HYDROGENICS

SHIFT **POWER** | **ENERGIZE** YOUR WORLD

IERE Malaysia

November, 2017

Mississauga, Canada


Glaubeck, Germany


Oevel, Belgium

HYDROGENICS OVERVIEW


Mississauga, Canada


Glaubeck, Germany


Oevel, Belgium


Our raw materials, water & renewable power are
infinite!
2,000+
fuel cell sites
1 single focus:
hydrogen solutions
HYDROGENICS
Publicly traded
NASDAQ (HYGS) and TSX (HYG) since 1995
65+ years
of experience
500+
electrolysis plants in operation
Global leader
in 2 main hydrogen technologies: electrolysis and fuel cells
1,500+
electrolysis plants sold since 1948

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Shifting Power Across Industries Around the World

An Established Leader with Established Technology

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Alstom, Germany

- World's first commercial contract for hydrogen fuel cell trains
- 10-year agreement, contract value of €50M

Kolon, S. Korea

- Providing MW power using excess hydrogen
- Multi-MW fuel cells running 24/7

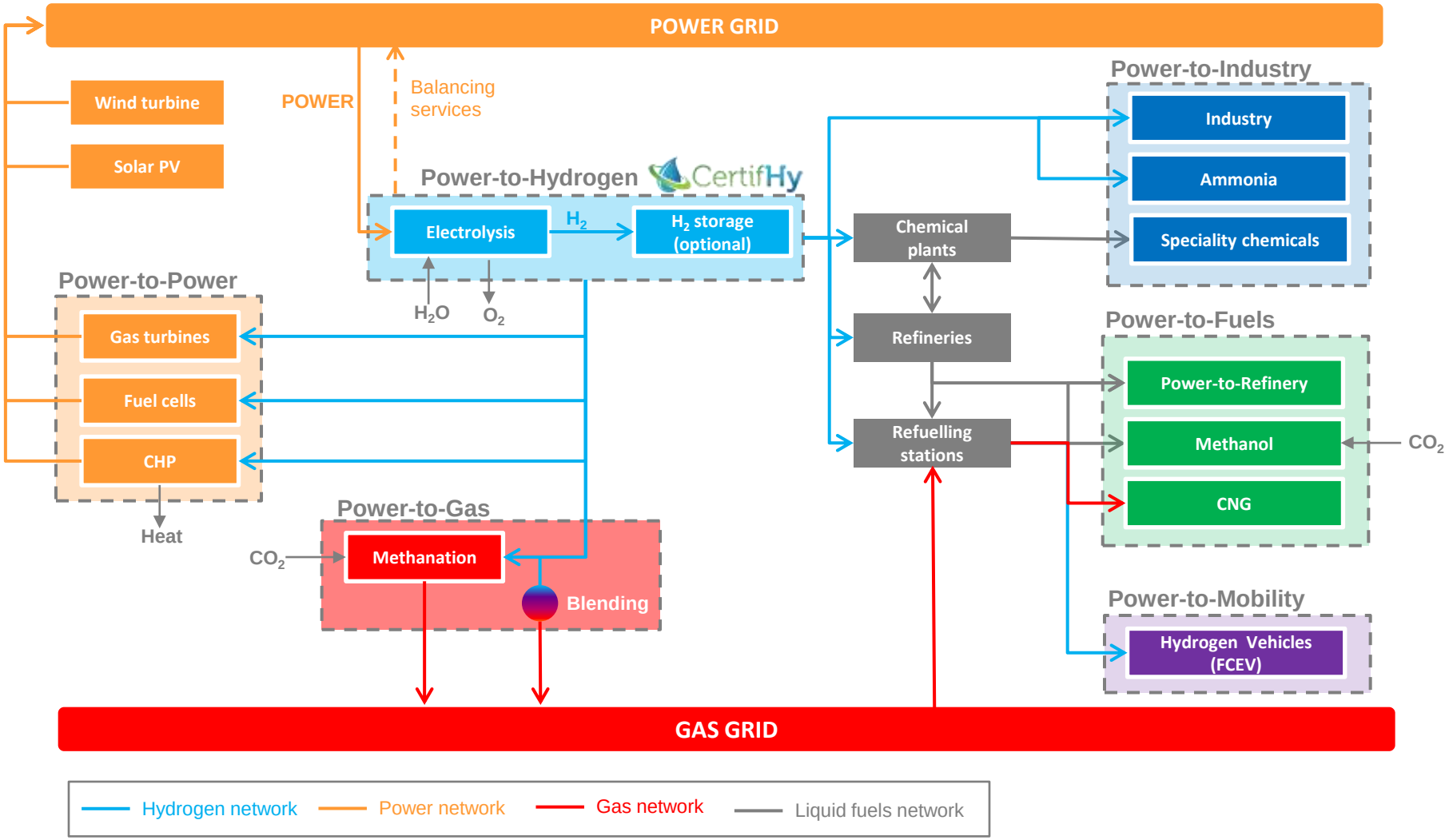
Uniper, Germany

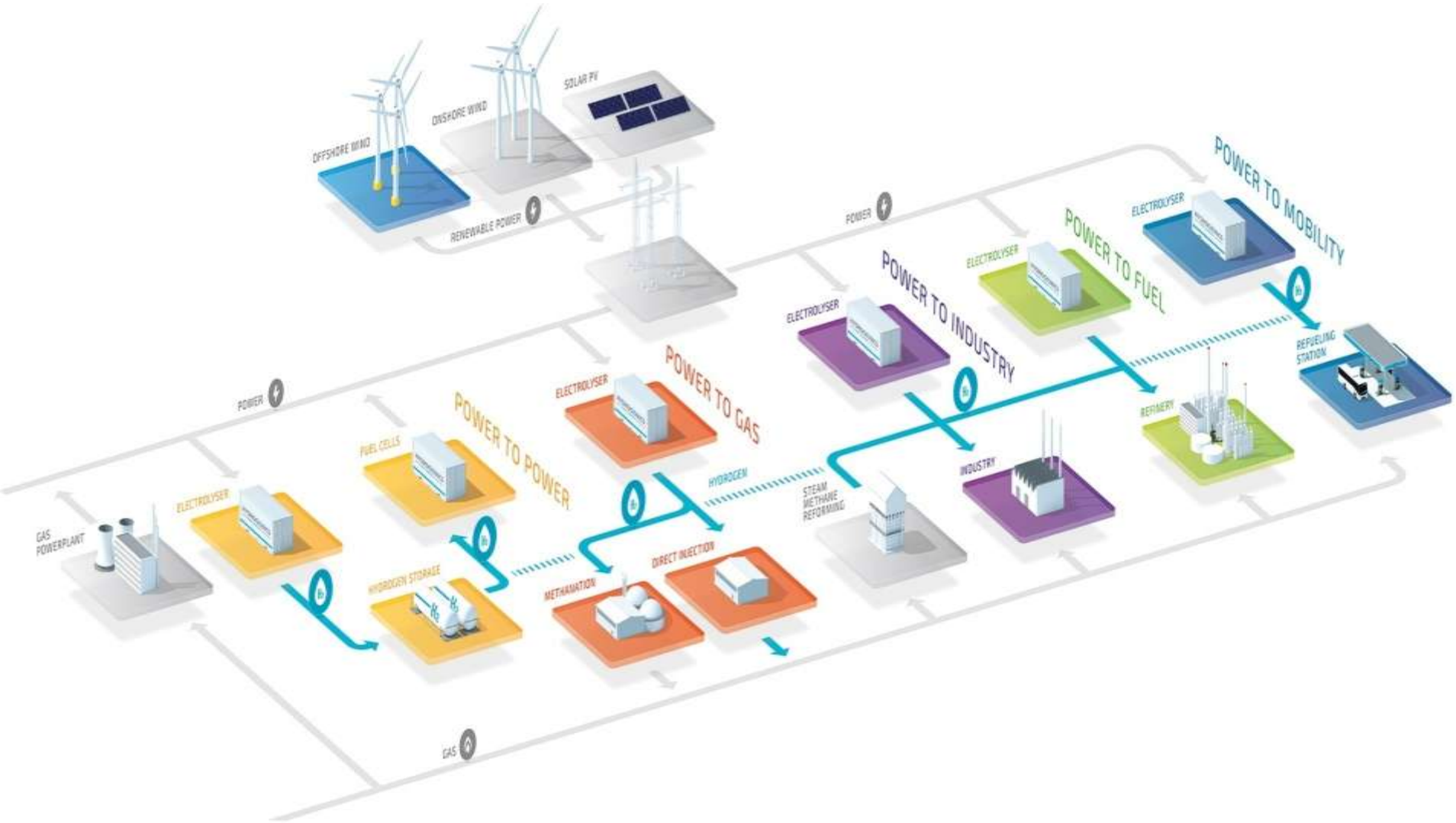
- MW-scale Power-to-Gas facility in Germany
- Wind power and Hydrogenics electrolysis equipment to transform water into hydrogen

