Biocat – Power to Gas technology by Biological methanation
Integration to a resource treatment plant

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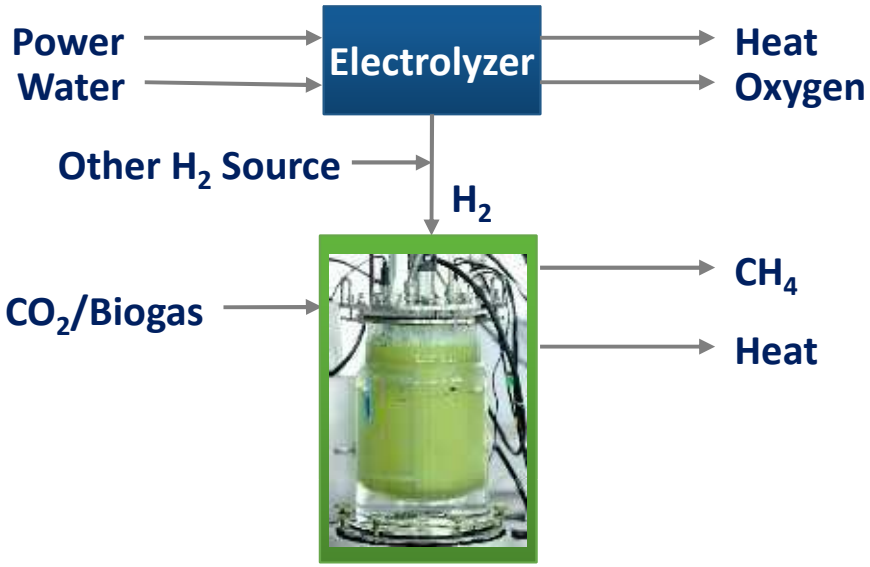
What is the Power-to-gas ?

Charging the natural gas grid

- Excess renewable power
- Grid congestion
- CO_2 emissions

- Established grid, storage and uses for natural gas.
- Decarbonization
- Need for renewable gas

What is Biological methanation ?



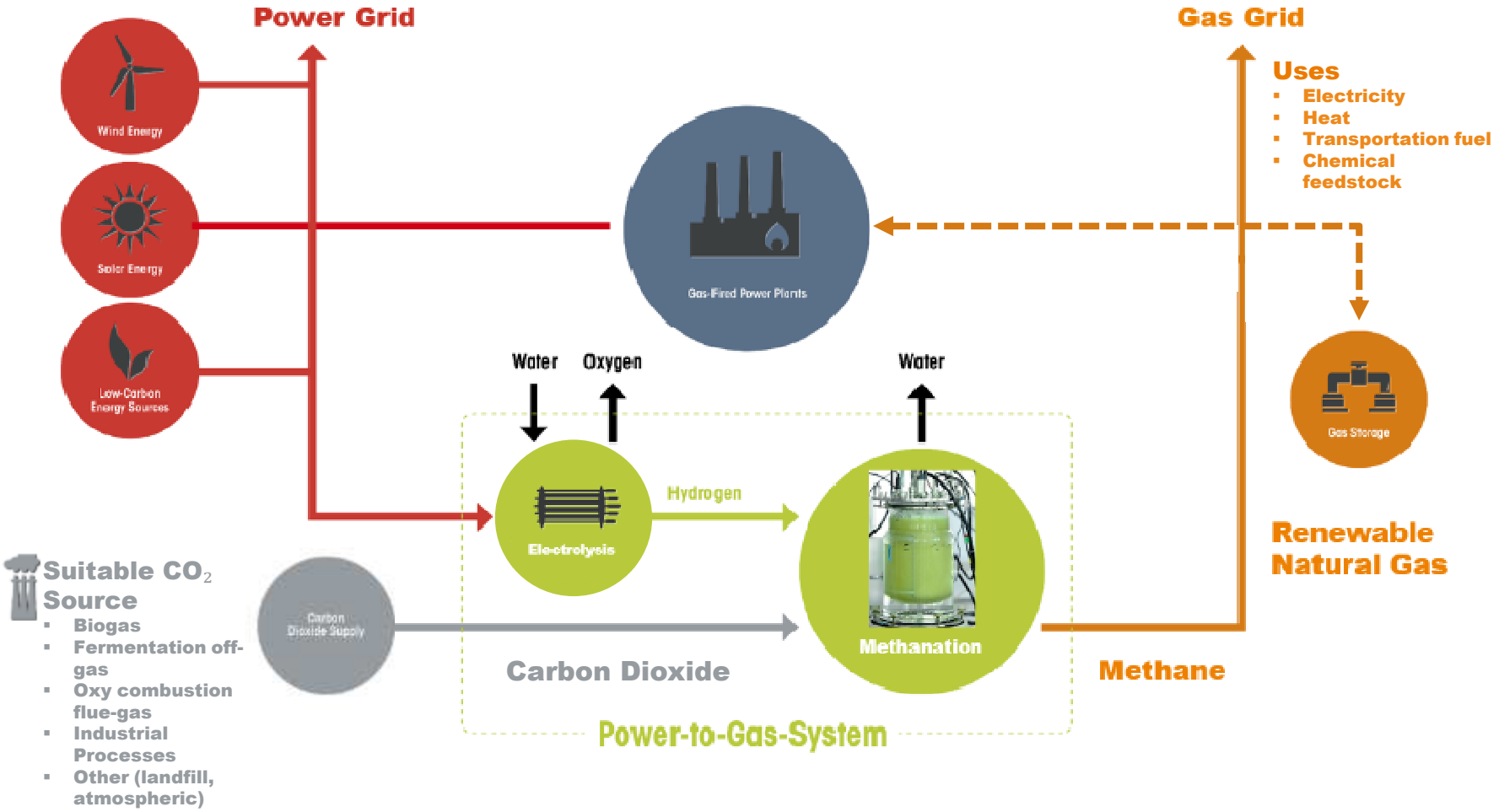
1) Electrolysis	$4H_2O \rightarrow 4H_2 + 2O_2 + Heat$
2) Methanation	$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O + Heat$
Net Reaction	$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2 + Heat$

