

# Contribution of hydrogen to decarbonization of EIs

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Chatou France • November 7th 2019

Fabrice Del Corso • R&D

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# 40 years of development in Hydrogen for our customers

## Production & Supply chain

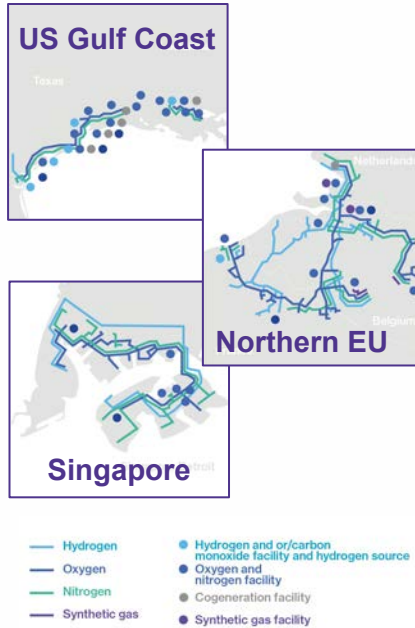
### Production



### Supply-chain



## Distribution Networks



## Markets Segments

### Process industries

#### Oil & Gas



#### Steel, Glass



#### Electronics



#### Transportation Space



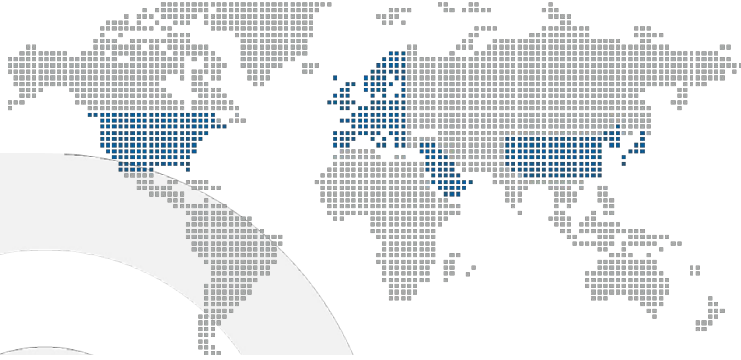
## Key Figures

- > 14 bn m<sup>3</sup>/yr
- > 1,850 km H<sub>2</sub> pipeline
- ~ 50 large H<sub>2</sub>/CO plants
- ~ 40 electrolyzers in operation
- > 2 bn € sales

# Air Liquide : Co-founder of the Hydrogen Council

## Widening of sector and geographic interest at CEO level

INTERNATIONAL COOPERATION IS KEY TO UNLOCKING THE HYDROGEN ECONOMY



## H<sub>2</sub> COUNCIL

covers Europe, Japan,  
Korea, US, Middle  
East & China

60 members



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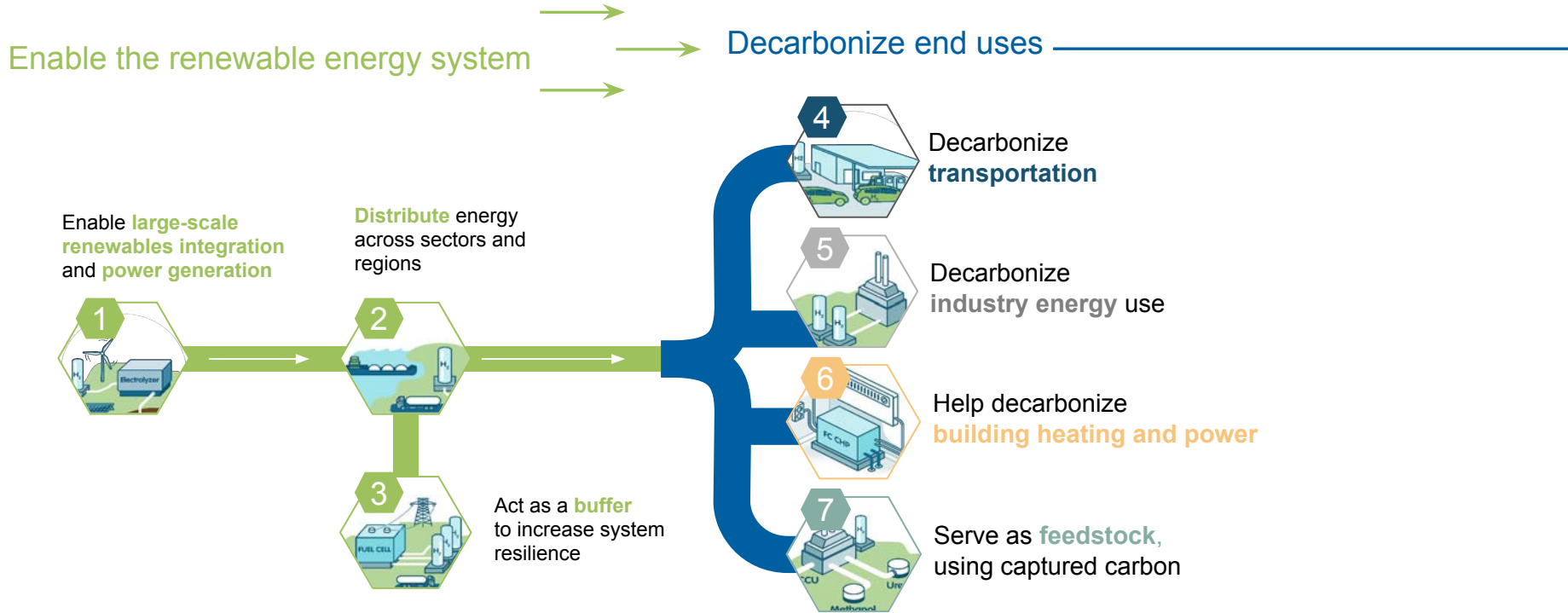
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AIR LIQUIDE, THE WORLD LEADER IN GASES, TECHNOLOGIES AND SERVICES FOR INDUSTRY AND HEALTH

