Biocat project:

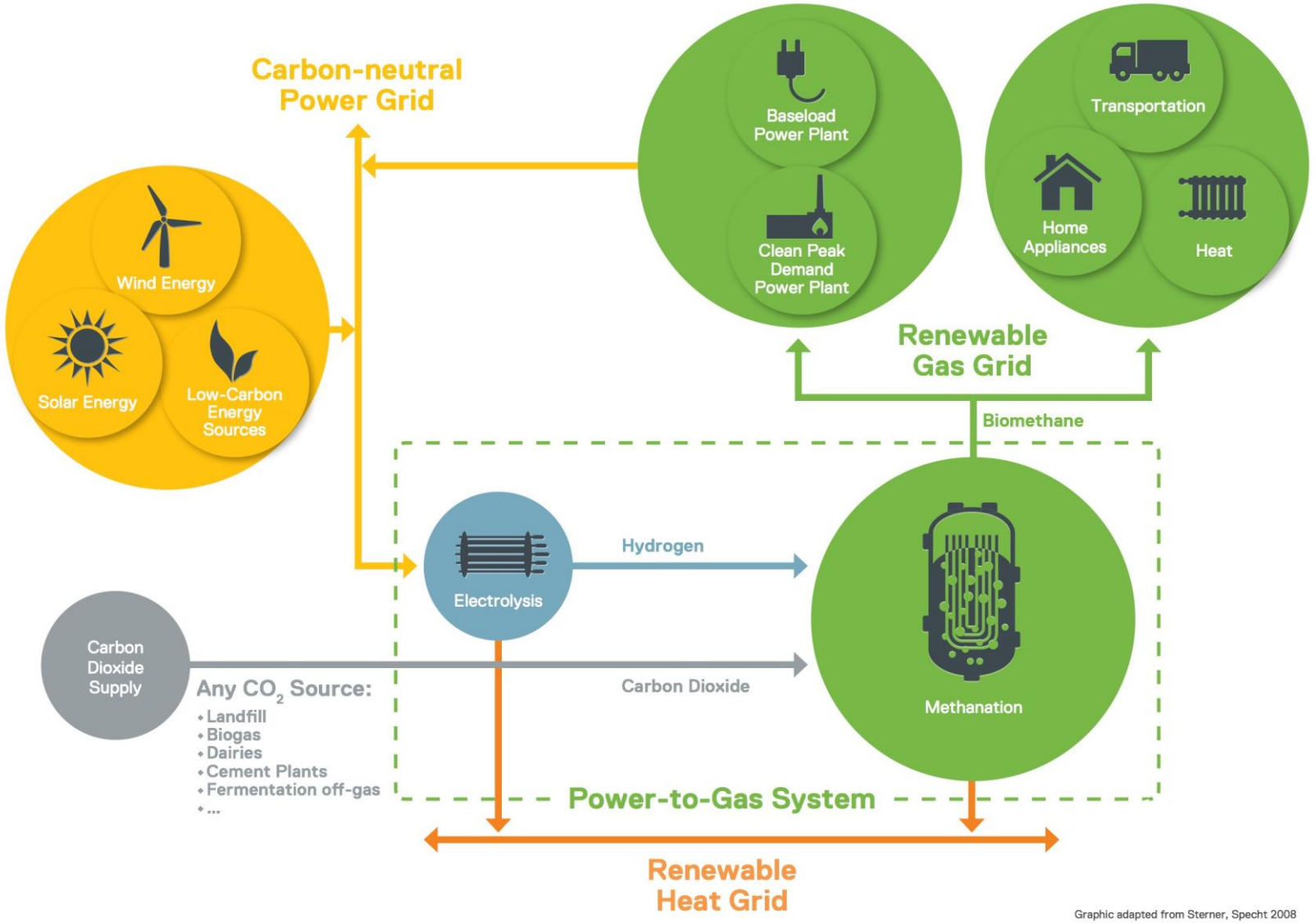
A commercial-scale power-to-gas facility and its capabilities to provide energy storage services to the Danish energy system

