Electrochaea

CO_2 Capturing. Energy Storage. Renewable Fuel.

Oslo
April 9th, 2019

Electrochaea

1. **How much energy do you still want to waste?**
2. **What are we doing to lower the world's carbon footprint?**
3. **What if methane becomes the perpetual renewable fuel?**

Electrochaea is partnering with nature to
capture CO_2, store energy and produce renewable fuel

Partnering with Nature

THE UNIVERSITY OF CHICAGO

From basic research ...

Meet the Archaea!

- Archaea are among the oldest organisms on the planet (appeared >3,6 billion years)
- Archaea are a species of their own and are not bacteria nor viruses
- Are extremophyles (live on ocean vents, volcanoes, geysers) and extremely resilient

What do they do?

Archaea **combine** H_2 molecules with CO_2 molecules, use a fraction of the energy available with H_2 and **generate** CH_4 (methane), water and heat (65°C)

... to commercial-scale application

Electrochaea

What do we do?

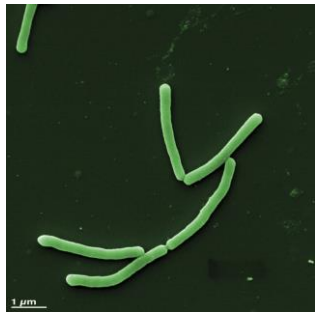
Based on this Archaea, **Electrochaea** developed a proprietary process technology (electrolysis and biological methanation) with the aim to convert every molecule of CO_2 into CH_4

CO_2 Capturing. Energy Storage. Renewable Fuel.

Green energy

H_2

Electrolyzer



Picture: Courtesy Dr. Klingl

CH_4

-Water

-Heat (60°C)

Raw gas/

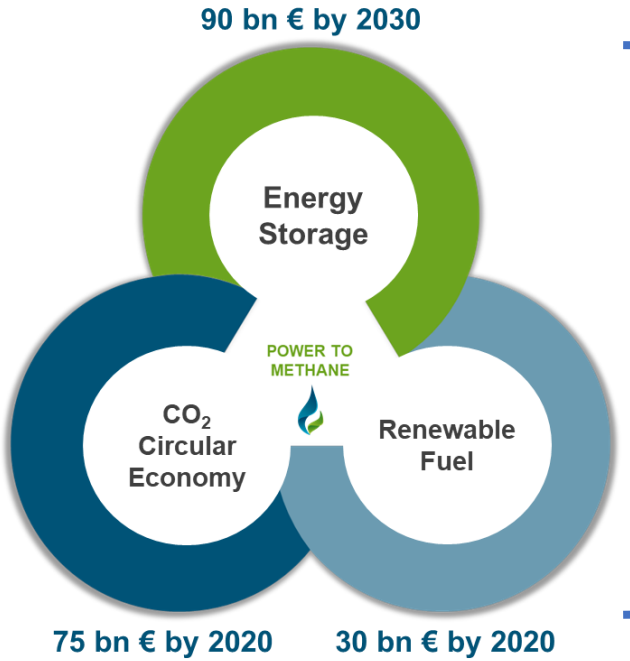
CO_2

Wastewater TP

Waste TP

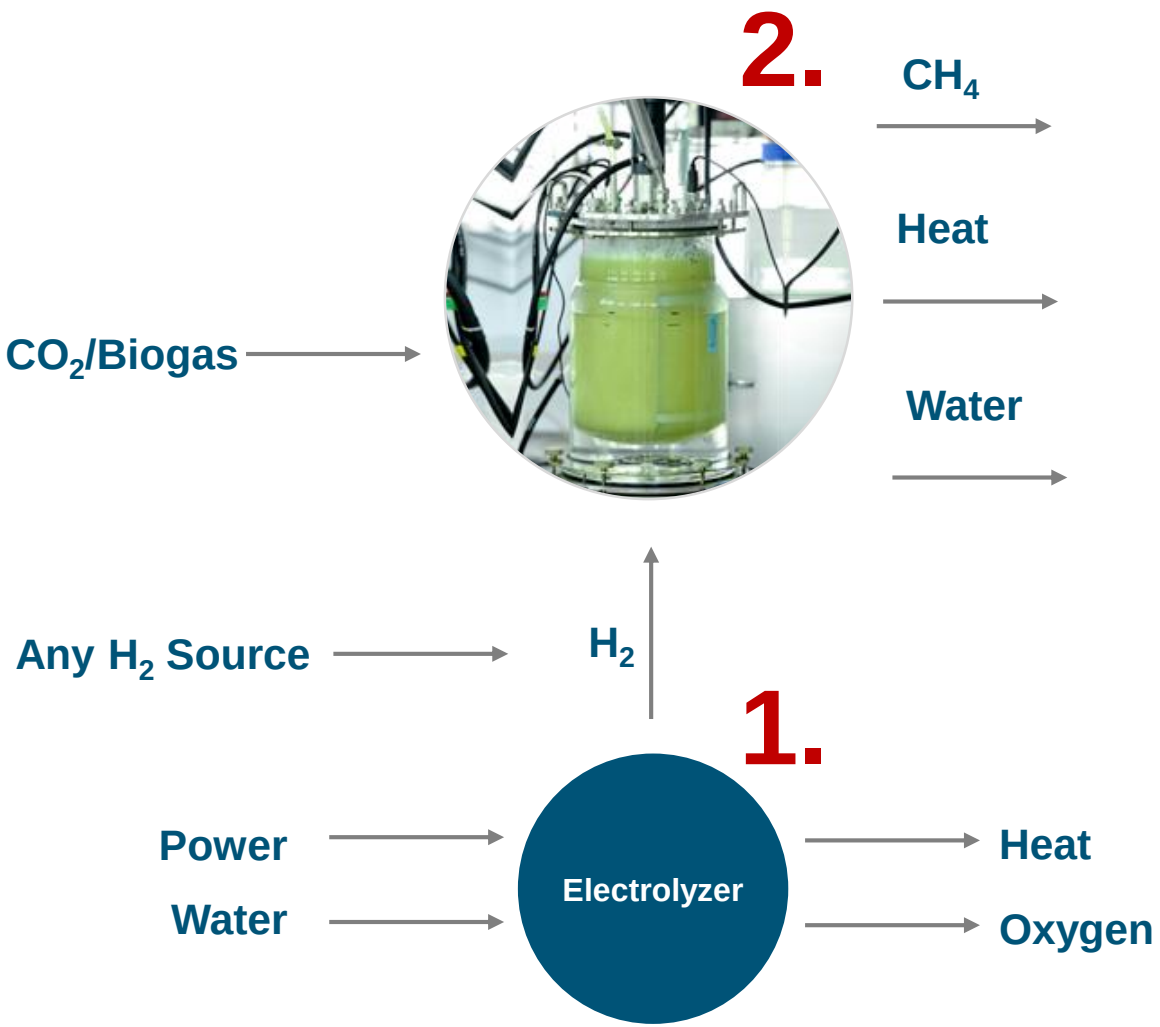
Biogas farms

……



200 bn € by 2030

From Power to Gas in Two Steps:



