BIO GASCLEAN

the key to efficient and successful utilization of biogas

Biological desulfurization and methanation of biogas

Biogasclean is only 12 years old – but our technology is based on 4 billion years of evolution

Biogasclean - Danish Technology
General presentation

Biogasclean in numbers

2 Locations

Headquarter and management in Denmark; engineering and production in Thailand

+25 employees

Employees in Denmark, Thailand, Malaysia and Brazil

+285 References

In 40 different countries

+600 MW

Biogasclean supplies clean gas to more than 600 MW gas engines and boilers and removes sulfur from +20 upgrading plants

Our mission

Contribute to the transformation from fossil fuels to renewable energy by innovative and efficient production of biogas

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What is biogas?

- Biogas is a renewable energy source like wind power and solar power. But biogas is not only produced to provide renewable energy; the production of biogas is an integral part of sustainable treatment of organic waste from the production of the many products that are the prerequisite for our modern life.
- Furthermore, biogas has the great advantage that it can be produced all year round regardless of weather and wind and that the energy can be stored.
- Biogas is formed during anaerobic digestion of organic waste streams at livestock farms, food processing plants, breweries, palm oil mills, ethanol distilleries, paper mills, wastewater treatment plants and sorted household waste.
- When the H_2S is removed, biogas can substitute oil and gas and be used for power and heat production or upgraded to natural gas quality.
- Already today 20% of Denmarks' gas consumption is bio-methane.

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What is hydrogen sulfide (H_2S)?

- Wastewater streams contain different amounts of sulfur compounds. Under atmospheric conditions – in the presence of oxygen - the sulfur is mainly bound as sulfate (SO_4) and dissolved in the wastewater.
- In the anaerobic digesters the organic matters are degraded by anaerobic bacteria. In the absence of oxygen the sulfate is converted to hydrogen sulfide (H_2S) which is a gas.
- Thus, after the anaerobic digestion process, the sulfur compounds present in the inlet stream leave the reactor through the biogas as H_2S.
- Typically, the H_2S in the biogas will be in the range from 0.1% to 3.0% (1,000-30,000 ppm).

"H_2S occurs as a natural part of the AD process in the reactor"

"H_2S is poisonous, corrosive, and flammable"

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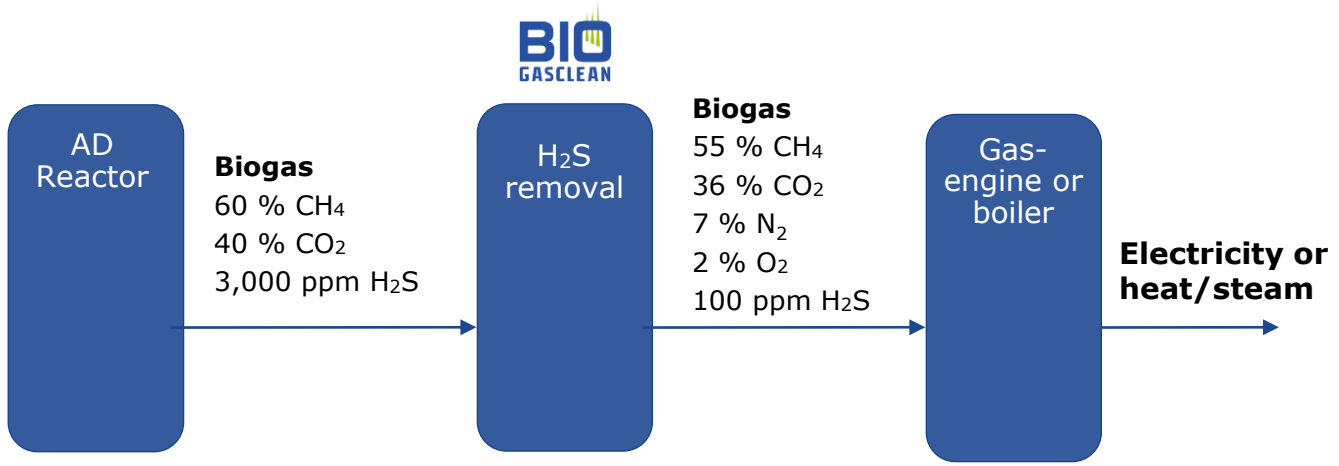
Removal of H_2S from biogas

Why it is mandatory to remove H_2S from biogas

H_2S will form sulfur dioxide (SO_2) and sulfuric acid (H_2SO_4) during combustion which results in a very aggressive corrosion. The corrosion will literally reduce the lifetime of the downstream equipment by years! This is why gas engine manufacturers require that H_2S in the clean gas must not exceed 100-250 ppm. Otherwise, operating costs for change of engine oil, sparkplugs and other maintenance will increase significantly.

