Emerging Gas Technologies for Lower GHG Emissions
Growing public and policy discussion on how to meet Paris commitments to 80% GHG reduction (COP21)

Various source/process/end use scenarios can achieve 2050 GHG emission goals. Mixed case generally less costly.
Emerging gas technologies can make substantial and cost-effective contributions to GHG reduction goals

~100
Innovative Gas Technologies for Residential / Small Commercial identified from around the world

25-40%
GHG reduction potential on a customer basis by integration of these technologies and other efficiency practices

60-80%
GHG reduction – sufficient to meet COP 21 goals – with inclusion of future CHP technologies and Renewable Gas

• Policy goals for sustainable energy can be achieved at significantly lower consumer cost through integrating innovative gas solutions into long-term resource planning, while offering customers more choice and improved affordability and reliability.

• Gas technologies can enhance energy system reliability (system-wide and as a local backup) and efficiency, while reducing the need for new electric generation and T&D infrastructure and preserving the future value of gas infrastructure.

• Electric technologies will also improve, and are supported by incentives, but their GHG impacts depend on the generation fuel mix. In some regions electrification will increase GHG emissions through the 2030s.
Emerging Gas Technologies for Lower GHG Emissions

MODERATOR: BILL KEMP
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Director, Market Development, Europe, Middle East and Africa, Westport Fuel Systems

MICH HEIN
CEO, Electrochaea
Better Ways for Methane than Flaring
Methane is produced as a side product from the oil and gas fields, and also generated via biogas by fermentation of manure, waste and other biodegradable feedstock.

After rising slowly from 2000 to 2006, the concentration of methane in the air has climbed 10 times more quickly in the last decade.

Methane is far more potent than CO2 as a greenhouse gas, capturing more of the sun’s radiative force, but it persists for less time in the atmosphere.

Scientists calculate that over a 100-year period the “global-warming potential” of the gas is 28 times greater than for CO2.
Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living.

Research estimates that livestock accounted for 44% of human-induced methane and 16% of human-induced greenhouse gas emissions.

Contribution on global emissions is expected to raise sharply.
Flaring is one way to solve the problem with methane...

Flaring the excess gas provides an opportunity to reduce emissions.

Process creates CO2 but it destroys methane which is 21 times more potent than CO2.

The combustion of methane gas releases 50.1 kJ/g.

Turning the heat from flaring into electricity does not stop CO2 from being emitted, but it recycles the heat to be used as power.
Flaring of gas contributes to climate change and impacts the environment through emission of CO2, black carbon and other pollutants.

It wastes a valuable energy resource that could be used to advance the sustainable development of producing countries.

Annual waste could provide about 750 billion kWh of electricity, or more than the African continent’s current annual electricity consumption.

"Zero Routine Flaring by 2030" initiative, introduced by the World Bank, aims to eliminate routine flaring no later than 2030.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Pounds of CO2 emitted per million British thermal units (Btu) of energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal (anthracite)</td>
<td>228.6</td>
</tr>
<tr>
<td>Coal (bituminous)</td>
<td>205.7</td>
</tr>
<tr>
<td>Coal (lignite)</td>
<td>215.4</td>
</tr>
<tr>
<td>Coal (subbituminous)</td>
<td>214.3</td>
</tr>
<tr>
<td>Diesel fuel and heating oil</td>
<td>161.3</td>
</tr>
<tr>
<td>Gasoline (without ethanol)</td>
<td>157.2</td>
</tr>
<tr>
<td>Propane</td>
<td>139.0</td>
</tr>
<tr>
<td>Natural gas</td>
<td>117.0</td>
</tr>
</tbody>
</table>
Argentina’s National Institute of Agricultural Technology (INTA) has come up with a solution

The backpack captures and collect the gases emitted through the cow’s mouth or intestinal tract via a tube inserted through the cow’s skin

The gas is then condensed and ready to use to provide power for the farm on which the cow lives

The 300 liters of methane per day a cow emits can be used to operate a fridge capacity of 100 liters at a temperature of between two and six degrees for a full day
Finno Energy has developed a clean, pressure-gain combustion process for power generation in micro turbines.

