



Algae – Wastewater – Biogas

AlgaeBioGas: Establishment of Large Scale Demonstration Centre for
Algal-Bacterial Digestate Treatment and Algal Biomass Production

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Agenda

- Algae – Wastewater – Biogas
 - Algae
 - Algal Bacterial Wastewater treatment
 - Biogas landscape
 - Biogas: carbon and nutrient cycle
- AlgaeBioGas project
 - algal-bacterial treatment of biogas digestate
 - algae as biogas feedstock
- Saltgae project
 - Introduction



Algae

- Aquatic **photosynthetic** organisms

- Macro algae
- Micro algae
- Cyanobacteria

Algae = technical term

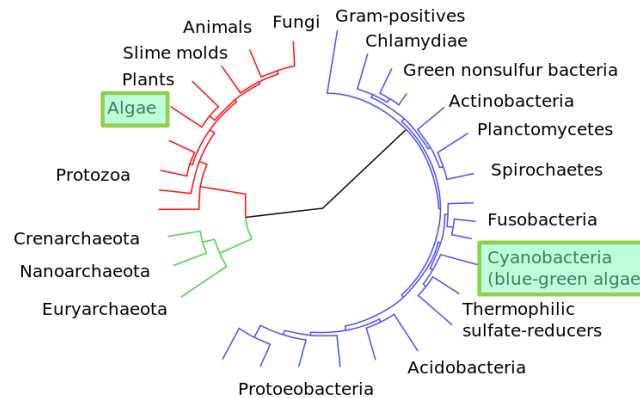
- Algal technology

Botanics ⇔ agronomy

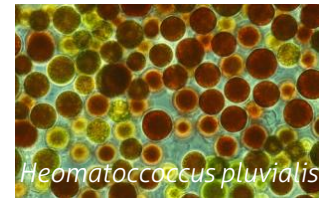
Phycology ⇔ algal technology

thousands of years

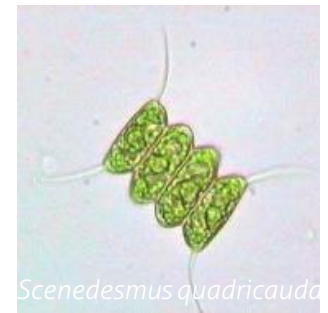
tens of years



Macrocystis pyrifera



Heomatococcus pluviatilis



Scenedesmus quadricauda



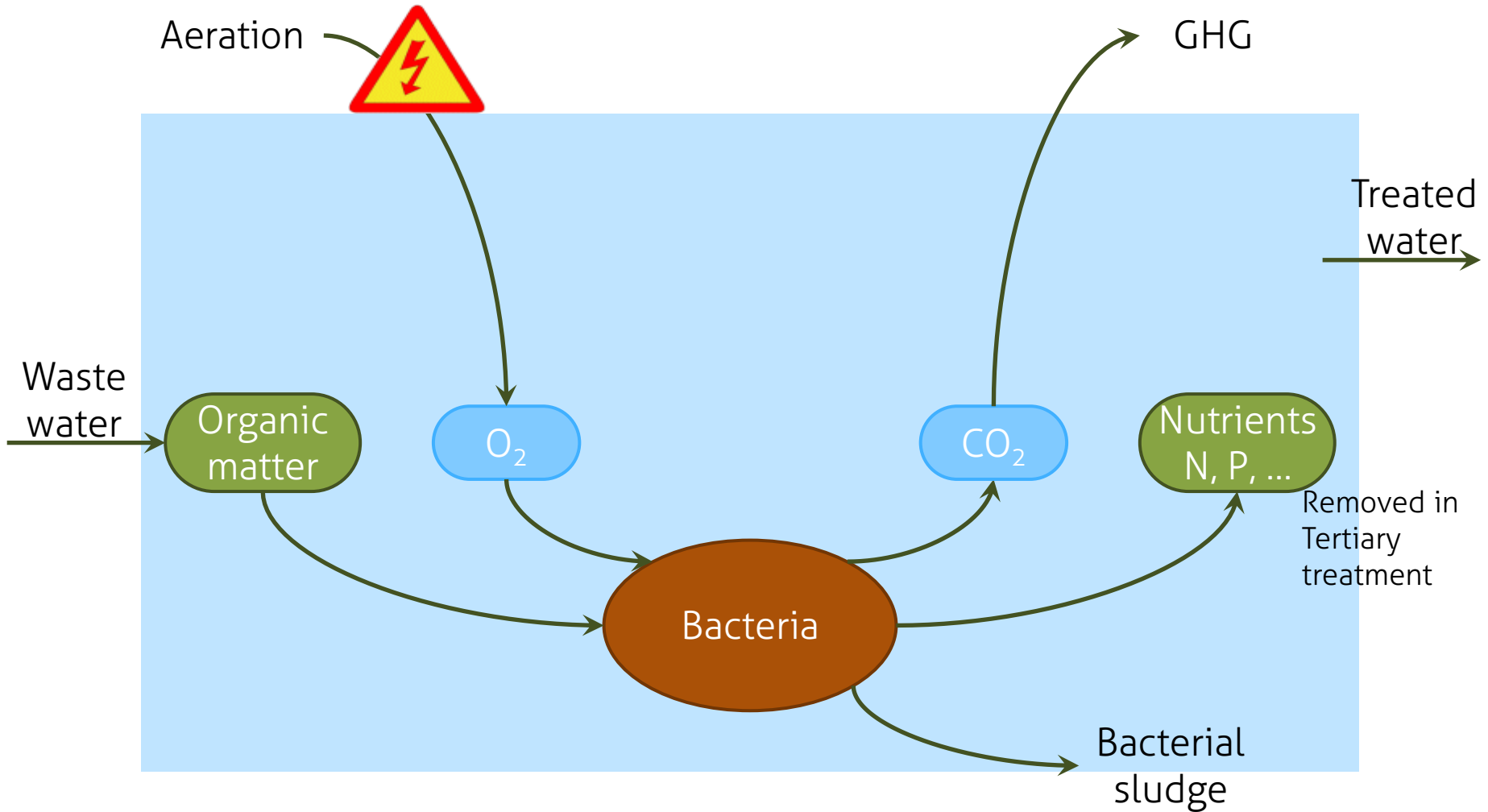
Arthrospira (Spirulina) sp.

