Hydrogen from power-to-gas for use in refineries

Patrick Schmidt
Werner Weindorf
LBST · Munich

COPYRIGHT: HINICIO & LBST
Contents

- LBST
- Regulatory
- Hydrogen in refineries
- Conclusions
Securing your sustainable decisions.

- Independent expert for sustainable energy and mobility for over 30 years
- Bridging technology, markets, and policy
- Renewable energies, fuels, infrastructure
- Technology-based strategy consulting, System and technology studies, Sustainability assessment
- Global and long term perspective
- Rigorous system approach – thinking outside the box
- Serving international clients in industry, finance, politics, and NGOs
### Regulatory framework

#### Fuel greenhouse gas emission reduction

<table>
<thead>
<tr>
<th>Criteria</th>
<th>EU Fuel Quality Directive (FQD)</th>
<th>France Code de l'énergie</th>
<th>Germany BImSchG/V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime</td>
<td>2020</td>
<td>2020</td>
<td>2020</td>
</tr>
<tr>
<td>GHG targets</td>
<td>-2 % by 2015, -4 % by 2017, -6 % by 2020</td>
<td>-10 % by 2020</td>
<td>-3.5 % by 2015, -4 % by 2017, -6 % by 2020</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Supplier</td>
<td>Energy tax responsible entity (usually the refinery)</td>
<td>Energy tax responsible entity (usually the refinery)</td>
</tr>
<tr>
<td>Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>upstream:</td>
<td>Flaring/venting</td>
<td>Flaring/venting</td>
<td>–</td>
</tr>
<tr>
<td>refinery:</td>
<td></td>
<td>Refinery GHG emissions reduction</td>
<td>–</td>
</tr>
<tr>
<td>downstream:</td>
<td>Biofuels and alternative fuels from non-biological sources</td>
<td>Biofuels, electricity</td>
<td>Biofuels</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂ eligible as transportation fuel (2015/652/EU, ANNEX I), not for use in refineries yet</td>
<td>H₂ not yet eligible as transportation fuel. Reduction of refinery emissions through use of low carbon hydrogen is eligible</td>
<td>H₂ not yet eligible; ‘further renewable fuels’ (e.g. PtG) and ‘other measures’ are subject to enforcement of a legal ordinance (§37d (2), point 13)</td>
</tr>
<tr>
<td>Infringement penalty</td>
<td>Subject to national implementation, which shall be ‘effective, proportionate and dissuasive’</td>
<td>Not yet defined (application decrees to be published in 2017)</td>
<td>470 €/t CO₂eq</td>
</tr>
</tbody>
</table>

---

Sole reference for information is the final report.
Major refinery locations in Europe:

1. Germany
2. Italy
3. UK
4. France
5. Spain
6. The Netherlands
7. ...

Source: LBST with data [E3M et al. 2015]
There is a trade-off between crude oil cost and quality.

In Europe, a wide range of crude oil qualities is processed.

French and German refiners source rather better qualities.

Average crude oil quality [EXERGIA et al. 2015]:
- France: 36.0 API gravity, 0.7 wt.-% sulphur
- Germany: 37.3 API gravity, 0.5 wt.-% sulphur
Hydrogen sources and uses in a refinery

- Calculation: Net hydrogen demand = process sources – process uses
- Desulphurisation is a sensitive parameter to net hydrogen demand
- By tendency,
  - crude oil quality is further deteriorating → increasing sulphur content
  - demand for heavy fuel fractions is decreasing → maritime emission areas
Life-cycle assessment (LCA)
Pathways for gasoline and diesel supply

TODAY (SMR H₂)
- Extraction of Crude oil → Transport → Refinery → Distribution → Refuelling station
- Natural gas → Extraction & processing → Transport → Steam reforming → H₂

NEAR FUTURE (GREEN H₂)
- Extraction of Crude oil → Transport → Refinery → Distribution → Refuelling station
- Renewable electricity → Electrolysis → Compression & storage → H₂

Fossil reference pathway

Sole reference for information is the final report
Scenario

Refinery net H₂ demand supplied from 100% green H₂
FQD minimum target is -6% GHG emissions by 2020
Refinery GHG emission reduction (gate-to-gate)
France and Germany

<table>
<thead>
<tr>
<th>GHG mitigation of refinery emissions</th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.33 Mt CO$_2$eq/a</td>
<td>1.50 Mt CO$_2$eq/a</td>
</tr>
<tr>
<td></td>
<td>14.1 %</td>
<td>7.2 %</td>
</tr>
<tr>
<td></td>
<td>331 €/t CO$_2$eq</td>
<td>339 €/t CO$_2$eq</td>
</tr>
</tbody>
</table>

→ Economic option for German refineries against 470 €/t CO$_2$eq

To give an impression about the quantities, this is equivalent to annual GHG emission of C segment cars in the order of

<table>
<thead>
<tr>
<th></th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline car @ 7.0l/100km</td>
<td>575,000</td>
<td>648,000</td>
</tr>
<tr>
<td>Diesel car @ 5.5l/100km</td>
<td>658,000</td>
<td>740,000</td>
</tr>
</tbody>
</table>

→ Tangible action for refinery corporate social responsibility (CSR)
## Regulatory framework