We are first to successfully employ the Humphrey cycle (pressure-gain) technology in microturbine size range.

Our **PULSE TURBINE** achieves an electrical efficiency over 40%.

**PULSE TURBINE** can utilize methane and other biogas as fuel, with tolerance for high levels of water.

Units are fully remotely monitored and controlled, and can be brought close to the fuel source and energy production needs.
IDEAL FOR DISTRIBUTED ENERGY PRODUCTION

Industry Parks  Food Productions  Biogas Producers  Hotels & Real Estate

Airports  Data Centers  Water  Hotels
Excess methane flaring produces huge waste of energy across oil and gas production and livestock industry.

Flaring will be eventually reduced.

We will solve the problems with excess methane to enable utilizing it efficient fuel for CHP production with distributed units close to the energy needs.
THANK YOU
Emerging Gas Technologies for Lower GHG Emissions

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MICHELE HEIN
CEO, Electrochaea
boostHEAT, A global player for energy transition
PIioneer of a new world of energy.

Boostheat manufactures the world's most energy-efficient boiler. Thanks to biogas this boiler is 100% green today.
The innovative combination of a standard condensing heating unit with a CO2 heat pump cycle driven by thermal compression instead of mechanical work sums up to a condensing heating unit supplying 20kW heat at 65°C and a seasonal gas utilization (SGUE) of up to 200%.

This heating system hence comes with up to 50% renewable ambient thermal energy available all year round.

The heat pump cycle is driven by external combustion heat. It can be operated with whatever type of gas: natural, liquid, biogas, fluegas or even hydrogen.

The development was started in the year 2004 and supported by strong partners holding stakes in the gas sector. The market entry will take place in mid 2018.
A STARTUP IN TRANSFORMATION

A brief history of boostHEAT

2004
Starting Research and Development

2009
Thermal compressor concept validation

2011
boostHEAT incorporation - 1st patent

2013
1st compressor prototype

2015
1st boiler prototype

2017
Vénissieux (Lyon FR) Industrialization

2018
Boiler launch for residential market

2019
Boiler launch for commercial & tertiary market
A STARTUP IN TRANSFORMATION

boostHEAT fundamentals

14 years of Research & Development

7 FAMILIES OF PATENTS

OWNER of its technology

Key partners

Supported by famous partners

Financial supports

Shareholding

2 co-founders, Fluxys, Holdigaz and 3 family offices focused on energy representing more than 70% of the shareholding.

2018 : START OF SALES

Financial summary (in Million of Euros)

- Private equity
- Grants & Partnerships
- Debts

Human Resources as of today (employees)

- R&D Lab
- Plant
- Sales and supports

OWNER of its technology

Supported by famous partners

Financial supports

Human Resources as of today (employees)
Innovation

A thermal compressor at the service of the heat pump
THE THERMAL COMPRESSOR AT THE SERVICE OF THE HEAT PUMP

A design using the boostHEAT thermal compressor to activate the heat pump cycle

The boostHEAT heat pump boiler principle
THE THERMAL COMPRESSOR AT THE SERVICE OF THE HEAT PUMP

General architecture: an association of technologies

3 MODULES
made separately and interconnected by the installer at the end customer:

- **INDOOR UNIT** brings comfort
- The **THERMODYNAMIC CHARIOT** brings energy efficiency
- **OUTDOOR UNIT** for renewable energy capture.

Performance Up to 200%*  
*Compared to the best current boilers
Performance curve – seasonal performances

AUDIT BY GDF SUEZ JUNE 2013

Gas Utilization Efficiency - EN 12309 - medium (-10°C/48°C)

+ DHiW at 85°C available whatever the heating temperature

GUE heat pump alone

GUE with booster heater (comfort)

Relative number of hours in a year for each external temperature

A++

A+

A

Expected values based on lab tests and modelling - EN 12309
boostHEAT, a disruptive innovation contribution

- **Divide by 2 energy consumption** compared to the condensing boiler, **divide by 3** compared to the old boiler
- **We provide up to 50% of renewable energy**
- **Performance up to 200%** VS primary energy

