

PORT CO. INNOVATION HAPPY HOURS

INTRODUCTION ON HYDROGEN
ASTRID BEHAGHEL



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What will we do today?

Introduction

1. The production of hydrogen
2. The value chain of hydrogen
3. The demand side: how to use hydrogen?
4. Government supports and policies
5. Industry announcements
6. What do we do at BNPP?

In a nutshell



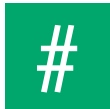
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INTRODUCTION



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What is hydrogen?

- Hydrogen = H₂

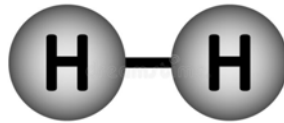
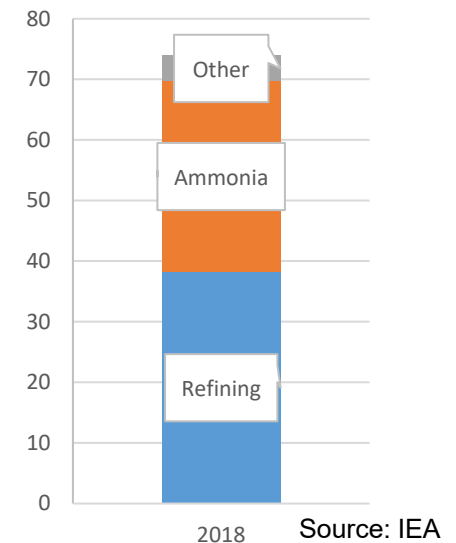


Tableau périodique des éléments chimiques

- Today's World production: around 70 Mt per year, mostly for oil refining and chemical production.
- To produce these amounts, that is 6% of global natural gas and 2% of global coal.
- the production of hydrogen is responsible for CO₂ emissions of around 830 million t of CO₂/y (eq to UK + Indonesia emissions)

Global demand for hydrogen in 2018 in Mt



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Why do we need hydrogen today?

In order to keep a global temperature rise this century well below 2 degrees Celsius (aim of the Paris' Agreement), carbon neutrality for the 2nd half of the 21st century.

-> EU, Japan, South Korea and China announced their ambition to reach net-zero.



More than 67 countries and 6 US states:

- 2035: Finland
- 2040: Austria
- 2045: Sweden, California
- 2050: EU, Germany, France, UK, Spain, Canada, Japan
- 2060: China



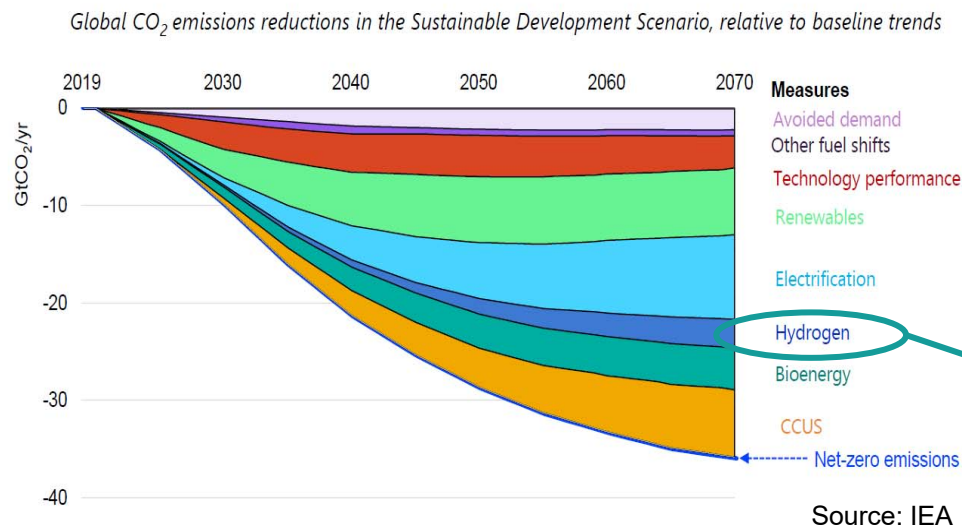
My administration declared that by 2050 Japan will aim to reduce greenhouse gas emissions to net-zero.

Climate change: China aims for 'carbon neutrality by 2060'

BBC, Sept 22th, 2020

Global heating could stabilize if net zero emissions achieved, scientists say

The Guardian, Jan 07th, 2021



Hydrogen is one of the tools that are necessary to reach net-zero



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1

THE PRODUCTION OF HYDROGEN



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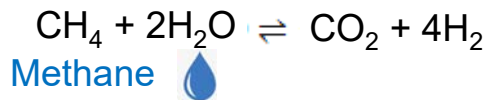
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How to produce hydrogen? Basic principles

Steam reforming (SMR) ~75%



Methane + steam +
nickel (catalyst)

Heated at
~1000°C

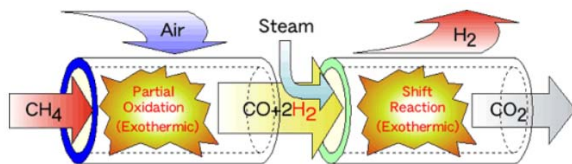
CO + H₂



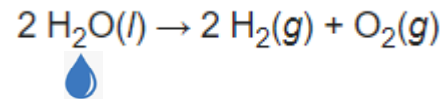
steam + iron oxide

H₂

CO₂



Electrolysis of water ~5%



Electricity

Electrolyseur

H₂

O₂



Coal gasification ~20%



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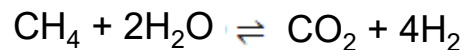
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How to produce hydrogen? Few metrics

Producing 1kg of hydrogen means:

Steam reforming (SMR)
~75%



Electrolysis of water ~5%



Inputs

20 l of water

9 l of purified water
50-60 kWh

CO2 outputs

~12 kg of CO2e/kg H2

Depends on the carbon mix of the electricity used.

Examples:

- Pure renewable: 1 kgCO2e/kgH2
- France mean mix: 3 kgCO2e/kgH2
- German mix: 22 kgCO2e/kgH2
- EU mix: 15 kgCO2e/kgH2

Few numbers to have an idea:

Today around 70 Mt per year of grey H2 is produced/consumed.

What if we convert this to electrolysis?

1 kg H2 = 50 kWh → 70 Mt = 3500 TWh.

Equivalent to the production of electricity of Europe / renewable electricity produced in the World

Any efficiency of electrolysis is welcome



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




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Few shades of hydrogen

From Wikipedia:

Colors that refer to method of production

Color		Production source	Notes	CO2e emission /kg H2
green		renewable electricity	via electrolysis of water	1kg
blue		fossil hydrocarbons with carbon capture and storage	CCS networks required	3-5kg
gray		fossil hydrocarbons	often via steam reforming of natural gas	12kg
brown or black		fossil coal		~20kg
turquoise		thermal splitting of methane	via methane pyrolysis	Still R&D
purple or pink or red		nuclear power	via electrolysis of water	3kg
white		—	refers to naturally occurring hydrogen	

According to the EU Taxonomy, to be considered “sustainable”, the hydrogen needs to be produced by:

- Green or low carbon electricity
- Natural gas with at least 50% of carbon capture



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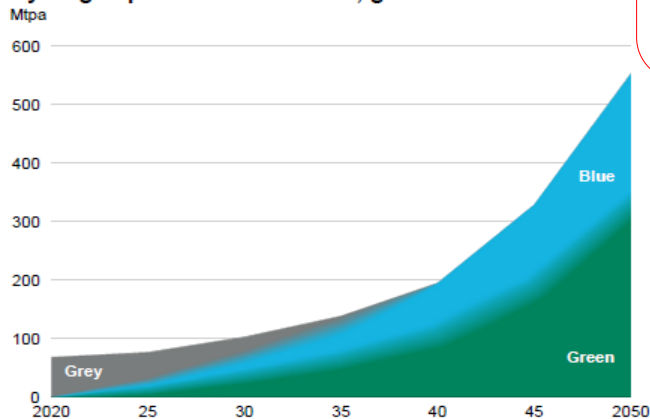
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The production of hydrogen: a cost issue

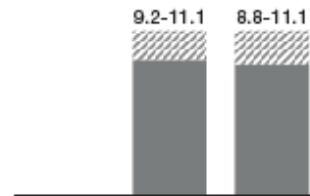
- Today producing green hydrogen is between 3,7 and 6 USD/kg, not competitive with grey/blue hydrogen.
- But:
 - Highly dependent on electricity cost
 - Grey is not suitable from a CO2 point of view
 - Blue is uncommon these days, lack of projects.