- Biogas is typically used in gas engines for heat and power production (CHP) or in boilers for steam or power production.
- During combustion the H_2S will convert to H_2SO_4 (sulfuric acid). This acid is extremely corrosive and will destroy the engine or boiler in a very short time. Therefore, it is absolutely necessary to remove the H_2S before combustion.



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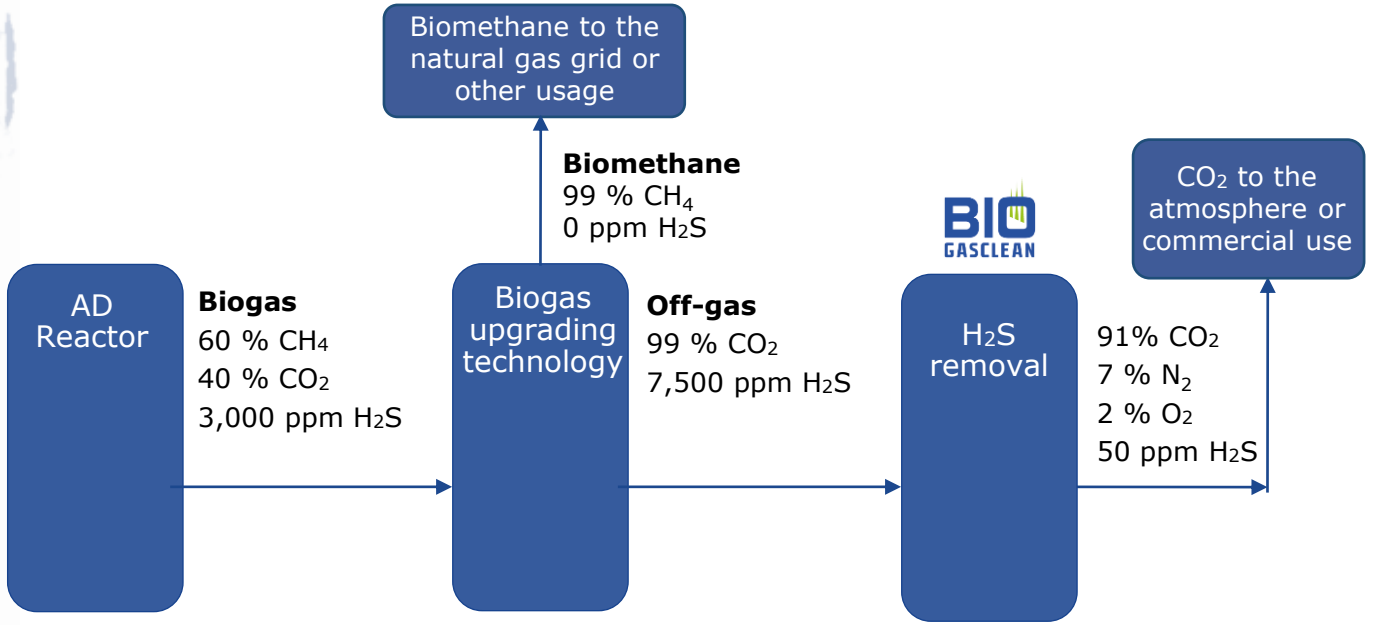
Removal of H_2S from CO_2

Why it is mandatory to remove H_2S from CO_2

Air quality standards are another driver for H_2S removal. Combustion of un-cleaned biogas will result in sulfur dioxide (SO_2) emissions which causes serious odor problems as well as acid rain. Also health and safety standards require H_2S removal as H_2S is toxic even in small concentrations.

- In upgrading projects the biogas is converted to bio-methane or Renewable Natural Gas (RNG) by separating the CO_2 from CH_4. The H_2S will follow the CO_2 stream. Before releasing the CO_2 into the atmosphere the H_2S has to be removed.



