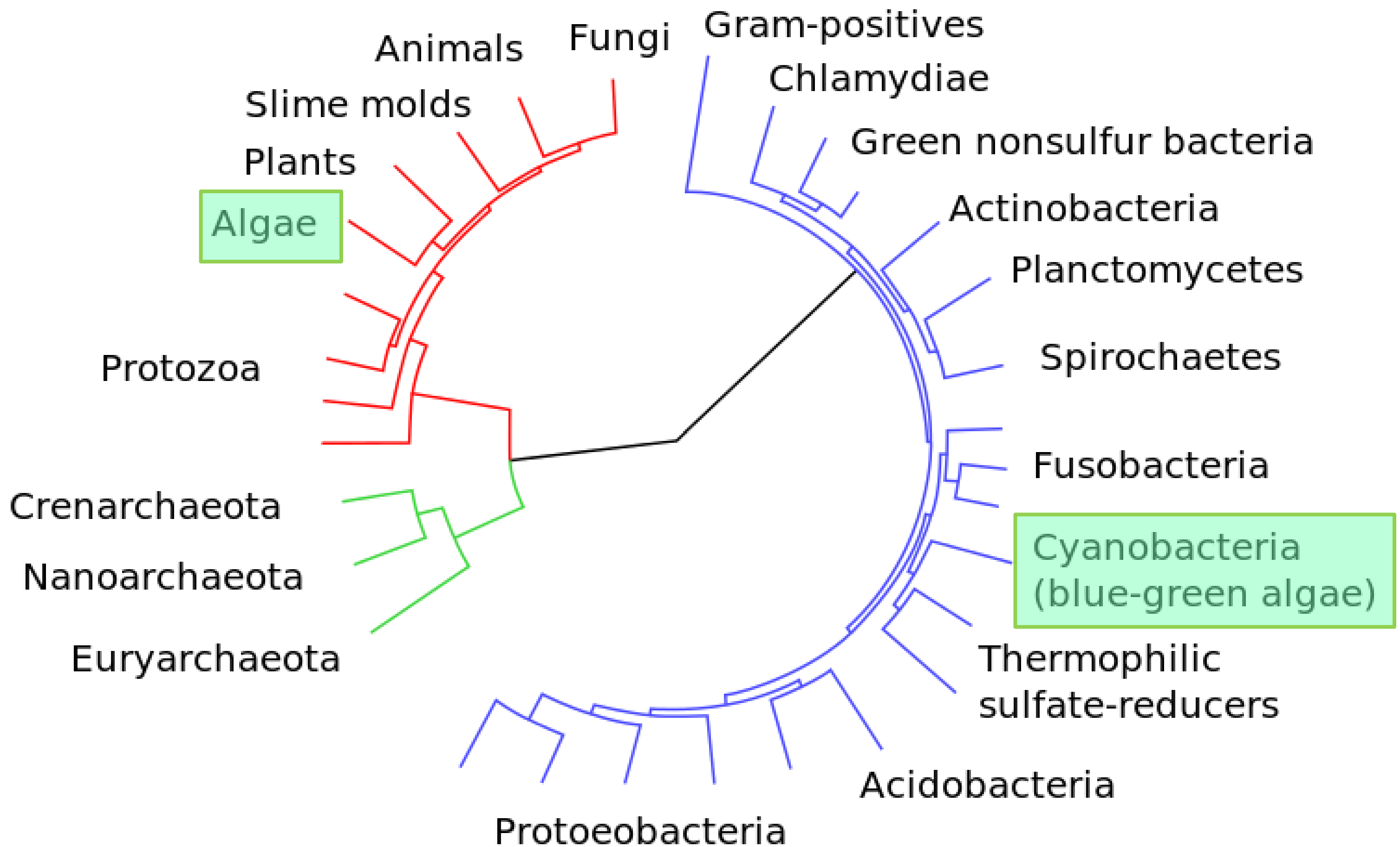
Agenda

- Introduction to Algae
- Algae and biogas: **recycling nutrients** and **CO_2**
- Algal-bacterial **treatment** of biogas digestate
- Algae as biogas **feedstock** with 3-5 times better efficiency compared to energy crops
- Biogas digestate as algal **nutrient** - higher value products
- AlgaeBioGas project

Algae

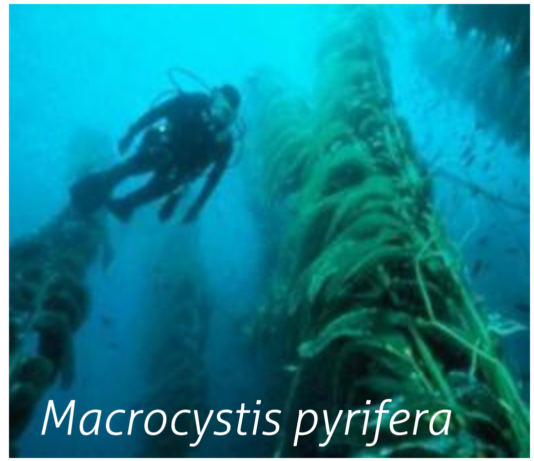
- very large and diverse group of simple organisms
- mostly aquatic
- typically autotrophic - photosynthetic
- from unicellular to multicellular
- not organized into distinct (plant) organs
- cyanobacteria, microalgae, macroalgae
- taxonomy ≠ technology

Modern (microbial) taxonomy

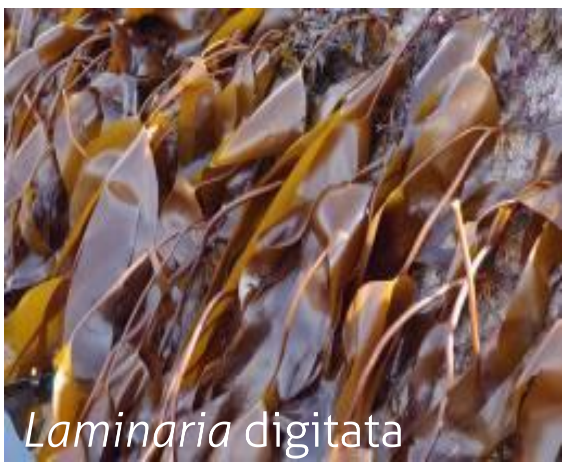


Macroalgae


Ulva sp.


Macrocystis pyrifera

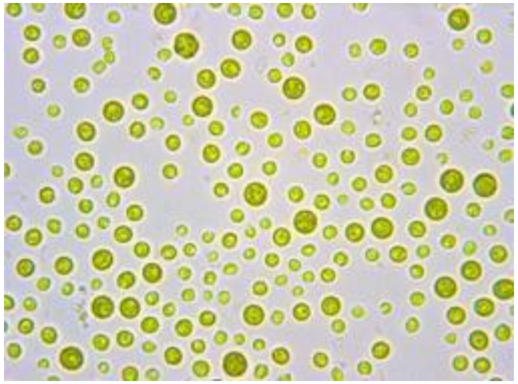

Sargassum natans


Laminaria digitata


Lattissima saccharina

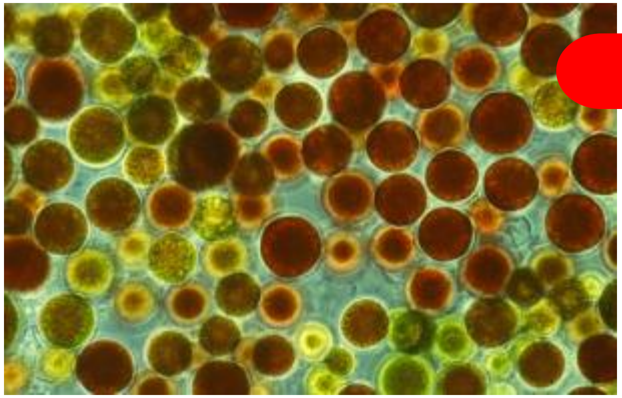

Laminaria hyperborea

Microalgae & cyanobacteria

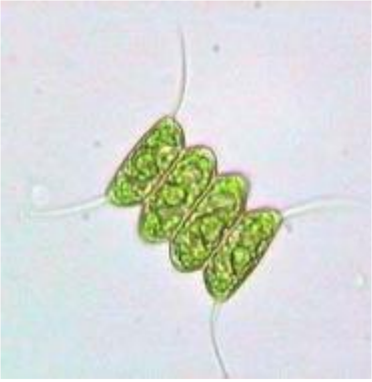


Chlorella vulgaris

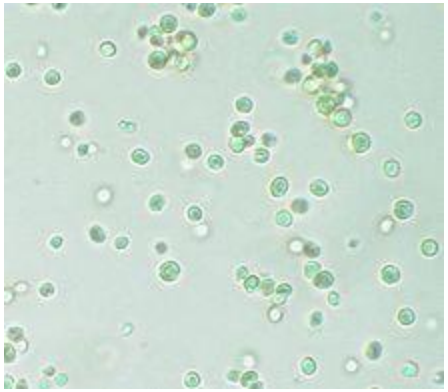
Arthrospira (Spirulina) sp.