Contribution of hydrogen to decarbonisation of EILs

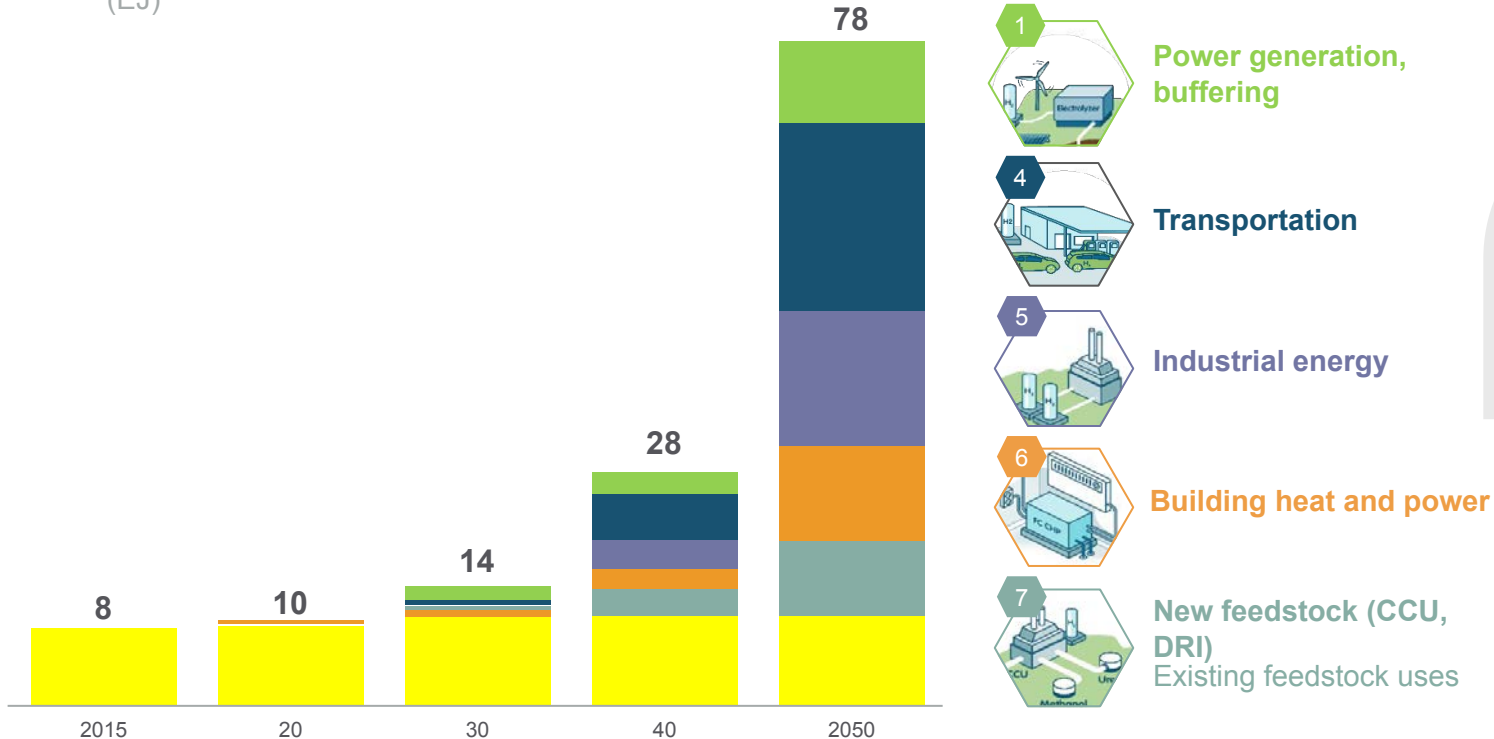


# There are seven roles for hydrogen in the energy transition



# In a 2-degree-world, hydrogen could contribute ~18% of demand

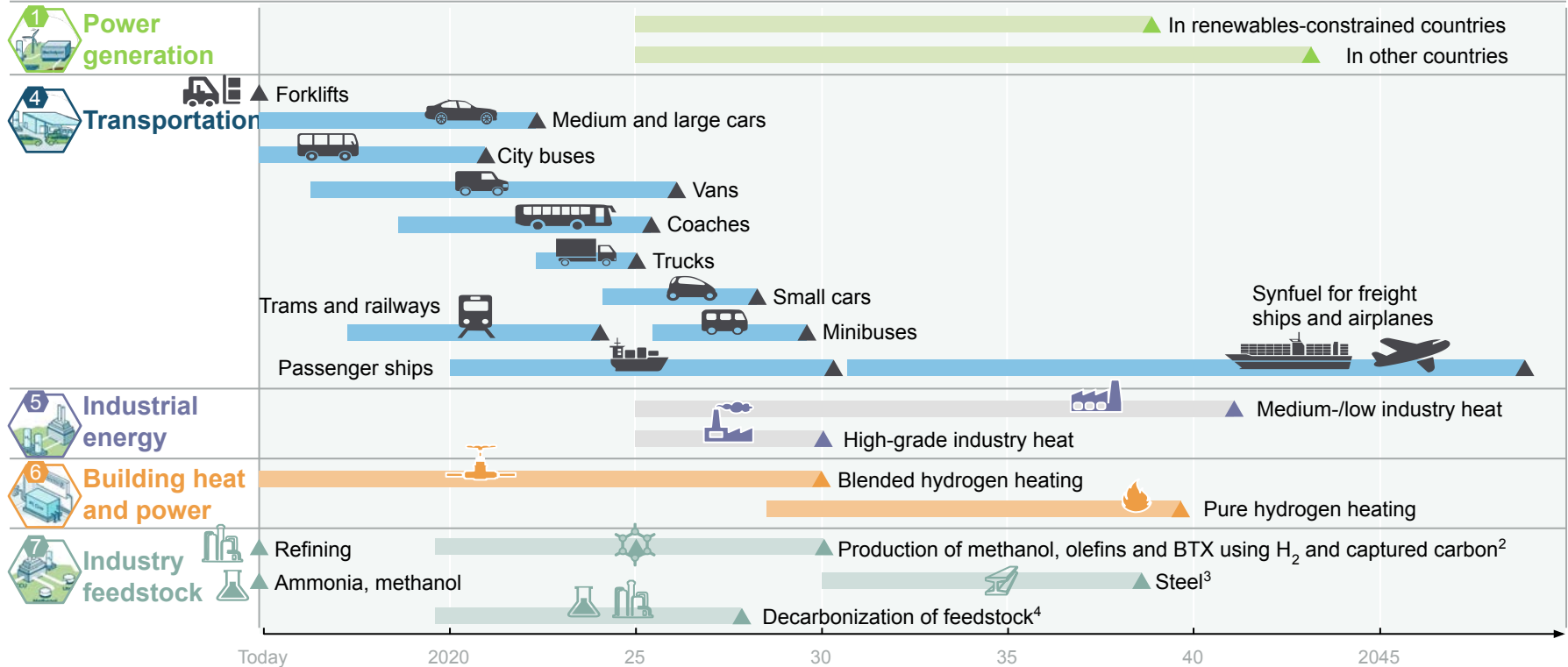
Potential global energy demand supplied with hydrogen, Exajoule (EJ)



SOURCE: Hydrogen Council

**18%**  
of final energy  
demand

# The technologies exist and are ready to be deployed



<sup>1</sup> Mass market acceptability defined as sales >1% within segment in priority markets

<sup>2</sup> Market share refers to the amount of production that uses hydrogen and captured carbon to replace feedstock

