eGHOST

eco-design
Guidelines for Hydrogen
Systems and Technologies

eGHOST Spring School (20-24 May 2024)

Hydrogen Use Technologies

Jade Garcia (SYMBIO France)

Co-funded by the European Union

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007166.
This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

Short introduction

eGHOST

- Jade GARCIA – jade.garcia@symbio.one
- LCA project manager at Symbio since 1,5 years
- 15 years of experience in Life Cycle Assessment and Ecodesign
- Part of the Eghost and SH2E projects

SYMBIO
A FRONT-RUNNER HYDROGEN COMPANY

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HYDROGEN USE TECHNOLOGIES

TABLE OF CONTENT

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1. INTRODUCTION

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The specificities of Hydrogen

- Hydrogen is the simplest and most abundant element known
- It is an energy carrier, not an energy source and can deliver or store energy
- Hydrogen is energy-dense – with 120 MJ per kilogram, compared to natural gas (55 MJ/kg), coal (24 MJ/kg), and oil (44 MJ/kg)
- Hydrogen doesn’t produce any emissions when burned

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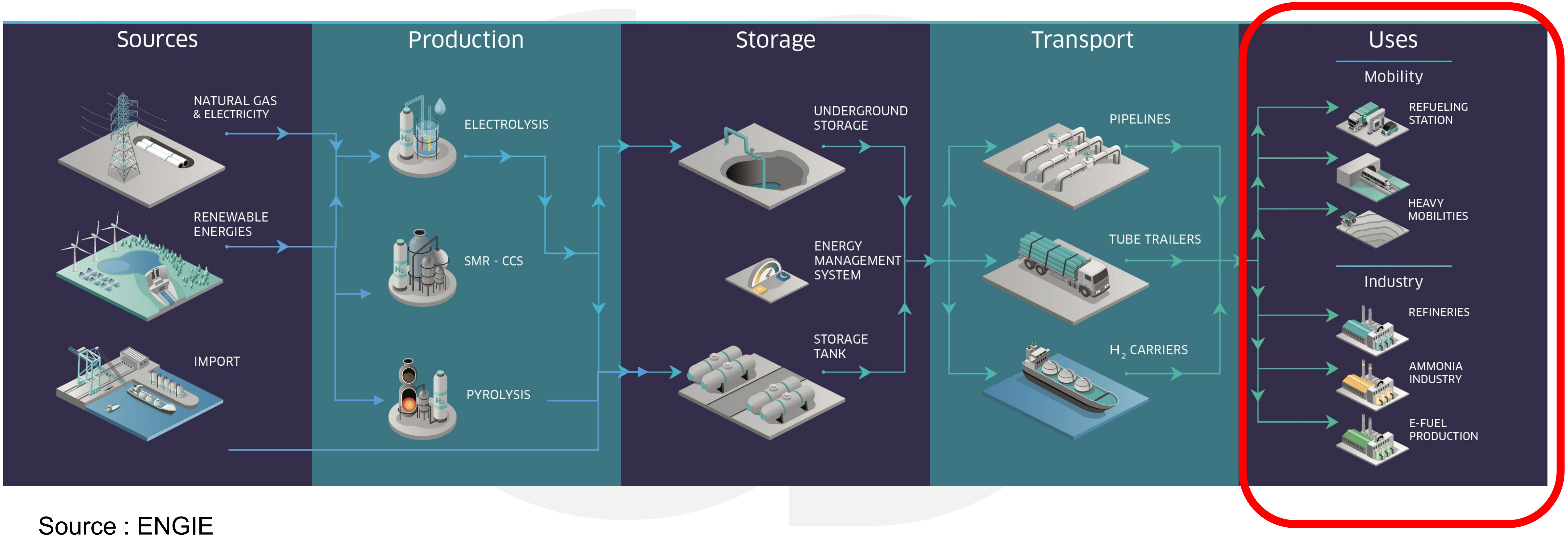
The hydrogen supply chain



Source : ENGIE

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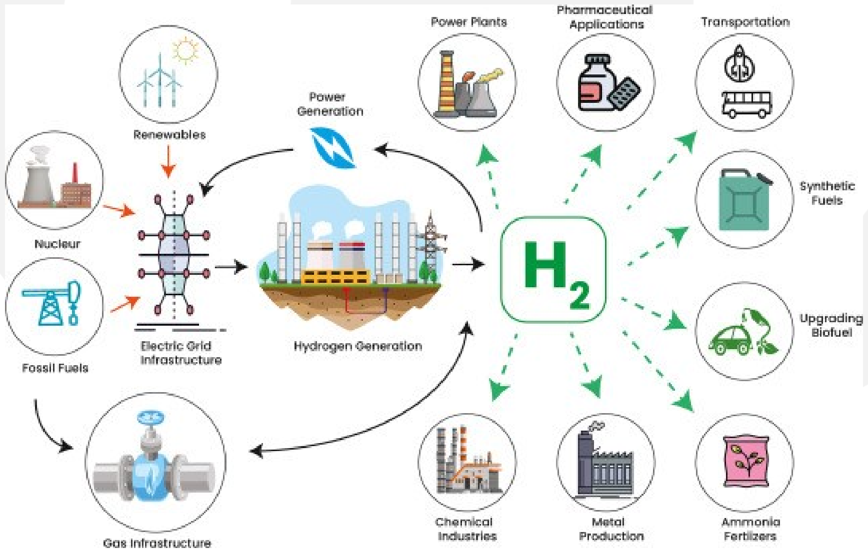
2. MAIN USES OF HYDROGEN



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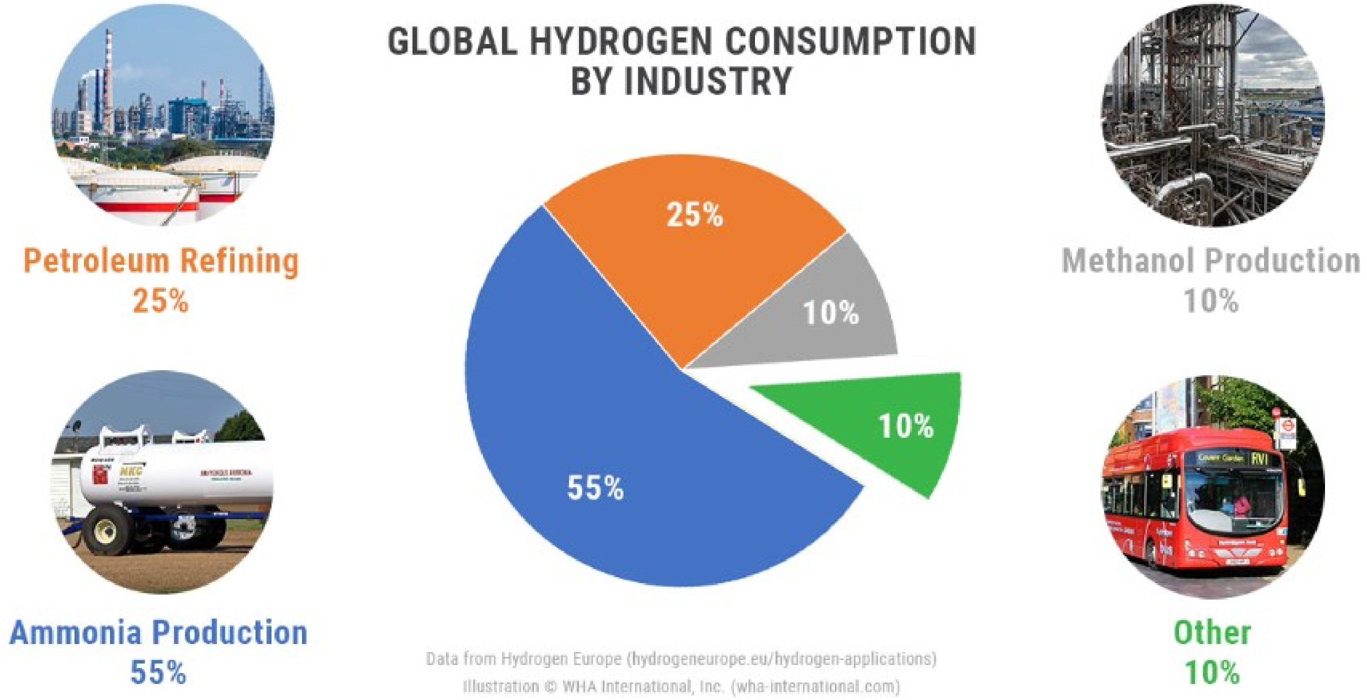
The main uses of Hydrogen today



Source: WHA International

2022 data for Europe

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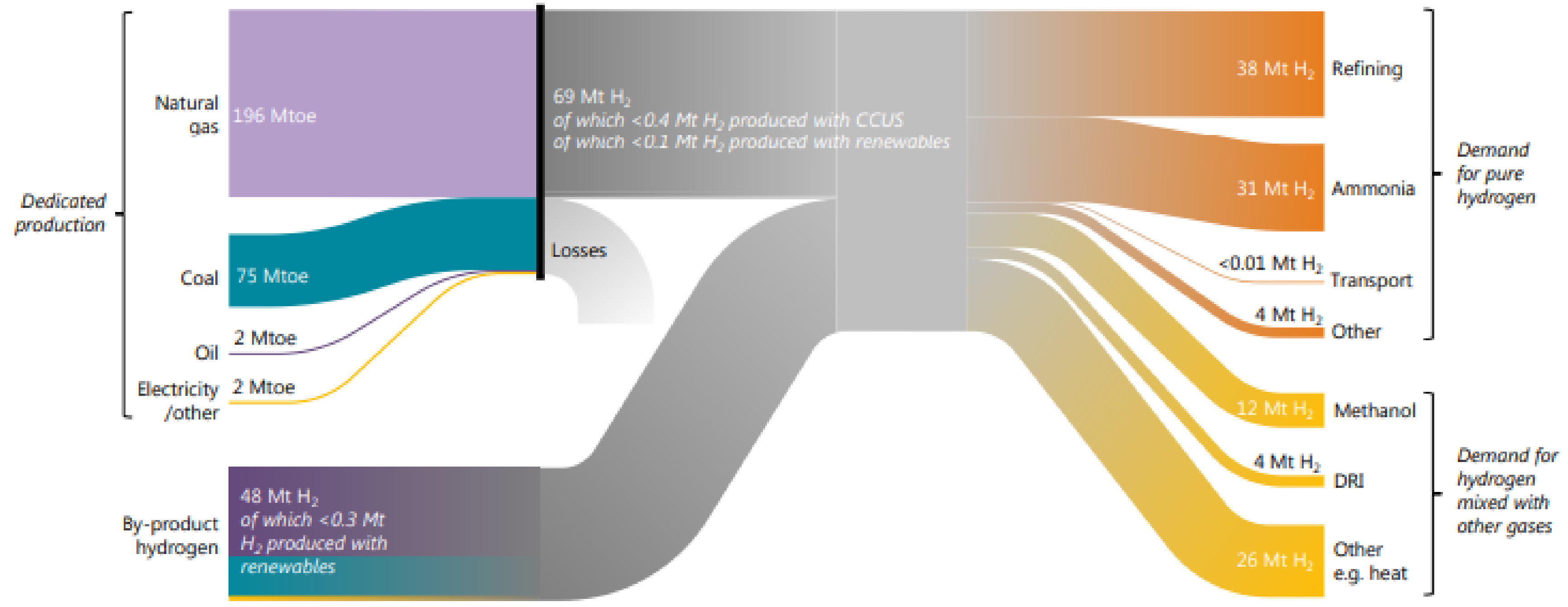
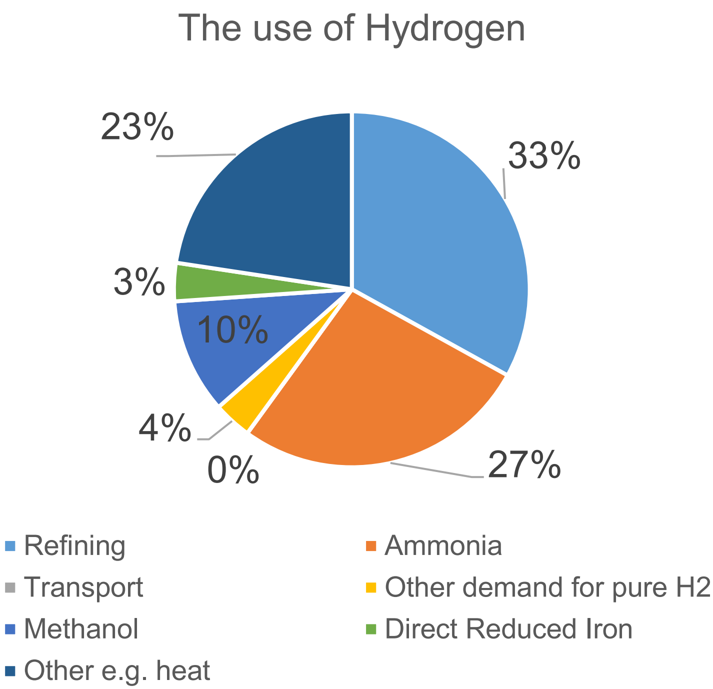
The main uses of Hydrogen today

Figure 6. Today's hydrogen value chains





Today's hydrogen industry is large, with many sources and uses. Most hydrogen is produced from gas in dedicated facilities, and the current share from renewables is small.

