Biogasclean is a **world leader** in **biological desulfurization and methanation** of biogas

General Presentation
XXXX 2022

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

Corporate video

Biogasclean

Biogasclean is represented in four locations on three continents

Europe

1. Headquarter in Denmark

Asia

2. Production and engineering in Thailand
3. Sales office in Malaysia

South America

4. Sales office in Brazil

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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 +309 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.
- **Guaranteed performance.** Biogasclean's H_2S removal systems operate efficient and robust and performance guarantees are offered on all projects.
- **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**.

Market and technologies

Market

- Biogasclean focusses on **biogas plants with relatively large flows** and **high H_2S loads**.

Technologies

- Biogasclean has developed **two technologies** for **biological desulfurization of biogas** and developed a technology for **biological methanation of carbon dioxide (CO_2) and hydrogen (H_2) to electro-methane (CH_4) or E-Fuel**

Biological desulfurization

- Biogasclean has developed two different technologies – **BTF** (Bio Trickling Filter) 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 together with Nature Energy and two Danish universities developed a **Power-To-X project called E-Fuel**. E-Fuel will enable biogas plants - from the same amount of organic input - to **increase their production of green gas by more than 60%**!

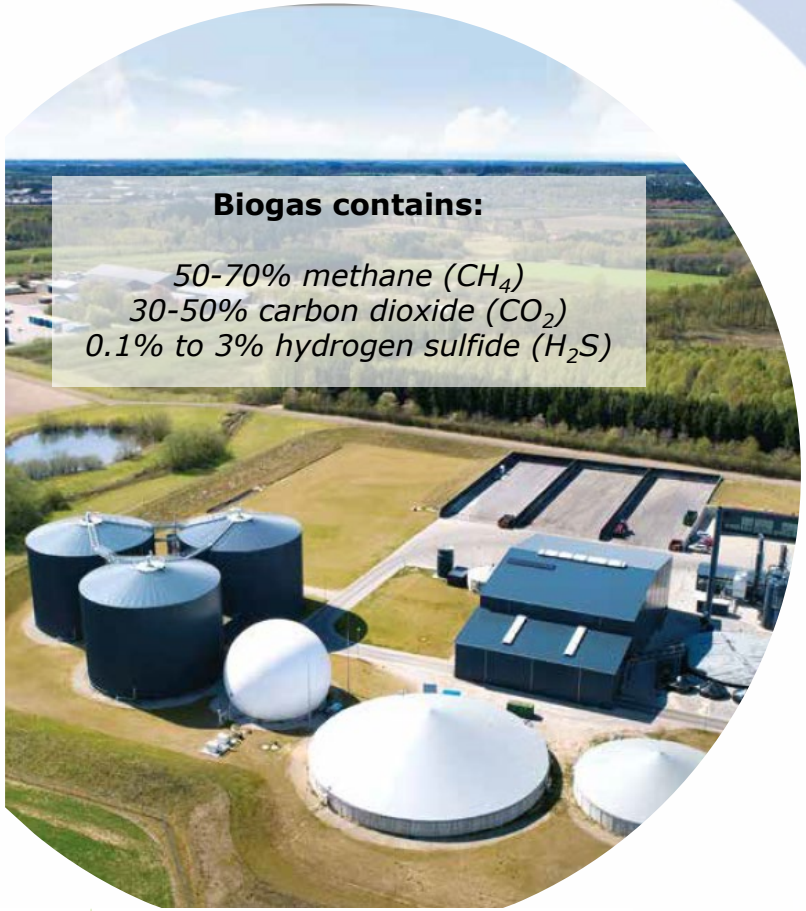
References

309 references in **40** countries

No.	Country	No.
1	Thailand	62
2	Malaysia	61
3	Indonesia	44
4	Denmark	36
5	USA	18
6	Other markets	88
	TOTAL	309

No.	Substrate	Typical H_2S load ppm	No.
1	Palm oil waste water	3,000	126
2	Animal waste	2,000 - 5,000	71
3	Public WWTPs	2,000 – 5,000	36
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		309

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.

What is hydrogen sulfide (H_2S)?

- Waste 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).

