

Biological **desulfurization** and **methanation** of biogas and CO₂

Biological methanation at a large industrial biogas plant in Denmark

Hydrogen & P2X 2023

June 15th 2023

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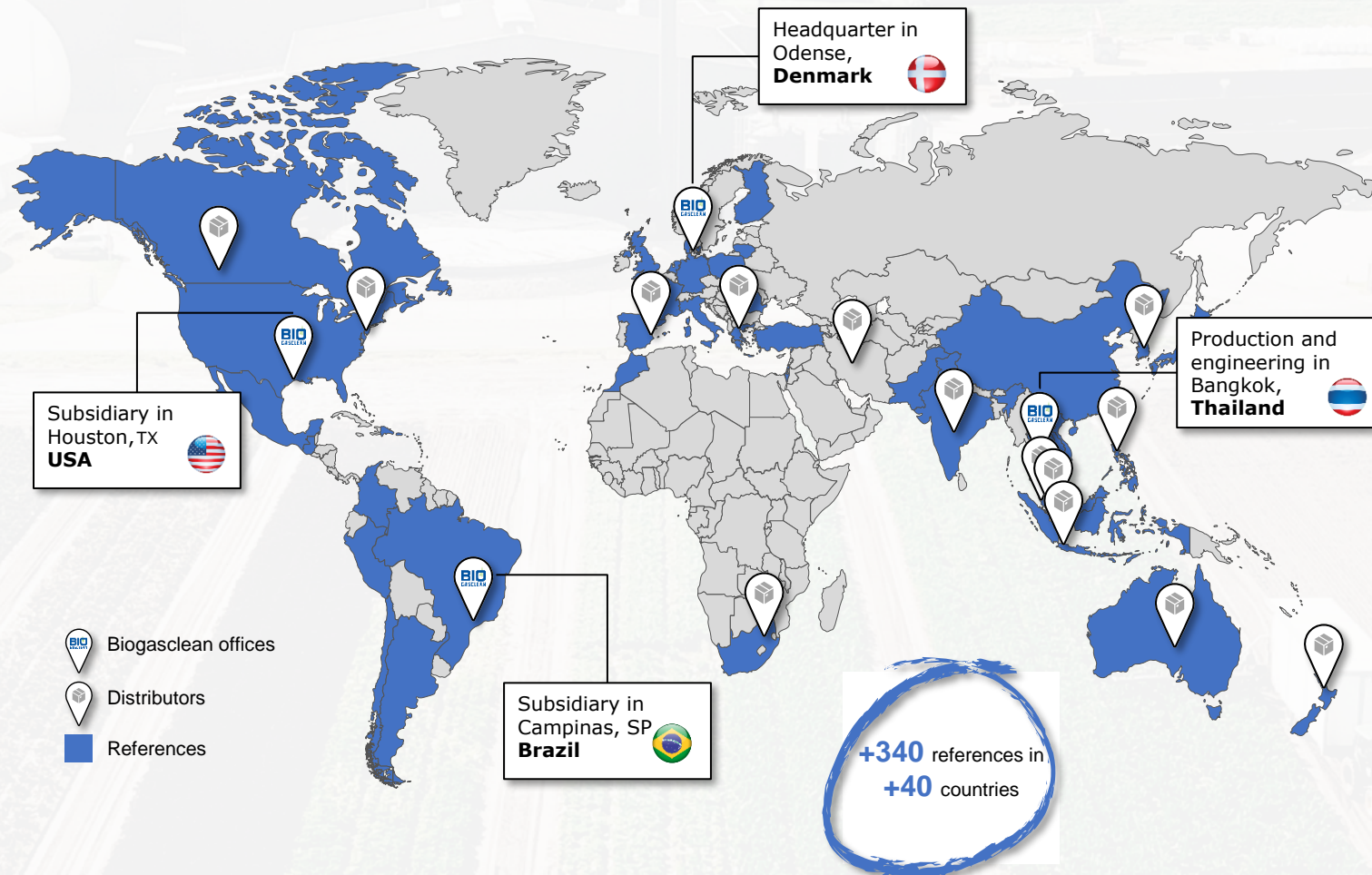
Innovative solutions for efficient
production of biogas and e-fuels