Hydrogen production scenario, global

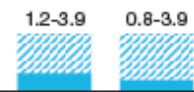


Grey
Natural gas reformed to H₂ and CO/CO₂ in a Steam Methane Reformer (SMR)

CO₂ emissions
kg/kg H₂
(lifecycle)
■ Max
■ Min



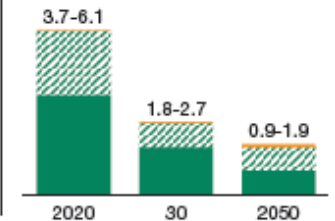
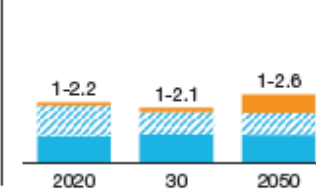
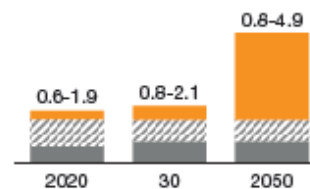
Blue
Natural gas reformed to H₂ and CO/CO₂ in an Autothermal Methane-Reformer (ATR); remaining CO₂ stream is sequestered (CCS)



Green
Water is split into H₂ and O₂ using renewable electricity in an electrolyzer (Alkaline, PEM or SOEC)



Production cost¹
USD/kg
■ CO₂ tax
■ Max
■ Min



¹ Costs for hydrogen produced in new installations; Assuming CO₂ tax of USD 28/ton in 2020, USD 48/ton in 2030, USD 300/ton in 2050, excluding vectorization/transport
Source: LBST; Hydrogen Council – Path to Cost Competitiveness; McKinsey

Source: “Hydrogen Decarbonization Pathways”, McKinsey for the Hydrogen Council, 2021

McKinsey for Hydrogen Council



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THE VALUE CHAIN OF HYDROGEN



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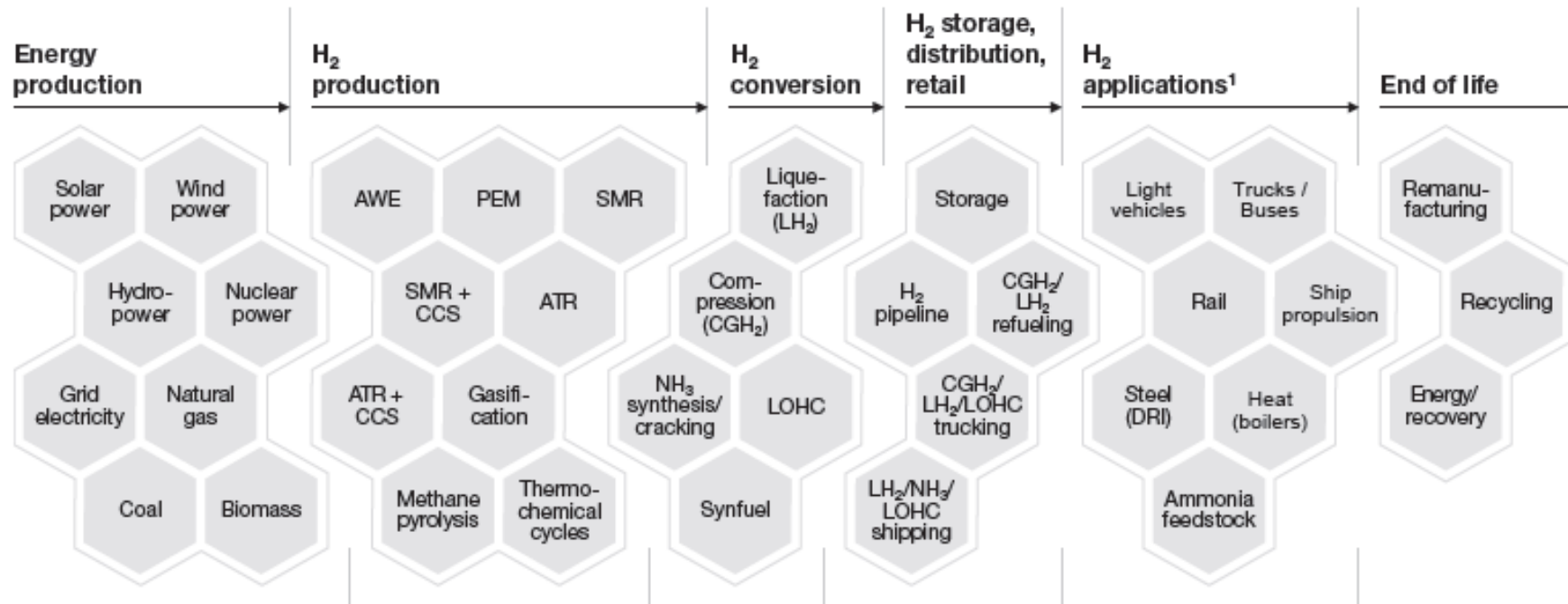
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The hydrogen value chain



Source: "Hydrogen Decarbonization Pathways", McKinsey for the Hydrogen Council, 2021

On each part of the value chain, multiple ways to produce/convey/use hydrogen.



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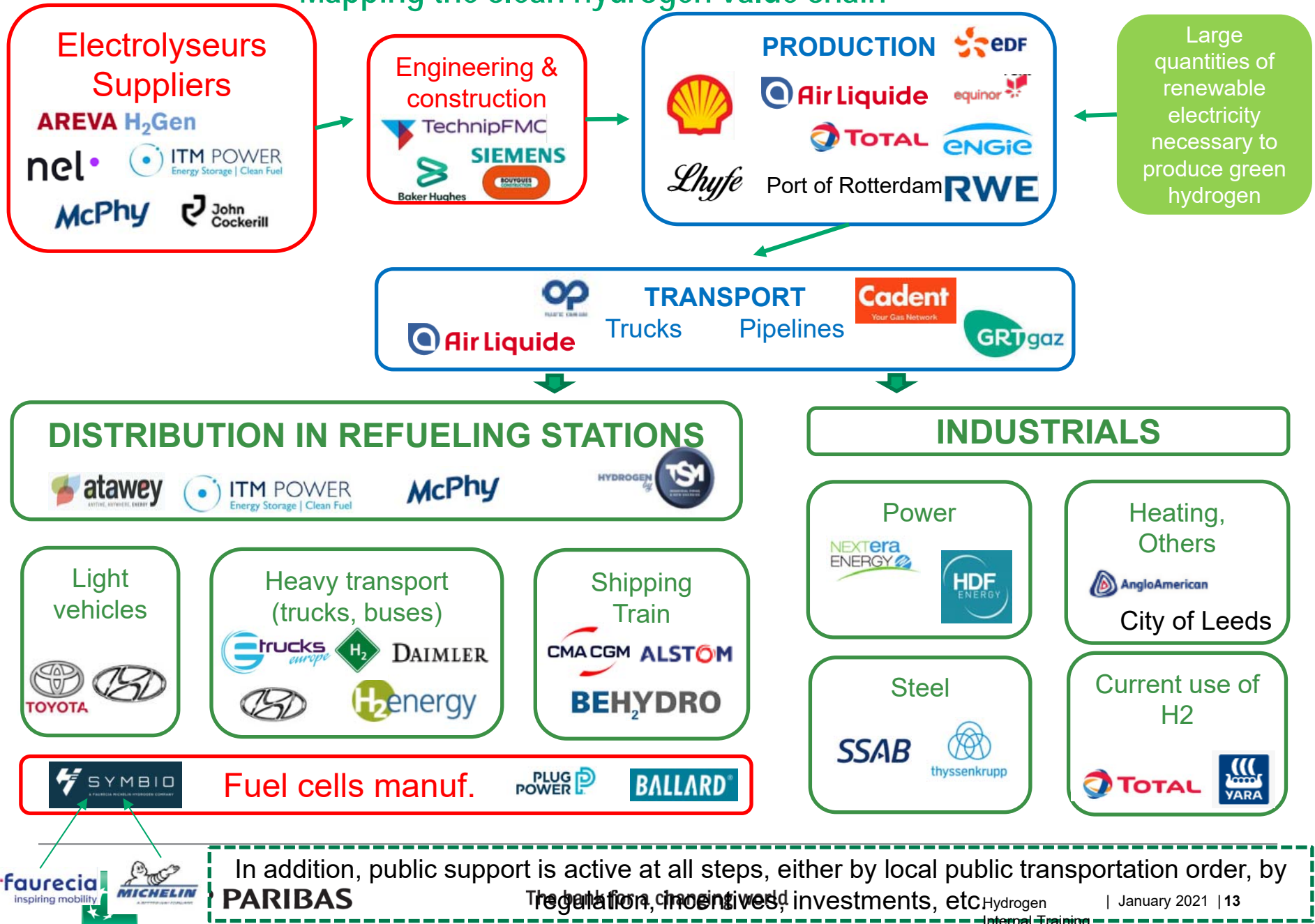
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Mapping the clean hydrogen value chain