**COMSUMPTION REDUCTION**

- Up to 30%
- Up to 65%
- Up to 50%

BoostHEAT, A HUGE EFFICIENCY GAP IN A CONSERVATIVE BUT STABLE MARKET

*capturing calories in the air
Industrialization

A production plant in Vénissieux (LYON) FRANCE
An industrial site of excellence in Lyon

- An industrial site in the heart of a city with industrial sensitivity
- An exceptional site for its transport access, for its highways and its logistical interests
- Very fast access to our ecosystem of suppliers
- 35% of the HVAC industry is made in Lyon
- At the heart of an industrial campus of 11 ha

Key dates

2016
BOSCH REVITALIZATION AGREEMENT
SEPTEMBER 2016: INSTALLATION
SPRING 2017: PIAVE & BANKS INDUSTRIALIZATION FINANCING
JUNE 2017: COMPRESSOR PRODUCTION LINE ORDER

AT THE HEART OF THE FRENCH HVAC ECOSYSTEM
A PRODUCTION PLANT IN VÉNISSIEUX (LYON), FRANCE

Flows blue print
Compressor production line
Pressure + Leak test bench
Product Marketing

Two products for two major market segments
TWO PRODUCTS FOR TWO MAJOR MARKET SEGMENTS

1 technology : 2 products

boostHEAT
20 kW
START OF PRODUCTION : Q4 2018

boostHEAT
50 - 250 kW
START OF PRODUCTION : Q4 2019

BtoC
RESIDENTIAL

BtoB
COMMERCIAL
SALES AND MARKETING STRATEGY BOOSTHEAT 20KW

A disruptive approach
boosTHEAT20kW: A DISRUPTIVE APPROACH

Breaking business strategy

boostHEAT, owner of the customer relationship:
- Leads qualification
- Validation of the laying
- Installation
- Maintenance
- After sales service

BOOSTHEAT CONTROLS ITS ENTIRE VALUE CHAIN
Axe of renewal
A targeted offer for a calm decision

A **turnkey** heating **solution**, with:

- Financing with a boostHEAT partner
- The boostHEAT boiler supplied, installed
- A maintenance contract
- A warranty extension
- A green Gas supply option
- Easy to understand
- Easy to use
- Comfortable a single interlocutor: the manufacturer
- Reassuring: leading partners

**A PRECISE, PERSONALIZED PROCESS, WITH SLOW MATURATION AND THOUGHTFUL DECISION**
A DISRUPTIVE APPROACH

Objective & planning

- **Mass Marketing**
- **First installations**: Ambassadors
- **Launch of the pre-series production**
- **Team Mar Com Providers search**: AO: call center, training, …
- **Construction of the commercial scheme Organization**
- **ERP- AO CRM Deployment Internal Service Recruitment**

- **Sept 2018**: Mass Marketing
- **June 2018**: First installations Ambassadors
- **Nov 2017**: Launch of the pre-series production
- **Sept 2017**: Team Mar Com Providers search AO: call center, training, …
- **June 2017**: Construction of the commercial scheme Organization
- **1st half of 2019**: Mass Marketing
The future

By boostHEAT
THE FUTURE BY BOOSTHEAT

boostHEAT: the biotech of the energy

**Initial offer**
- **Ergonomic**
- **Custom-built**
- HOME: 20 KW
- SMALL RESIDENCES: 50-250 KW
- RESIDENTIAL & COMMERCIAL: > 250 KW

**Future developments**
- **Reversible** range with cooling system
- **Micro-cogeneration**
- Integration in **Smart-Grid** networks, remote control, free energy billing...