Heomatoccoccus pluvialis

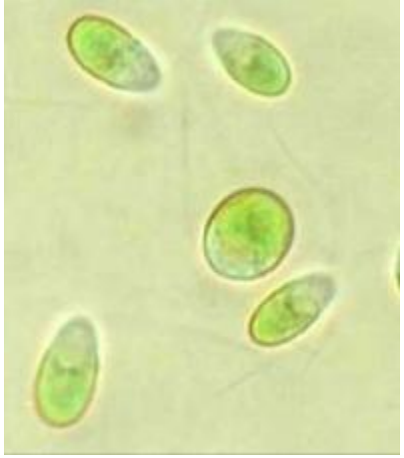


Scenedesmus quadricauda



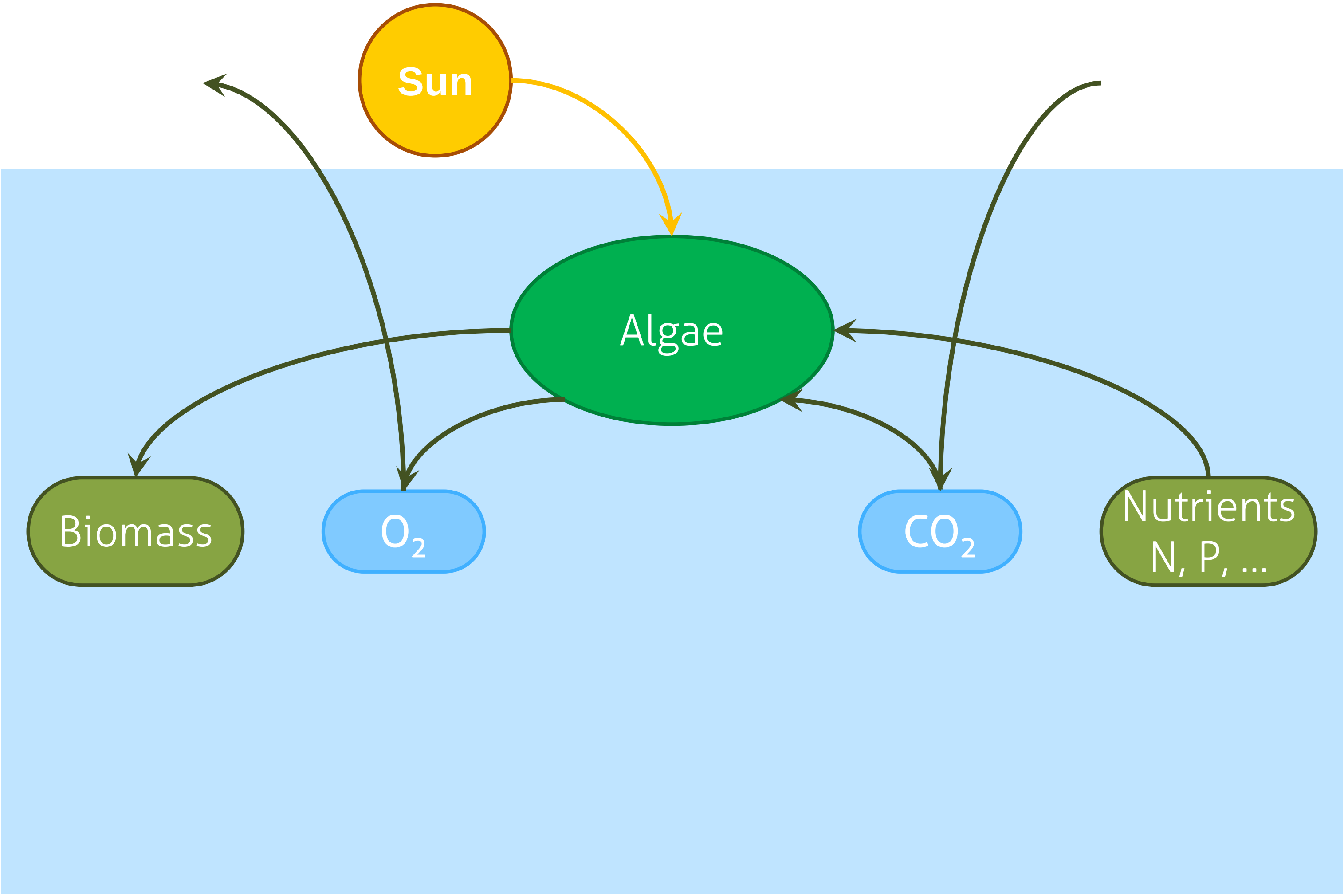
Nannochloropsis

Botryococcus braunii



Dunaliella salina

Photosynthesis



Algae uses

- Energy use
  - Lipids -> biodiesel
  - Sacharids (carbohydrates) -> bioethanol
  - Biogas feedstock
- Organic fertilizers
- Animal food, fish food
- Human food
- Nutriceuticals (antioxydants, vitamines, PUFA – poly-unsaturated fatty acids)
- Many more (mostly unknown) bio-active compounds

High protein content (Organic fertilizers, Animal food, fish food, Human food)

Increasing value

Algal Technology

- How to **grow and use algae**

- Biology – species, content, growth conditions
- Technology – nutrients, CO_2, light
- Economy – energy and cost efficiency

