Biological Methanation: An industrial-scale application for energy storage, CO2 reuse and renewable fuel

Webinar BioRECO2VER – 23 November 2021
Value from CO_2: The power of Biotechnology

Jose Rodrigo, Group Leader Innovation

Electrochaea

Energy storage, a new challenge for renewable energy

The Archaea Transform Virtually Every Molecule of CO2 into CH4 Without Using Fossil Fuel

Electrochaea

Electrolysis is the process that produces hydrogen.	Renewable hydrogen is synthesized in the electrolyser from water and renewable electricity.

Electrolysis

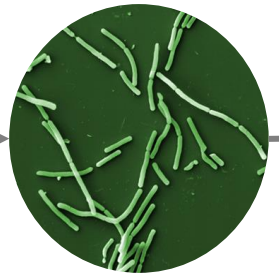
$4\ H_2O + e^- \rightarrow 4\ H_2 + 2\ O_2$

water electricity hydrogen oxygen

Carbon Dioxide

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

carbon dioxide hydrogen methane water

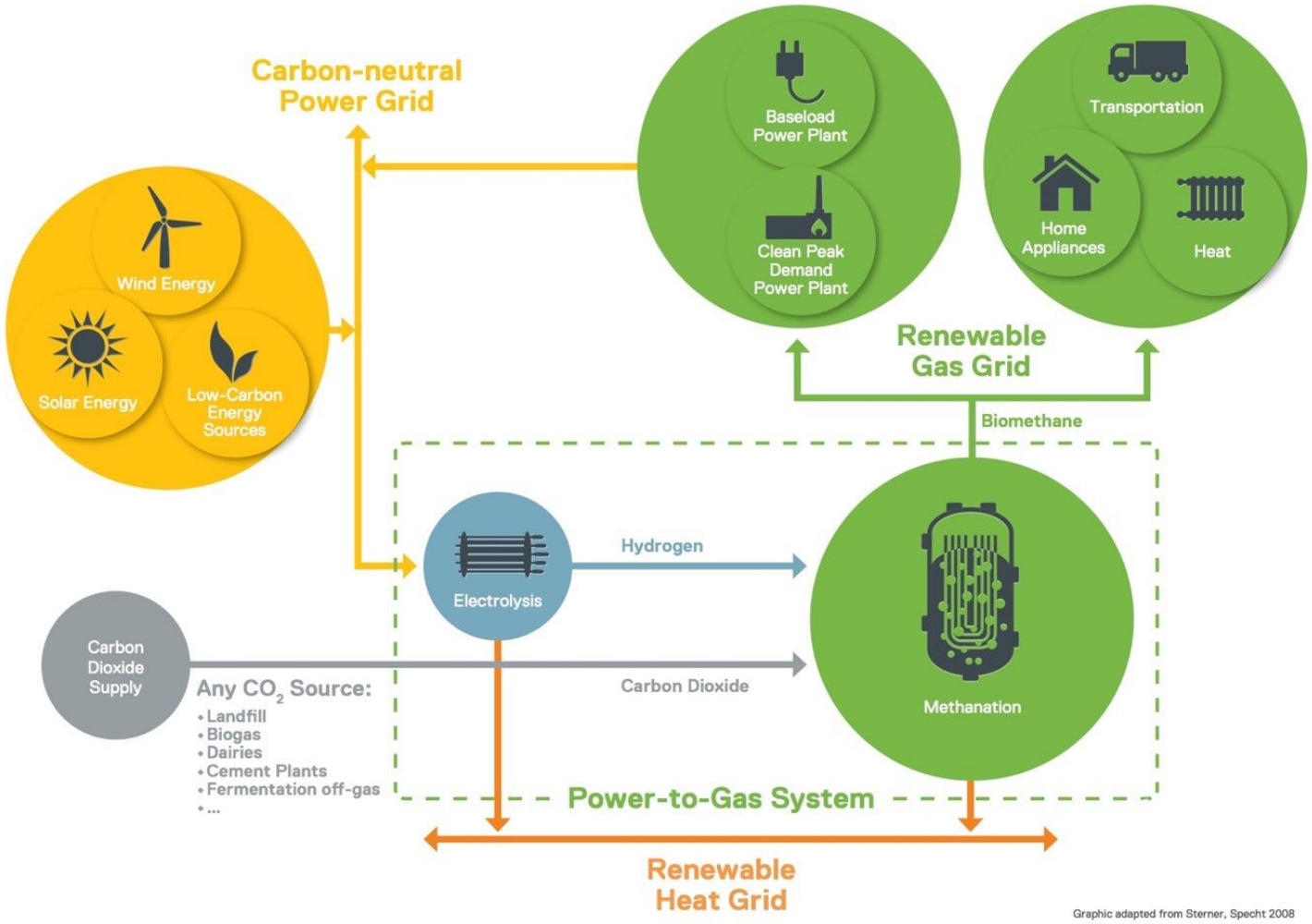


Methanation

The methane is synthesized in each cell of the biocatalyst. There are trillions of cells working to produce methane in the reactor.	The biocatalyst is a single-celled microorganism that belongs to the domain of Archaea.	The cells are self-replicating in the reactor; the system is sustainable