Operating Conditions:

Temperature 62°C, Pressure 1 to 10 bar(a)

Opportunities for process integration

Power-to-Gas Energy Storage



Source: Adapted from ZSW, *Erneuerbares Methan aus Ökostrom,* April 2012

Electrochaea Executive Summary

Electrochaea's vision is to become the world's leading technology provider in power-to-gas energy storage

- **Opportunity**
  - Conversion of low cost energy and carbon dioxide into natural gas, leveraging existing infrastructure
  - Decarbonization of power generation, transport fuel, and industrial processes
- **Technology**
  - Proprietary, simple and robust biocatalytic methanation system
  - Dynamic and scalable process to meet a broad range of conversion and storage applications (1 to >100 MW)
- **Execution**
  - Expert team with proven track record
  - 1 MWe commercial scale operation commissioned in 2016
  - 1 MWe plant erected in 2017-2018
  - 10 MWe study for Hungary
- **Funding**
  - Consortium of venture and strategic investors with 1:1 non-diluting capital

Mich Hein, PhD
Managing Director

- Co-founder and managing partner at Nidus Partners
- Passionate entrepreneur
- Raised $50 Mio for start-ups

Doris Hafenbradl, PhD
CTO

- 20 years of experience in biotech and pharmaceutical industries
- Expert in hyperthermophilic archaea

Markus Forstmeier, PhD
VP Business Development

- 15 years of experience in renewable energy and water treatment space
- Closed major partnerships and contracts >$25 Mio

Laurent Lardon
Biocat Project Leader

- 15 years of experience in development and technology maturation of biological processes
- Anaerobic processes and Process Control specialist

Rapid technology de-risking and scale-up

1 MW — **Commercial-Scale Field Trial**

Preparing for market entry with a commercial-scale demonstration unit, using an optimized reactor, Avedøre (DK)

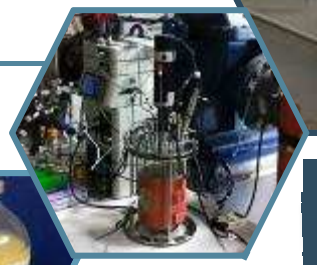
BioCatProject
POWER-TO-GAS VIA BIOLOGICAL CATALYSIS

50 kW — **Pre-Commercial Field Trial**

Process demonstration in a 5m³ stirred tank bioreactor using raw biogas, Foulum (DK)

