Rethink Methane – June 2015, Sacramento

HYDROGEN = ENERGY + FUEL
Contents:

- Introduction to ITM Power Inc.
- Renewable natural gas
- Energy - Power to Gas (P2G)
- The link
- Summary
ITM POWER
ENERGY STORAGE | CLEAN FUEL

ITM Power | History

- First AIM listed fuel cell & hydrogen company
- 2004 IPO
- 2011 Established ITM Power GMBH
- 2012 Established ITM Power Inc.
- +/- 80 staff
- 2015 JCB Strategic Investment in ITM
- Positioned for growth

www.itm-power.com
What does RNG mean for my industry??

HYDROGEN = ENERGY + FUEL
Hydrogen is the only viable hybrid solution.

- Clean Fuel
- Energy Storage
- Renewable Heat

Wind Power

Grid

Solar Power

Electrolyser

Clean Fuel

Energy Storage

Renewable Heat

HYDROGEN IS THE ONLY VAILABLE HYBRID SOLUTION
POWER TO GAS: RATIONALE – HYBRID SYSTEMS

Biomass Pyrolysis

Electrolyzer

Wind

Other Renewables: Solar, Geothermal, Hydro

CO₂ Storage

Bioreactor

Natural Gas Storage

CNG Fueling

CNG-Fueled Vehicles

Hydrogen Energy Systems

Source - NREL

Electric Grid

Natural Gas Turbine

Hydrogen Piping

CO₂ Piping

Electric Line

Home Heating and Hot Water

Fueling Station Electrolyzer

Fuel Cells and Engines

Short-Term Energy Storage

Power to Gas: Rationale – Hybrid Systems

Hydrogen Energy Systems

Source - NREL
HGAS
HGas brings together rapid response and self-pressurising PEM electrolysis into a fully integrated package.

Power-to-Gas

HFUEL
HFuel is a self-contained module suitable for refuelling hydrogen-powered road vehicles and forklift trucks.

Refuelling Stations

REFUELLING STATIONS | P2G UNITS
HYDROGEN ENERGY SYSTEMS
1MW P2G SKID | HANNOVER LAUNCH

New 1MW Skid | 3 x 350kW stacks

- Hannover launch April 2015
- Smallest 1MW on the market
- Based on the new 350kW stack
- Rapid response | Modular unit
- Developing projects now

1MW P2G SKID | HANNOVER LAUNCH
HYDROGEN ENERGY SYSTEMS
RENEWABLE NATURAL GAS

Methanation for BioGas | CO₂ removal

• A modular and scalable technology for CO₂ removal
• BioGas typically 30-50% CO₂
• Upgrade Biogas to 95+% yeild
• Increases calorific value | Increases output
• High value application

REMOVING CO₂ FROM BIOGAS

ENERGY STORAGE | CLEAN FUEL
ENERGY STORAGE

POWER TO GAS (P2G)/ HYDROGEN ENERGY STORAGE (HES)
THE NEED
THE MARKET
CURTAILMENT = WASTED ENERGY AND MONEY

- RE curtailment is a growing occurrence
- Storage is required not just for hours but days/weeks/months
- The traditional route of storing energy has limitations of capacity
- GWhrs (weeks/months) of energy storage is only achievable with hydrogen

50% renewable future NEEDS large storage

Europe leading the way so far....
EU STUDIES CONFIRM IT

- P2G has massive potential
- One of, if not the only way do do massive storage of renewable electricity

<table>
<thead>
<tr>
<th>Study</th>
<th>Result (P2G potential size)</th>
</tr>
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<tbody>
<tr>
<td>Electricity storage in Germany - Energiewende</td>
<td>16GW 2023</td>
</tr>
<tr>
<td></td>
<td>130GW 2050</td>
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<tr>
<td>Energy storage in Europe - McKinsey</td>
<td>170GW by 2050</td>
</tr>
<tr>
<td>P2G in the Dutch energy system – ECN &amp; DNVGL</td>
<td>20GW by 2050</td>
</tr>
<tr>
<td>UK P2G potential – Haines et al</td>
<td>23GW by 2050</td>
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</tbody>
</table>
GERMAN POWER TO GAS SCHEMES

