Biological **desulfurization** and **methanation** of biogas and CO_2

Hydrogen & P2X 2022
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Thorkil Dahlgreen, CEO

BIO GASCLEAN | The key to innovative and efficient production of biogas

Corporate video

Biogasclean in key points

- **The mission of Biogasclean** is to contribute to the **transformation from fossils fuels to renewable energy by innovative and efficient production of biogas**.
- Biogasclean is a **world leader in biological desulfurization** of biogas with **more than +320 plants** in operation or under construction in **40 countries**.
- **100% biological.** Why destroy the green image of biogas with chemical desulfurization? Biogasclean can do the job without ferric chloride, caustic soda, iron sponge or activated carbon.
- **High availability.** The uptime of a Biogasclean system **exceeds 98%.**
- **Low operating costs gives most economic solution.** When considering both CAPEX and OPEX **biological H_2S removal is much more cost effective than chemical gas cleaning**.
- **Elimination of odors and corrosion** from biogas. Biogasclean can handle any biogas flow and sulfur load without use of chemicals **on both CHP and RNG projects**.

Technologies

Biological desulfurization

- Biogasclean has developed two different technologies – **BTR** (Bio Trickling Reactor) and **MBR** (Moving Bed Reactor) and offer **five different types** of gas cleaners. The gas cleaners can be designed to handle **any flow and H_2S content** in the **raw biogas** or **tail gas (CO_2 stream)** from biogas upgrading and can be installed at **greenfield projects** or **refurbishment of existing plants**.

Biological methanation

- Biogasclean has in cooperation with Nature Energy and two Danish universities developed a **biological Power-To-X technology**. Bio E-Fuel is a biological process converting CO_2 and H_2 to CH_4. Hydrogen is made from electrolysis of water powered by wind and solar. Bio E-Fuel will enable biogas plants - from the same amount of organic input - to **increase their production of green gas by more than 60%**!

Biotrickling video

Bio E-Fuel

A biological Power-To-X (P2X) technology

Bio E-Fuel – biological methanation of CO_2

- Bio E-Fuel is a biological process **converting (CO_2) and hydrogen (H_2) to methane (CH_4)** in a **Bio Trickling Reactor.**
- Bio E-Fuel can be applied everywhere where you have a CO_2 source. Biogas typically consists of 55-60% CH_4 and 40-45% CO_2. With Bio E-Fuel biogas plants can increase the methane content in biogas to +95%, i.e. **the efficiency of biogas production increases by more than 60%.**
- The biological methanation process is **+10 times more efficient than anaerobic digestion**. The process is very robust and handles untreated biogas and CO_2 without prior removal of sulfur and other impurities.