Proprietary Biocatalyst

4 issued patents, active patent applications worldwide

Operating Conditions

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

Chemical Reactions

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

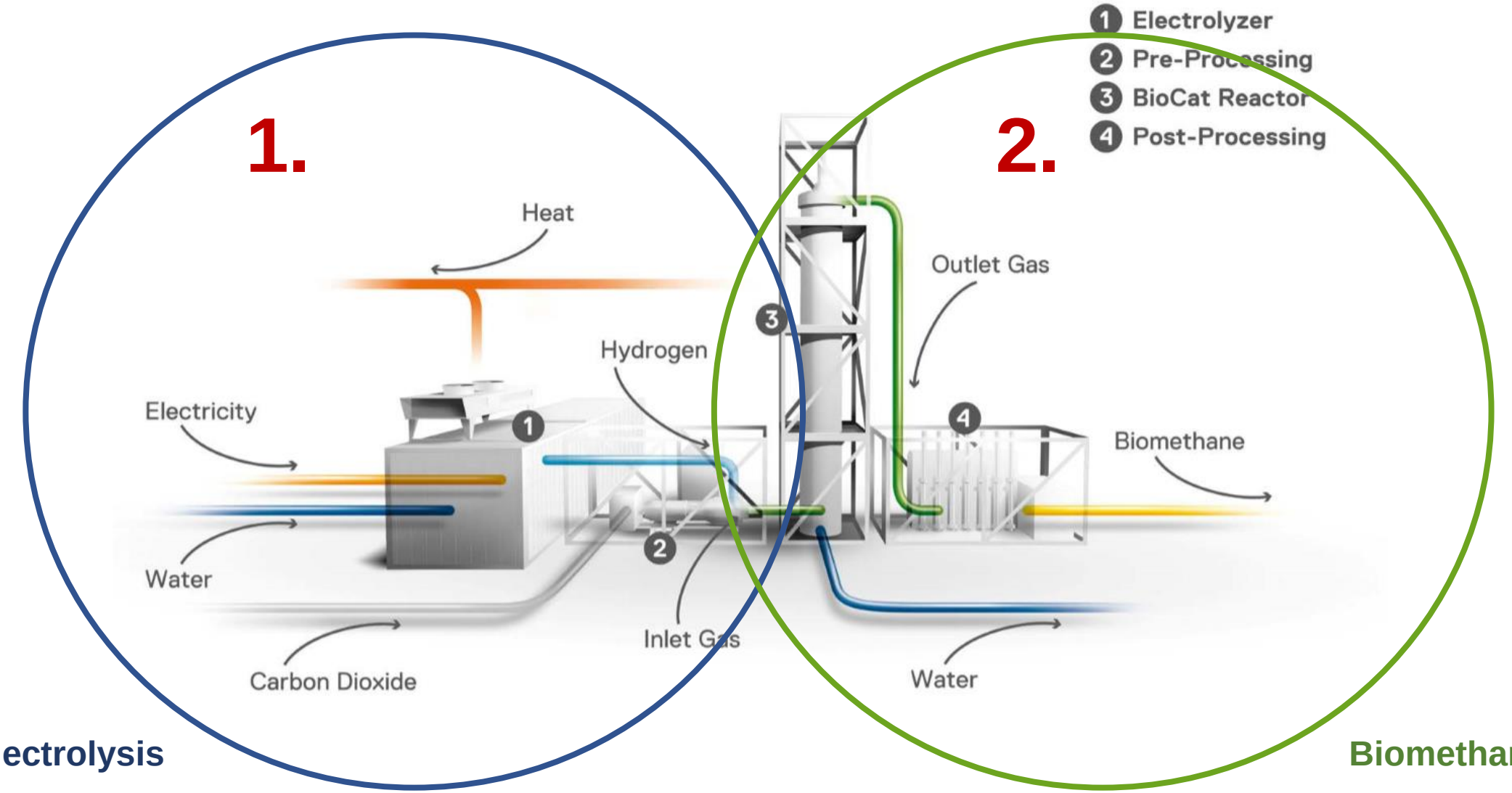
Electrolysis $4H_2O \rightarrow 4H_2 + 2O_2 + Heat$

Net Reaction

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

How does our technology work? 2 Steps process

Electrochaea



Electrolysis

Biomethanation

Flexible. Intermittent.

2019 - Three commercial-scale pilot plants

0.25 MWe

Golden, Colorado, US
(June 2019)

1 MWe

Solothurn, Switzerland
(February 2019)

1 MWe

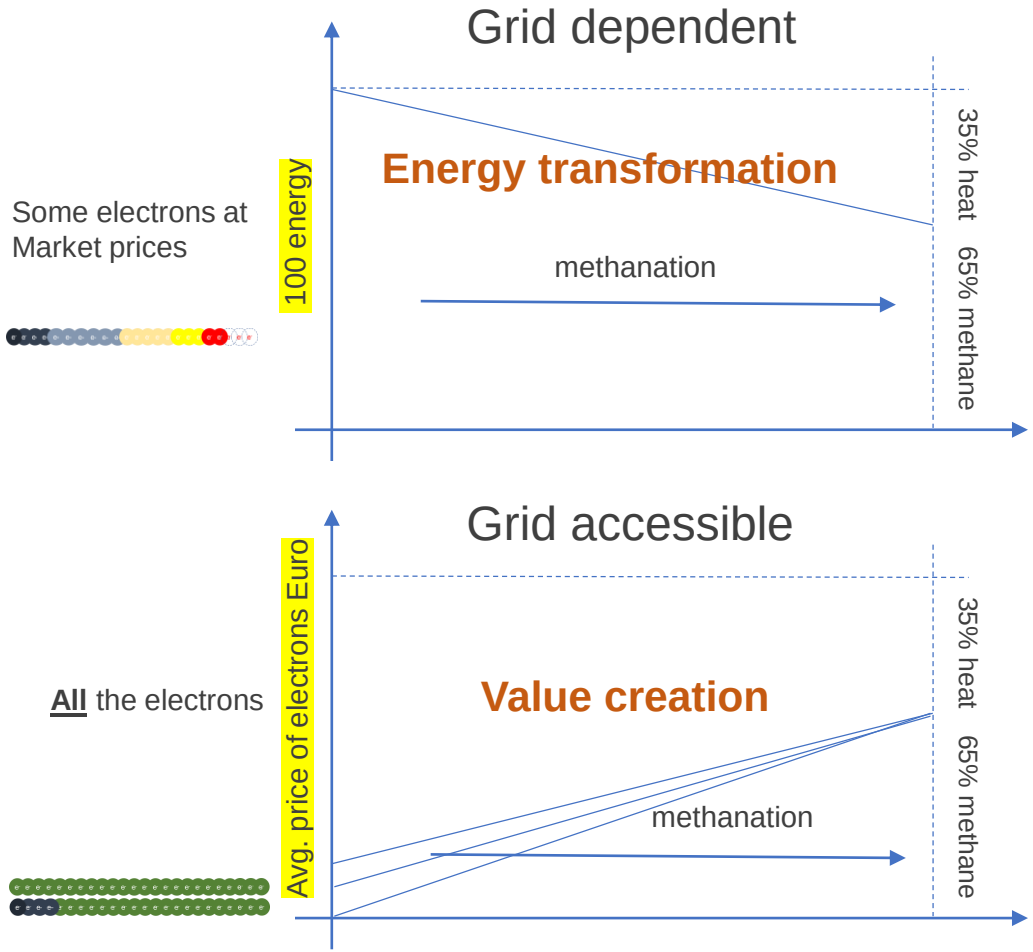
Avedøre, Denmark
(April 2016)

