H₂ Energy
At the heart of the energy transition

Liberum - Future of E-Mobility Conference
December 11th 2019
AGENDA

1. The urgency for Energy Transition
2. The role of Hydrogen
3. On-going dynamic
4. The case of Air Liquide
5. Priorities – Hydrogen Council views
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Despite COP21, Emissions continue to rise…

Global energy-related carbon dioxide emissions by source, 1990-2018
The “Kaya” Equation to summarize the issue

\[ \text{CO2} = \frac{\text{CO2}}{\text{Energy}} \times \frac{\text{Energy}}{\text{GDP}} \times \frac{\text{GDP}}{\text{POP}} \times \text{POP} \]

- **Carbon Content of Energy**
- **Energy Efficiency of the Economy**
- **Economic Wellfare**
- **Population**

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP (as % of World)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>10</td>
</tr>
<tr>
<td>China</td>
<td>8</td>
</tr>
<tr>
<td>US</td>
<td>57</td>
</tr>
<tr>
<td>FR</td>
<td>37</td>
</tr>
<tr>
<td>Philippines</td>
<td>3</td>
</tr>
<tr>
<td>Senegal</td>
<td>1</td>
</tr>
</tbody>
</table>

- **World CO2/Toe**: 7.6 today, 8.6 2030, 9.8 2050
Small remaining budget not to exceed +2°C

Billion tonnes of CO₂-eq

2°C Carbon budget emissions to 2100

3,670

1,060

939

790

~900

2°C carbon budget

1750-1985

1985-2015

CH4/N20/F, 2015-2100

2016-2100

Historical emissions

Future emissions

Carbon budget compared to carbon reserves

3,000-5,400

3,000-5,400

~900

200

2°C carbon budget

1,5°C carbon budget

Gas, unconventional

Gas, conventional

Oil, unconventional

Oil, conventional

Coal

Historical emissions

Future emissions

Four major levers to enable the energy transition

Final energy consumption 1, 2013 and 2050, in EJ

1. Increasing energy efficiency limits the rise of energy consumption
2. CCS/U decarbonizes the use of fossil fuels
3. Switch to zero emission energy carriers, e.g., electricity or hydrogen
4. Renewables replace fossil fuels

<table>
<thead>
<tr>
<th>Year</th>
<th>Fossil Fuels</th>
<th>Power sector – Fossil fuels</th>
<th>Power sector – Renewables</th>
<th>Biomass and Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>373 EJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>640 EJ</td>
<td></td>
<td>431 EJ</td>
<td></td>
</tr>
</tbody>
</table>

1. Final energy consumption within the 2DS of the IEA
2. Increase of energy demand is determined via the relative increase of CO₂ emissions w/o energy efficiencies
3. The fossil fuels amount processed using CCS/U was determined to be 25% of the total amount of fossil fuels by relating the CO₂ emission reduction compared for the 2DS and 6DS
4. The fossil fuel power sector also includes nuclear energy

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The 7 roles of hydrogen in the energy transition

1. Enable large-scale renewables integration and power generation
2. Distribute energy across sectors and regions
3. Act as a buffer to increase system resilience
4. Decarbonize transportation
5. Decarbonize industry energy use
6. Help decarbonize building heating and power
7. Serve as feedstock, using captured carbon

Enable the renewable energy system → Decarbonize end uses

Potential demand for H2 in a +2°C Scenario

Potential global energy demand supplied with hydrogen, Exajoule (EJ)

1. Power generation, buffering
2. Transportation
3. Industrial energy
4. Building heat and power
5. New feedstock (CCU, DRI)
6. Existing feedstock uses

18% of final energy demand

SOURCE: Hydrogen Council
Potential of Hydrogen across all applications

*Bubble size indicates hydrogen potential in 2050 in EJ (1 EJ)*

**Power generation**
- Power generation
- Buffer

**Transportation**
- Small cars
- Trucks
- Trains & tramways
- Synfuel
- Vans & minibuses
- Coaches & buses
- Forklifts

**Industrial energy**
- Medium-/low industry heat
- High-grade industry heat

**Building heat and power**
- Heating/co-generation in countries without gas networks
- Heating/co-generation in countries with gas networks