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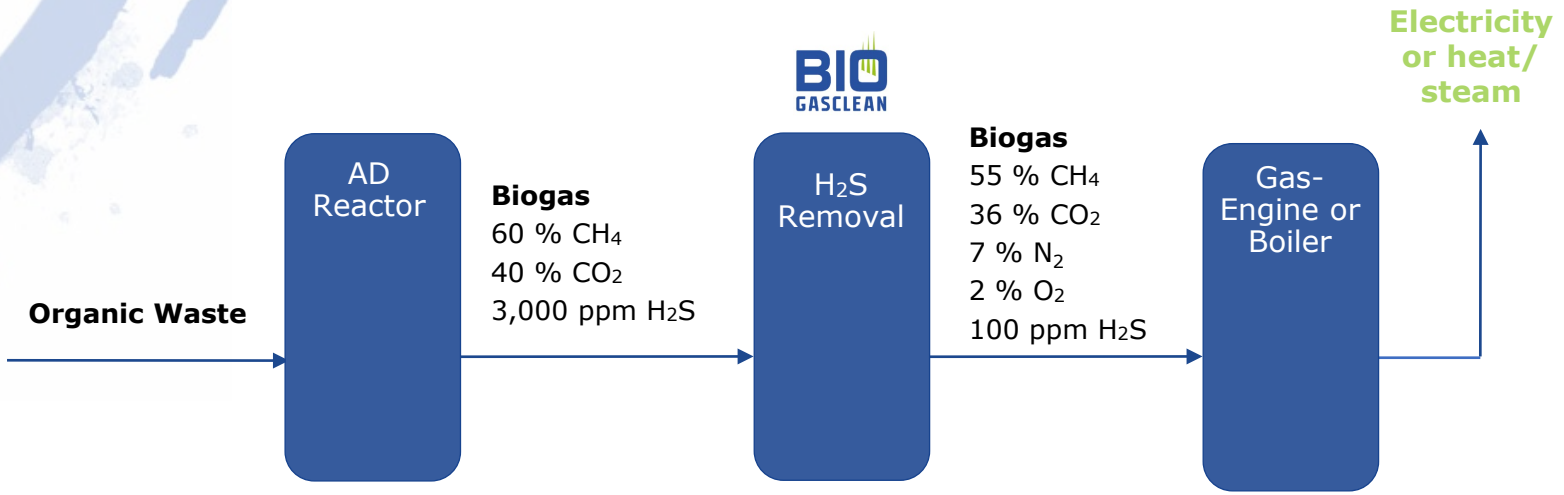
Removal of H_2S from biogas

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.
- The oxygen is supplied as air as the dilution of the heating value with N_2 and O_2 typically does not represent any problem for combustion in engines or boilers.