Methanation Integrates Renewable Power Across Sectors

Storage of CO_2 and renewable power into chemical bonds of CH_4

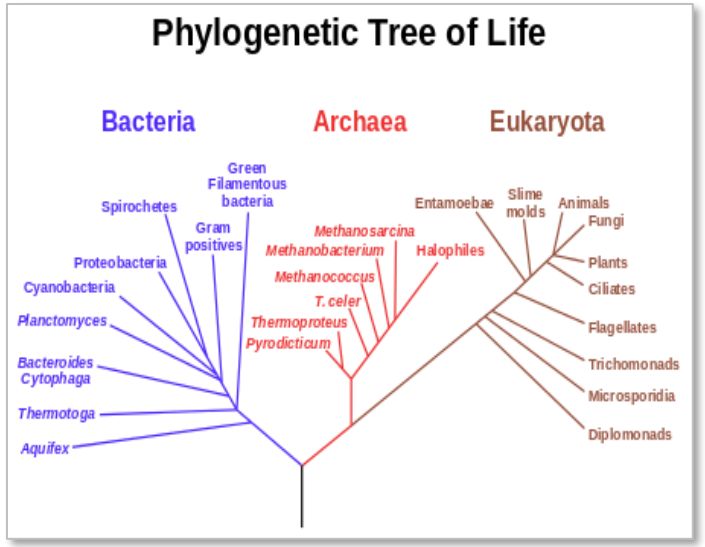


Power-to-Gas promotes:

- Renewable gas production
- Renewable energy storage
- Large-scale CO_2 mitigation
- Sector Coupling
- Lower CI for gas and power

Unique Features of Electrochaea's Biocatalyst

Productive, effective, responsive, selective, robust, simple & proprietary

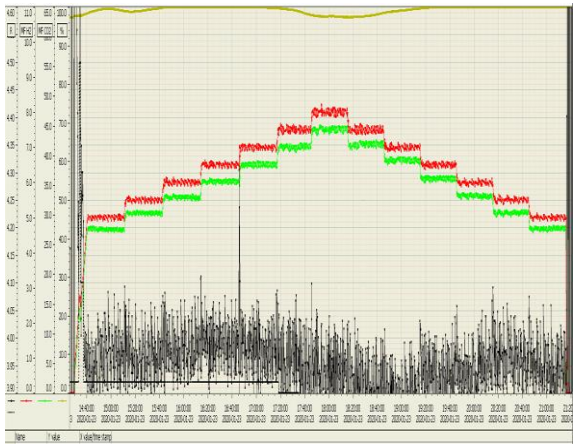


- **Methanogenic Archaea:**
  - 3.5 billion year-old single-celled organisms
  - Described only 30 years ago by pioneers Prof Carl Woese (Illinois) and Prof Karl Stetter (Regensburg)
  - Specialized „tiny chemical plants" pre-engineered by nature
  - „Archaeal diet": CO_2 and H_2 (no other carbon source needed!), 65°C
- **Electrochaea biocatalyst:** proprietary, selectively evolved, highly efficient, optimised Archaea

Unique Features of Electrochaea's Biocatalyst

Productive, effective, responsive, selective, robust, simple & proprietary

Unique Biocatalyst
- Patented strain
- Optimized methane productivity (20 x incease)
- Outstanding robustness
- Fast start/stop cycles



Productive	**98.6%** of carbon goes into **methane**
Effective	**VVD* of 850**, H_2 mass-transfer limited
Responsive	**Quick** return to methane production within seconds/minutes
Selective	**100% methane**, no intermediates
Robust	**Tolerant** to oxygen, H_2S, CO, sulfate, ammonia, particulates
Simple	**Moderate** temperature range (60-65°C) and pressure (1-10 bar)
Proprietary	**Patented biocatalyst** developed by L. Mets is licensed exclusively to Electrochaea by the University of Chicago

*VVD = volumes of gas per volume of reactor per day (24-hr)

International and Multidisciplinary Team

Highly Motivated, Skilled and Multidiciplinary Team

Biology/Chemistry/Engineering – Commercial Applications – Business Development

Rapid Technology De-risking and Scale-up

50 MW
10 MW
1 MW
50 kW
1 kW
n/a
Power Input

50 MW Commercial-Scale

Baker Hughes and Electrochaea joint scale-up activity – Combination of biomethanation and post-combustion carbon-capture technologies

10 MW Commercial-Scale

Scale-up for first commercial biomethanation plant co-funded by EIC Accelerator program

Commercial-Scale Field Trial

Preparing for market entry with a commercial-scale demonstration unit, using an optimized reactor, Copenhagen, Denmark

Pre-Commercial Field Trial

Process demonstration in a 5m³ stirred tank bioreactor using raw biogas, Foulum, Denmark