Corporate video



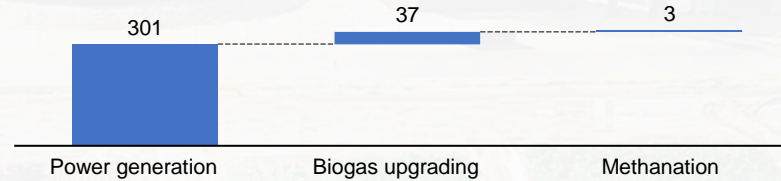
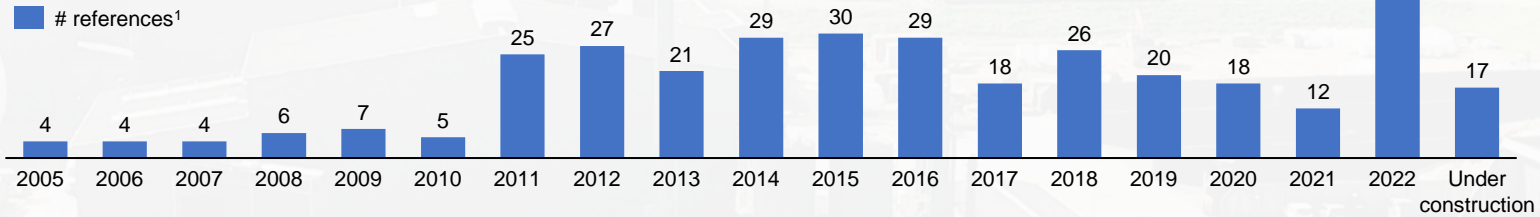
Watch online: <https://vimeo.com/530772603/1cc7ad0d1e>

Global footprint



References

No. of references per year



Power generation

By country	#	By substrate	#
Malaysia	72	Palm oil WW	138
Thailand	63	Codigestion	43
Indonesia	45	Public WWTP	36
Denmark	16	Cassava WW	34
USA	15	Food industry WW	12
India	14	Ethanol molasses	11
Other	76	Other	27
Total	301	Total	301

Biogas upgrading

By country	#	By substrate	#
Denmark	26	Codigestion	36
USA	9	Other	1
Other	2	Total	37
Total	37		

Methanation

By country	#	By substrate	#
Denmark	3	Codigestion	2
Total	3	Other	1
		Total	3

Biogasclean in key points

- Our mission is to contribute to the transformation from fossil fuels to renewable energy by development and supply of **innovative solutions** for **efficient production of biogas and e-fuels in industrial scale**.
- Biogasclean is a leading supplier of **biological desulfurization and methanation** for industrial scale biogas plants with **more than +340 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 H₂S 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 H₂S 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 **three 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

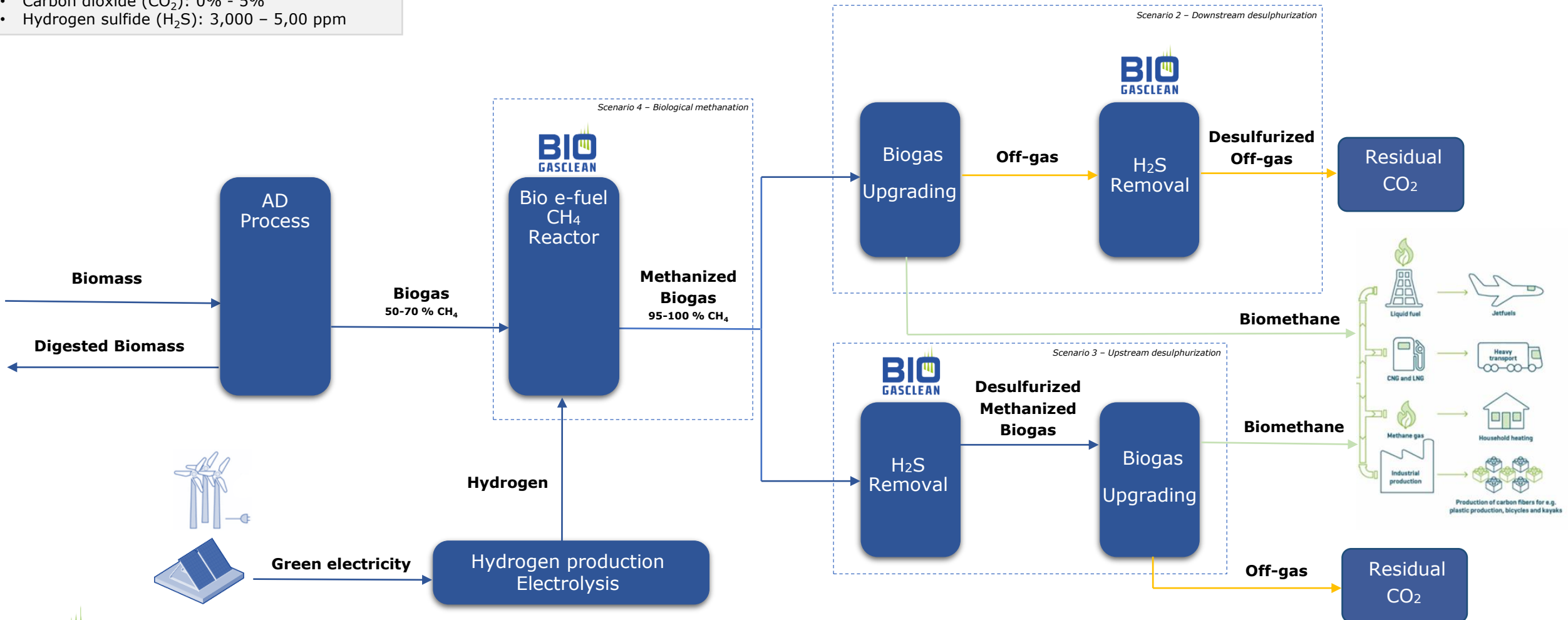
- Biogasclean has developed a biological Power-To-X technology – Bio E-Fuel - which is based on **BTR (Bio Trickling Reactor)**. Bio E-Fuel can be applied on all CO_2 sources. However, the lowest hanging fruit is biogas plants where the biogas typically consists of 55-60% CH_4 and 40-45% CO_2 . Bio E-Fuel will enable biogas plants - from the same input of organic waste streams - to raise the concentration of methane in the biogas from 55-60% to +97-98% CH_4 . With Bio E-Fuel, the production of renewable green gas will increase by up to 78%!

