Algae – Wastewater – Biogas

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Agenda

• Algae – Wastewater – Biogas
  ▪ Algal Bacterial Wastewater treatment
  ▪ Biogas – recover energy from biomass
  ▪ Algal-bacterial treatment of biogas digestate
  ▪ Algae as biogas feedstock

• AlgaeBioGas project
Wastewater

• Wastewater
  - organic compounds
  - nitrogen (mostly ammonia)
  - other nutrients (P)
  - other pollutants (heavy metals)
  - Chemical/Biological Oxygen Demand (COD/BOD)

• Algae & wastewater
  - Nature’s method to treat wastewater
  - Technologically used for at least 60 years
Algal bacterial process
Biological Aerobic Wastewater Treatment

Aeration ➔ Bacteria ➔ GHG

Waste water ➔ Organic matter ➔ Aeration ➔ Bacteria ➔ Nutrients (N, P, ...)

O₂ ➔ Bacteria ➔ CO₂

Bacterial sludge ➔ Removed in polishing process - Tertiary treatment ➔ Treated water
Algal bacterial process
Photosynthesis

- Sun
- Algae
- Biomass
- O₂
- CO₂
- Nutrients (N, P, ...)

CO₂ + H₂O → O₂ + Biomass
Algal Bacterial (ALBA) Wastewater Treatment

Sun

Waste water

Organic matter

O₂

CO₂

Nutrients N, P, ...

Algae

Bacteria

Treated water

Algal Bacterial sludge
Algal Bacterial (ALBA) Wastewater Treatment

• lagoon treatment
• shifting objectives in the past (energy was “free”, no GHG paranoia)
• purpose 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
- algae bacterial community is unstable → needs to be tightly 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 - how long oxygenation lasts?
- floc ecology, auto-flocculation
Wastewater as nutrient source

• Negative price of nutrients
• Essential for any large scale low cost products

• Algae & biogas – basic technology for energy and nutrient recuperation from wastewater
Biogas

• Anaerobic digestion
  ▪ Anaerobic bacteria (Archaea) converting organic matter to methane (and $H_2$, $CO_2$, $H_2S$, …)

• A waste treatment technology
Biogas flavours

- Landfill gas
- Wastewater sludge
- Bio waste
- Wastewater (anaerobic treatment)
- Agricultural waste
- Energy crops

- Biogas is the most efficient biofuel
Biogas plants

• Different technology levels
• Mesophilyc / thermophilic
• Biogas use
  ▪ Heat
  ▪ Combined heat and power (CHP)
  ▪ Gas networks (enriched biogas)
• Legislation & subsidies
  ▪ Gas grid ↔ CHP
  ▪ Waste ↔ energy crops
  ▪ Access to power grid
  ▪ Nitrogen vulnerable zones
Biogas digestate

• Ideally: all organics consumed
• 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, with only limited application to soil

• Waste, end-of-waste directive, control & monitoring
Liquid biogas digestate

- One of the hard-to-treat substances
- COD 8000 – 50000 mg O₂/L
- Classical WW processing (3 – 20 €/m³)
  - Energy consuming conversion or organics and nutrients to CO₂ and N₂
  - Loss of energy and nutrients
- Alternatives:
  - Drying
  - Ultrafiltering
  - Reverse osmosis
  - ...
- Algal treatment
AlgaeBioGas Basic Cycle

digestate as source of nutrients

CO₂

biogas heat & power

algal biogas substrate

algal products
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 wastewaer or digestate
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 32/36:
  • Demonstration centre operational
  • Legislation analysis, LCA, business planning
  • Complementary technologies being tested
  • Technical development (controls, ponds)
  • Presentations & visits
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, \( \text{CO}_2 \)
Digestate preparation
Control & instrumentation
Observed performance (digestate treatment)

• 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 waste paper pulp (or other carbon rich substrate)
  ▪ replacing 120 – 400 t dry mass of corn = 360 – 1200 t of corn silage
  ▪ replacing 8 – 26 ha of corn fields
Future

• Installation #2 in Italy (0.5 ha)
• Complementary technologies:
  - Digestate pre-treatment
  - Auto(bio)floculation, 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
Future

• An H2020 project Saltgae: Demonstration project to prove the techno-economic feasibility of using algae to treat saline wastewater from the food industry (in negotiation phase)

• Demonstration site for treating tannery wastewater
Thank you for your attention

• Questions?

• Welcome to visit the demonstration centre.