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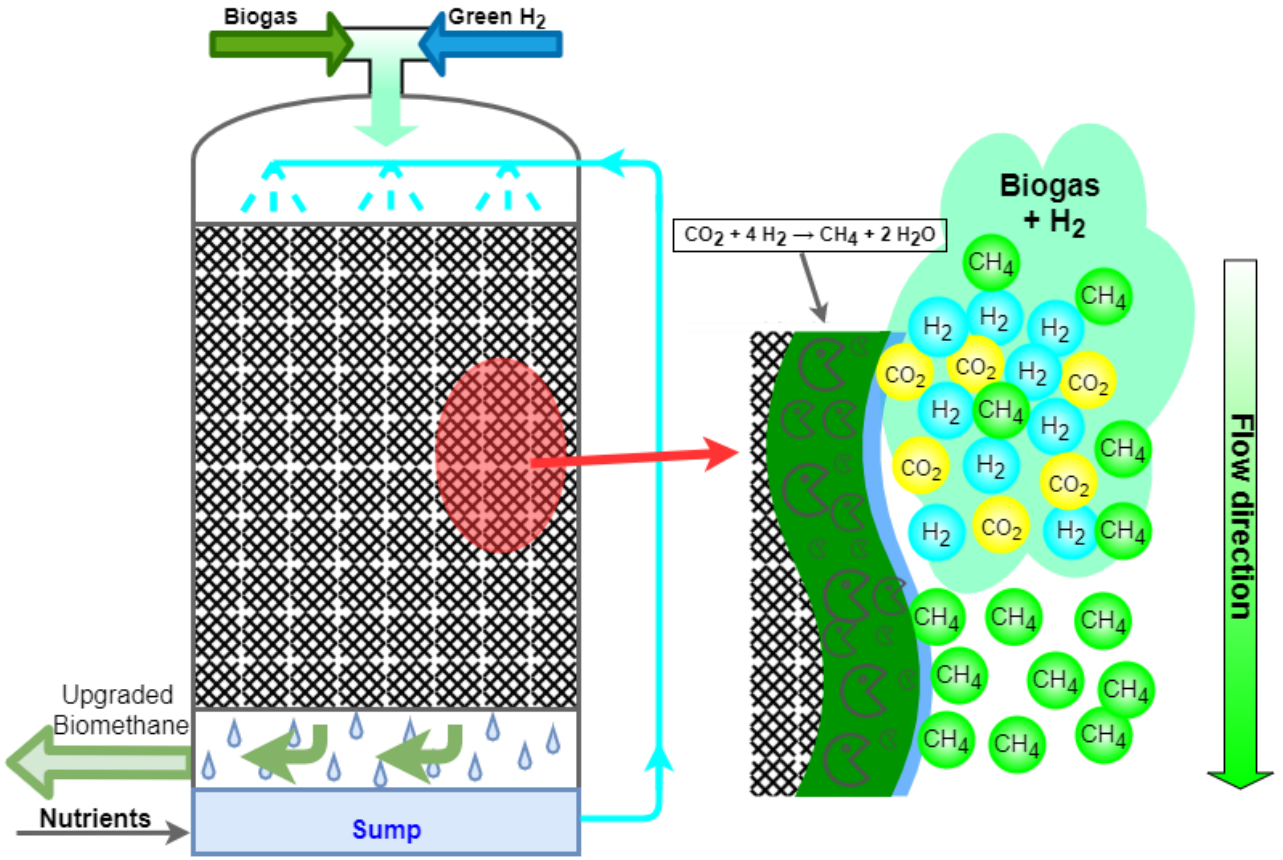
Process in Bio Trickling Reactor

Biological Methanation

$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$



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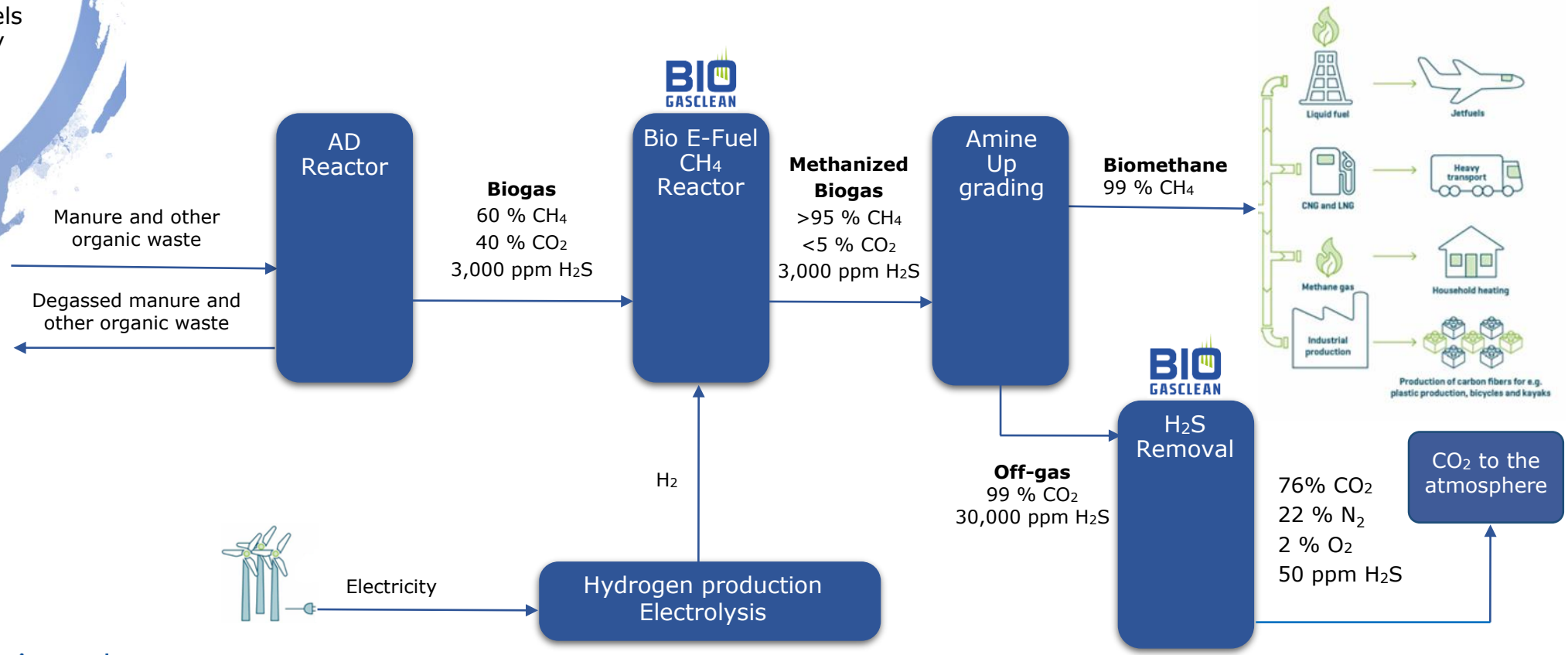
Bio E-Fuel