Fuel Cell Buses, China

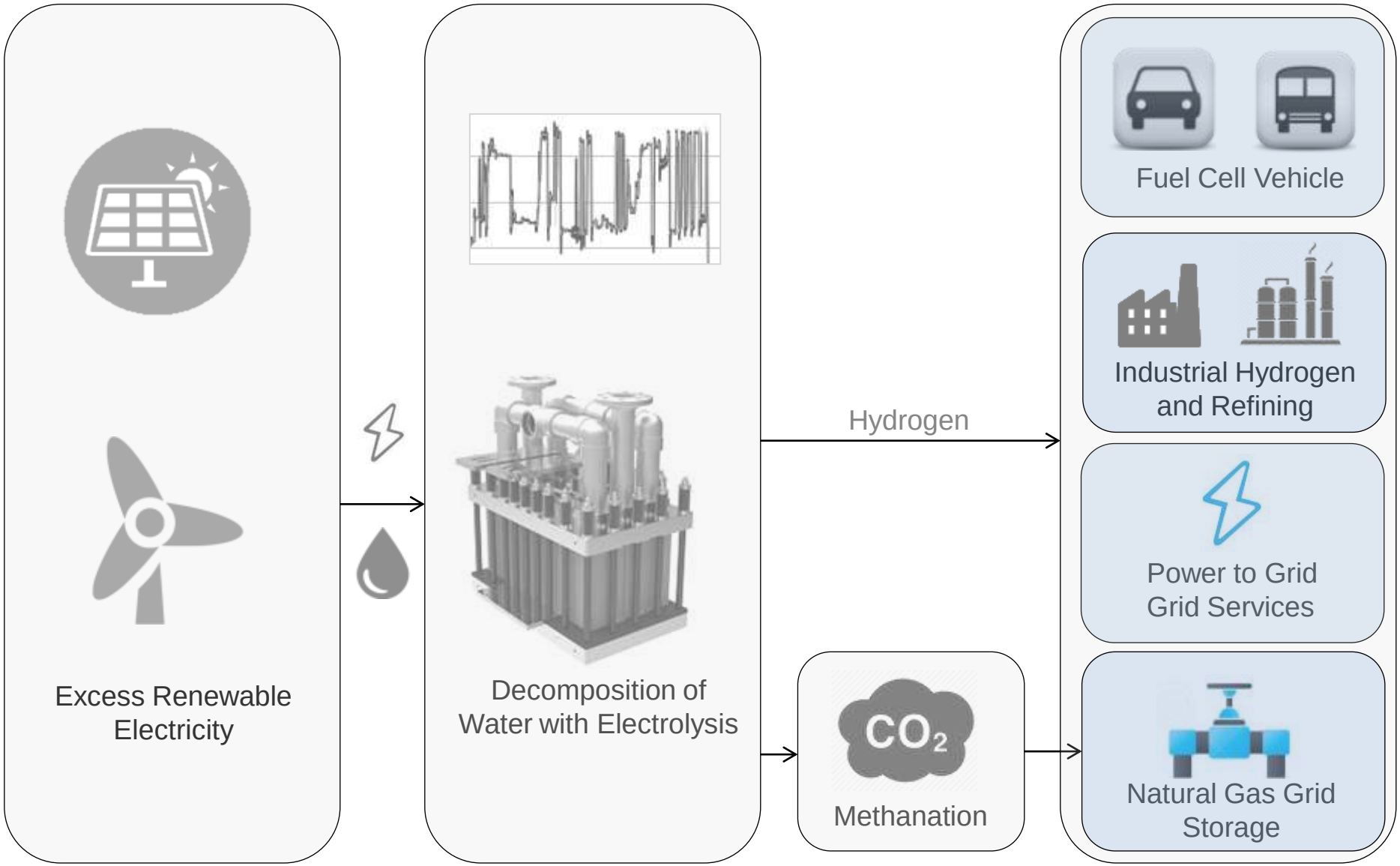
- Multiple agreements for thousands of fuel cell buses throughout China in the next 2-4 years

Renewable hydrogen usage in power, gas, transportation and industry sectors

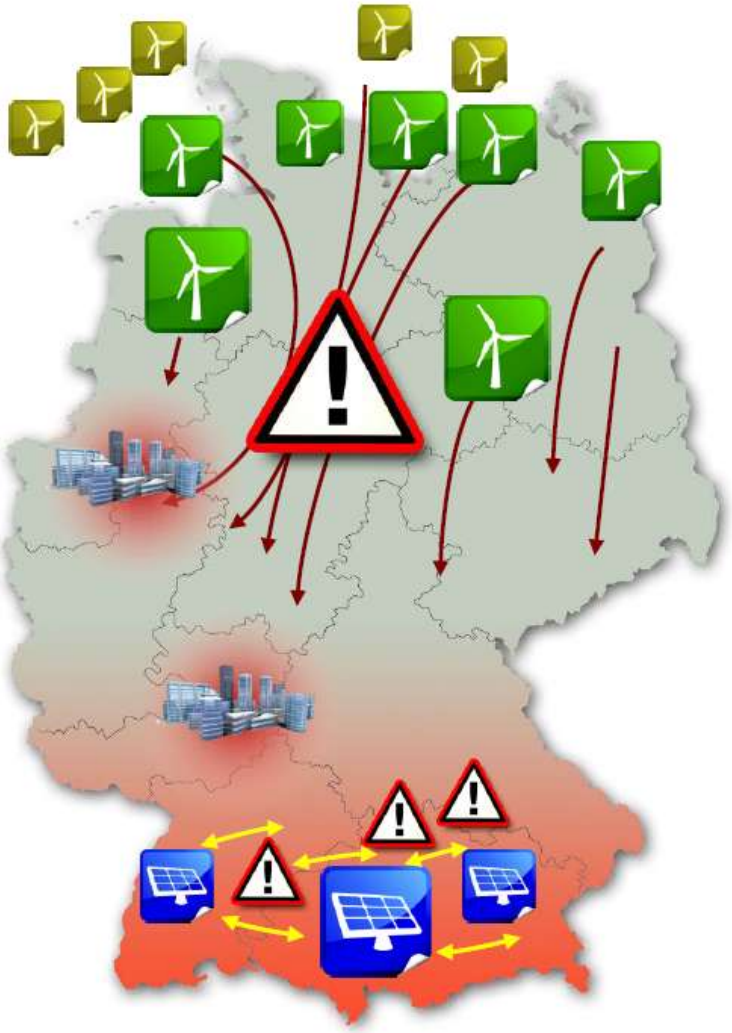



OFFSHORE WIND
ONSHORE WIND
SOLAR PV
RENEWABLE POWER
POWER
POWER TO MOBILITY
POWER TO FUEL
POWER TO INDUSTRY
POWER TO GAS
POWER TO POWER
ELECTROLYSER
ELECTROLYSER
ELECTROLYSER
ELECTROLYSER
REFUELING STATION
REFINERY
INDUSTRY
FUEL CELLS
HYDROGEN
STEAM METHANE REFORMING
DIRECT INJECTION
METHANATION
HYDROGEN STORAGE
GAS POWERPLANT
GAS