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The advantages of biological H_2S removal

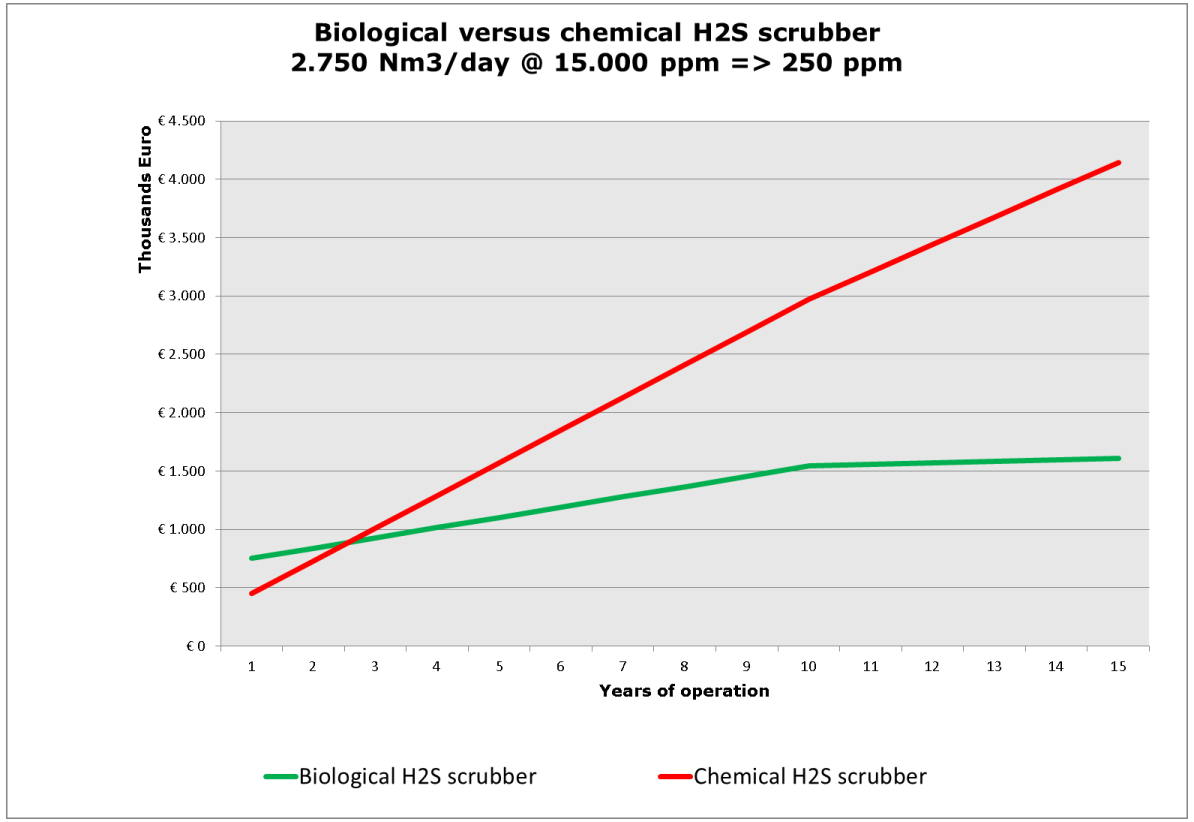
The advantages of biological desulfurization

The H_2S removal process is 100% free of chemicals and OPEX are only **10-20%** of chemical gas cleaning systems.

Just comparing alternative technologies on CAPEX doesn't make sense – when you include OPEX for the lifetime of your project biological H_2S removal is much more cost effective than chemical gas cleaning.

The only residue from the process is a **sulfur rich fertilizer** which can be **recycled** together with the treated waste water **supplementing or replacing industrial fertilizers.**