QSR - Quick Sludge Removal

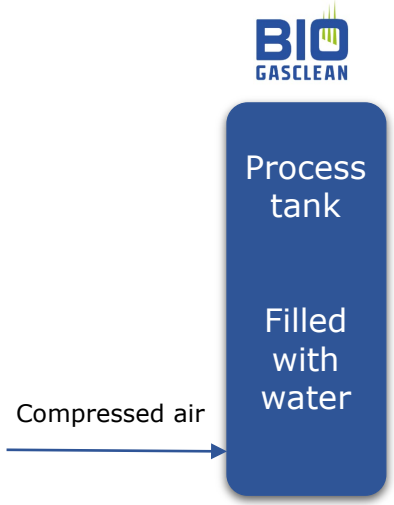
QSR

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

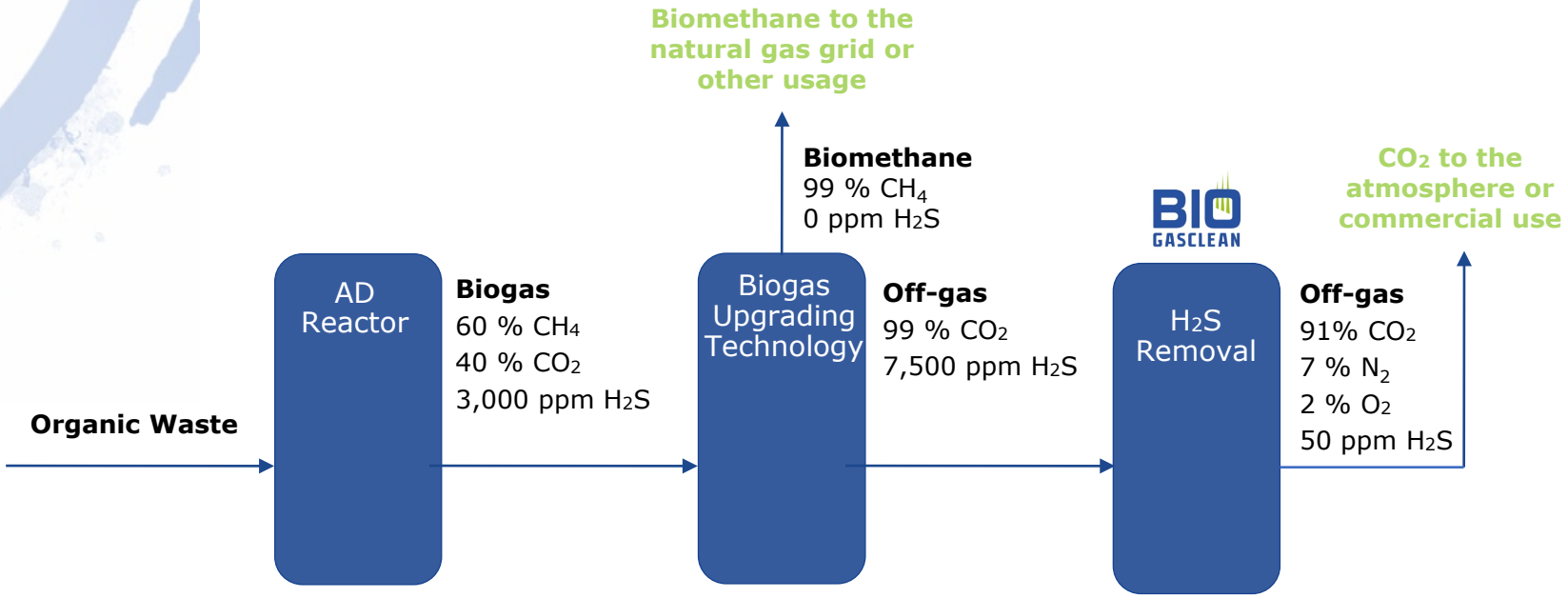
After QSR

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.
- If the CO_2 is released into the atmosphere oxygen is supplied as air. If the CO_2 shall be further processed to food grade CO_2 or catalysts based Power-To-X technologies pure oxygen is used (e.g. from an electrolysis process).



Biotrickling video

BTF product program

BTF product program

- Fully finished product line with 4 product types: ECO, BASIC, QSR and OS.

- ECO can be shipped on a truck or in one 40’ container.
- BASIC without QSR (Quick Sludge Removal) cleaning and grating.
- QSR with QSR cleaning and grating.
- OS with field erected tanks.

BTF references

- Biogasclean has **more than +292 BTF plants** in operation or under construction in **40 countries.**
- **Europe:** Denmark, Finland, UK, Netherlands, France, Spain, Italy, Greece, Poland, Lithuania and Romania.
- **Middle East:** Turkey and Israel.
- **Africa:** Morocco and South Africa.
- **Asia:** Thailand, Malaysia, Indonesia, Cambodia, Laos, Vietnam, Philippines, Singapore, Hong Kong, Taiwan, China, India and Pakistan.
- **Pacific:** Australia and New Zealand.
- **North America:** USA and Canada.
- **Latin America:** Mexico, Guatemala, Dominican Republic, Colombia, Peru, Chile, Argentina and Brazil.

MBR status

MBR – Status

- 4 large plants in operation in Thailand and 1 under construction.
- The biggest potential is Brazil with +380 large ethanol factories.
- The organic content in wastewater (vinasse) is significantly lower in Brazil than in Asia and the rest of Latin America, therefore MBR must be tested before final design and release for sales.
- Biogasclean's MBR Pilot Plant to be tested in Q4-21 on a biogas plant at an ethanol distillery in Brazil for verification of design assumptions.

MBR video

Biogasclean MBR versus biotrikling 15-30,000 ppm H2S on molassess ethanol distilleries

	Biotrickling	MBR
Media type	Fixed bed	Moving bed
Tank volume	100%	25-30%
Service per tank	4-6 days/year	1-2 day/year
Initial start up time	48-72 hour	0.5-2 hour
O2 consumption	100%	25%
O2 after scrubber	1.5%	0.75%
CH4 dilution	15-20%	7.5-10%
Main process	H_2S (gas) + $2O_2$ (gas) => H_2SO_4 (liquid)	H_2S (gas) + ½ O_2 (gas) => S (solid) + H_2O (liquid)
pH of effluent	1-3	7 (no change of pH)
Sulfur in effluent	SO_4 (liquid)	S (solid)
Sulfur recovery	Not possible	Possible