A 100% owned technology platform for multiple applications: industry, chemical, HVAC,...
boostHEAT,
THE POSITIVE ENERGY

THANK YOU
The heart of our Tri-thermes boiler

The regenerative thermal compressor

> COMPRESSION
The heart of our Tri-thermes boiler

The regenerative thermal compressor

> DISCHARGE
The heart of our Tri-thermes boiler

The regenerative thermal compressor

> EXPANSION

![Diagram of the regenerative thermal compressor](image_url)
The heart of our Tri-thermes boiler

The regenerative thermal compressor

> INTAKE

Cylinder

Heater
Regenerator
Cooler
The heart of our Tri-thermes boiler

The regenerative thermal compressor

- Technology from engines and compressors
- Simplicity and reliability
- Lifetime greater than 50,000 hours without maintenance
- Economic (replace an engine and a compressor)
- Performance

A UNIQUE SOLUTION from 10 years of research
Emerging Gas Technologies for Lower GHG Emissions

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Director, Market Development, Europe, Middle East and Africa, Westport Fuel Systems

**MICH HEIN**  
CEO, Electrochaea
Lower GHG Emissions with Gas Technology Innovations in the Transportation Sector
THE WORLD OF WESTPORT FUEL SYSTEMS

$247M
2017 Revenue

800+ Patents/ Applications

$247M
2017 Revenue

800+ Patents/ Applications

1300 Employees

>100 Distributors

70 Countries customers served

14 Offices & facilities

THE WORLD OF WESTPORT FUEL SYSTEMS

Broad Applications

Locations

Alternative Fuels

Key Priorities

- Broaden product offering
- Deploy market-ready solutions
- Continue to focus on cash management
- Increase engagement with key OEMs and industry partners

Driving innovation to power a cleaner tomorrow

Note: Approximate number of employees and products as of December 31, 2017
DELIVERING THE WORLD’S MOST ADVANCED NATURAL GAS TECHNOLOGIES FOR COMMERCIAL TRANSPORTATION

Leadership and focus on natural gas technologies for commercial transportation

Reduced environmental footprint without compromising performance

Agile and collaborative partnerships

The fierce pursuit of science and innovation
EU28 goal to reduce transport GHG by 80-85% from 1990 levels by 2050*

Share in Road Transport Greenhouse Gas Emissions (GHG) by Transport Mean: EU-28 (2015)

- Cars: 61.0%
- Light duty trucks: 11.8%
- Heavy duty trucks and buses: 25.9%
- Motorcycles: 1.3%
- Other Road Transportation: 0.0%

Greenhouse Gas Emissions (GHG) from Road Transport, by Transport Mean: EU-28

Source: European Commission: “Statistical Pocketbook 2017”
*Source: European Commission, A European Strategy for Low-Emission Mobility, 2016
"Heavy Duty Commercial Vehicles: only natural gas drives offer potential (…for meaningful GHG reductions…) until 2026"

Deloitte, Global Truck Study 2016 – The truck industry in transition

Natural gas offers an attractive pathway towards sustainable fuels like biomethane and e-methane

Source: Deloitte: "Global Truck Study 2016 – The truck industry in transition"
## WESTPORT ENGINE TECHNOLOGY SOLUTIONS

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>FUEL CHOICE</th>
<th>ENGINE TECHNOLOGIES</th>
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</thead>
<tbody>
<tr>
<td>High Horsepower</td>
<td>LNG*</td>
<td>high pressure direct injection</td>
</tr>
<tr>
<td>• mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• rail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• marine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy-Duty Vehicles</td>
<td>CNG**</td>
<td>high efficiency spark ignited</td>
</tr>
<tr>
<td>• on-highway trucks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-Duty Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-Duty Vehicles</td>
<td></td>
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</tr>
</tbody>
</table>

* Liquefied natural gas  
** Compressed natural gas
WESTPORT™ HPDI 2.0 HIGHLIGHTS

THE RIGHT FIT FOR HEAVY-DUTY TRUCKS
Long Distance, >400hp Euro VI engines, LNG

> High Pressure Direct Injection (HPDI) gas technology
  ▪ Natural gas >90% of the total fuel consumption*
  ▪ <10% diesel*, for ignition only

> Diesel engine performance remains
  ▪ Same high power and torque
  ▪ Similar efficiency (fuel economy) ±1%
  ▪ Same drivability and engine braking

> 18-20% tailpipe GHG emissions reduction vs. diesel**

> Commercially available, preliminary sales in 2017

A FULLY OEM INTEGRATED SYSTEM

OEM Engine with HPDI 2.0 Injectors

LNG Tank Module with Submerged Pump

And other specific truck components (controls, sensors, etc.)