Simplified Power-to-Gas Diagram



German Renewable Challenge



Wind

Wind being planned

PV

Congestion

Transmission grid

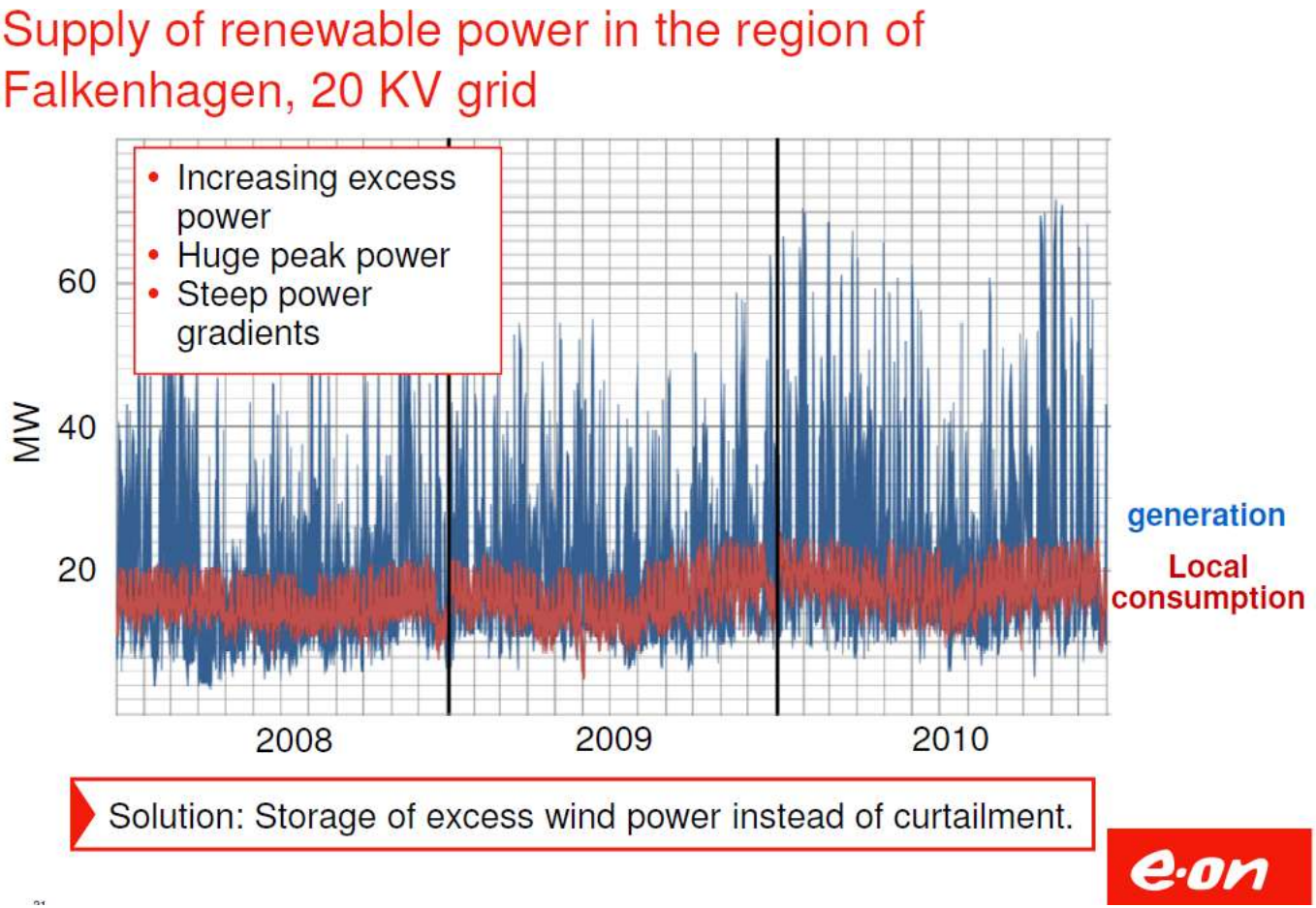
Necessary: 2000 km

Distribution grid

Load centers

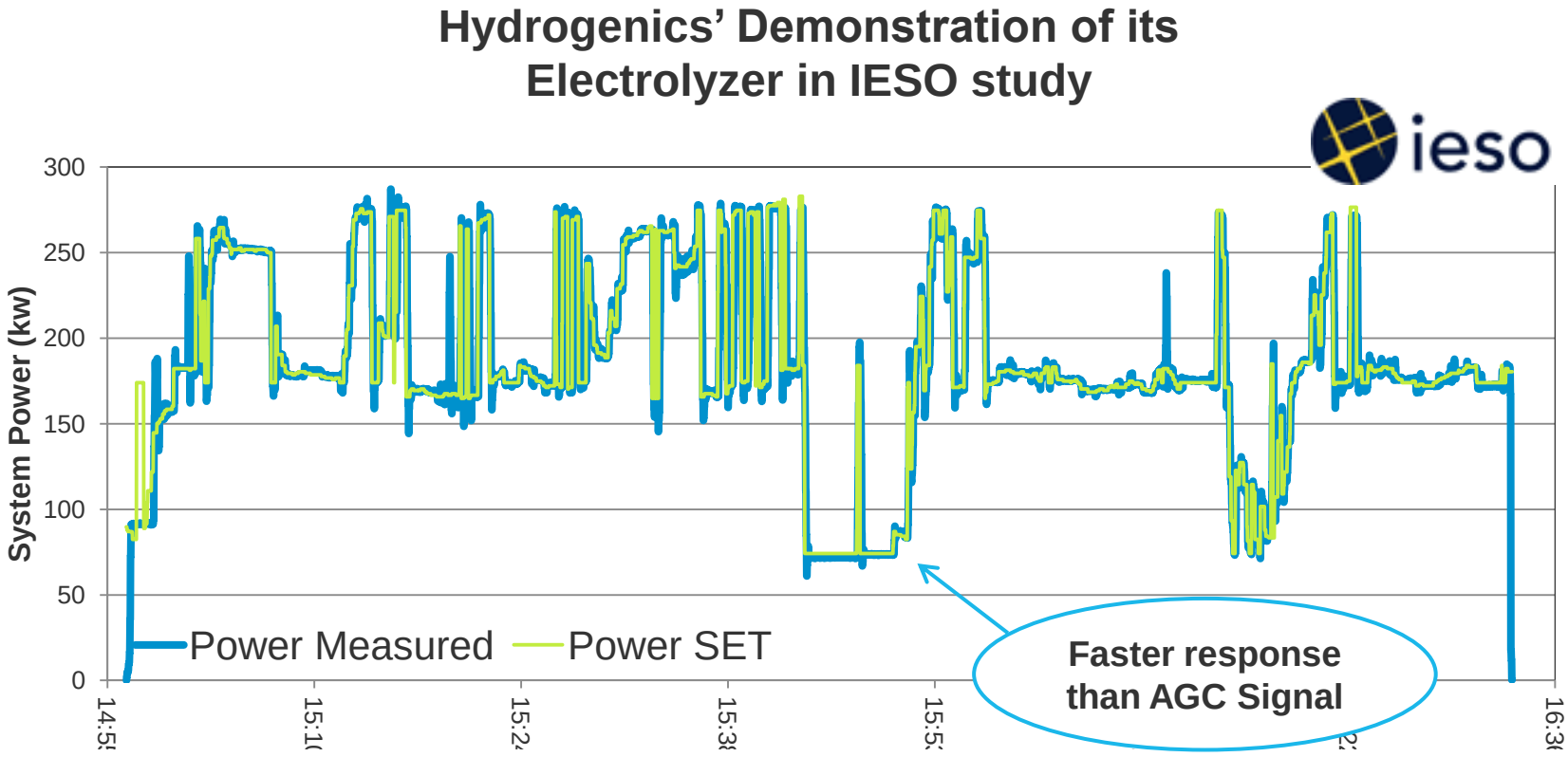
Source: Ahmels, 2011

Wind Generation often in Surplus in Northern Germany



Source: Presentation by Dr. Alexander Vogel, Head of Alternative Energy Systems, E.ON Ruhrgas at Gas to Power Conference, Cologne, Germany – November 2012

Unparalleled Energy Storage Capability *and* Real Time Dynamic Response



Note: IESO signal test completed June 2011

Hydrogen has the best potential for Energy Storage

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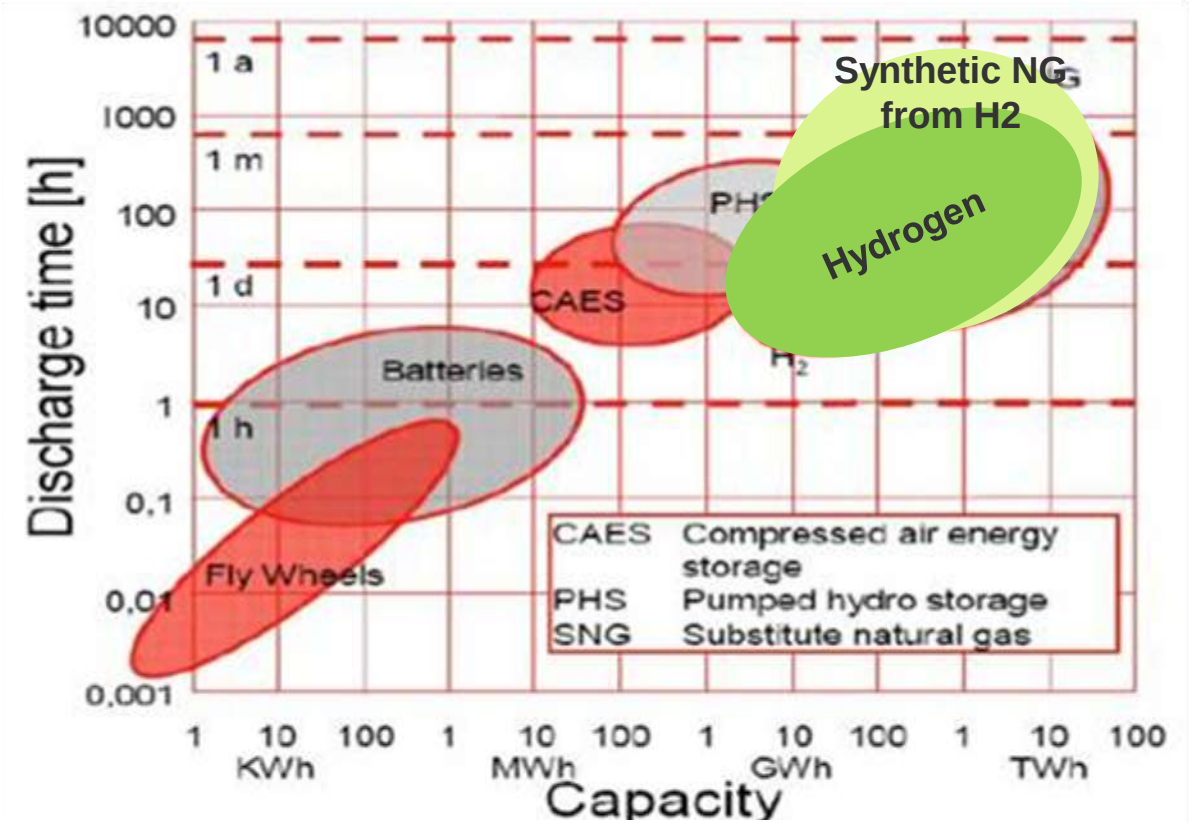
Among alternative energy storage technologies hydrogen provides large capacity with longer duration capabilities