Wastewater

- Wastewater
 - Organics, Nitrogen, Phosphorus = nutrients
 - Other pollutants (heavy metals, micro-pollutants)
 - Chemical/Biological Oxygen Demand (COD/BOD)
- Wastewater treatment
- Algae & wastewater
 - Nature's method to treat wastewater
 - Technologically used for at least 60 years

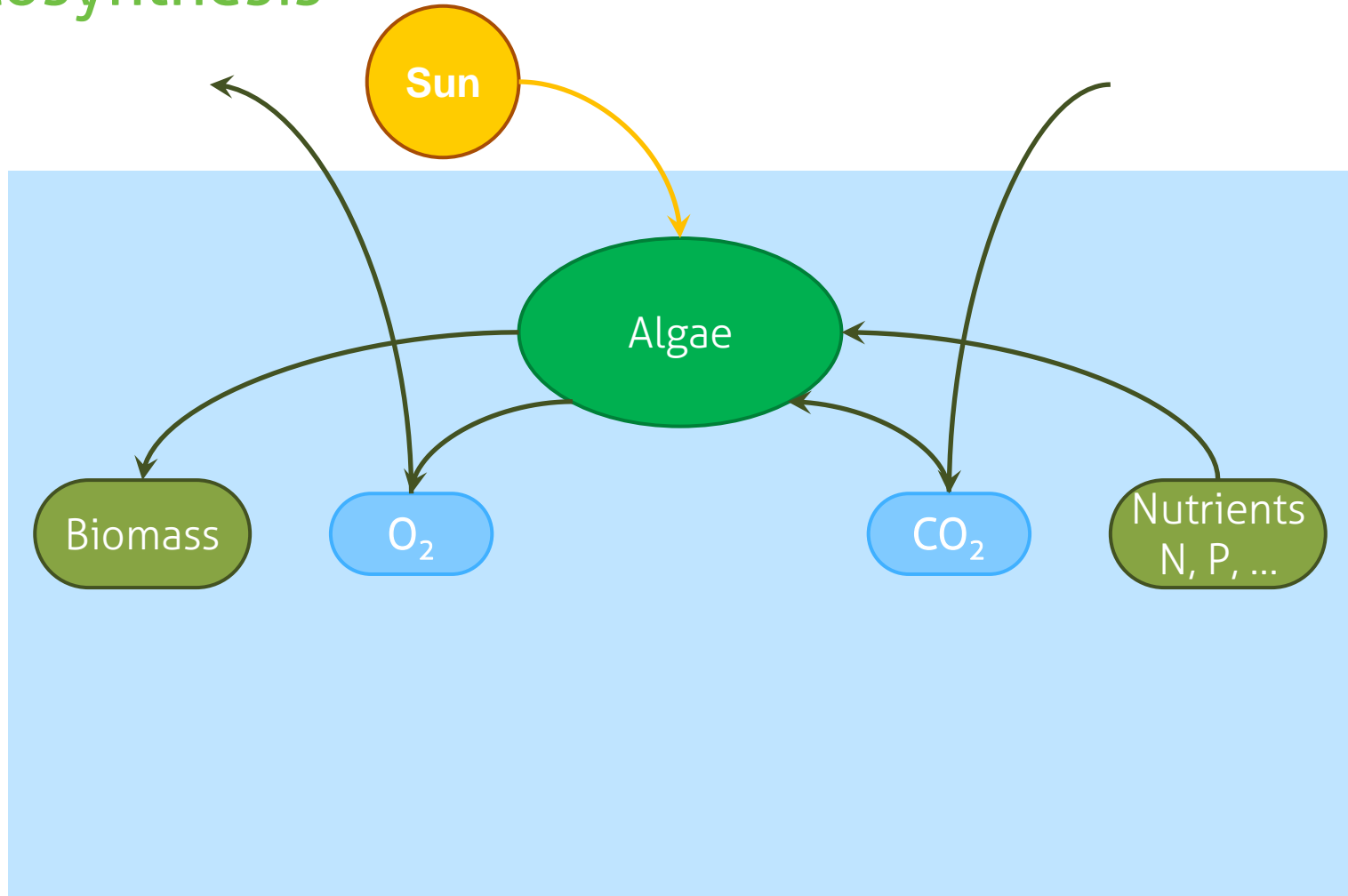
Algal bacterial process

Biological Aerobic Wastewater Treatment

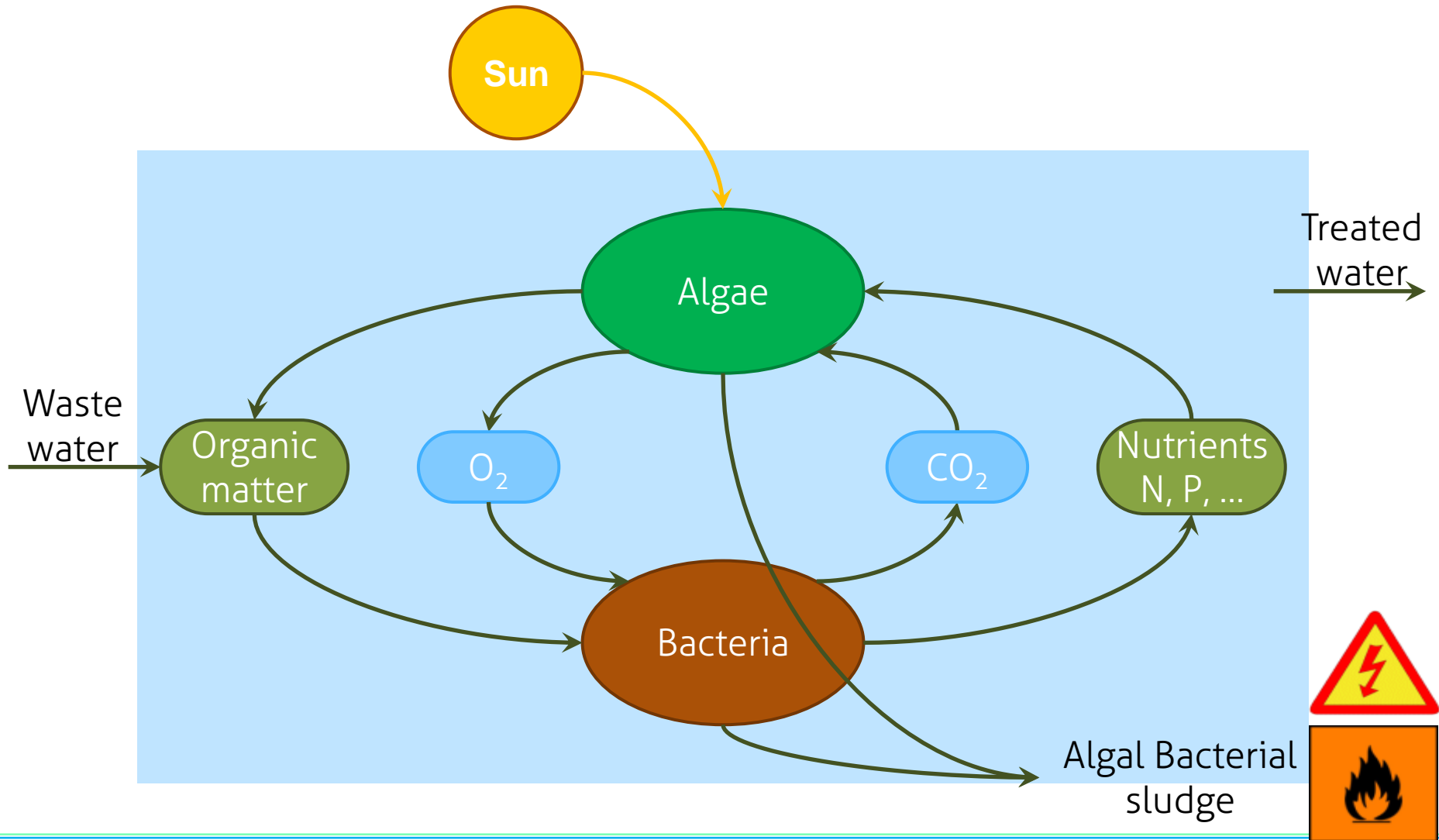


Algal bacterial process

Photosynthesis



Algal Bacterial (ALBA) Wastewater Treatment



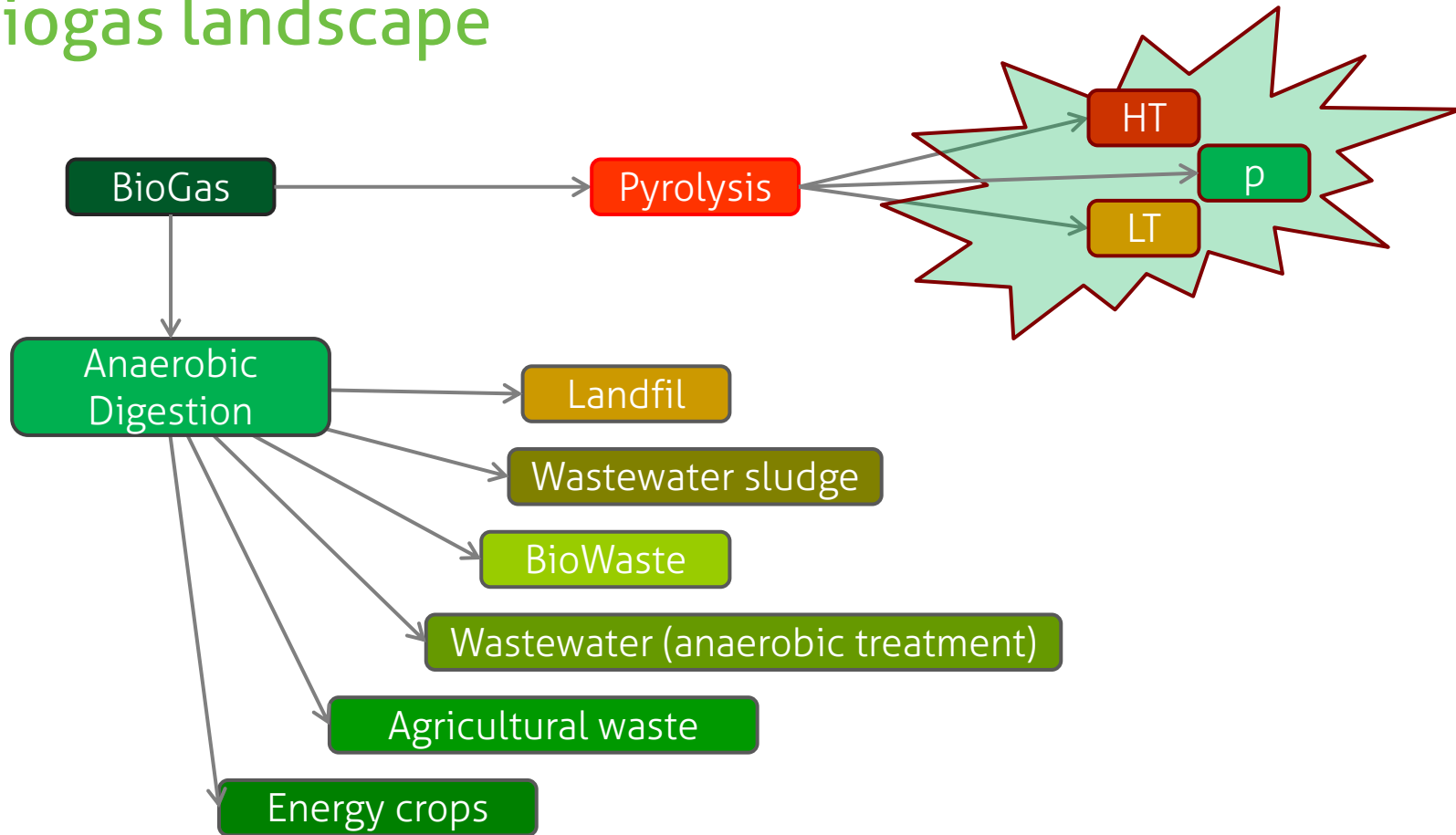
Algal Bacterial (ALBA) Wastewater Treatment

- lagoon treatment