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THE DEMAND SIDE: HOW TO USE HYDROGEN?



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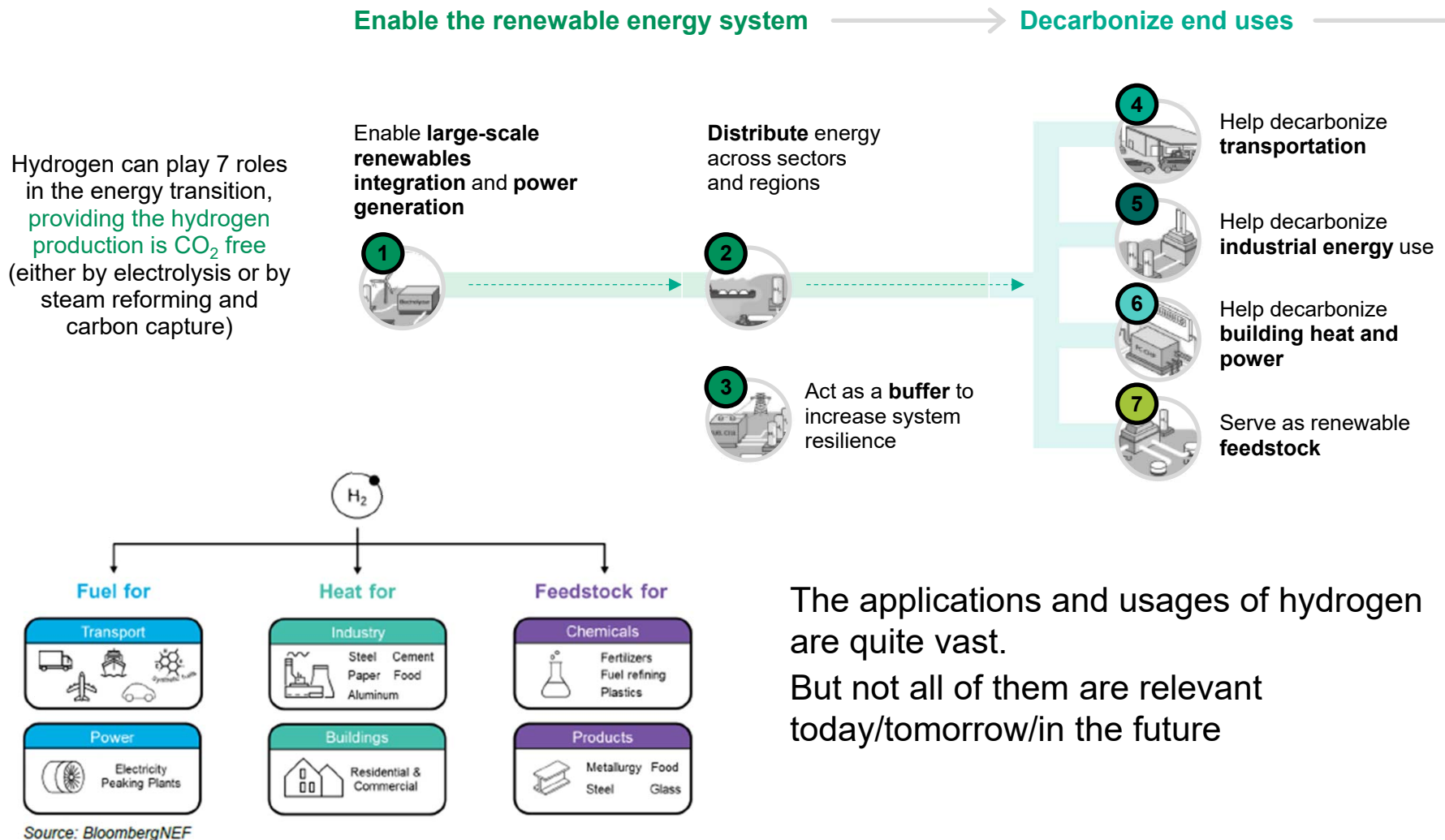
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What can we use hydrogen for?



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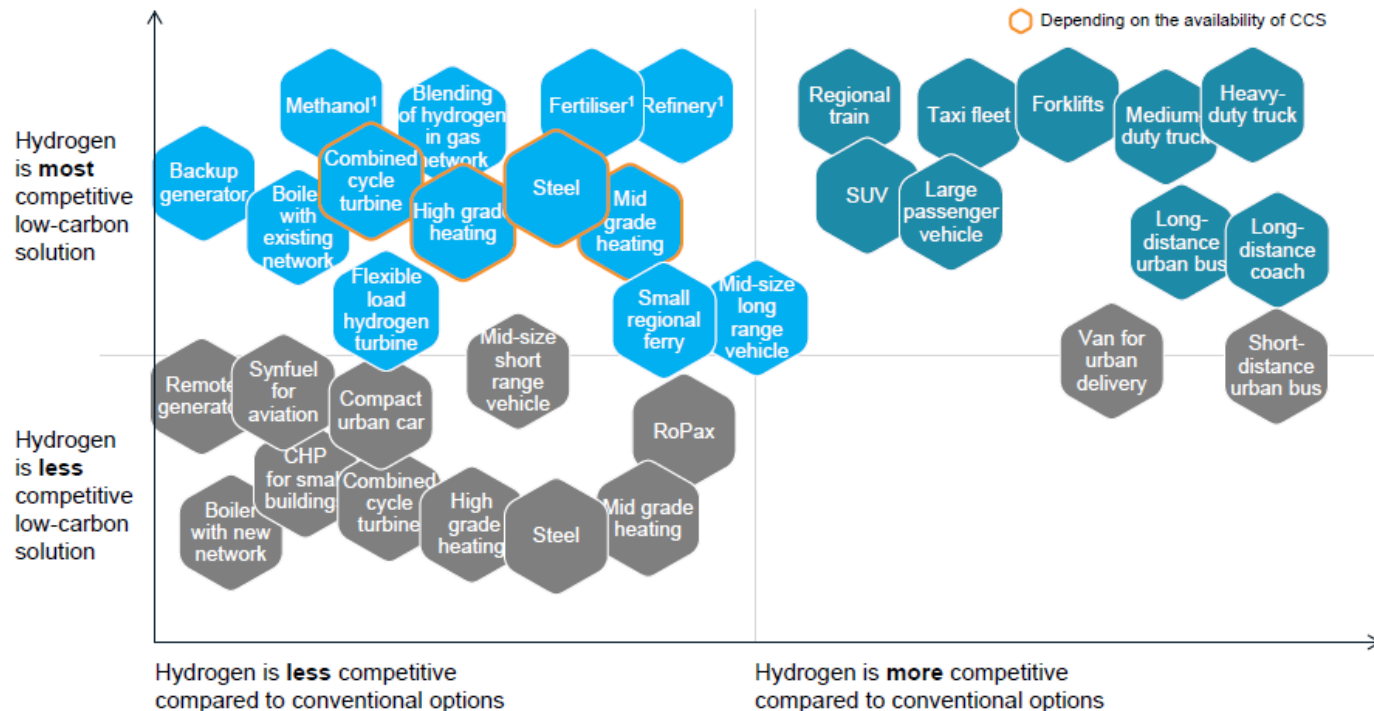
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Which ones are relevant?