- CAPEX and OPEX for biological and chemical gas cleaning



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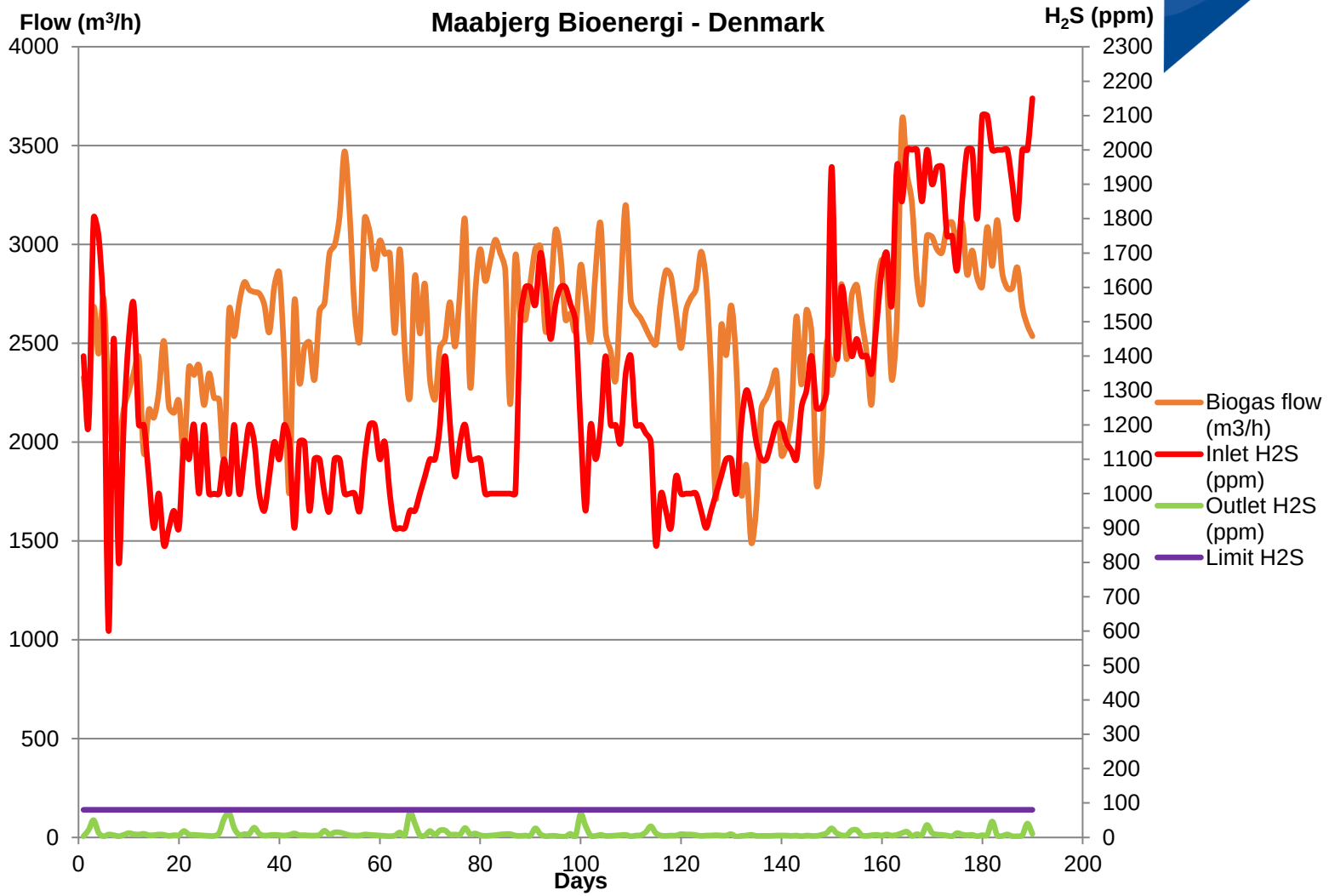
Efficient and robust H_2S removal

Performance guarantee

In this project Biogasclean guaranteed max. 80 ppm H_2S in the clean gas. The performance was measured over 6 months. The outlet did never exceed the guaranteed max. 80 ppm H_2S.



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MUW - Make Up Water

Running the biological H_2S removal proces on digestate gives ultra low OPEX

Biological H_2S removal has much lower OPEX than chemical gas cleaning. In addition to a small power consumption the biological process requires supply of liquid and nutrients. Normally this is supplied as water + NPK fertilizer. But with prober pre-treatment degassed water (digestate) can be used instead.

Waste water with small amounts of particles (palmoil, cassava, paper & pulp) only requires a simple screening. Waste water with significant amounts of particles (pig and cattle manure) requires separation into a liquid and solid fraction by screw press or decanter.

After removal of particles the degassed waste water is processed in the MUW system before being used af scrubber liquid.

- The Make Up Water technology allows you to use degassed waste water or the liquid fraction of separated degassed manure.
- Biogasclean has supplied the MUW system to more than 150 biogas plants.