- shifting objectives in the past (energy was “free”, no GHG paranoia)
- use / valorisation of ALBA biomass
- algae : bacteria - C : N
- more diverse microbial community → less sensitive to sudden changes (antibiotics, biocides, salt, ...)
- can use additional CO₂

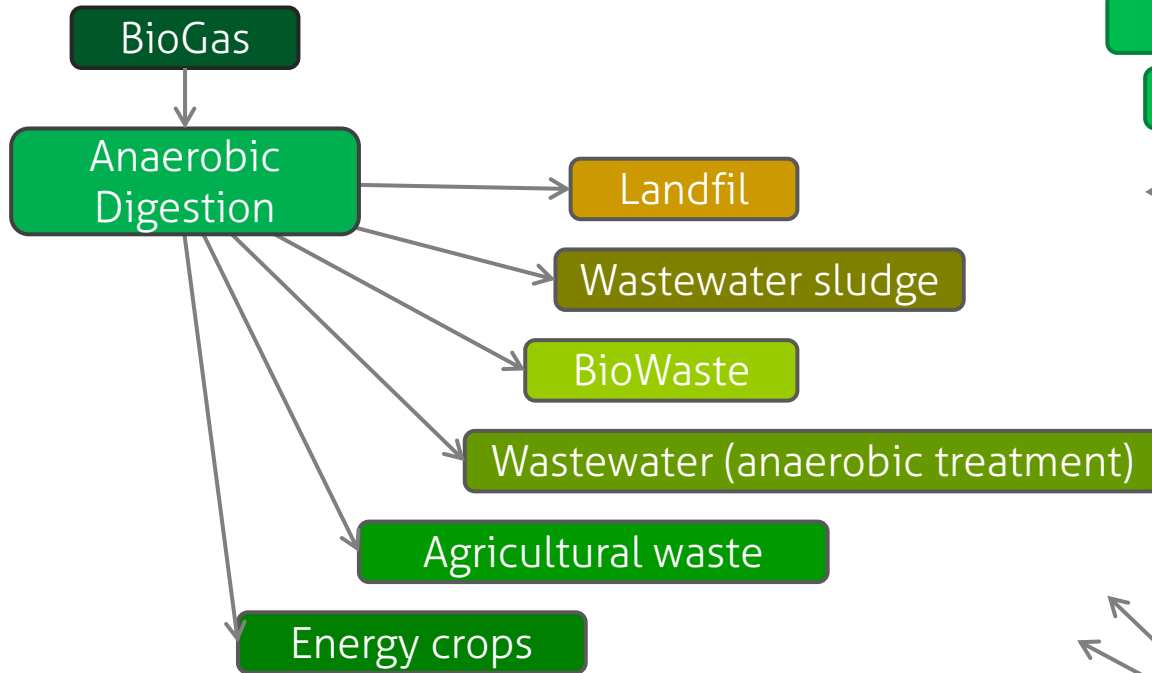
A research topic of today

- no state of the art universal solutions
- Algal – bacterial community is unstable → needs to be controlled
- WW may be dark – no light for algae – no oxygen for bacteria
- removal of heavy metals, accumulated toxic substances, salt, ...
- should be independent of weather
- harvesting – sedimentation, DAF, ...
- dark / light sections
- floc ecology, auto-flocculation