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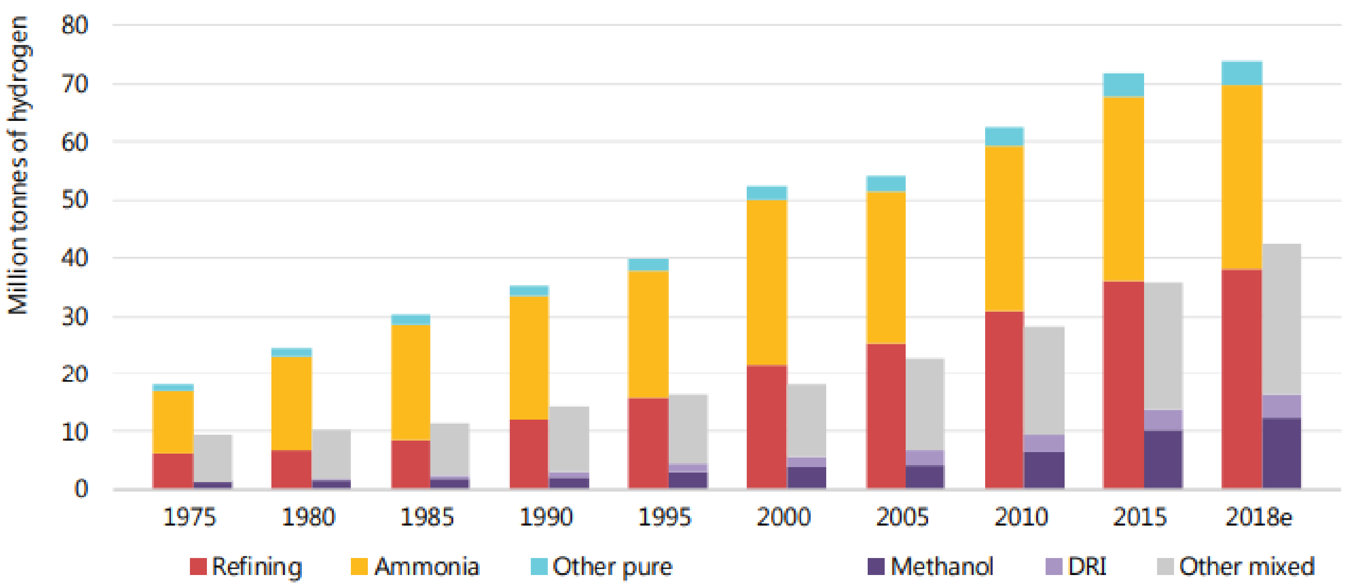
History of hydrogen demand

Figure 1. Global annual demand for hydrogen since 1975



Notes: DRI = direct reduced iron steel production. Refining, ammonia and "other pure" represent demand for specific applications

Source: IEA 2019.

- Hydrogen use has always been dominated by industrial applications
- Around 115 Mt consumed every years
- Hydrogen used today is quasi-totally produced from fossil sources

Around 70 MtH_2/yr is used today in pure form, mostly for oil refining and ammonia manufacture for fertilisers; a further 45 MtH_2 is used in industry without prior separation from other gases.

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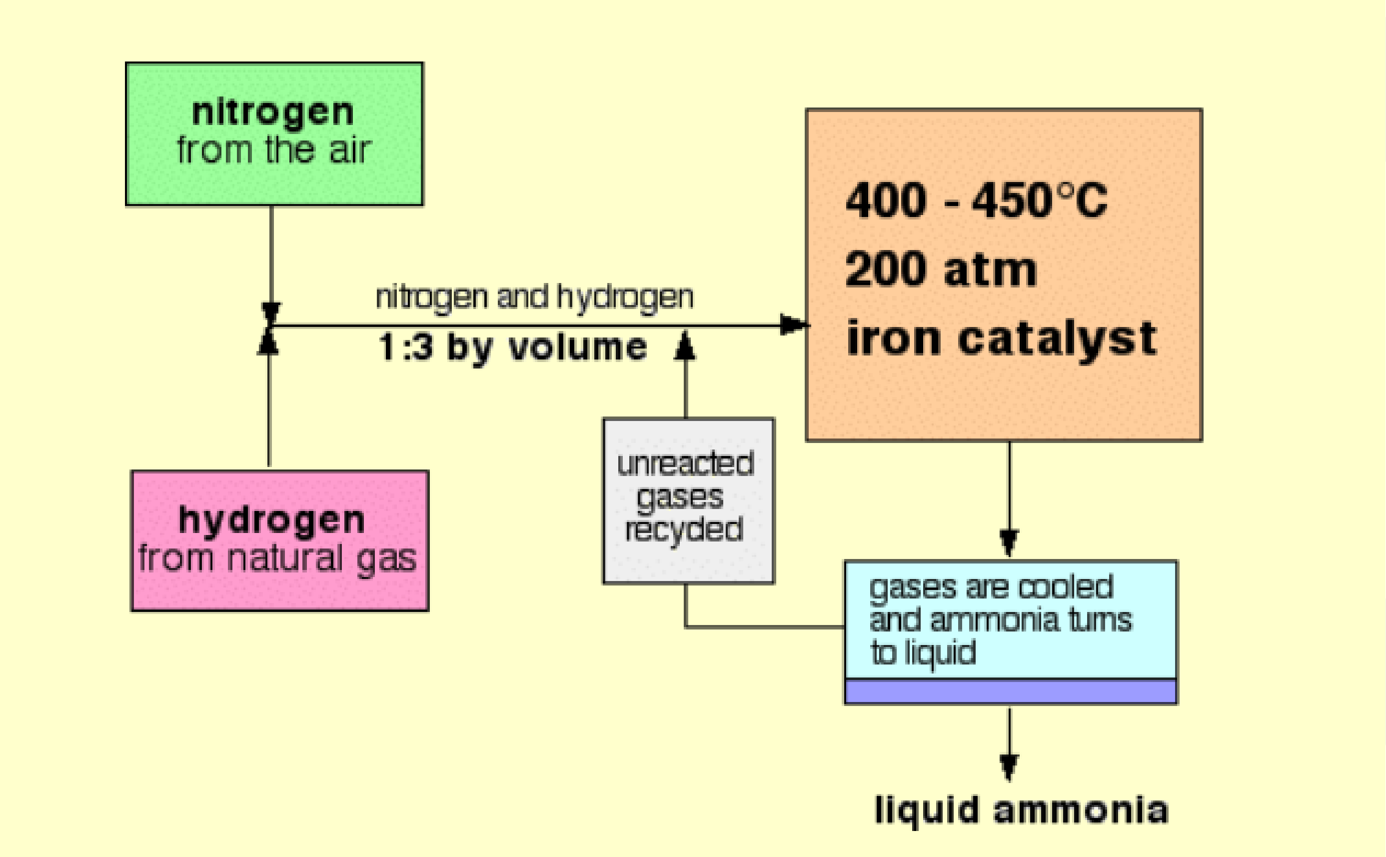
Ammonia production



The HABER-BOSCH process

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

$$\Delta H = -92\ kJ\ mol^{-1}$$

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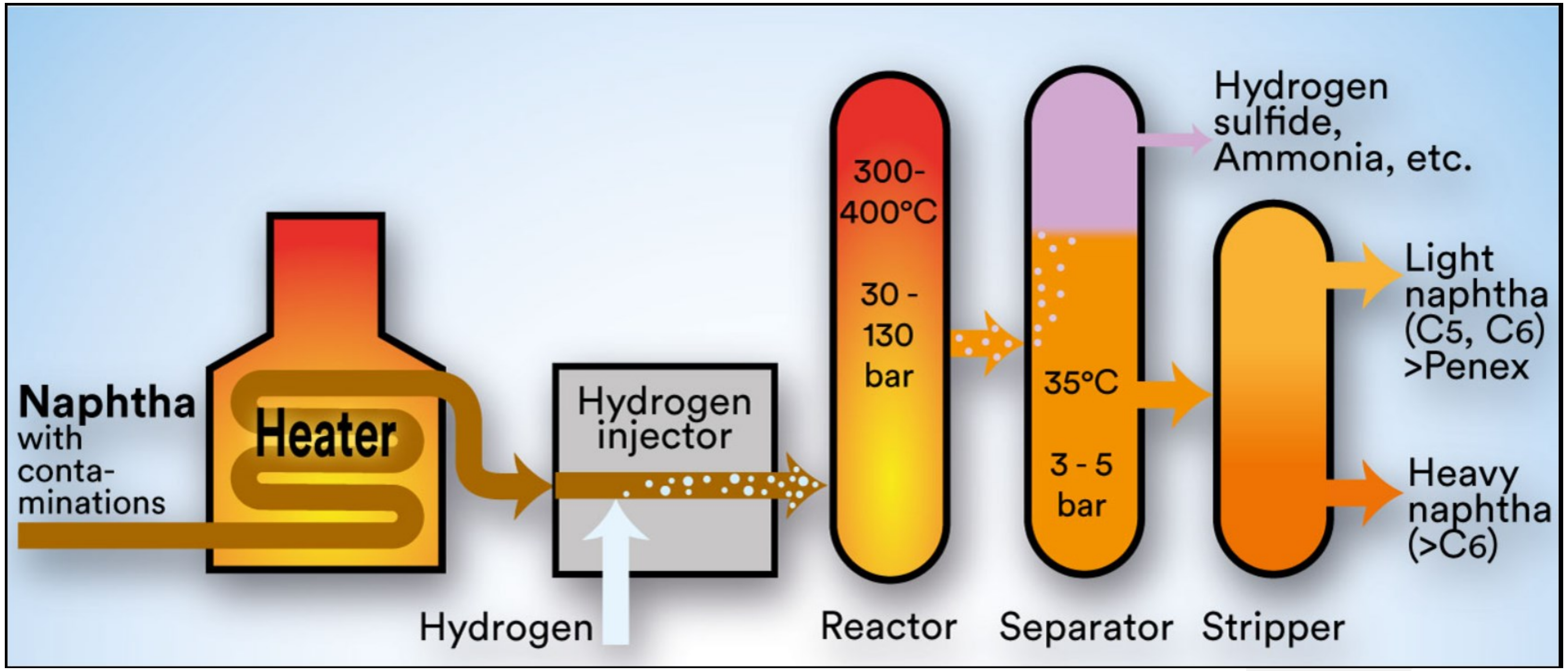
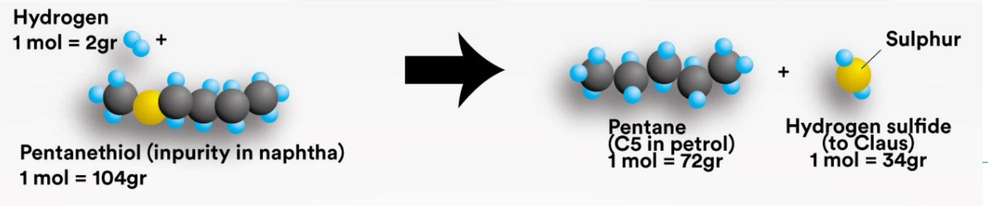
Petroleum refining



$$\underset{\text{Ethanethiol}}{C_2H_5SH} + \underset{\text{Hydrogen}}{H_2} \longrightarrow \underset{\text{Ethane}}{C_2H_6} + \underset{\text{Hydrogen sulfide}}{H_2S}$$



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Methanol production

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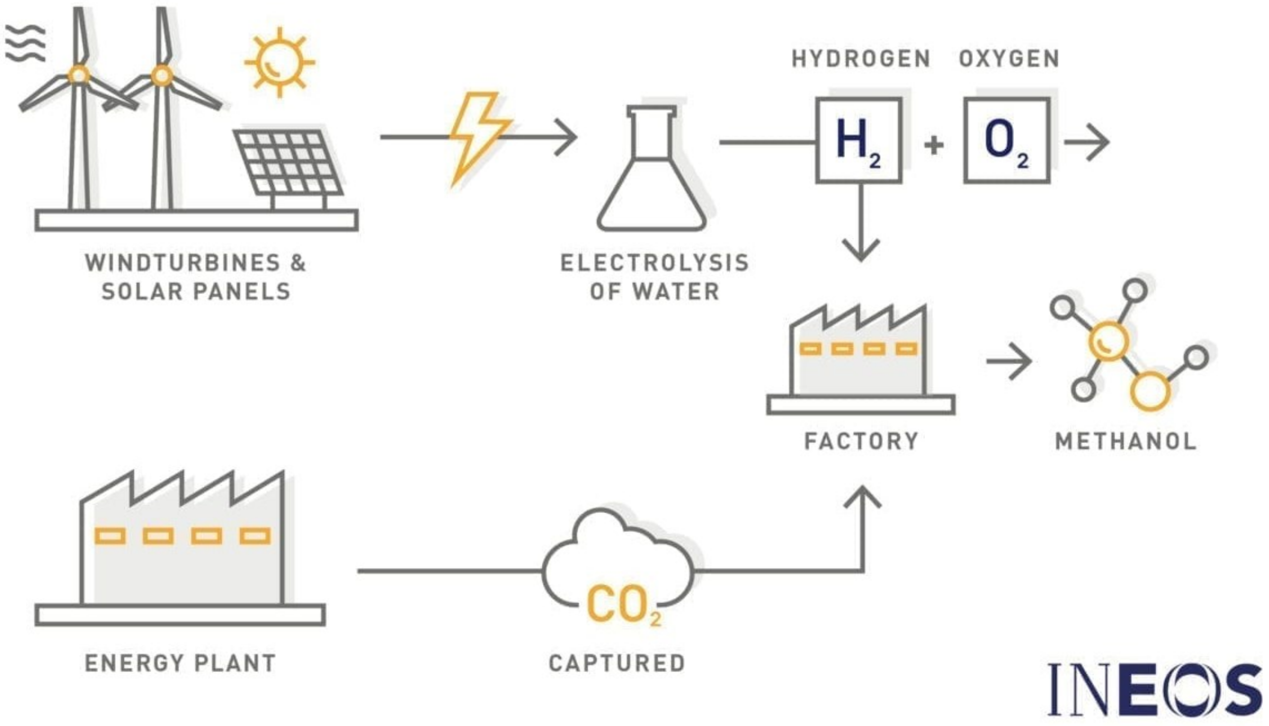