Lab-Scale Field Trial

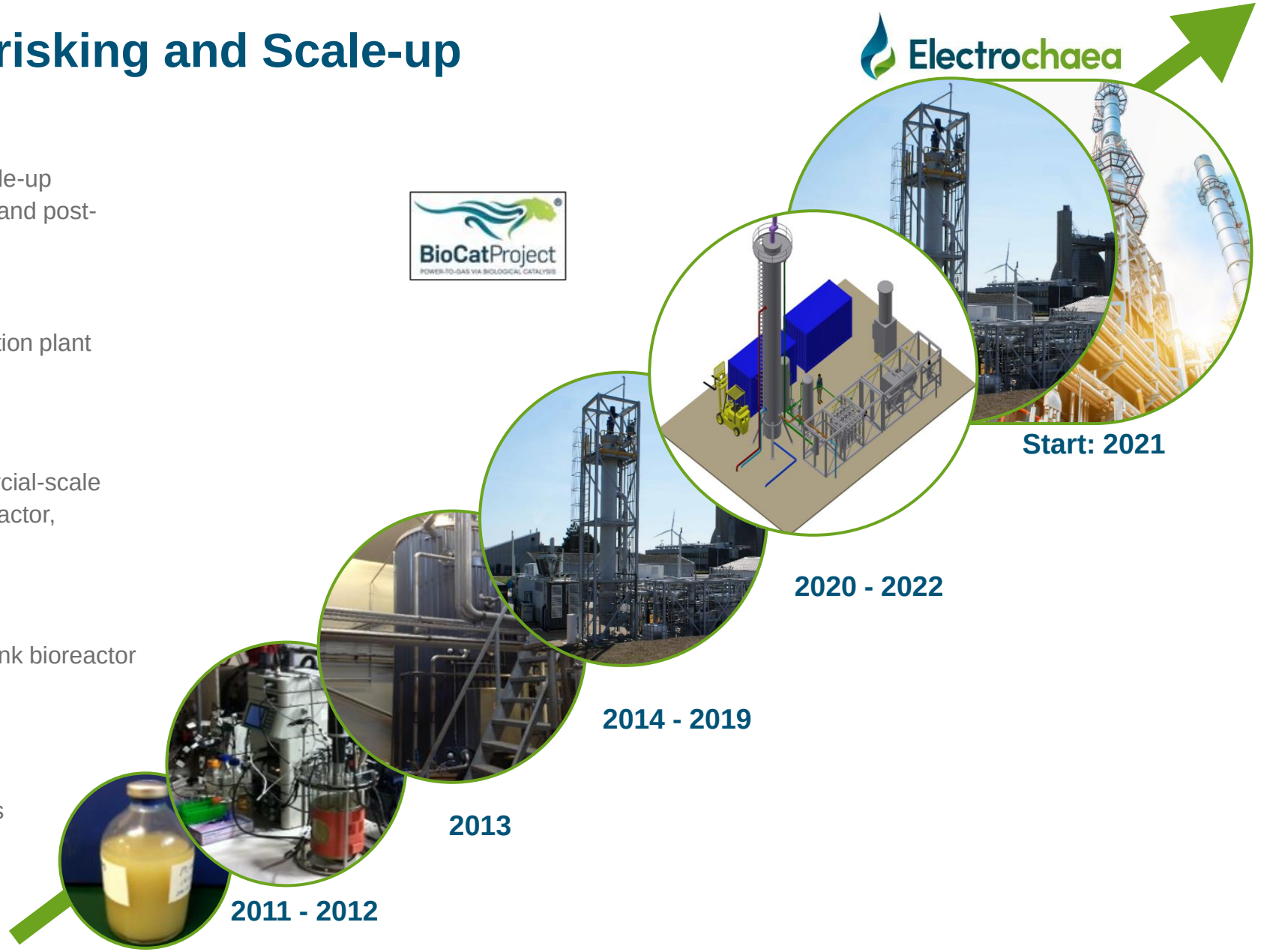
Biocatalytic capability test with raw biogas