Bulk System Storage/ Load Shifting

Distributed Storage/ Renewables Integration

Power Quality Applications



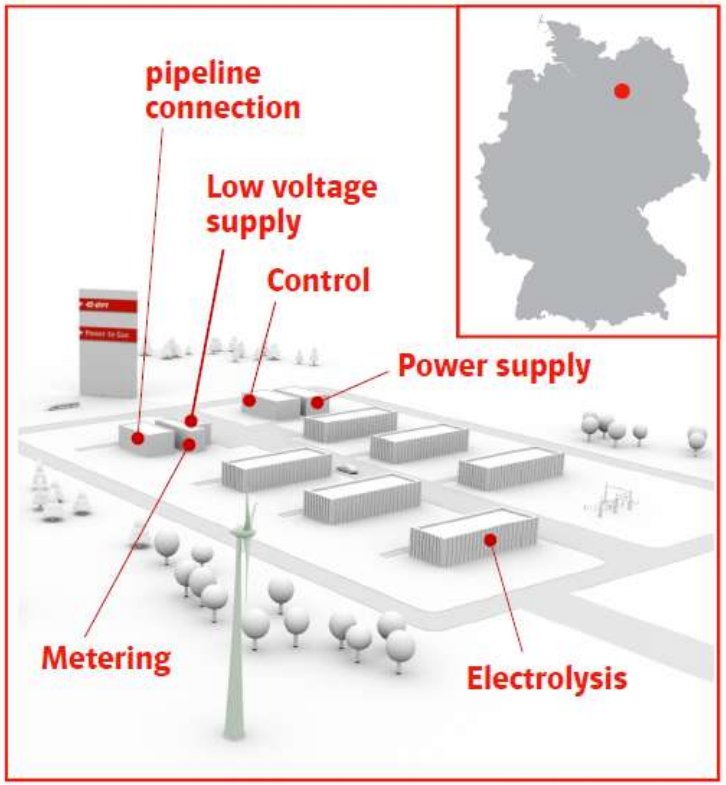
E.ON 2MW Power-to-Gas Demonstration Project

Key Parameters

- Power: 2 MW_{el}
- Hydrogen production: 360 m^3/h
- Fed into the local gas grid (ONTRAS)
- Planned start of operation Q3/2013
- Owner is E.ON Gas Storage

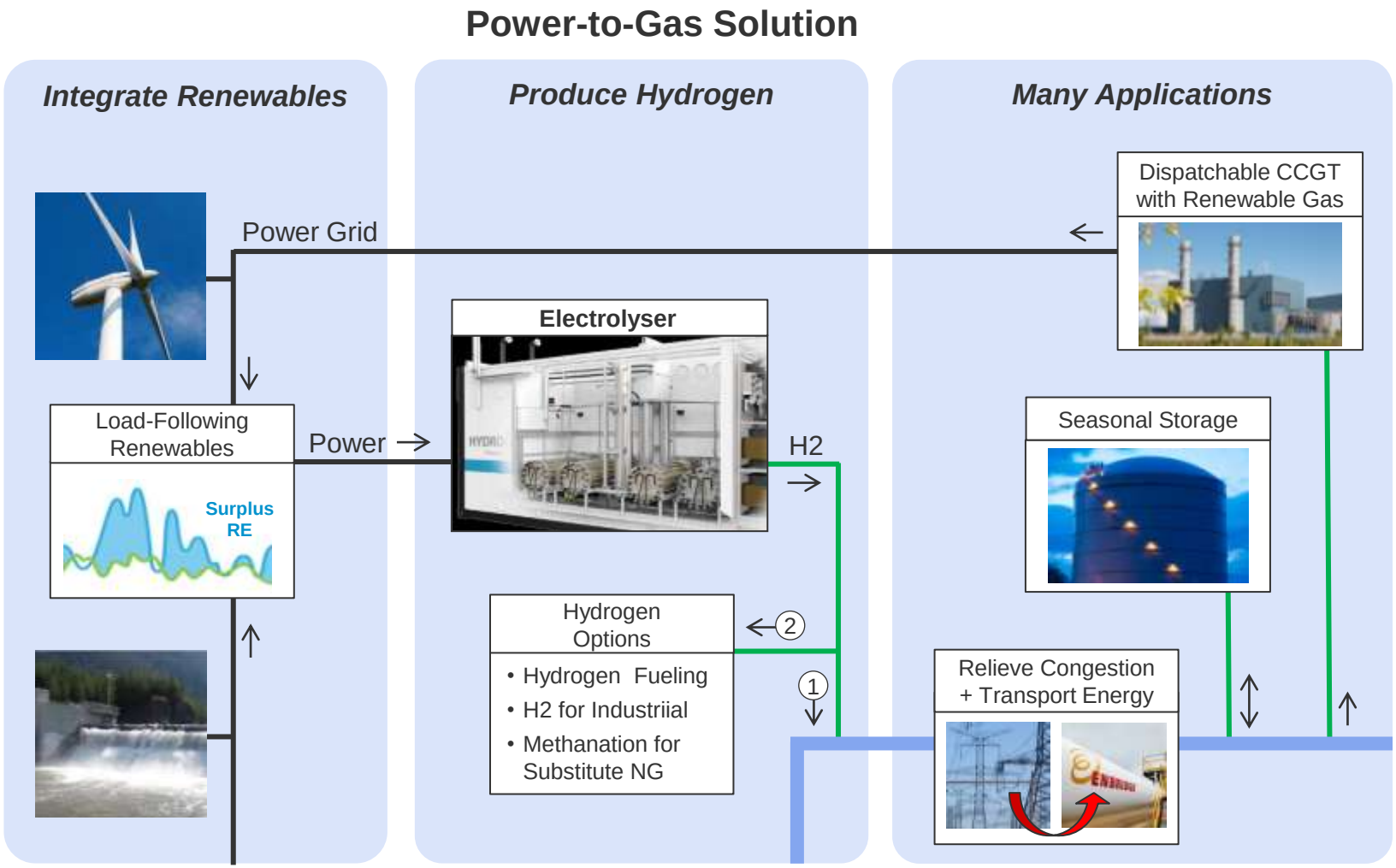
Goals

- Demonstration of the process chain
- Optimize operational concept (fluctuating power from wind vs. changing gas feed)
- Gain experience in technology, costs, consenting

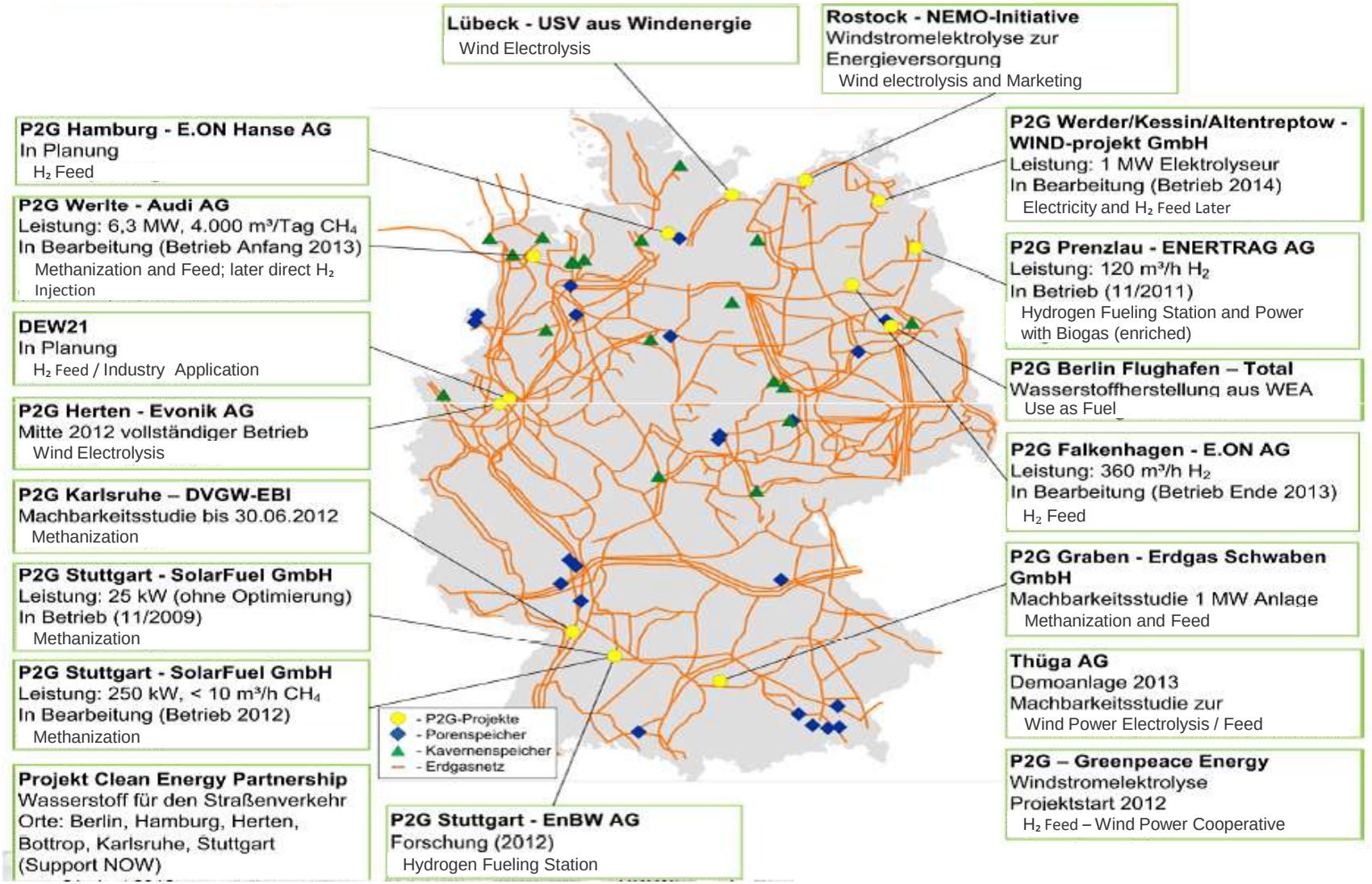


Source: Presentation by Dr. Alexander Vogel, Head of Alternative Energy Systems, E.ON Ruhrgas at Gas to Power Conference, Cologne, Germany – November 2012