Key synthesis reaction is

$$CO_2 + 3H_2 <=> CH_3OH + H_2O$$

-49 kJ/kmol

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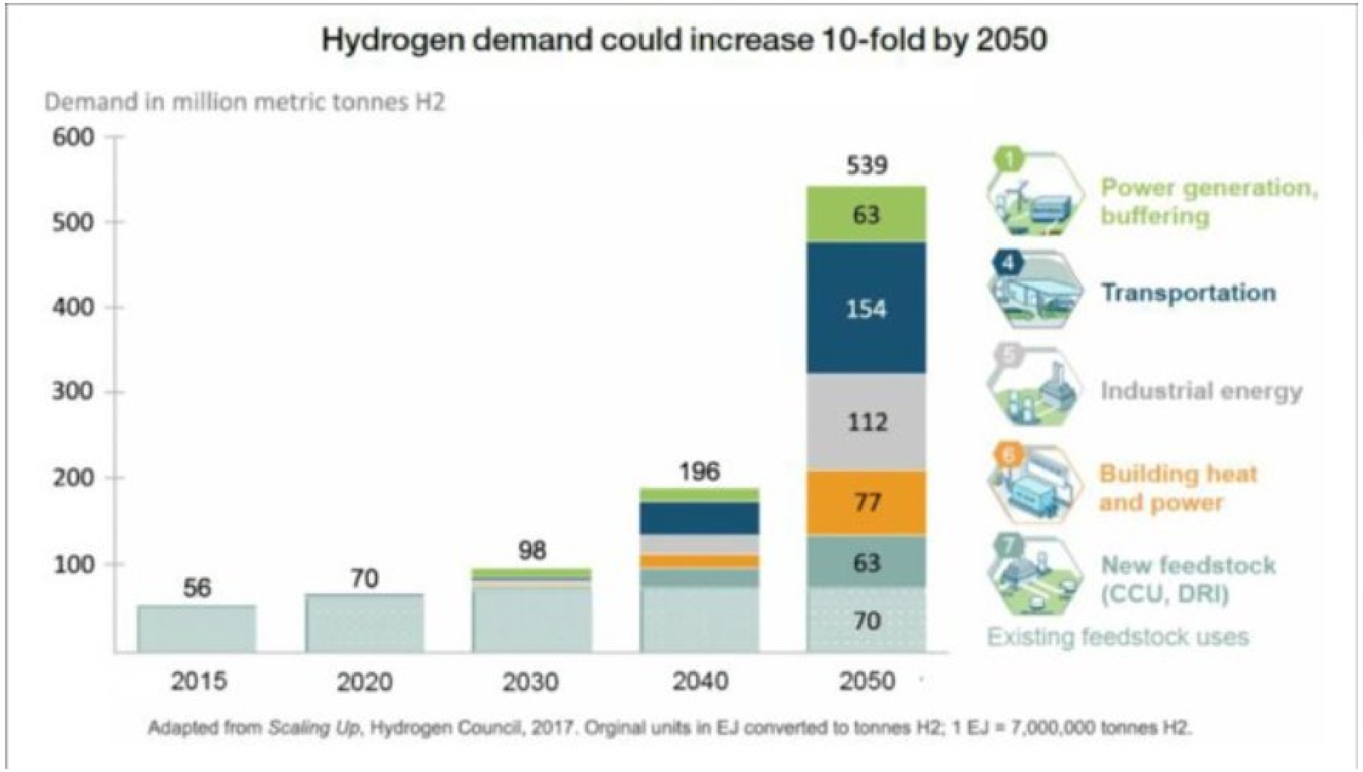
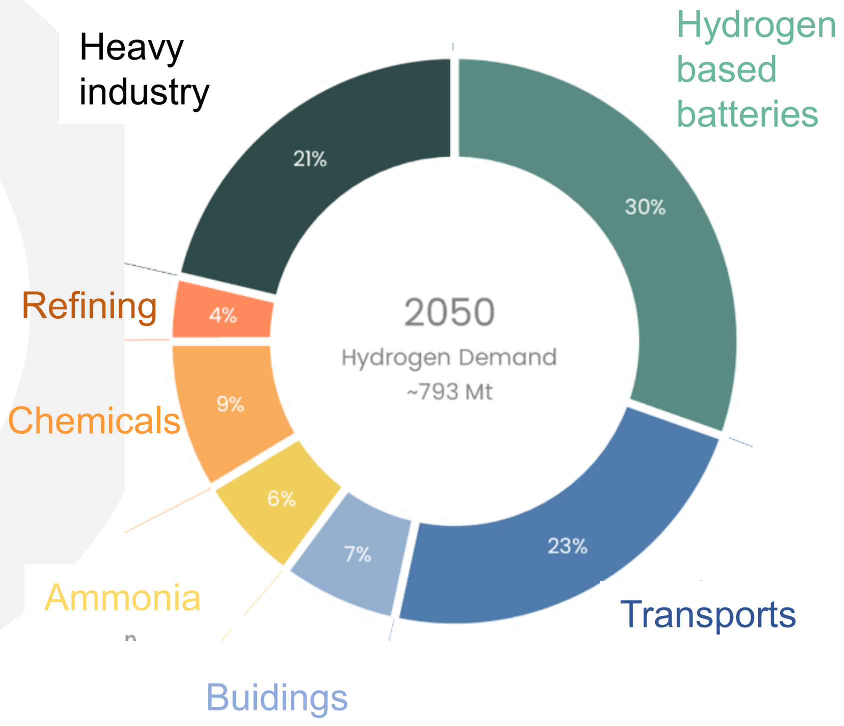
The future use of Hydrogen for decarbonation





Sources : IEA, BNEF Green

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3. FOCUS ON MOBILITY

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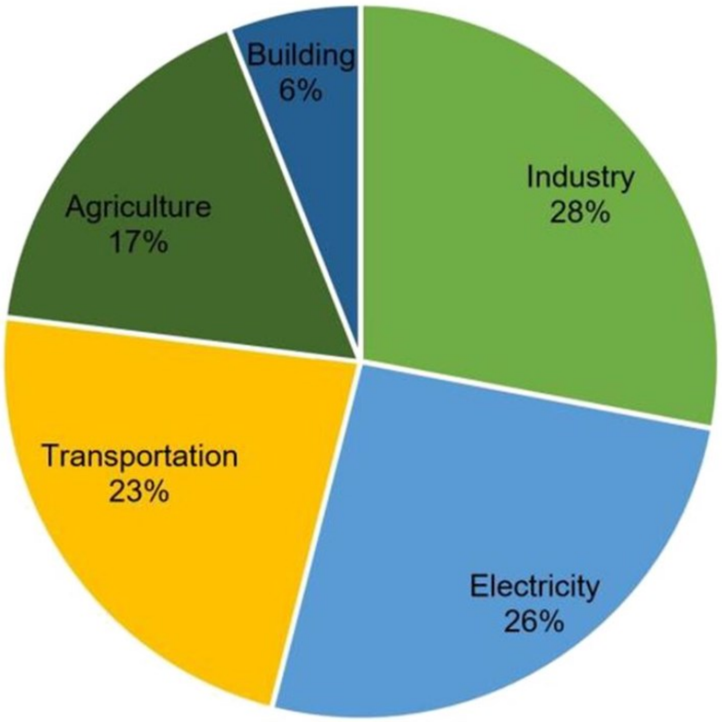
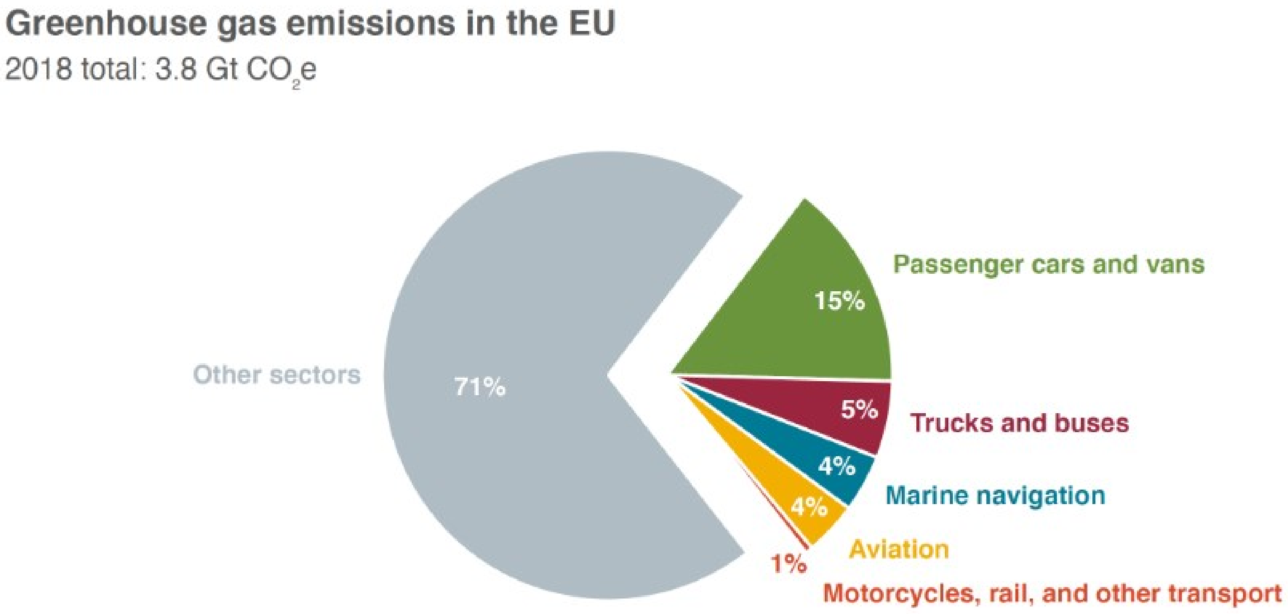
The share of emissions per sector



Global CO2 emissions by sector (IEA 2020)



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Policies for the mobility sector

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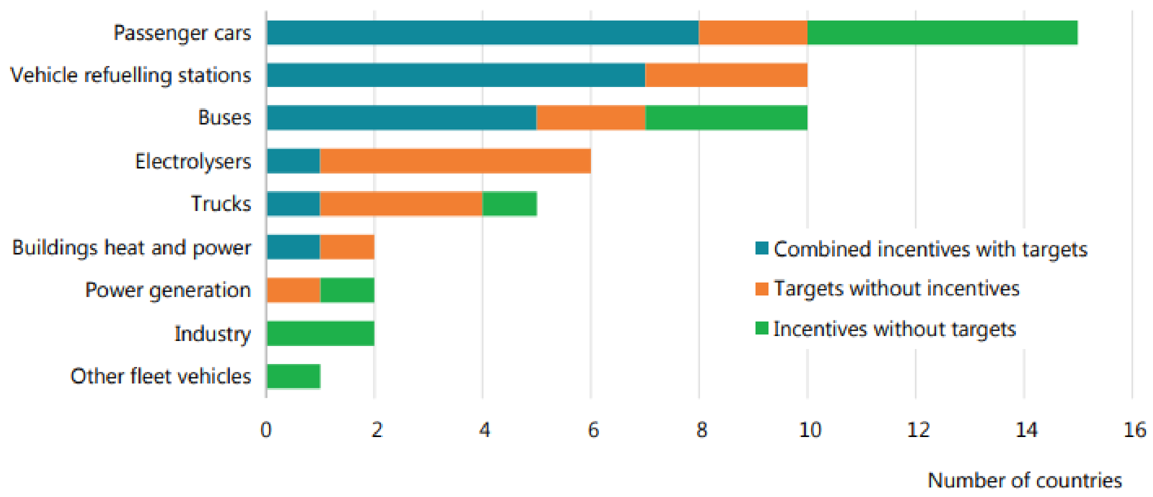
Figure 2. Policies directly supporting hydrogen deployment by target application



Note: Based on available data up to May 2019.