The potential of Bio E-Fuel

Converting CO_2 from greenhouse gas to the future non fossil fuels for aircrafts, ships and heavy trucks and plastic.

On biogas plants you have already the CO_2 source. The CO_2 can without any further cleaning and conditioning be injected into the Bio E-Fuel reactor as raw biogas. The Bio E-Fuel reactor works at pressure <200 mBar and temperatures <60°C and will increase the production of CH_4 from typically 55-60% to +95%



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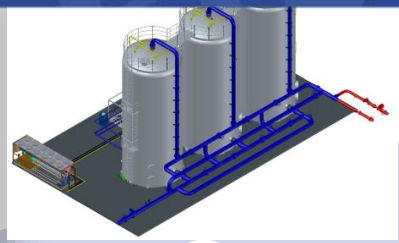
Bio E-Fuel Up-scale plan

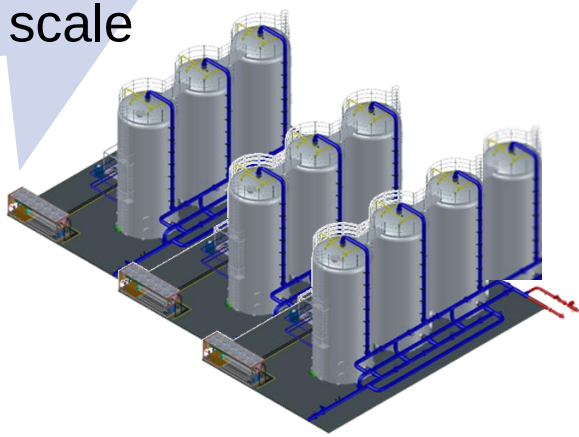


2019-2020 – Lab skala