A 20 MWe plant under development in a major market

1. **How much energy do you still want to waste?**
2. **What are we doing to lower the world's carbon footprint?**
3. **What if methane becomes the perpetual renewable fuel?**

Does it make sense to transform electricity into methane and heat?

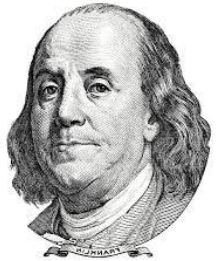
Electrochaea



This is how the model is wrongly perceived (residual)

Usage of “residual” electrons:
- Below market prices
- Negative prices
- curtailed

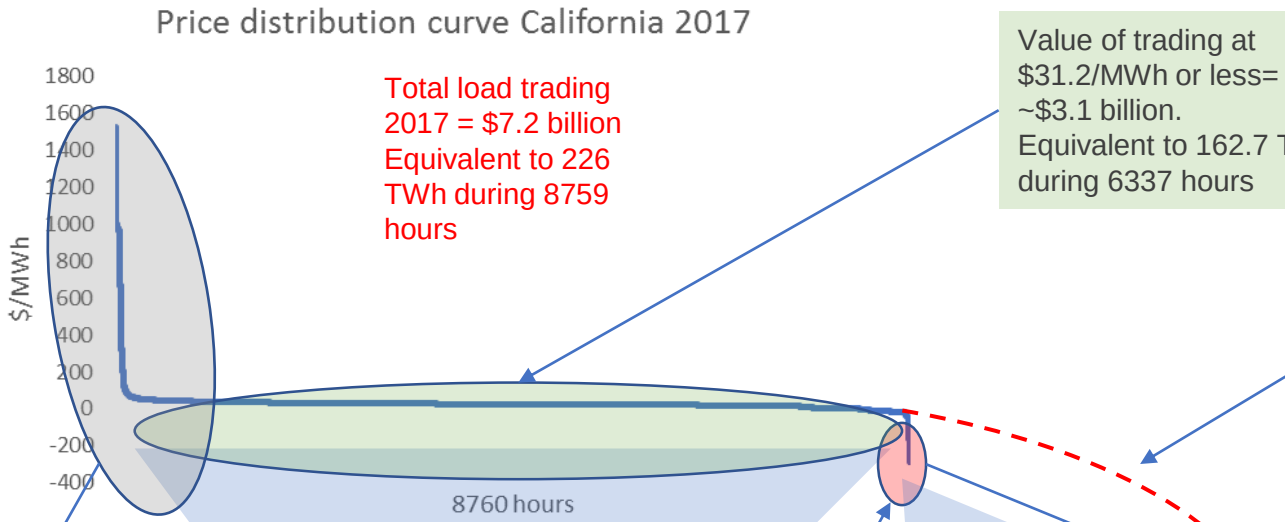
This is how the model actually works (methanocentric)



Usage of “all” electrons:
Sell to the grid when the energy is expensive

Yes!

Energy storage: the purgatory model



Total load trading 2017 = $7.2 billion Equivalent to 226 TWh during 8759 hours

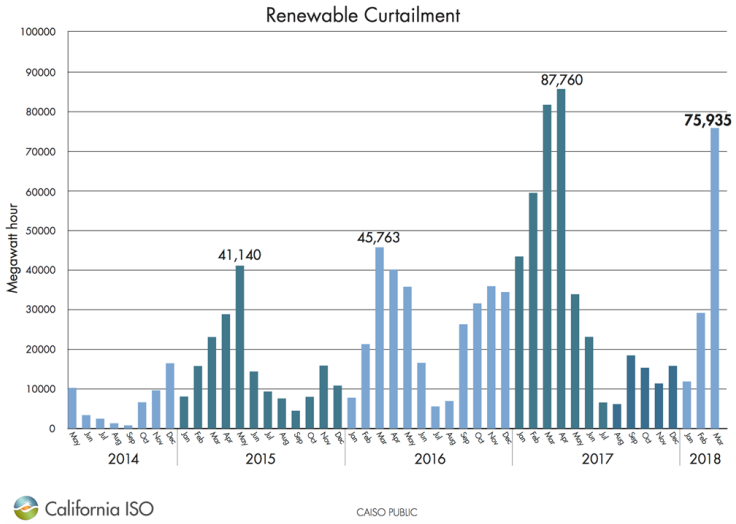
Value of trading at $31.2/MWh or less= ~$3.1 billion. Equivalent to 162.7 TWh during 6337 hours

Value of trading at > $31.2/MWh = ~$4 billion Equivalent to 63.7 TWh during 2422 hours

"hell-ectrons"

"electrons in the purgatory"

"lost electrons"