1 kW — **Lab-Scale Field Trial**

Biocatalytic capability test with raw biogas



n/a — **Basic Research**

In Dr. Mets' laboratory at the University of Chicago

Power Input

2006 - 2010

2011 - 2012

2013

2014 - 2016

Rapid technology de-risking and scale-up

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How it Began: Chicago, USA

Dr. Laurens Mets‘ Laboratory, University of Chicago

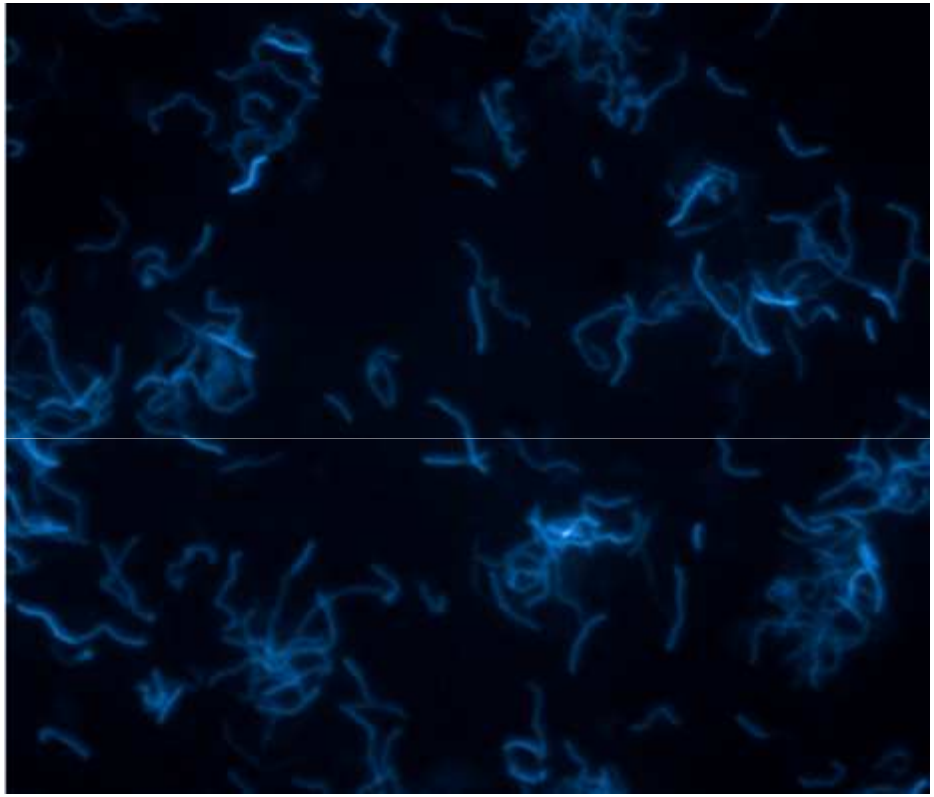
The seeds were planted in the laboratory of Dr. Laurens Mets at the University of Chicago

- Demonstration of high efficiency conversion of carbon dioxide and electrical energy into methane
- Optimization of a unique strain of Archaea
- Filed patent applications on stirred cell system and bioelectrochemical systems

How it Began: Chicago, USA

Dr. Laurens Mets‘ Laboratory, University of Chicago

- Highly efficient biocatalysis with Archaea in stirred cell reactors and in bioelectrochemical systems was established
- Scalability towards commercial storage of renewable energy was demonstrated



Foulum, Denmark

Foulum Project "Carbon Dioxide to Methane – System Integration"

- In 2012, Electrochaea.dk proposed the project "Carbon Dioxide to Methane – System Integration" with its partners Aarhus University, EON and NEAS Energy

- The 12mio DKK project was supported with a 6.6mio DKK grant from EUDP and additional project support from Electrochaea LLC, EWZ, and Energie 360°

Foulum, Denmark

Continous Operation for 3 600hrs

- The reactor operated in 4 800 liters of reactor volume for 3 600 hours, demonstrating scalability and process efficiency
- product gas was used in the local CHP generator

The BioCat Project

Avedøre, Denmark

- As part of the Foulum project, Electrochaea.dk identified potential sites for its first megawatt scale reactor, called “BioCat”, with the capacity to inject biomethane into the Danish gas grid
- Funding for the project was secured from the ForskEl program in 2014
- Detailed engineering and construction for the BioCat Project began in 2015 after completion collaboration agreements among the Project Partners

The BioCat Project, Avedøre

Can We Reach High Efficiency at this Scale?