---

* Over vehicle operating cycle
** Over various transient cycles, including methane emissions; also varies with natural gas composition
First OEM product featuring Westport HPDI 2.0™ commercially available

Economically viable solution today

Fully renewable gas compatible

LNG fueling infrastructure is being built

- >150 stations in operation today
- And over 400 stations planned to be in operation by 2021*

Source: Westport analysis, January 2018
* based on projects announced as of Jan 2018
THE HPDI 2.0 OPPORTUNITY
Well-to-Wheel GHG Reduction

Fossil LNG

2017: -15%*
2020: -26%*
2025: -31%*

20% BioLNG blend

Source: Thinkstep "Greenhouse Gas Intensity of Natural Gas", on behalf of NGVA Europe, 2017
* Well-to-Wheel Analysis  ^ Calculated based on EU-28 2030 Electricity grid mix.
Increased engine efficiency thanks to injection pressure increase and other technology improvements

- Further optimized combustion, improved power density and system efficiency, exceeding diesel engine attributes
  - E.g. by injection pressure increase, multiple injections of both pilot and gas
- Further system simplification including ignition improvement (Westport combustion sensor strategy to better adapt to fuel quality)
- Transfer of other diesel engine technology improvements to HPDI (after-treatment efficiency, waste heat recovery, etc.)

Combined with vehicle level technology improvements as for diesel

- Driveline efficiency, aerodynamics, tires, mass reduction, hybridization, etc.

Compatibility with future renewable fuels e.g. e-fuels, maximizing Well-to-Wheel GHG emissions reduction

* Current product Tank-to-Wheel GHG emissions reduction, Source: Thinkstep “Greenhouse Gas Intensity of Natural Gas”, on behalf of NGVA Europe, 2017
** Indicative range of Tank-to-Wheel GHG emissions reduction potential related to engine level technology improvements (without accounting for vehicle level improvements), compared to 2015 diesel engine, based on preliminary Westport analysis and 2017 ICCT data
THE FUTURE OF NATURAL GAS ENGINES

Next Generation HPDI

> HPDI 2.0 is the ideal natural gas solution for 85% of the current commercially available HD truck engines*

> The primary change from HPDI 2.0 will be an increase in the available fuel system pressure coupled with incremental improvements to the entire system to improve efficiency and cost, leveraging Westport’s 20+ years of HPDI experience

* Arnberger, A., Golini, S., Mumford D., Hasenbichler, G., "Commercial Natural Gas Vehicles: Tomorrow’s Engine Technologies for most stringent NOx and CO2 Targets", Internationaler Motorenkongress 2018, Baden-Baden
WESTPORT HESI FOR MEDIUM DUTY ENGINES
High Efficiency Spark Ignited Natural Gas Technology

> Game changing solution that allows natural gas medium duty engines to:

  ▪ Match the performance of the donor base engine – same power and torque with a downsized engine solution – 4 cylinder HESI engine matches 6 cylinder diesel engine

  ▪ Improve the fuel economy by 8-10%, resulting in 20% lower GHG emissions vs. base diesel engine (Tank-to-Wheel)

  ▪ In a cost competitive way – 15% product cost reduction compared to diesel engine & after-treatment

  ▪ Meet most stringent emission requirements – lowest US standards thru MY 2027 and CARB Optional Low NOx Standard

  Dramatic technology shift comparable to introduction of gasoline turbocharged direct injection engines in passenger car market

> Concept running on engine test now and in various stages of development with several vehicle and engine OEMs

Performance comparison for HESI 5.2L engine (4 cylinder, 264 hp) vs. 2018 MY 7.XL base diesel engine (6 cylinder)
WESTPORT HESI GHG EMISSIONS
Vs. EPA HD Phase 2 GHG Rules

- High Efficiency NG Engine Avoids Expensive Electrification and Hybridization
- Phase 1
- Phase 2 (Proposed)

GHG Emissions Limits Versus 2014 Standard

- Diesel Vehicle
- Diesel Engine
- Possible 2027 Diesel Engine
- ESI High Efficiency SI Natural Gas Engine

Model Year

- Additional Vehicle Costs Relative to 2017
  - Electrification and Hybridization
  - Idle Reduction
  - Transmission
  - Axle Related
  - Weight Reduction
  - Tires
  - Air Conditioning
In France, up to 460 TWh of renewable gas could be produced in 2050, which would be sufficient to cover 100% of the 2050 gas demand.