1. Hydrogen is the only alternative and low-carbon/renewable hydrogen competing with grey (optimal renewable or low-carbon shown)

Source: McKinsey for the Hydrogen Council

Applications where low carbon hydrogen is the only viable decarbonisation solution as of now or where it has a proven advantage over all competing solutions for decarbonisation

Applications where the possibility of hydrogen proving to be a better solution for decarbonisation is relatively high but only in the future



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Applications where low carbon hydrogen is the only viable decarbonisation solution as of now

- Industries currently using hydrogen in their process (e.g. fertilizer production, oil and gas refineries, chemical production...)
- Feedstock used in iron and primary steel making industry (pilot projects on-going to produce “Green Steel”).
- Fuel use in shipping
- Inter-season storage of renewable energy in the form of hydrogen, which can then be re-injected into the electric grid via fuel cell in islanded power generation systems. This allows a longer storage than electric batteries.



Applications where the possibility of hydrogen proving to be a better solution for decarbonisation is relatively high

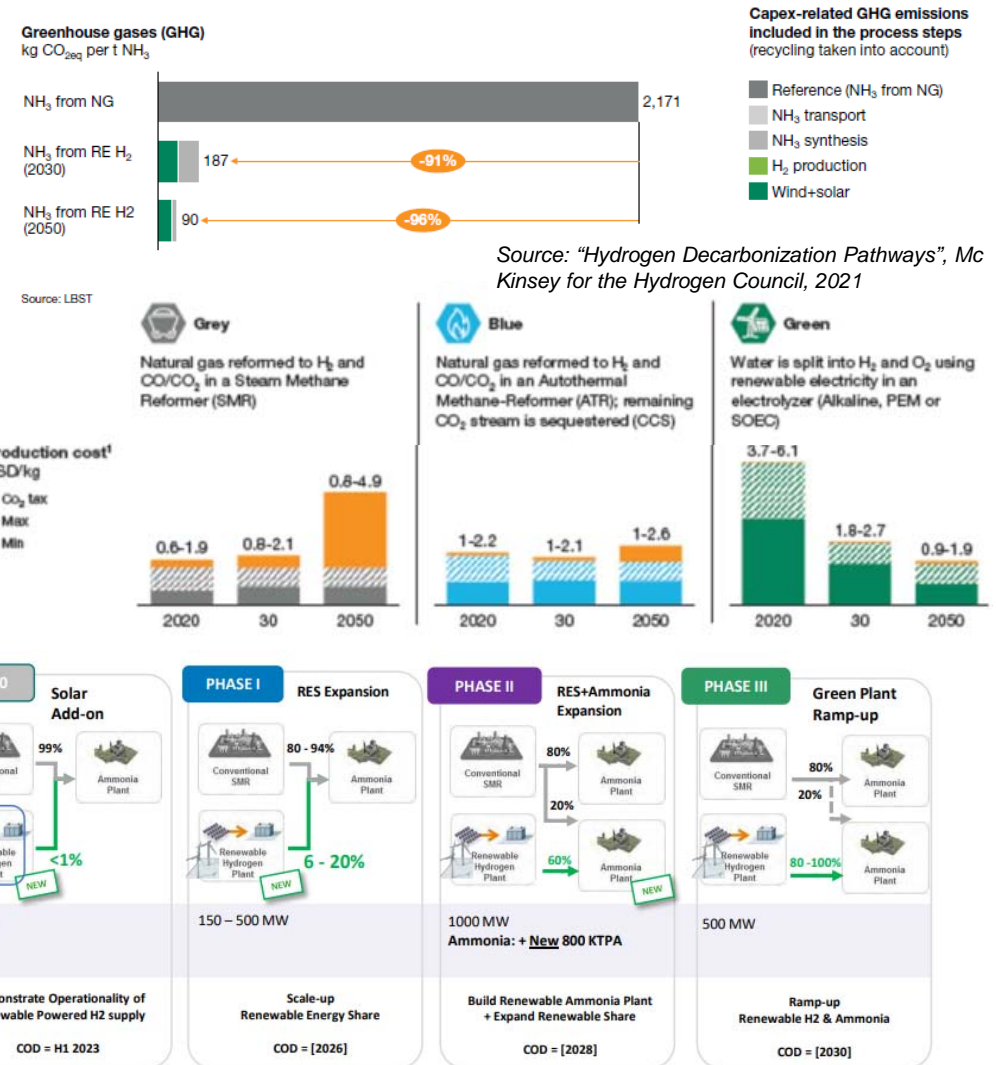
- Fuel use for long-distance and heavy road transportation (main competitor: biofuels), rail transportation (main competitor: direct electrification with batteries and electric road systems).
- Domestic heating: for heat production, replacing methane by hydrogen can reduce the overall CO₂ emissions of residential buildings (main competitor: electrification and efficiency improvements).
- Fuel use in airport facilities and aviation (main competitor: biofuels)
- Electricity storage in interconnected networks (after 2035).



Industries currently using hydrogen

- The two main industries already using (grey) hydrogen are fertilizers and refining.
- Two reasons why sustainable hydrogen is very relevant for these industries:
 - Solve the chicken&egg issue of hydrogen
 - Low carbon hydrogen is the only way for them to decarbonize themselves.
- The main issue is the cost of low carbon hydrogen
- Despite the cost, several projects, to cover at least a portion of the hydrogen, are on going:
 - Engie-Yara: Yara is a fertilizer company, in Australia. A joint-project to produce on-site renewable (PV) with electrolyseurs, to produce green H₂, then converted in green NH₃.
 - Engie-Total: 100MW of PV + 40 MW electrolyseurs to produce 5t of green hydrogen per day for the biorefinery of La Mède in France.
 - Fertiberia + Iberdrola also on green hydrogen for fertilizer in Spain
 - Etc.

Exhibit 9: Ammonia fertilizer from green hydrogen



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Steel making: a major CO2 issue, H2 might be the solution

- The steel industry is responsible for 8% of total fossil fuel CO2 emissions.
- So how to produce low-carbon steel?
- Already some commitments from steelmakers:
 - ArcelorMittal: -30% of CO2 by 2030
 - ThyssenKrupp (the largest steelmaker in Germany): -30% by 2030, 400,000 mt of green steel by 2025, 3 million mt of green steel in for 2030.
- How to make steel today?

Blast Furnace - Basic Oxygen
Furnace (BF-BOF)

70% of today's production,
>2t CO2/ t of steel

Electric Arc Furnace (EAF)
From scrap

30% of today's production,
0,5-0,6t CO2/ t of steel

- How to make low carbon steel?

BF-BOF with H2 injected to
replace coke

-20/30% of CO2 emissions

BF-BOF with carbon capture

Requires access to specific
infrastructure

Renewable EAF + Direct Iron
Reduction using hydrogen

Allows for full decarbonization but early
stage

- Pilot projects:
 - ThyssenKrupp: H2 DRI and green power for 2025, 1,2 million tons/y
 - ArcelorMittal: small DRI facility, run on H2
 - Celsa Armeringsstal (Norway): introduce H2 in the process, in collaboration with Statkraft
 - China Baowu (2nd world): R&D in partnership with BHP.