- Biorefinery – separation and down-stream processing

Open systems

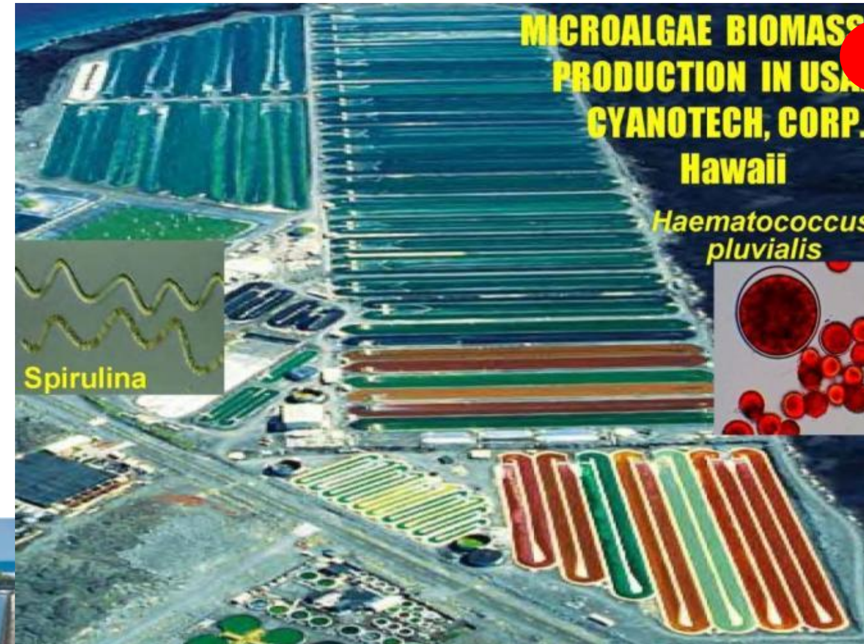
Cyanotech, Hawaii

Sapphire Energy, USA

Sunchlorella, China

Seambiotic, Israel

Large open production



Closed systems - photobioreactors

Algomed, Germany

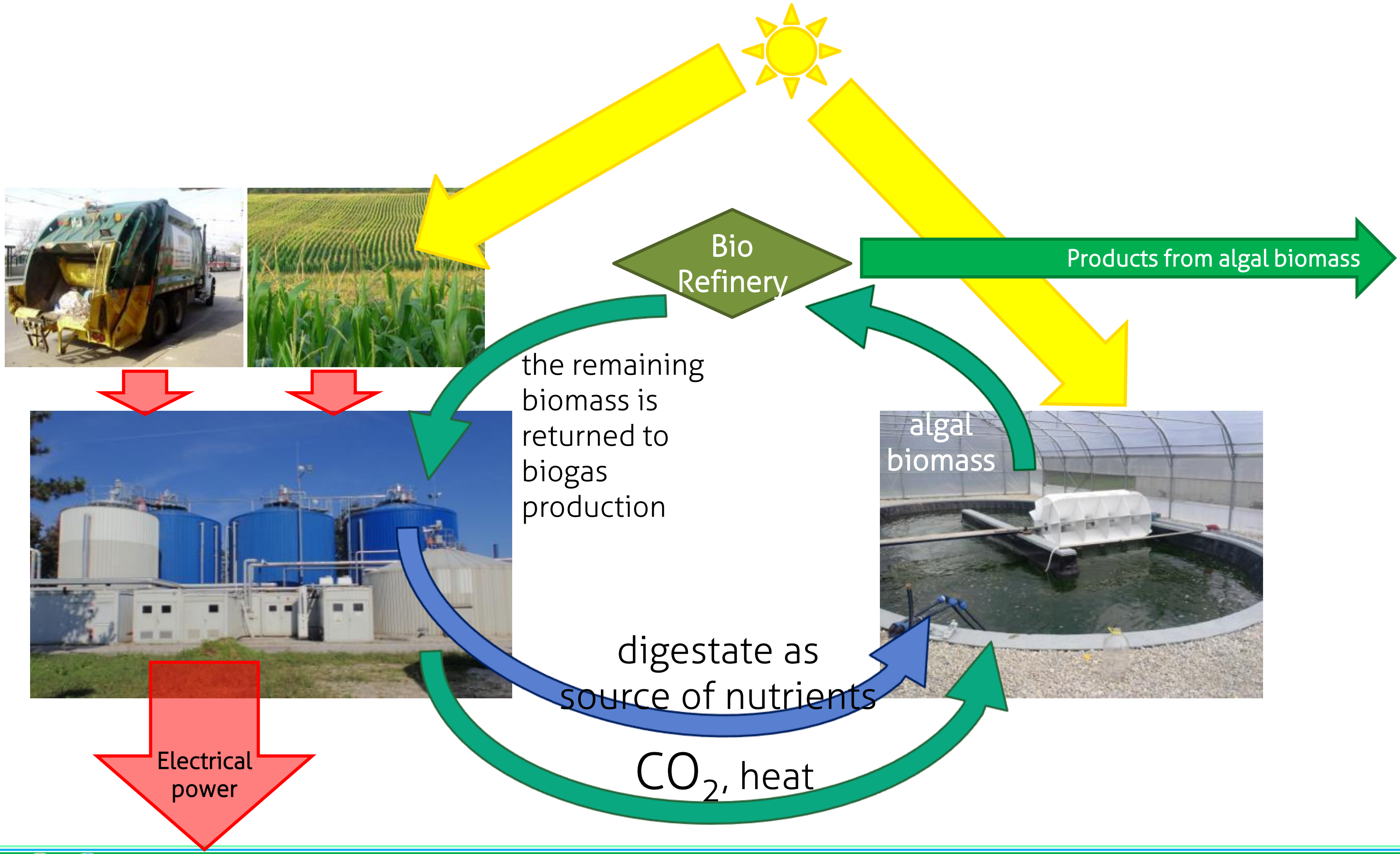
Provirion, Belgium

Kibutz Kitura, Israel

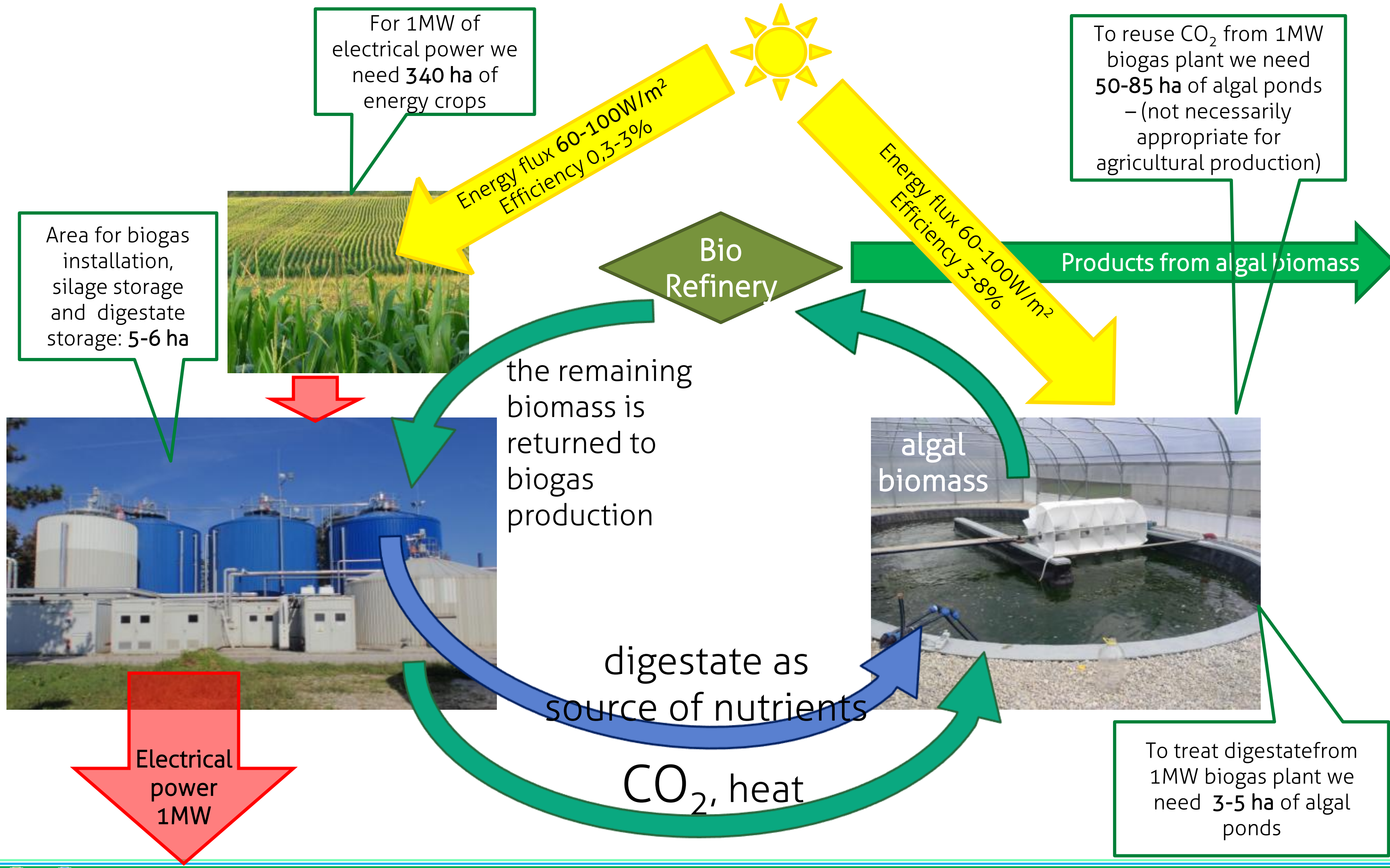
A large closed system

- Roquette Klötze: Chlorella for food & feed
- 500 km glass tubes (600m^3)
- 130 t/year