Power-to-Gas bridges the power grid and natural gas system to unlock new options for energy conversion and storage



18 Power-to-Gas Demo Projects announced in Germany
Hydrogenics wins 6 of 7 contacts settled to date



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Power-to-Gas pilots developing to Commercial Scale in the near future

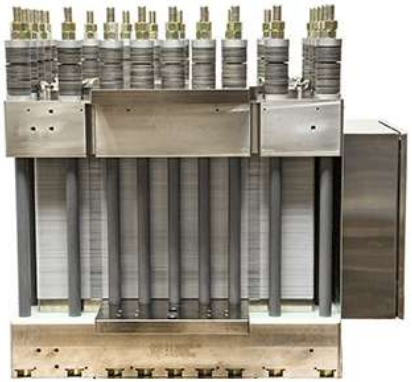
Today…

Among the most proven and utilized technology

2 MW Alkaline

Needs…

Tailored for large scale energy storage



MW PEM Stack

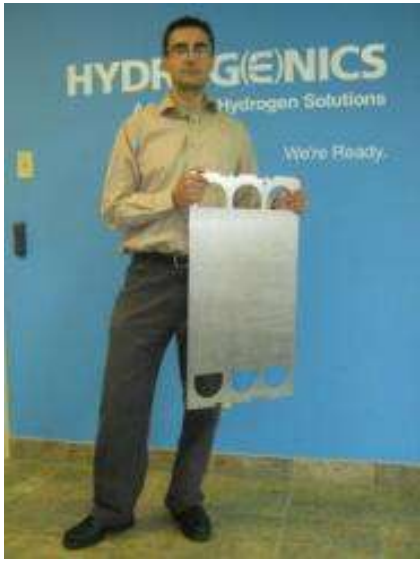
Latest …..

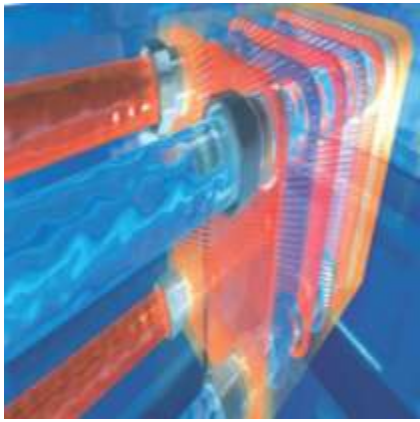
MW-scale next platform with compact footprint

1.5 MW PEM Module

GEN3 - PEM Electrolysis Technology Focus

1. **MW Scale Electrolyzer Technology**
2. **Reduction of System Capital Costs**
3. **Stack Efficiency Improvements**
4. **Fast Response and Dynamic Operation**



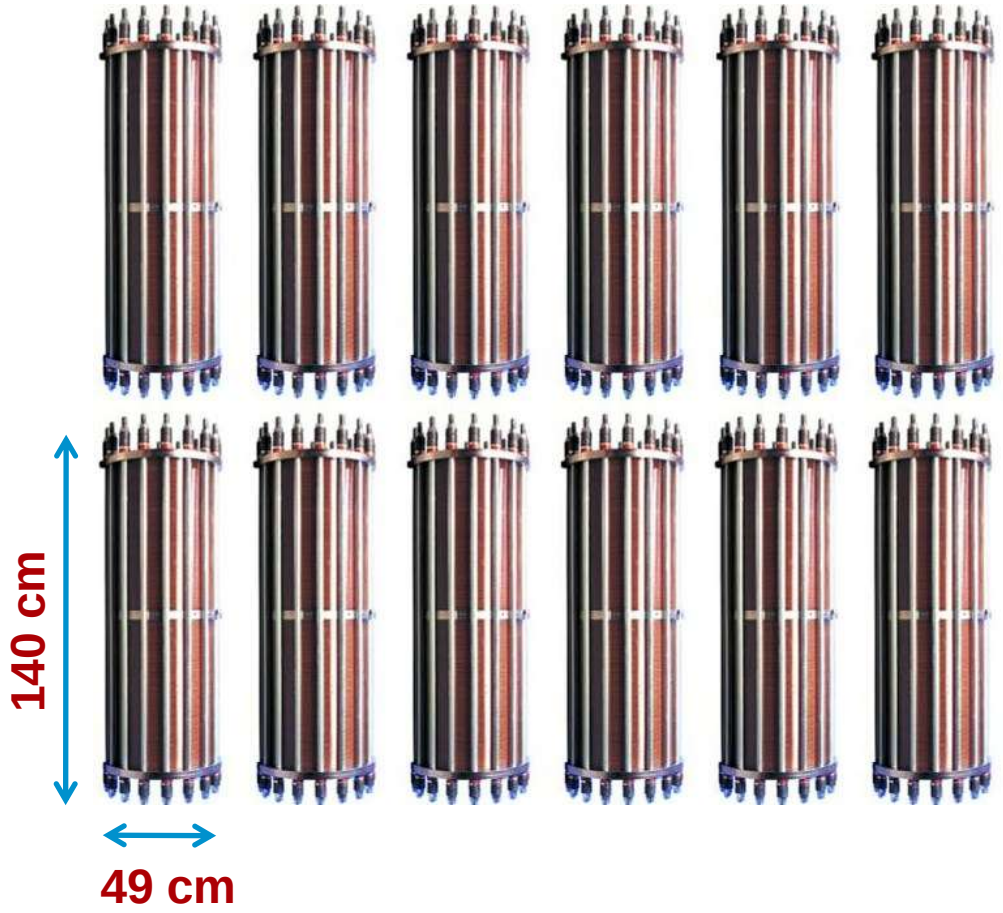


Breakthrough in Stack Power Density

1 MW GEN3 Electrolyser

=

1 MW Industrial GEN2 Electrolyser



Simultaneous Scale and Technology

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Attacking cost per watt and enabling energy storage

World's First 3MW Stack Platform

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HYLYZER 600
Technical Specifications

- **Input Power:** 3.0 MW
- **Hydrogen Production:** 620 Nm3/h (or 1350 kg/day)
- **Output Pressure:** up to 35 bar
- **Stack Efficiency at** 3.0 MW: 75% HHV
  2.5 MW: 78% HHV
  2.0 MW: 80% HHV
- **Stack Dimensions:** 550 mm x 880 mm x 1150 mm

PURE HYDROGEN PRODUCTION
1350 kg of clean hydrogen produced each day

280 fuel cell electric vehicle fills per day

30 fuel cell electric bus fills per day

7 Alstom iLint Coradia fuel cell electric train fills per day

DECARBONIZED LIQUID FUELS
A pathway to the Fuel Quality Directive

4,500 tonnes of CO_2 reduced annually by producing 8 million litres of fuel

COST EFFECTIVE
The most competitive utility scale storage solution

Smallest plant size = lowest capital costs

High efficiency = lowest operating costs

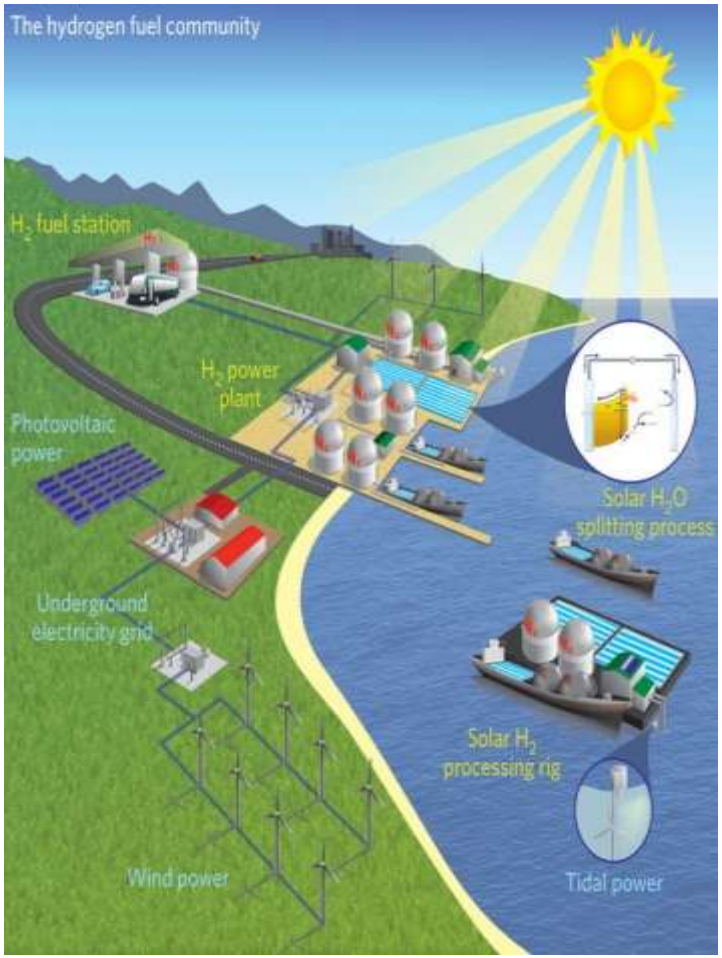
RENEWABLE NATURAL GAS
Grid scale energy storage