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Shipping:

- International shipping accounted for around 2%-3% of global energy-related CO₂ emissions in 2019.
- In April 2018, the IMO adopted a strategy to reduce GHG emissions from international shipping to align the sector with Paris Agreement climate goals. The strategy proposes to cut absolute GHG emissions by at least 50% by 2050, and thereafter to attempt to eliminate them altogether.
- What are the options to reach this?
 - Reduce speed -> up to -30% of reduction
 - Switch to LNG -> only 10-25% of reduction (without any leaks)
 - Switch to low carbon fuel (renewable methane, synthetic fuels)
 - Innovation like hydrogen, wind and kites?

- ➔ Hydrogen is one of the two solutions to reach zero net.
- ➔ On our client side, they are all interested but still R&D level.

Exhibit 6: Ships fueled with Norwegian blue hydrogen



Source: "Hydrogen Decarbonization Pathways", McKinsey for the Hydrogen Council, 2021

The CMA CGM Group, a world leader in shipping and logistics and a pioneer in the field of energy transition, is joining forces with Energy Observer, the first hydrogen-powered vessel to embark on a round-the-world voyage.



Maersk Parent Invests EUR 20m in Green Hydrogen Project

by Ship & Bunker News Team
Friday, December 25, 2020

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"MSC is working to accelerate the development of clean hydrogen for shipping. Strong partnerships and investment in technology, R&D and procurement, are needed to bring alternative fuels and technologies to the marketplace to decarbonise industries. The Hydrogen Council helps facilitate R&D and cross-industry collaboration."

Bud Darr

Executive Vice President, Maritime Policy & Government Affairs, MSC Group



Denmark and Norway team up to build world's largest hydrogen ferry

7 December 2020

NYK Becomes Member of the Hydrogen Council



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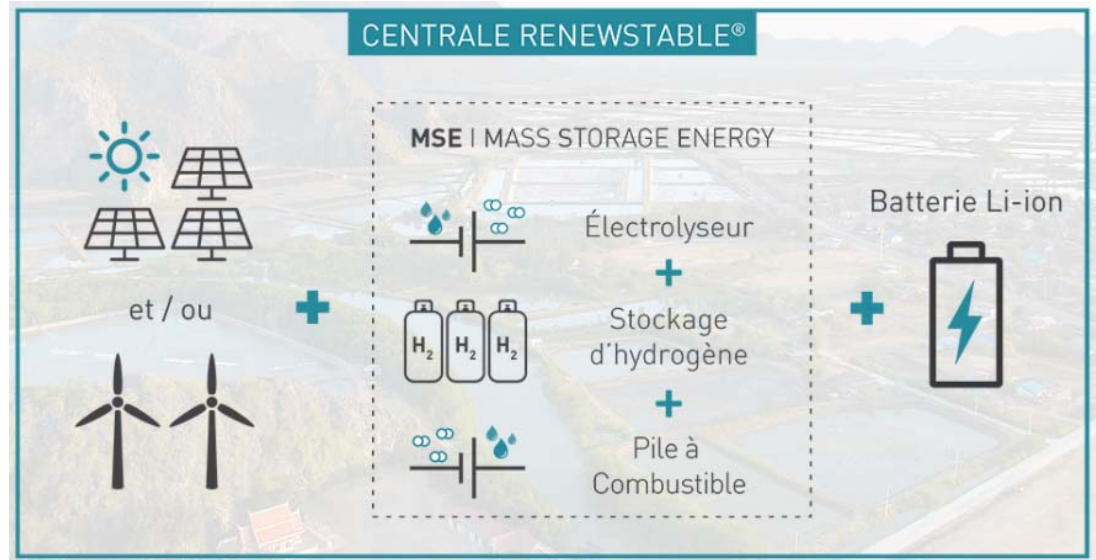
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Storage of electricity/ islanded power generation

- For non-connected network or “islanded” systems, the current generation is made from diesel generator, or small coal.
 - The system is extremely expensive (>200-300€/MWh)
 - Renewable is gaining shares, because of its price.
 - But blending in the network is difficult, because of the size.
 - Batteries (Li-on) is a good solution but for few hours.
- Hydrogen can store renewable electricity and produce when needed.
- On principle can be done everywhere, but for cost reason, only relevant for islands.



From website of Hydrogen de France (HDF)



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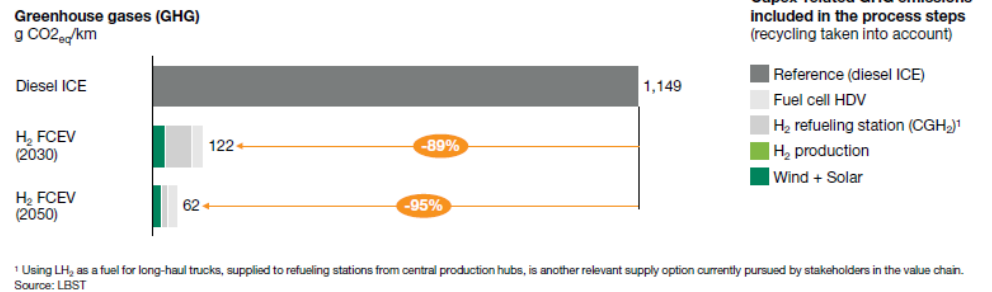
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Heavy road transportation

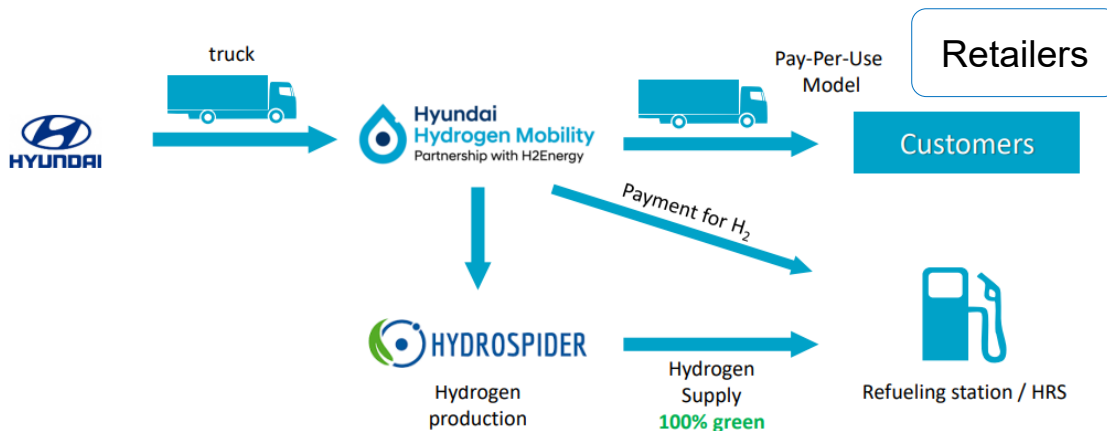
- With road transport representing 18% of global GHG emissions, its decarbonization is key.
- For light vehicle, electrical vehicle has mostly won the game.
- But for long distance, or intensive usage, like heavy-duty trucks or buses, hydrogen is seen as the good solution.
- This is widely accepted within our clients, and many projects are built up on this.
- Either for local ecosystems (buses for cities)
- Either larger infrastructure for heavy trucks recharging.

Exhibit 11: Heavy-duty trucks fueled with green hydrogen



Source: "Hydrogen Decarbonization Pathways", McKinsey for the Hydrogen Council, 2021

A concrete example: The swiss project



Why in Switzerland?