MUW system at Lundsby Biogas
Vinkel Bioenergy, Denmark

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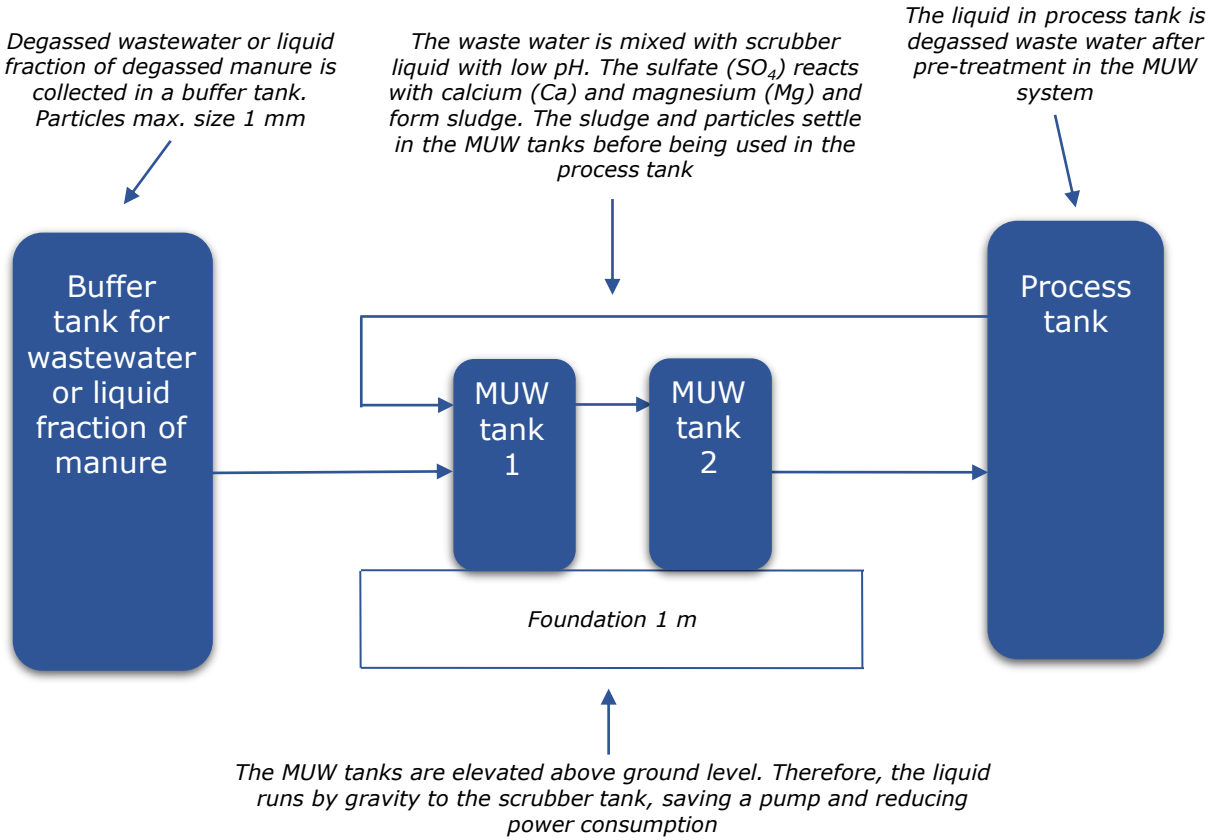
Make Up Water - how does it work?

Significant savings

Using treated water does not only generate a direct saving in water and NPK fertilizer. It also causes that the degassed manure is not diluted by water. This reduces the amount of degassed manure to be transported from the biogas plant to the farmer and the amount to be applied to the fields.

Raw biogas (Nm^3/h)	1,000	2,000	3,000	4,000	5,000
Savings (EUR/y)	11,000	22,000	33,000	45,000	56,000

Saving the environment and money at the same time



QSR - Quick Sludge Removal

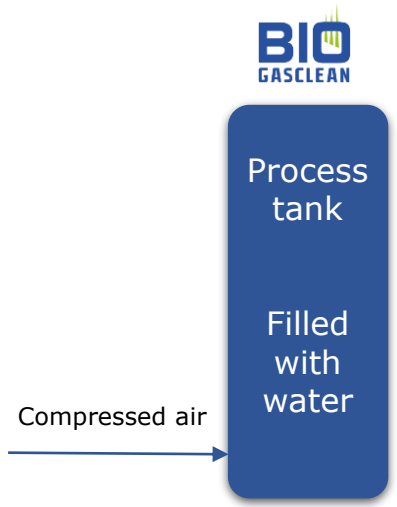
QSR

Biogasclean is the only company offering the QSR® cleaning for efficient cleaning of the packing media inside the tank.