Biogas landscape



Biogas landscape



Mesophilic – Thermophilic

Low – High tech

Liquid – Solid

Stages

Salinity

Bio Methane

Grid

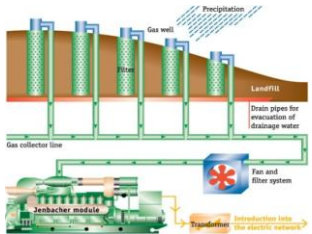
Fuel

CHP

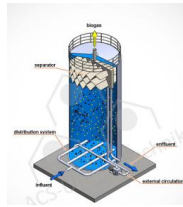
Fuel-cells

Turbine

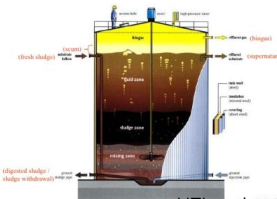
Piston



LSI group



www.acs-environment.com

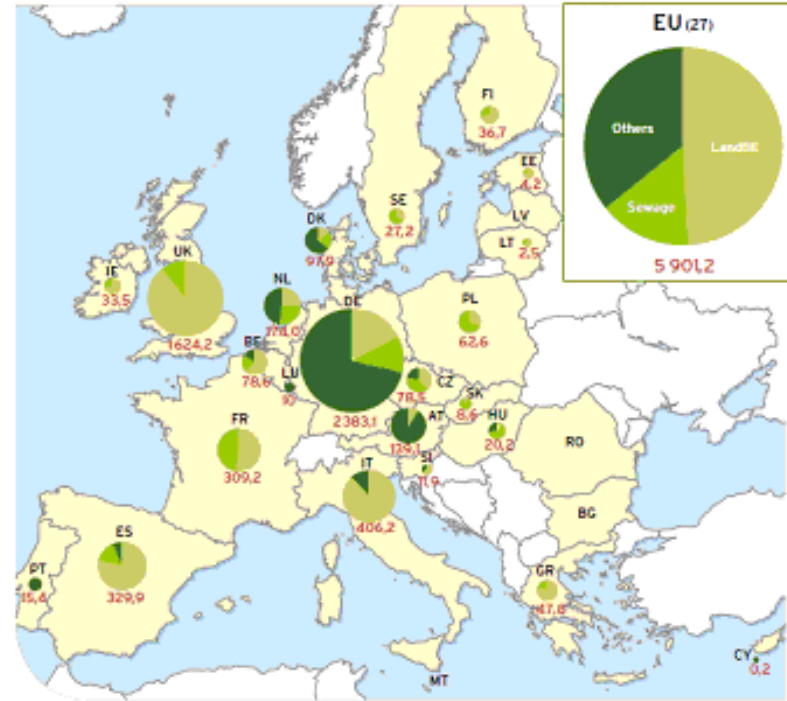


HTI tanks



Biogas plants

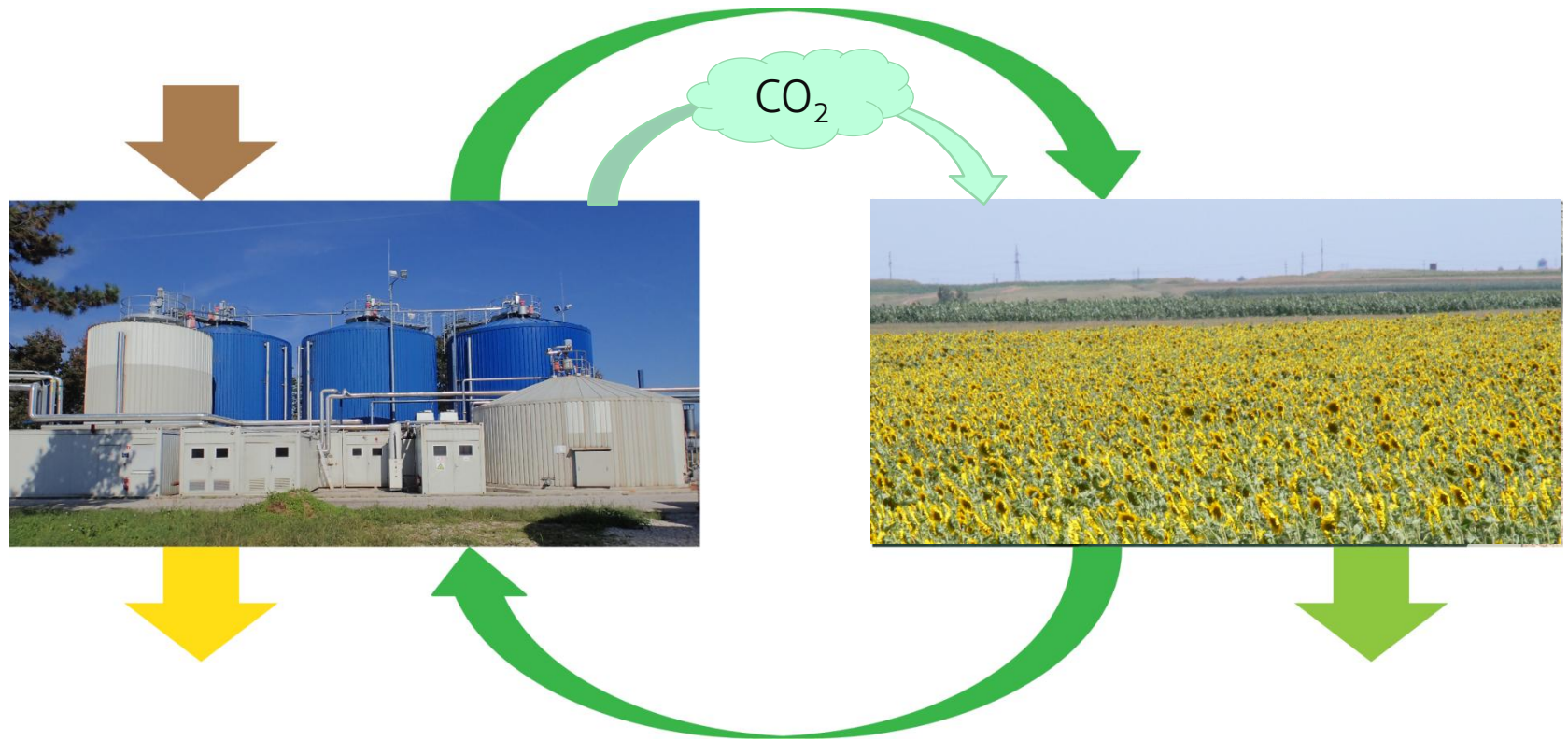
- Legislation & policy
 - Gas grid ↔ CHP
 - Waste ↔ energy crops
 - Access to power grid
 - Nitrogen vulnerable zones
 - Subsidies
- 15000+ biogas plants in EU