- Road tax for heavy duty transportation was established already two decades ago
- Depending on km per year and vehicle weight
- Emission free vehicles are exempted from this regulation
- So Switzerland has already a CO₂ tax benefit for ZEV
- Adds up to about 65'000 CHF per year



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GOVERNMENT SUPPORTS AND POLICIES



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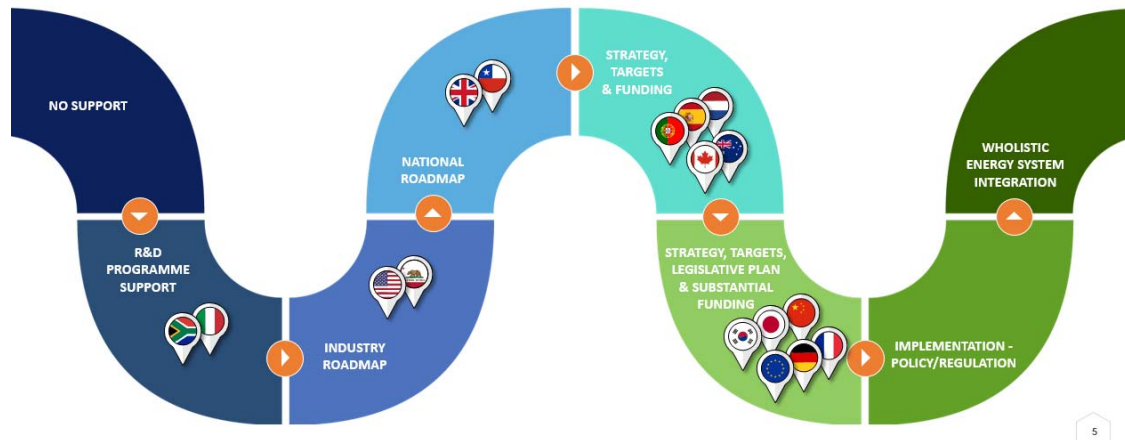
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The development of government support along 2020



In 2020, several countries have announced hydrogen strategies, including large envelopes for possible subsidies.

These strategies integrate the diversity of the hydrogen question: from production to users.



Ursula von der Leyen at the CEO meeting of the Hydrogen Council on January 19th 2021, expressing the commitment of the UE over the long term to support the development of hydrogen



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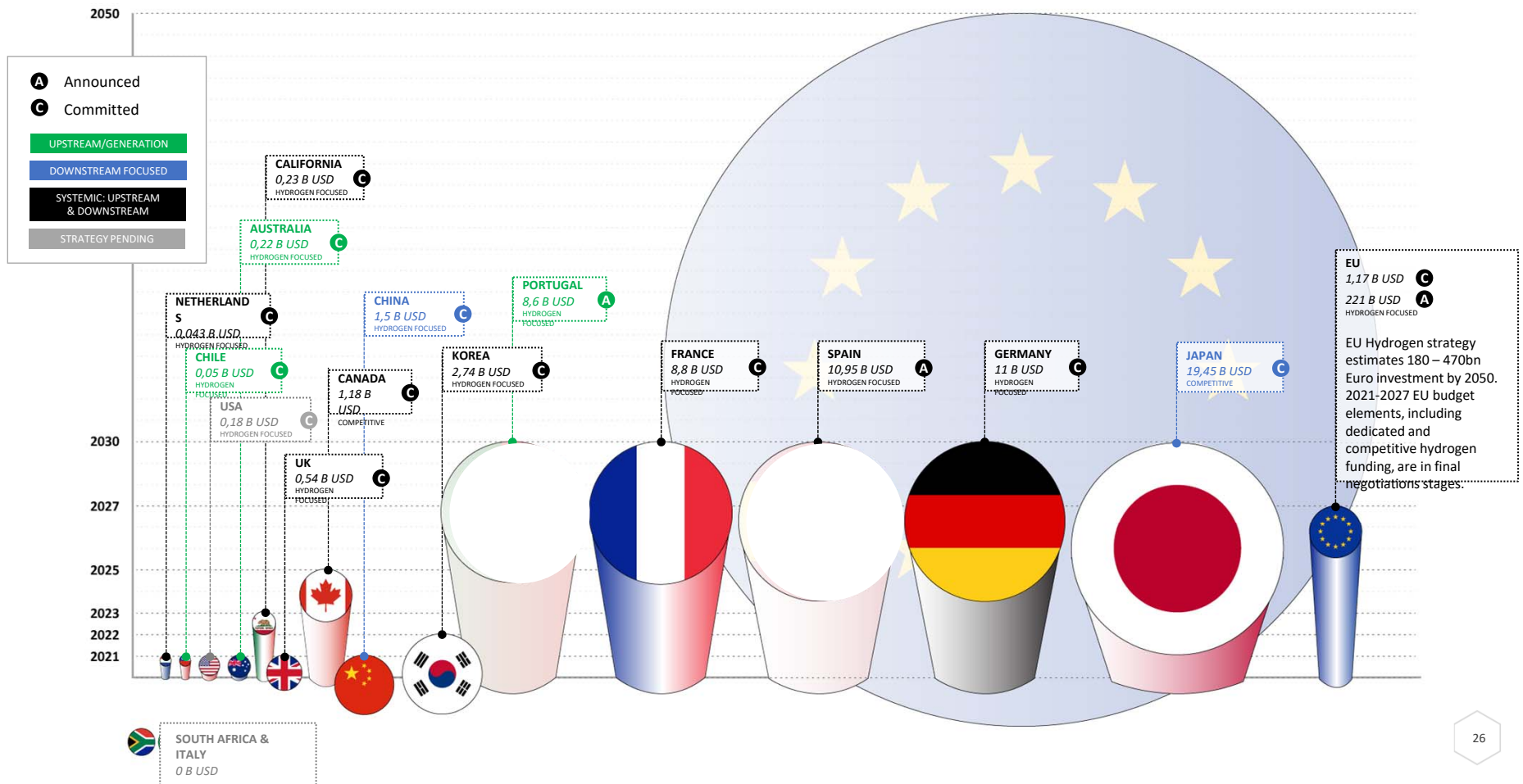
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Government strategies



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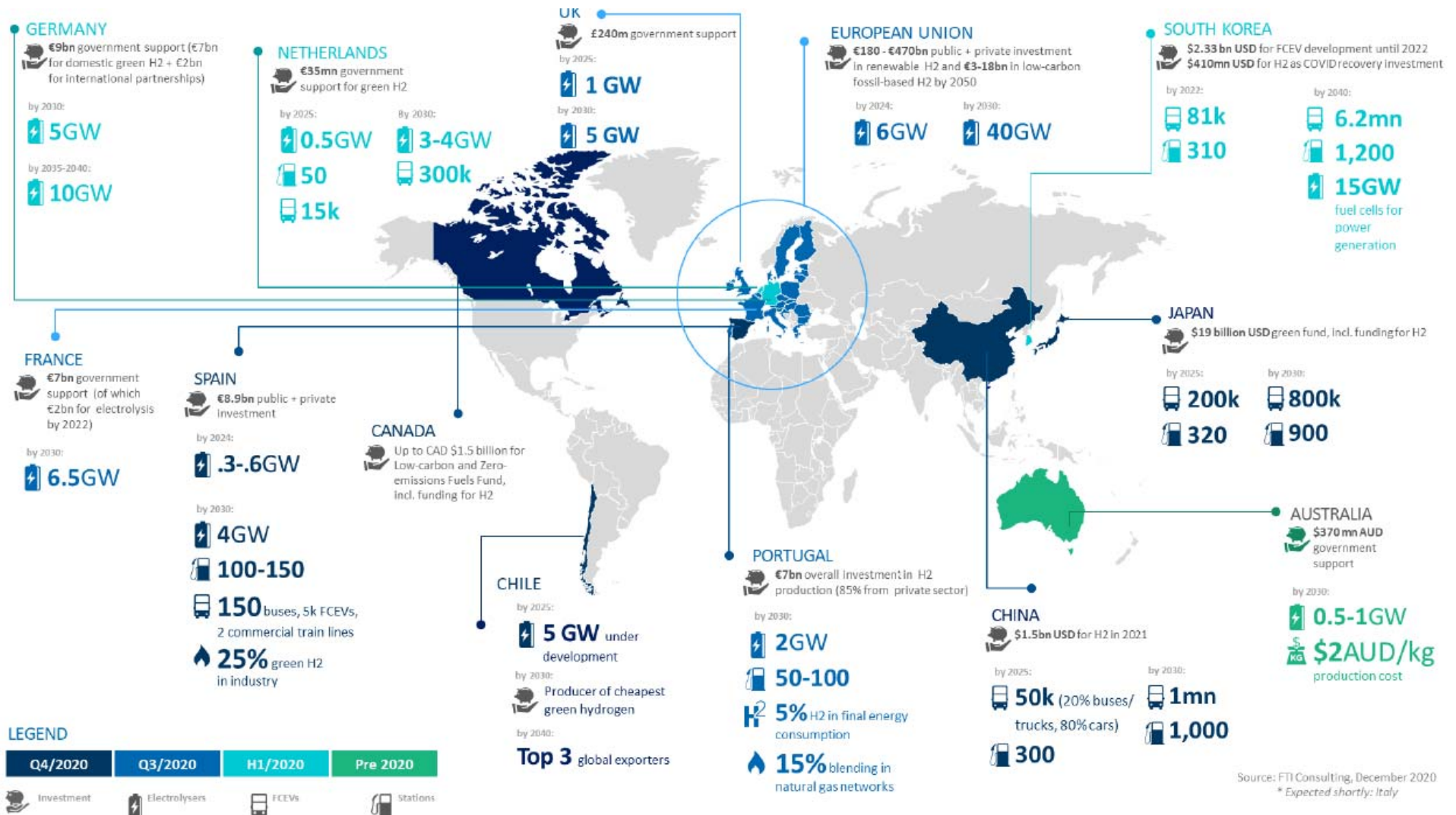
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>30 countries have announced a hydrogen strategy