2017 Curtailment: California ~ 400GWh

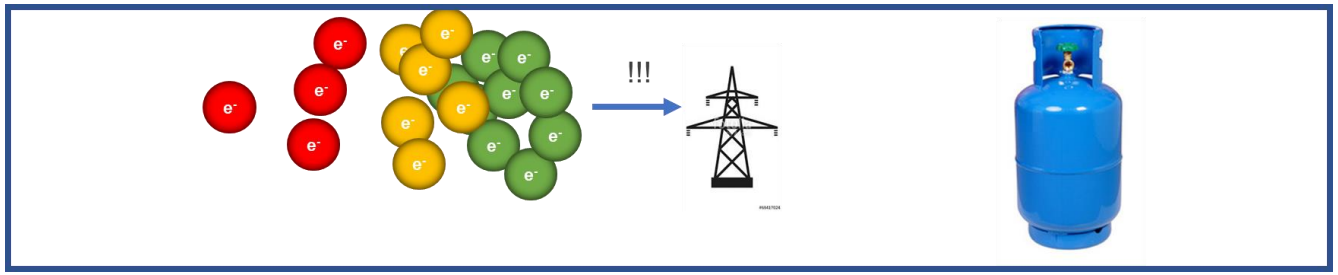
Aug 18 curtailment: California ~ 750GWh

Value of negative trading = $152 mio. Equivalent to 13 TWh during 577 hours

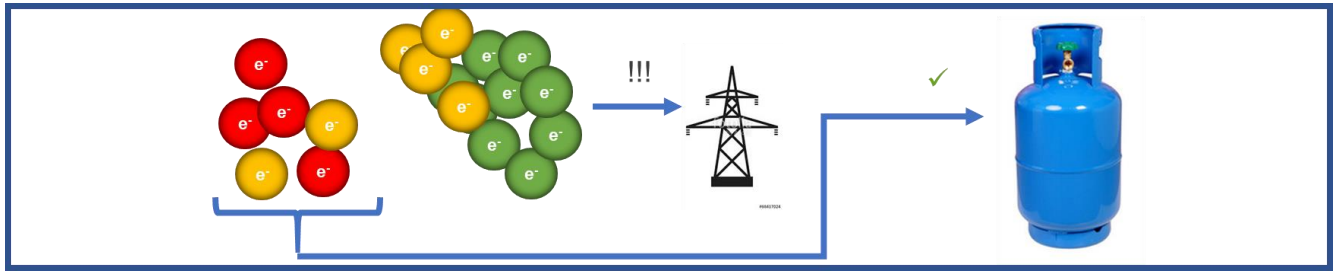
we waste way too much renewable energy

Electrochaea's technology permits the recovery of "purgatory and lost" electrons

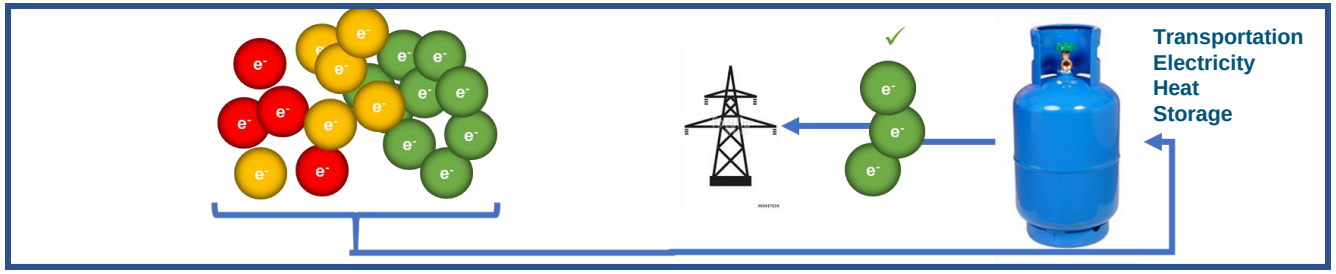
Energy storage:
Paradigm change- efficient coupling of gas and electricity grid



Current mode of operation

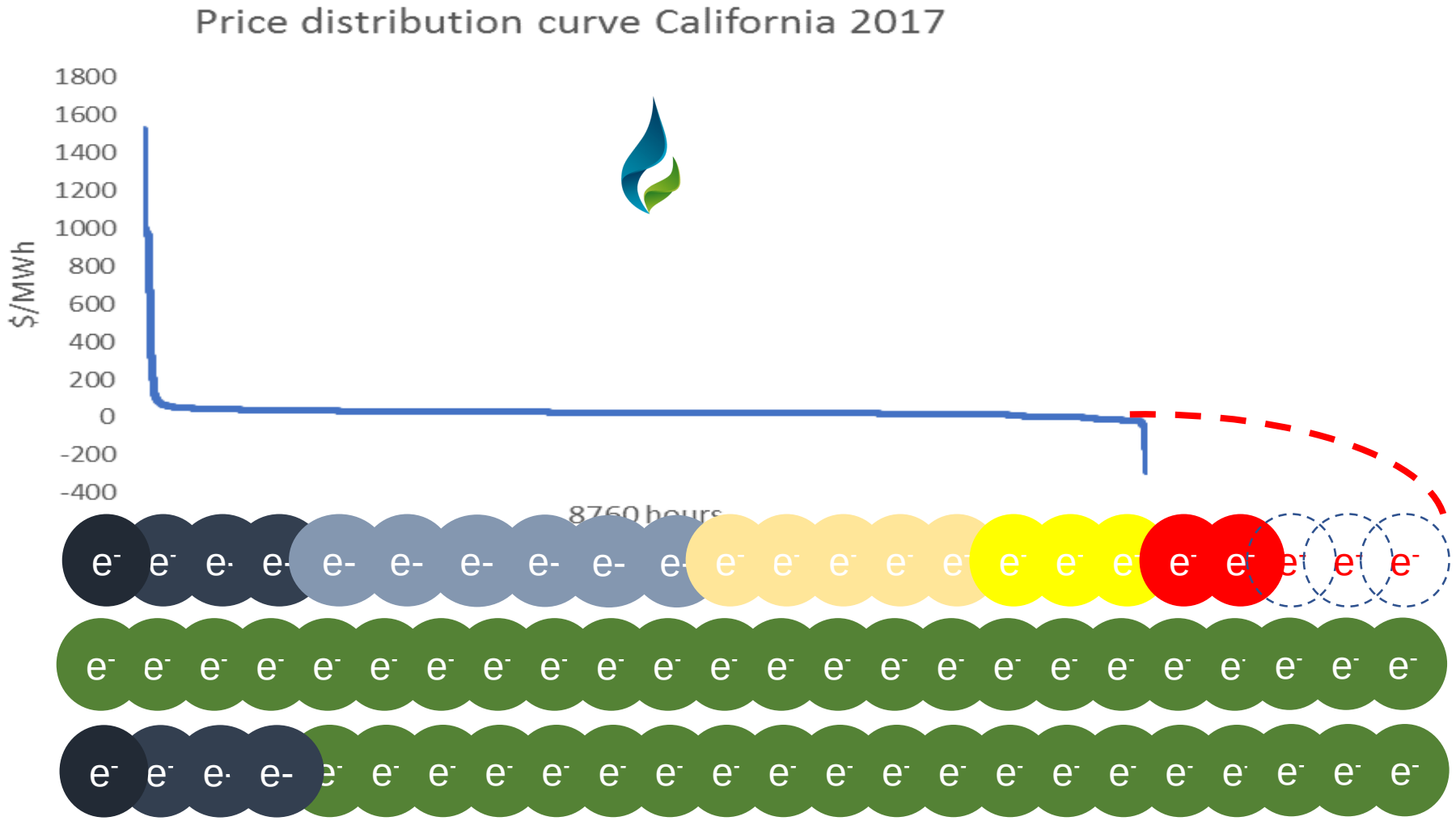


Grid dependent model
(EC just gets the scrap electrons nobody wants/needs)



Grid available model
(EC gets dedicated electrons and make them grid available when the e-grid needs them)

Energy storage: Methanization is more profitable than simply selling energy



Energy storage:
In a nutshell, dear World…..

