Objectives:

- Connection to 10 MW wind-farm and local Network (20 kV).
- Develop an energy storage plant in order to provide grid services (balancing mechanisms to avoid grid bottlenecks).
- Injection in local gas grid and multi-use trailer-filling.
- New conditioning concept (ionic wet gas compressor).
- Demonstrating safe handling of hydrogen and create awareness in public, politics

Technical and production aspects:

- 6 MW Electrolyzer (3 Stacks à 2 MW peak) delivered in 07/2015
- 1000 kg storage (33 MWh)
- 200 tons target annual output.

Economic aspects:

- Budget: Total: 17€ - Funding: ~50% (BMWi)
- Timeline: 4 years (03/2013 – 12/2016)
Energiepark Mainz – Layout
Main characteristics of the PEM Electrolyser

<table>
<thead>
<tr>
<th><strong>Silyzer 200</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rated stack power</strong></td>
</tr>
<tr>
<td><strong>Start up time (from stand-by)</strong></td>
</tr>
<tr>
<td><strong>Output pressure</strong></td>
</tr>
<tr>
<td><strong>Purity H₂</strong></td>
</tr>
<tr>
<td><strong>Overall efficiency (system)</strong></td>
</tr>
<tr>
<td><strong>Dimension skid / weight</strong></td>
</tr>
<tr>
<td><strong>Design life time</strong></td>
</tr>
<tr>
<td><strong>H₂ – Production</strong></td>
</tr>
</tbody>
</table>
Energiepark Mainz – Scope of supply
Hydrogen storage and handling facility

3 x 1.25 MW nominal load
(2.0 MW peak) 35 bar outlet pressure

2 x 82 m³ 80 bar, 5.0
0.7 – 0.9 Mpa 10% H₂

Max. output /station: 3500A DC
Input voltage 20 KW 3-ph

Max. water consumption: 1 m³/h
Produced water quality < 1µS/cm

Power grid connection 20kV
Transformer-Rectifier Unit
Electrolysis 2-3.5 MPa
DeOxo Unit
Water purification
Condensate recycle
Min. pressure inlet 15 bar
Max. pressure outlet 250 bar

Condensate trap
Compressor 1st stage
Compressor 2nd stage
Final drying
Trailer filling 22.5 MPa

NG grid injection

Gas storage (max. 8 MPa)

Max. water consumption: 1 m³/h
Produced water quality < 1µS/cm

Trailer pressure 200 bar,
300-600 kg duration fueling ~3h
Energiepark Mainz – Status
First experience of operation

→ Normal operation between 01.09 and 23.10.2015
  - Electricity supply through EPEX Spotmarket (during the week 8:00 -18:00)
  - Approx. 700 MWh electricity consumed
  - Approx. 40 Trailer filled

→ Expected dynamic and power consums is achieved

→ No critical breakdown
Hydrogen as Energy Storage and Energy Vector
Technical and Economical Optimization in 3 steps

Installation Optimization Objective
« Energie Park Mainz »

Minimization of purchase prices
- Use of the wind overproduction
- Participation to the Grid Services
- Purchases on the SPOT market

conditions of use of the installation
- Technical characteristics (peak & nominale load, ...)
  - Efficiency evolution of the installation.
  - Installation shutdowns
  - Others

Maximization of the sale prices
- Methane pipeline injections
- Tube trailers filling

Quelle: Hochschule RheinMain, Martin Kopp
Next step 1 (Q4/15): Automatic operation of the plant
Secure Remote Access between Mainz and Leuna

- Supervisory Control And Data Acquisition (SCADA)-System.
- Distributed Control System (DCS)-System.
- Connected Field Devices for Process Automation (Pressure, Temperature, Gas analysis,...).

Linde Remote Operation Centre (ROC)
- Automatic Load Control (ALC)
- Linear Model Predictive Control (LMPC)

Source: Linde AG

Reference: Google
Next step 2 (Q1/16) : Wind farm Operator Cooperation
New contract / new negotiation

Challenge :

• Submission of production predictions

• Avoid additonal costs / penalties

Solution :

▪ Adjustment of prognostic errors

contractual terms
Short term pronostics

Identified overproduction
Identified underproduction
Next step 2 (Q1/16) : Wind farm Operator Cooperation
PtG as flexible load for wind energy overproduction

Assumption : PtG use till max. 1,15 MWh per 1/4h
contractual terms < Short term pronostics → H2 injection increase
contractual terms > Short term pronostics → H2 injection decrease

Needs of compensation energy without PtG injection (absolute value 416 MWh)
Needs of compensation energy with PtG injection (absolute value 330 MWh)

(registration during 477 quarter/hour (approx. 120 hours))

Source: Hochschule RheinMain, Martin Kopp
Black start capability
- From standby to full load: < 10sec
- Stack load cycles 0 % … 160 %

Primary & secondary reserves
Pooling with other installations

Full dynamic behavior (positive, negative or combined mode control power)
Numerous variable determinants affect the economic viability of the hydrogen out of electrolyze on the energy market.

- Weather (case of Wind- and PV-farms)
- Stock Exchange price
  (arbitrage business in case of reconversion into electricity)
- Revenue from grid services
- Gas price
- Fuel price
- H2 Price as raw material
- Price CO2-certificate

⇒ Necessity of a period of time for the optimization of different processes and revenue possibilities.

Source: Dr. Christoph Stiller Linde AG
Hydrogen as Energy Storage and Energy Vector
Regulatory environment and suggestions

- Previous promotion of the Power-to-Gas-Technology limits itself to research project and demonstration intention.

- Creation of a market environment with specific incentive systems necessary. Moreover the legal frame must be concretized (market launch instruments).

- Analogously to other storage technologies renunciation of electricity taxes by electrolyze processes (not-last consumer concept):
  - Transmission grid fees
  - Electricity taxes
  - EU-Contribuition

- Electricity adjustment incentive: when storage installations avoid new grid extentions, their costs should be taken into consideration by the calculation of the transmission grid fees (Opportunity costs).

Source: Dr. Christoph Stiller Linde AG
Questions?

Further information:

www.energiepark-mainz.de

www.forschung-energiespeicher.info