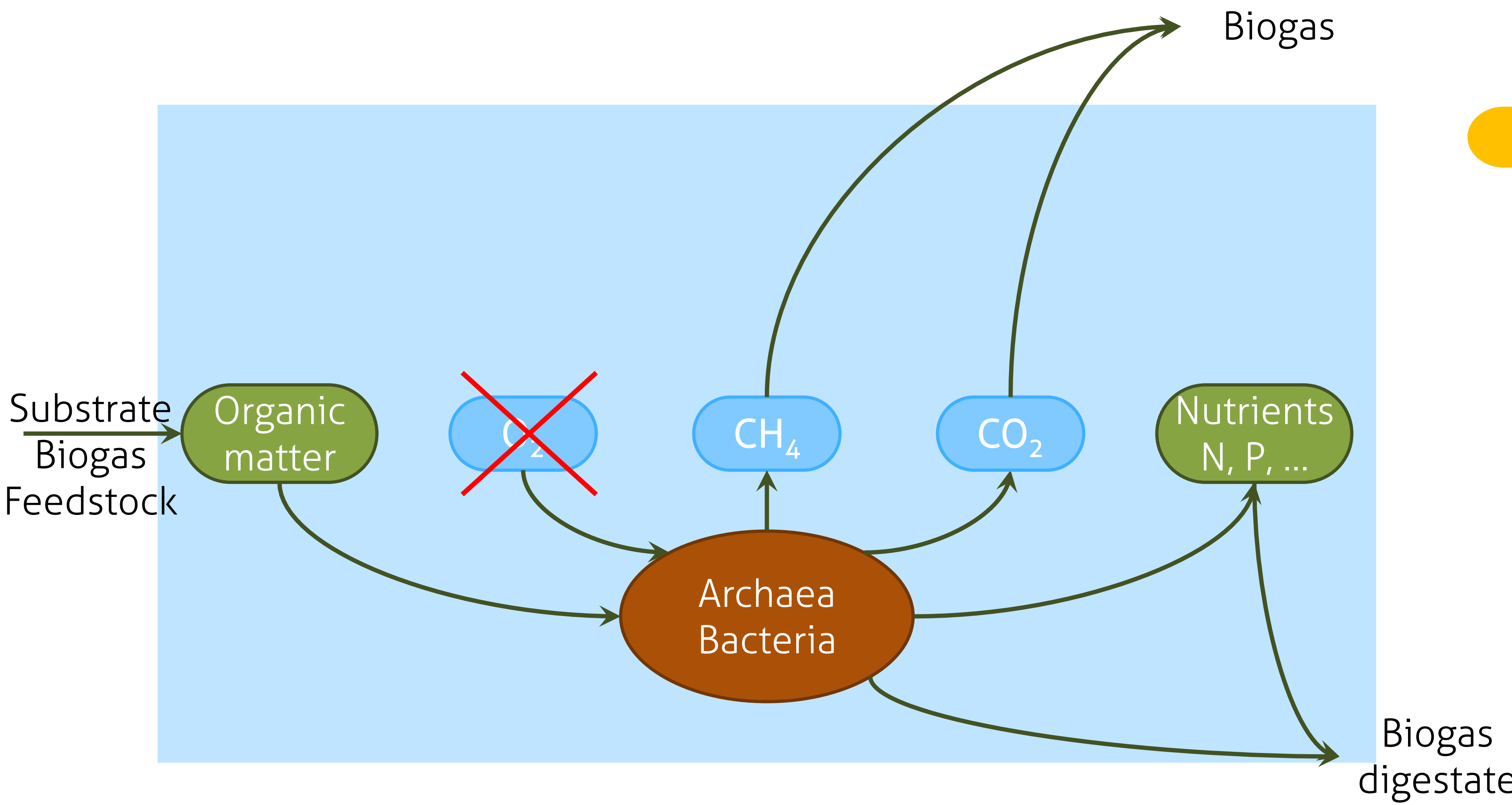
AlgaeBioGas Basic Cycle



AlgaeBioGas – model 1MWe plant



Anaerobic digestion



Possible optimizations

- Digestate treatment
- Feedstock production
- Algae production

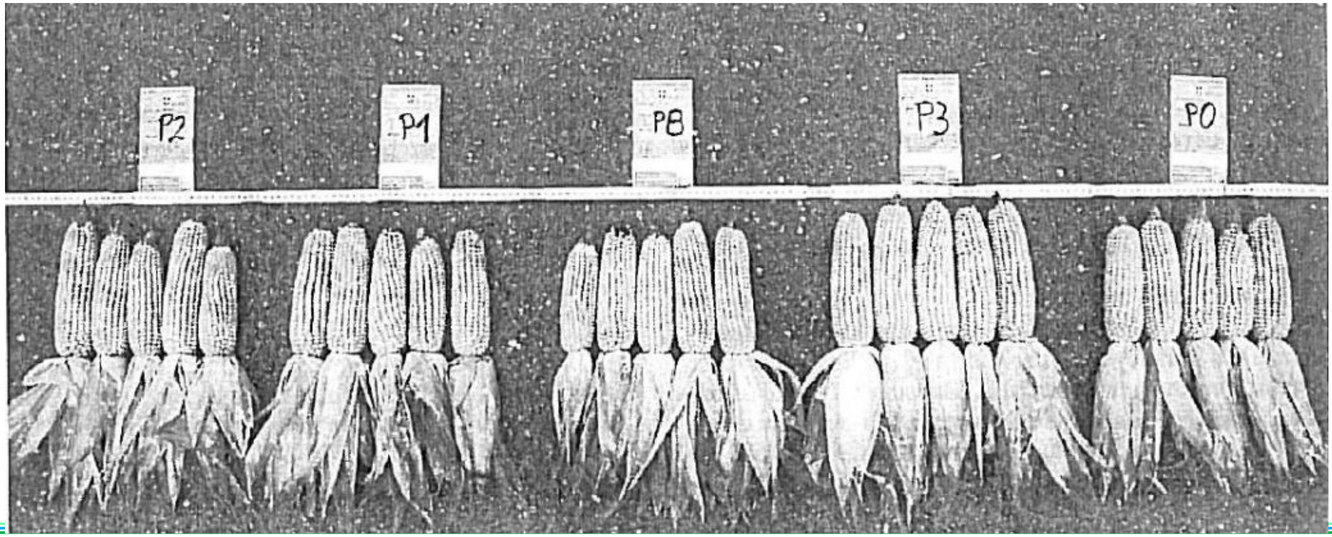
Digestate as Fertilizer

Warning: This topic may be politically controversial

- By spreading the digestate we return exactly the same minerals that we removed by harvesting the energy feedstock
- Assumption: SAME area
- YES, but in liquid form:
  - highly diluted
  - high logistic cost (storage, transportation)
  - flushing the CEC of the soil
- Separation into solid and liquid phase
  - solid phase is useful as fertilizer
  - better logistics
  - same machinery
  - no liquid flush

Unterfrauner, 2010

- 40 weeks trial, 50 m^3/ha
- Application of biogas fermentation residues can adversely affect soil fertility
- High content of free K ions -> acidification, overloading of the sorption complex, destruction of the aggregates
- Addition of $CaCO_3$, $MgCO_3$, $CaSO_4$, Al silicate improved the results significantly
- Unterfrauner, H, et al. 2010, *Auswirkung von Biogasguelle auf Bodenparameter*, 2. Umwelt oekologisches Symposium 2010, 59-64, Raumberg-Gumpenstein.