Table 10. Applications for low-carbon hydrogen classified by the theoretical size of the 2030 opportunity and the long-term potential

Type of application	Application	Size of the 2030 opportunity (ktH2/yr)	Long-term potential scale
Major hydrogen uses today	Chemicals (ammonia and methanol)	Over 100	High
	Oil refineries and biofuels	Over 100	Medium
	Iron and steel (blending in DRI)	10-100	Low
New hydrogen uses for a clean energy system	Buildings (conversion to 100% hydrogen)	Over 100	High
	Road freight	Over 100	High
	Passenger vehicles	Over 100	Medium
	Buildings (blending in the gas grid)	Over 100	Low
	Iron and steel (conversion to 100% hydrogen)	10-100	High
	Aviation and maritime transport	Under 10	High
	Electricity storage	Under 10	High
	Flexible and back-up power generation	Under 10	Medium
	Industrial high-temperature heat	Under 10	Low

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The decarbonation targets in EU

Regulations "Fit for 55":

Objective: Reduce GHG emissions by 55% by 2030 (compared to 1990)

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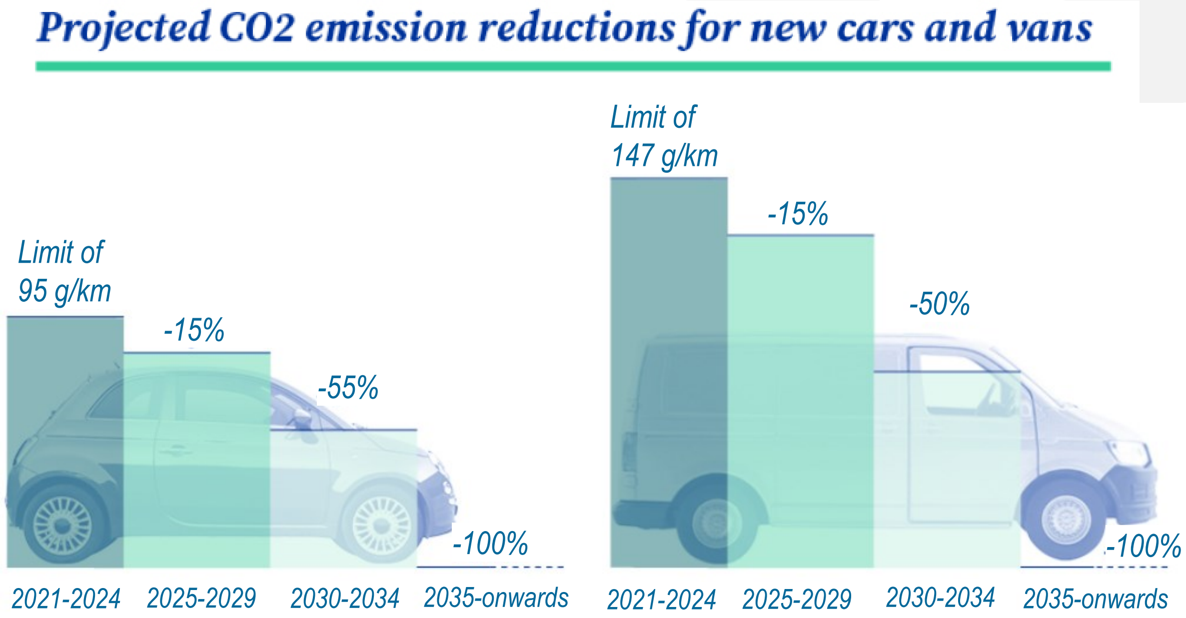
Fit for 55 for cars



Only “Zero emissions” (in use phase) vehicles in 2035

Revised regulation on CO_2 emission limits for new cars and vans explained

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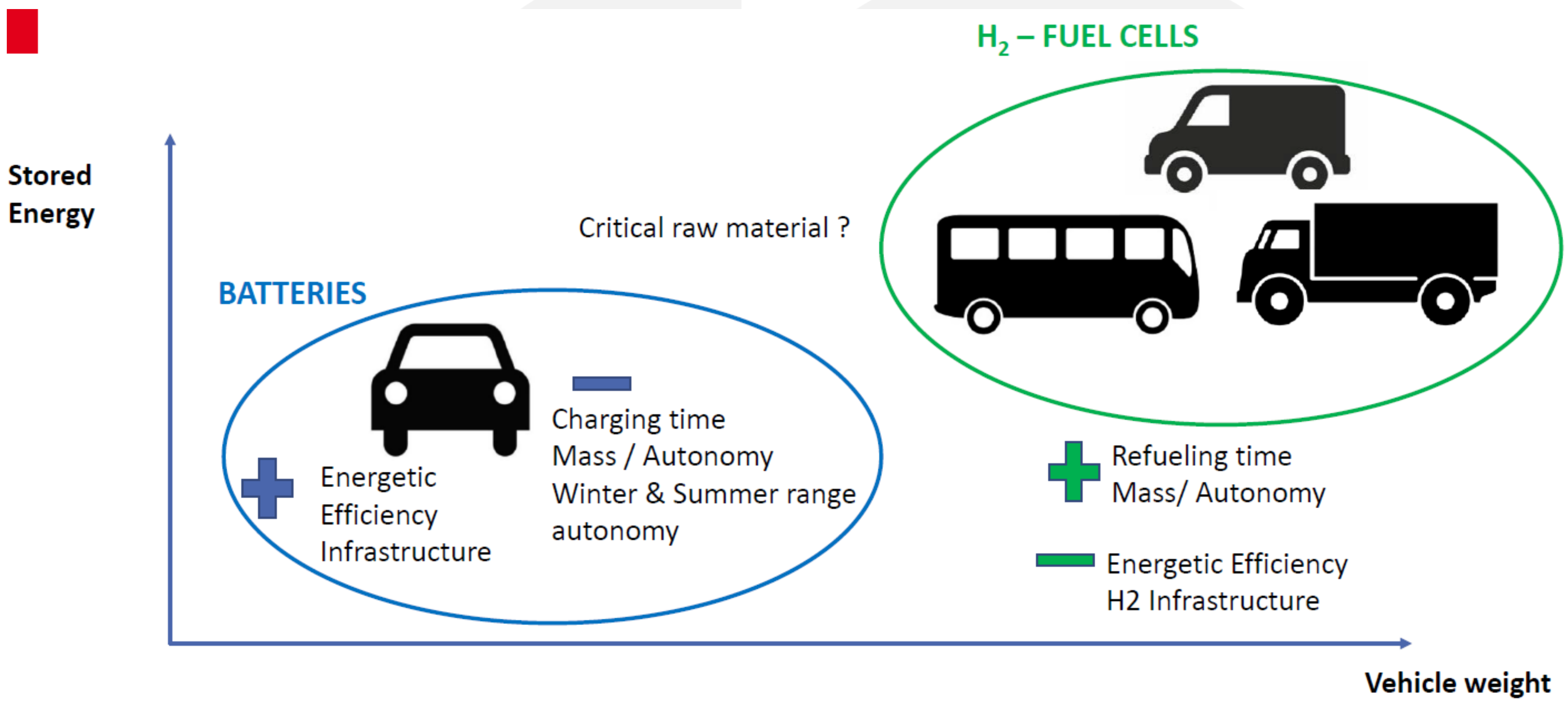
Complementarity battery/Fuel cell



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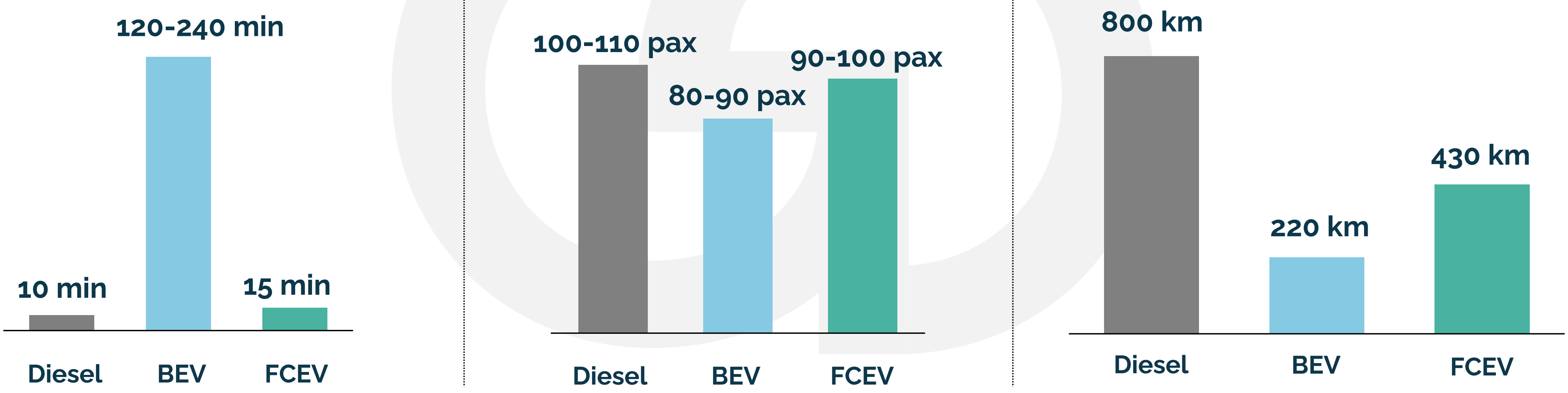
Use case: Citybus 12m

/ Refueling time
min

/ Payload
passenger capacity

/ Range
km



Source: Symbio studies on the EU bus market

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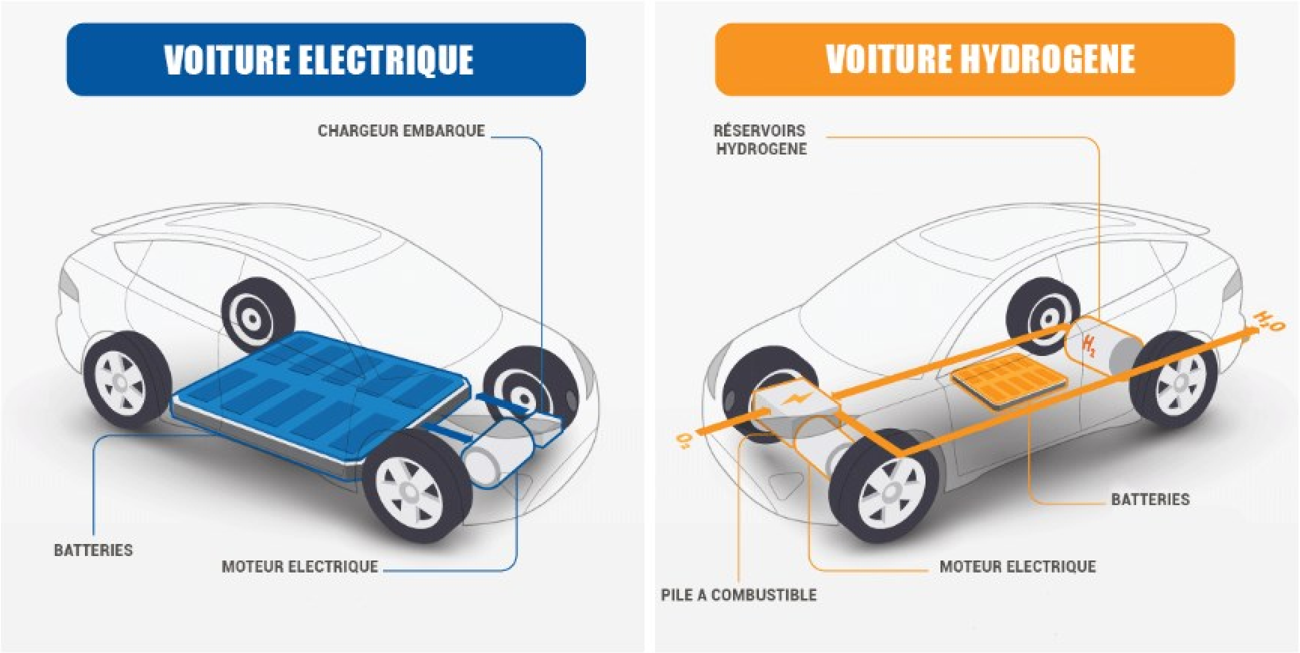
Development of “zero emission vehicles”



	Battery	Hydrogen
Zero emission at tail pipe	yes	yes
Maturity (market)	+++	-
Autonomy	+	+++
Charging time	-	+++
Price	++	

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4. SYMBIO’s FUEL CELLS

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Over 30 years of experience, Engaged builder of the hydrogen ecosystem

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MICHELIN
UNE MEILLEURE FAÇON D'AVANCER