Electrochaea

electricity grid
is not a battery!

gas grid
It is the planet's largest battery indeed!!

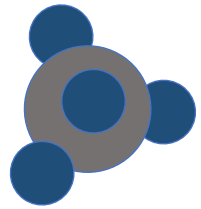
What if methane becomes the perpetual renewable fuel?

Germany (2018)
Grid capacity: 300 TWh (28 bil Nm3)
Value: ~9.6bio€

Denmark (2018)
Grid capacity: 11 TWh (1.0 bil Nm3)
Value: ~350mio€

California, US (2018)
Grid capacity: 117 TWh (10.6 bil Nm3)
Value: ~2.5bio€

- Limited capacity
- Limited storage cycles
- Short duration storage
- Fixed installation



- Virtually unlimited capacity
- Unlimited storage cycles
- Long-term storage
- Extensive distribution network

Electrochaea eliminates the time factor from the energy storage equation

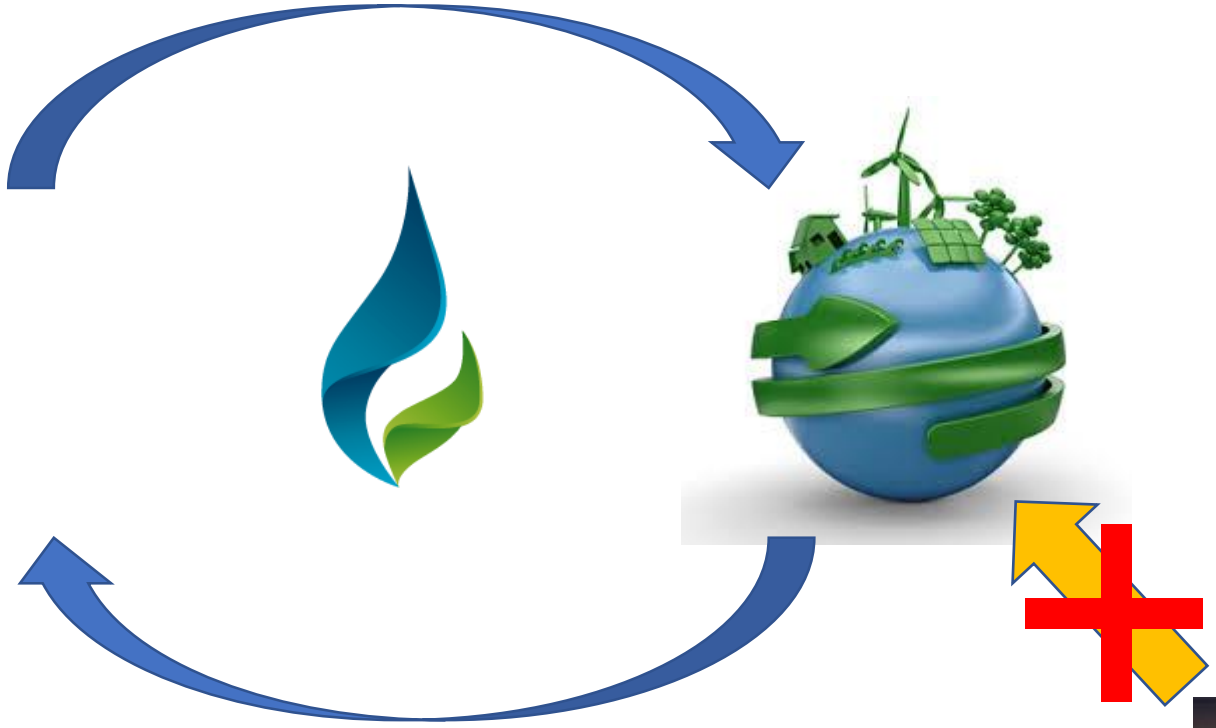
The present battery technology cannot meet the world‘s storage needs

1. How much energy do you still want to waste?

2. **What are we doing to lower the world's carbon footprint?**

3. What if methane becomes the perpetual renewable fuel?

Why our methane is clean?



By using “green” CO_2 from agriculture and organic human waste we displace fossil fuel and reuse what plants and animals use

Why our methane is good?

By allowing countries to produce their own fuel from waste and agriculture we reduce the need for energy to cross geopolitical borders

Sizing of a methanation plant: raw bio/landfill gas

Electrochaea

INPUT

Gas flow
100 Nm^3/h
62 scfm

Gas composition
~50% CO_2
= 50 Nm^3/h = 31 scfm

Hydrogen requirement
4: 1 molecules of CO2 to H2
= 200 Nm^3/h = 124 scfm

Electrolyzer sizing
1 MWe at 5 kWh /Nm3 efficiency
= 200 Nm^3/h = 124 scfm

1 MWh

OUTPUT

Methane
~100 Nm3/h
62 scfm

Heat
65°C = 143.6 F
~330 kWth

O2
~100 Nm3/h
62 scfm

Water
~75 l/h
19.8 gallons

Product stream

Sizing of a methanation plant: CO_2

Electrochaea

INPUT

Gas flow
100 Nm^3/h
62 scfm

Gas composition
100% CO_2
= 100 Nm^3/h = 62 scfm

Hydrogen requirement
4: 1 molecules of CO_2 to H_2
= 400 Nm^3/h = 248 scfm

Electrolyzer sizing
2 MWe at 5 kWh /Nm3
efficiency
= 400 Nm^3/h = 248 scfm

2 MWh

OUTPUT

Methane
~100 Nm3/h
62 scfm

Heat
65°C = 143.6 F
~330 kWth

O_2
~100 Nm3/h
62 scfm

Product stream

Water
~75 l/h
19.8 gallons

In order to achieve the same amount of output, the double amount of energy is needed