Digestate separation

1MWe model case

Digestate

80-100 m³/day
30.000 m³/yr

Liquid phase (centrate)

65-90 m³/day

Volume 80-95%

Biological treatment (anaerobic / aerobic)

- Loss of nutrients
- High energy consumption

Environment

Sludge

Solid phase

5- 20 m³/day
6000 m³/yr

Fertilizer (Incineration if waste)

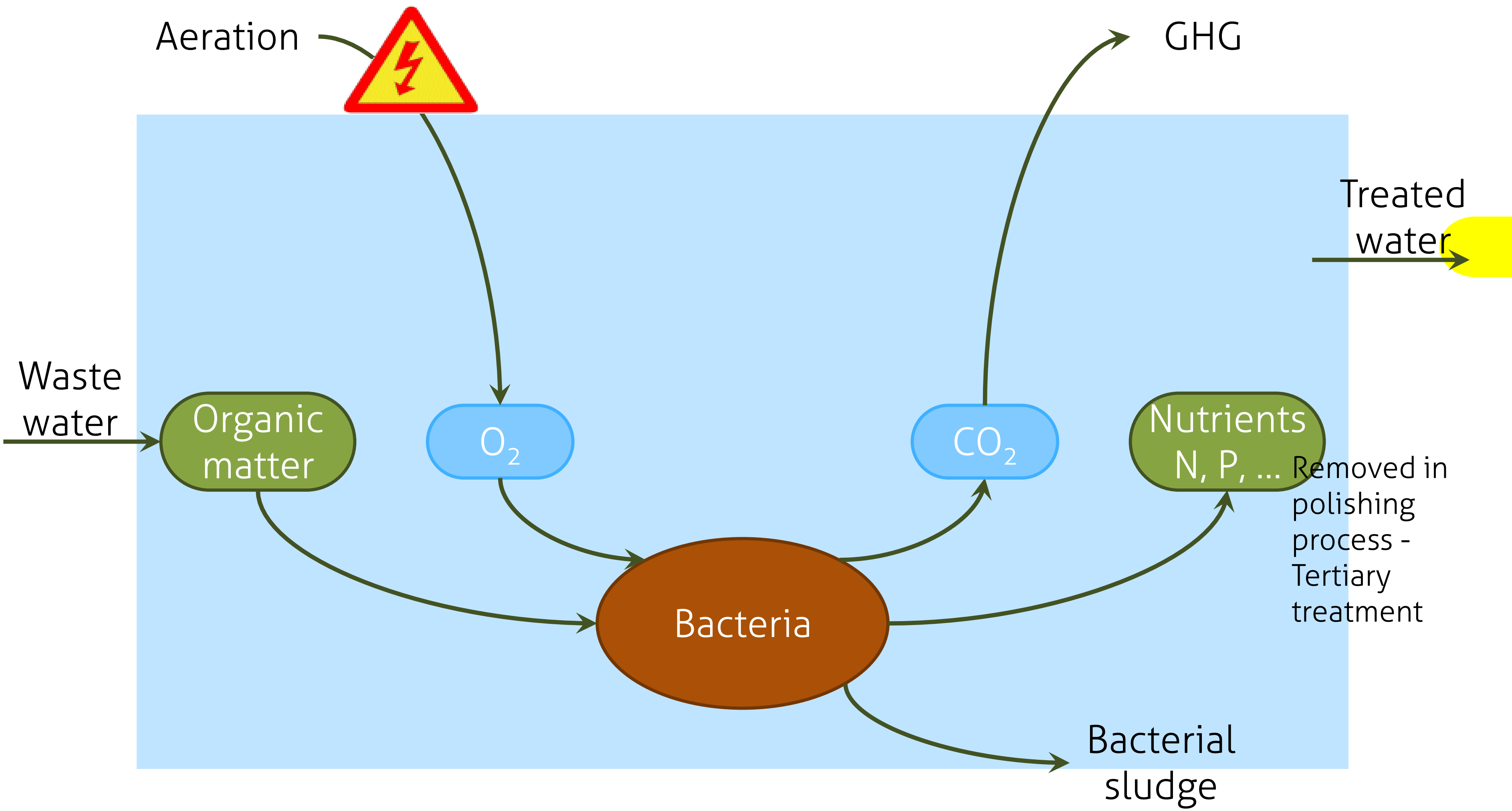
Volume 5-20%

- Simpler and less costly logistics (storage, transport, spreading)
- Existing spreading technology
- Mixing with other components (adjusted nutritional and soil conditioning value)

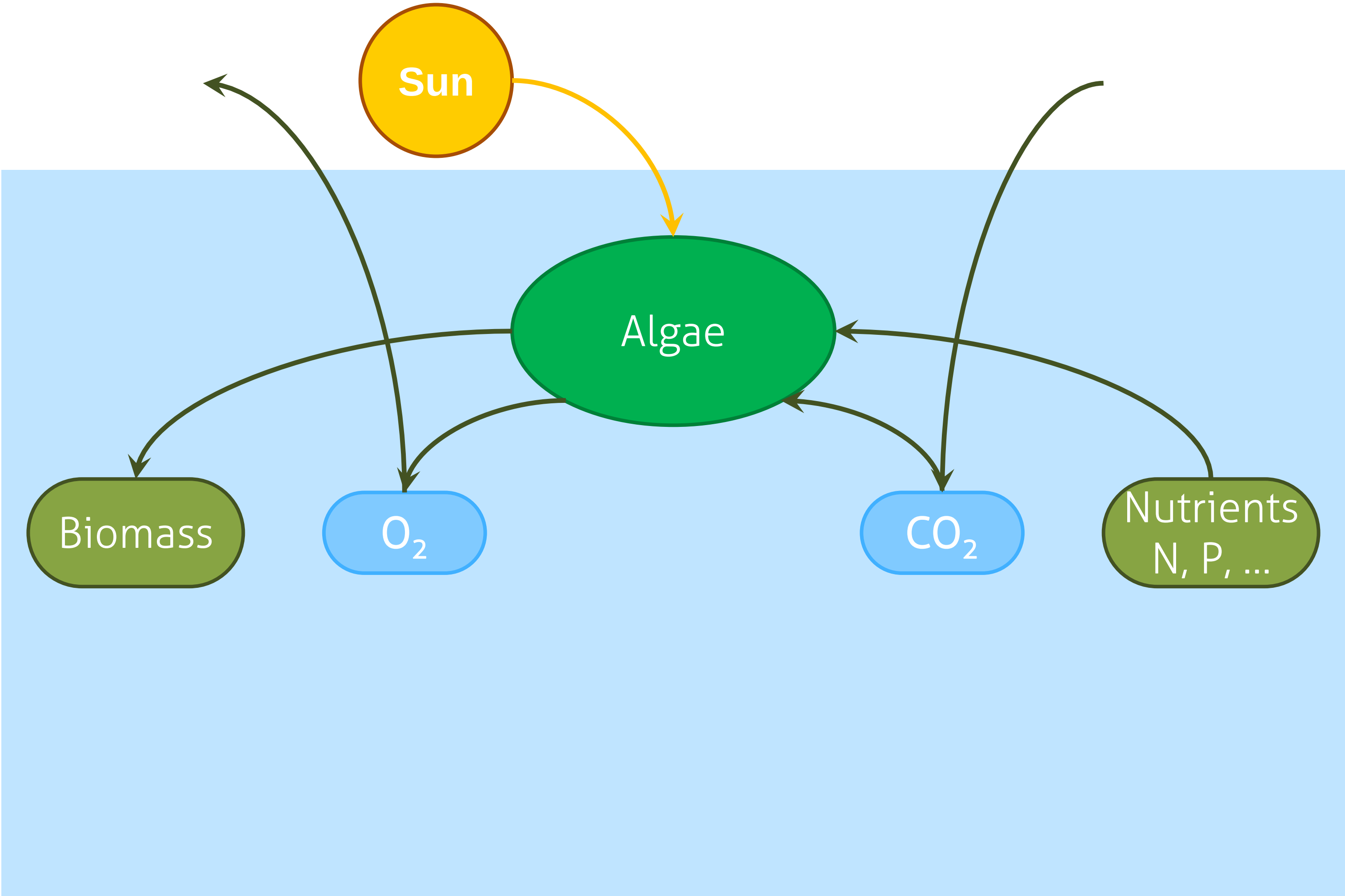
Digestate centrate

- What do we do with the liquid phase?
  - classical biological WWT is the most frequent answer
  - high cost:
    - investment,
    - aeration power
    - bacterial sludge disposal
  - Nutrients are lost
    - C, N-loss = energy
    - P-loss = substance, eutrophication
  - GHG emissions
    - Aerobic treatment mostly converts biomass to CO_2