EurObserv'ER

Biogas digestate

- Ideally: all organics consumed
- Digestate = ideal agricultural fertilizer



Biogas digestate

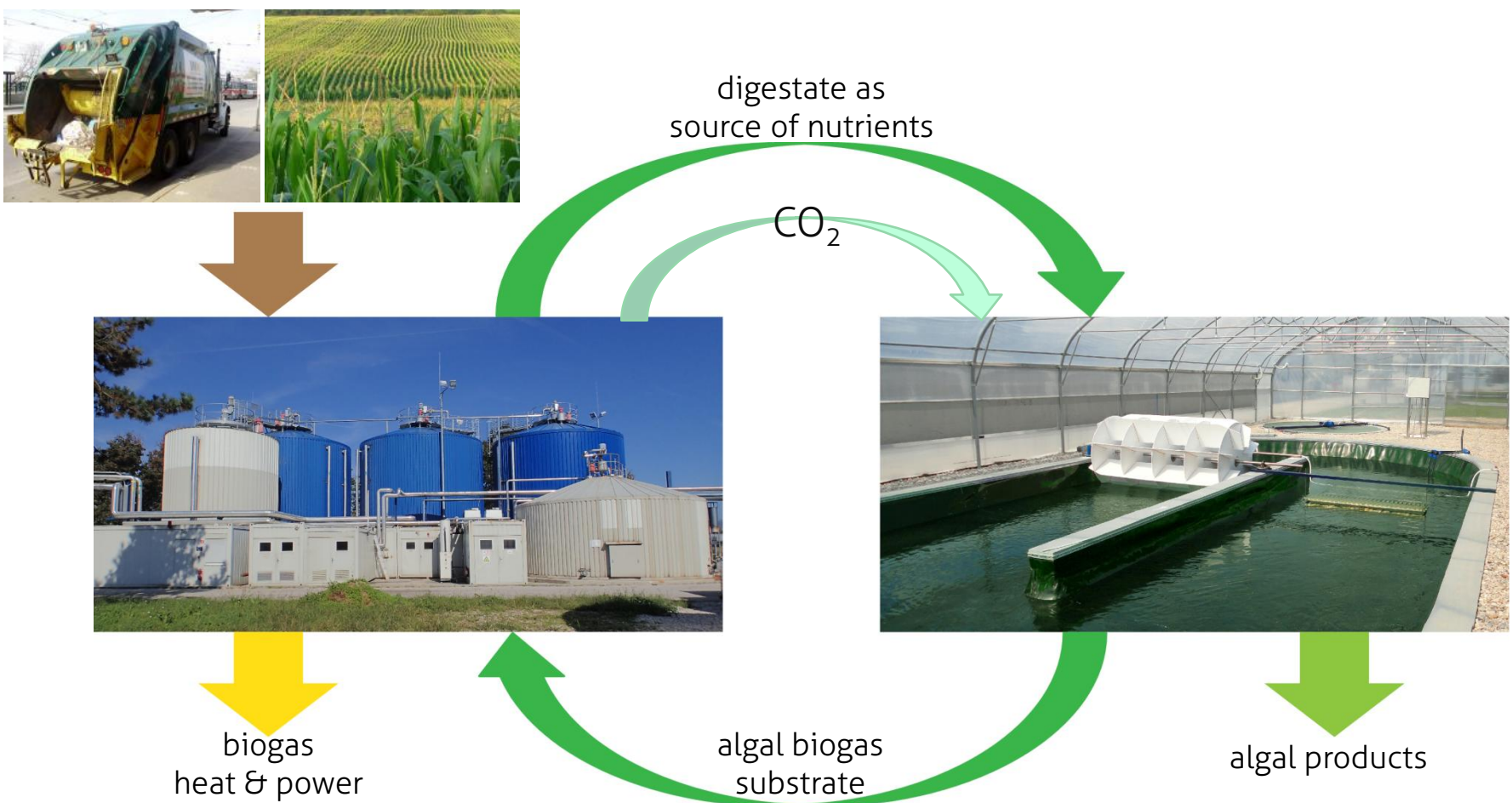
- In reality:
 - Very dilute (80-150 m³/ha)
 - Logistics
 - Storage
 - Transportation
 - Machinery
 - Agro-technical problems
 - Liquid
 - Nutrient flushing from soil
- Separation to liquid and solid phase
 - Solid – like ordinary fertilizer
 - Liquid – wastewater – only limited application as fertilizer
- Waste, end-of-waste directive, control & monitoring



Liquid phase of biogas digestate

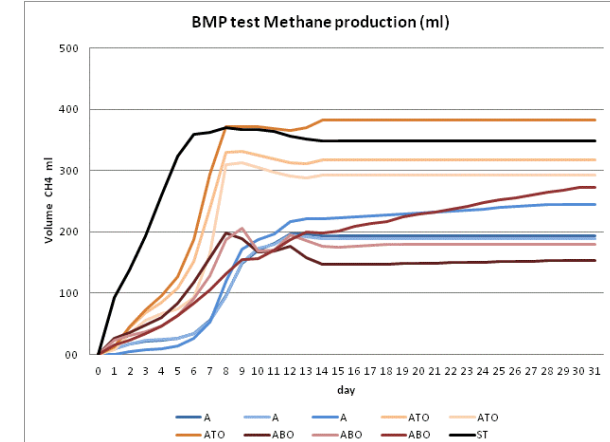
- One of the hard-to-treat substances
- COD 5000 – 50000 mg O₂/L
- Classical WW processing (3 – 20 €/m³)
 - Energy consuming conversion of organics and nutrients to CO₂ and N₂
 - Loss of energy and nutrients
- Alternatives:
 - Drying
 - Ultrafiltering
 - Reverse osmosis
 - ...
 - Algal treatment

AlgaeBioGas Basic Cycle



Algae as biogas substrate

- Hard to digest
- C : N ratio (high C substrate should be added)
- Pre-treatment 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
- Cannot be cost effective unless grown on wastewater or digestate (nutrients with negative cost)
- Fundamental technology for WW nutrient and energy recovery