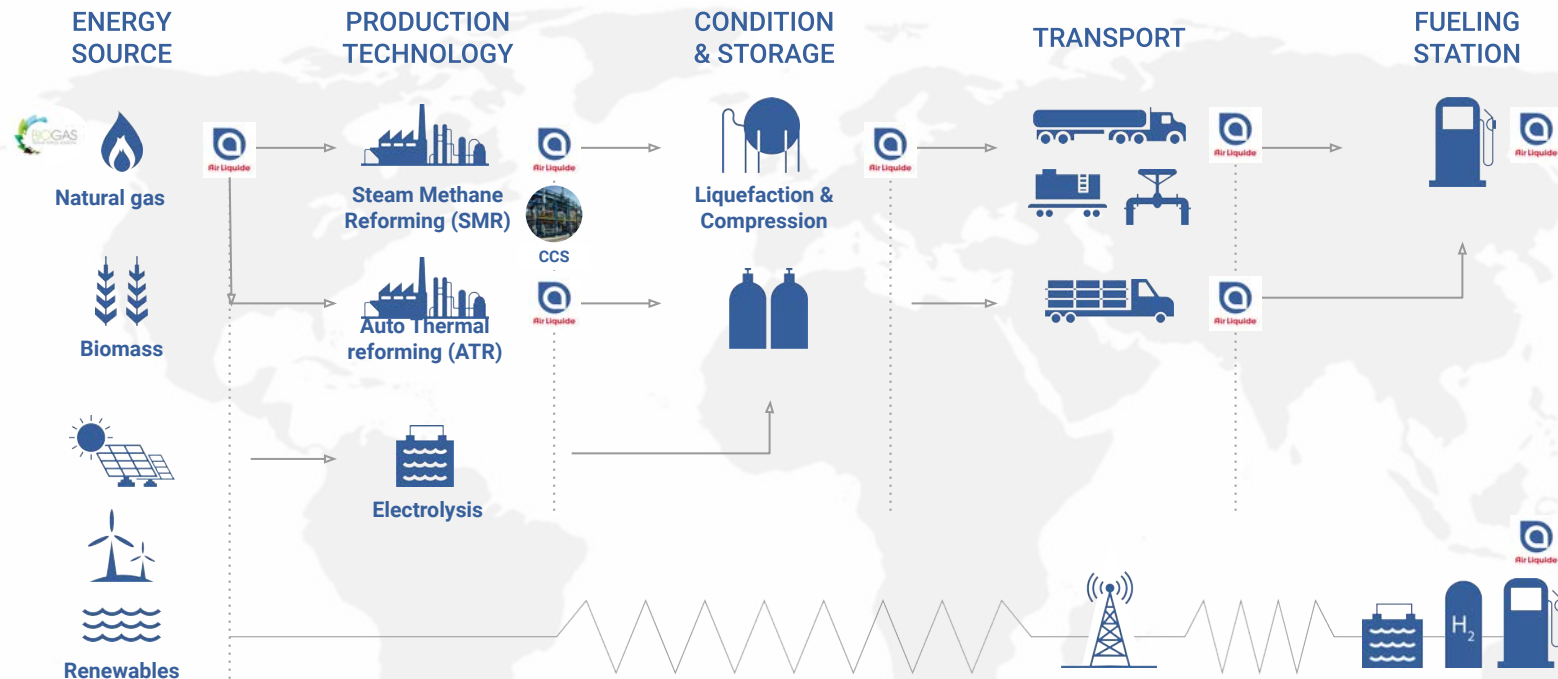
<sup>3</sup> DRI with green H<sub>2</sub>, iron reduction in blast furnaces and other low-carbon steel making processes using H<sub>2</sub>

<sup>4</sup> Market share refers to the amount of feedstock that is produced from low-carbon sources

Source: McKinsey & Hydrogen Council 2017

Start of : commercialization : Mass market acceptability<sup>1</sup>

# Blue Hydrogen supply chain- Air Liquide Technology portfolio



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# Mastering a complete portfolio of low carbon, safe and efficient solutions

## Electrolysis

Air Liquide fait un investissement stratégique dans la production d'hydrogène décarboné par électrolyse

Communiqué de presse | Jeudi 24 janvier 2019



**HYDROGENICS**  
SHIFT POWER | ENERGIZE YOUR WORLD

Air Liquide signs long-term power purchase agreement for renewable electricity

Press release | Friday, November 30, 2018

**A Levier 1** : Augmenter les achats d'électricité renouvelable de **+67%** (de 6 à 10 TWh)

→ Démarche volontariste d'**acheter de l'électricité renouvelable** (contrats directs d'achat d'énergie auprès des producteurs)

