Fuel Cell & Hydrogen activities

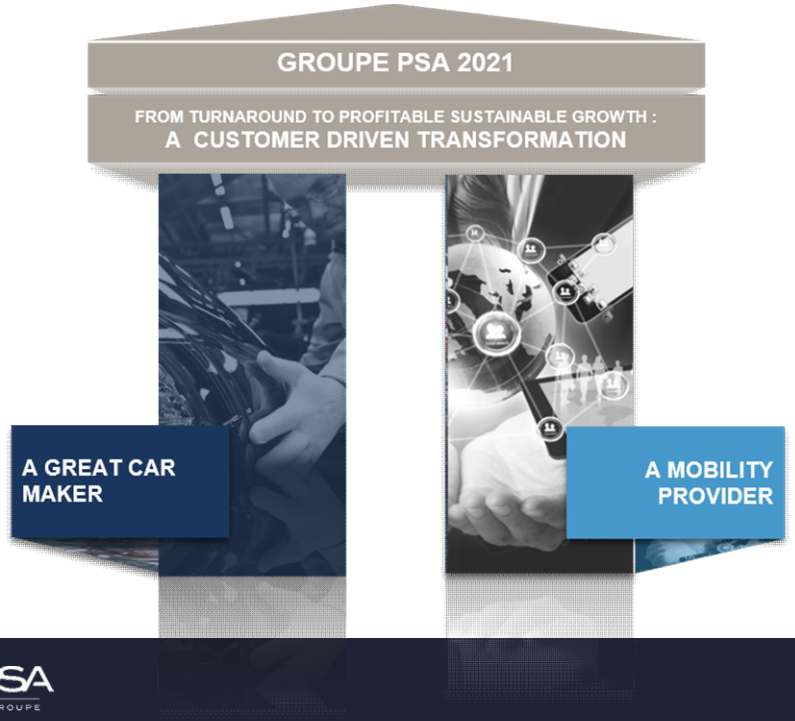
4th of February 2019
Arts & Métiers

PSA GROUPE

01798_19_00007

Confidential

Our vision: Becoming a great global carmaker with cutting edge efficiency and the preferred mobility provider worldwide for lifetime customer relationship



Peugeot, Citroën, DS Automobiles, Opel and Vauxhall: 5 car brands and a portfolio of complementary products

WHICH ENERGY FOR A GREEN PLANET?

> Drivers :

- CO_2 emission pressure (global warming)
- Deployment of areas restricted to low emission vehicles in big cities
- Hybrids and electric vehicles purchase incentives
- Charging infrastructure availability and deployment
- Greenhouse gases are confirmed to be responsible for global warming
- Customers demands = green vehicles

CO_2 REGULATORY FORECAST PER REGIONS

> Common text for PC & LCV

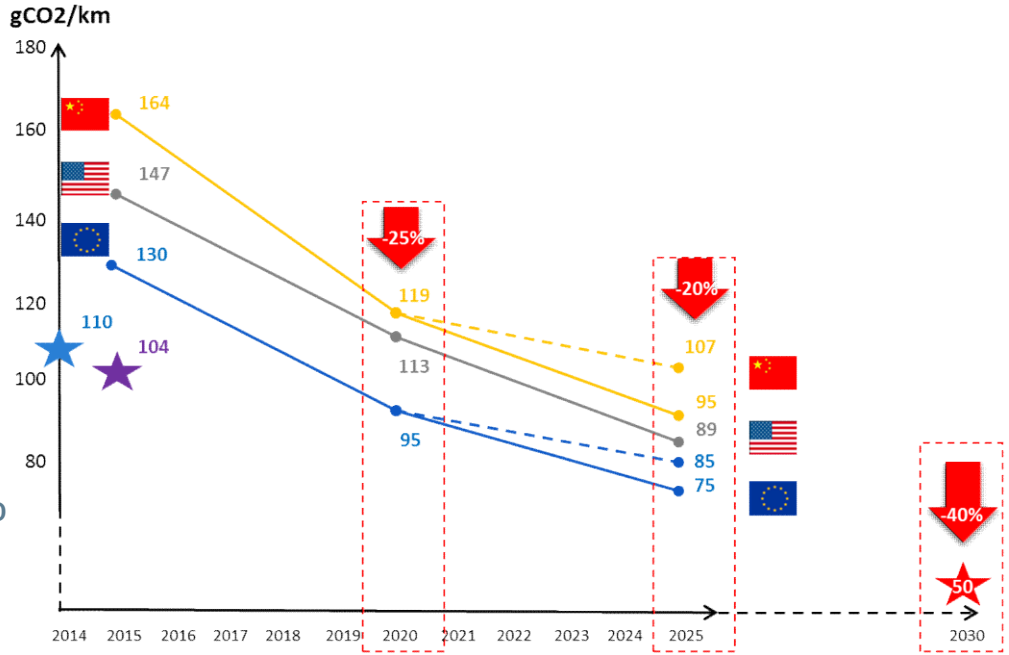
> CAFE targets:
-15% in 2025 vs 2021 and -30% in 2030 vs 2021