POWER TO GAS
ENERGY STORAGE | CLEAN FUEL
P2G (HES): ELEMENTS OF VALUE

- Value to the power grid
- Value to the gas grid
- Value to the economy

Value to the Power Grid
- Avoided wind curtailment
- Avoided infrastructure upgrades
- Reduced reserve power
- Reduce CO₂ from open cycle GTs
- Absorbing reactive power

Value to the Gas Grid
- Decarbonising gas
- Providing renewable heat
- Reducing GHG emissions from gas transportation

Value to the US Economy
- Reducing fuel imports
- Improved energy security
- Creating jobs in manufacturing
PEM Electrolyser: A menu of operating options

PEM Electrolyser Outputs und Cash Flows (CF)

Cash Flow 1: Hydrogen (H2)
Cash Flow 2: Grid-Balancing Services
Cash Flow 3: Heat
Cash Flow 4: Oxygen (O2)
Cash Flow 5: Avoiding new transmission lines

CF: Merit Order
CF A: Fuel
CF B: P2G
CF C: Re-powering

Application
Transport
Gas Network
Electricity Grid
District Heating Network
Sewage Treatment Plant
Network

User/Beneficiary
Fleet operator
Power / Gas Utility
Network Operator

Situation specific – dictated by the market dynamics + POLICY
Example of a H2 Hub – P2G + Grid Balancing + H2 Refueling Station

Power-to-Gas:
Gas Mixing Plant / Methanation Plant

Electrolyser:
On-site H2 production
Grid Balancing

H2 / SNG Dispenser

PEM ELECTROLYSER HYDROGEN HUB

40kWhrs electricity = 1 therm hydrogen

DELIVERING LOWEST COST FUEL
ENERGY STORAGE | CLEAN FUEL
Assembly Bill 32
Global Warming Solutions Act

State of California AB 8
Hydrogen Infrastructure
Roadmap

CPUC sets
energy
storage goals
for utilities

$250m for 10yrs
+ Hydrogen
Infrastructure

Min. 33%
Green H₂
Legislation

Energy Storage
Mandated for
1.3 GW

CA - a world leader for policy and action – BUT we need to break down the silos
CPUC Sets the energy storage mandate for the power sector

- Energy storage target of 1,325 megawatts
- 3 major CA utilities by 2020
- Optimization of the grid, including peak reduction
- Integration of renewable energy
- Reduction of GHG emissions to 80% below 1990 levels by 2050

“This decision represents an important first step in encouraging the storage market and supporting grid reliability,”

Commissioner Carla J. Peterman, the lead Commissioner for this proceeding.
Electrolysis uses water to make hydrogen gas.

Natural gas and petroleum use more water in their production.

Switching to 100% FCEVs would lead to a 0.2% increase in water consumption statewide.

Releases water vapour back into the atmosphere once the hydrogen is combusted or used in a fuel cell.

Electrolysis technology will NOT significantly impact the current drought situation in CA.
What needs to be done?

- Natural gas is cheaper and cleaner than petroleum
- CA, unlike most, strives for more
- Development needs to be focused on long term success – how to get to the end game
- Dependent on policy to drive change
- Energy storage – does P2G count? CPUC
- Mandate – CO$_2$ intensity – RGS
- Incentives - RGS, RINs, LCFS etc

LINK energy & fuel
What needs to be done?

HES – recognised as a viable technology in the mix
Legislated / incentivised
Links with utility providers (Gas and Electric)
Links to fuelling infrastructure
Joined up thinking
Get projects installed
Show the value
ITM POWER
ENERGY STORAGE | CLEAN FUEL

Steve Jones
Managing Director
ITM Power Inc.
Irvine, California

sj@itm-power.com    +1 (714) 453 8141

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P2G PROJECTS

THÜGA / REW PROJECTS
METHANATION
UREA
BALANCING SUPPLY AND DEMAND – ANCILLARY SERVICES: SECOND BY SECOND – GRID BALANCING

THE NEED: GRID BALANCING

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LOAD FOLLOWING

Rapid response Electrolysis

- Full system test program
- Set Point v’s Actual (blue)
- Multiple start/stop tests
- Load modulation for full range
- Challenge system reliability
- Validate system to assimilate intermittent renewable power