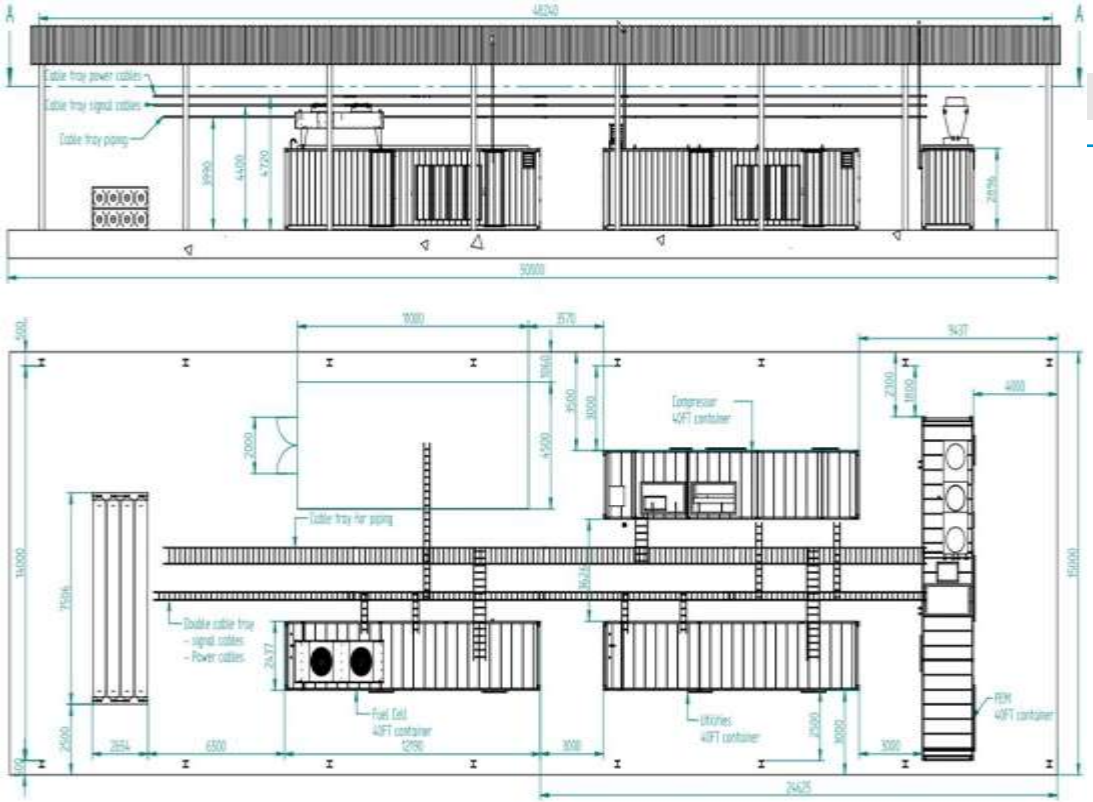
Hours	Energy Stored	Equivalent to the annual natural gas consumption of
17 hours	130 GJ	**1** household
100 hours	800 GJ	**6** households
200 hours	1600 GJ	**12** households

SMALLEST PLANT FOOTPRINT
Unparalleled efficiency in logistics, siting and installation

Plant Size	Dimensions
5 MW	14m x 9m
25 MW	20m x 25m
100 MW	35m x 50m
300 MW	50m x 100m

References and Applications





EGAT Lam Takhong Wind Energy Storage

OBJECTIVES

- Research and technological demo centre aimed at improving the implementation of renewable energy systems.
- Production of H_2 from a wind farm featuring 24 wind turbines.
- Use the H_2 in a 300kw fuel cell for Energy Storage to produce electricity.

SOLUTION

- **1 MW PEM HyLyzer** Outdoor with all peripherals and storage technology.
- H_2 compression & storage system and HyPM 300kw fuel cell in a container

EGAT
Power for Thai Happiness

Phase II : 1.5 MW Power-to-Gas « WindGas » in Hamburg, Germany (2015)

OBJECTIVES

- Development of a 1,5 MW PEM Electrolysis Stack
- Optimize operational concept (fluctuating power from wind vs. changing gas feed).
- Gain experience in technology and cost.
- Feed H2 into the medium-pressure distribution natural gas pipeline at 30 bar.

SOLUTION

- 1x 1,5 MW PEM Electrolyser with all peripherals in 40Ft. housings for max 285 Nm³/h H2.
- This 1,5 MW building block is now the foundation for multi MW P2G plants

Partners:

uniper

SolviCore Fuel Cell Technologies

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DLR

Fraunhofer ISE

Sponsors:

Coordinators:

für Verkehr und digitale Infrastruktur

NOW

nip

Halle, Belgium

- Don Quichote (FCH JU project, 9 partners)

▪OBJECTIVES

• Direct use of highly fluctuating RE into the electrolysers & peripheral equipment..
• Feasibility study of electrochemical compressor
• Use H_2 for transport in FC vehicles

WaterstofNet

▪SOLUTION

• Development of a new 30Nm³/h HyLYZER™ PEM electrolyser.
• Electrochemical Compressor – higher efficiency, more sustainable and smaller footprint.
• Connection to existing wind turbines, expansion of the existing Colruyt fueling station

Meckl.-Vorpommern, Germany

RH_2 - WKA Grid Stabilisation

OBJECTIVES

- Produce electricity coming from a 140MW onshore wind farm (some turbines are rated at 7,5MW) using hydrogen as energy storage. Have CO_2 savings of +/- 250.000 t/year.
- Use the H_2 in an internal combustion engine to produce electricity and retrieve the heat from the system for the building. In a further stage, use H_2 for transport and demonstrate the PtG (Power to Gas) solution by injecting the produced H_2 in the nearby pipeline.

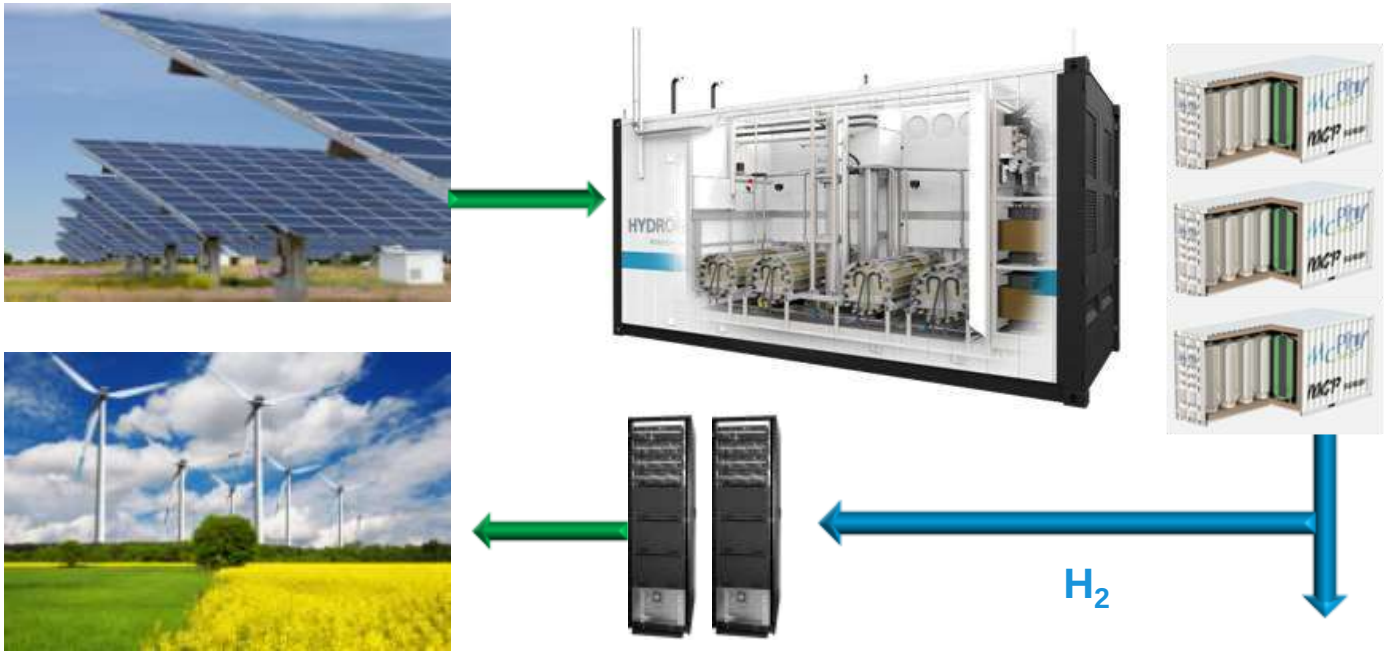
SOLUTION

- 1MW HySTAT™ indoor solution with all peripherals to produce 210Nm³/h H_2.
- H_2 compression and storage system (4'500Nm³ H_2 at 310bar) with 90 + 150kW HICE.

Falkenhagen, Germany

OBJECTIVES
- Demonstration of the process chain.
- Optimize operational concept (fluctuating power from wind vs. changing gas feed).
- Gain experience in technology and cost.
- Feed H_2 into the high-pressure transmission natural gas pipeline at 55bar (ONTRAS).