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



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

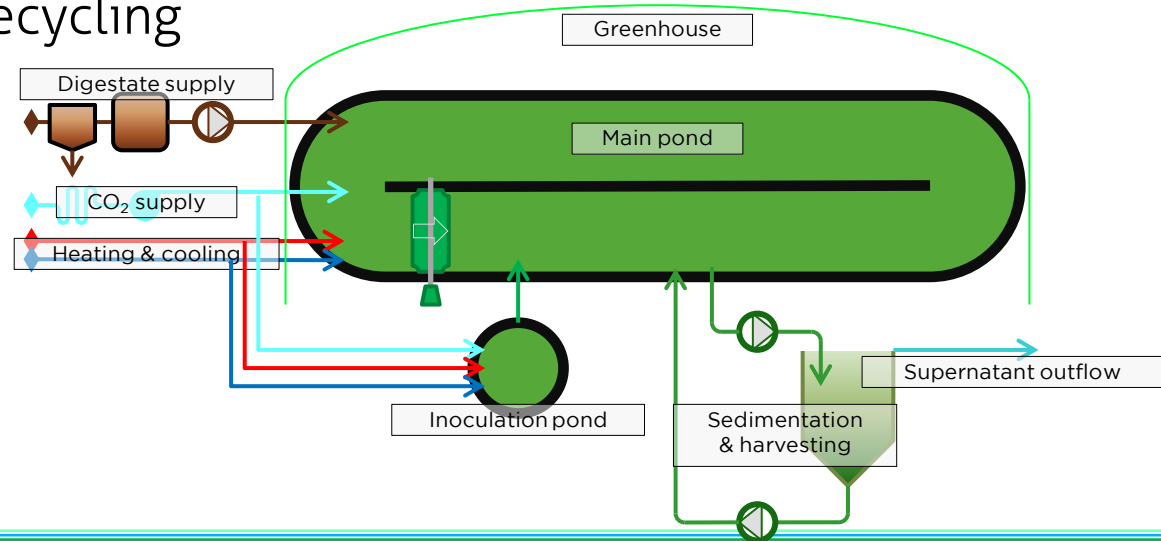
AlgaeBioGas Objectives



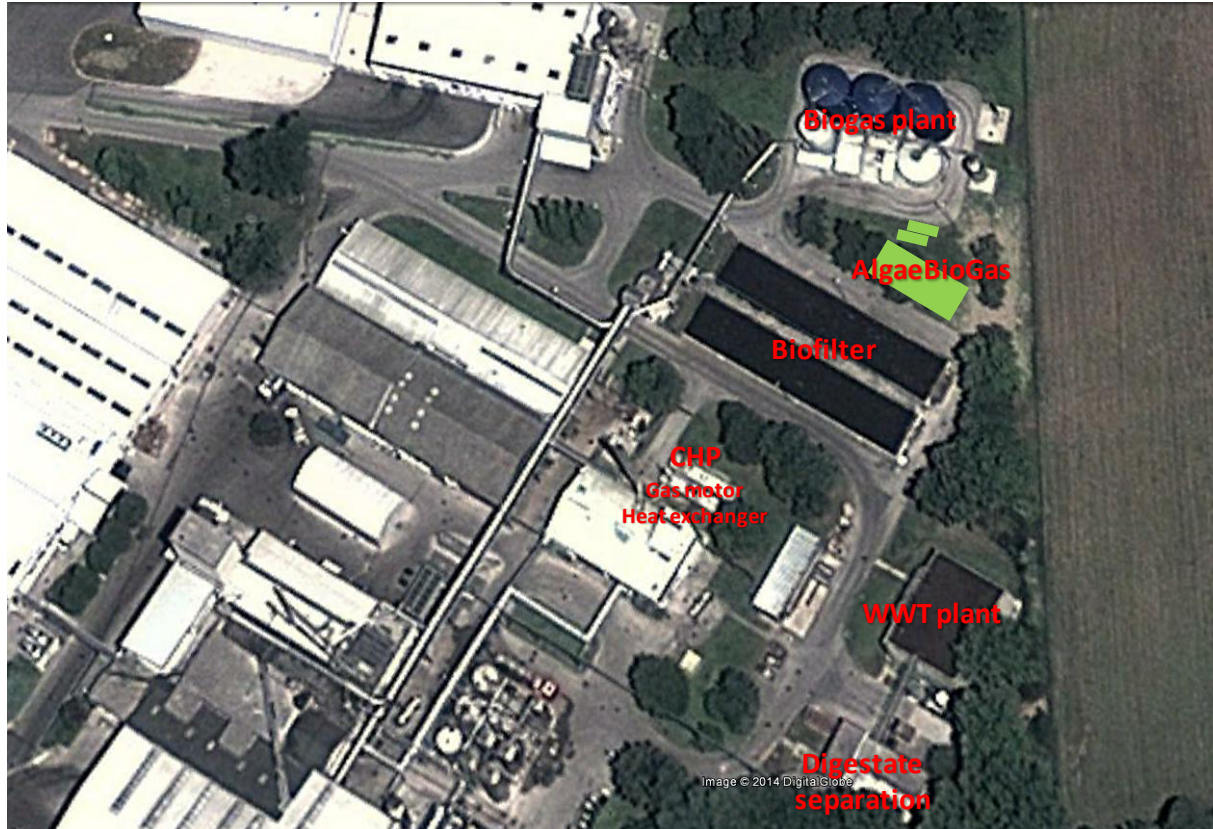
- Objectives:
 - Demonstration centre design, construction, operation
 - Prepare technology for replication
 - Market development activities
- Finished in August 2016:
 - Demonstration centre operational
 - Legislation analysis, LCA, business planning
 - Complementary technologies being tested
 - Technical development (controls, ponds)
 - Presentations & visits
 - Installation #2 is being built

Subsystems

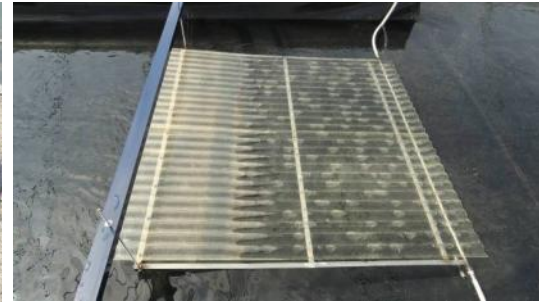
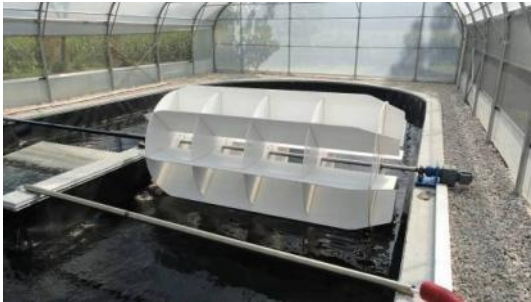
- Ponds: main & inoculation
- Mixing equipment
- Greenhouse
- Heating & cooling
- Exhaust gas supply (cooling, purification)
- Digestate supply (separation, anaerobic filter, storage)
- Sedimenter / clarifier & recycling
- Switching to DAF
- Control system



