
May 12, 2016
Housekeeping

All participants are in “Listen-Only” mode. Select “Use Mic & Speakers” to avoid toll charges and use your computer’s VOIP capabilities. Or select “Use Telephone” and enter your PIN onto your phone key pad.

Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

You will find a recording of this webinar, as well as previous Resilient Power Project webinars, online at:

www.resilient-power.org
Who We Are

RESILIENT POWER
Evolution of a New Clean Energy Strategy to Meet Severe Weather Threats
September 2014

www.cleanegroup.org
www.resilient-power.org
Resilient Power Project

- Increase public/private investment in clean, resilient power systems
- Engage city officials to develop resilient power policies/programs
- Protect low-income and vulnerable communities
- Focus on affordable housing and critical public facilities
- Advocate for state and federal supportive policies and programs
- Technical assistance for pre-development costs to help agencies/project developers get deals done
- See www.resilient-power.org for reports, newsletters, webinars, and more.
With the Resilient Power Project, Clean Energy Group and Meridian Institute are working to accelerate market development of clean energy technologies for resilient power applications that serve low-income communities and vulnerable populations during disasters and power disruptions, and to address climate adaptation and mitigation goals through expansion of reliable renewable energy deployment. To reduce impacts and dangers of power outages in communities now and in the future, the Resilient Power Project works to provide technology and policy solutions to address three challenges facing the country: Community Resiliency, Climate Adaptation, and Climate Mitigation.

Clean Energy Group’s role in this process is to help inform, coordinate, and support federal, state, and local officials, policy makers and developers with the goal of deploying resilient power projects in communities across the country. In addition to providing program guidance to policy makers and limited technical assistance funding for project development, we also process grants and contract on resilient power projects.
Northeast Electrochemical Energy Storage Cluster (NEESC)

NEESC is a network of industry, academic, government and non-governmental leaders working together to help businesses provide energy storage solutions.

www.neesc.org
Today’s Guest Speakers

- **Prabhu Rao**, CEO North America, McPhy Energy
- **Steve Jones**, Managing Director, ITM Power
- **Giuseppe Artizzu**, Energy Strategy Director, Electro Power Systems (EPS)
Hydrogen Energy Storage
CONTENTS

1\textsuperscript{st} ACT: WHY ?
The energy revolution

2\textsuperscript{nd} ACT: HOW?
• The European Experience

3\textsuperscript{rd} ACT: WHAT?
• McPhy Energy solutions
1st ACT: WHY?

The energy revolution

H₂

Je roule à l'hydrogène et ne rejette que de l'eau.
Emerging global awareness

COP21
Global consensus to limit the impact of human activity on the climate

France
Article 121 of the French Energy Transition Act
Deployment of a hydrogen refueling infrastructure for mobility
Large-scale experimentation of energy storage using hydrogen
Environmental Mobility Priority for the "Nouvelle France Industrielle" plan
100 hydrogen refueling stations and 1,000 vehicles in 2018

Germany
Energiewende
Renewables: 50% of electricity production in 2030, 80% in 2050

As a consequence: the need to reduce greenhouse gas emissions and fine particles in transportation, industry and energy production

(1) Source: Information report of the French Senate, 18 December 2013
Time for a change

Think of energy in new ways!

REVOLUTION
Energy: increased use of renewables (1/2)

The European energy giants are switching to renewable energy (1)

"Empowering customers. Shaping markets"
30 November 2014
100% focus on renewable energy, networks and customer solutions

29 July 2015
Three-year strategy to become the global energy transition leader

1 December 2015
Creation of a new subsidiary specialized in renewable energies, networks and distribution

FOCUS
"ENGIE launches today an ambitious 3-year transformation plan to become leader in the world energy transition. This plan aims at redesigning the portfolio of activities of the Group, thanks to a EUR 22 billion Capex program and a EUR 15 billion portfolio rotation program (...). We want to focus on low carbon activities ...