**Industry feedstock**
- Steel (DRI)
- CCU for methanol, olefins, BTX3
- Refining
- Ammonia, methanol

Hydrogen: a clean, safe and versatile energy carrier

- Can be transported over long distances, allowing the distribution of energy between countries
- Hydrogen is suitable for long-term storage
- Produces clean power and/or heat for transport and stationary applications
- Can be produced without a carbon footprint through electrolysis, biomethane and SMR + CCS
- Required as a clean feedstock in industry when recycling captured CO₂
Hydrogen mobility markets: Ready to scale TODAY
Low carbon hydrogen pathways

- Biomethane
- Electrolysis
  - low carbon electricity
- Natural Gas + Carbon Capture and Storage (CCUS)
Hydrogen for industry

Existing industrial usages of H₂

Objective: Shift to low carbon H₂

New H₂ markets

Objective: Develop new applications for H₂ to replace fossil fuels

Air Liquide to deliver hydrogen for thyssenkrupp’s pioneering project for lower carbon steel production

News | Monday, July 22, 2019
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The Hydrogen Energy World today - widely shared view
The Hydrogen Energy World
Promising market developments in many areas, going beyond mobility

> 300

> 23,000

> 500

15,000 FCEVs

> 60 demo projects

1,150

> 300

250,000 installed

<5€/kg

Source: Hydrogen Council

Air Liquide
First large scale projects at sight
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Hydrogen - 40 years of development for industries

Production & Supply chain

- Production
- Supply-chain

Distribution Networks

- US Gulf Coast
- Northern EU
- Singapore

Markets Segments

- Process industries
  - Oil & Gas
  - Steel, Glass
  - Electronics
  - Transportation
  - Space

Key Figures

- > 14 bn m$^3$/yr
- > 1,850 km H$_2$ pipeline
- > 46 large H$_2$/CO plants
- > 40 electrolysers in operation
- > 2 bn € sales
Air Liquide already started to invest

- 14 bn m³/yr
- 1,850 km H₂ pipelines
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- 40 electrolyzers in operation
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More than 120 Hydrogen recharging stations (HRS) installed by Air Liquide in the world in which 58 directly invested and operated by Air Liquide.
H2 Council...

We call on governments to build a global alliance that will help us deliver on an ambitious goal of decarbonizing 100% of hydrogen fuel used in transport by 2030. Transport may be our first target—but with the right level of support, we will see positive effects across many sectors.

GLOBAL CLIMATE ACTION SUMMIT

Hydrogen Council
AIR LIQUIDE: A catalyst for new markets, to enable the development of core activities

- SMR w/ CCS and/or Biogas
- Electrolysis
- H2 Production
- H2 Conditioning
- H2 Distribution
- Dispensing and Retail
- Technology / Know-how / Expertise

Build – Own - Operate

Minority Stake
TWO MAJOR INVESTMENTS to enable growth of Fuel-Cell Vehicles in North America

150 MUSD
Air Liquide to build new hydrogen production plant in Las Vegas

SMR w/ Biogas
30 Tonnes/day H2 Liquefier

20 MW Electrolysis (Hydropower - Quebéc)

Air Liquide to construct PEM electrolyser for carbon-free hydrogen
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2nd Hydrogen Energy Ministerial

Tokyo, Japan
25 September 2019
KEY STEPS NEEDED TO SUCCESS

- **SHARED VISION BETWEEN KEY COUNTRIES**
- **ARCHETYPE DEPLOYMENTS ALONG THE VALUE CHAINS**
- **CLEAR REGULATIONS FAVOURING COMPETITIVE DEPLOYMENTS**
- **SUPPORTING SCHEMES TO BRIDGE GASP TO COMPETITIVENESS**

- **ONGOING**
- **ONGOING**
- **SCATTERED**
- **MISSING**
CONCLUSIONS

- HYDROGEN TECHNOLOGIES ARE READY FOR SCALE UP
- VOLUME WILL BRING COST DOWN
- REGULATIONS WILL BRING VOLUME
- URGENCY FOR ENERGY TRANSITION AND ITS INVESTMENT POTENTIAL SHALL CAUSE REGULATIONS TO COME
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