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INDUSTRY ANNOUNCEMENTS



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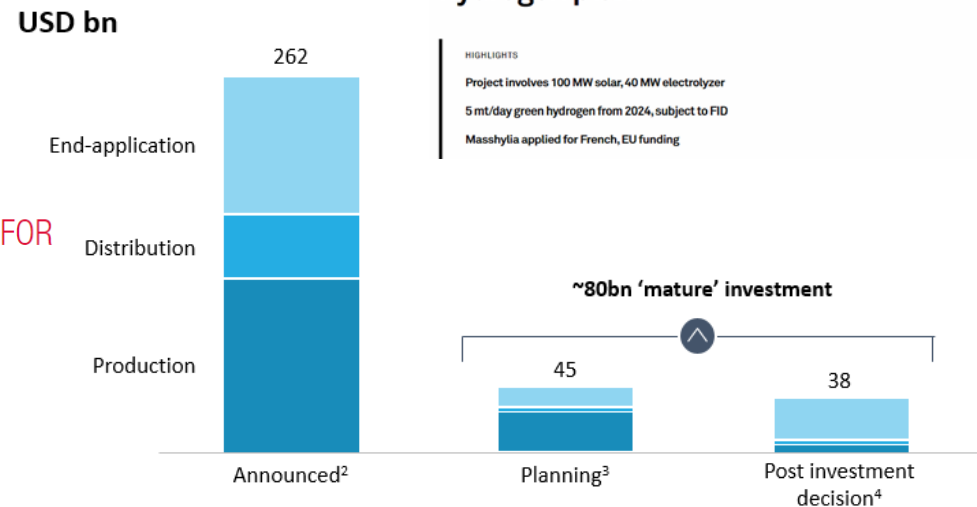
Our clients are announcing large number of projects

- In the past couple of years, a large number of companies announced their ambition in hydrogen.
- Around 80bnUSD of announced investment are considered mature.
- In 2020, dozen of meetings have been held with our clients, either on their hydrogen strategies, either on concrete projects/financing needs.
- Almost everyday, a new partnership is announced:

"People talk about climate change, people talk about energy efficiency and clean energy sources; hydrogen is potentially at the forefront of this conversation."

Mark Cutifani, Chief Executive, Anglo American

Engie, Total plan France's largest green hydrogen plant



1. Final Investment Decision
2. Includes projects at preliminary studies or at press announced stage. It also includes required investment to reach national targets and governments funding
3. Includes projects that are at the feasibility study or front-end engineering and design stage
4. Includes projects where a final investment decision (FID) has been taken, under construction, commissioned-and operational

TOTAL AND ENGIE PARTNER TO DEVELOP FRANCE'S LARGEST SITE FOR THE PRODUCTION OF GREEN HYDROGEN FROM 100% RENEWABLE ELECTRICITY

Shell, Mitsubishi Heavy Industries, Vattenfall and Wärme Hamburg sign Letter of Intent for 100MW Hydrogen Project in Hamburg
2021-01-22



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The Hydrogen Council

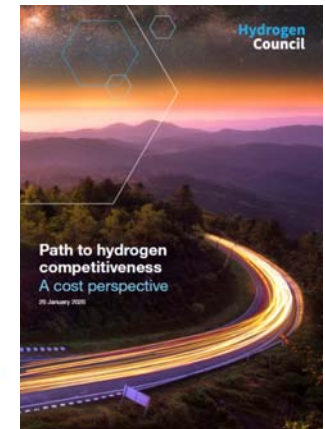
Hydrogen Council

BNP Paribas joined the Hydrogen Council as one of the first in the « investor group »

The Hydrogen Council is CEO-led organisation launched in Davos in January 2017.

The Hydrogen Council's mission is to **increase the visibility of existing hydrogen solutions** and the progress being made in the sector.

As of today, 109 companies joined the Hydrogen Council, including large multinationals, innovative SMEs and investors



Jean-Laurent Bonnafé

“The membership of BNP Paribas in the Hydrogen Council is a natural path for the Group to accompany our clients in the development and the financing of hydrogen, which we believe will be a key element of the energy transition of the next decade.”



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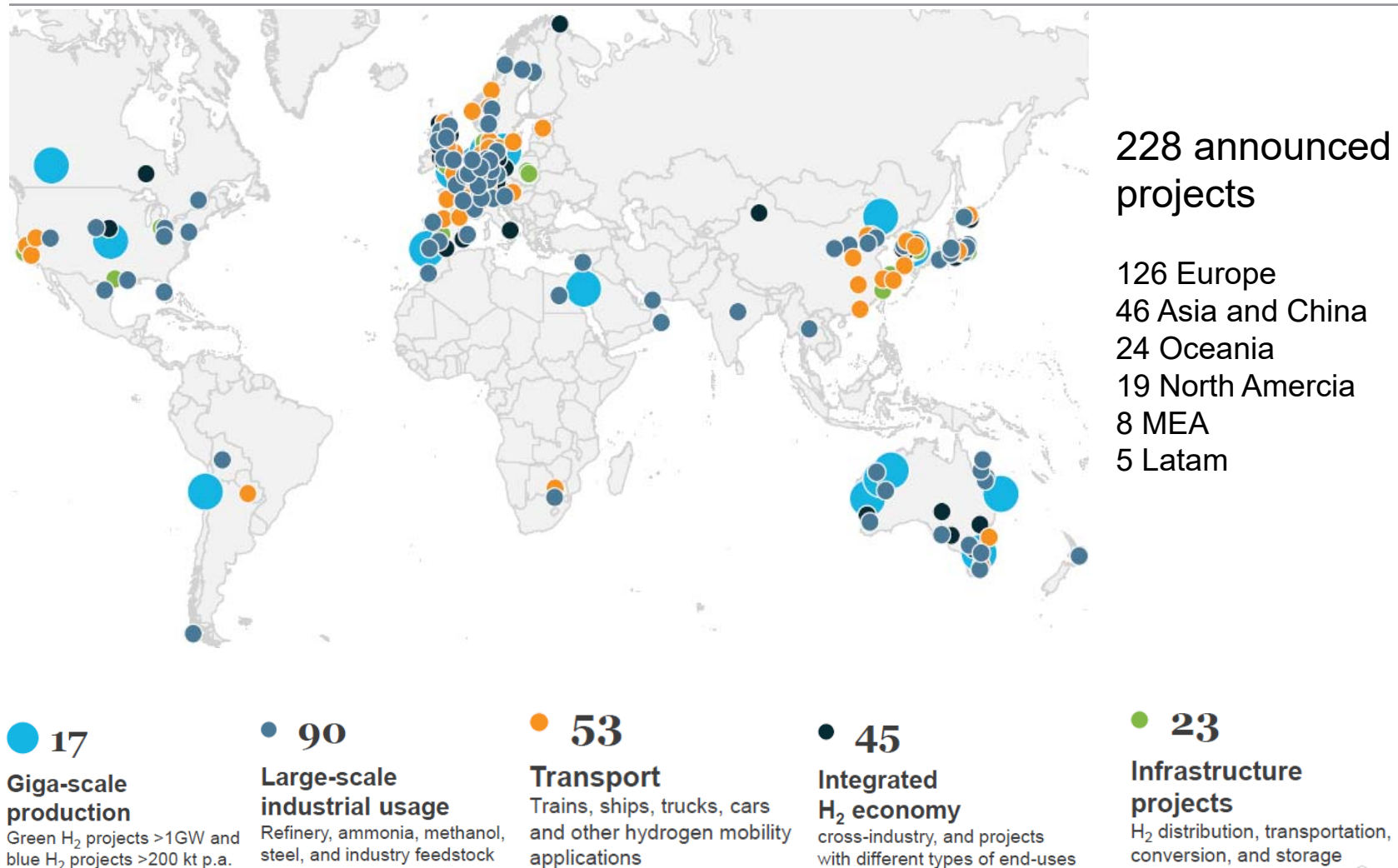
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Around the World projects announced at a rapid pace