Technologies

Biogas plants – Methanation & desulfurization

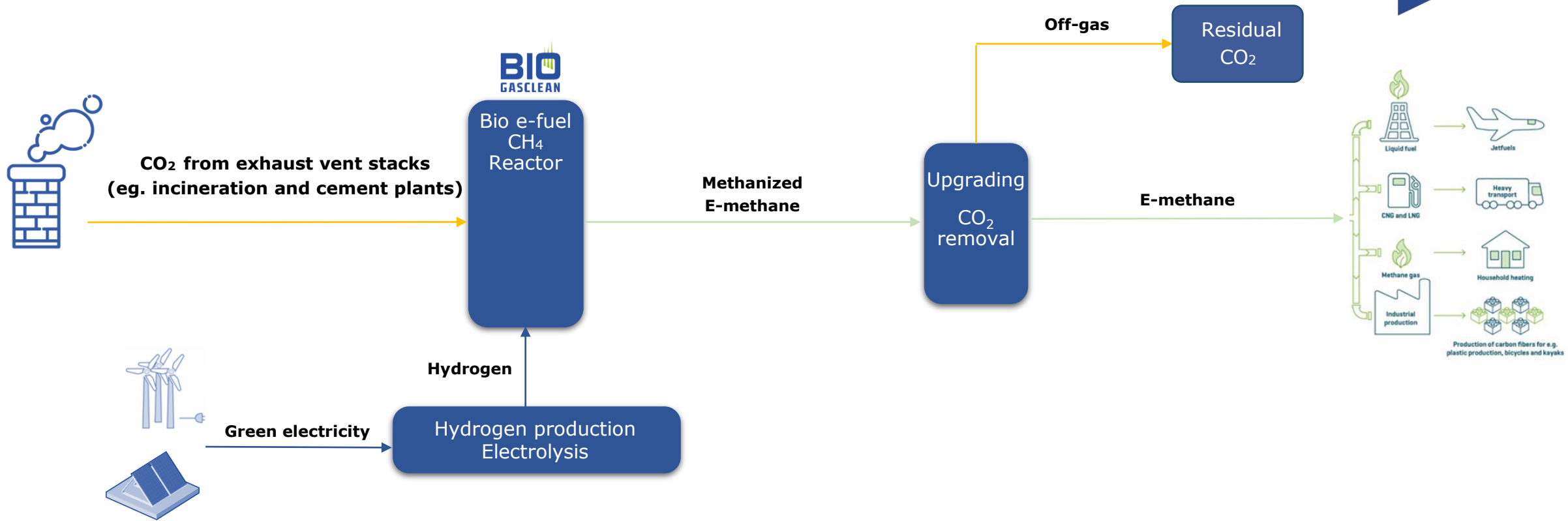
The composition of Methanized biogas is:

- Methane (CH_4): 95% - 100%
- Carbon dioxide (CO_2): 0% - 5%
- Hydrogen sulfide (H_2S): 3,000 – 5,00 ppm



Technologies

Carbon Capture & Utilization (CCU) – Methanation



Carbon Capture and Utilization (CCU) projects aim to capture carbon dioxide (CO₂) from industrial processes or from the atmosphere and convert it into useful e-fuels, such as e-methane. Sources of captured CO₂ that can be used for CCU projects include:

- I. **Power plants and industrial facilities:** Large sources of CO₂ emissions are power plants and industrial facilities such as cement and steel production, which release large quantities of CO₂ during their operations. Carbon capture technology can capture CO₂ from these sources and redirect it to CCU projects.
- II. **Direct air capture:** Direct air capture (DAC) technologies use machines to capture CO₂ directly from the atmosphere. This method can be used to capture CO₂ that is not associated with an industrial process or for which there are no other sources.
- III. **Natural carbonates:** Some natural carbonates can be mined and processed to capture CO₂, which can then be used in CCU