Dr. Laurent Lardon

Electrochaea

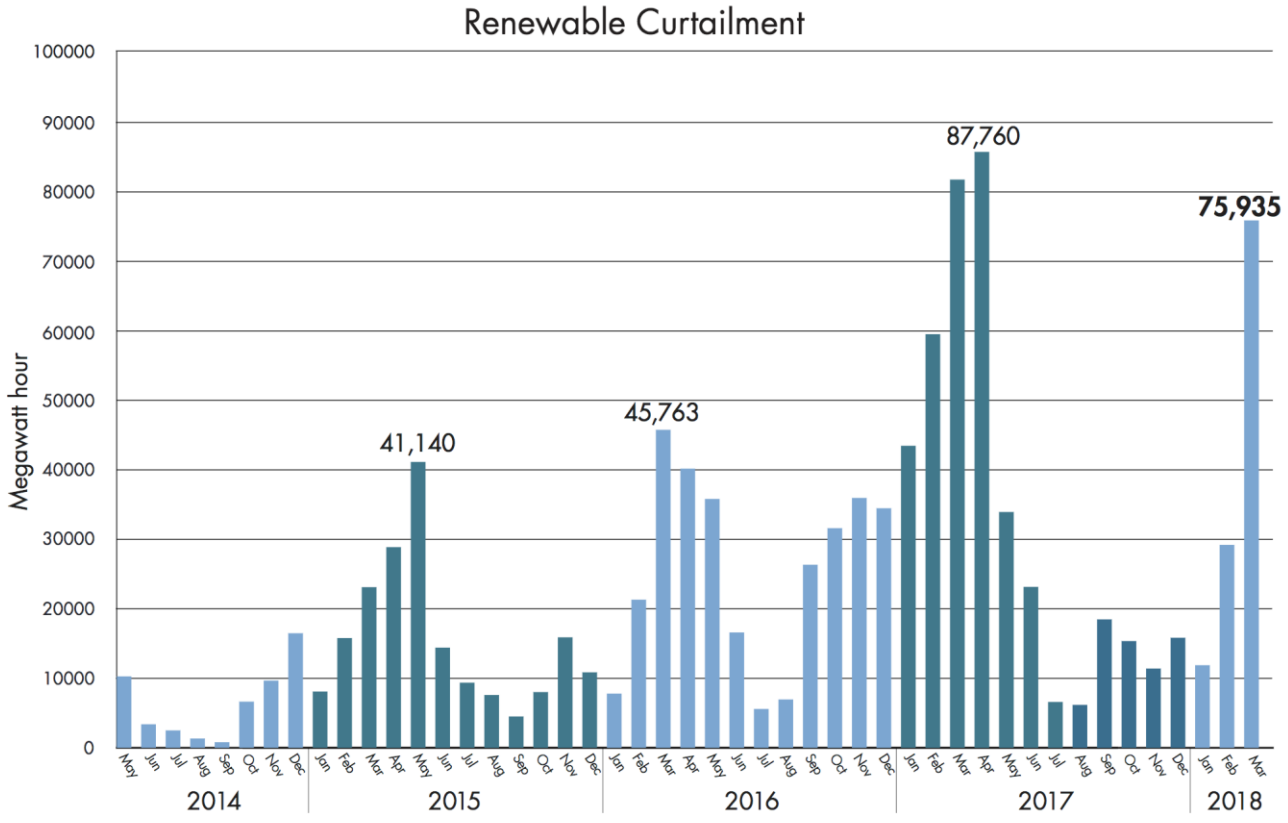
Renewable gas charges our largest battery: the gas grid

Electrochaea



Graphic adapted from Sterner, Specht 2008

How much energy can you afford to lose?



2017 Curtailment:

California ~ 400GWh

Denmark ~102GWh

Energy sold below market prices is not included!

Electrochaea‘s technology allows you to indefinetly store curtailed energy

Why using Natural Gas Grid for electricity storage

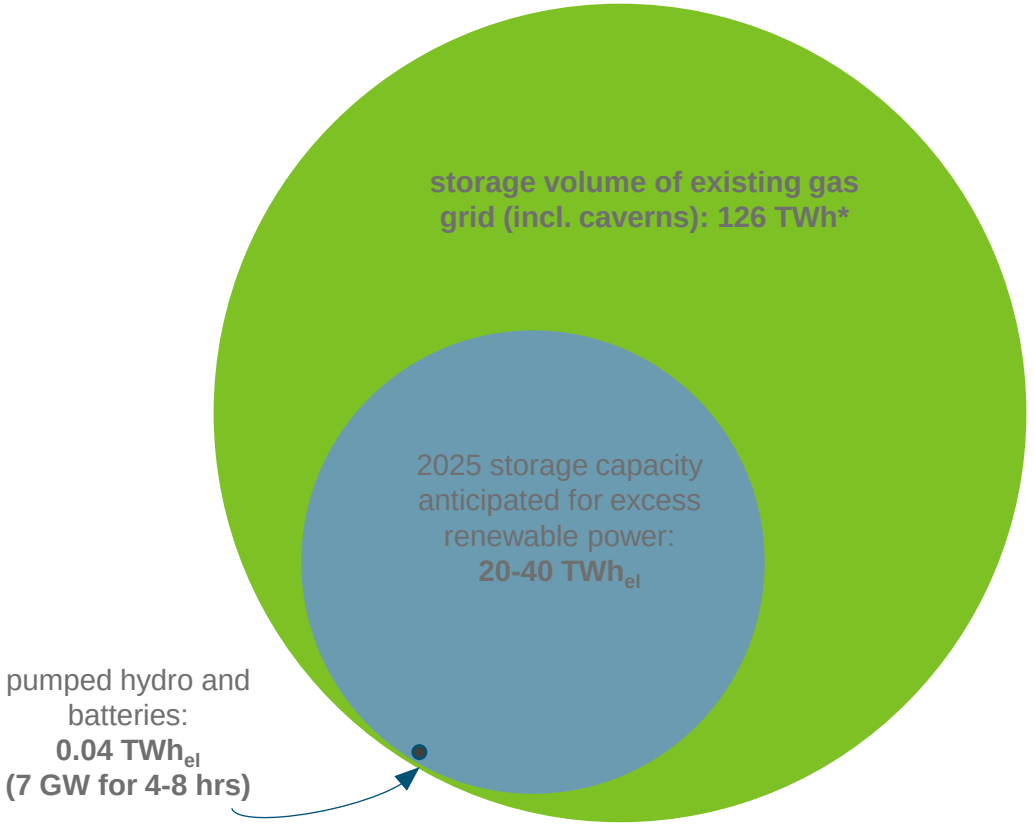
Big enough: Gas and power grids in major markets are currently large enough to support industrial, utility, commercial and residential needs