Location



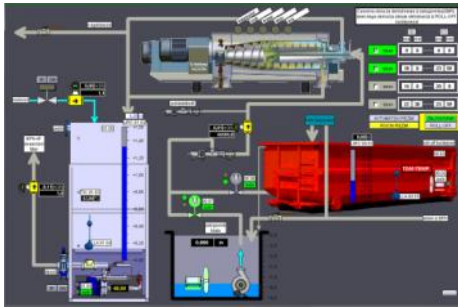
Greenhouse, ponds, mixing, CO₂



Digestate preparation



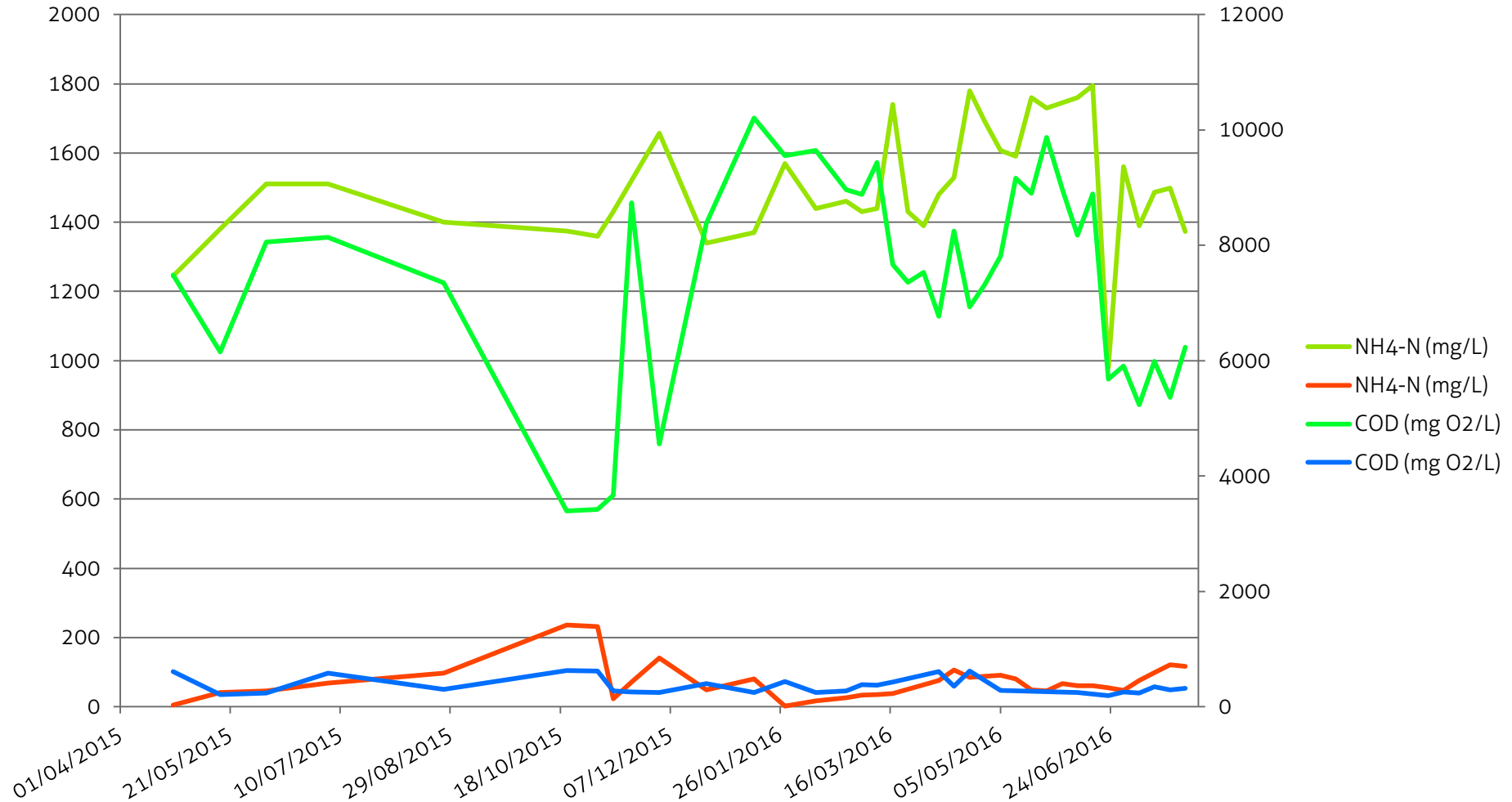
Control & instrumentation



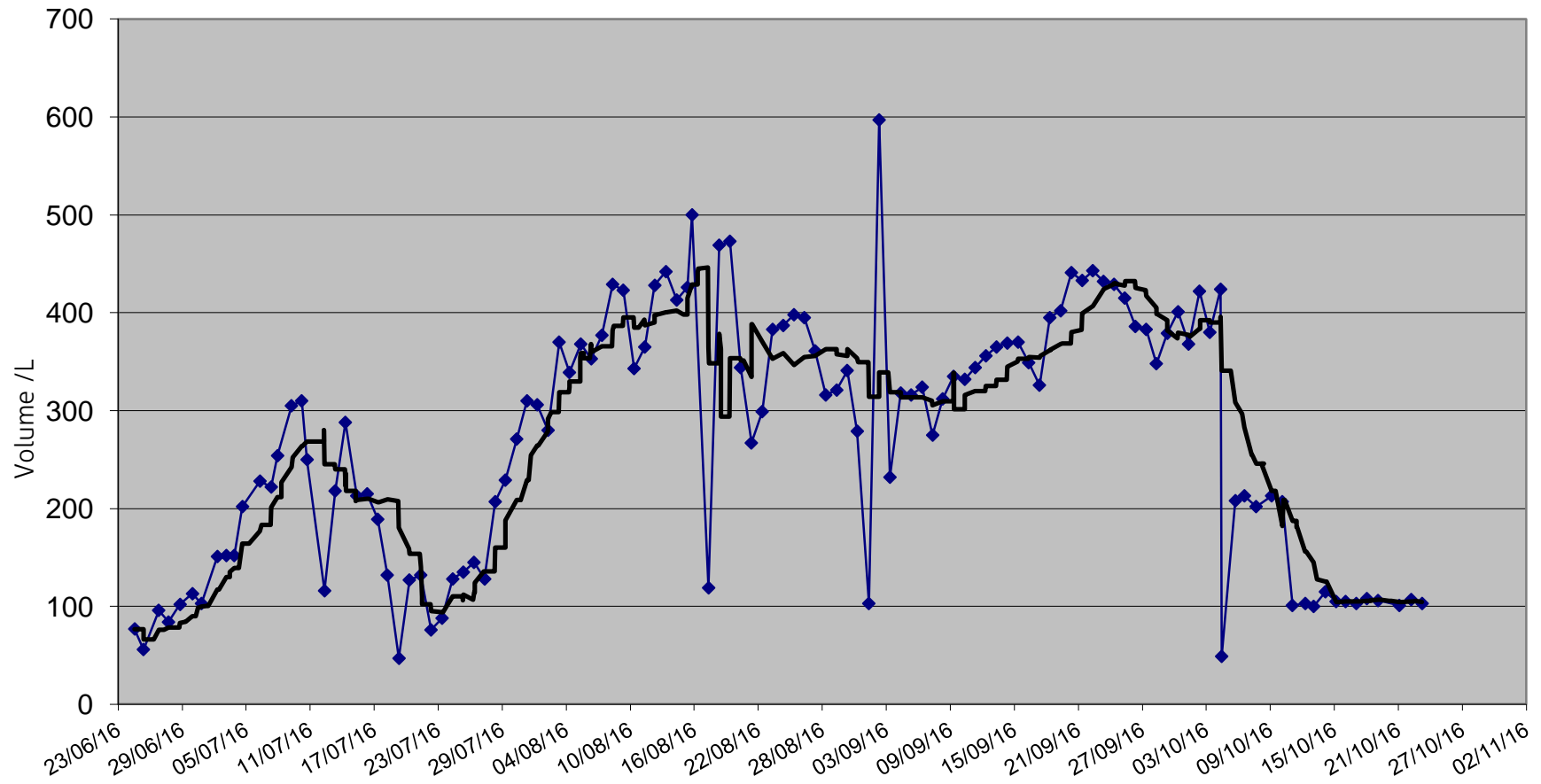
Observed performance in digestate treatment