SYMBIO

SYMBIO
A FAURECIA MICHELIN HYDROGEN COMPANY

SYMBIO HYDROGEN ACADEMY

Entry in China and USA

INNOPLATE
A Schaeffler Symbio Hydrogen Company

STELLANTIS

New Shareholder effectiveness expected in Q3 2023*

2000 | 2010 | 2019 2020 | 2021 | 2022 | 2023

STELLANTIS

SAFRA
Accélérateur de mobilité décarbonée

CALIFORNIA ENERGY COMMISSION

GAUSSIN

green corp

And 6 million Km of On-road vehicle experience

* Closing is expected in the third quarter of 2023. Transaction subject to customary regulatory approvals

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Fast-forwarding Symbio in the European fuel cell industry

INDUSTRIAL CAPACITIES

Accelerating the industrialization and mass production of current generation FC systems in Saint-Fons

Phase 1 : FC *development and industrialization to reach a capacity of* ***50,000*** *units/year* ***in Saint-Fons*** *as of 2026*

&

CUTTING-EDGE INNOVATION

- Developing and industrializing a new generation
- of innovative Fuel Cell technology, containing disruptive technology to boost performance of our StackPacks® while drastically reducing unit production costs

Phase 2 : *New FC gen R&D and industrialization to reach additional capacity of* ***50,000*** *units/y* ***in another plant*** *in France as of 2028*

Phase 1 + Phase 2 : ***100,000*** *units/y in France as of 2028*

1 billion EUR investment

Financé par l'Union européenne NextGenerationEU

FRANCE 2030

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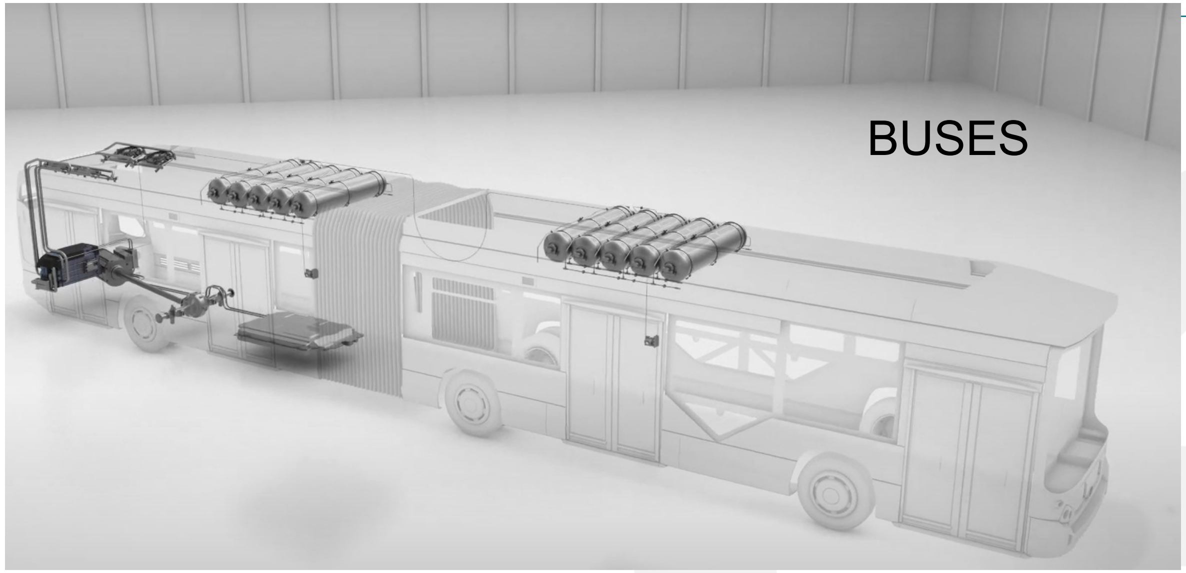
Fuel cells used in different vehicles



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Partnership
Undertaking (now Clean Hyd ... the
European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen

Fuel Cell markets are gaining momentum

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World FCEV market* 2030
on-road & off-road

~1,5 million

	Passenger cars	LCV	Buses & coaches	MDV & HDV	Pick-up trucks
On-road	<1%	4-6%	7-9%	6-8%	2-4%

	Handling equipment	Construction & Mining	Agriculture	Maritime	Rail
Off-road	5-10%	1-5%	< 1%	>10%*	>10%*

Penetration rate

*Of retrofitted fleet

World FCEV market* 2035
on-road & off-road

>3 millions

*China included

Source: Symbio studies

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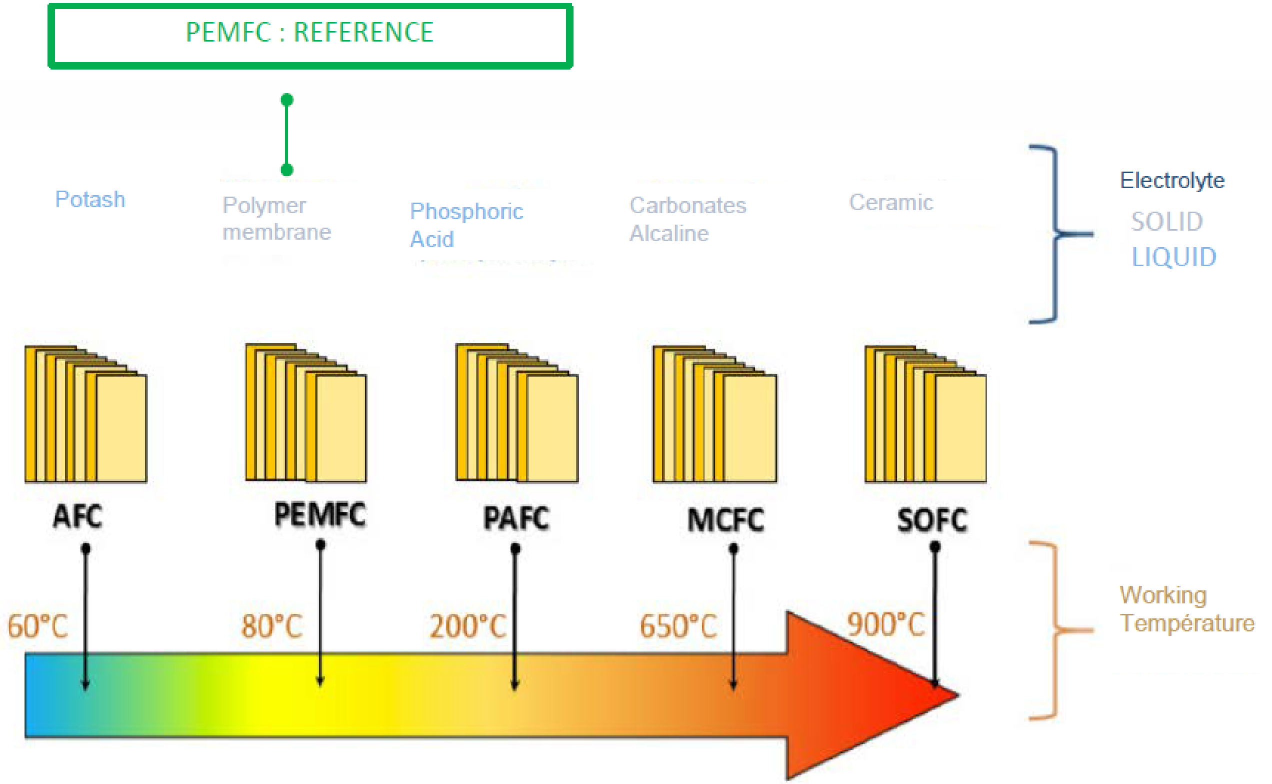
The Fuel Cell : how does it work

Proton Exchange Membrane Fuel Cell

> Automotive conditions

- Low T (<200 °C)
- Solid Electrolyte



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The Fuel Cell : how does it work

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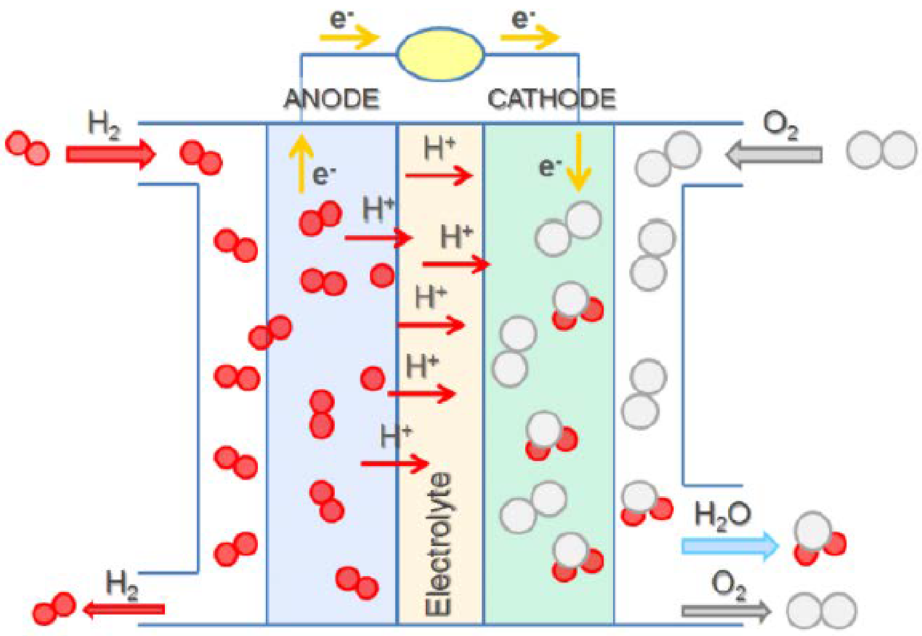

Anode : H_2 oxidation

H_2 (g) ➔ $2H^+(aq) + 2e^-$

Cathode : O_2 Reduction

$O_2(g) + 4H^+(aq) + 4e^-$ ➔ $2H_2O$ (l)

> **Fuel cell = Open Generator**

> ➔Transformation of **chemical energy** provided by a spontaneous oxidation-reduction reaction into **electrical energy**

> ➔Two separate compartments called **half-cells** each containing an **electrode and an electrolyte**

> Two **Redox couples**
- Cathode : O_2 (g)/ H_2O (l),
- Anode : H^+ (aq) / H_2 (g)

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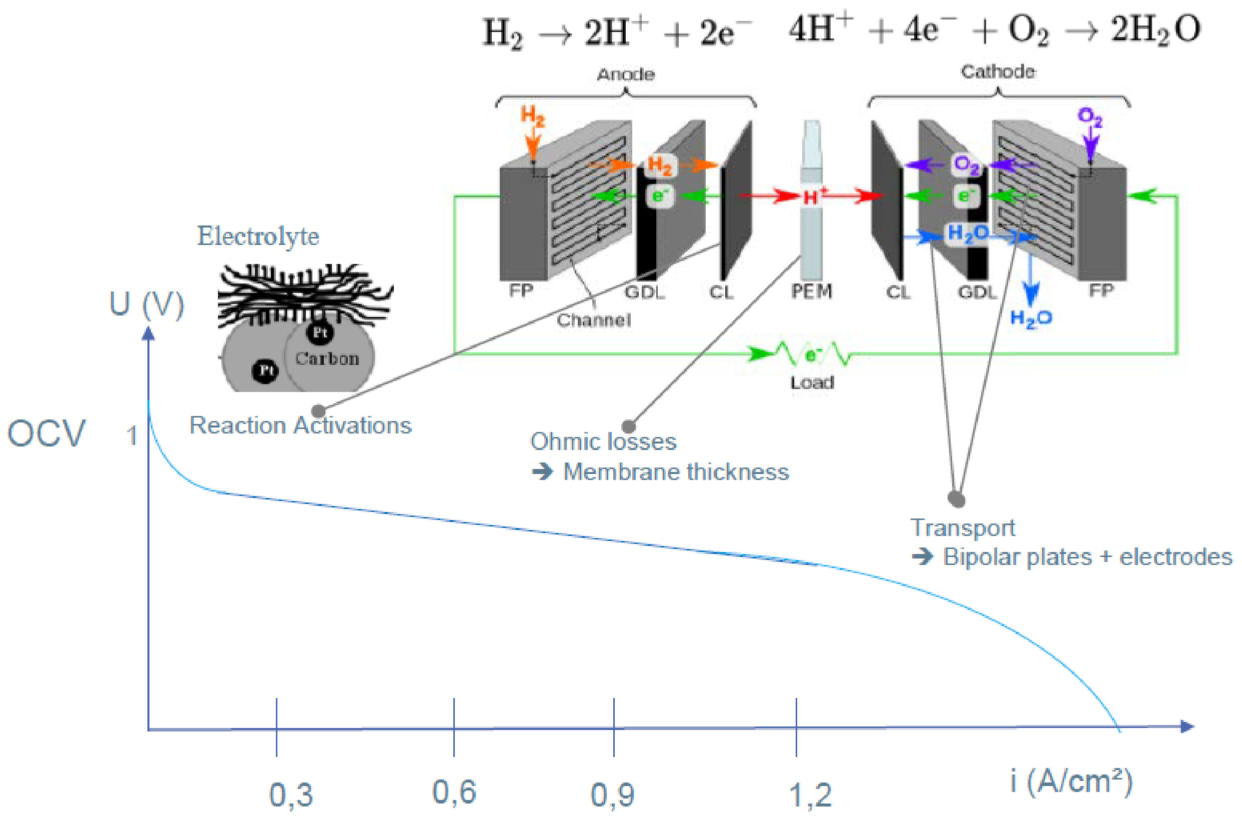
Electrochemical notions