Germany (2015)
Grid capacity: 126 TWh (11.4 bil Nm^3)
Annual consumption: 824 TWh/a (75 bil Nm^3/a)

Denmark (2015)
Grid capacity: 11 TWh (1.0 bil Nm^3)
Annual consumption: 26.5 TWh/a (2.4 bil Nm^3/a)

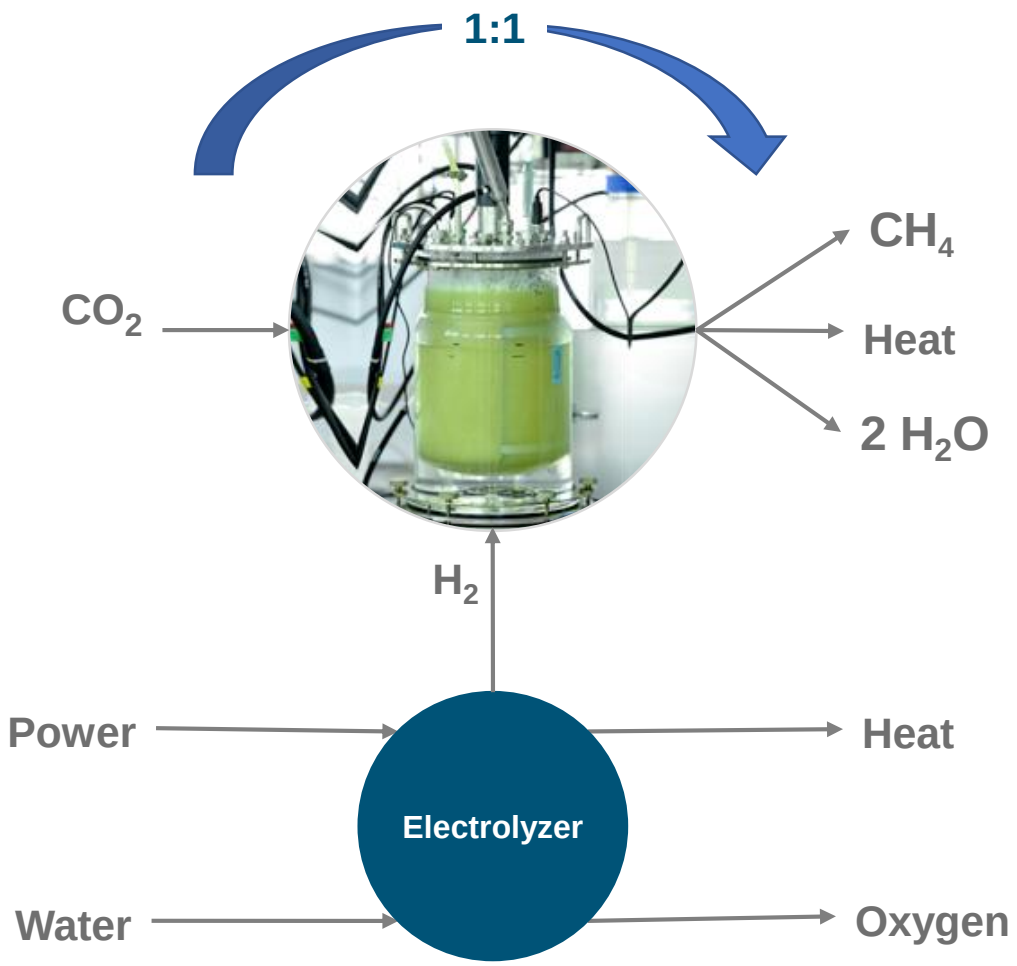
California, US (2015)
Grid capacity: 117 TWh (10.6 bil Nm^3)
Annual consumption: 722 TWh/a (65.4 bil Nm^3/a)