References QSR

Client: Nature Energy, Korskro

Sector: Grid injection

Location: Esbjerg, Denmark

Year: 2018

Project: 41228

CO₂ flow: 2,000 m³/h

CO₂ flow: 1,176 scfm

H₂S inlet: 8,000 ppm

H₂S outlet: 50 ppm



Production of 22 million m³ (777 million scf) CH₄ per year

The CO₂ is utilized in breweries

References QSR

Client: Lundsby Biogas, Vinkel

Application: Grid injection

Location: Skive, Denmark

Year: 2019

Project: 41245

CO₂ flow: 2,700 m³/h

CO₂ flow: 1,588 scfm

H₂S inlet: 6,700 ppm

H₂S outlet: 30 ppm



References QSR

Client: E.ON - Greenlab

Application: Grid injection

Location: Skive, Denmark

Year: 2020

Project: 41247

CO₂ flow: 2,250 m³/h

CO₂ flow: 1,323 scfm

H₂S inlet: 7,400 ppm

H₂S outlet: 50 ppm



References QSR

Client: Nature Energy, Koeng

Application: Grid injection

Location: Koeng, Denmark

Year: 2022

Project: 41287

CO₂ flow: 2,500 m³/h

CO₂ flow: 1,470 scfm

H₂S inlet: 7,000 ppm

H₂S outlet: 50 ppm



Bio E-Fuel Up-scale plan



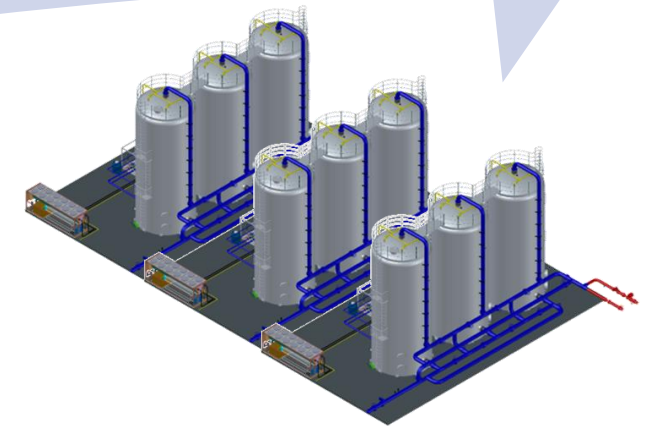
2019 - Lab scale



2021 – Pilot scale



2022-2023 – Full scale



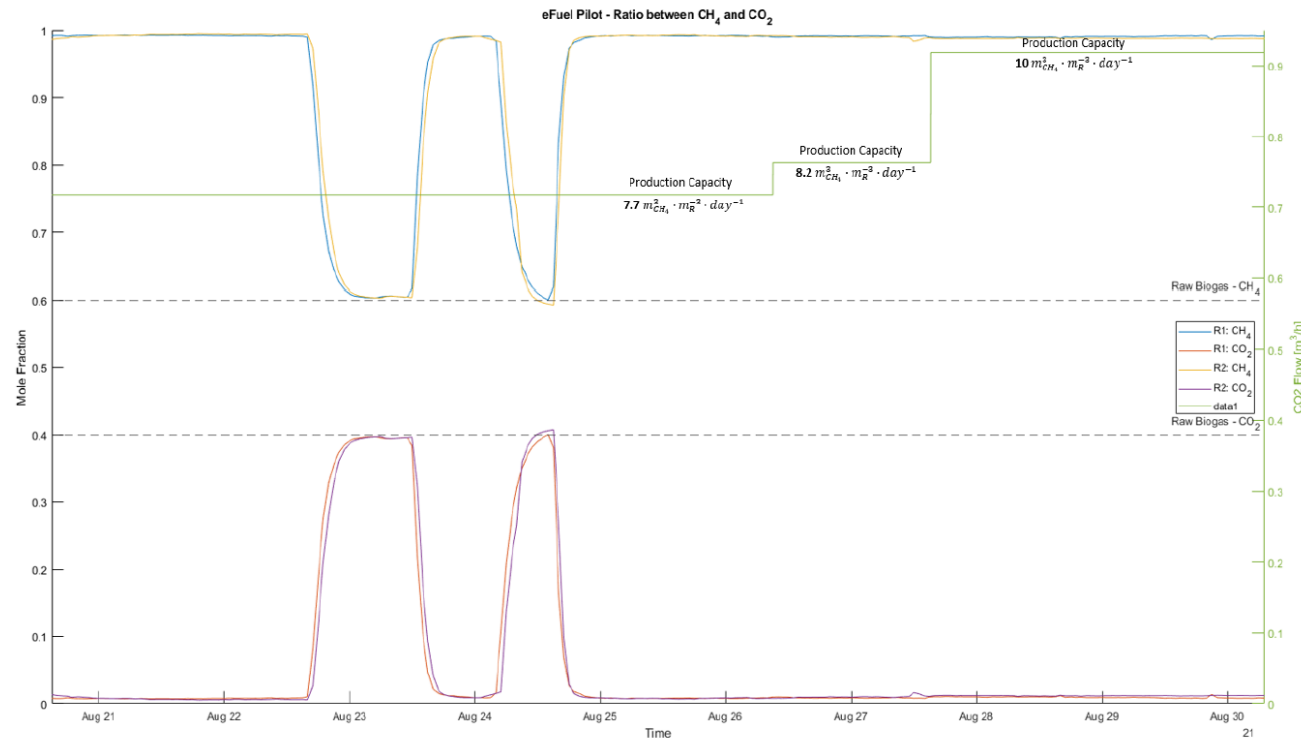
2024 – Multiple full scale



	Lab scale	Pilot scale	Full scale	Multiple Full scale
Effective reactor volume (m ³)	4 x 0.008	2 x 1	3 x 300	9 x 400
E-methane (m ³ CH ₄ /day)	0.3	20	9,000	36,000
E-methane at full load (GWh/year)			32	130
Capacity of electrolyzer (MW)			7 MW	30 MW