Basic Research

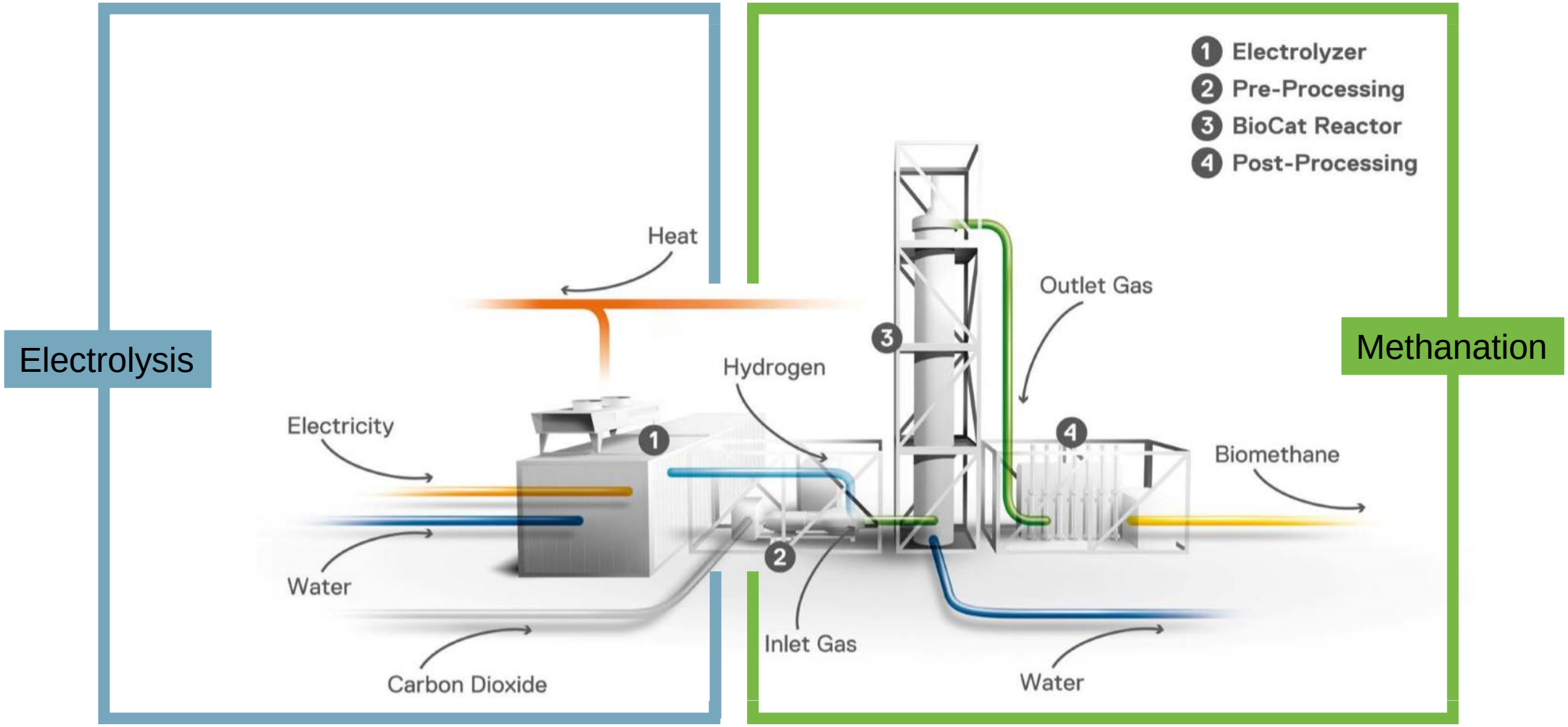
In Dr. Mets' laboratory at the University of Chicago

Electrochaea

BioCatProject
POWER-TO-GAS VIA BIOLOGICAL CATALYSIS



A Scalable and Simple System Design



Our Technology in Commercial Scale Pilot Plants

De-risking and scale up work

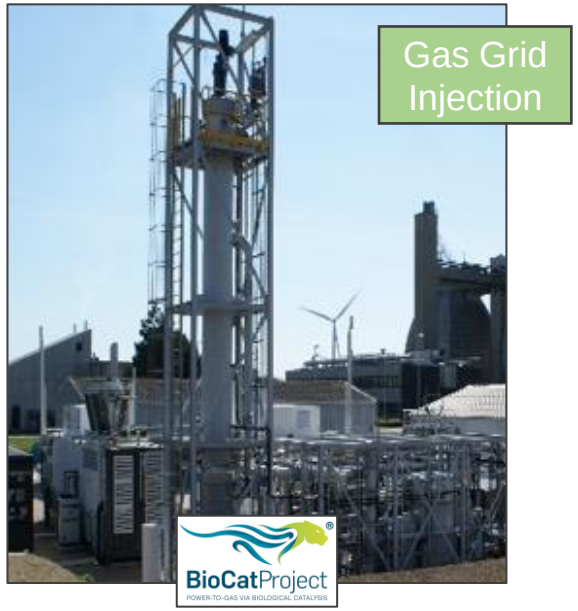
0.25 MWe
Golden, Colorado, US
July 2019

- ✓ Commissioning completed
- ✓ 1st US biological methanation
- ✓ High pressure (18 bar)
- ✓ Project support SoCal Gas, NREL (US DOE)

0.7 MWe
Solothurn, Switzerland
May 2019

- ✓ Gas grid injection within 96h
- ✓ Operation >1200h, 17 216 Nm³ RNG injected
- ✓ Automated operation
- ✓ Commercial design
- ✓ Project support EC (H2020), RES
- ✓ Click here for a virtual tour of Solothurn

1 MWe
Avedøre, Denmark
April 2016



- ✓ WWTP site integration
- ✓ Flexible operation, load following
- ✓ 1st grid scale demonstration
- ✓ Project support EUDP, Energinet, HMN, AUDI, Insero, Hydrogenics, BioFos