Biomethanation can deliver neomethane at grid scale to the German gas grid



sources: Trost et al. (2012); ZSW, *Schwerpunktbericht 2009*

What we are doing to lower the world's carbon footprint



Proprietary Biocatalyst

4 issued patents, active patent applications worldwide

Operating Conditions

temperature 65°C, pressure 1 to 10 bar(a)

Chemical Reactions

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

Electrolysis $4H_2O \rightarrow 4H_2 + 2O_2 + Heat$

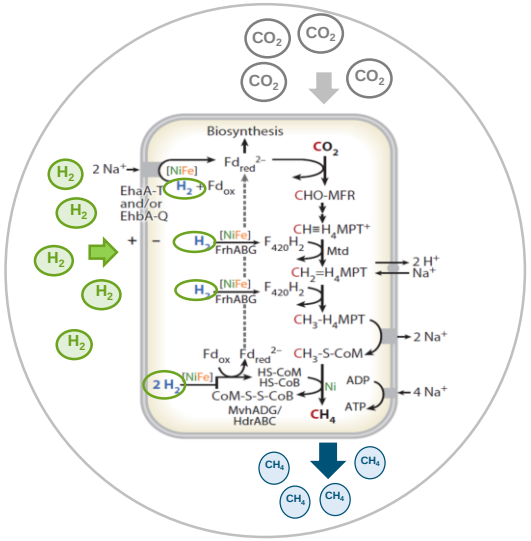
Net Reaction

$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2 + Heat$

Our archaea transform virtually every molecule of CO_2 into a molecule of CH_4 without using fossil fuels

A scalable biocatalytic system

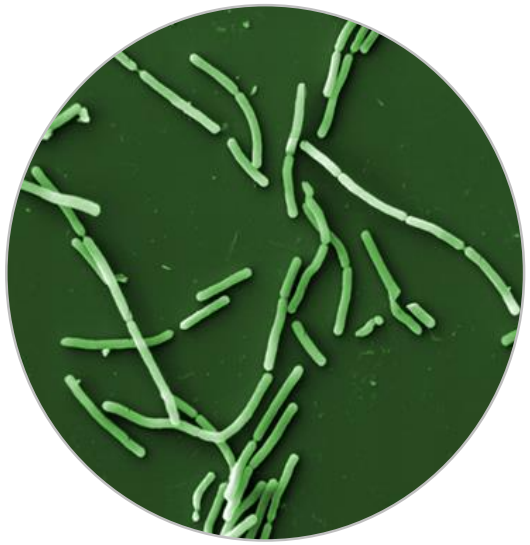
1 enzyme complex



Peak measured productivity*:
Current productivity:

1 cell

1 single cell



8.3x10^{-14} Nm^3/hour
nd

5.5x10^{14} cells

1.5L bioreactor

0.045 Nm^3/hour
0.007 Nm^3/hour

1.83x10^{18} cells

3500L bioreactor

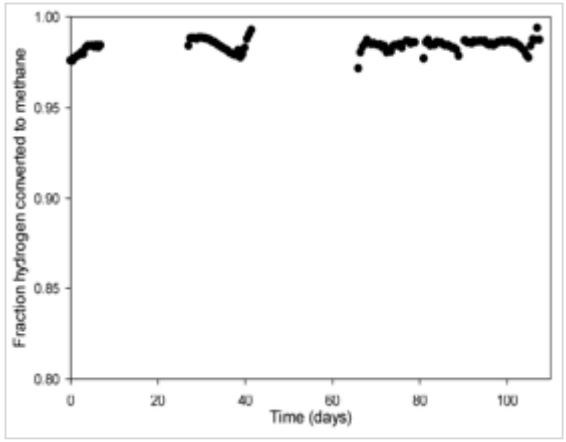
152 Nm^3/hour
50 Nm^3/hour

*assuming that vvd=800VolCH4/VolBioreactor/Day at a dry weight of 10g/L can be reached

Unique Features of Electrochaea Technology

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

Scalable Bioreactor
- Mild operating conditions
- Optimized and proprietary design
- Broad range of applications