During cleaning the tank is filled with water and pressurized air injected and the packing media is washed like in a big washing machine.

In other biological H_2S removal systems the packing media has to be moved and cleaned outside the tank. This is a dirty job and will have a huge negative impact on the uptime.

- The biological desulfurization process produces sulfate (SO_4) and elemental sulfur (S). The SO_4 is drained out but the elemental sulfur will stick to the packing media and has to be removed on a regular bais. Biogasclean's QSR technique is a vast improvement. Cleaning is required 2-3 times a year and can be done within one working day.



Before QSR

After QSR

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Danish model of amine upgrading with biological H_2S removal - advantages

Highest effiency and lowest OPEX

Amine upgrading of the raw biogas together with H_2S removal from the CO_2 stream (off-gas) provides the highest methane efficiency and the lowest OPEX.

- Highest possible methane recovery: **>99.9%**
- Lowest electricity consumption: **<0.13 kWh/m³ raw biogas**
- Net heat consumption: **0.1 – 0.2 kWh/m³ raw biogas**
- **No need for pretreatment** of the raw biogas
- **No need for high pressure** of the raw biogas
- Valuable integration between Biogasclean and the amine upgrading plant (reuse of low temperature water, control signals, pressurized and warm off-gas, etc.)

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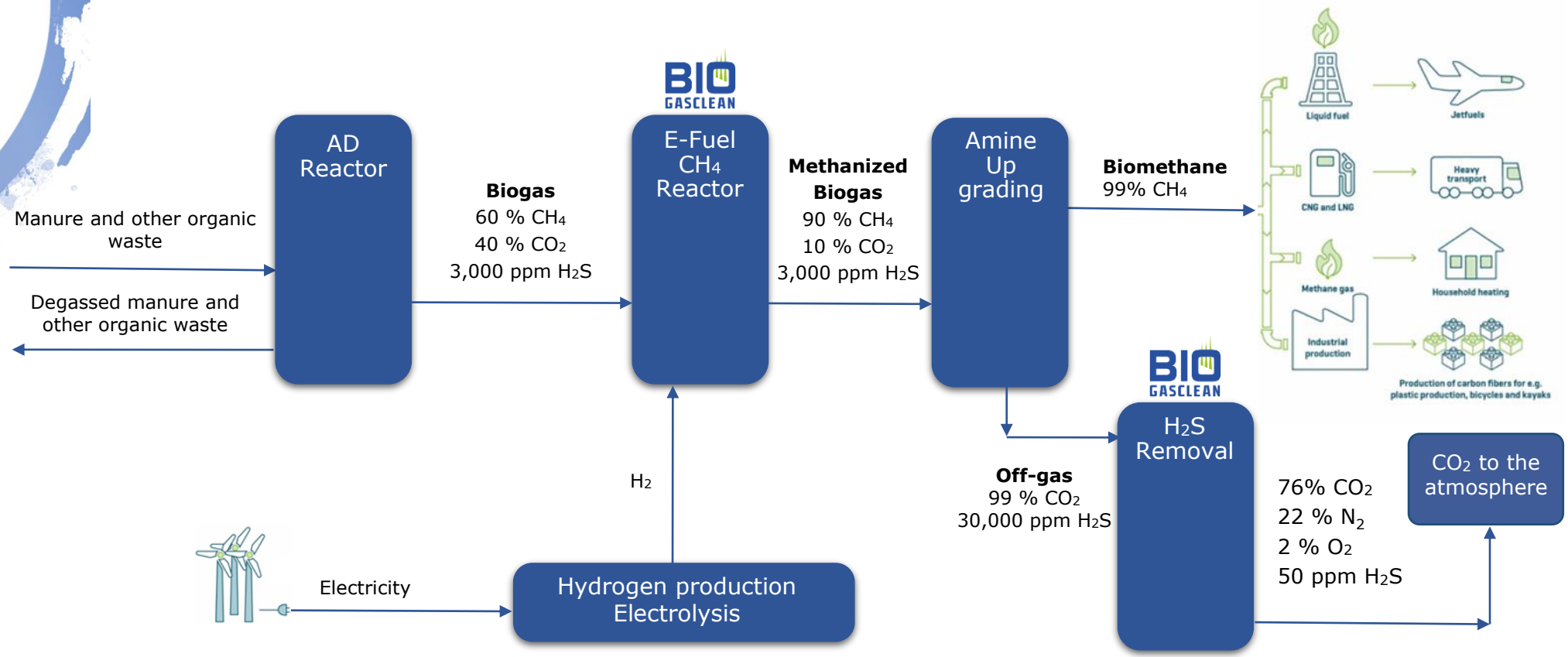
E-Fuel the future of Power-To-X (P2X)