Gérard Mestrallet, Chairman-CEO of ENGIE (presentation meeting for 2015 annual results)

(1) Source: company press releases
Energy: increased use of renewables (2/2)

Continuing increase of capacity in Europe for wind and solar energies (1)

Renewable energy
77% of new installations 2015(2) + 22.3 GW in 2015
Eight consecutive years where renewables contributed over 55% of all additional power capacity in the EU(2)

Wind: 142 GW installed in Europe at the end of 2015
3rd source of electricity
+ 12.8 GW in 2015
44% of new installations 2015

Solar: 95 GW in Europe at the end of 2015
+ 8.5 GW in 2015
29% of new installations 2015

Out of 908 GW installed in Europe at the end of 2015 237 GW of wind and solar power

Need for increased flexibility through energy storage solutions

Percentage expressed for total capacity of new installations

McPhy Energy, CESA Webinar, May 12, 2016
No good deed goes unpunished!

The Duck: The California ISO’s Flexibility Curve

- **Head:** growing evening peak demand
- **Neck:** the combined effect of decreasing midday and increasing evening net load results in a longer, steeper neck, requiring generators to respond much faster to keep up with electricity needs.
- **Belly:** significant midday decrease in net load may result in having too much electricity on the grid which could result in low or negative prices.
- **Belly:** additional demand or storage may help absorb excess generation in overgeneration conditions.

*(the ISO’s Building A Sustainable Energy Future; 2014-2016 Strategic Plan)*
2nd ACT: WHAT?
Benefits of Hydrogen
H₂: essential today, disruptive tomorrow

- Power generation
  - Solar Power
  - Wind power
  - Fossil
- Power conversion
  - Electrolyzer
  - Grid
- Energy storage
  - H₂ Refilling Station
  - Gas grid storage
  - Methanation / CO₂ / others
- Utilization
  - Mobility (H₂-Fuel)
  - Energy/ Heat
  - Industry (H₂-Utilization)

McPhy Energy, CESA Webinar, May 12, 2016
Focus on Power-to-Gas

The solution for storage selected by major energy companies

Hydrogen and the synthesis of methane recognized as a vector for energy storage
Large-scale storage capacity
Long-term storage

FOCUS

Power-to-Gas technologies

1. Injecting wind-generated hydrogen directly into the gas supply network

2. Transformation of hydrogen into synthesis of methane that is then injected in the guest network

(1) Sources: Study on hydrogen and methanation as a process for recovering surplus electricity, Ademe, September 2014 / McPhy Energy

McPhy Energy, CESA Webinar, May 12, 2016
3rd ACT: HOW?

How does McPhy address the H₂ challenges
McPhy Energy value proposition

“As a designer, manufacturer and integrator, McPhy Energy provides sustainable & efficient hydrogen solutions, ready to be integrated into your process.”

TARGETED MARKETS
- Energy
- Mobility
- Industry

MASTERING THE WHOLE HYDROGEN VALUE CHAIN
with global solutions tailored to your needs

INTEGRATED H₂ SOLUTIONS
A complete range of hydrogen equipment

**McLyzer**
**Hydrogen Production**
On site generators to produce “clean” hydrogen from renewable energy sources
- Wide range of electrolyzers for all hydrogen uses
- Full offer of additional services
- Technology partnership with De Nora, the electrochemistry market leader

**McStore**
**Hydrogen Storage**
Solutions to store large amounts of hydrogen with safe / logistics free solutions
- Full range dedicated to the energy and industry sectors
- Partnership with GKN Powder, the global leader in metallic powders
- Exclusive technology of solid-state storage

**McFilling**
**Hydrogen Distribution**
Putting our energy to work for zero emission mobility
- McFilling, our refueling station
- A compact, modular and upgradable solution
- A turnkey product

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**H₂ Supply Chain**
From renewable energy to a clean hydrogen power

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*McPhy Energy, CESA Webinar, May 12, 2016*
Audi e-Gas plant (Germany) 1/2