SOLUTION
- 6 x HySTAT™ 60 with all peripherals in 20Ft. housings to produce 360Nm³/h H_2.
- A 40 Ft container including 2 compressors to compress the hydrogen to 55barg.
- Power: 2MW



Puglia, Italy

INGRID (24Mio€ FCH JU project, 7 partners)

OBJECTIVES

- Allow increased penetration of highly fluctuating RE into the grid using electrolysis and supply-demand balancing.
- Improvement of distribution operation through active/reactive power control for optimal voltage regulation and power quality.
- Use H_2 for transport, industry, grid balancing and injection into the gas network.

SOLUTION

- 1MW HySTAT™ electrolyzer in a 40Ft. Housing to produce 200Nm³/h H_2.
- 60kW Fuel Cell backup system.
- 39 MWh, 1,000kg solid hydrogen storage

Enel

Mississauga, Canada

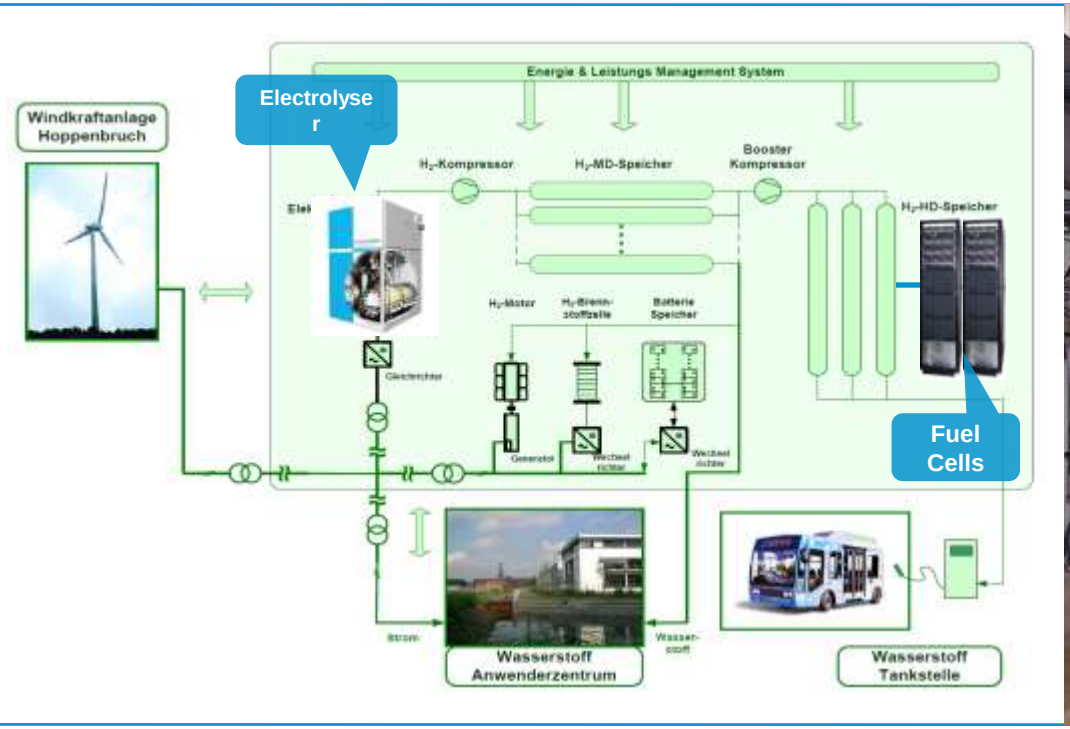
Enbridge invests 5Mio. CAD in Hydrogenics

OBJECTIVES

Develop utility scale energy storage in North America to:

- Bridge the electricity and natural gas networks.
- Demonstrate Load- Following of Renewables.
- Bring seasonal storage capabilities to electricity networks.
- Set Gas Inter-Operability Standards and Metering.

ENBRIDGE



Herten, Germany

Herten Smart Grid System

OBJECTIVES

- Convert excess wind power (8600 kW turbine) into hydrogen to store surplus energy.
- The hydrogen will be used to provide backup power or to refuel vehicles.

SOLUTION

- HyPM-R™, 50kW Fuel Cell System.
- HySTAT™ 30 Indoor electrolyser with all peripherals to produce 30Nm³/h H_2.
- 50bar compressor and 500kg H_2 storage.

Raglan, Quebec (Canada)

Integrated wind-diesel-storage in operation at Arctic mine

OBJECTIVES

- Reduce Diesel Consumption by adding a wind turbine in Arctic conditions combined to energy storage technologies

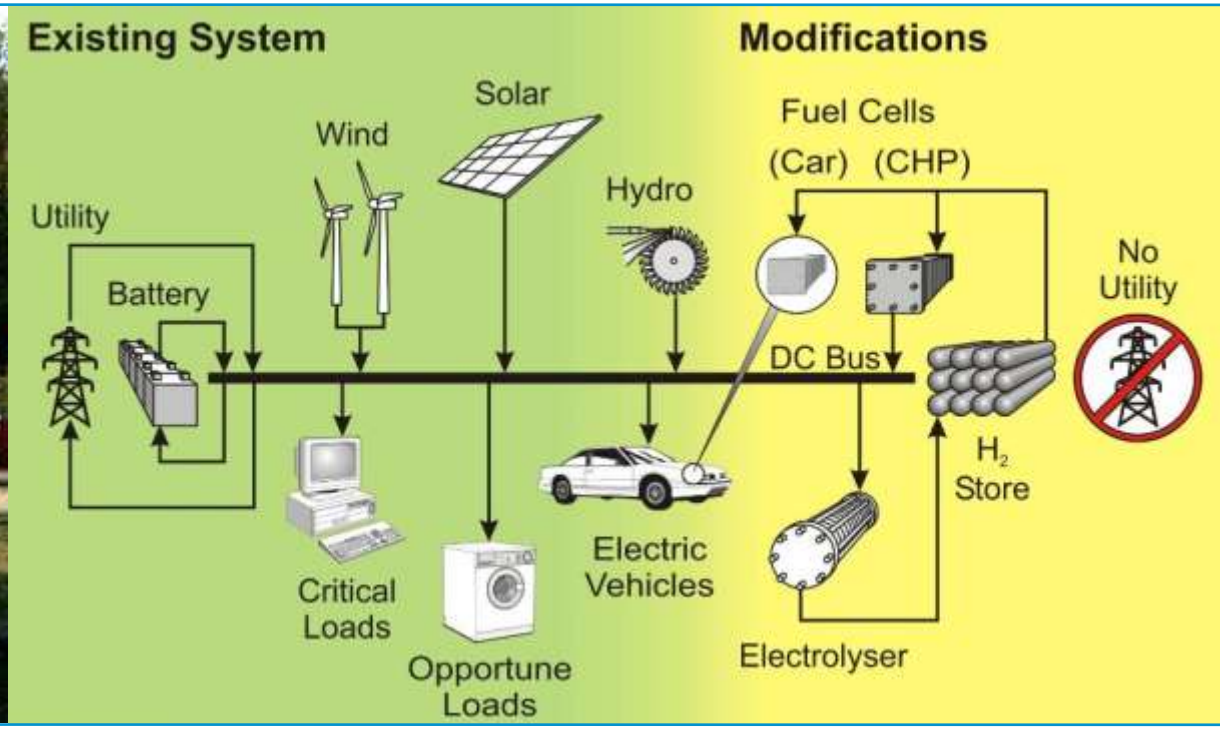
SOLUTION

•Hydrogen Energy Storage composed of a HySTAT-60 (315kW) electrolyzer, 200 kW Fuel Cell, 300 kg of hydrogen storage, -50C design

GLENCORE

Tugliq Energy Co.

HATCH



Leicestershire, UK

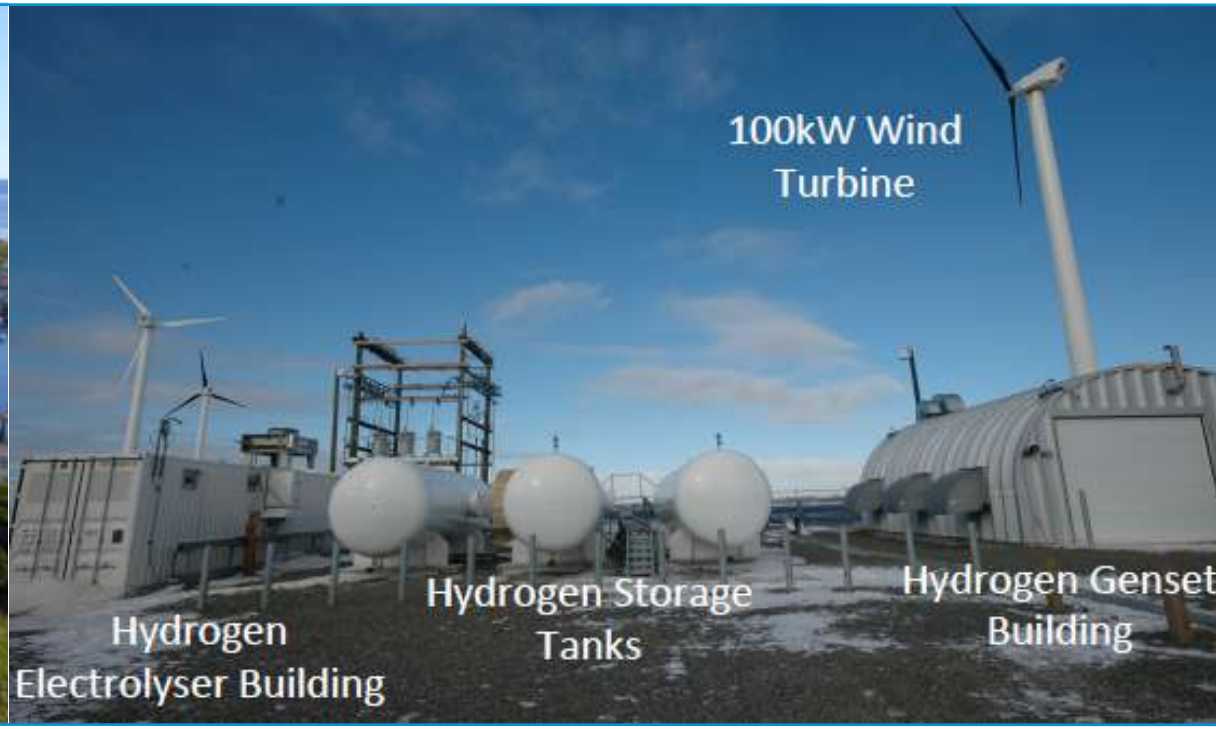
West Beacon Farm, HARI: H_2 & Renewables