## bio-CH4 + SMR/ATR



## SMR/ATR + CCS



ENTREPRISES ET MARCHÉS

**AIR LIQUIDE : COLLABORATION SUR LE PROJET NORTHERN LIGHTS EN VUE**

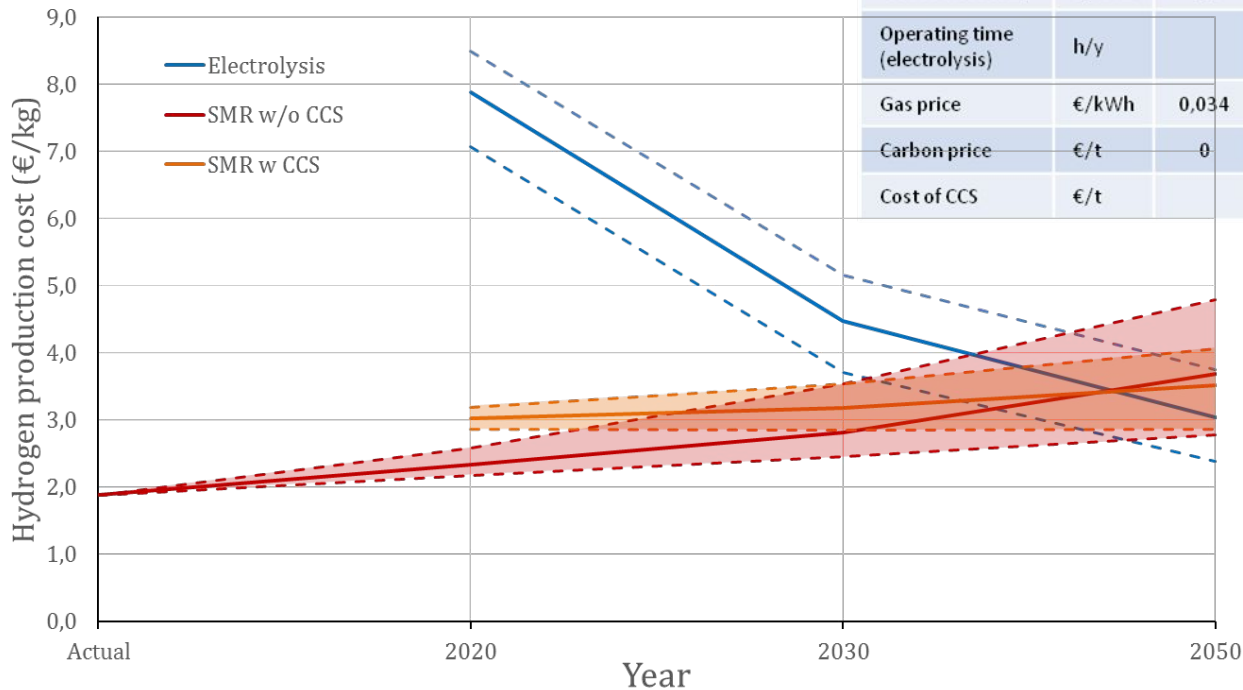
PUBLIÉ LE 05/09/2019 À 10H01



# What about production costs ?

## Hydrogen production cost comparison

Parameter	Unit	Actual	2020		2030		2050	
			Low	High	Low	High	Low	High
Cost of electricity	€/kWh	0,1	0,65	0,100	0,060	0,090	0,050	0,080
Operating time (electrolysis)	h/y		3500	3500	3750	4500	4000	6000
Gas price	€/kWh	0,034	0,037	0,044	0,041	0,054	0,044	0,068
Carbon price	€/t	0	15	25	30	80	50	150
Cost of CCS	€/t		100		80		60	



Based on 100,000 m<sup>3</sup>/h SMR

Source = ZEP (Zero Emission Platform), "Commercial Scale Feasibility of Clean Hydrogen", April 2017.

# Hydrogen Carbon footprints

Alkaline Water electrolysis (Electricity for operations only)	Netherlands Market electricity mix	Quebec market electricity mix	Wind Mill offshore (Denmark)
gCO <sub>2</sub> /kWh of electricity	593	22	15
kg CO <sub>2</sub> eq/kg H <sub>2</sub>	<b>35</b>	<b>1.4</b>	<b>0.9</b>

SMR from Natural Gas (Netherlands conditions)	SMR without CCS	Partial CCS on SMR 60% CO <sub>2</sub> capture rate
kg CO <sub>2</sub> eq/kg H <sub>2</sub>	<b>10</b>	<b>5</b>