MBR references

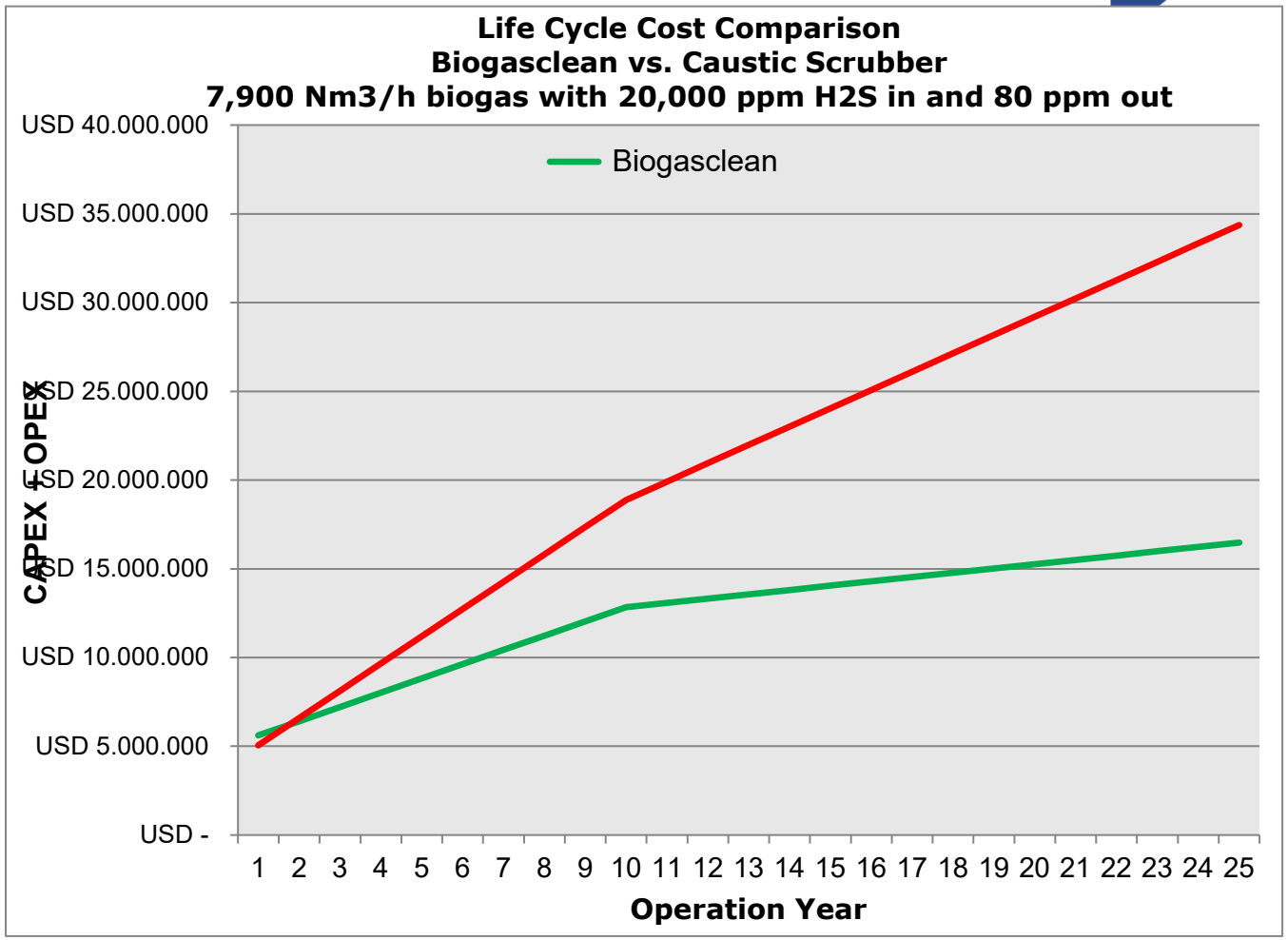
5
references in
Thailand

No.	Client	Project	Flow Nm3/h	H_2S load ppm
1	TRE, Saraburi	MBR No. 1	2,100	15,000
2	PSTC, Arun	MBR No. 1	3,000	15,000
3	KSL, Bobloy	MBR no. 1	3,000	20,000
4	TRE, Saraburi	MBR No. 2	1,200	17,000
5	KSL, Khon Kaen	MBR No. 2	5,000	15,000

Comparison MBR versus Paques' chemical scrubber

MBR – Comparison

- The comparison has been submitted to Brazil's largest ethanol producer 50/50 owned by a Brazilian sugar group and a leading international oil company.
- The group has 25 sugar mills; one of them now producing biogas. They plan to invest in biogas plants on the remaining 24 sugar mills over the next 10 years.
- The biogas plant where Biogasclean's MBR Pilot plant will be tested in Q4-21 is owned and operated by the AD technology supplier to this group. The AD supplier will retain a 15% ownership in each of the 25 biogas plants.