1MWe Demonstration Plant Achievements

Electrochaea technology feedstock flexibility demonstrated by pilot facility

CO_2 Operation

1 MW electrical power

200 Nm^3/h H_2

50 Nm^3/h CO_2

Heat 320 kW

Synthetic Biomethane 50 Nm^3/h

grid

Biogas Upgrade

1 MW electrical power

Biogas

200 Nm^3/h H_2

50 Nm^3/h CO_2 (from Biogas)

75 Nm^3/h CH_4 (from Biogas)

Heat 320 kW

Synthetic Biomethane 50 Nm^3/h

Organic Biomethane 75 Nm^3/h

grid

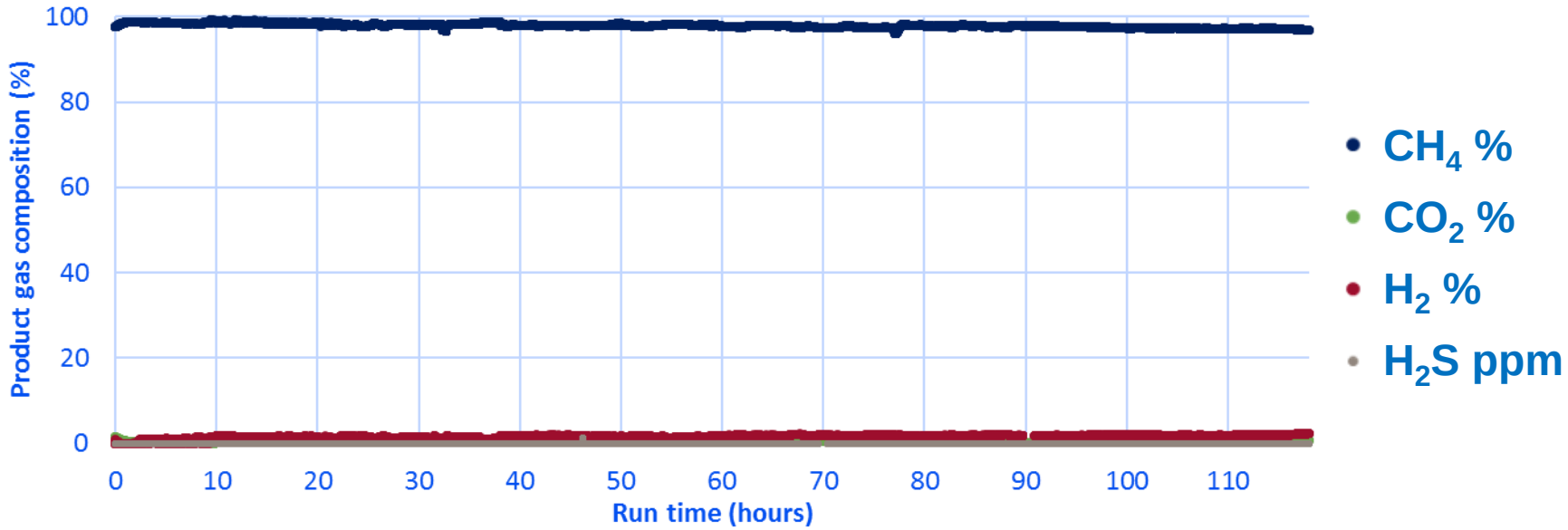
Horizon 2020 funding

Our Accomplishments

1 MWe Biocat Plant in Avedøre, Denmark

Our propietary Archaea Produce Grid Quality Gas

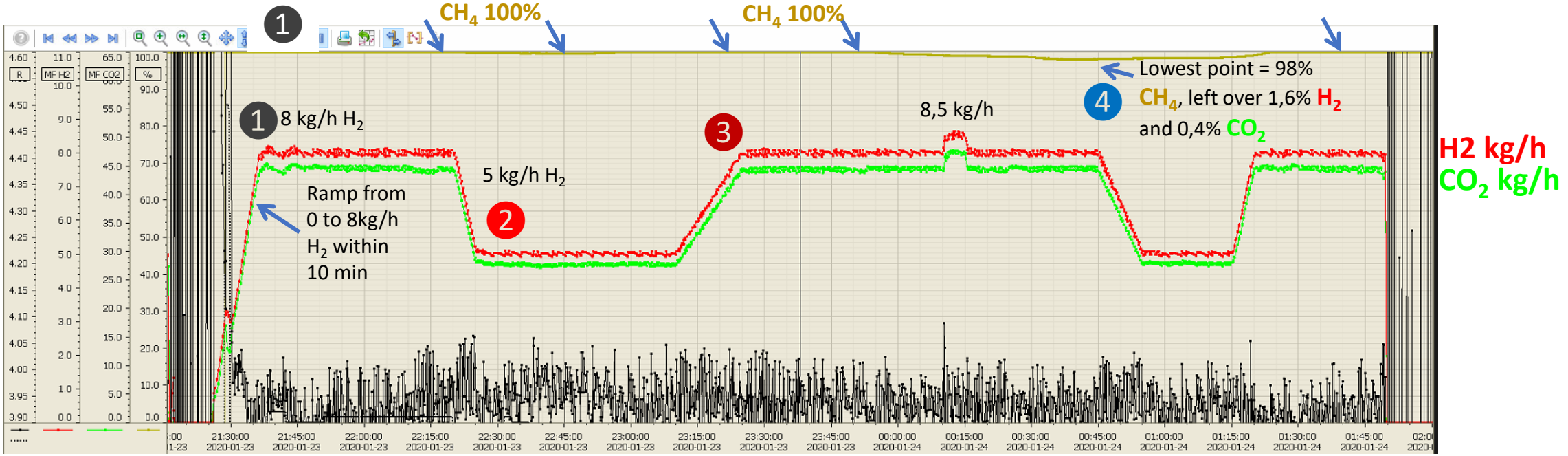
OD: 50 | **pH:** 7.5 | **Mixing energy:** 1.2 kW/m³culture | **Pressure:** 9 bar | **Flows:** H2: 67 Nm³/h & Biogas: 42 Nm³/h



Measurement	Average product gas BioCat	Required value for grid injection
CO_2 mole % (Carbon dioxide)	1	Max. 3,0
CH_4 mole % (Methane)	97	Min. 97
H_2S (Hydrogen Sulfide) mg/ m_n^3	Under detection limit	Max. 5
H_2 mole % (Hydrogen)	2	Max. 2