Open Circuit Voltage (OCV) : Nernst

→ $E_{Nernst} = E°(H_2/O_2) + \frac{RT}{2F} \ln\left(\frac{P_{H_2}(P_{O_2})^{0,5}}{P_{H_2O}}\right)$

→ Standard potential (1 bar, 298 K)

$E°(H_2/O_2) = 1,23$ V

Losses

→ Activation of reactions

→ Ohmic

→ Transport

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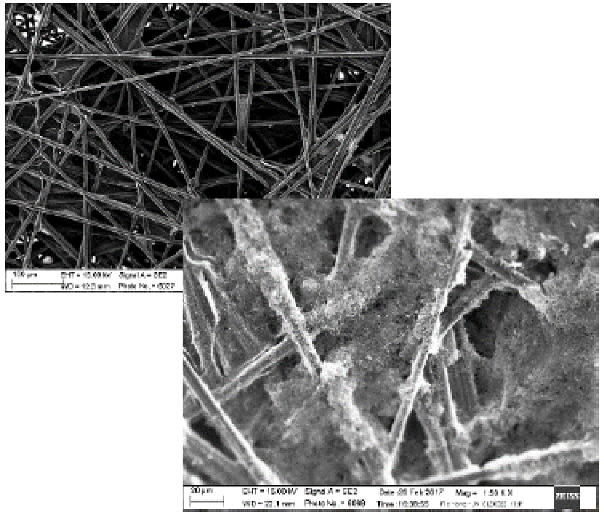
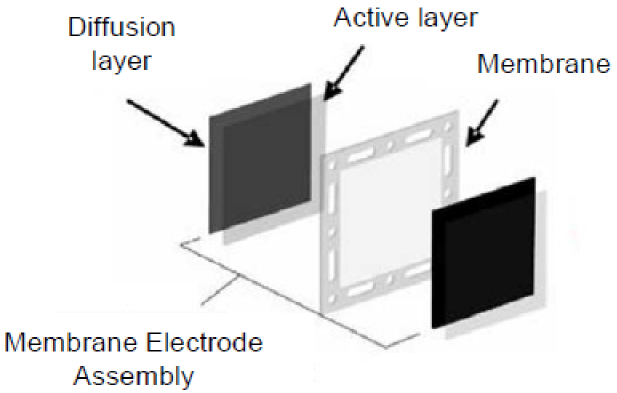
The core of the Fuel Cell : The MEA

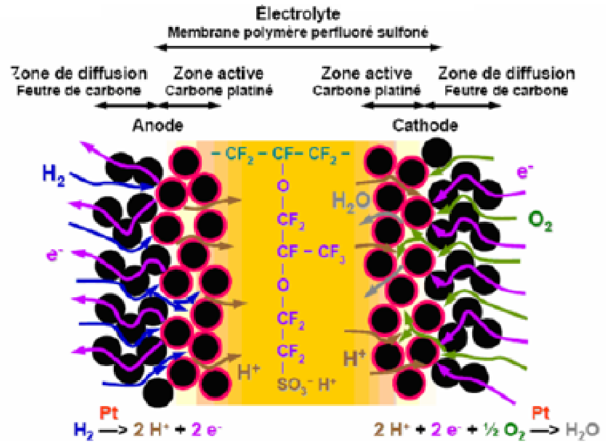
1. Gas diffusion layer – GDL

Gas distribution – from macro to micro scale

Electronic conduction





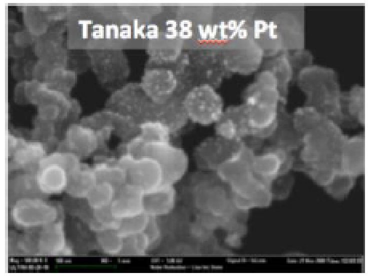


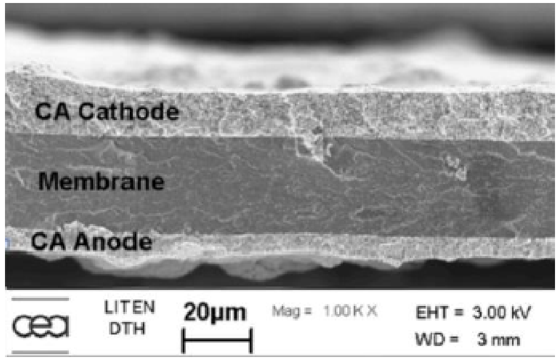
2. Catalyst layer – Active layer

Gas distribution – from micro to nano scale

Electronic conduction

Anodic and cathodic electrochemical reactions





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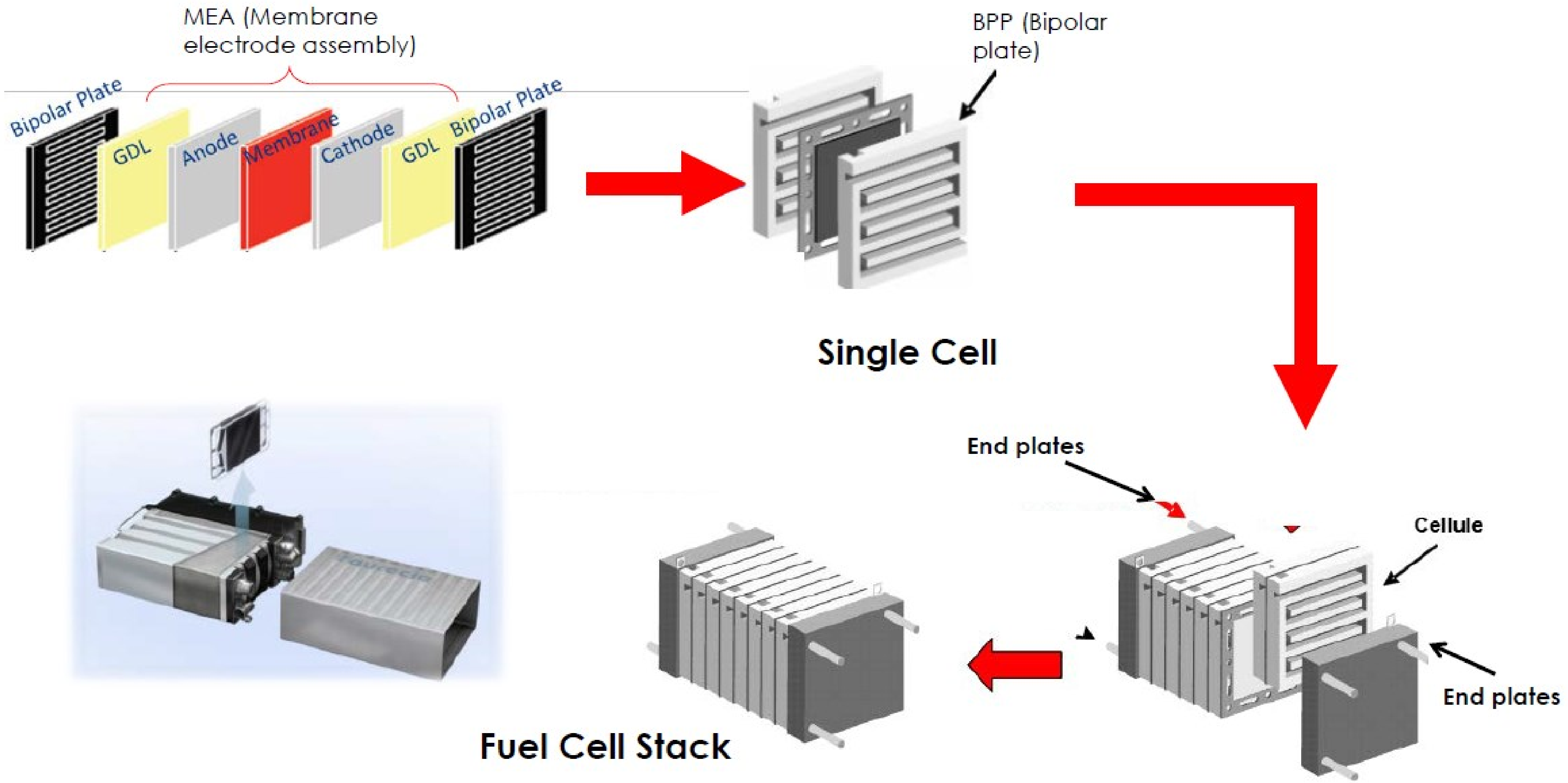
From single MEA to complete stack



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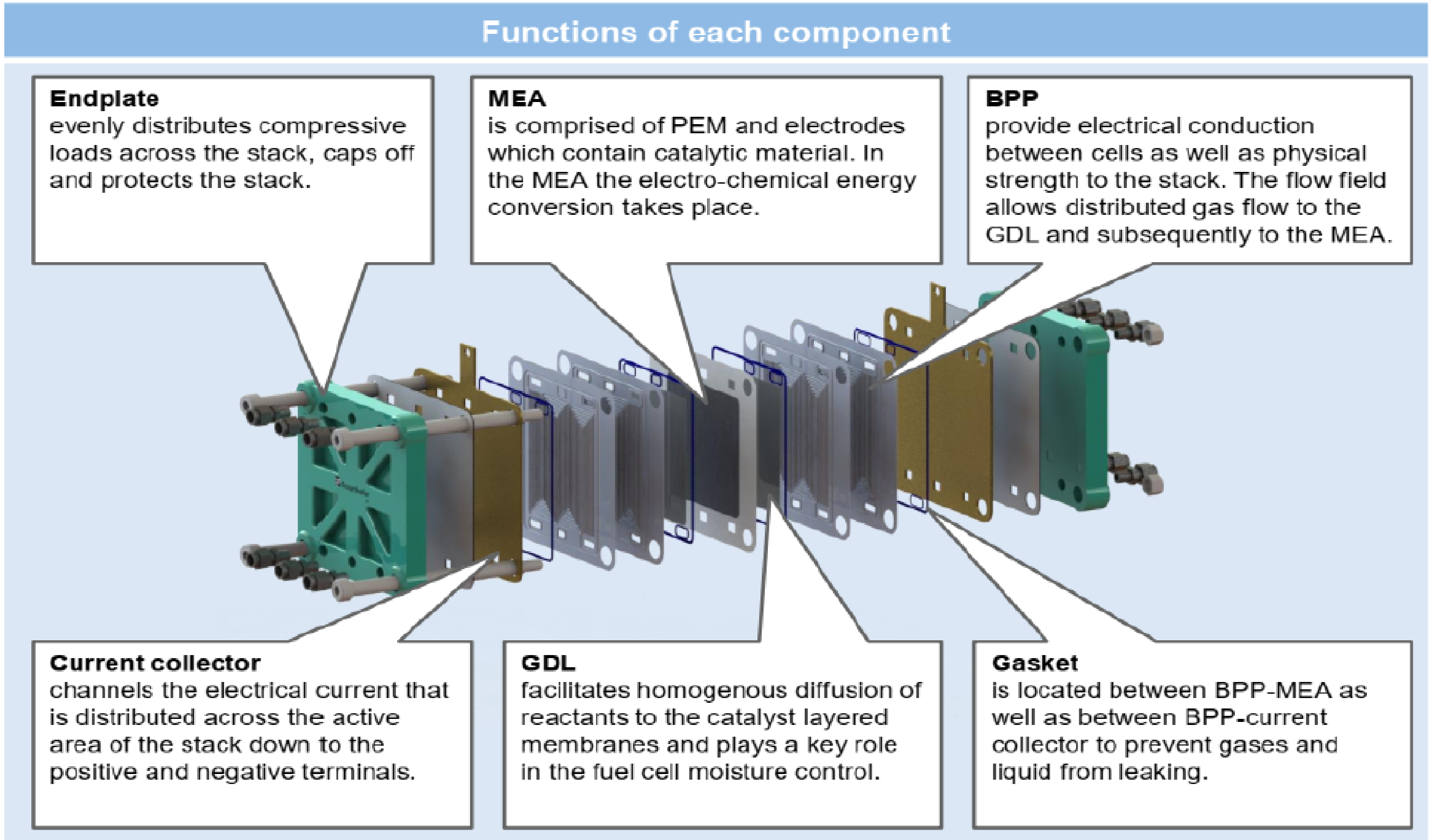
The components of the stack