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WHAT DO WE DO AT BNPP?



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BNP Paribas and the Energy Transition: Partnering with our clients in the transition to a low-carbon economy

Aligning our credit portfolio with the goal of the Paris Agreement

- Sector policies (coal, unconventional O&G)
- Increasing investment in renewable energy
- Developing ad hoc financing tools for specific customers (energy efficiency loans...)
- Partnering with start-ups to accelerate the development of low-carbon technologies

Developing innovative low-carbon offers in all our business lines, for all our clients

- Bonds and loans linked to sustainability-related targets (green bonds, sustainability linked loans...)
- Real Estate: certified and low-carbon buildings
- Arval: electric and hybrid vehicles, car-sharing schemes...
- Leasing Solutions: Electric charging stations, LEDs...

Influencing investors: Bringing money where it has an impact

- Developing cutting edge financing solutions to facilitate the transition to new business models for corporates (green bonds...)
- Managing assets in a sustainable way (low-carbon indices)
- Promoting carbon compensation (ClimateSeed)
- Sustainable financing facility in emerging countries (TLFF...)

Influencing our clients and the companies in which we invest: Beyond black and white, many shades of gray

- Using our voting rights (e.g. Exxon, Repsol)
- Specific support to entrepreneurs (Fortis' Sustainable Energy Services)
- Developing innovating incentivising tools



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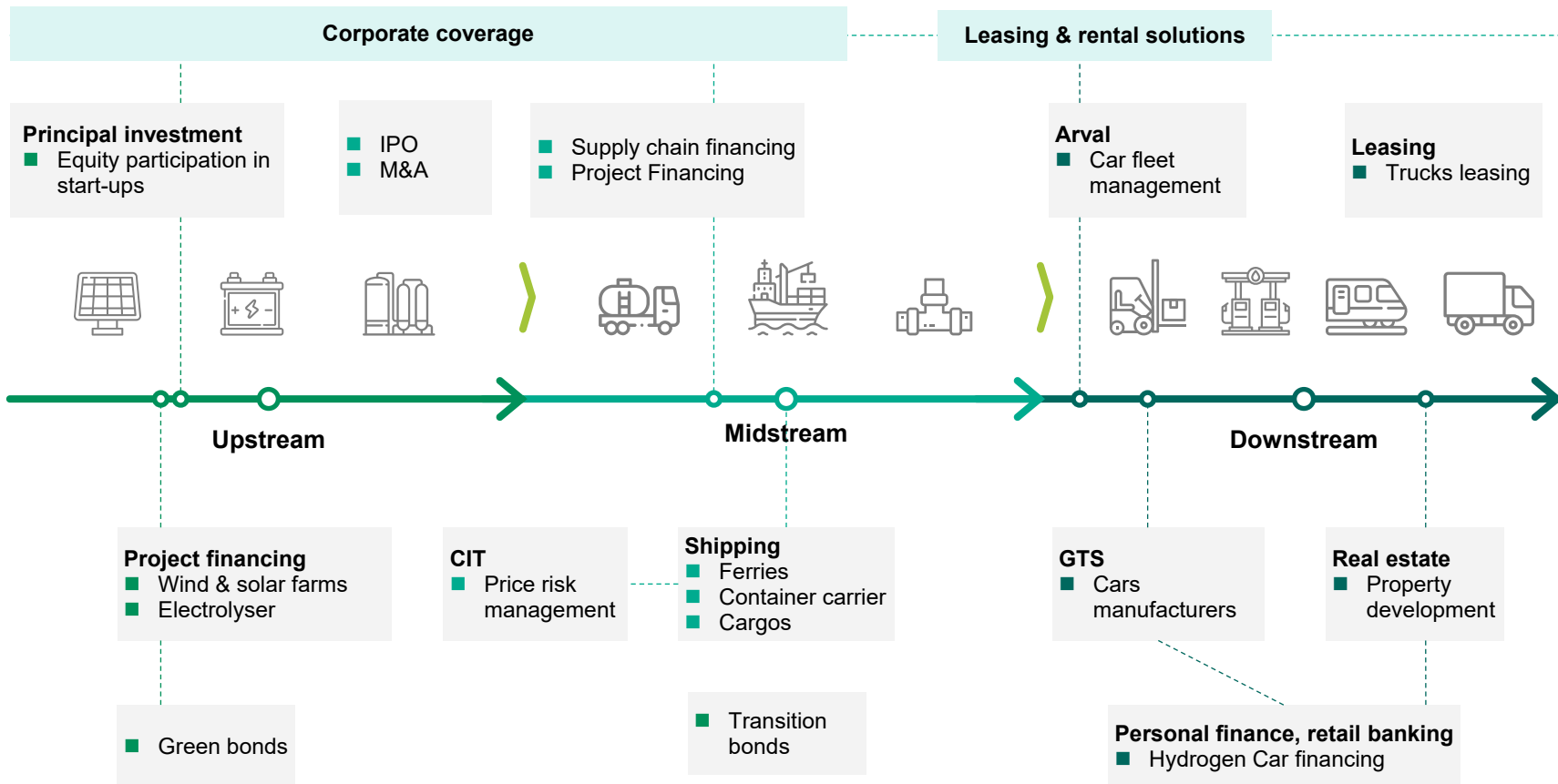
Energy transition

09/12/2020 | 33

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BNP Paribas can support H₂ value chain globally

As a universal bank, BNP Paribas will help accelerate the H₂ market development by financing H₂ actors, whatever their position in the value chain



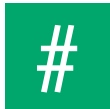
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IN A NUTSHELL



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In a nutshell

- Low carbon hydrogen is key to decarbonize the overall economy, and for some sectors (almost) the only way. The most promising sectors are:
 - Heavy mobility (trucks, trains, shipping),
 - Industry: decarbonizing current users of grey hydrogen, steel making
- There are different ways to produce hydrogen, the key aspect is the production of CO2.
 - Hydrogen produced with renewable electricity is the best solution
 - But low carbon hydrogen can also be achieved with nuclear electricity or via carbon capture and sequestration.
- There are high ambitions of both governments and companies to scale up hydrogen projects, with an acceleration of announcements in 2020.
 - Projects are often thought via ecosystems, from production to end-user, including transportation and storage.
 - Great variety of actors (utilities, supply chain, automotive industry, steel, ports, shipping, etc.)
- At BNP Paribas, we aim at building on an expertise to better accompany our clients in this wide development.