The potential of E-Fuel

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

"Why talk about carbon capture? On biogas plants we have already captured and cleaned the carbon? Why not use it to make even more methane for our future energy supply?"



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E-Fuel at Nature Energy Holsted, Denmark

Electrolyzer from Green Hydrogen Systems

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References

285 references in **40** countries

No.	Country	No.
1	Thailand	59
2	Malaysia	57
3	Indonesia	40
4	Denmark	33
5	USA	15
6	Other markets	81
	TOTAL	285

No.	Substrate	Typical H_2S load ppm	No.
1	Palm oil waste water	3,000	116
2	Animal waste	2,000 - 5,000	58
3	Public WWTPs	2,000 – 5,000	35
4	Cassava waste water	3,000	34
5	Ethanol distillery - molasses	20,000 - 30,000	16
6	Food industry waste water	3,000 - 10,000	11
7	Paper & pulp	10,000 - 20,000	6
8	Breweries	3,000	4
9	Ethanol distillery - cassava & wheat	3,000 - 5,000	2
10	Landfills	1,500	2
11	Petro gas	1,500	1
	TOTAL		285

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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: 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

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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

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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

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References QSR

Client: Nature Energy, Glansager

Application: Grid injection

Location: Sønderborg, Denmark

Year: 2020

Project: 41269

CO_2 flow: 2,160 m^3/h
CO_2 flow: 1,270 scfm
H_2S inlet: 7,500 ppm
H_2S outlet: 50 ppm

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References QSR

Client: MEC Biogas

Sector: Livestock and Co-digestion

Location: Maabjerg, Denmark

Year: 2012

Project: 41063

Biogas flow: 3,600 m^3/h
Biogas flow: 2,117 scfm
H_2S inlet: 3,000 ppm
H_2S outlet: 80 ppm

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References QSR

Client: Clarke Energy

Enduser: Freemont

Sector: Food industry

Location: Michigan, USA

Year: 2012

Project: 41066

Biogas flow: 1,360 m^3/h
Biogas flow: 800 scfm
H_2S inlet: 3,000 ppm
H_2S outlet: 200 ppm

BIO GASCLEAN the key to efficient and successful utilization of biogas

References QSR

Client: Clarke Energy

Enduser: MMPA, Hometown Bioenergy

Sector: WWTP

Location: Minnesota, USA

Year: 2013

Project: 41098

Biogas flow: 3,900 m^3/h
Biogas flow: 2,294 scfm
H_2S inlet: 2,500 ppm
H_2S outlet: 200 ppm

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References QSR

Client: Eneraque

Sector: Livestock

Location: New South Wales, Australia

Year: 2018

Project: 41230

Biogas flow: 1,200 m^3/h
Biogas flow: 705 scfm
H_2S inlet: 4,000 ppm
H_2S outlet: 150 ppm

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References OS

Client: ADI Systems

Enduser: Slave Lake Pulp

Sector: Paper and pulp

Location: Alberta, Canada

Year: 2015

Project: 41101

Biogas flow: 1,846 m^3/h
Biogas flow: 1,085 scfm
H_2S inlet: 20,000 ppm
H_2S outlet: 100 ppm

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References MBR

Client: Power Solutions Technologies (PSTC)

Sector: Ethanol molasses

Location: Arun, Thailand

Year: 2017

Project: 41209

Biogas flow: 3,000 m^3/h
Biogas flow: 1,764 scfm
H_2S inlet: 15,000 ppm
H_2S outlet: 200 ppm

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References MBR

Client: KSL Green Innovation PLC (KSL)

Sector: Ethanol molasses

Location: Boploy, Thailand

Year: 2019

Project: 41237

Biogas flow: 3,000 m^3/h
Biogas flow: 1,764 scfm
H_2S inlet: 20,000 ppm
H_2S outlet: 200 ppm