"The German Turnaround – Storing Excess Electricity as Renewable Gas in the Gas Grid"

7th Pipeline Technology Conference
28th March 2012
Motivation for Power to Gas

Brief overview on the existing gas grid

Potential of the gas grid

Effect of hydrogen on the existing gas grid

Experiences with hydrogen in the last 200 years

Conclusion
Motivation for

POWER TO GAS
Motivation

Factors

Demography

Energy efficiency

Structural change

Decentralised generation

Source: RWE with adoptions of DBI
Motivation

Regional Power Balance 2008

Conventional Power Plants

Offshore Windpower

Abandonment of Nuclear Power Plants

Estimated Regional Power Balance 2030

Source: RWE Transportnetz Strom anl. FWEW Fachtagung 2009
Existing

GAS INFRASTRUCTURE
Transport Pipelines in Europe
Gas Grid Key Figures

- Total length (EU 25) ca. 1,8 Mio. km [2]
  - Transport pipelines approx.: 200,000 km
  - Distribution pipelines approx.: 1,600,000 km

- Estimated current replacement value of existing pipelines: approx.: 500 bill. €

- 120 underground gas storages in EU 25 [2]


→ Existing, safe, reliable and long living infrastructure it would be sensitive to use this asset for the transport and distribution of renewable gases (hydrogen and methane)
Gas Grid

POTENTIAL
## Storing of renewable Energy - Potential of the Gas Grid

### Basis:
Storing 10% of the expected daily wind power generation of the year 2030 equals to: 24 GWh (Summer day)  100 GWh (Winter day)

<table>
<thead>
<tr>
<th>Storage capacity</th>
<th>E-car „V2G“</th>
<th>Pump Storage „Goldisthal“</th>
<th>Electrolyser</th>
<th>NG filling station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage capacity</td>
<td>30 kWh/Car</td>
<td>8,5 * 10^6 kWh/PS</td>
<td>5 kWh/m³ H₂</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td>4-6 kW/Car</td>
<td>1060 MW/PS</td>
<td>5 MW/Electrolyser **</td>
<td></td>
</tr>
</tbody>
</table>

### Winter day
- 4,2 Mio. Cars *
- ca. 12 PS ***
- ca. 830 Electrolyser 20 Mio. m³ H₂ (5,3 Vol.-% in gas grid)

### Summer day
- 1 Mio. Cars *
- ca. 3 PS ***
- ca. 200 Electrolyser 4,8 Mio. m³ H₂ (2,8 Vol.-% in gas grid)

* Cars, available at the same time, ** Example, *** Goldisthal, charging level 0 %

### Remark:
In preparation of pilot plants an estimation of the available injection potential are needed.
Standard values for power transfer capacities of power lines and gas pipelines [1, DBI]

<table>
<thead>
<tr>
<th>High voltage Power lines</th>
<th>Gas pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>60</td>
</tr>
<tr>
<td>220</td>
<td>350</td>
</tr>
<tr>
<td>380</td>
<td>1200</td>
</tr>
<tr>
<td>800</td>
<td>4.400</td>
</tr>
</tbody>
</table>
Energy Storage-Efficiency

Transport of Power

- renewable energy (wind turbines and photovoltaic)
  - transformer: 100.0%
  - efficiency 95.0% loss 5.0%
  - 380 kV power line (500 km)
  - efficiency 95.1% loss 4.7%
  - pumped-storage hydropower plant
    - efficiency 80.0% loss 18.1%
  - electricity transport and storage: 72.2%

October 2011

Power-to-Gas „H₂“

- transformer and rectifier
  - efficiency 95.0% loss 5.0%
  - electrolysis including off-site facilities
    - efficiency 75.0% loss 23.7%
  - compressor, storage and H2-pipe
    - efficiency 98.5% loss 1.1%
  - gas transport (500 km)
    - efficiency 99.5% loss 0.3%

„Power-to-Gas CH₄“

- transformer and rectifier
  - efficiency 95.0% loss 5.0%
  - electrolysis including off-site facilities
    - efficiency 75.0% loss 23.7%
  - methanation
    - efficiency 80.0% loss 14.2%
  - compressor, storage and CH4-pipe
    - efficiency 98.5% loss 0.8%
  - gas transport (500 km)
    - efficiency 99.5% loss 0.2%

October 2011

28th March 2012 PTC 2012
### Efficiency of different application routes

<table>
<thead>
<tr>
<th></th>
<th>Transport and storage of power 72,2 %</th>
<th>Power-to-Gas „H₂“ 69,9 %</th>
<th>Power-to-Gas „CH₄“ 56,1 %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gas&amp;steam power station (η* = 50,8 %)</td>
<td>35,5 %</td>
<td>Gas&amp;steam power station (η* = 50,8 %) 28,5 %</td>
</tr>
<tr>
<td>E-Heating (η = 100 %)</td>
<td>Condensing boiler (η* = 99 %)</td>
<td>69,2 %</td>
<td>Condensing boiler (η* = 99 %) 55,5 %</td>
</tr>
<tr>
<td>Li-Ion-battery (η = 90 %) + E-Motor (η = 80 %)</td>
<td>FC (H₂+O₂-PEM η = 60 %) + E-drive (η = 80 %)</td>
<td>33,6 %</td>
<td>Gas engine (η = 35 %) 19,6 %</td>
</tr>
</tbody>
</table>
Effect of hydrogen on the existing NATURAL GAS GRID
Effect of hydrogen on the existing natural gas grid