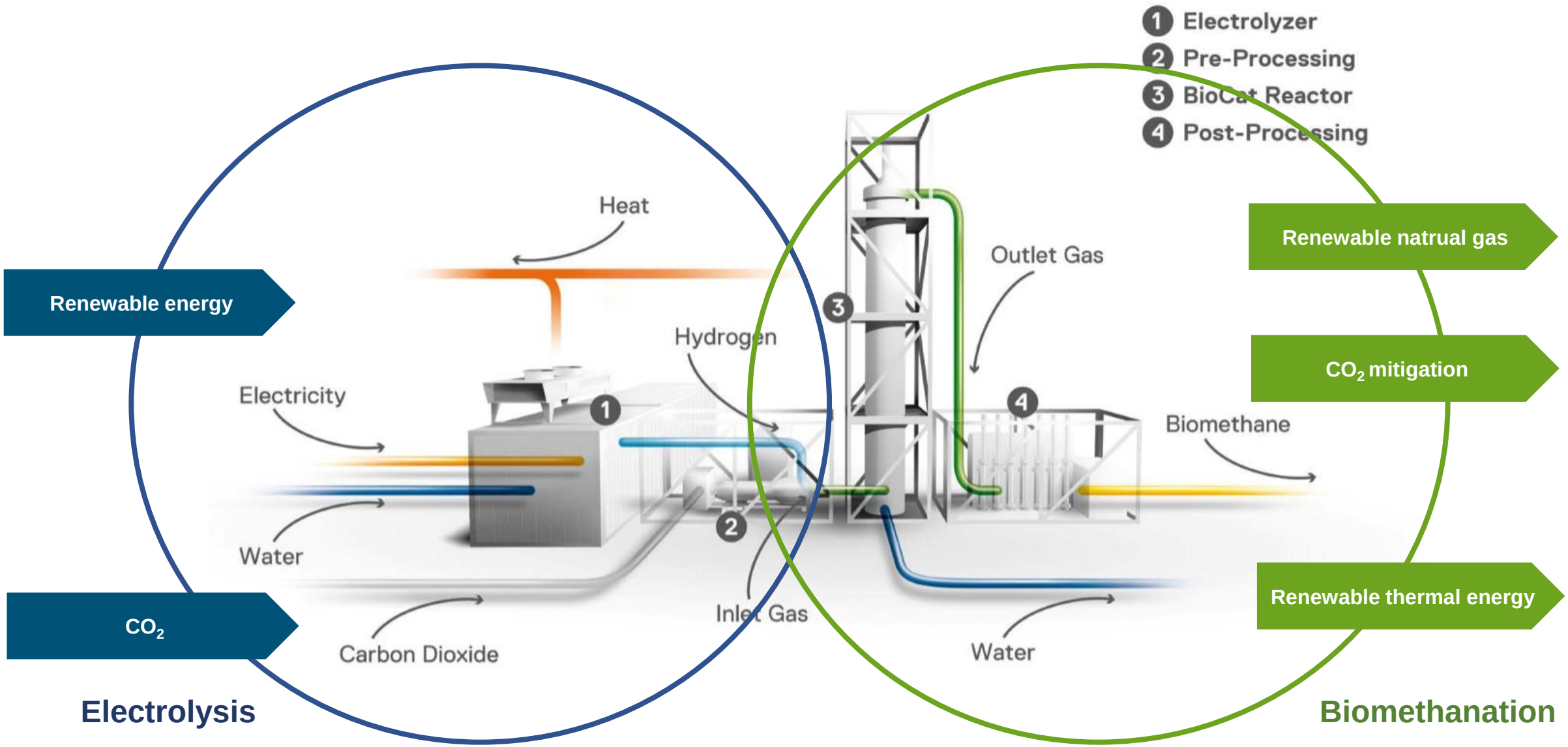


Efficient	**98.6%** of carbon goes into **methane**
Productive	**VVD* of 800**, H_2 mass-transfer limited
Responsive	**Quick** return to methane production within seconds/minutes
Selective	**100% methane**, no intermediates
Robust	**Tolerant to oxygen, H_2S, CO, Sulfate, Ammonia, particulates**
Simple	**Moderate** temperature range (60-65°C)

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

A simple and scalable system design

Electrochaea



2019 - three commercial-scale pilot plants

0.25 MWe

Golden, Colorado, US
(July 2019)

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

0.7 MWe

Solothurn, Switzerland
(May 2019)

- Grid injection within 96h
- Automated operation
- Commercial design
- Project support from EC (H2020), RES

1 MWe

Avedøre, Denmark (April 2016)