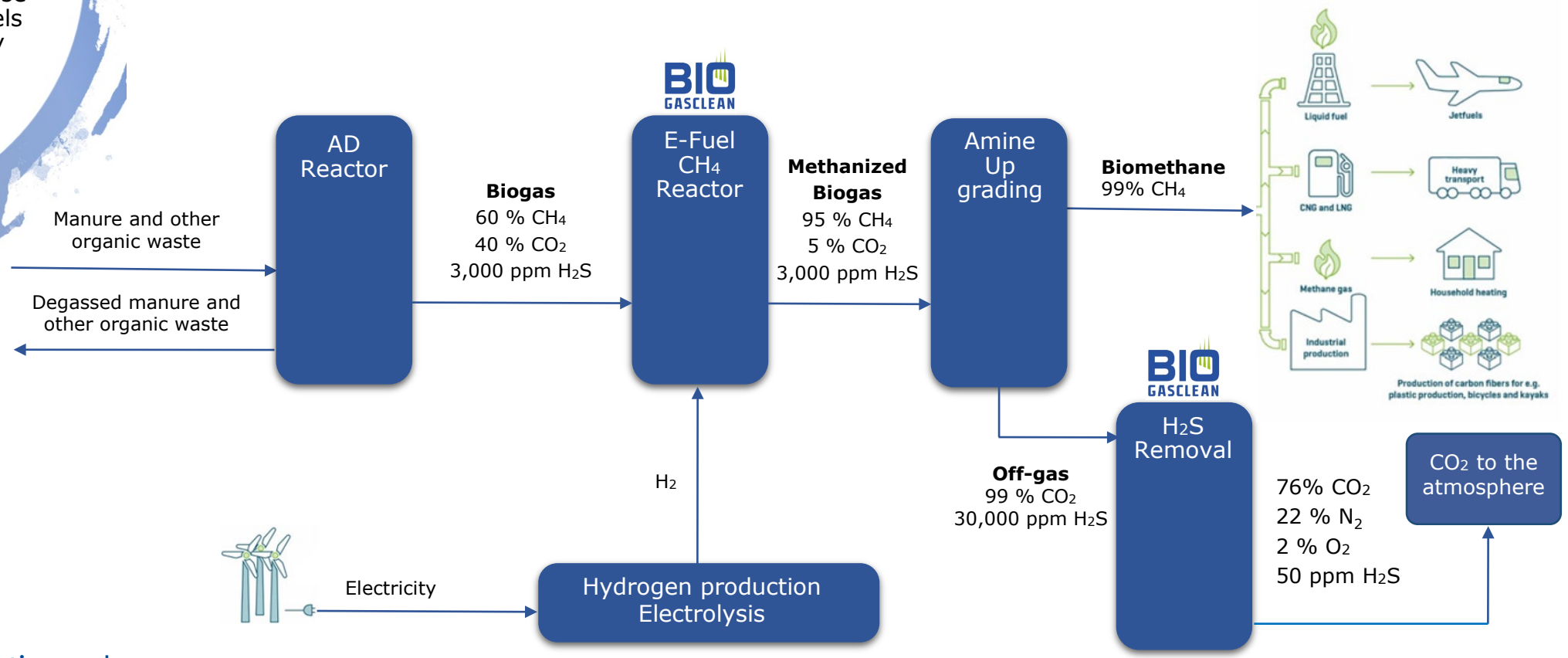


E-Fuel a biological Power-To-X (P2X) technology

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.

On biogas plants you have already the CO_2 source. The CO_2 can without any further cleaning and conditioning be injected into the E-Fuel reactor as raw biogas. The 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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E-fuel video