2021 – Pilot scale

2022-2023 – Demo scale

2024 – Full scale

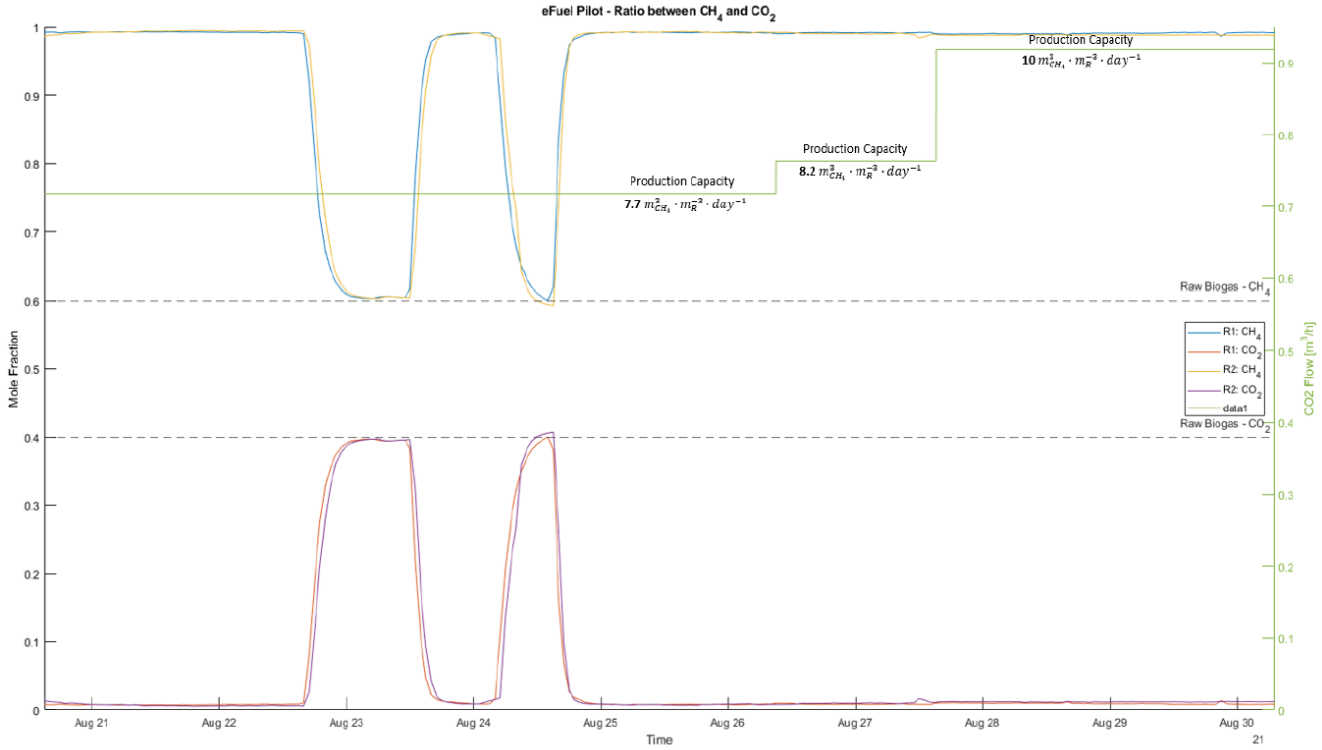


	Lab scale	Pilot scale	Demo scale	Full scale
Size [m3]	4 x 0,008	2 x1	3 x 400	10 x 400
+CH_4 [m^3 CH_4/day]	0,08	20	12.000	40.000
-CO_2 [% of normal prod.]	-	0,05%	30%	100%
Effect [from electrolyzer]	-	0,009 MW	7 MW	23 MW

Bio E-Fuel Pilot Plant

Pilot Scale E-Fuel - Status

- Bio E-Fuel Pilot Plant installed in Q1-21 together with electrolyzer from Green Hydrogen Systems at Nature Energy Holsted.



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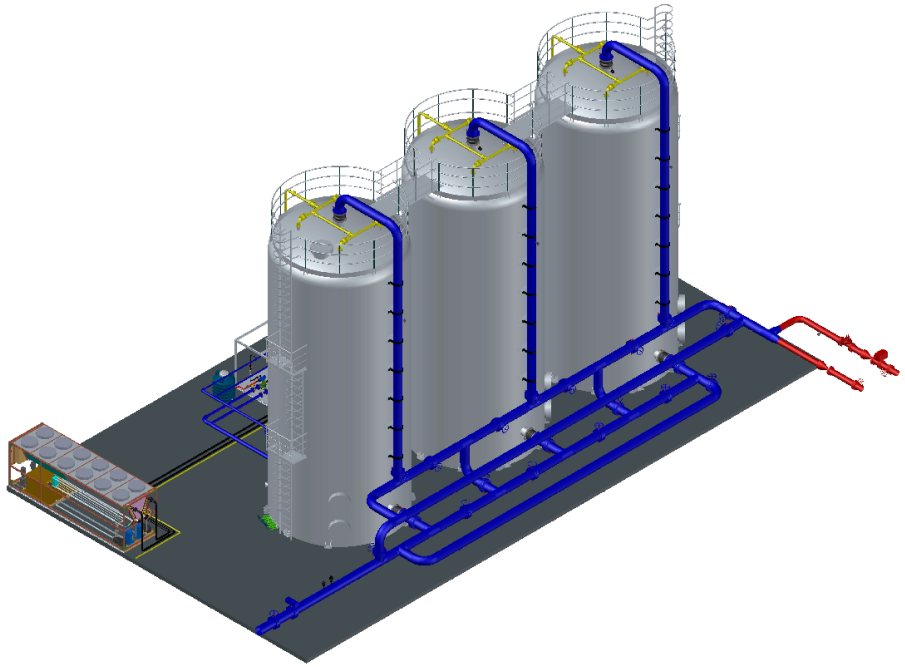
Demo Scale E-Fuel Plant