We started with a greenfield site adjacent to the planned gas testing and gas injection site for HMN‘s commercial grid in Copenhagen

The BioCat Project, Avedøre

Managing Full Site and System Integration

The methanation reactor and balance of plant systems were contracted to Zeton, Inc., in Enschede NL

The BioCat Project, Avedøre

Managing Full Site and System Integration

The biomethanation reactor, agitator and balance plant were laid in place in less than one day

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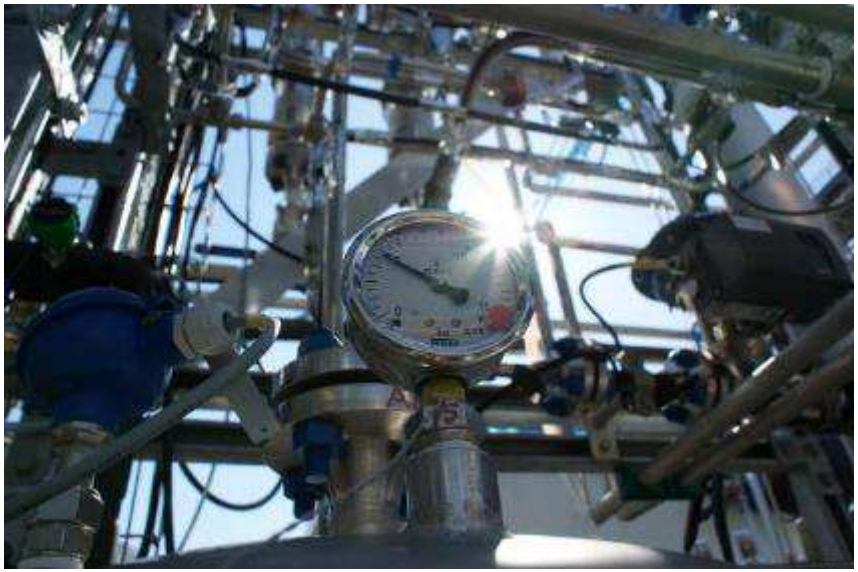
The BioCat Project, Avedøre