Bio E-Fuel Pilot Plant

- The 2 reactors are each 1 m³, i.e. totally 2 m³ reactor volume, in operation from Q1-21 to Q1-23.
- The product gas is composed of >95% CH₄ and <5% CO₂ and H₂.

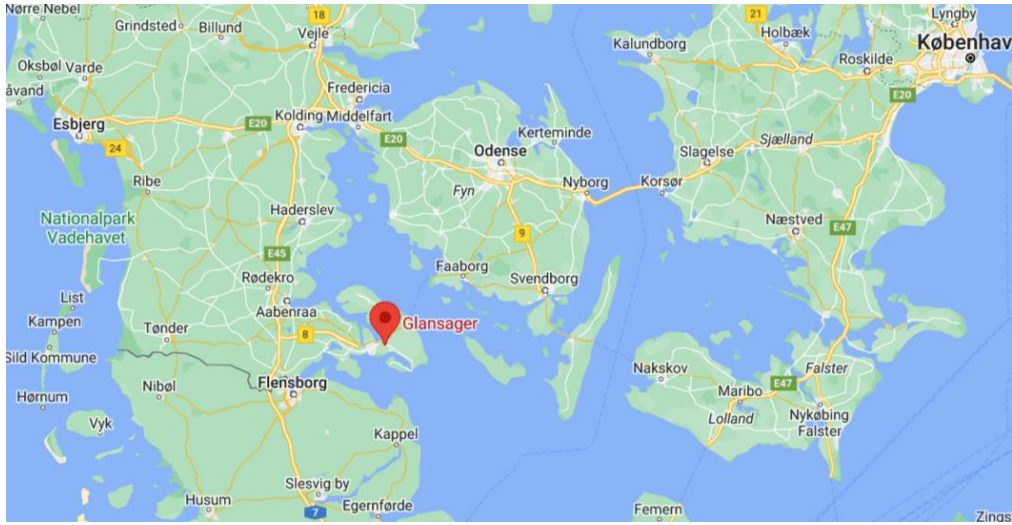


PTX Plant at Nature Energy, Glansager - Overview

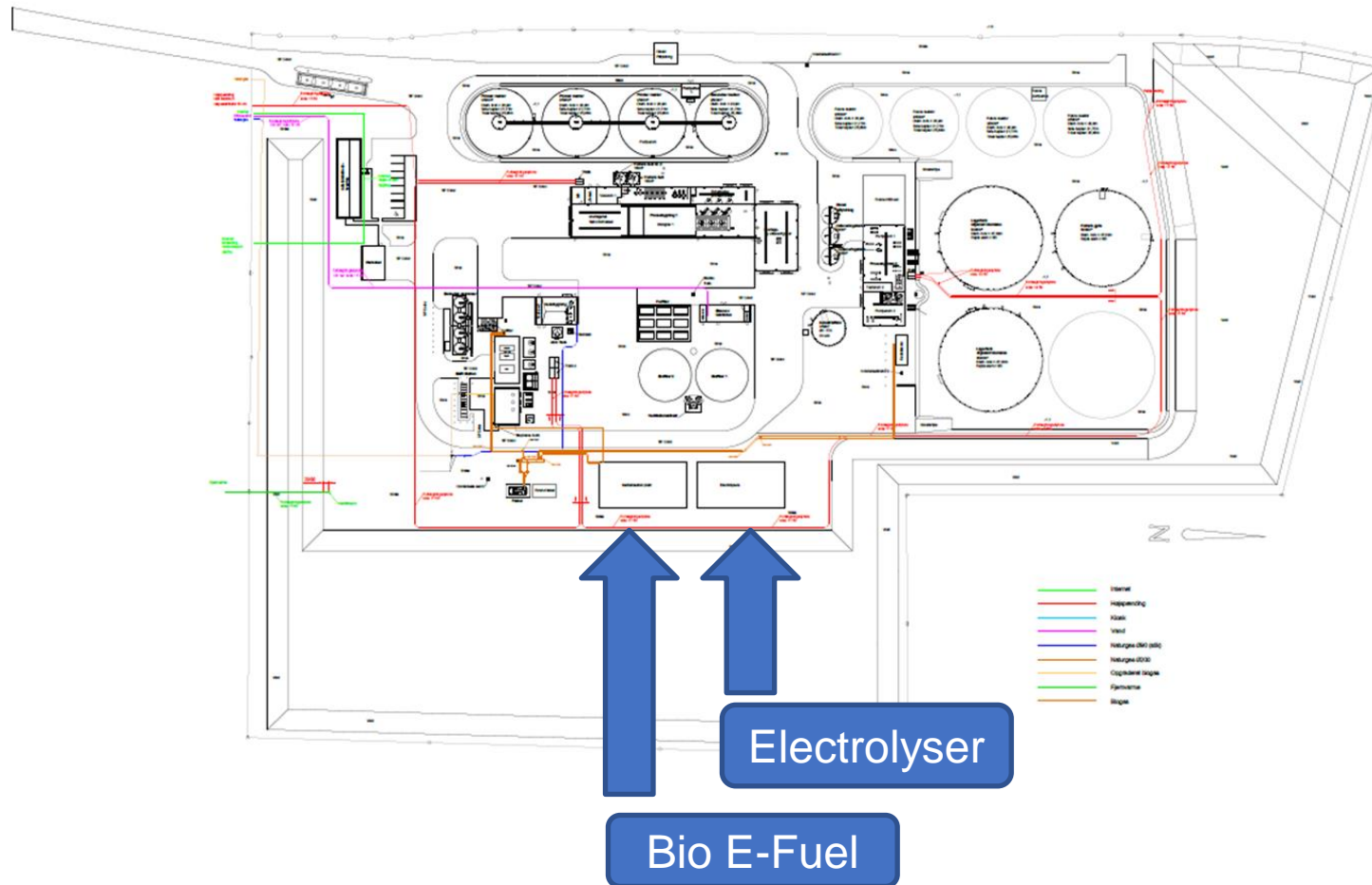
- Nature Energy's Board of Directors asked in the Summer 2021 the Executive Management to prepare an investment decision for a Full Scale PTX Plant at Glansager Biogas Plant in Denmark.
- Nature Energy and Andel, a leading Danish distribution and energy company, agreed to execute the PTX project in a 50/50 Joint Venture.
- Nature Energy's main role is overall engineering, permitting and supply of the biological methanation plant with Biogasclean as supplier.
- Andel's main role is grid connection and supply of the electrolysis plant with Stiesdal Hydrogen and BWSC as suppliers.
- The project has been supported by "Business Lighthouse South" with funds from EU's Regional Development Fund.