- Gas quality → Wobbeindex, rel. density, calorific value…
- Grid → Steel- and polymer pipes
- Operation → Inspection, maintenance
- End appliances → Burner, cars, filling stations
- Facilities → Govenor, Gas turbines, compressors
- Safety → Risk assessment
Effect of hydrogen on the existing natural gas grid
Basis of information

NaturalHy (Natural gas + Hydrogen)

“…Development of hydrogen as an energy carrier, using the existing natural gas system as a catalyst for change…”
- Project duration 2004 – 2009
- EU FP6 (39 partners - Gasunie, GDF, NUON, DBI, GERG, ...)
- 8 work packages (LCA, Safety, Durability, Integrity, End Use, …)
- Budget: 17 Mio. EUR

Energy storage concepts

Development of concepts for generation and injection of renewable gases (H₂ und CH₄)
- Project duration 2010 – 2012
- Frame: DVGW Innovation initiative
- 5 Partners
Effect of hydrogen on the gas quality

Calorific value $H_s$ [kWh/m$^3$] vs. Wobbeindex $W_s$ [kWh/m$^3$]

Current thresholds

Expected future threshold

[5]
Effect of hydrogen on materials of the existing gas grid

- The elevated permeation through plastic pipes is not precautious from a safety perspective.
- The installed plastic pipes show a good resistance over hydrogen (no degradation observed).
- Percentage reduction of area after fracture can be reduced (steel).
- Elevated crack growth when higher H₂ concentrations and critical tensions are present.

[4, 6]
Pipeline inspection focusing on cracks are necessary when hydrogen concentrations are in the range of 50 Vol.-% and the pipes faces dynamic loads.

Existing PIMPS (Pipeline Integrity Management Systems) can be adopted.

Suitable inspection technologies have been investigated but needs field testing.

Effect of hydrogen on inspection and maintenance
Effect of hydrogen on gas appliances

**Burners**
- Tested modern boilers showed a good tolerance regarding hydrogen shares up to max. 50 Vol.-% but this result can not be extrapolated to all appliances.
- Improved emissions behaviour.
- Older especially not premixed burners needs to be investigated.

**CNG vehicles**
- Max. 2 Vol.-% $H_2$ Kraftstoffnorm DIN 51624.
- Number of acceptable load cycles of steel tanks needs to be justified.
- $H_2$ lowers the methane number but has positive effects at least up to 8 Vol.-% (Malmö, CUTE).
- NG filling stations need for modification needs to be investigated.
Effect of hydrogen on gas facilities

- **Gas turbines**
  - Few experiences, manufacturer information are show a tolerance in the range of 1-3 Vol.-% \( \text{H}_2 \)
  - \( \rightarrow \) R&D

- **Compressors**
  - Calofice value of \( \text{H}_2 \) is lower in comparison to methane \( \rightarrow \) higher volume flow needed to deliver same energy
  - Restriction of the existing facilities by drives, volumetric opportunities and materials \( \rightarrow \) R&D

- **Gas pressure regulation stations**
  - Design and installation according to DVGW guidelines (1. und 2. Gasfamily) hydrogen contents up to 67 Vol.-% are covered
  - E.ON Ruhrgas operates GPRS with coke oven gas (up to 60 Vol.-% \( \text{H}_2 \))
  - Reduction of heating capacity due to the negative J.-T.-Effect of \( \text{H}_2 \)
Effect of hydrogen on the existing gas grid - Safety aspects

Explosions

- Addition of hydrogen increases explosion severity but the increase is modest for up to 30% hydrogen.

Fires

- Little difference in flame size and thermal characteristics.
- Reduced mass outflow and faster depressurisation of pipeline rupture.

Individual Risk

- Slight increase in risk near pipeline for up to 50% H2 addition.
- Reduced hazard range as H2 added.
Experiences with HYDROGEN
Experiences with hydrogen in the last 200 years

- 1807: First high pressure gas pipeline in London (illumination)
- 1826: Illumination „Unter den Linden“ in Berlin
- 1959: 2. Issue G 260, H₂ (43–50 Vol.-% für group A and 50-60 Vol.-% für group B)
- 1950 – 87: ca. 650 bill. m³ town gas produced, distributed and consumed (BRD)
- 1950 – 88: ca. 176 Mrd. m³ town gas produced, distributed and consumed [10]
Further experiences with hydrogen

- Air Liquide H₂-grid 240 km
- Linde H₂-grid 150 km
- EIGA guideline for H₂-Pipelines (IGC Doc 121/04/E)

Hydrogen grid in middle Germany
CONCLUSION
Conclusions

The generation of renewable gases (hydrogen or methane) is the only seasonal storage opportunity in Germany.

Transport and distribution of hydrogen via the existing natural gas grids is technical feasible however adoptions are necessary depending on the hydrogen concentration as well as several topics needs to be addressed in R&D projects.

Major R&D topics are:

- $\text{H}_2$ Tolerance of CNG vehicle tanks
- Effect of $\text{H}_2$ on gas turbines, compressors and underground storages (surface and subsurface facilities)
- Adoption of measuring systems and state equations
- Comprehensive investigation of end user appliances
Conclusions

Over a period of 150 years hydrogen has been generated, transported, distributes and consumed – The gas industry is able to handle hydrogen
Thank you for your attention!

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Sources


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[8] Forschungsprojekt NATURALHY

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