Hydrogen: a European Approach

November 4\textsuperscript{th} 2020
Europe: green hydrogen as a vector to replace fossil fuels

Green hydrogen is the centerpiece of the EU Green Deal as a key enabler to Net-Zero by 2050 and green industry. The EU has announced a Hydrogen Strategic Roadmap on July 8th featuring 10 million-ton green hydrogen (390 TWh) by 2030. The Clean Hydrogen Alliance bringing together industry. Support schemes with CCFD mechanism, IPCEI, Innovation Fund and EIB funding.

Germany introduces National Hydrogen strategy with 37 measures (covering production, usage (mobility, industry, heat, infrastructure, R&D, European market, international trading) and 9 bn€ funding by 2030 aiming at 14 TWh green hydrogen by 2030 aiming at making Germany #1 with focus across the value chain and global partnerships.

Oil & gas majors

<table>
<thead>
<tr>
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<th>Share performance since 1/1/2020</th>
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<tbody>
<tr>
<td>Total</td>
<td>-28.5%</td>
</tr>
<tr>
<td>BP</td>
<td>-47.4%</td>
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<tr>
<td>Shell</td>
<td>-56.9%</td>
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Electrolysis OEMs

<table>
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<tr>
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<th>Share performance since 1/1/2020</th>
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<tbody>
<tr>
<td>Nel</td>
<td>+114.7%</td>
</tr>
<tr>
<td>ITM</td>
<td>+314.2%</td>
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<tr>
<td>McPhy</td>
<td>+559.1%</td>
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The HyDeal project: a systemic approach
Solar power prices have fallen to levels around 15 $/MWh in auctions in Latin America, Southern Europe and the Middle East. Cell efficiencies (heterojunction and tandem cells) are expected leap from 20% to 30% in the next decade, and 10 $/MWh by 2025 is likely to be achieved, 80% cheaper than most conventional generation.

The global solar PV market reached 116 GW in 2019 (x 2.5 in 5 years) representing 48% of net global power capacity additions. Estimated 500 GW of annual production capacity across the value chain (polysilicon, ingots/wafers, cells, modules...) is planned for the next 3-5 years.

The capacity to export massive volumes of solar under the form of hydrogen through gas pipelines and shipping opens the door for TW-scale power producing hubs (and water desalination) in the Mediterranean, Latin America, the Middle East, South Asia and Australia.
A clear roadmap to fossil fuel parity: 1.5 $/kg hydrogen delivered

**Electrolysis Gigafactories are being planned** by several key OEMs (Nel, McPhy, ITM, Thyssenkrupp…) targeting larger stacks (from 1 MW to 5 MW) and higher efficiencies, following the model of the wind turbine industry.

Higher efficiencies, effects of scale, plant automation, Balance-of-plant optimization, plant load maximization through vertical integration with downstream value chain help **target electrolysis plants costs (including installation) reduced by 60% to 300 $/kW by 2025**, and **200 $/kW in 2030**.

The combination of **super low solar and electrolysis costs** and the ramp up of midstream infrastructure (transmission and underground storage) should allow **delivered costs of green hydrogen to end consumers below 1.5 $/kg by 2025 and 1 $/kg by 2030**, matching the cost of delivered natural gas in Europe.
A booming market driven by the race to global green leadership

**European green hydrogen market**
(in millions of tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
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<tbody>
<tr>
<td>Value</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>32</td>
<td>64</td>
<td>128</td>
<td>256</td>
<td>512</td>
<td>1024</td>
</tr>
</tbody>
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Source: European Commission

**Hydrogen-fired power generation**
- **Business model** Convert gas and coal-fired plants, contract 24/7 PPAs with RE100 users, trade on seasonal power grid volatility
- **Financial characteristics** Opportunity to acquire stranded fossil assets with subsidized retrofit, reliable cash flows
- **Equity story USP** Turning lead (stranded fossil assets) into gold (dispatchable RE)

**Green ammonia production**
- **Business model** Build green ammonia plants to capture the zero-carbon chemicals and shipping fuel markets at fossil parity
- **Financial characteristics** High capital intensity, fair return on capital employed, high growth (in shipping)
- **Equity story USP** Market leadership and dash to scale allow to aim at “winner takes all”

**Green steel production**
- **Business model** Convert existing steel plants with DRI from coking coal to hydrogen to capture the green steel market
- **Financial characteristics** Opportunity to acquire stranded steel assets with subsidized retrofit, reliable cash flows
- **Equity story USP** Market leadership and dash to scale allow to aim at “winner takes all”