Of this renewable gas, over 100 TWh is expected to be used in the transport sector in 2050.

A 30% share of renewable gas in the grid is realistically achievable by 2030 according to GRTgaz**


Reduction of GHG emissions from transport is needed but challenging

Decarbonizing the trucking sector will require several alternatives, with natural gas being one of the most attractive options.

Next generation of Westport technologies will be as transforming as Westport HPDI 2.0™, already providing 18% Tank-to-Wheel GHG emissions reduction vs. Euro VI diesel today.

Gradually transitioning to a greater share of renewable gas is expected to be an effective and cost-efficient way to decarbonize heavy duty transport.
THANK YOU!

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MICH HEIN
CEO, Electrochaea
Emerging Gas Technologies for Lower GHG Emissions

Mich Hein, CEO, Electrochaea GmbH
CleanTech Forum Antwerp - May 16, 2018
How much energy can you afford to lose?

What are we doing to lower the world’s carbon footprint?

What if methane becomes the perpetual renewable fuel?
Renewable Energy Generation is Growing...

World Renewable Energy Generation Projections

- Growth in renewable power generation will continue near the current rate, (EIA)
- This power is intermittent, not responsive to demand
- Challenges increase with greater renewable energy production

... we need to store it or lose it

Own elaboration from, [https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-IEO2016&region=4-0&cases=Reference&start=2010&end=2040&l=1A&linechart=Reference-d021916a.48-15-IEO2016.4-0&ctype=linechart&sourcekey=0](https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-IEO2016&region=4-0&cases=Reference&start=2010&end=2040&l=1A&linechart=Reference-d021916a.48-15-IEO2016.4-0&ctype=linechart&sourcekey=0)

How much energy can you afford to lose?

2017 Curtailment:

California ~ 400GWh
Denmark ~ 102GWh

Electrochaea’s technology allows you to indefinitely store 65% of the currently curtailed energy
Fossil Gas has a limited role as a ‘good guy’

- Carbon intensity of power generation is declining due to renewable energy
- Fossil methane is a good guy until ~2020, then it’s a bad guy (*this is an existential threat to the NG industry*)
- Renewable gas is a good guy for the future
- Renewable natural gas makes GAS GREAT AGAIN!

---

**Own elaboration, from IEA, An assessment of the potential of biogas from digestion in the EU beyond 2020, CE Delft, 2016**
What are we doing to lower the world’s carbon footprint?

Our archaea transform virtually every molecule of CO$_2$ into a molecule of methane.
They produce high quality gas

**Measurement** | **Required value for grid injection** | **Average product gas BioCat**
--- | --- | ---
CO2 mole % (Carbon dioxide) | Max. 3.0 | 1
Methane mole % | Min. 97 | 97
H₂S (Hydrogen Sulfide) mg/ m³ | Max. 5 | 0
Hydrogen % vol. | Max. 2 | 2
Electrochaea eliminates the time factor from the energy storage equation

**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€

What if methane becomes the perpetual renewable fuel?

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

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

_Electrochaea_
A 50 MW BioCat System…

**Capabilities of a 50 MW BioCat System**

- Storing 400 GWh/a of electrical energy*
- More than 125,000 households consumption per year
- Achieving a CO₂ 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 h/a of operation, electrolysis included

…sequesters 37,000 tons/a of CO₂
The EU Prognosis for renewable gas...