Database Ecoinvent v3.4  
Method IPCC 2013 GWP 100a  
H2 pressure = 100 bar

# Electrolyzer: scale up has started

Scale up to  
**100 MW +**  
Preparing the  
next step



**HYBALANCE 1.25 MW**  
**One of largest PEM**  
**In operation**

Hydrogenics announces \$20.5m private placement and technology partnership with Air Liquide

By Nadine Sampson | 3 January 2019

2019

2018

**BECANCOUR 20 MW**  
**Largest PEM project**  
**Under execution**

Air Liquide signs long-term power purchase agreement for renewable electricity

Press release | Friday, November 30, 2018



< 2017

more than 30 electrolyzers in operation worldwide  
usual range: 50 - 100 Nm<sup>3</sup>/h H<sub>2</sub>  
Mainly Alkaline technology

ONSITE

Air Liquide invests in the world's largest membrane-based electrolyzer to develop its carbon-free hydrogen production



• Design and build Group's industrial gas production units

- Solution oriented towards our gas customers
- Plant life-cycle optimization
- Supporting operations

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# Guarantee of H<sub>2</sub> origin



- **Definitions** : build on CertifHy framework

**Low Carbon** = Foot print < 60%<sup>(\*)</sup>

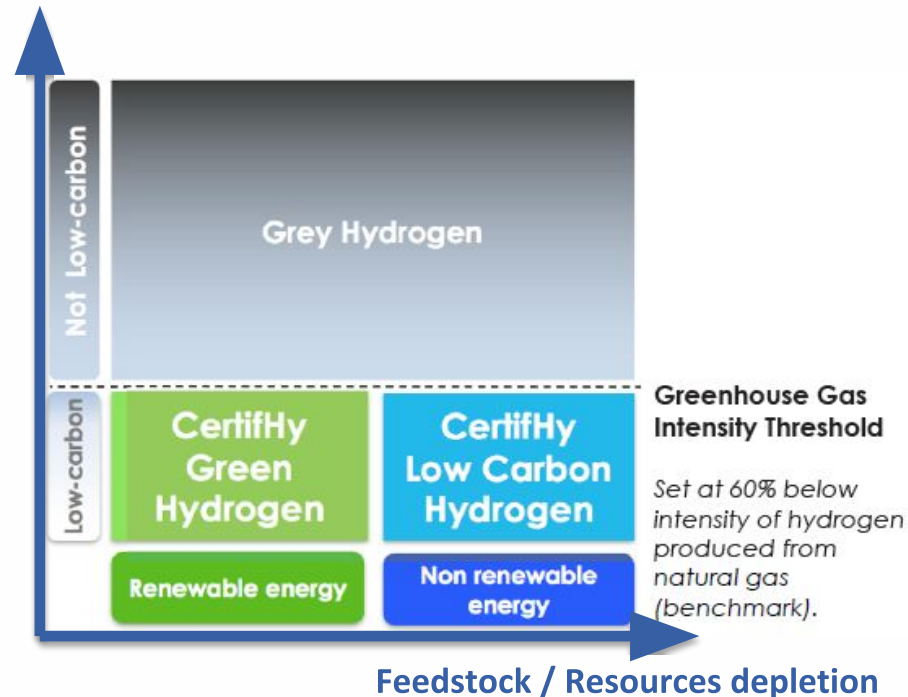
below Benchmark (SMR) from cradle to gate

**Green H<sub>2</sub>** = From REnewable **AND** **Low Carbon**

- **Both** low carbon and renewable H<sub>2</sub> needed

- An **harmonized GoO system** covering both attributes

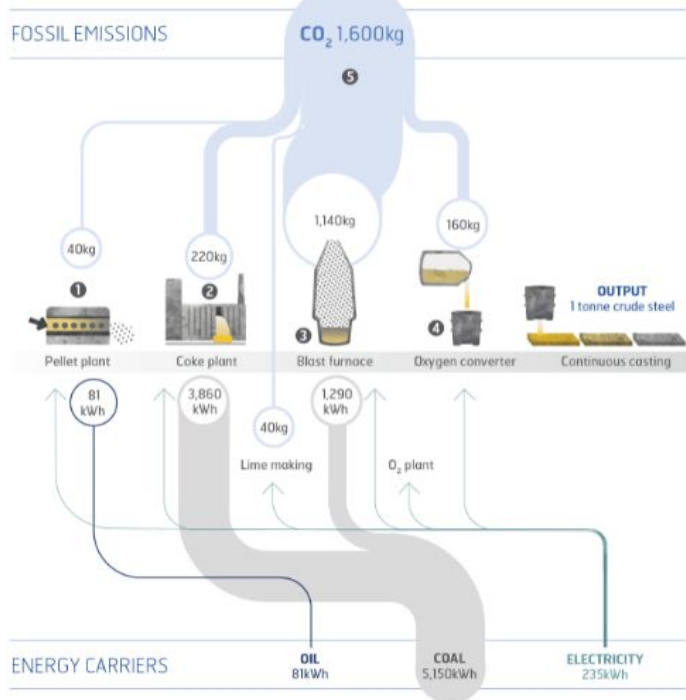
GHG / Global Warming



(\*) Value to be updated to keep consistent with sustainability criteria of other fuels