Sizing of a methanation plant: raw bio/landfill gas

Electrochaea

INPUT

Gas flow
1000 Nm^3/h
622 scfm

Gas composition -
assumed
50% CO_2
= 500 Nm^3/h = 311 scfm

Hydrogen requirement
4: 1 molecules of CO2 to H2
= 2000 Nm^3/h = 1240 scfm

Electrolyzer sizing
10 Mwe at 5 kWh /Nm3 efficiency
= 2000 Nm^3/h = 1240 scfm

OUTPUT

~125 Nm^3/h CH_4
… MWth

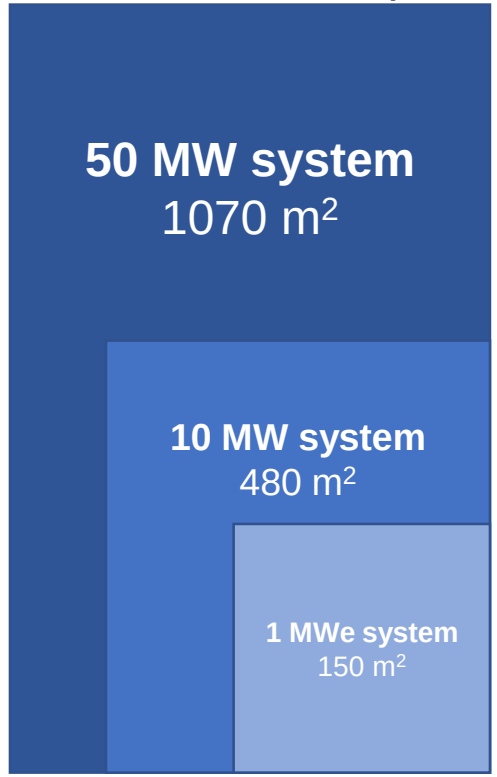
~1250 Nm^3/h CH_4
… MWth

~6250 Nm^3/h CH_4
… MWth

Gas flows operating with biogas 50% CO_2 50% CH_4

Input CO2	500 Nm^3/h 311 SCFM	1000 Nm^3/h 622 SCFM	2500 Nm^3/h 1555 SCFM
Input CH4	**500 Nm^3/h 311 SCFM**	**1000 Nm^3/h 622 SCFM**	**2500 Nm^3/h 1555 SCFM**
Input H2	2000 Nm^3/h 1240 SCFM	4000 Nm^3/h 2480 SCFM	10000 Nm^3/h 6223 SCFM
Output CH4	1000 Nm^3/h 622 SCFM	2000 Nm^3/h 1244 SCFM	5000 Nm^3/h 3110 SCFM
Output Heat	3.2 MWth	6.5 MWth	16 MWth
Electrolyzer Size MWe	**~10 MWe**	**~20 MWe**	**~50 MWe**

Methanation Footprint



Sizing of a methanation plant: CO_2

Electrochaea

INPUT

Gas flow
500 Nm^3/h
311 scfm

Gas composition -
assumed
100% CO_2
= 500 Nm^3/h = 311 scfm

Hydrogen requirement
4: 1 molecules of CO2 to H2
= 2000 Nm^3/h = 1240 scfm

Electrolyzer sizing
10 Mwe at 5 kWh /Nm3 efficiency
= 2000 Nm^3/h = 1240 scfm

OUTPUT

~125 Nm^3/h CH_4
… MWth

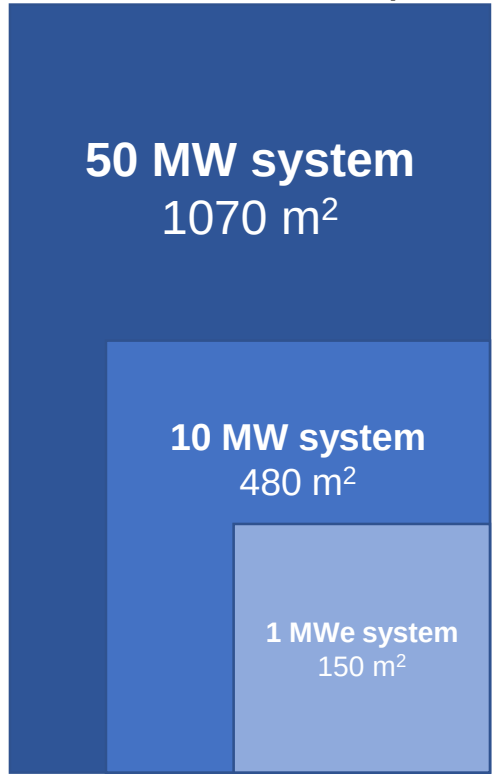
~1250 Nm^3/h CH_4
… MWth

~6250 Nm^3/h CH_4
… MWth

Gas flows operating with biogas 50% CO_2 50% CH_4

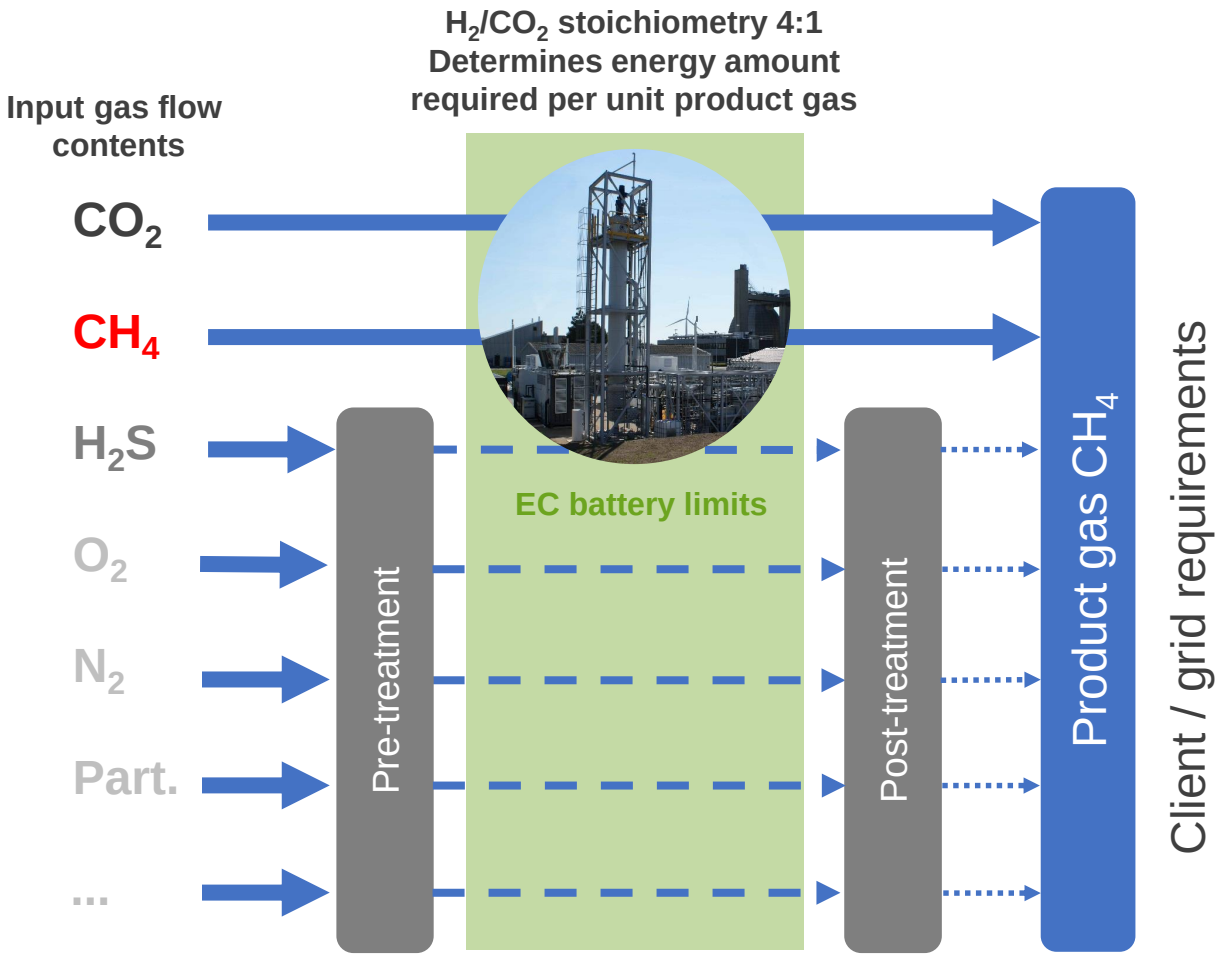
Input CO2	500 Nm^3/h 311 SCFM	1000 Nm^3/h 622 SCFM	2500 Nm^3/h 1555 SCFM
Input CH4	**500 Nm^3/h 311 SCFM**	**1000 Nm^3/h 622 SCFM**	**2500 Nm^3/h 1555 SCFM**
Input H2	2000 Nm^3/h 1240 SCFM	4000 Nm^3/h 2480 SCFM	10000 Nm^3/h 6223 SCFM
Output CH4	1000 Nm^3/h 622 SCFM	2000 Nm^3/h 1244 SCFM	5000 Nm^3/h 3110 SCFM
Output Heat	3.2 MWth	6.5 MWth	16 MWth
Electrolyzer Size MWe	**~10 MWe**	**~20 MWe**	**~50 MWe**