Assumptions

- RNG will replace Natural Gas to fulfill decarbonization policies
- Biogas production is constrained by available biomass
- Biomethane produced by Power-To-Gas with available CO2

Estimated Market Value of renewable gas products (9.5 €cent/Kwh)

<table>
<thead>
<tr>
<th>Product/Year</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
<td>€ 24 bio</td>
<td>€ 44 bio</td>
<td>€ 45 bio</td>
</tr>
<tr>
<td>Biomethane</td>
<td>€ 26 bio</td>
<td>€ 55 bio</td>
<td>€ 116 bio</td>
</tr>
</tbody>
</table>

... requires a scalable solution
There is sufficient power…

Renewable Energy Generation and Expected Biomethane Production
From P2G (EU 28 + CH)

- Renewable gas target for EU + 28 is less than 10% of renewable power generation through 2035
- Curtailed renewable power can provide capacity for renewable gas in the current power environment

... to charge the grid

Own elaboration from, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-IEO2016&region=4-0&cases=Reference&start=2010&end=2040&f=A&linechart=Reference-d021916a.48-15-IEO2016.4-0&ctype=linechart&sourcekey=0
Own elaboration from, Biogas Domestic Supply EU: http://www.iea.org/statistics/statisticssearch/report/?country

*European Gas consumption expected to decline
Addressable markets are large: up to €195 bn by 2030

**Storage**
- Reliability fees & fines
- Demand balancing
- Long term storage
- Off grid storage
  - Range €0.45 – €1.2/Wh

**CO₂ Value**
- Taxes & Credits
- Certificates of origin
- LCA – benchmarking
- Cap and Trade
  - Range €6 – €200/ton

**Clean Fuel**
- Energy value (€6/MWh)
- Customer preference
- Carbon Source
  - Range (€6 – €22/MWh)

* €300/kWh storage @ 300GWh storage in 2030 (US DOE & Bloomberg)
** €38bn EU market in 2017@ C price of €6/tonne; anticipated price in 2010 of €24/tonne (Bloomberg); conservative estimate to double market size ~ €75bn
*** estimated value of world biogas market in 2020 (fmi https://www.futuremarketinsights.com/reports/biogas-market)

€30bn by 2020***

€75bn by 2020**

€90bn by 2030*

€75bn by 2020**
Renewable Gas meets a market need

• Low carbon gas to fill the grid
• Large scale storage from renewable energy
• Low risk, low cost, long term energy storage
• Opportunities are large, worldwide, growing in size and number—‘go big, or go home’
Our Vision

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

• The time is now and the place is here to invest in this disruptive technology

• Support Electrochaea to reduce the world’s carbon footprint!
Experienced Executive Team

Mich Hein, PhD
Managing Director, CEO
Co-founder and managing partner at Nidus Partners
Passionate entrepreneur
Raised $70 mn for start-ups

Doris Hafenbradl, PhD
Managing Director, CTO
20 years of experience in biotech, biofuels and pharmaceutical industries
Expert in hyperthermophilic archaea

Francesco di Bari
Director of Business Strategy, CFO
24 years of experience in finance, business development, M&A and change management
Expert in building up and establishing businesses
## Strong Network and Collaborations

<table>
<thead>
<tr>
<th>Investors</th>
<th>Memberships</th>
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<td>MVP: MUNICH VENTURE PARTNERS</td>
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<td>IBB (Nordic Green Energy)</td>
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<td>Sirius Venture Partners</td>
<td>DANMARKS VINDMØLEFORENING</td>
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<td>Partners</td>
<td>Sponsors and Funded Projects</td>
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<td>DBU: Deutsche Bundesstiftung Umwelt</td>
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<td>Store &amp; Go</td>
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<td>NREL: NATIONAL RENEWABLE ENERGY LABORATORY</td>
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<td>Energistyrelsen</td>
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Thank you

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2650 Hvidovre, Denmark

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Semmelweisstrasse 3
82152 Planegg
Germany

Ausgezeichnete Orte
im Land der Ideen

STEP AWARD
Winner 2017

Start Up
Energy Transition
Award
Finalist 2017

ECOSUMMIT AWARD
Bronze Medalist 2016