One of the first PtG project in Europe
Audi e-Gas plant (Germany) 2/2

One of the first PtG project in Europe

Operated by Etogas

Hydrogen production equipment with power of 6 MW

In operation since October 2013

Preventive and corrective maintenance contract
Power-to-Gas: Jupiter 1000 (France) 1/2

A large demonstrator in South of France, close to Marseille

- An installed capacity of 1MW
- Hydrogen injection: up to 200 m³/h
- Methane production: up to 25 m³/h
- Commissioning: 2018
POWER-TO-GAS WEBINAR
MAY 2016

Contents:

• Company Snapshot
• Power to gas
• Energy storage
• Economics
• Example Systems
• Summary
ITM Power | History

- First AIM listed fuel cell & hydrogen company
- Two facilities in Sheffield | 70 staff
- Subsidiaries in Germany & California
- Manufacturing business model
- www.itm-power.com
ENERGY STORAGE: THE NEED

HYDROGEN ENERGY SYSTEMS

RENEWABLE ELECTRICITY CURTAILMENT

• Evidence of grid balancing problems from Germany and Denmark
• Problems start at 20% capacity – US approaching this in some areas
• UK hit this threshold at the end of 2013
• Wind curtailment is rising faster than wind capacity

• Grid resiliency primary concern
• US RPS goals require long term storage
• East US – heating and electricity needs (like EU)
• Seasonal shifts in energy generation
• Renewable electricity generation increasing
• Electric vehicles increasing

• Long term planning required
ENERGY STORAGE TECHNOLOGIES

Power-to-gas is efficient | long term | low energy cost

Source: ITM Power plc
US PIPELINE ISSUES

- New & expansion Gas pipeline projects being held up
- Gas supply a potential pinch point – seasonal demand
- Renewable supply of gas required
- Distributed generation of renewable gas to ease central supply constraints
- Biogas projects can play a role but not a total solution
- RPS on the gas system too?

- Long term planning required
WHY POWER-TO-GAS?

Electricity cannot be stored easily | Hydrogen can be stored easily in the gas grid

ALSO CLEAN FUEL
Fuel cell electric vehicles
HYDROGEN IS THE ONLY VIABLE HYBRID SOLUTION
MARKET SIZE | NEW EU REPORT

Germany: 46 GW (£46bn) in 2030 | 115 – 170 GW in 2050

4.4 At realistic values of hydrogen, large installed electrolyzer capacity would be viable and able to utilize nearly all excess RES energy in the 2050 horizon

Germany archetype

Non-hydrogen P2P and heat storage will only be able to absorb a small part of the excess energy generated, resulting in the necessity of curtailment – from societal point of view, such electricity could be used at close to zero cost.

The excess energy can be used to produce hydrogen via water electrolysis for re-electrification or use outside of the power sector.

If the value of hydrogen at the point of production can reach a price in the range of 2-4 €/kg very large installed electrolyzer capacity would be economically viable and able to utilize nearly all of the excess electricity.

Such use of the excess electricity would create value for the society and the surplus could be divided between the electricity and hydrogen producer.

Economic demand\(^1\) for electrolyzers assuming a best case of 2 EUR/kg of H2

GW

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<th>2050 High-RES</th>
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Reduction in excess energy

Percent

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<th>2030 High-RES</th>
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POWER-TO-GAS

HYDROGEN ENERGY SYSTEMS
THE VALUE OF ENERGY STORAGE

Bundled value like an iPhone

• Store and reply power | energy
• Frequency control
• Voltage stabilisation
• Load following
• Black start
• Transmission line investment deferral
• Energy Storage
• Heating decarbonisation
• Clean fuel
• Industrial feedstock

Specific to the location and tariff landscape
PEM ELECTROLYSER: A DISRUPTIVE TECHNOLOGY

PEM Electrolyser: Potential Cash-Flows (CF)

Cash Flow 1: Hydrogen (H2)