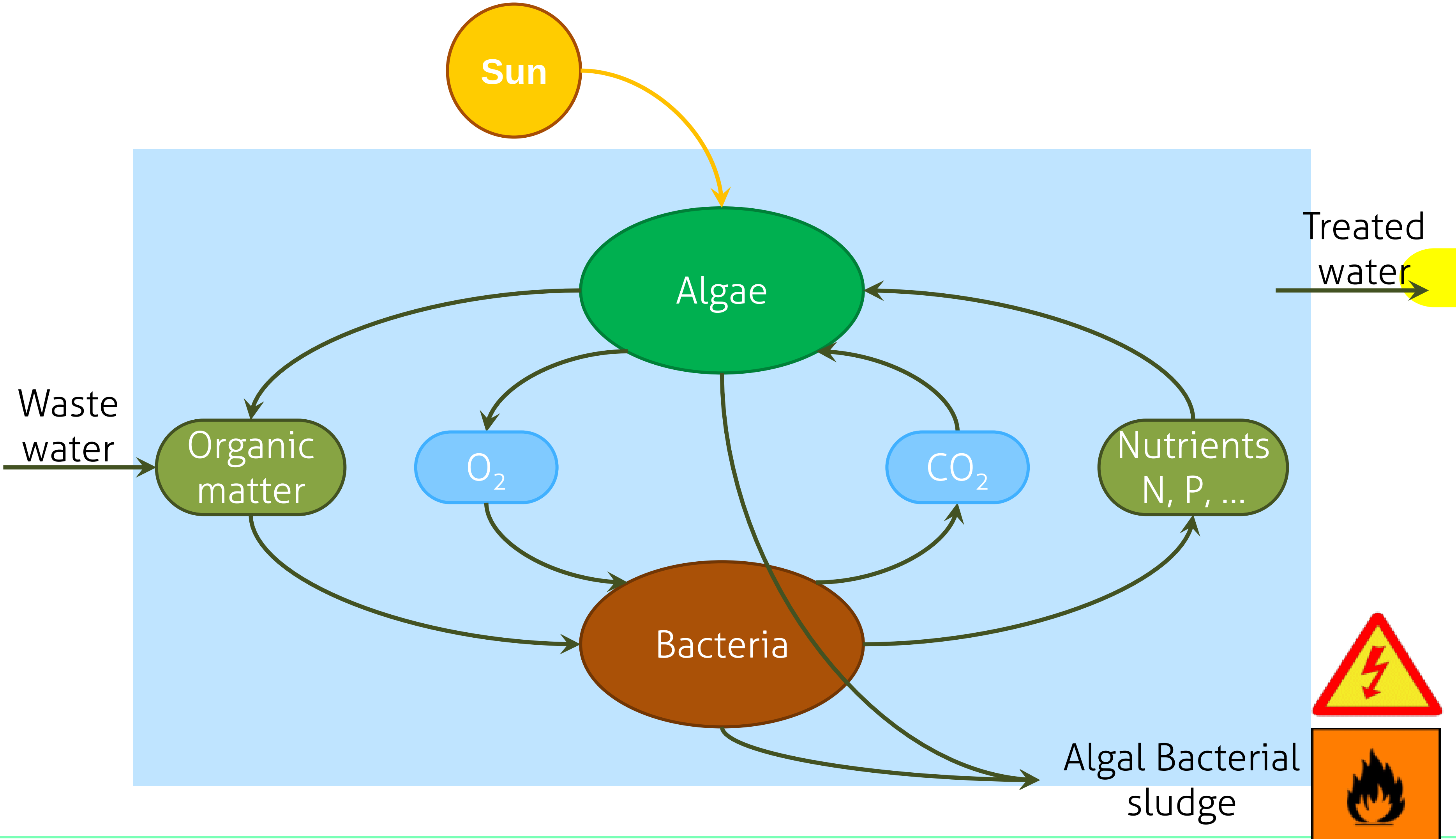
Biological Wastewater Treatment



Photosynthesis

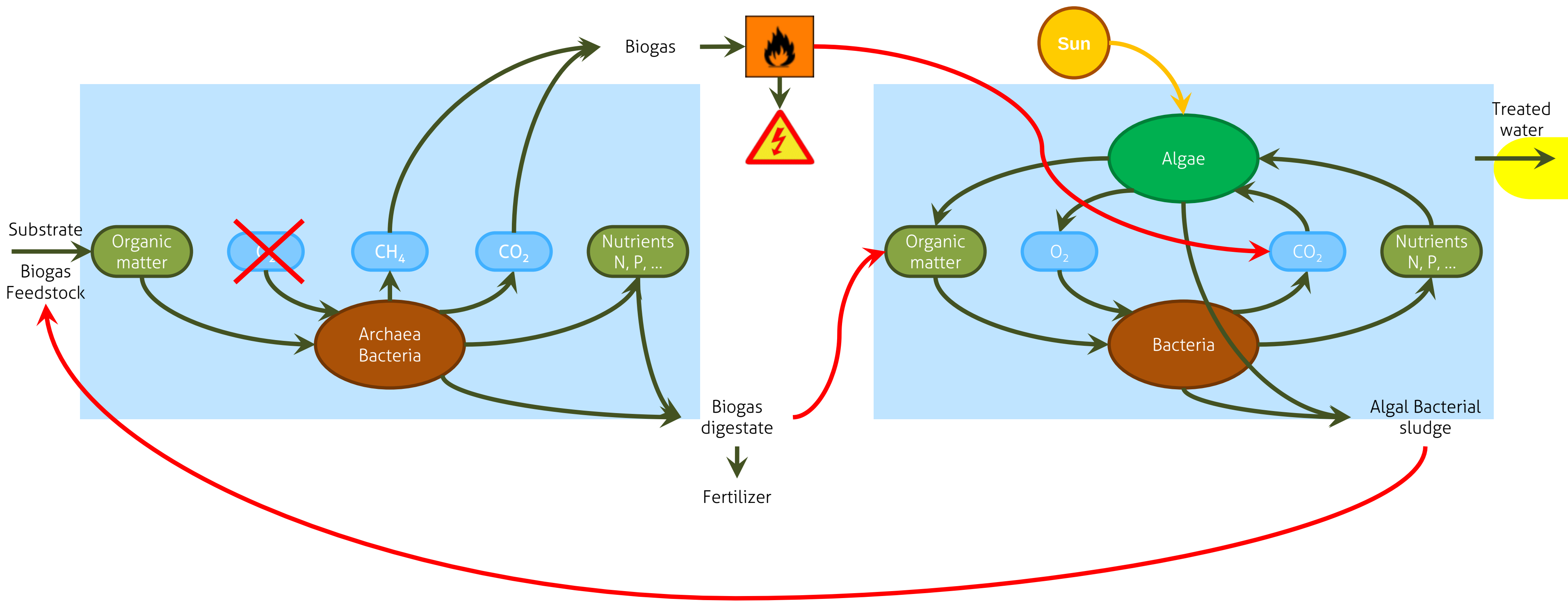


Algal Bacterial (ALBA) Wastewater Treatment



Co-funded by the Eco-innovation Initiative of the European Union

Digestate treatment



Algal bacterial WWT (ALBA WWT) ideas

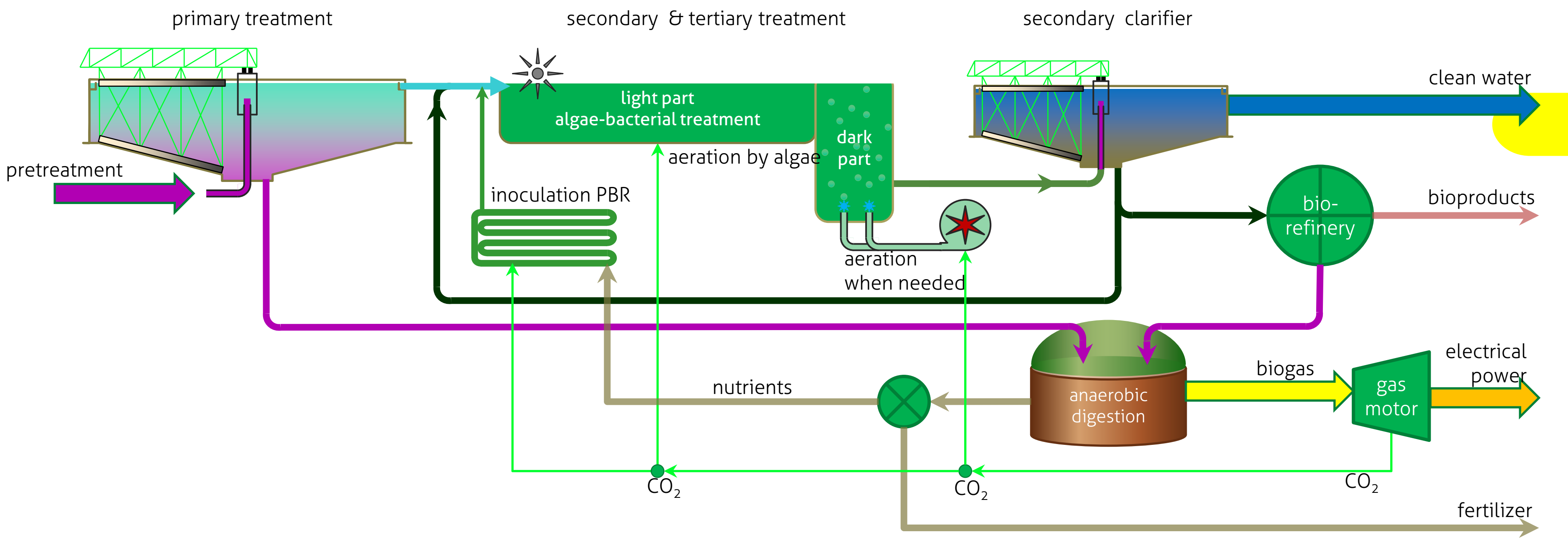
- at least 55 years old (e.g. Oswald 57)
- lagoon treatment
- shifting objectives in the past
- purpose of algal biomass
- algae : bacteria - C : N
- more diverse microbial community → less sensitive to sudden changes (antibiotics, biocides, salt, …)

A research topic of today

- No state of the art universal solutions
- Algae bacterial community is unstable
- Needs to be tightly controlled
- Digestate may be black – no light for algae
- Removal of heavy metals, endocrine disruptors, accumulated toxic substances, …
- Should be independent of weather

The ALBA pilot (Cornet Albaqua 2011)

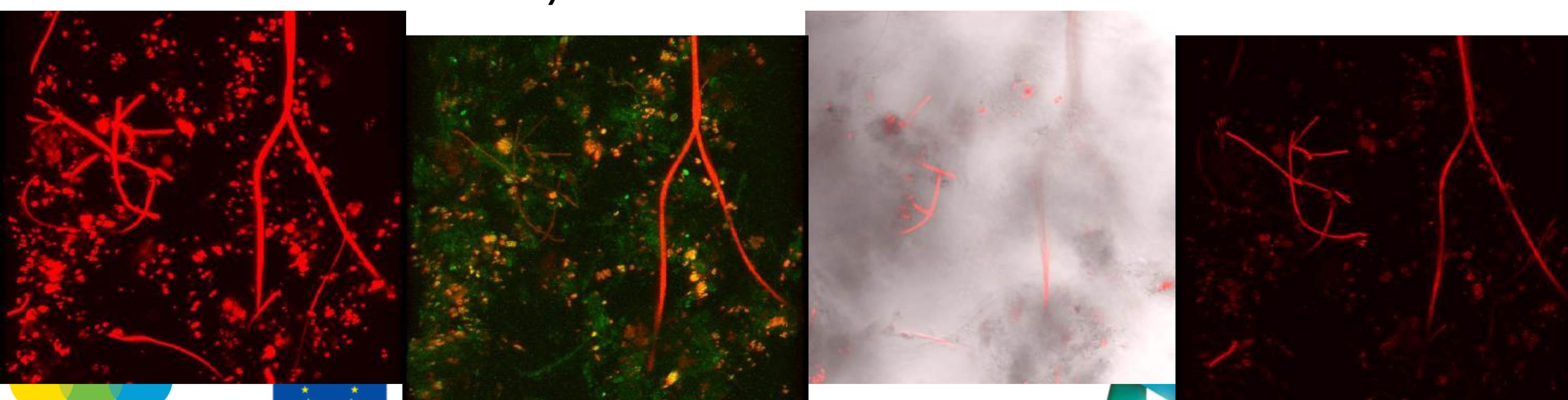
Hybrid ALBA WWT



Co-funded by the Eco-innovation Initiative of the European Union

Many open issues

- dark – light sections
- how long good oxygenation lasts?
- floc ecology
- Auto-flocculation
- how to control the microbial composition (algae-bacteria balance)



Expected performance (digestate treatment)

- Model **biogas CHP with 1 MWe**
- to recycle major part of nutrients
- area 3 - 5 ha
- volume 3000 – 17000 m^3
- 60 – 200 t algae bacterial biomass p.a.
- use approx the same amount of waste paper pulp
- replacing 120 – 400 t dry mass of corn = 360 – 1200 t of corn silage
- replacing 8 – 26 ha of corn fields

Optimization for biomass production