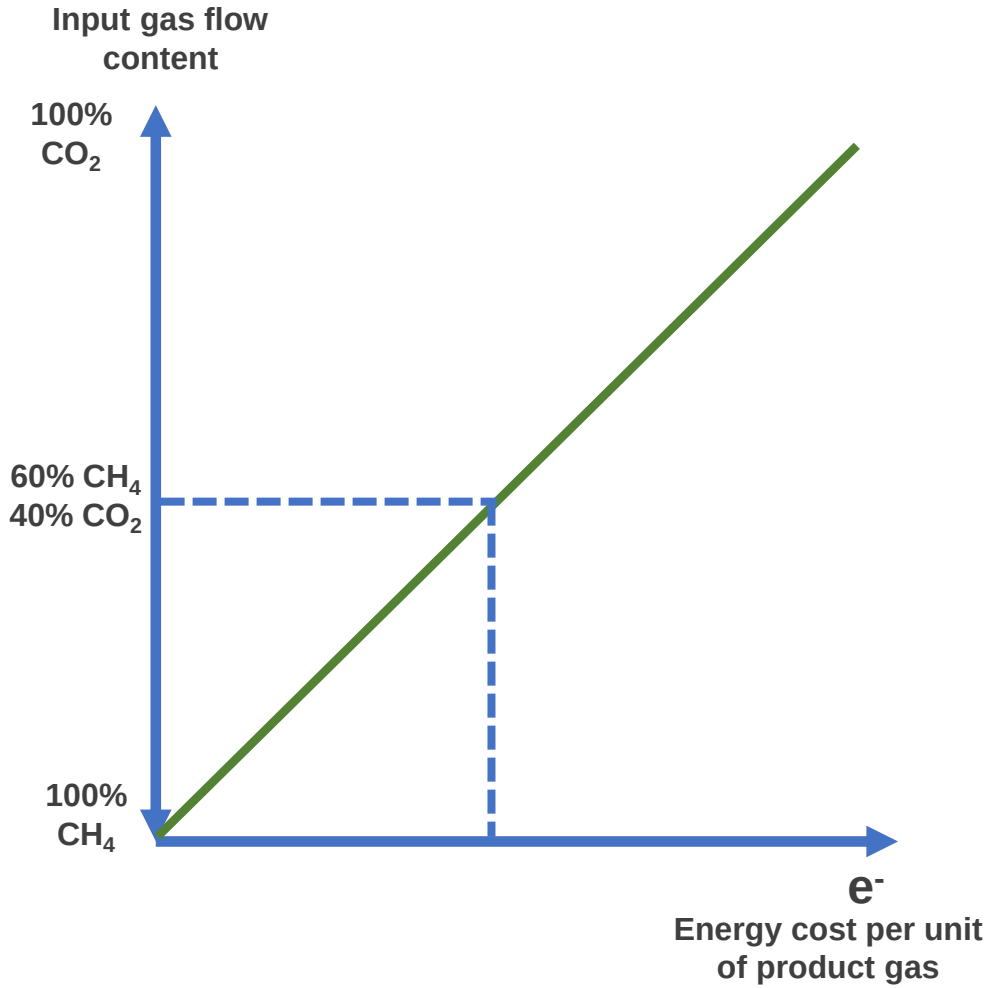
Methanation Footprint



Energy required to convert CO_2 into CH_4 per unit of product gas

Electrochaea





50 MWe plant with Electrochaea technology…

Stores 400 GWh/a of electrical energy*

= More than **125,000** households consumption per year

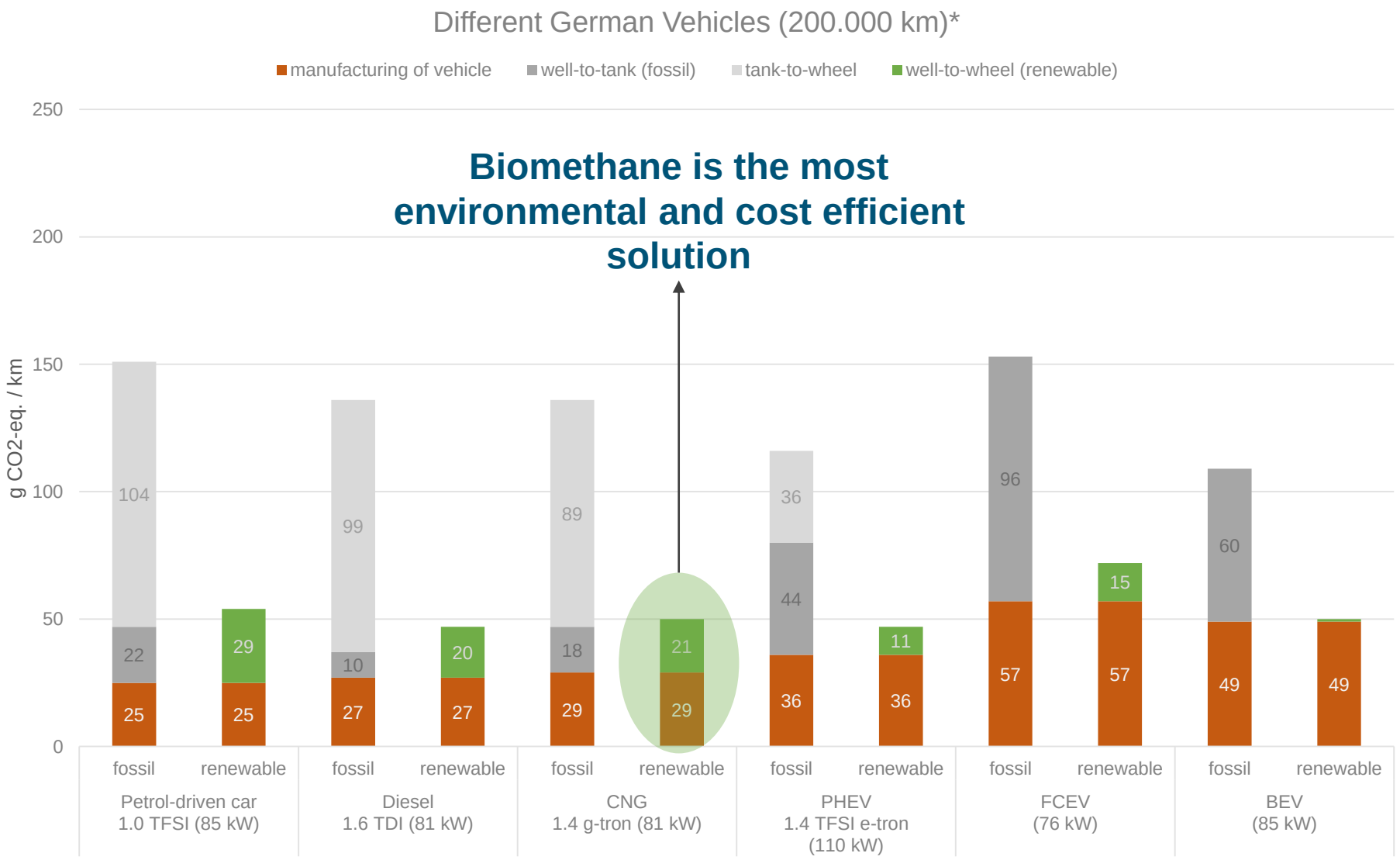
Achieves a CO_2 sequestration of 37,000 tons/a*

= Emissions of **~20,000** cars per year

*assumptions:

- Heat and electricity for one year 3,200 kWh in a household with 4 person in Germany (2013)
- 132.6 gr/km emission per car and 14,000 km driving average km per year in Germany (2014)
- 8,000 hr/a of operation, electrolysis included

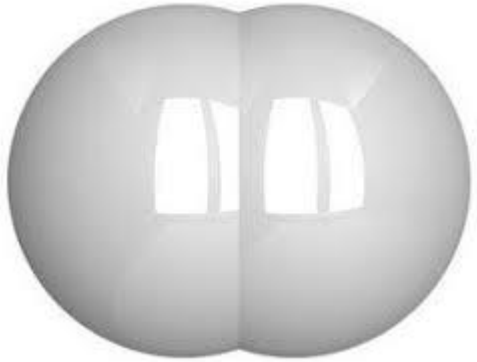
Cradle to grave LCA for different vehicles



*Adapted from: https://www.dena.de/fileadmin/dena/Dokumente/Veranstaltungen/Jahreskonferenz_Power_to_Gas/Praesentationen/Block_II_1_Pengg_NEU.pdf

Why CH_4 in stead of H_2

H_2



Parasitic energy
Difficult to compress
Challenging to transport
Embrittlement
Infrastructure insanelyexpensive and not available

CH_4

Easier to compress
Easier to transport
Safe to distribute
Infrastructure existing
Ideal carrier of energy content

Vision, Mission, Strategy

Vision
Become the Leading Provider of Power-to-Methane Technology
for Carbon and Energy Storage

Mission
To link the gas and electricity grid with the power-to-gas storage technology
to store energy and decarbonize the gas system

Strategy
Enable, via partnerships, the construction of commercially viable plants where the regulatory framework and market prices enable profitability and create partnerships to spread the technology worldwide

Enable revenues via gas sales and carbon mitigation for or our partners and licensees, and for Electrochaea via licenses, technology and engineering fees, and royalties