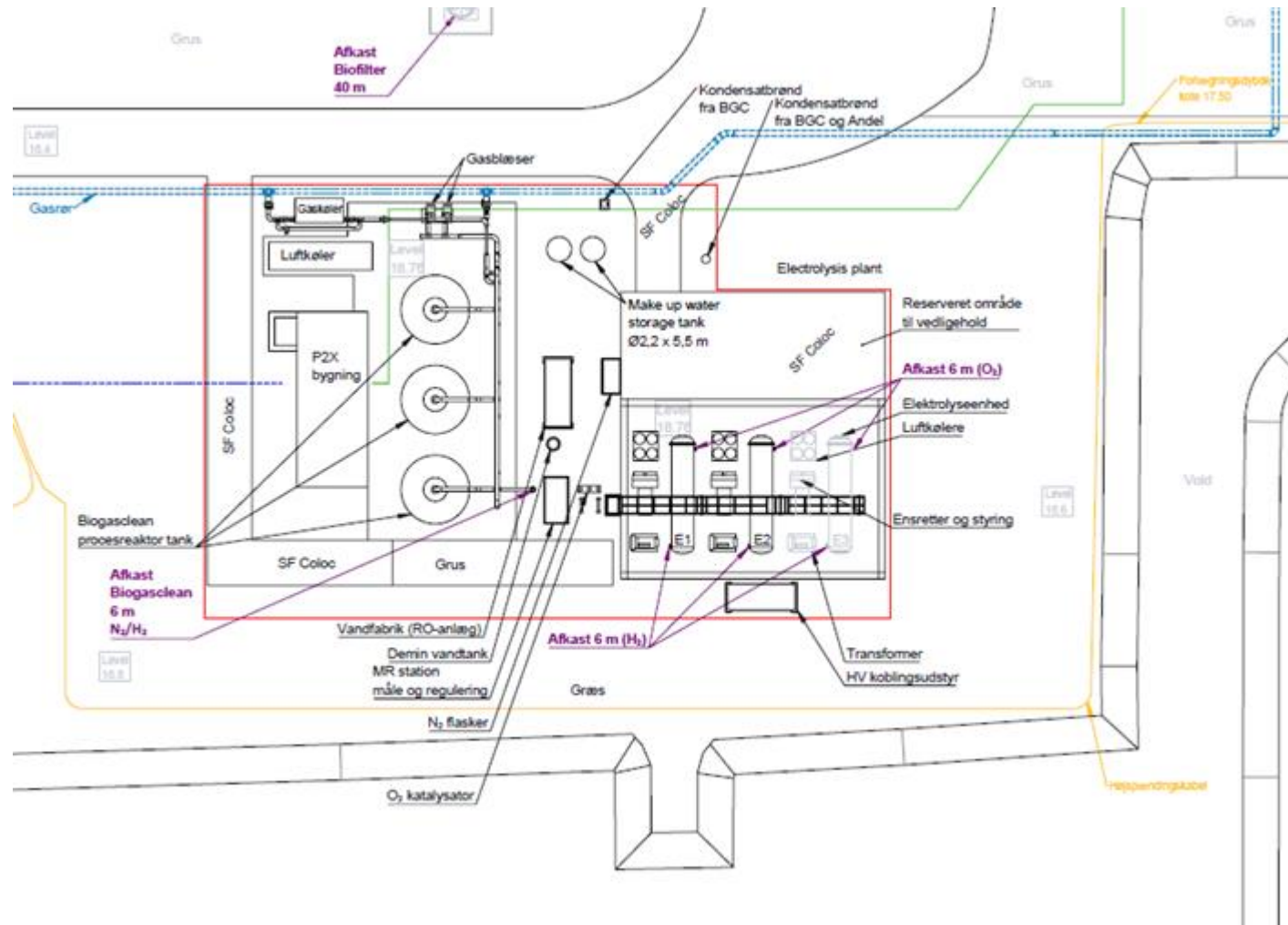
P2X Plant at Nature Energy, Glansager - Location