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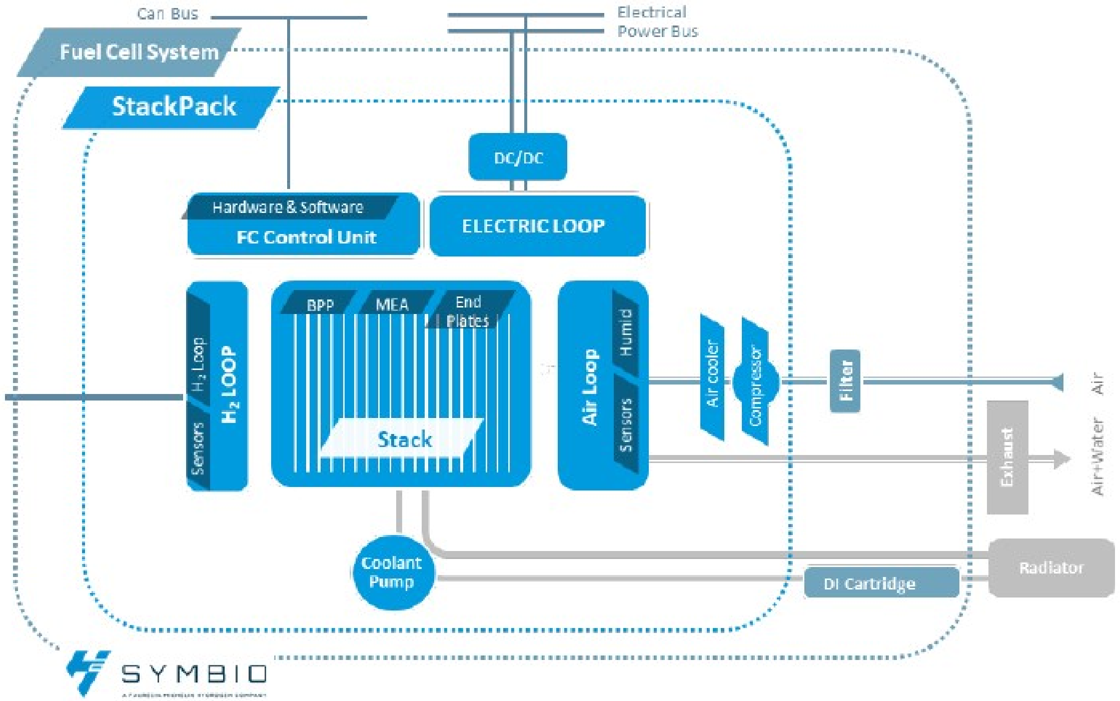
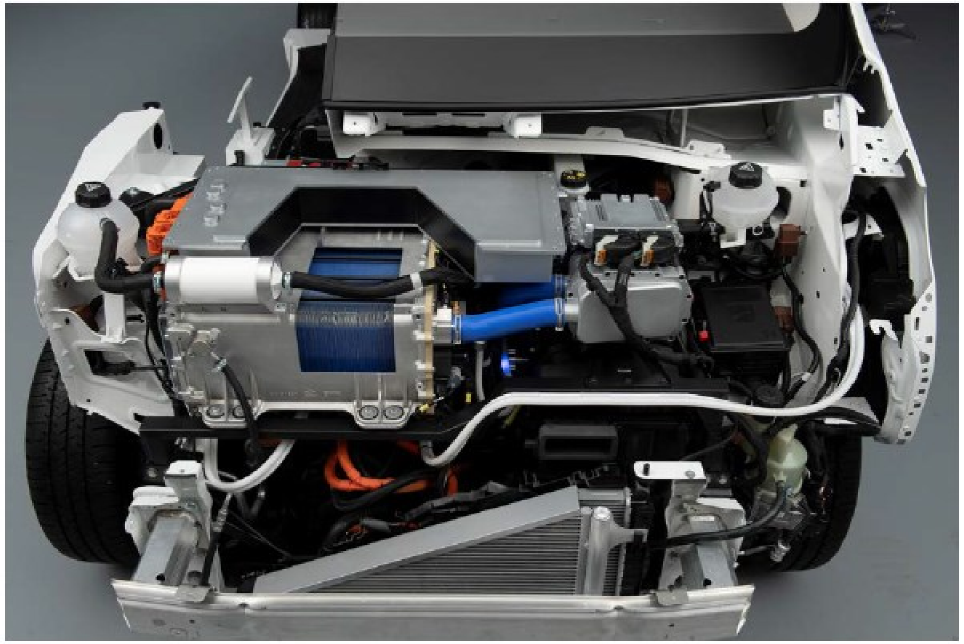
The Fuel Cell system : Stack + loops

4 system loops

- Air loop
- Hydrogen Loop
- Cooling Loop
- Electric Loop





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This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007166. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

The Fuel Cell system : Air loop

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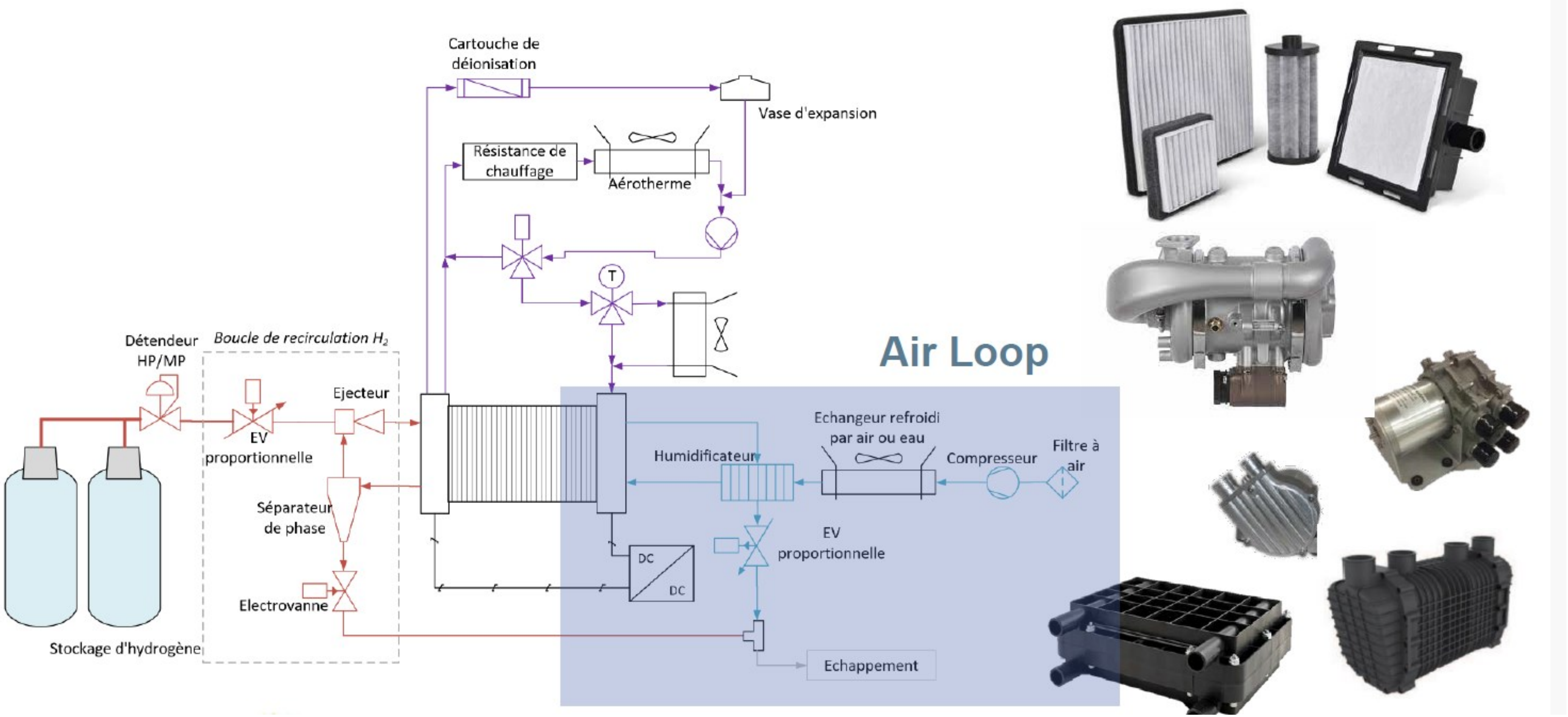

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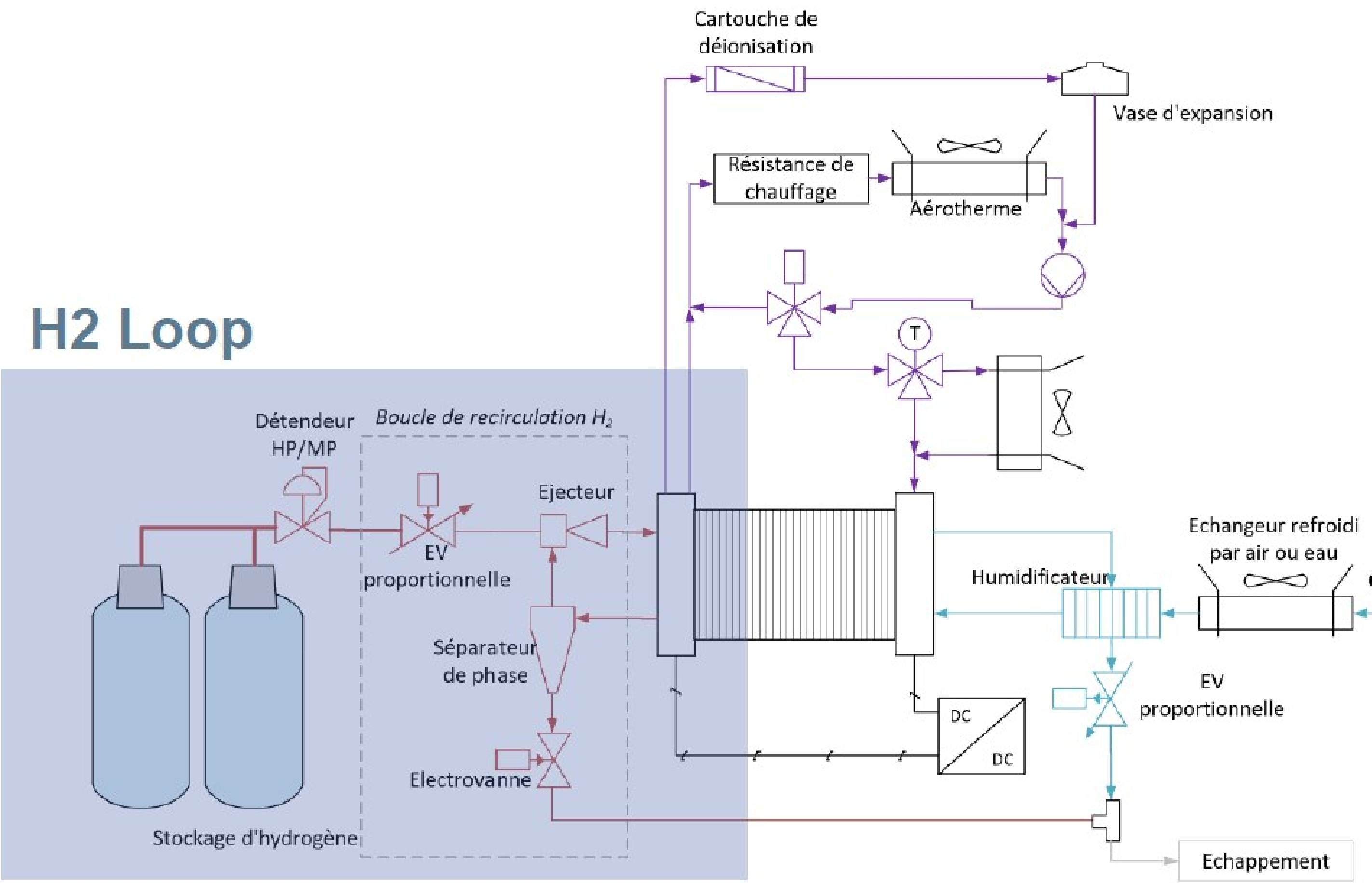
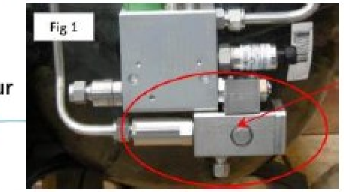
The Fuel Cell system : Hydrogen loop





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The Fuel Cell system : Cooling loop