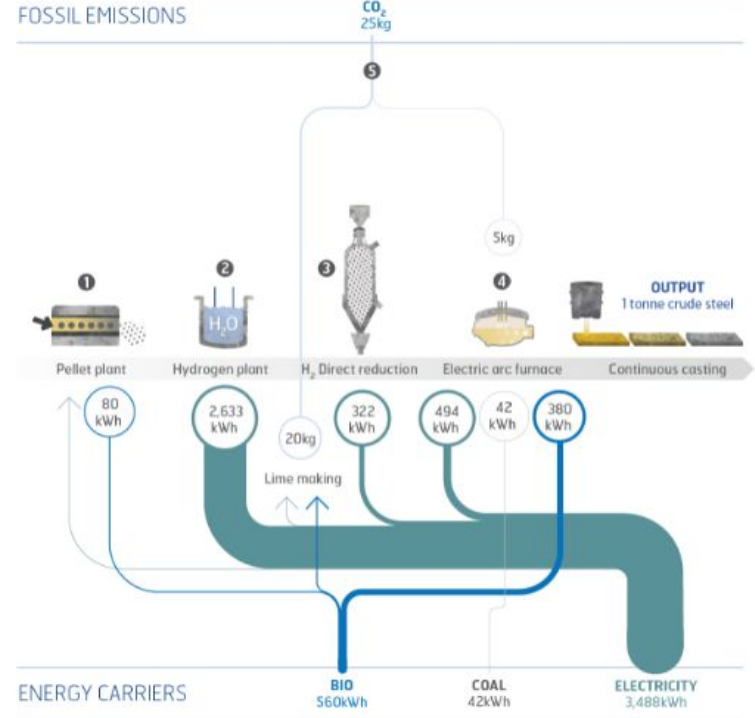
# Hydrogen for steel - H<sub>2</sub> for Direct Reduction of Iron

## SWEDISH REFERENCE



Principal system description. Numbers do not reflect a specific production site or time period. All numbers per tonne of crude steel.

## HYBRIT



All numbers per tonne of crude steel.

Source :  
HYBRIT project

# Hydrogen for steel - H<sub>2</sub> for Blast Furnace

Steel

## Hydrogen for the blast furnace

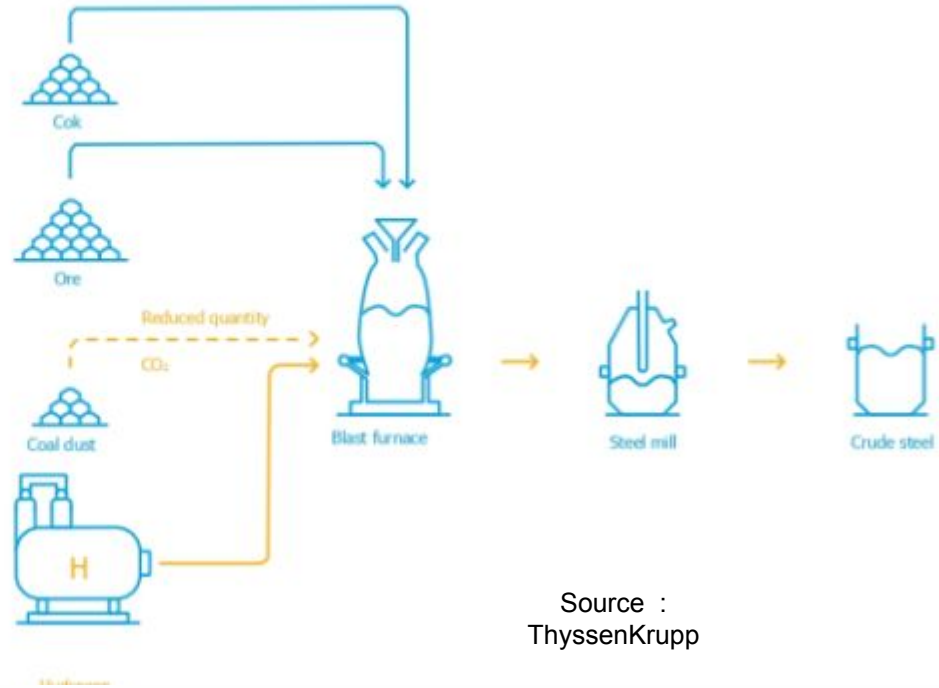
On the way to climate-friendly steel production, we have started using hydrogen at our blast furnace in an initial test. The basic idea is to reduce the amount of coal required for injection and replace it with hydrogen (H<sub>2</sub>) in order to reduce CO<sub>2</sub> emissions.