Highy Flexible and Responsive System Operation with >98% CH_4 in Product Gas

- Electrochaea's biocatalyst produces grid-quality gas through start-up, ramp-up and ramp-down of the methanation process in minutes, without post-reactor gas purification



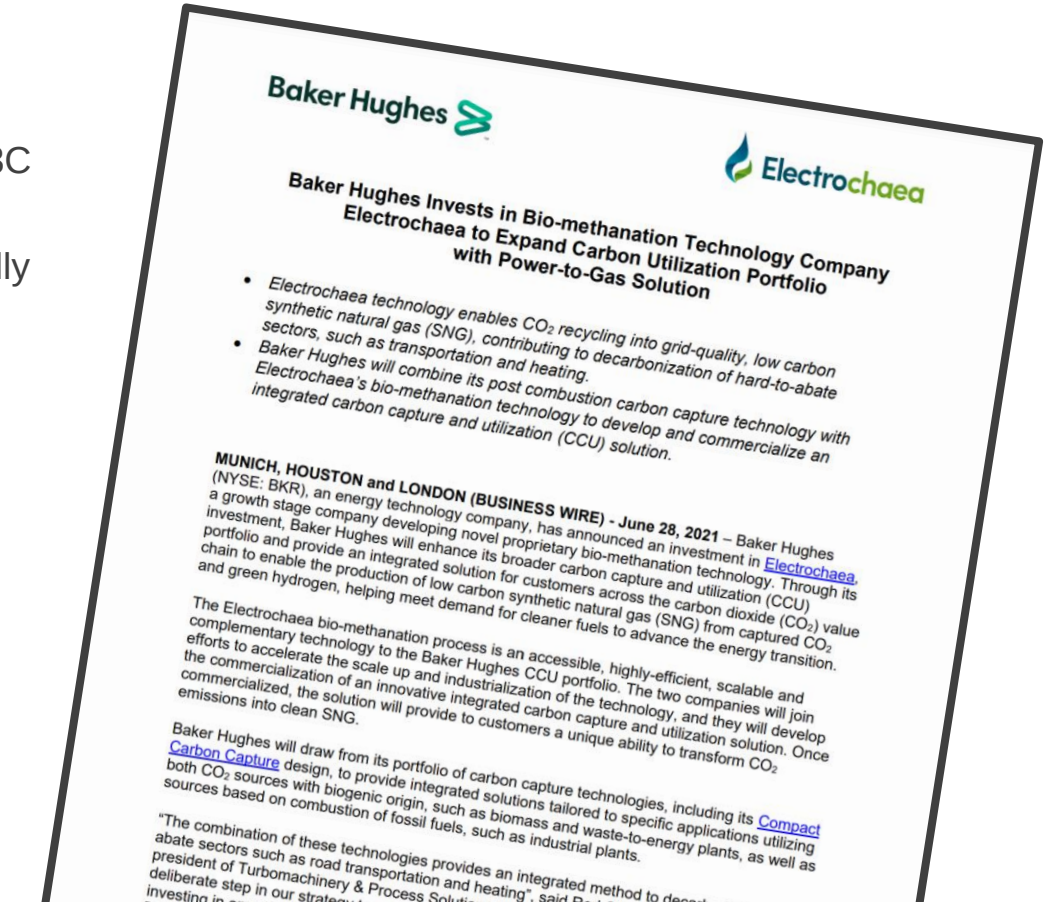
1. Start-up within minutes, **CH_4 production achieves designed scale of the test performed**
2. Ramping down H_2 and CO_2 flow, **no change in product gas quality**
3. Ramping up H_2 and CO_2 flows, **no change in product gas quality**
4. CO_2 conversion is **not affected by change in input flows**

Store&Go project, Switzerland

Investment in Electrochaea

- Baker Hughes' investment **strengthens Electrochaea's position as a leading provider of Power-to-Methane** technology for carbon and energy storage.
- Baker Hughes and Electrochaea will jointly develop and commercialize an innovative **integrated carbon capture and utilization solution** for specific applications utilizing both biogenic and industrial CO_2 sources.

- **Baker Hughes' Expanding CCU Portfolio:**
  - Baker Hughes has announced several investments in CCU (carbon capture utilization) over the last several months, including acquisition of 3C and a technology license from SRI.
  - These investments build on an existing portfolio of technologies, especially chilled ammonia.
  - These technologies will offer applications in a wide range of industries, including CO2 from biomass, waste-to-energy plants, and fossil-fuel combustion.
- **Energy Industry – Core Capabilities:**
  - Power generation efficiency, uptime
  - Compression performance
  - Industrial controls, cybersecurity



Baker Hughes Electrochaea

Baker Hughes Invests in Bio-methanation Technology Company Electrochaea to Expand Carbon Utilization Portfolio with Power-to-Gas Solution

- *Electrochaea technology enables CO_2 recycling into grid-quality, low carbon synthetic natural gas (SNG), contributing to decarbonization of hard-to-abate sectors, such as transportation and heating.*
- *Baker Hughes will combine its post combustion carbon capture technology with Electrochaea's bio-methanation technology to develop and commercialize an integrated carbon capture and utilization (CCU) solution.*

MUNICH, HOUSTON and LONDON (BUSINESS WIRE) - June 28, 2021 – Baker Hughes (NYSE: BKR), an energy technology company, has announced an investment in Electrochaea, a growth stage company developing novel proprietary bio-methanation technology. Through its investment, Baker Hughes will enhance its broader carbon capture and utilization (CCU) portfolio and provide an integrated solution for customers across the carbon dioxide (CO_2) value chain to enable the production of low carbon synthetic natural gas (SNG) from captured CO_2 and green hydrogen, helping meet demand for cleaner fuels to advance the energy transition.