OBJECTIVES

- Demonstrate and gain experience in the integration of H_2 energy storage with renewables.
- Develop software models for the design of future energy systems.
- Production of hydrogen from surplus electricity from wind, PV and micro turbine.

SOLUTION

- HySTAT™ - 8/25 Indoor solution to produce 8Nm³/h H_2 .
- H_2 high pressure energy storage system.
- Fuel Cells to produce electricity when required.



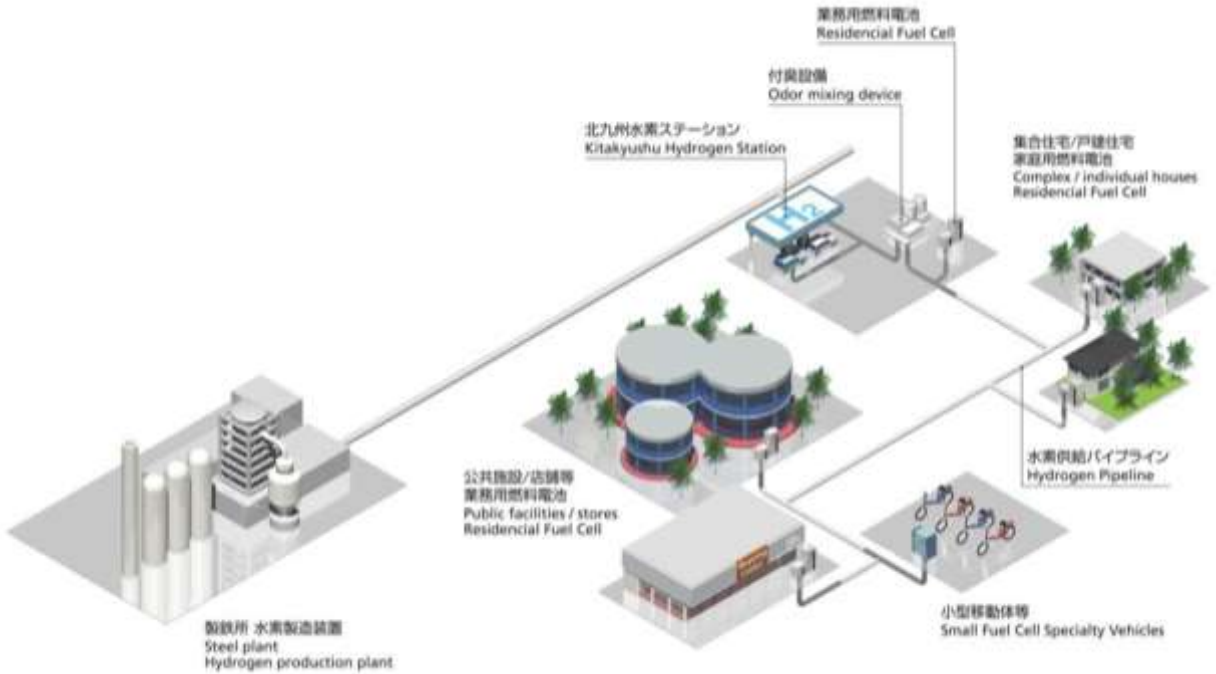
Newfoundland, Canada

Ramea Island: Newfoundland and Labrador Hydro (NLH)

OBJECTIVES
- Solve the cost and storage issues associated with intermittent RE generation.
- Investigate the potential to combine wind turbines and hydrogen generation as an alternative to diesel power currently installed.
- Provide continuous high quality power.

NEWFOUNDLAND POWER
A FORTIS COMPANY

SOLUTION:
- HySTAT™ -30 outdoor solution with peripherals to produce 30Nm³/h H_2.
- Hydrogen compression and storage system to provide 24/7



Hydrogenics Scope

HyLYZER® PEM Electrolyser

HyPM™ FC Rack

Fukuoka, Japan

Kitakyushu Hydrogen Town Project

OBJECTIVES

- Develop a complete independent and green community system.
- Use different electricity streams to produce H_2 (PV, Wind, etc.).
- Develop a Community Energy Management System using the H_2 to produce power and use the heat generated by the system.

SOLUTION:

- One HyPM™ HD 10, 10 kW Fuel Cell, integrated in a FC rack.
- 2Nm^3 HyLYZER™ PEM Electrolyzer.
- H_2 compressor and storage.
- Car refueling station.

Iwatani

Fuji Electric

Brügg, Switzerland

- 130kg/day, 350bar dispensing

• The station is part of the CHIC project and is installed at the Postauto bus station near Brügg.

• Five Daimler Citaro H_2 busses are being operated and can be refueled in the same time as traditional busses.

• The station has a HySTAT™ 60Nm^3/h electrolyser , two mebrane compressors and 5’500Nm^3 high pressure storage at 410bar.

PostAuto DIE POST

CHIC H_2

AIR LIQUIDE

Hobro, Denmark (S&C Nov 2017)

HyBalance

- HyBalance Project

- OBJECTIVES
  - validate the highly dynamic PEM electrolysis technology in a real industrial environment
  - provide grid balancing services on the Danish power market
  - validate innovative hydrogen delivery processes for fueling stations at high pressure
  - hydrogen is used by industrial customers and for clean transportation (refueling stations)

- SOLUTION
  - 1x HyLYZER™ 230 (PEM, dual cell stack design) with all peripherals to produce 230 Nm^3/h H_2.
  - power: 1,2 MW

- This project receives financial support FCH-JU (GA No 671384) and ForskEL program, administered by Energinet.dk.

More info: www.hybalance.eu

AIR LIQUIDE Creative Oxygen
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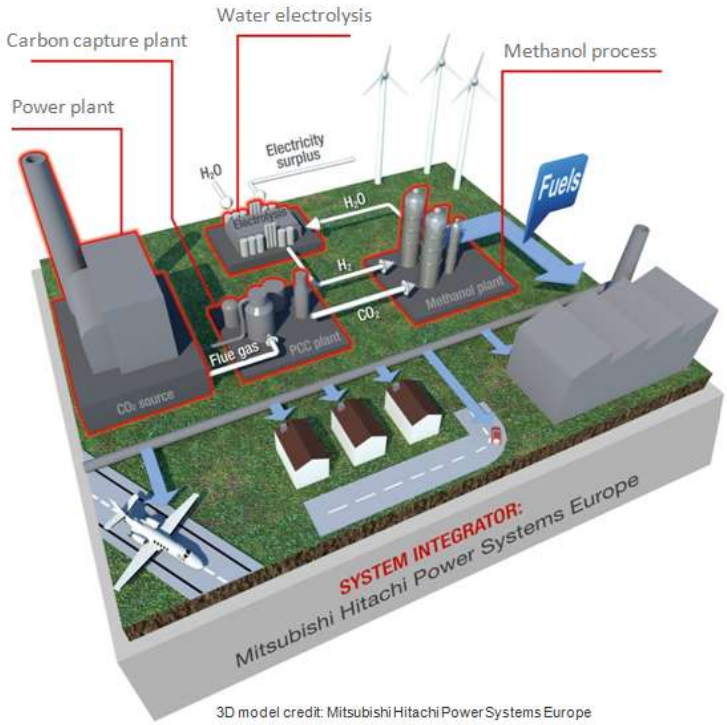
HYDROGEN VALLEY
NEAS ENERGY
ludwig bölkow systemtechnik
FCH
FORSK EL Energinet.dk

Lünen, Germany



3D model credit: Mitsubishi Hitachi Power Systems Europe

- MefCO2 project (Methanol Fuel from CO2)

▪OBJECTIVES
- Increase efficiency and reduce emissions of STEAG's coal fired power plant
- Leverage existing carbon capture pilot plant (= CO_2 source) owned by UDE

▪SOLUTION
- 1 MW PEM electrolyser for 200 Nm³/h of Hydrogen
- EU Horizon 2020 research and innovation programme funding (SPIRE)
- Flexible methanol synthesis.
- Power: 1MW

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Mitsubishi Hitachi Power Systems Europe
Cardiff Catalysis Institute
Carbon Recycling International
DIME - University of Genoa
Hydrogenics Europe
University of Duisburg Essen