Aiming for Grid Injection

Biocatalyst inoculation and first conversion of CO2 to methane in April



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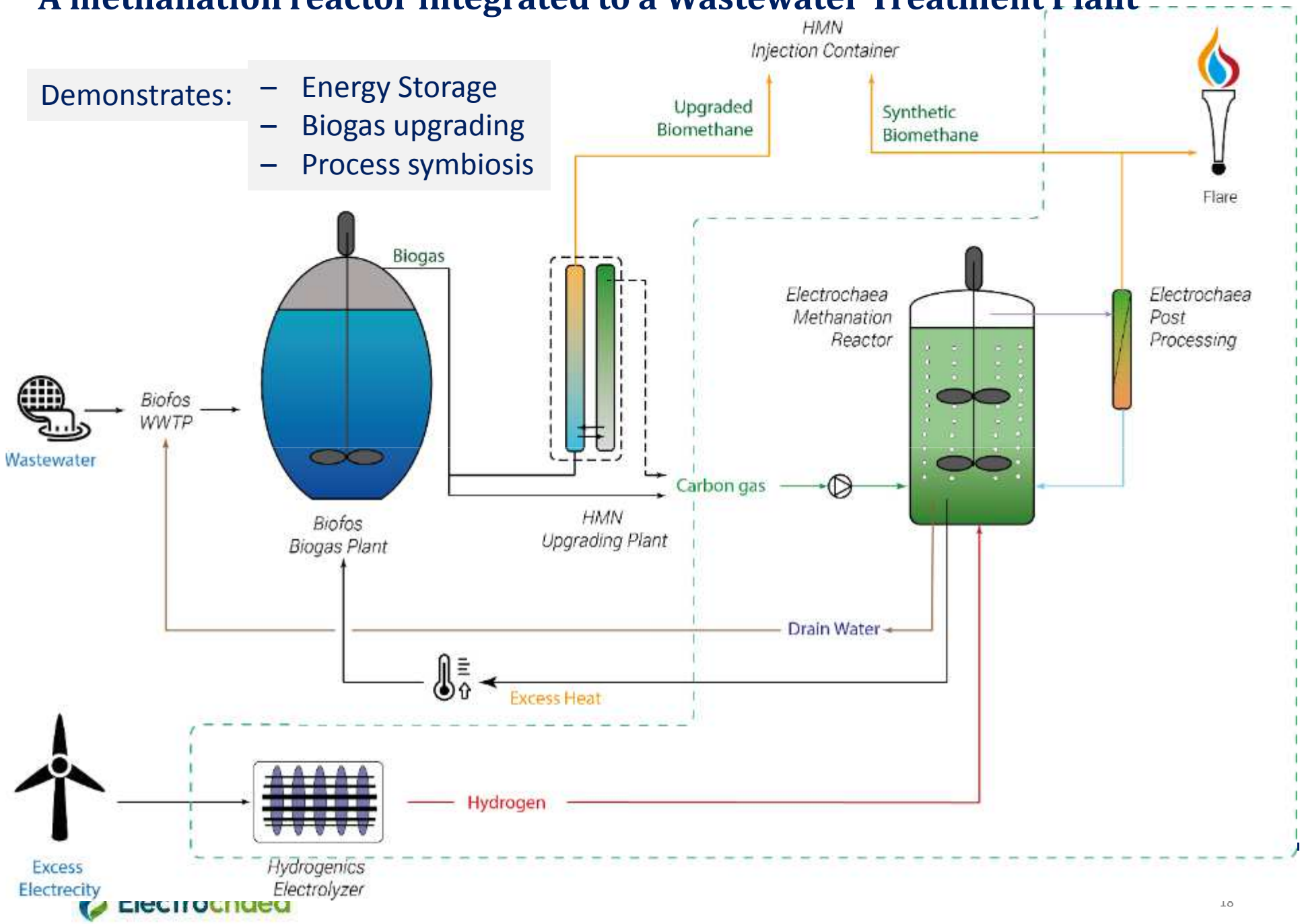
Who are these bugs?

- Here our most valuable employees, the Archaea should be presented

A methanation reactor integrated to a Wastewater Treatment Plant

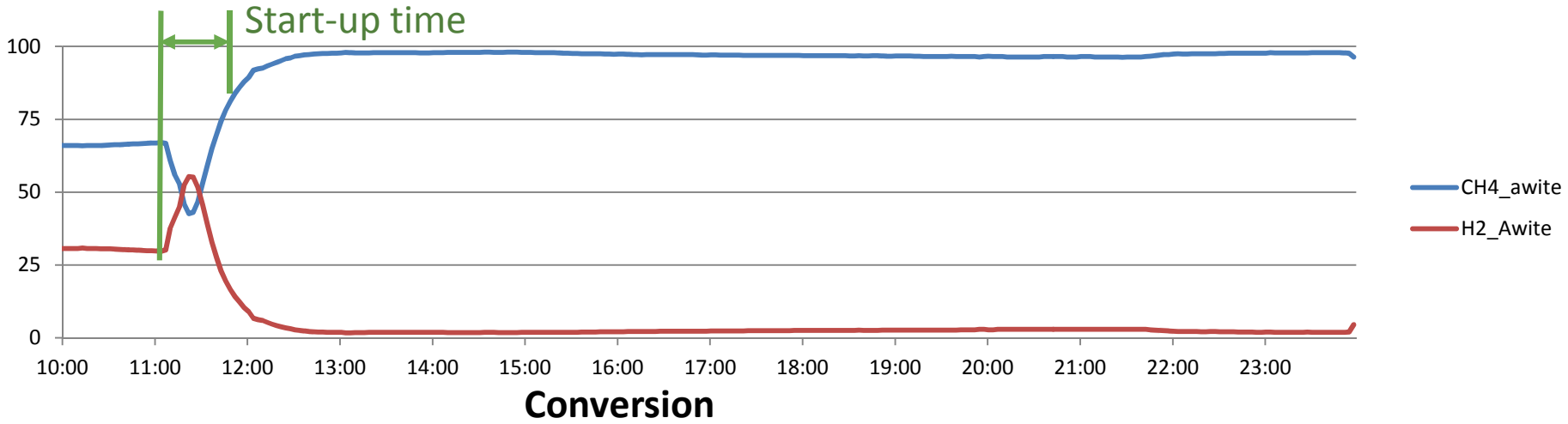
Demonstrates:

- Energy Storage
- Biogas upgrading
- Process symbiosis

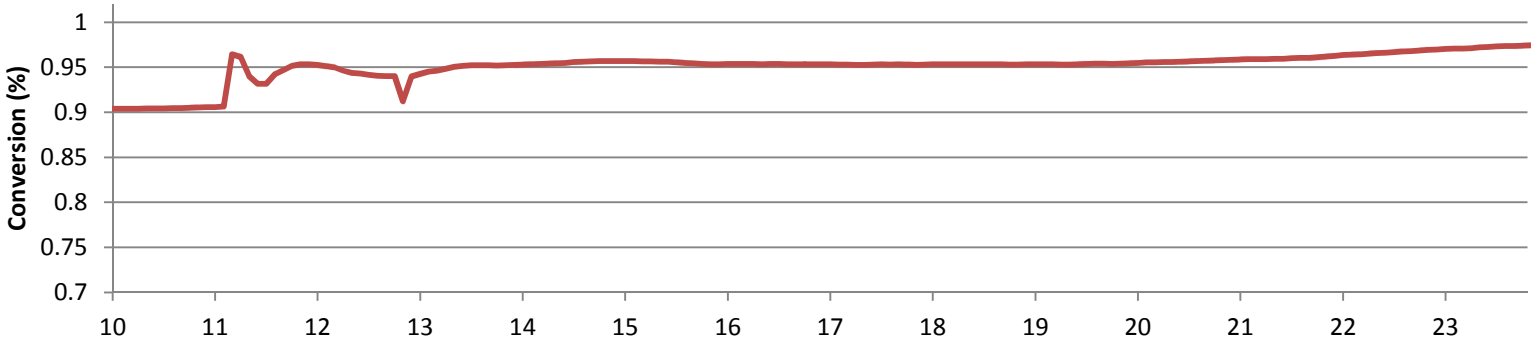


Operational results

- Cold start in 45 minutes after 60 hours idle
- Methane content > 97% before polishing
- CO_2 conversion > 98%