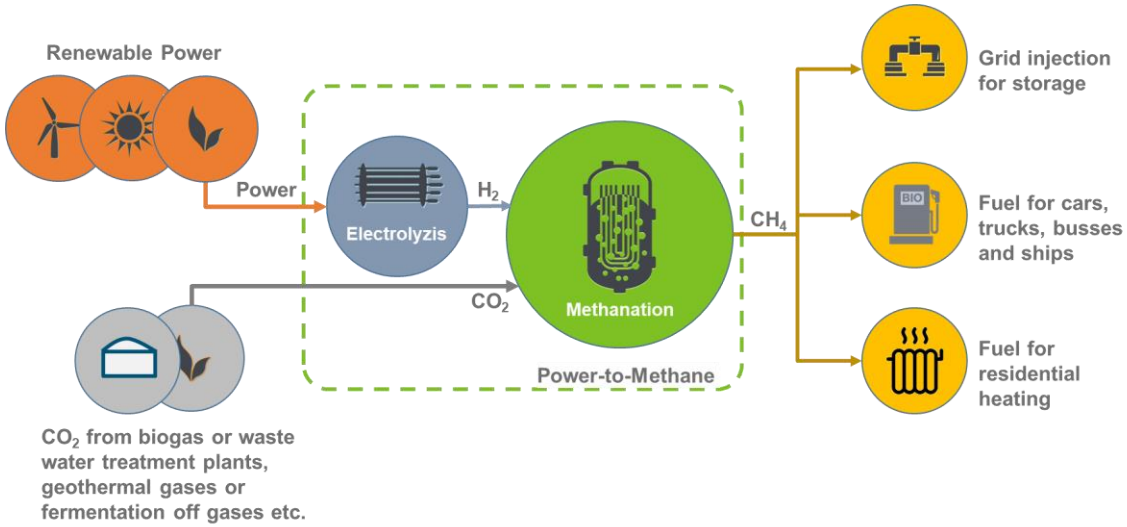
The Electrochaea bio-methanation process is an accessible, highly-efficient, scalable and complementary technology to the Baker Hughes CCU portfolio. The two companies will join efforts to accelerate the scale up and industrialization of the technology, and they will develop the commercialization of an innovative integrated carbon capture and utilization solution. Once commercialized, the solution will provide to customers a unique ability to transform CO_2 emissions into clean SNG.

Baker Hughes will draw from its portfolio of carbon capture technologies, including its Compact Carbon Capture design, to provide integrated solutions tailored to specific applications utilizing both CO_2 sources with biogenic origin, such as biomass and waste-to-energy plants, as well as sources based on combustion of fossil fuels, such as industrial plants.

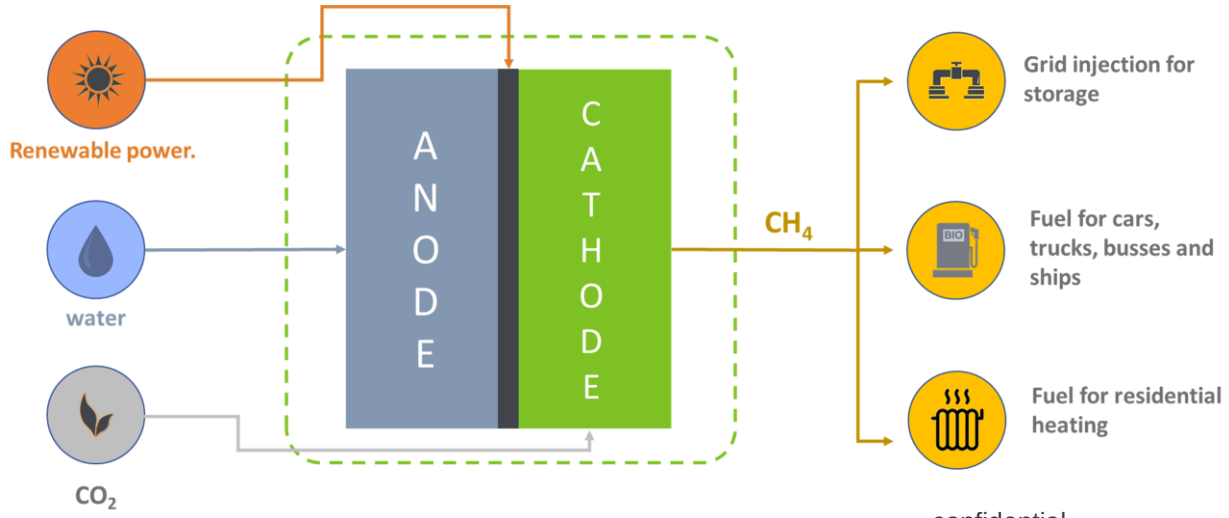
"The combination of these technologies provides an integrated method to decarbonize abate sectors such as road transportation and heating", said [illegible], president of Turbomachinery & Process Solutions deliberate step in our strategy [illegible]