**Fuel greenhouse gas emission reduction**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>EU Fuel Quality Directive (FQD)</th>
<th>France Code de l'énergie</th>
<th>Germany BImSchG/V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lifetime</strong></td>
<td>2020</td>
<td>2020</td>
<td>2020</td>
</tr>
<tr>
<td><strong>GHG targets</strong></td>
<td>-2 % by 2015</td>
<td>-10 % by 2020</td>
<td>-3.5 % by 2015</td>
</tr>
<tr>
<td></td>
<td>-4 % by 2017</td>
<td></td>
<td>-4 % by 2017</td>
</tr>
<tr>
<td></td>
<td>-6 % by 2020</td>
<td></td>
<td>-6 % by 2020</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Supplier</td>
<td>Energy tax responsible entity (usually the refinery)</td>
<td>Energy tax responsible entity (usually the refinery)</td>
</tr>
<tr>
<td><strong>Options</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>upstream:</strong></td>
<td>Flaring/venting</td>
<td>Flaring/venting</td>
<td>–</td>
</tr>
<tr>
<td><strong>refinery:</strong></td>
<td>–</td>
<td>Refinery GHG emissions reduction</td>
<td>–</td>
</tr>
<tr>
<td><strong>downstream:</strong></td>
<td>Biofuels and alternative fuels from non-biological sources</td>
<td>Biofuels, electricity</td>
<td>Biofuels</td>
</tr>
<tr>
<td><strong>Hydrogen</strong></td>
<td>H₂ eligible as transportation fuel (2015/652/EU, ANNEX I), not for use in refineries yet</td>
<td>H₂ not yet eligible as transportation fuel. Reduction of refinery emissions through use of low carbon hydrogen is eligible</td>
<td>H₂ not yet eligible; ‘further renewable fuels’ (e.g. PtG) and ‘other measures’ are subject to enforcement of a legal ordinance (§37d (2), point 13)</td>
</tr>
<tr>
<td><strong>Infringement penalty</strong></td>
<td>Subject to national implementation, which shall be ‘effective, proportionate and dissuasive’</td>
<td>Not yet defined (application decrees to be published in 2017)</td>
<td>470 €/t CO₂eq</td>
</tr>
</tbody>
</table>
Green hydrogen in refineries is an attractive GHG mitigation option
- Introduction of green H₂ in an established bulk H₂ application
- Volume production of H₂ reduces electrolyser costs
- Electrolysers 'valley of death' is bridged by all fuel users

→ **Deployment of power-to-hydrogen for refineries is a strategic move entailing long-term benefits for all hydrogen uses.**
Establish regulatory grounds for accountability at EU level
- Open FQD for greenhouse gas mitigation options in refineries
- Sustainability criteria and certification for renewable/green hydrogen

Fast-track implementation rather at national level, e.g.
- In Germany through legal ordinance BImSchG § 37d (2)
- In France through ordinances currently under development
- Other EU Member States?

Avoid regulatory pitfalls, like
- Carbon leakage: RES-E deployment targets to reflect increasing demand
- Double counting/residual mix between companies, sectors, geographies
- Interventions ‘behind-the-fence’: Fees/taxes on RES-E own generation & consumption raises the bar for early markets
Vanhoudt, W., Barth, F. (Hinicio), Schmidt, P., Weindorf, W. (LBST), et al.: Power-to-gas – Short term and long term opportunities to leverage synergies between the electricity and transport sectors through power-to-hydrogen; Brussels/Munich, 19 February 2016

- Application A: Hydrogen from power-to-gas for use in refineries
- Application B: Semi-centralised power-to-hydrogen business cases

→ Download
http://www.fondation-tuck.fr/jcms/r_16975/fr/hinicio-sa
Patrick Schmidt (Dipl.-Ing.)
LBST · Ludwig-Bölkow-Systemtechnik GmbH
Daimlerstr. 15 · 85521 Munich · Germany
http://www.lbst.de
E: Patrick.Schmidt@LBST.de

Werner Weindorf · LBST
Tetyana Raksha · LBST
Jan Zerhusen · LBST
Jan Michalski · LBST
Wouter Vanhoudt · Hinicio
Frédéric Barth · Hinicio
CO₂ avoidance costs well-to-tank [€/t CO₂eq] for PtX in EU

![Graph showing CO₂ avoidance costs well-to-tank for various fuel production routes.]

Liquid fuels (PtL)
- Gasoline/kerosene/diesel
- EE-PtL methanol route
- EE-PtL FT route
- EE-PtL SOEC methanol route
- EE-PtL SOEC-FT route

Gaseous fuels (PtG)
- EE-CH₄ (CNG)
- EE-CH₄ (LNG)
- EE-CH₄ (CNG) SOEC
- EE-CH₄ (LNG) SOEC
- EE-CGH₂ (onsite)

Electricity for BEV

Benchmarks:
- Fuels from crude oil (0 €/t CO₂)
- -58%
- -57%
- -67%
- -67%
- -58%
- -60%
- -62%
- -68%
- -70%

Least-cost short-term: Electricity
- -22%

Least-cost long-term: Electricity and CGH₂

CO₂ from air
- 100 US$/bbl fossil liquids (IEA)
- 0 €/t CO₂

Source: LBST, Renewables in Transport 2050, FVV (ed.), 2016

Ludwig-Bölkow-Systemtechnik GmbH
16 March 2016

[LBST.de]