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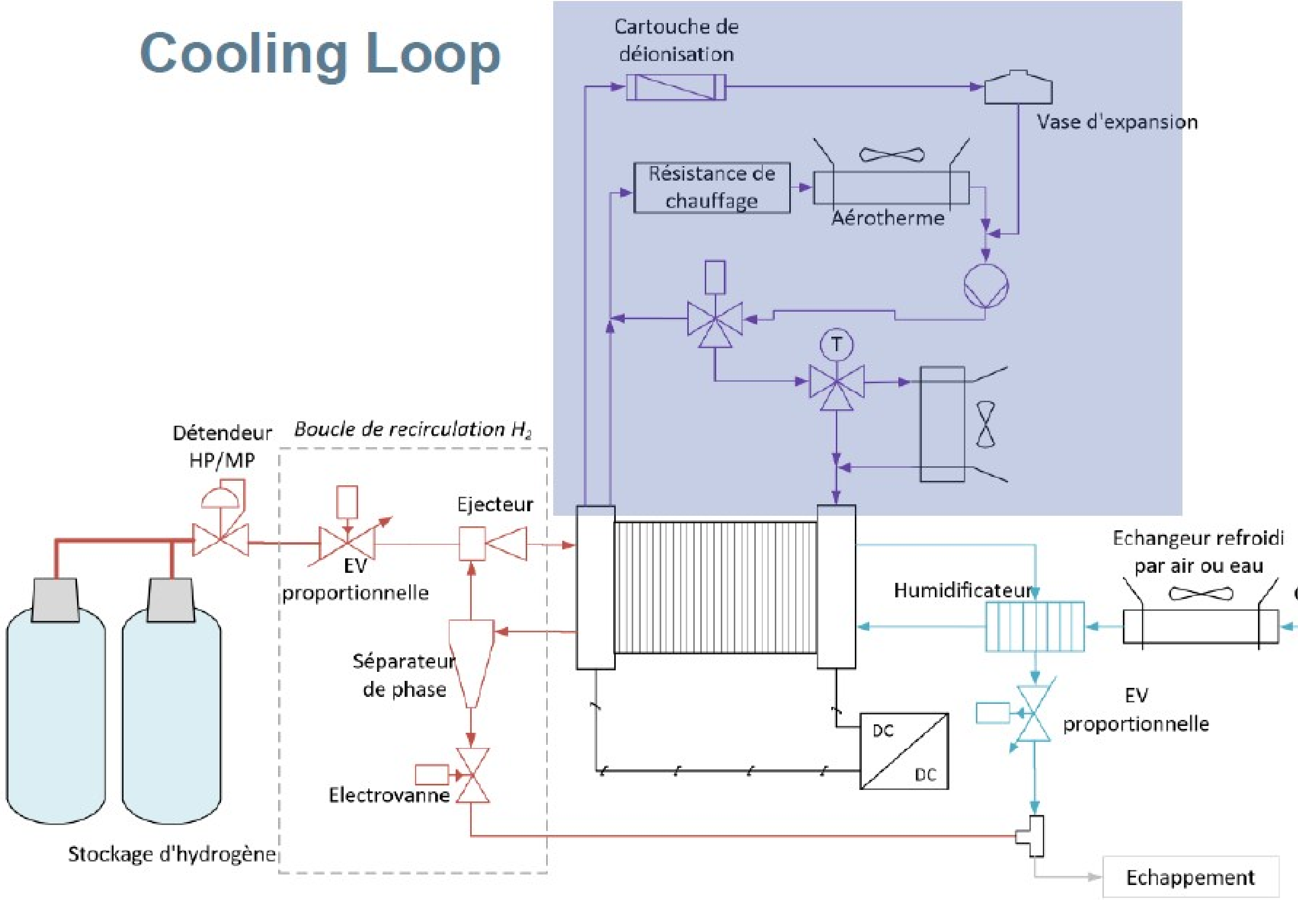
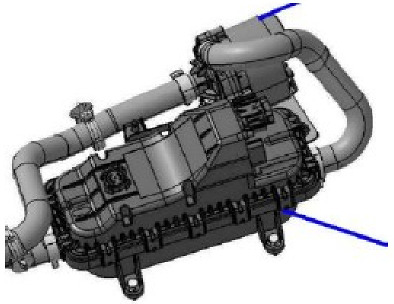
Cooling Loop





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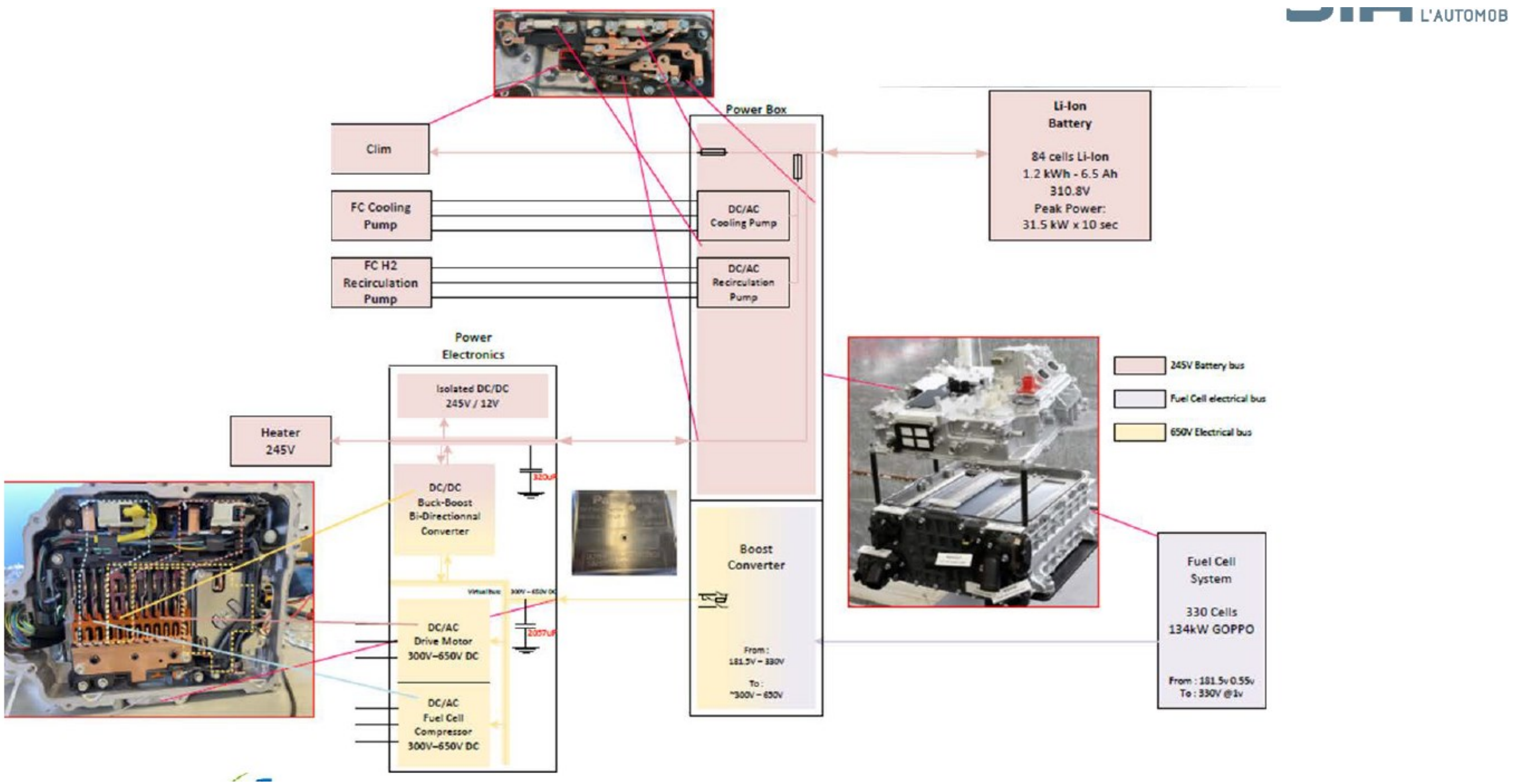
The Fuel Cell system : Electric loop



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eGHOST Spring (20-24 May 2024)

Symbio Product offer 2026 onwards

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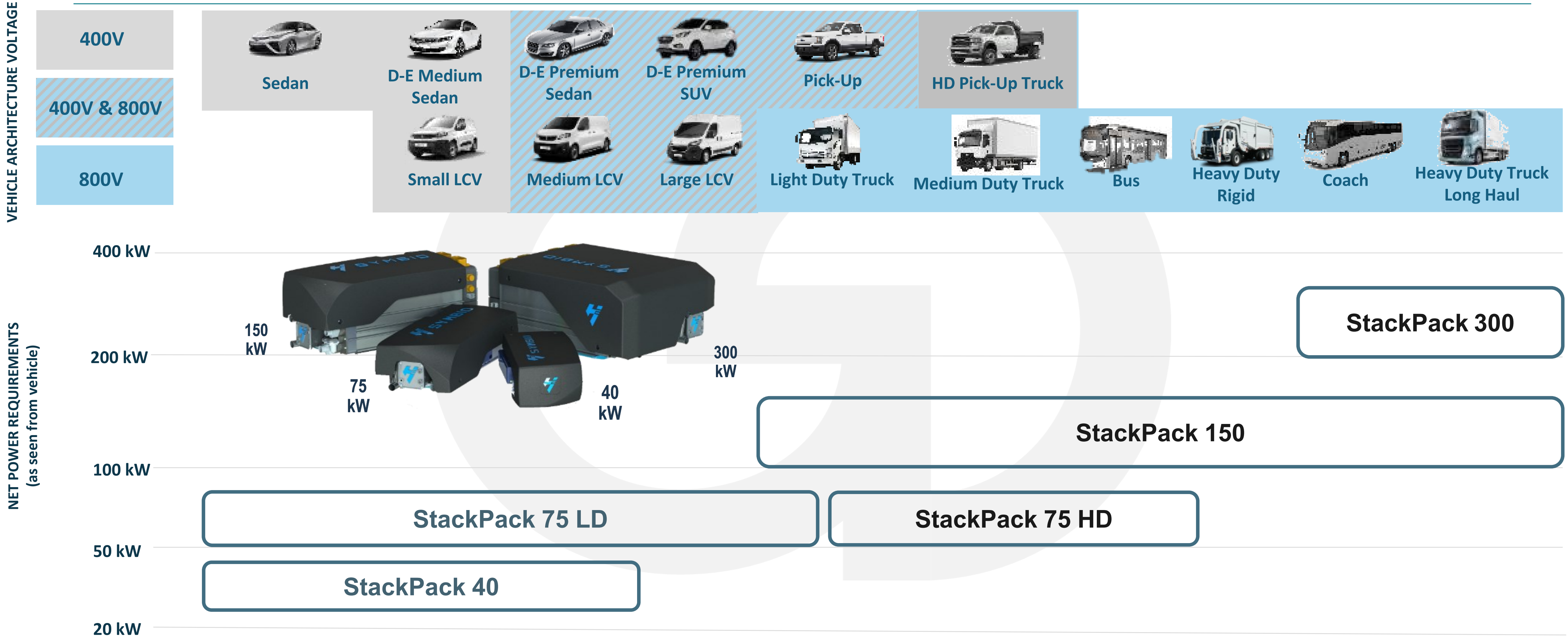

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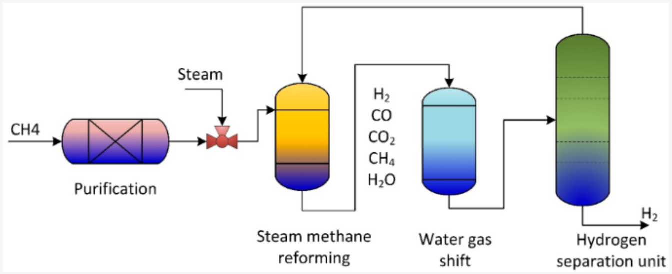
Environmental issues for hydrogen

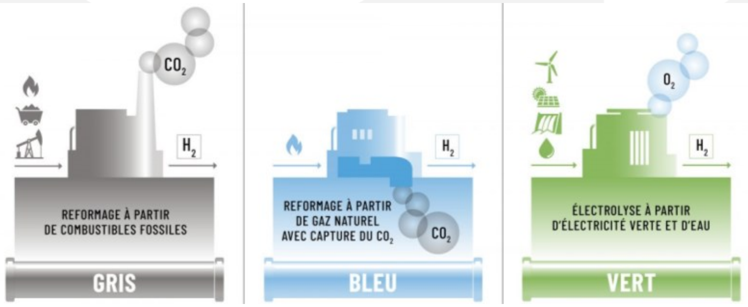
The hydrogen mobility aimed to decarbonise transport : It will develop only if we have green or low carbon hydrogen!

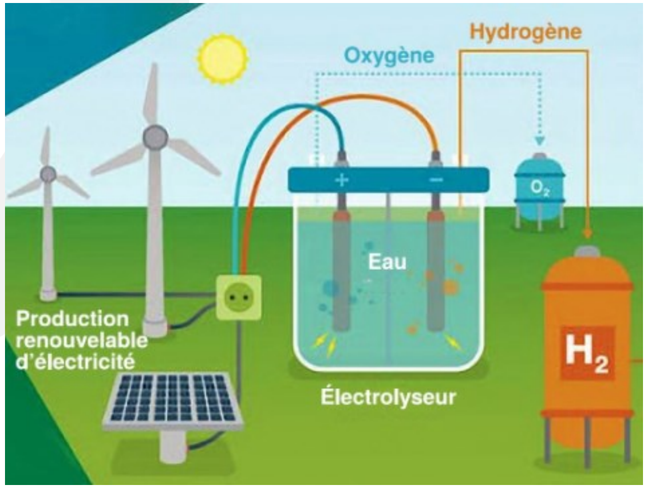
For now, 95% of the hydrogen produced is grey hydrogen from Steam Methane Reforming (SMR)

Figure 1. Schematic of traditional methane reforming unit for hydrogen production.



The alternative that is developping is the water electrolysis : use electricity in an electrolyser to split the water molecules in hydrogen and oxgygen.
If low carbon electricity is used, this produce low carbon hydrogen





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THANKS FOR YOUR ATTENTION

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eco-design Guidelines for Hydrogen Systems and Technologies

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