Click Here for Press Release

Power-to-methane 2G: Microbial Electrolysis Cell (MEC)



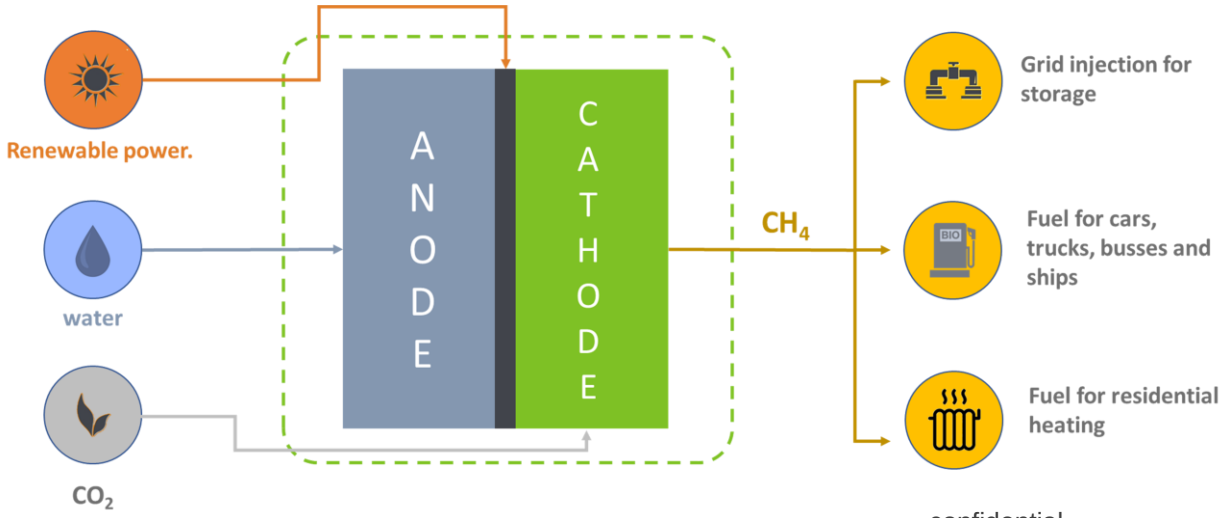
Power-to-methane in 2-steps



Power-to-methane in 1-step

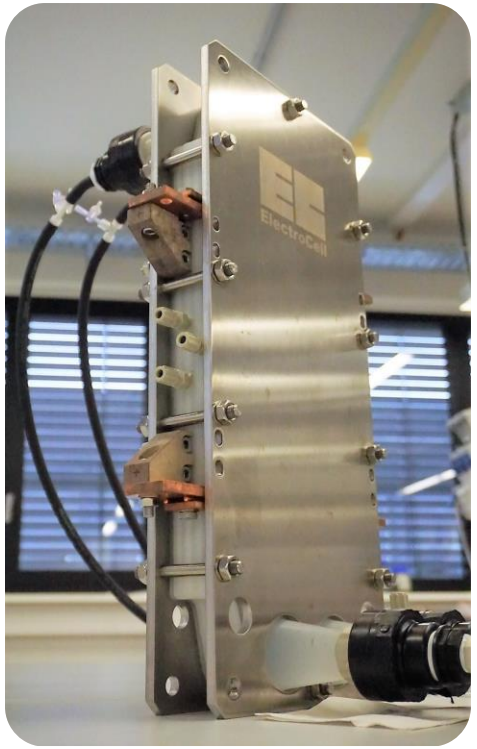
Power-to-methane 2G: Microbial Electrolysis Cell (MEC)

- ✓ Elimination of the capital cost associated with separate electrolyzer and stirred bioreactor
- ✓ H_2 production in the same reactor as the microorganism converting CO_2 into CH_4, thus overcoming productivity limitations associated with low solubility and poor mass transfer of H_2 in water
- ✓ Reduced material cost due to low pressure system design



Power-to-methane in 1-step

Our Accomplishments



- ✓ **Continuous operation** for more than 1000 hours
- ✓ Above 98% **electron and CO_2 conversion** to CH_4
- ✓ **Energy efficiencies** of 25 gCH_4/kwh
- ✓ **Process flexibility:**
  - a) **On/off cycles** with immediate recovery
  - b) Dynamic **CO_2 loading rates** (25-45% CO_2)
- ✓ Electrochaea's proprietary **biocatalyst actively grows** in the biocathode with CO_2 as the only carbon source
- ✓ **Scale-up** progress by means of MEC stacking and modularization

*VVD = volumes of gas per volume of reactor per day (24-hr)

Electrochaea – Investors

Electrochaea

VENTURE INVESTORS

MVP MUNICH VENTURE PARTNERS

CALIZA

b to v

Sirius Venture Partners

kfw

STRATEGIC INVESTOR

storengy

Baker Hughes

energie360°

Electrochaea

Thanks!!!