Attract Partners and or Equity to facilitate global footprint and an attractive exit for all parties

Definition of EC business model
"Provider of P2M technology for Carbon and Energy storage"

Electrochaea

University of Chicago

Electrochaea

functions

Technology development	Project Management	BD Finance	Engineering

sources of revenues

Recurring revenues

- Royalties on licensed prod
- Service contracts

Fees

- Sale of catalyst +warranty
- Upfront fee
- Technology fee

Project Charges

- Design and engineering
- Project Management
- Commissioning and training

suppliers

- Electrolyzers
- Plants' parts/components
- (Chemical) consumables

partners

- EPC
- Solution providers

clients

- Utilities
- Operators Gas distr. & transmission
- Large private clients
- Industry with high carbon footprint
- Waste operators
- Biogas plants
- Breweries
- Ethanol plants

Thank you

Electrochaea

Electrochaea GmbH
Semmelweisstrasse 3
82152 Planegg, Germany
www.electrochaea.com
info@electrochaea.com

Strong Network and Collaborations

Investors

MVP MUNICH VENTURE PARTNERS, b·to·v, storengy, Sirius Venture Partners, CALIZA, energie360°, kfw, NIDUS

Memberships

BVES BUNDESVERBAND ENERGIESPEICHER, IBB Netzwerk GmbH, DANMARKS VINDMØLLEFORENING, Brintbranchen Hydrogen Denmark, UseCO2 Kooperationsnetzwerk

Partners

ENERGINET, NEAS ENERGY, nel, Audi Vorsprung durch Technik, INSERO BUSINESS SERVICES, HMN GASHANDEL, HYDROGENICS, BIOFOS, Aalborg University

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

2019 GLOBAL CLEANTECH100 Produced by Cleantech Group — Winner 2019

pv magazine 2018 Energy Storage Highlights — Winner 2018

Ausgezeichnete Orte im Land der Ideen — Winner 2017

STEP AWARD — Winner 2017

Start Up Energy Transition Award — Finalist 2017

ECOSUMMIT AWARD Fame and Fortune for the Best Smart Green Startups — Bronze Medalist 2016

2014 Global Cleantech 100 TOP 100 COMPANY Cleantech Group