E-Fuel Pilot Plant

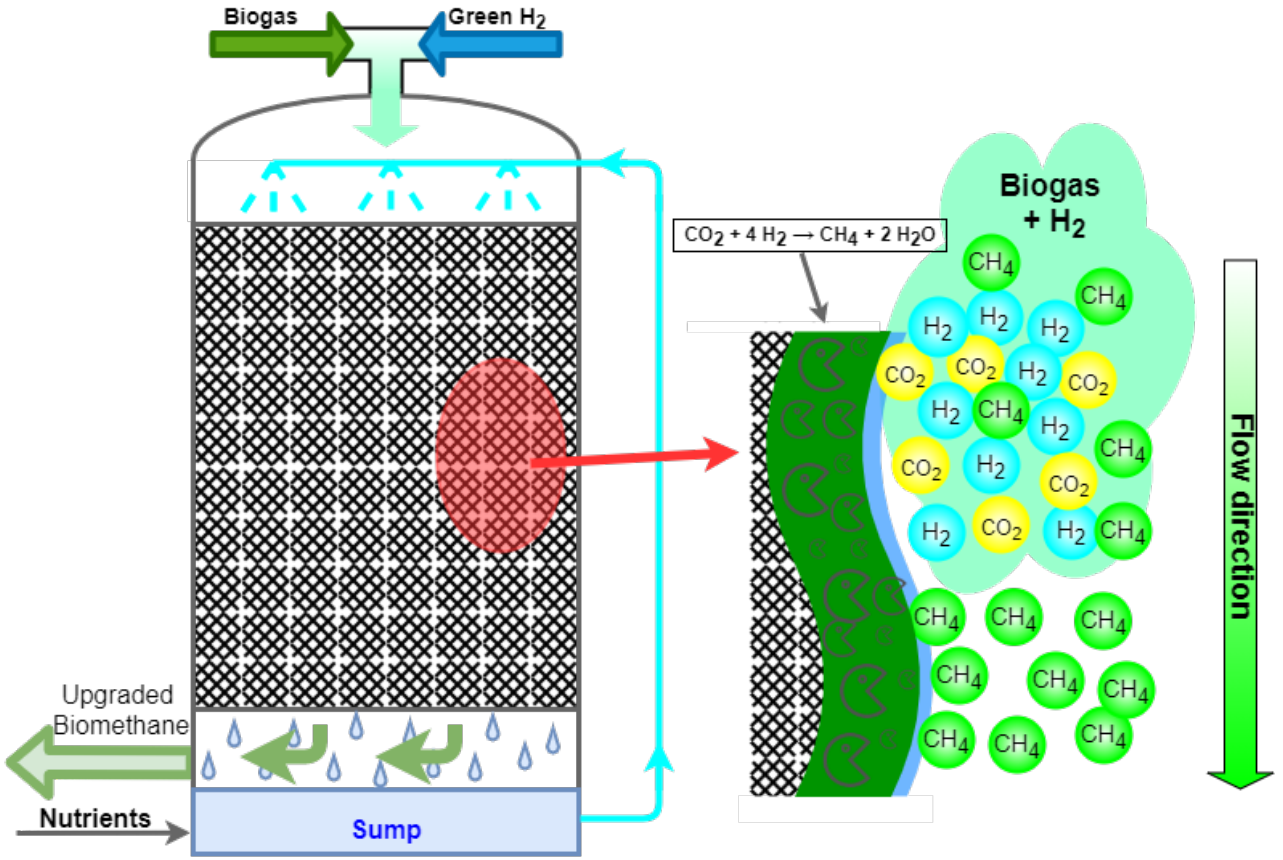
E-Fuel Pilot Plant – Status

- Pilot Plant installed at Nature Energy Holsted Biogas Plant in Q1-21 together with electrolyzer from Green Hydrogen Systems.
- 2 E-Fuel reactors of each 1.5 m3.
- Equation: $CO_2 + 4\ H_2 => CH_4 + 2\ H_20$.
- Methanation of raw biogas and hydrogen to >97% CH_4 + <3% CO_2 + 0% H_2.
- The E-Fuel reactor requires a volume of only 10% compared to the AD reactor to produce the same amount of CH_4.
- E-Fuel can increase the methane production by 60-70%, i.e. from 55-60% to plus 95% CH4.

Process

Biological Methanation

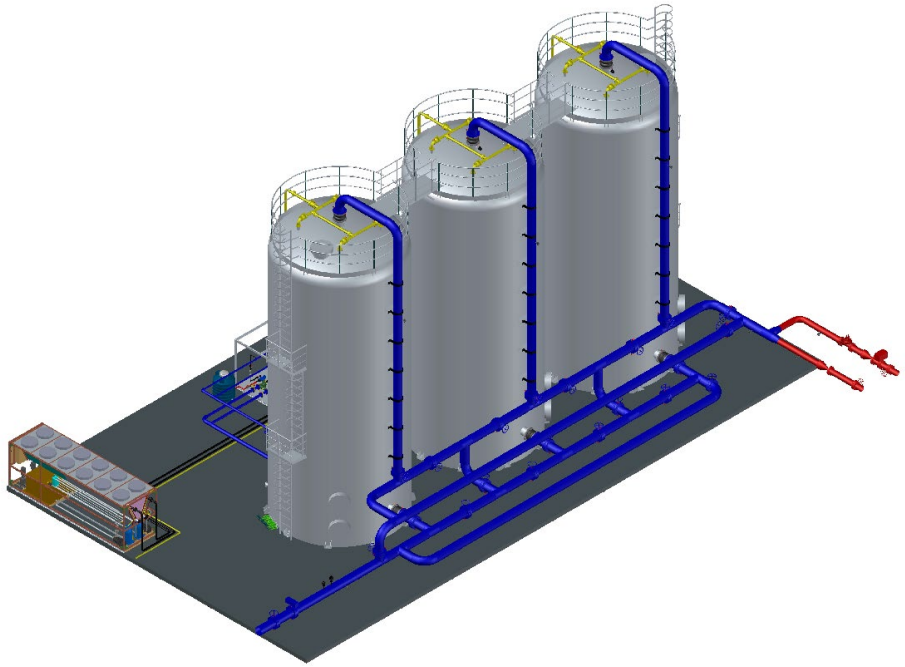
$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$



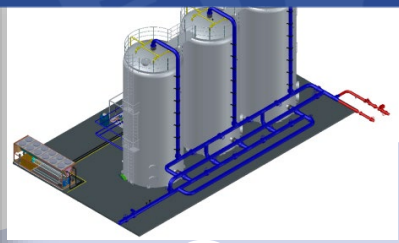
Demo Scale E-Fuel Plant

Demo Scale E-Fuel - Status

- Demo Scale E-Fuel Plant designed for a large industrial biogas plant in Denmark; expected construction and installation in 2022.
- Methanation of the CO_2 stream from one of the biogas plant's four AD reactors.
- Required electrolysis capacity 8 MW.
- Production capacity 381 Nm3/h E-Methane or >3,000,000 Nm3/y or 30 GWh/y E-Methane.