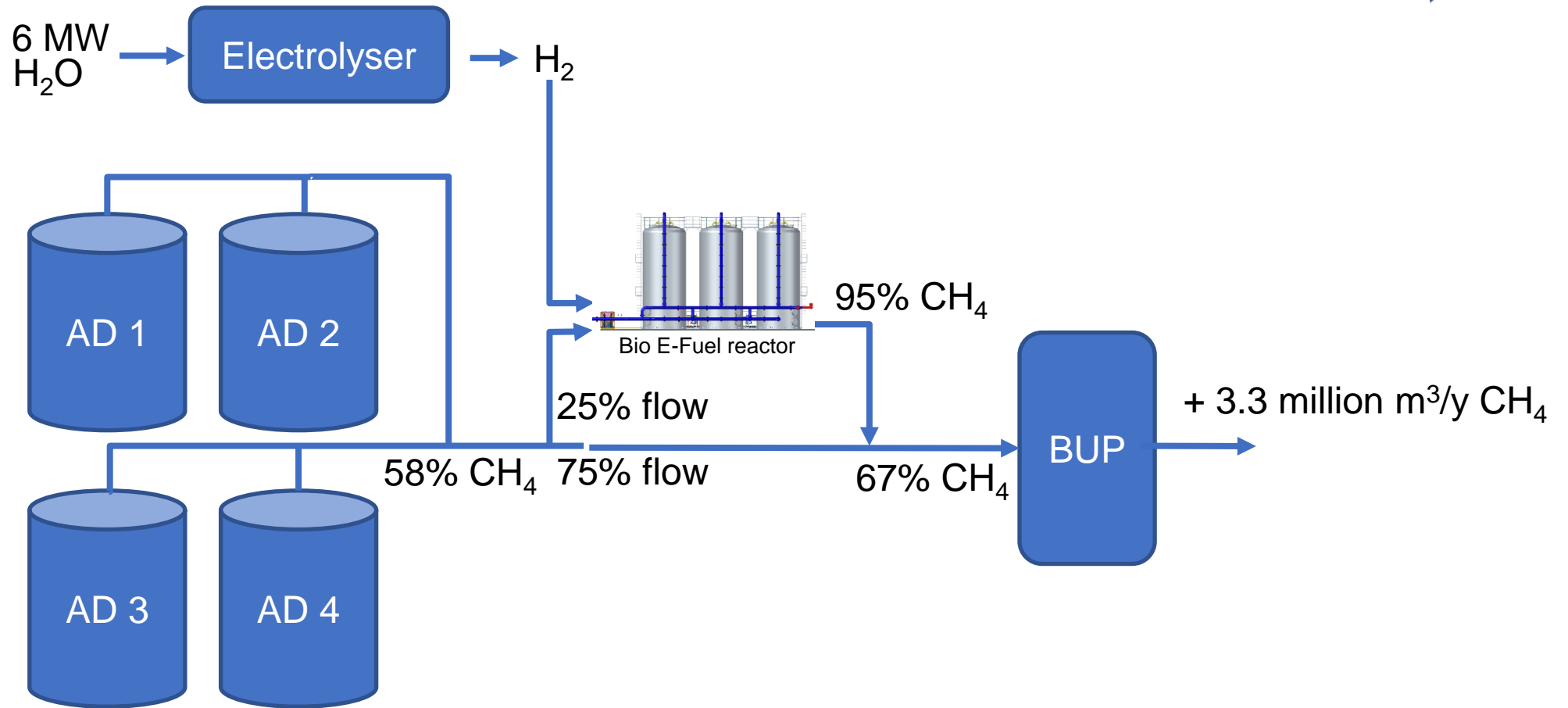
PTX Plant at Nature Energy, Glansager – General lay-out