- Larger area
- Longer retention time
- More diluted digestate
- CO_2 introduction
- More algae, less bacteria

Algae as biogas substrate

- Hard to digest
- C : N ratio
  - high C substrate should be added (i.e. cellulose)
- Pretreatment required
  - Heating, enzymatic, fungal, bacterial, ultrasonification, pressure shock, …
- Thermophilic process optimal
- If done properly biogas productivity comes close to corn silage (based on dry weight)
- Depends on species & composition

Economy

- More expensive than corn
- Makes sense:
  - if we have substantial non agricultural area available
  - if we leverage on energy crop subsidies
  - if we are co-producing high value products
- Digestate treatment makes sense:
  - always when the required area is available

High value products

- Extract some components of the biomass before returning it to AD
- Obvious ideas:
  - extract lipids for biodiesel (not really high value)
  - biofuels from algae are to be counted quadruple
  - extract proteins for animal feed
- Other uses – biorefinery:
  - antioxydants, pigments, PUFA
  - biomass for food – organic production
- Need for thorough preprocessing before use for animal feed, food or nutriceuticals – hygienization, removal of toxic substances, heavy metals, …
- A combination of physical and biological pre-treatment
- Very high-valued products can afford high-priced nutrients

Economy

- Corn silage replacement: 200€/t
- Biofuels: 900€/t (tax release included)
- Spirulina for animal food: 7000€/t
- Organic spirulina for human food: 20-70€/kg
- Astaxantin: 150 - 3000 €/kg (depends on purity)
- Phycocyanin: 20 - 2000000 €/kg (depends on purity)