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

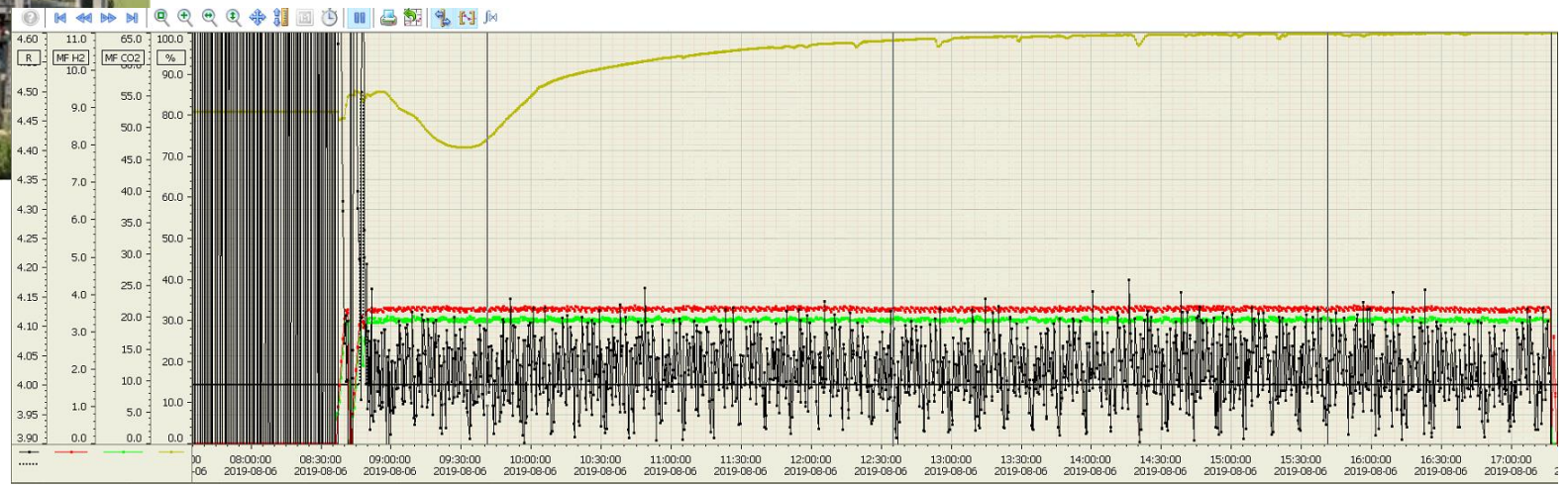
Biomethanation in Switzerland – Hybridkraftwerk Solothurn

Electrochaea

STORE&GO

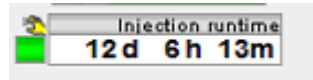
The Horizon 2020 project funds three pilot plants in three countries

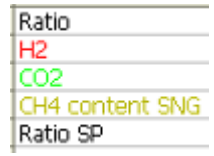
- Achieved **400 h of operation** and **2900 kg of SNG** injected in the local gas grid
- Remote operation from Electrochaea offices
- 100% biomethane product gas achieved at stable performance



Overall totalizer

Injection totalizer





regio energie solothurn

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL
FHO Fachhochschule Ostschweiz