THÜGA P-2-G PLANT PERFORMANCE
HYDROGEN ENERGY SYSTEMS
SYSTEM EFFICIENCY:
ELECTRICAL ENERGY IN, CHEMICAL ENERGY OUT

THÜGA P-2-G TOTAL SYSTEM EFFICIENCY
FIRST P2G SALE: THÜGA GROUP

Won competitive tender on performance & price

- One of the world’s largest utility groupings
- 18,200 employees
- 5.7m customers (electricity, 3.6m, gas 2.1m)
- Sales of €21.3bn
- Plant located at Mainova AG in Frankfurt
- 1 year of operation – exceeded average efficiency. Achieved up to 77%

360KW POWER-TO-GAS MODULE
ENERGY STORAGE | CLEAN FUEL

Source: Thüga-Gruppe
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.
ISLAND & REMOTE SYSTEMS

Sale of 0.5MW PEM Electrolyser System to EMEC

- Integrated hydrogen system for Tidal Energy Storage
- Eliminate island grid constraints for Tidal Testing Site
- Hydrogen for back-up power to EMEC’s data & control systems
- Local community wind turbine – fully utilised for clean fuel
- Separate applications project for Eday Renewable Energy Ltd.

ENERGY INDEPENDENCE

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HELES PROJECT

Rapid Response PEM electrolysis, Solar PV, Landfill gas

- Demonstration
- Combining technologies
- Seasonal storage of PV
- Power In: Storage: Power Out
- Avoiding network constraints
- Future applications
CLEAN FUEL

HYDROGEN REFUELLING STATIONS
WHAT’S UNIQUE ABOUT ITM ELECTROLYZERS?

Rapid response | Self pressurising

- 1 sec response time
- 80 bar self pressurising
- 1MW and modular
STATION LOCATION
ENERGY STORAGE | CLEAN FUEL
Hyundai, Chino 100% Renewable Hydrogen Station
## ITM POWER | REFUELING STATIONS

<table>
<thead>
<tr>
<th>Code</th>
<th>Status</th>
<th>Project</th>
<th>Location</th>
<th>Specification</th>
<th>Funding</th>
<th>Contract Value</th>
<th>Ownership</th>
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<tbody>
<tr>
<td>HRS 001</td>
<td>Operating</td>
<td>Nottingham</td>
<td>Univ of Notts</td>
<td>5kg/day 350 bar</td>
<td>TSB (UK Gov)</td>
<td>£275k</td>
<td>Univ of Notts</td>
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<td>HRS 002</td>
<td>Operating</td>
<td>HOST</td>
<td>Mobile refueller</td>
<td>15kg/day 350 bar</td>
<td>TSB (UK Gov)</td>
<td>£326k</td>
<td>ITM Power</td>
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<td>HRS 003</td>
<td>Operating</td>
<td>Ecoisland marine</td>
<td>Ventnor, Isle of Wight</td>
<td>15kg/day 350 Bar</td>
<td>TSB (UK Gov)</td>
<td>£326k</td>
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<td>HRS 004</td>
<td>Commissioned</td>
<td>M1 vehicle</td>
<td>M1 Junction 33</td>
<td>80kg/day 350Bar</td>
<td>TSB (UK Gov)</td>
<td>£1.2m</td>
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<td>HRS 005</td>
<td>In Build</td>
<td>HyFive</td>
<td>3 stations in London</td>
<td>80kg/day 700 bar</td>
<td>FCH JU (EU)</td>
<td>£1.55m</td>
<td>ITM Power</td>
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<tr>
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<td>In Build</td>
<td>CHINO Hyundai</td>
<td>Chino, California</td>
<td>100 kg/day 700bar</td>
<td>CEC</td>
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<td>HRS 009</td>
<td>In Build</td>
<td>Riverside</td>
<td>Riverside, California</td>
<td>33kg/day 700 bar</td>
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<td>HRS 010</td>
<td>Contracts</td>
<td>UKH2M</td>
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<td>HRS 011</td>
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<td>FCH JU</td>
<td>£1.80m</td>
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### REFERENCE PLANT | ASSETS

HYDROGEN ENERGY SYSTEMS