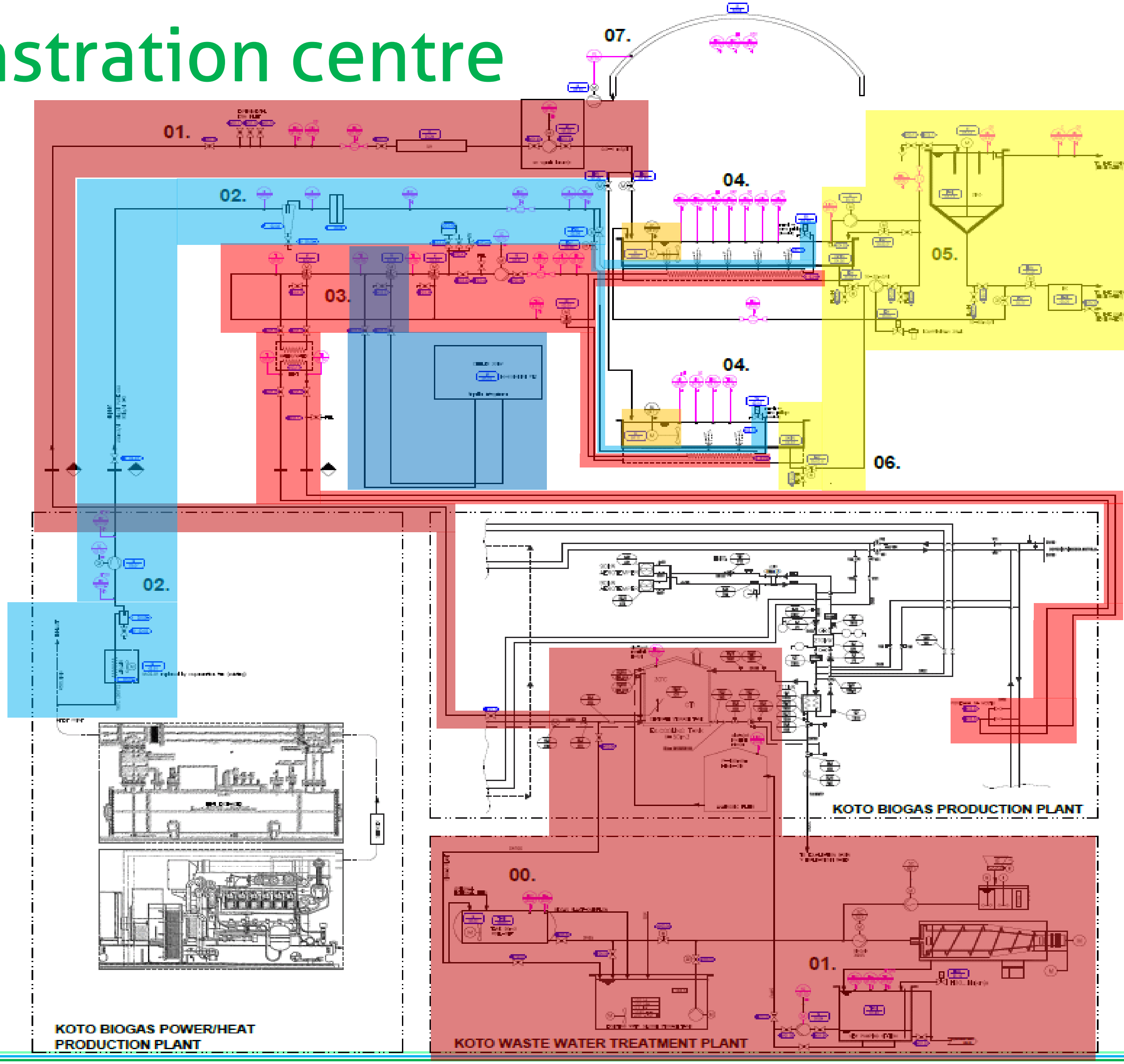
AlgaeBioGas Project

- Algal treatment of biogas digestate and feedstock production
- An Eco-Innovation project (CIP-EIP-Eco-Innovation-2012)
- Pilot and market replication project
- Two partners:
    - AlgEn, algal technology centre,
    - KOTO, biogas operator, animal waste treatment facility both in Ljubljana, Slovenia

AlgaeBioGas Objectives

- Objectives:
  - Demonstration centre design, construction, operation
  - Prepare technology for replication
  - Market development activities
- Now in Month 15:
  - Demonstration centre operational
  - Legislation analysis, LCA, business planning
  - Complementary technologies being tested
  - Technical development (controls, ponds)
  - Presentations & visits starting

Demonstration centre



Subsystems

- Ponds: main & inoculation
- Mixing equipment
- Greenhouse
- Heating & cooling
- Exhaust gas supply (cooling, purification)
- Digestate supply (separation, anaerobic filter, storage)
- Sedimenter/ clarifier & recycling
- Control system

Location

Biogas plant
AlgaeBioGas
Biofilter
CHP
Gas motor
Heat exchanger
WWT plant
Digestate
separation
Image © 2014 DigitalGlobe

Before construction

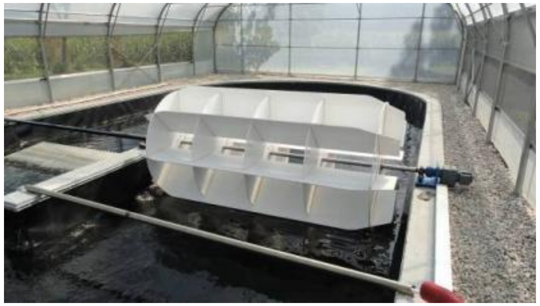
Construction

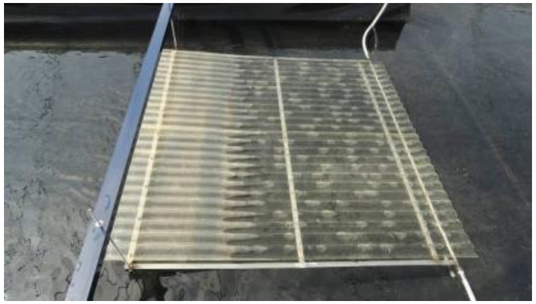


http://algaebiogas.eu/node/50

Greenhouse, ponds, mixing, CO_2






Co-funded by the Eco-innovation Initiative of the European Union

Digestate preparation

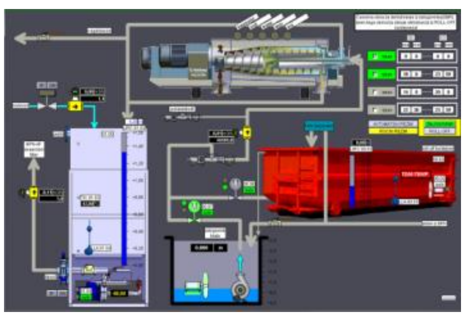
Co-funded by the Eco-innovation Initiative of the European Union

Control & instrumentation










Future

- Preparation for market replication
- Life Cycle Assessment
- Legislation analysis, marketing, partners
- Complementary technologies:
  - Digestate pre-treatment (Algadisk or "Algadisk 2.0" technology)
  - Auto(bio)flocculation
  - ALBA biomass pre-treatment for biogas
  - Animal feed trials (fish, chicken)
- Technical & manufacturing
  - More cost-effective
  - Better performance
  - More control
- **Partners**: marketing & implementation service
- **Ready for second replication (at an early-adopter site - challenge us)**

The project approach

PROJECT

lab scale testing & analysis
- nutrient content analysis
- heavy metals
- flue gases
- physical characteristics

microbial community
- maintenance of algal bank
- knowledge of species & their characteristics
- maintenance of algal mixes
- adaptation procedures
- clone library
- markers

feasibility study
- sizing and capacity planning
- energy balance
- materials balance
- life cycle assessment
- nutrient source, preparation & augmentation

project planning
- process design
- pre-treatment
- downstream process
- land use, permits
- construction
- installation
- financing
- outsourcing

pilot installation
- data collection: input, output & operating parameters
- variations of operating parameters
- extreme operations
- microbial community analysis

adjustments & optimisation
- optimizations for
  - biomass,
  - flocculation,
  - bioproducts
- seasonal influences & extreme operations
- predator analysis

final installation
- construction
- installation
- operation
- project management
- supervision & auditing

monitoring, maintenance and support
- data collection
- remote monitoring
- scheduled maintenance
- spares
- repairs
- upgrades

Future 2

- ALBA technology development:
  - Partnership with Aqualia (coordinator of FP7 All-Gas project), PTS (coordinator of Cornet Albaqua and AlbaPro) – ALBAtross proposal for H2020.
  - Cooperation with BFC (coordinator of similar Eco-innovation project CoFert).

Thank you for your attention

- Questions?
- Welcome to visit the ABG AlgaeBioGas demonstration centre.
- Grand opening in Spring 2015 – sign-in for invitation.
- Combined with an (EABA) event Algae & Wastewater (first pre-announcement)

Co-funded by the Eco-innovation Initiative of the European Union

algen algal technology centre