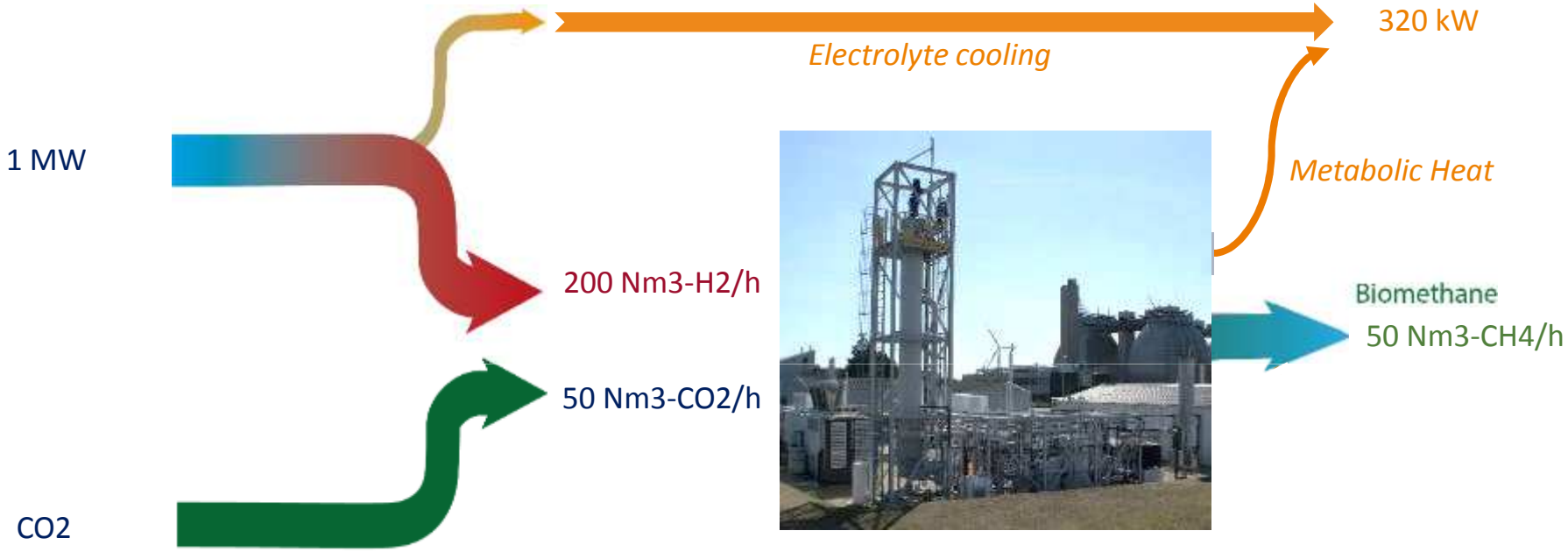


Conversion



BioCat: Biological methanation system in Megawatt scale

- Conversion of excess renewable power into biomethane



- Proprietary Bio-Catalyst (4 patents), in-house system design & operation
- Scaling: to 10 MW and 50 MW systems and regionally
- Competitive Advantage: dynamic operation, high tolerance to impurities

The Future

Continue Operation of BioCat Plant – Integration to WWTP

- Electrochaea and the project partners intend to continue operating the BioCat reactor and electrolyzers as a commercial scale power to gas facility
- Commercial sale of renewable biomethane to the Danish gas grid, to demonstrate conditions for economically viable power to gas conversion in Denmark
- Serve as a reference facility for future projects

Intensify industrial symbiosis

- Heat exchange from the electrolysers
- Scaling of Oxygen injection to activated sludge.

Environmental Technology Verification

- 1000 hours of operation
- Different operation modes: continuous, power-regulation, biogas / CO2

Business model and growth strategy

Be the key technology provider for biological methanation

Focus on key markets

Tap multiple revenue streams

- Payments for feasibility studies on special feed gases
- Fee for initial engineering of BioCat core and interfaces
- Royalties for utilization of proprietary bio-catalyst
- Operation & maintenance fees

What are the next steps?

- Expand BioCat plant size to grid scale at 10 MW and 50 MW
- Secure contracts and financing to execute first grid scale project
- Expand technology and IP advantage
- Reduce overall system cost
- Engage with industrial partners to identify first of a kind 50 MW project

Partners and Investors

Electrochaea

Electrochaea GmbH
Semmelweisstrasse 3
82152 Planegg, Germany
http://www.electrochaea.com

Markus Forstmeier, PhD, VP BD
markus.forstmeier@electrochaea.com

2014 Global Cleantech 100 – TOP 100 COMPANY

ECOSUMMIT AWARD – Fame and Fortune for the Best Smart Green Startups

Bronze medalist 2016
in early stage category

Electrochaea

Thank you for your attention and questions

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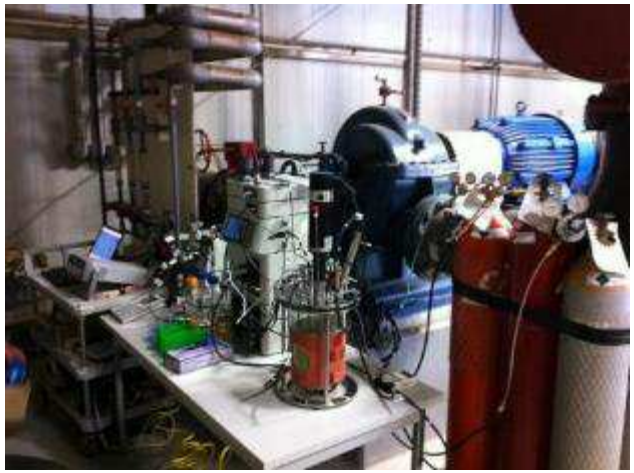
St Louis, USA

Does it Work as Advertised?

Electrochaea demonstrated the ability to replicate Dr. Met's work in an industrial environment and towards commercial application:

- Developed scalable protocols for biocatalyst production
- Designed the first generation reactor for commercial application



We are Moving to Europe

Targeting the Danish Market

- In 2011, Electrochaea identified Denmark and other northern EU markets as the target markets for technology scale up and sales of renewable natural gas
- Electrochaea.dk was formed in August 2011, with funding from Electrochaea LLC