- Running for more than 2 years
- Weather dependent (performance 3 to 1)
- Natural species only
- Sedimentation does not work - DAF
- Model **biogas CHP with 1 MWe** - to recycle major part of nutrients:
 - area 3 - 5 ha
 - volume 3000 – 17000 m³
 - 60 – 200 t algae bacterial biomass p.a.
 - use approx the same amount of carbon rich substrate
 - replacing 120 – 400 t dry mass of corn = 360 – 1200 t of corn silage
 - replacing 8 – 26 ha of corn fields

COD and NH₄ removal performance

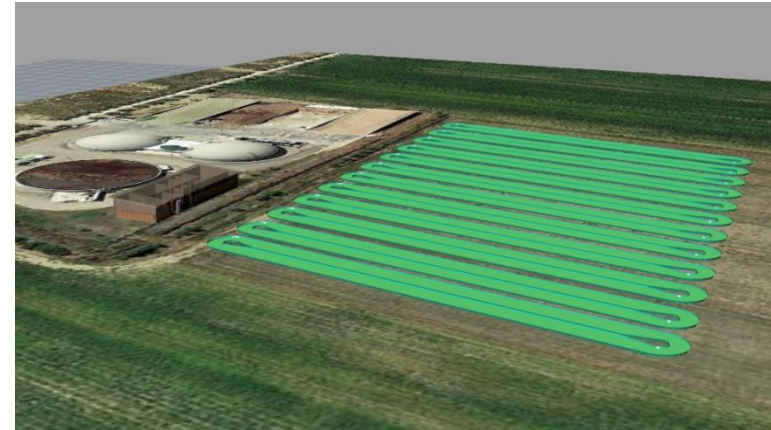


Digestate inflow



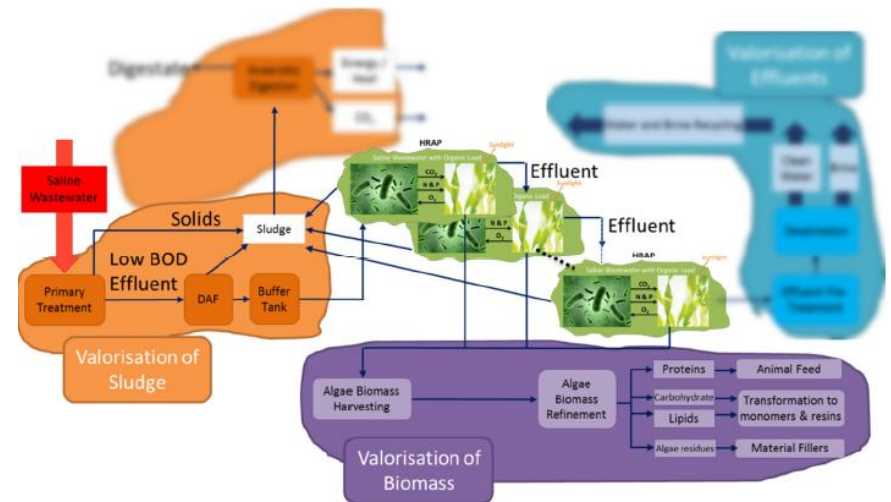
Future

- Installation #2 in Italy (0.5 ha)
- Complementary technologies:
 - Digestate pre-treatment
 - Auto(bio)flocculation, DAF
 - ALBA biomass pre-treatment for biogas
 - Animal feed trials (fish, chicken)
- Technical & manufacturing
 - More cost-effective ponds
 - Better performance & more control
- **Partners:** sales & implementation service



- Demonstration project to prove the techno-economic feasibility of using algae to treat saline wastewater from the food industry
- Horizon 2020 project
- Started in June 2016
- 19 partner consortium
- 3 demo sites:
 - Slovenia: AlgaeBioGas → demonstration site for treating tannery wastewater
 - Italy: salty whey from cheese industry
 - Israel: high intensity fish farming to algal products

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- The diagram illustrates a comprehensive valorisation system for wastewater treatment. It begins with **Saline Wastewater** entering **Primary Treatment**. This stage produces **High BOD Effluent**, **Solids**, and **Sludge**. The **Solids** are sent to a **Small Anaerobic Digester**, which generates **CH₄** and **Energy/Heat** (for **Valorisation of Sludge**) and **Sludge**. The **Sludge** and **High BOD Effluent** are then processed through **Two-Step Anaerobic Digestion** (consisting of **Acidogenesis** and **Methanogenesis**), which produces **CO₂** and **Clean Water**. The **Clean Water** is recycled. The **CO₂** is utilized in the **HRAP** (High Rate Algal Pond) and **Desalination**. The **HRAP** produces **Algae Biomass**, which is then **Harvested** and **Refined**. The refined biomass is used to produce **Proteins** (for **Animal Feed**), **Carbohydrate** (for **Transformation to monomers & resins**), **Lipids** (for **Material Fillers**), and **Algae residues** (for **Material Fillers**). The **Desalination** process produces **Clean Water** and **Brine**. The **Brine** is sent to **Effluent Pre-Treatment**, which then feeds back into the **Water and Brine Recycling** system, which provides **Clean Water** to the **Primary Treatment** and **Two-Step Anaerobic Digestion** stages.



Thank you for your attention

- Questions?
- Welcome to visit the demonstration centres



SaltGae
algae to treat saline wastewater