Demo Scale E-Fuel - Status

- Demo Scale E-Fuel Plant designed for a large industrial biogas plant in Denmark; construction and installation in 2022-23.
- Methanation of the CO_2 stream from one of the biogas plant's four AD reactors.
- Required electrolysis capacity 7 MW.
- Production capacity 381 Nm3/h E-Methane or >3,000,000 Nm3/y or 30 GWh/y E-Methane.



Biological versus catalytic methanation at biogas plants

	Biological	Catalytic
Methantion of raw biogas	Yes	No
Methanation of raw CO_2	Yes	No
Removal of H_2S required	No	Yes
Operating pressure	<200 mbar	<20 bar
Temperature	<60 ^{0}C	<700 ^{0}C
Max. H_2S	<30,000 ppm	<1 ppb

E-Methan (liquified) versus e-Methanol

	E-Methan as LBG	E-Methanol
Reaction	$CO_2 + 4\ H_2 =>$ $CH_4 + 2\ H_2O$	$CO_2 + 3\ H_2 =>$ $CH_3OH + H_2O$
Supply of H_2 in relation to CO_2	4 m3 H_2 per 1 m3 CO_2	3 m3 H_2 per 1 m3 CO_2
Higher heating value of 1 ton	14.6 MWh/ton or 52.7 GJ/ton	6.3 MWh/ton or 22.7 GJ/ton
Higher heating value of 1 m3	6.6 MWh/ton or 23.8 GJ/ton	5.0 MWh/ton or 17.9 GJ/ton

References QSR

Client: Nature Energy, Månsson

Application: Grid injection

Location: Brande, Denmark

Year: 2017

Project: 41206

CO_2 flow: 600 m^3/h
CO_2 flow: 352 scfm
H_2S inlet: 7,500 ppm
H_2S outlet: 50 ppm

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References QSR

Client: Nature Energy, Korskro

Sector: Grind injection

Location: Esbjerg, Denmark

Year: 2018

Project: 41228

CO_2 flow: 2,000 m^3/h
CO_2 flow: 1,176 scfm
H_2S inlet: 8,000 ppm
H_2S outlet: 50 ppm

Production of 22 million m^3 (777 million scf) CH_4 per year
The CO_2 is utilized in breweries

References QSR

Client: Lundsby Biogas, Vinkel

Application: Grid injection

Location: Skive, Denmark

Year: 2019

Project: 41245

CO_2 flow: 2,700 m^3/h
CO_2 flow: 1,588 scfm
H_2S inlet: 6,700 ppm
H_2S outlet: 30 ppm

References QSR

Client: E.ON - Greenlab

Application: Grid injection

Location: Skive, Denmark

Year: 2020

Project: 41247

CO_2 flow: 2,250 m^3/h
CO_2 flow: 1,323 scfm
H_2S inlet: 7,400 ppm
H_2S outlet: 50 ppm

References QSR

Client: Nature Energy, Koeng

Application: Grid injection

Location: Koeng, Denmark

Year: 2022

Project: 41287

CO_2 flow: 2,500 m^3/h
CO_2 flow: 1,470 scfm
H_2S inlet: 7,000 ppm
H_2S outlet: 50 ppm

References MBR

Client: KSL Green Innovation PLC (KSL)

Sector: Ethanol molasses

Location: Khon Kaen, Thailand

Year: 2021

Project: 41285

Biogas flow: 5,000 m^3/h
Biogas flow: 2,941 scfm
H_2S inlet: 15,000 ppm
H_2S outlet: 100 ppm

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