E-Fuel Up-scale plan

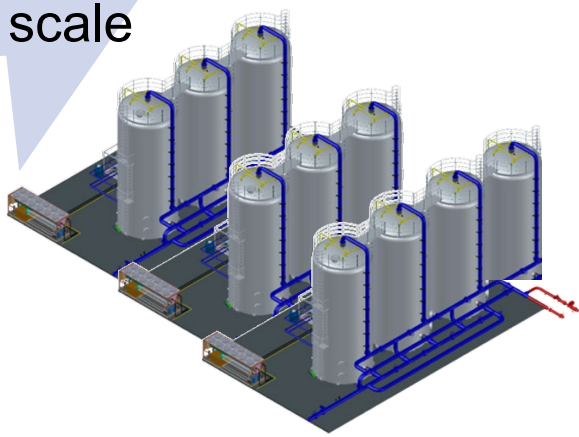


2019-2020 – Lab skala

2021 – Pilot scale

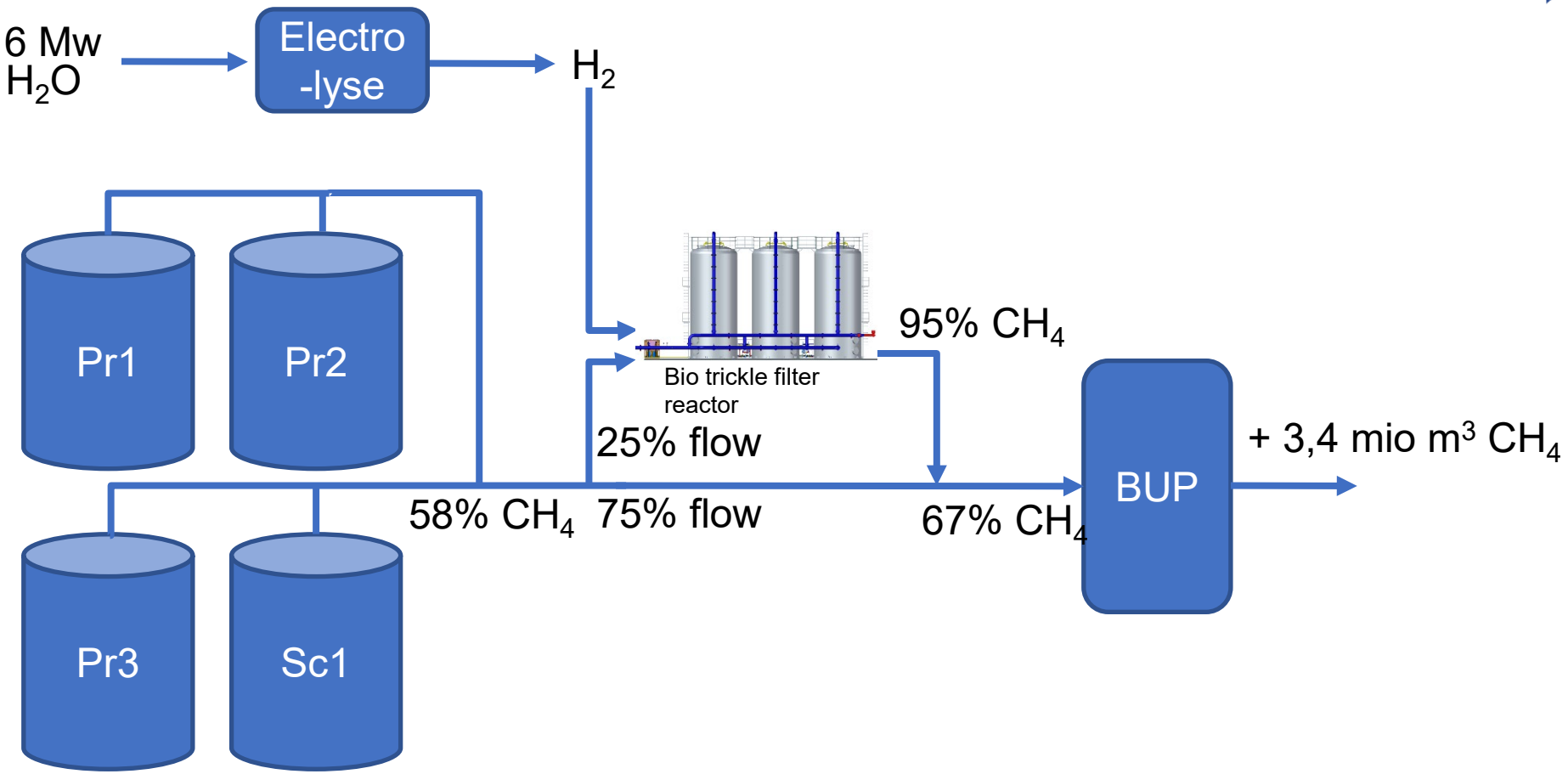
2022-2023 – Demo scale

2024 – Full scale

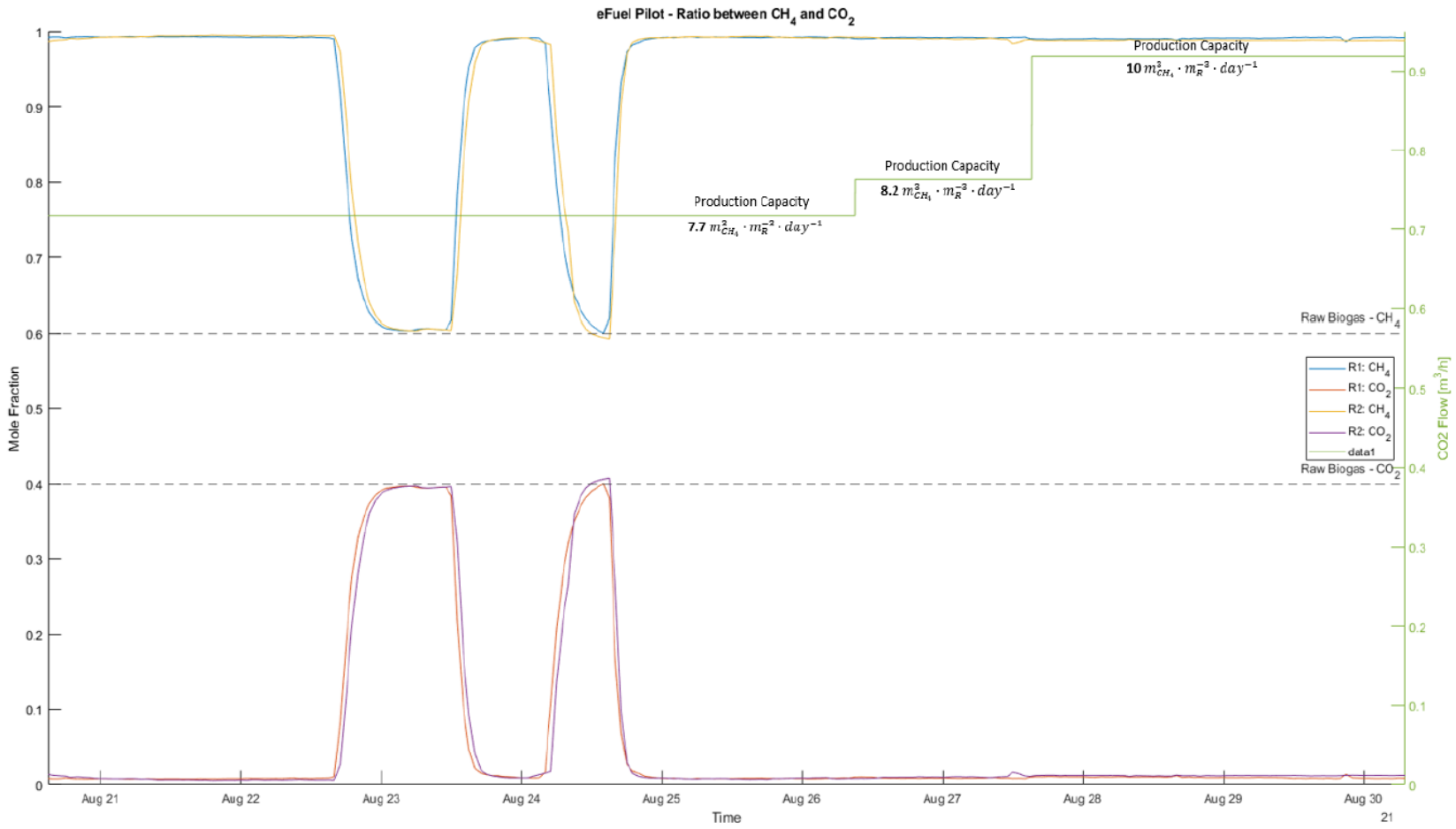


	Lab scale	Pilot scale	Demo scale	Full scale
Size [m3]	4 x 0,008	2 x1	3 x 400	10 x 400
+CH_4 [m^3 CH_4/day]	0,08	20	12.000	40.000
-CO_2 [% of normal prod.]	-	0,05%	30%	100%
Effect [from electrolyzer]	-	0,009MW	6MW	20 MW

E-Fuel Demo Plant



E-Fuel efficiency



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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
Volume of 1 ton	2.22 m3	1.26 m3
Higher heating value of 1 m3	6.6 MWh/ton or 23.8 GJ/ton	5.0 MWh/ton or 17.9 GJ/ton
Weight of 1 m3	450 kg	791 kg

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

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: 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, 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

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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

Enduser: Miller Western pulp

Sector: Paper and pulp

Location: Alberta, Canada

Year: 2017

Project: 41095

Biogas flow: 2,400 m^3/h
Biogas flow: 1,412 scfm
H_2S inlet: 15,000 ppm
H_2S outlet: 50 ppm

References OS

Client: Italthai Industrial

Enduser: KI Ethanol

Sector: Ethanol molasses

Location: Korat, Thailand

Year: 2009

Project: 41003

Biogas flow: 1,670 m^3/h
Biogas flow: 982 m^3/h
H_2S inlet: 20,000 ppm
H_2S outlet: 100 ppm

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

References MBR

Client: Thai Roong Ruang Energy (TRR)

Sector: Ethanol molasses

Location: Saraburi, Thailand

Year: 2017

Project: 41200

Biogas flow: 2,100 m^3/h
Biogas flow: 1,235 scfm
H_2S inlet: 15,000 ppm
H_2S outlet: 200 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

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