Cash Flow 2: Grid Balancing Services renewable fuel credits

Cash Flow 3: Heat

Cash Flow 4: Oxygen

CF: Merit Order

CF A: Fuel

CF B: P2G

CF C: Repowering

Application

Transport

Gas Network

Electrical Grid

District Heating

Sewage Depots

User

Fleet operators

Civil utilities

PEM ELECTROLYSER APPLICATIONS

ENERGY STORAGE | CLEAN FUEL
REVENUE ON BOTH ENDS

Wind Power

Grid

Solar Power

Electrolyser

Clean Fuel

Energy Storage

Renewable Heat

$$ + $$
EXAMPLE OF WHERE P2G MAKES SENSE – LONG TERM

**Lithium Ion System (6,300 sqft)**
- Project will cost $53.5m
- 8MW with 4hr duration | 32MWh
- $6.7m/MW | $1.67m/MWh

**Power-to-Gas System (3,530 sqft)**
- Project will cost $21.6m
- 8MW with 4hr duration | 32MWh
- $2.7m/MW | $0.67m/MWh

- 8MW with 12hr duration | 96MWh
- $2.7m/MW | $0.22m/MWh

Tehachapi Energy Storage Project

The Tehachapi Energy Storage Project features 604,832 lithium-ion battery cells, housed in 10,872 modules of 56 cells each, stacked in 604 racks arranged in rows.

**BATTERY | P2G COST COMPARISON**

**HYDROGEN ENERGY SYSTEMS**
SUMMARY

• Increased renewable electricity requires storage
• Grid resiliency is compromised by renewable integration
• Power-to-gas can store energy in vast amounts and for long duration
• Power-to-gas links electricity and gas sectors and allows energy shifting
• Power-to-gas decarbonises heat and transport
• Provides a synergistic benefit alongside batteries
• Long term renewables require multiple solutions
POWER-TO-GAS WEBINAR
MAY 2106

SJ@ITM-POWER.COM
ITM Power’s HGas System brings together rapid response and self-pressurising PEM electrolysis into a fully integrated package which injects hydrogen into the gas distribution network at the Mainova Aktiengesellschafts, Frankfurt, utilising pre-existing compliant gas mixing and grid injection infrastructure. The plant has undergone an extensive acceptance, compliance and commissioning phase before going live in December 2013. The sale was the result of a competitive tender, based on price and performance, and was commissioned ahead of schedule. Capable of addressing MW scale Power-to-Gas applications, and accommodates fluctuating power profiles while generating hydrogen at pressures suitable for either direct injection into natural gas networks or via methanation processes without additional compression.
NRM: MIXING PLANT
HYDROGEN ENERGY SYSTEMS
ITM Power's HGas System was delivered to RWE within 10 weeks of receiving the order, which was won as part of a competitive tender. The system is a second generation ITM Power PEM electrolyser system using a higher current density, permitting higher hydrogen output per stack. The system efficiency is also increased by simplification of the balance of plant.

CHP project
86% efficiency
German Energy Agency’s Power-to-Gas Strategy Platform

- Official government grouping
- Excellent consortium
- Largest P2G grouping in Germany | Globally
METHANATION

Production of SNG from Renewable Hydrogen and CO\textsubscript{2}

- Need to source pure CO\textsubscript{2}
- Process design can minimise or eliminate storage
- Multi stage depending on the level of H\textsubscript{2} compliance
Our Mission

We unlock the energy transition, mastering the intermittency of renewable energy sources. We advocate competitive and technology-neutral energy and emission markets. Through the seamless integration of the best battery technologies, and our hydrogen and oxygen platform for long autonomy, we enable renewable energies to power society: reliably, affordably and sustainably.
Storage is the global challenge of the Energy Transition: a mega-trend

- **BLACKOUTS** are less frequent but longer and more disruptive: natural events impact today a globalized ITC and datacenter worldwide infrastructure.
- A CENTRALIZED ENERGY MODEL built in 1882 is not capable to manage the renewables penetration, and needs investments in transmission and distribution.
- 2.4 BILLION PEOPLE, 35% of the global population, are OFF-GRID or under-electrified and generate electricity via a 600GW fleet of diesel generation.
- RENEWABLES INTERMITTENCY generates grid instability and a massive penetration of RES to manage global demand and base-loads is not feasible.