PTX Plant at Nature Energy, Glansager – Detailed lay-out

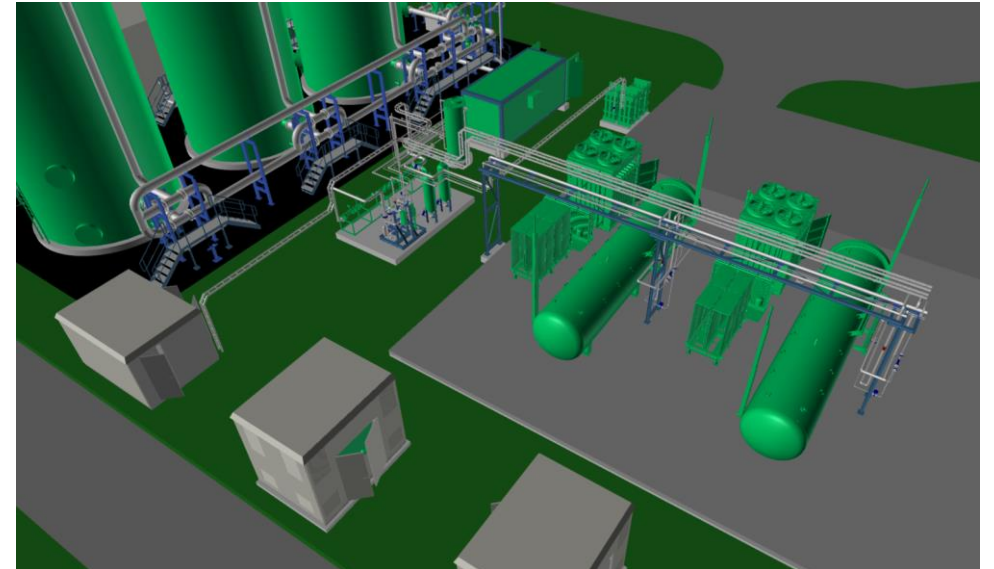


PTX Plant at Nature Energy, Glansager – Flow diagram



Electrolysis & grid connection

- The electrolysis plant will comprise 2 pcs. each 3 MW HydroGen Electrolyzers from Stiesdal Hydrogen. First unit will operate from Summer 2023 and second unit from Fall 2023. The plant is prepared for a later extension with a third unit.
- The HydroGen Electrolyzer is based on conventional alkaline electrolysis made of conventional metals; i.e. not rare metal catalysts.
- The electrode stack system is of a novel design that integrates cooling and reduces losses.
- The electrode stack is located in a pressurized tank, allowing hydrogen production directly at pressure.
- Air cooling; heat may in the future be used for district heating.
- City water supply; use of technical water to be investigated.
- Grid connection comprises 4 MW - 15/0.69 KV for each electrolyser unit.



Bio E-Fuel Plant I

- Biogasclean's Bio E-Fuel plants are based on a scalable and modular design with one or more tanks in stainless steel or reinforced fiberglass.
- The first full scale Bio E-Fuel Plant is under installation and will start operation in Summer 2023.
- At Glansager the CO₂ stream from one of the biogas plant's four AD reactors is methanized.
- Production capacity: Up to 381 Nm³/h E-Methane or 3,300,000 Nm³/y or 33 GWh/y E-Methane.



Bio E-Fuel Plant II

- The Bio E-Fuel plant comprises 3 pcs. insulated tanks in stainless steel filled with a random packed packing material.
- The technical equipment is skid mounted and comprise a.o. liquid supply and drain system, heating and cooling system and PLC based control system as well as gas analyzers, gas detectors, fire alarm system, etc. installed in a Technical House.
- Gas blowers and air cooler are located outside.
- The piping system for gas and liquid is made in stainless steel.



PTX Plant at Nature Energy, Glansager - Achievements

- During the past 3-4 years several large scale PTX projects have been announced, but many of them are still under development and delayed.
- Nature Energy's and Andel's PTX project in Glansager will probably be the first larger PTX project in operation – at least in Denmark - where green hydrogen is processed to a more suitable energy carrier such as e-methane, e-methanol or e-ammonia.
- The PTX project in Glansager has been completed in a remarkably short time.
- The idea for the project was launched in the Summer of 2021. Nature Energy and Andel have - together with their partners and authorities – been able to complete engineering, permitting, production and installation within 24 months.
- The PTX project will start operation in the Summer 2023.



Bio E-Fuel – The cost effective PTX solution for biogas plants

- **Bio E-Fuel can be applied everywhere where you have a CO₂ source**; however, it is a **perfect fit for biogas plants** as the CO₂ and the infrastructure for methane production are already available.
- Biogas consists of 55-60% CH₄, 40-45% CO₂ and 3-5,000 ppm H₂S; the cheapest source of biogenic CO₂.
- Bio E-Fuel increases the output on biogas plants from 55-60% to +97-98% CH₄; i.e. up to 78% more biomethane produced from the same amount of organic substrate.
- Bio E-Fuel can process the raw biogas or CO₂ flow without any prior removal sulfur or other impurities.
- Operation at low pressure (<200 mbar) and low temperatures (<60°C) gives low OPEX.

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