Electrochaea

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

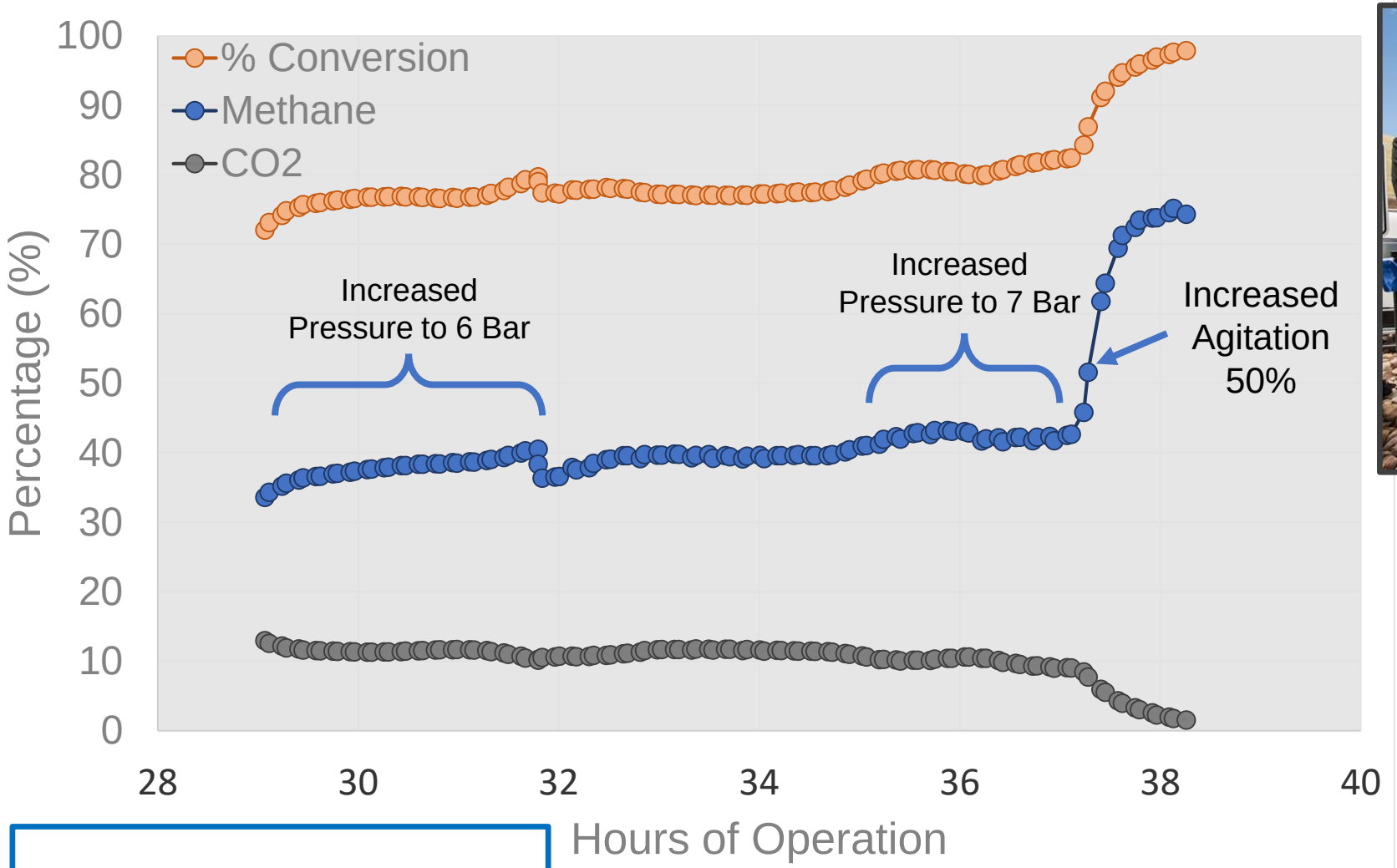
Co-funded by the European Union under grand agreement no. 691797

SVGW SSIGE

Supported by
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Under contract number 15.0333

Empa
Materials Science and Technology

The First Biomethanation Plant in North America



Operational State

- Start pressure 5 bar
- Returned to low agitation rate
- 0.6 kg/hr H_2
- 3.0 kg/hr CO_2

$$\text{Conversion} = \frac{\%\ CH4}{\%\ CH4 + \%CO2}$$

Successful Operation of BioCat

- **3.5 years of intermittent operation** with scheduled campaigns
- Continuous operations campaigns for ~500hrs with **>98% plant availability**
- Total operational hours ~ **4500hrs**
- Extreme robustness (**raw biogas and other CO_2** sources can be used)
- **Self-sustained** biocatalyst with original inoculum still in operation
- Highest methanation rates with optimised, patented biocatalyst
- Load factor tests: **10% - 100% capacity** tested
- **Process flexibility**: on/off cycles with immediate recovery after 10 min to 1 month shut-down periods
- Optimised protocols for flexible operation developed
- Protocols for **full automation** completed
- Grid injection into Danish gas grid at >98% CH4 in product gas

Grid quality product gas:

- > 97% CH_4
- 0.2-1% CO_2
- 1-2% H_2

Integration with WWTP and biogas

Electrochaea

Biogas

Heat

Oxygen

Excess Electricity,
Local Wind Turbines

Green Methane

Grid balancing

Up-regulation: Grid operator needs more power on the grid

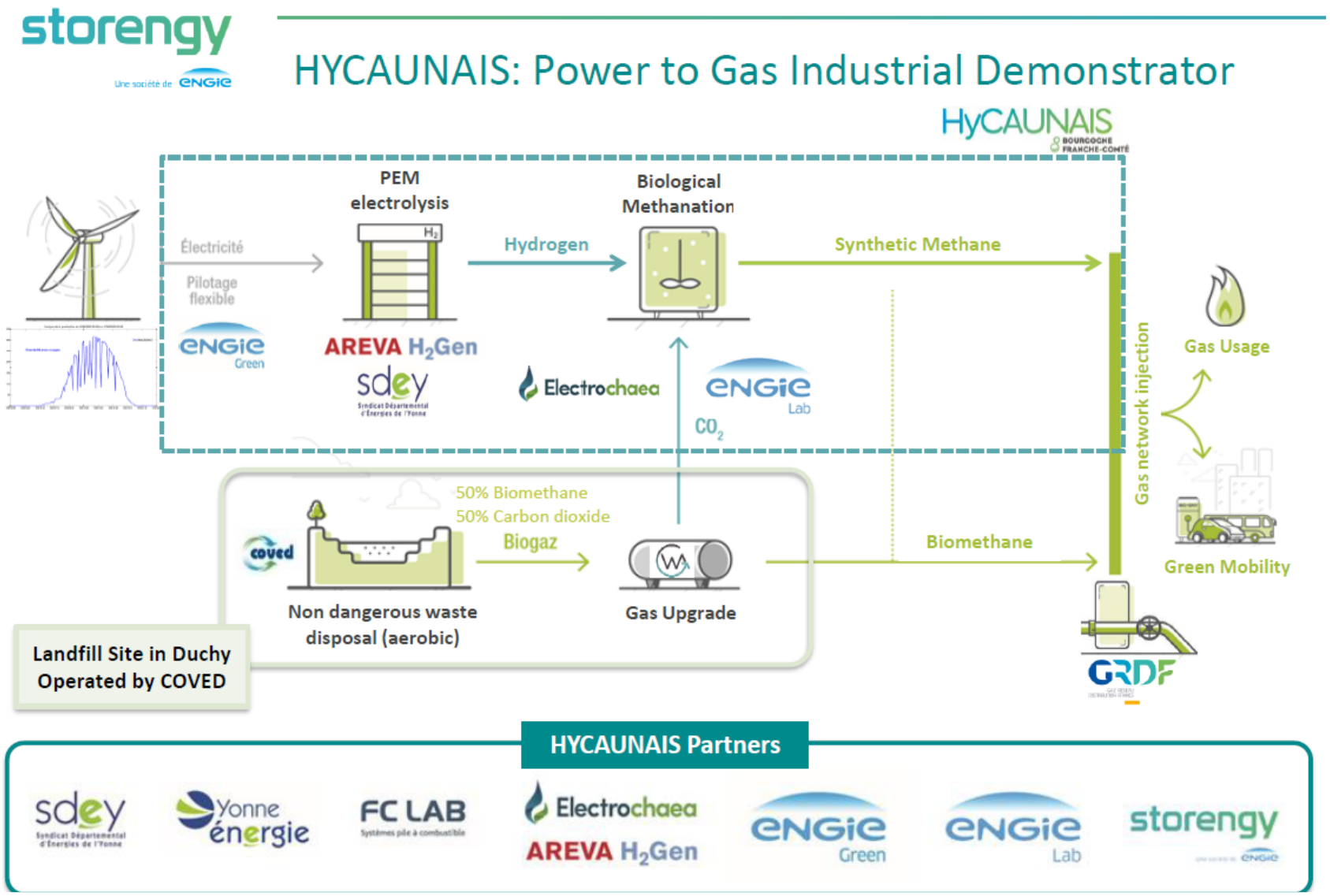
Bio-methanation allows immediate plant stop without consequence on the catalytic performance.

Down-regulation: Grid operator needs less power on the grid

The pair {electrolyser x bioreactor} can start and ramp-up in a short time with immediatly good gas quality

Hycaunais Project: 2MWe P2G with Landfill Gas in France

Electrochaea



Impact of a 250 MW biomethanation plant

2,000GWh$_e$ + 185,000t CO_2	250MW$_e$ BioCat® methanation system	12,500Nm^3/h RNG

energy of ~**625,000 households**

~103,000 passengers flying from London to NY

Renewable energy

CO_2

Renewable natural gas

CO_2 mitigation

Renewable thermal energy

yearly consumption of **~10,000 CNG cars**

147mn km with 1 CNG car (~3660x around the world)

CO_2 Mitigation of ~**15mn trees**

Re-utilization of resources

Reduction of CO_2 footprint

*assumptions:

- Heat and electricity for one year 3,200 kWh in a household with 4 person in Germany (2013)
- Consumption average CNG car: 4.5kg CNG/100km, yearly distance: 15 000km/year
- 8,000 h/a of operation, electrolysis included
- One beech binds 12,5 kg CO_2/year
- CO_2 emissions calculator www.atmosfair.de

Strong Network and Collaborations

Electrochaea

Investors

MVP Munich Venture Partners
storengy
b.to.v
Sirius Venture Partners
CALIZA
energie360°
kfw
NIDUS

Memberships

BVES Bundesverband Energiespeicher
IBB Netzwerk GmbH
Danmarks Vindmølleforening
Brintbranchen Hydrogen Denmark
UseCO2 Kooperationsnetzwerk

Partners

Audi Vorsprung durch Technik
NEAS ENERGY
HMN Gashandel
INSERO BUSINESS SE
BIOFOS
HYDROGENICS Shift Power | Energize Your World
FORSKEL

Sponsors and Funded Projects

Bundesministerium für Wirtschaft und Energie
DBU Deutsche Bundesstiftung Umwelt
POWERSTEP Your Flush, Our Energy
Energistyrelsen
EUDP
STORE&GO
NREL National Renewable Energy Laboratory