- **$426 billion** annual cost for downtime
- **$293 billion** investment need for T&D
- **200Mio tons CO2/year** diesel generators emissions
- **$30 billion** electricity value curtailed

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**Market applications**

- **$280 bn** global investments in energy storage by 2030 (BCG)
- **up to $635bn** annual economic impact of energy storage in 2025 (McKinsey)

www.electropowersystems.com
A technology-neutral approach to profitable storage applications

**FLEXIBILITY**
CONTROL & GRID INTEGRATION OF ANY BATTERY ENERGY STORAGE SYSTEM (BESS)

- Storage required for despatchability of large and small electricity systems featuring high penetration of intermittent energy sources:
  - Frequency and voltage regulation
  - Operating and contingency reserves
- Storage system can be located on generation, grid or demand-side in centralized electricity systems
- Storage system represents the core of microgrid operation in decentralized electricity systems

**CAPACITY**
HYBRID STORAGE and HYDROGEN SOLUTIONS TO REPLACE GAS AND DIESEL GENERATION

- Storage required to enable a RES-intensive electricity system to serve load in non-recurring demand/supply conditions:
  - Constrained or scarcity-priced supply
  - Extreme demand
- In centralized electricity systems, capacity is usually associated to extreme environmental conditions boosting demand and/or limiting generation
- In decentralized electricity systems, capacity requirements are associated to extended scarcity of primary renewable energy resources and/or non-recurring peak demand conditions

**FLEXIBILITY + CAPACITY = HYBRID**
HYBRID ENERGY STORAGE SYSTEM (HyESS)

www.electropowersystems.com
Positioning: hybrid solutions represent the core of the storage need

- **Hybrid Storage**: a unique system integration of:
  - **BESS** for grid flexibility
  - **H₂ STORAGE** or **DIESEL** for grid capacity

*Pure Energy Applications (which cannot be classified as a flexibility or capacity application), aimed at regularly time-shift energy, have not been represented as not profitable in current market environment.*
Our **Capacity Technology**: like a diesel generator with a lower generation cost. Fuelled by water, but more efficient.

**125**
Cleantech patents and applications in 48 countries. Unique generator running with water only.

**3MW**
Hydrogen systems power output utilized in aggregate.

**607**
Systems installed devoted mainly to mission critical applications and telcos.
We provide grid operators and renewable energy players with integrated storage solutions to master the intermittency of renewables, and address the burgeoning demand for primary, secondary and tertiary reserve, reactive power and black-start capabilities, at a lower cost for consumers, cutting electricity bills.

We compress energy bills, by peak-shaving the consumption profile of commercial and industrial users, optimizing the utilization of distributed generation, enabling participation in demand response schemes, and delivering sustainable back-up power.

We enable renewables as a reliable and affordable stand-alone power source in emerging markets, displacing diesel and oil-fired generation. We foster a bottom-up, decentralized model of greenfield electrification, providing clean energy 24/7 at cost lower than diesel generation, the only alternative in such areas.

EPS Resources allocation and long term growth expectations

Building credentials and reputation 20%
Regulation & Market Design driven 10%
Biggest market opportunity 70%

Off-Grid power generation
Distributed Smart Storage
Grid Support
An Energy Company with a clear Vision

We wish to be an Energy Company and the world’s reference for a clean energy culture and smart grid excellence. An innovative company which creates value for stakeholders by providing net-zero solutions completely safe, reliable, profitable and sustainable.

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Q&A

Moderator: Todd Olinsky-Paul, Project Director, Clean Energy Group

• Prabhu Rao, CEO North America, McPhy Energy
• Steve Jones, Managing Director, ITM Power
• Giuseppe Artizzu, Energy Strategy Director, Electro Power Systems (EPS)
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