Funded by the state of North Rhine-Westphalia as part of the IN4climate.NRW initiative. The hydrogen required for the project is supplied by Air Liquide, world market leader for industrial gases. The non-profit Institute for Applied Research BFI which belongs to the Steel Institute VDEh is providing scientific support for the project.

### Project details

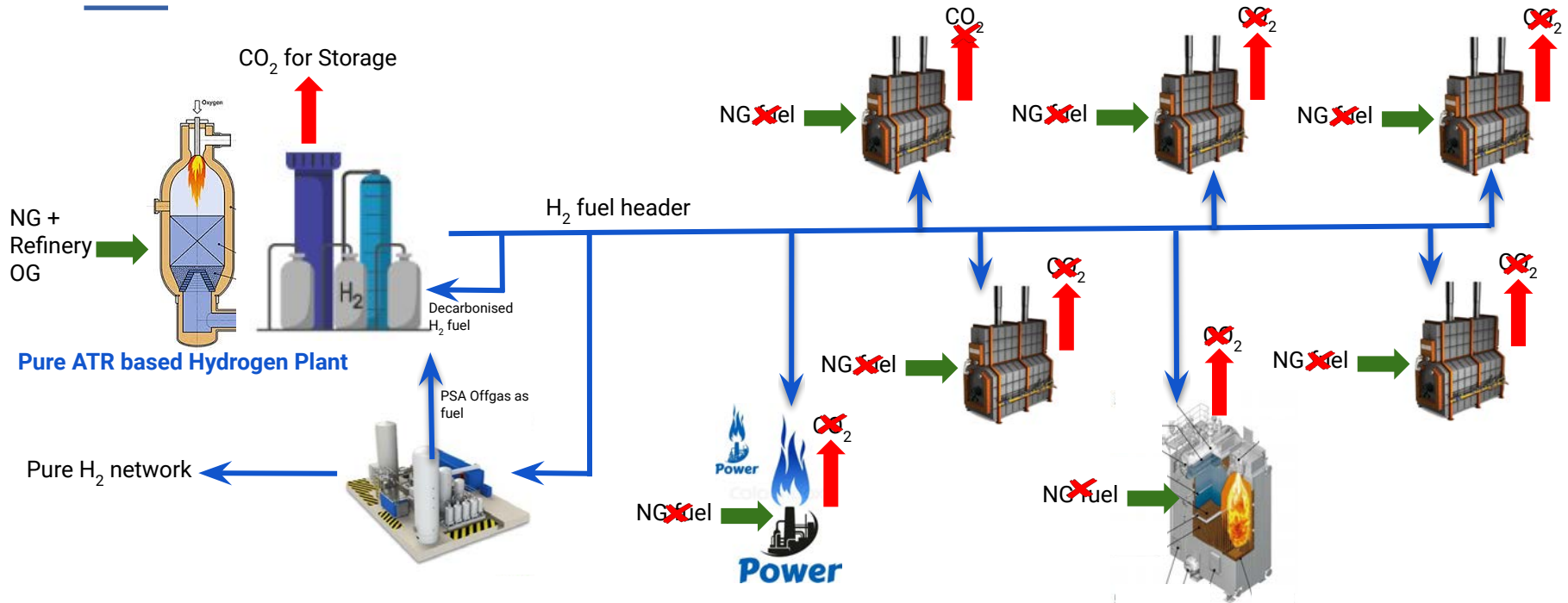
- Project duration: 14 months
- Project budget: 2.7 million euros
- 40 % funding by the Land
- Injection of 25,000 Nm<sup>3</sup> / h with a daily production of 4,600 t
- 11.7 kg (131 m<sup>3</sup>) hydrogen per tonne of pig iron
- Savings of up to 19 % CO<sub>2</sub> per tonne of pig iron

➔ Test phase for feeding hydrogen into the blast furnace 9



Source :  
ThyssenKrupp

# Example of ATR Based Hydrogen Production + CCS in Refinery





Thank you for  
your attention