~~-40%~~

> Slope reduced by -15% in 2025 and -30% in 2030

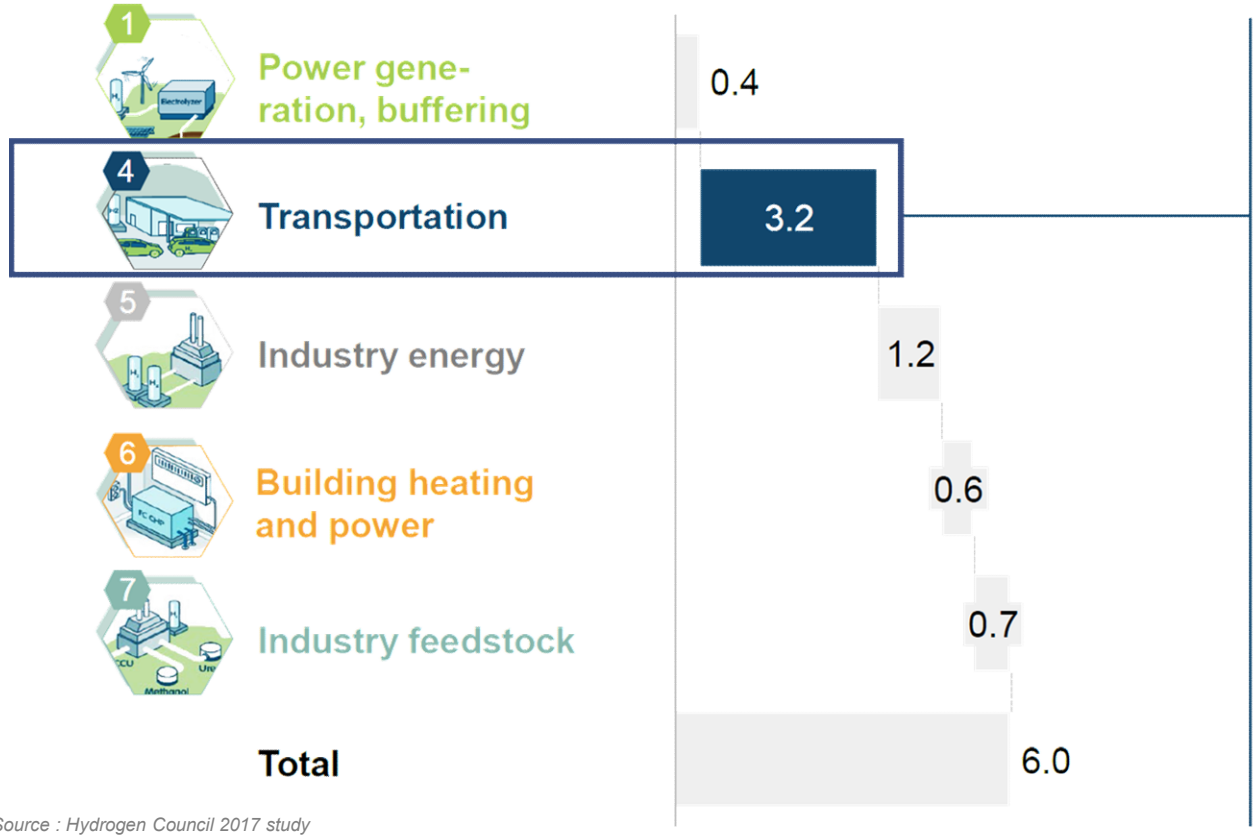
> LEV « Benchmark » 15% (2025) & 30% (2030)

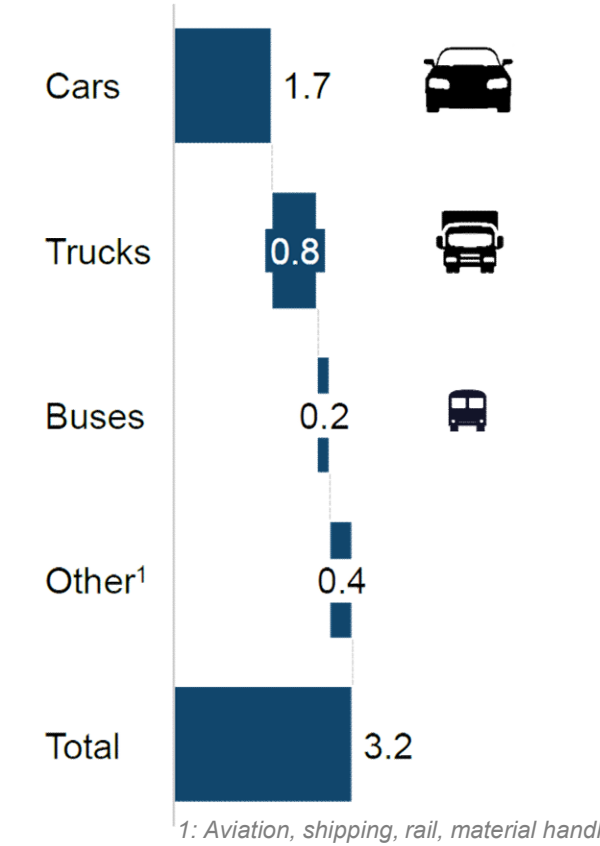
> Penalties up to 95€/g !!!



2030 : European Comission proposal

BREAKDOWN OF CO_2 REDUCTION ACHIEVABLE IN 2050 THANKS TO HYDROGEN, FOR EACH INDUSTRY SECTOR (IN GIGA TONS)

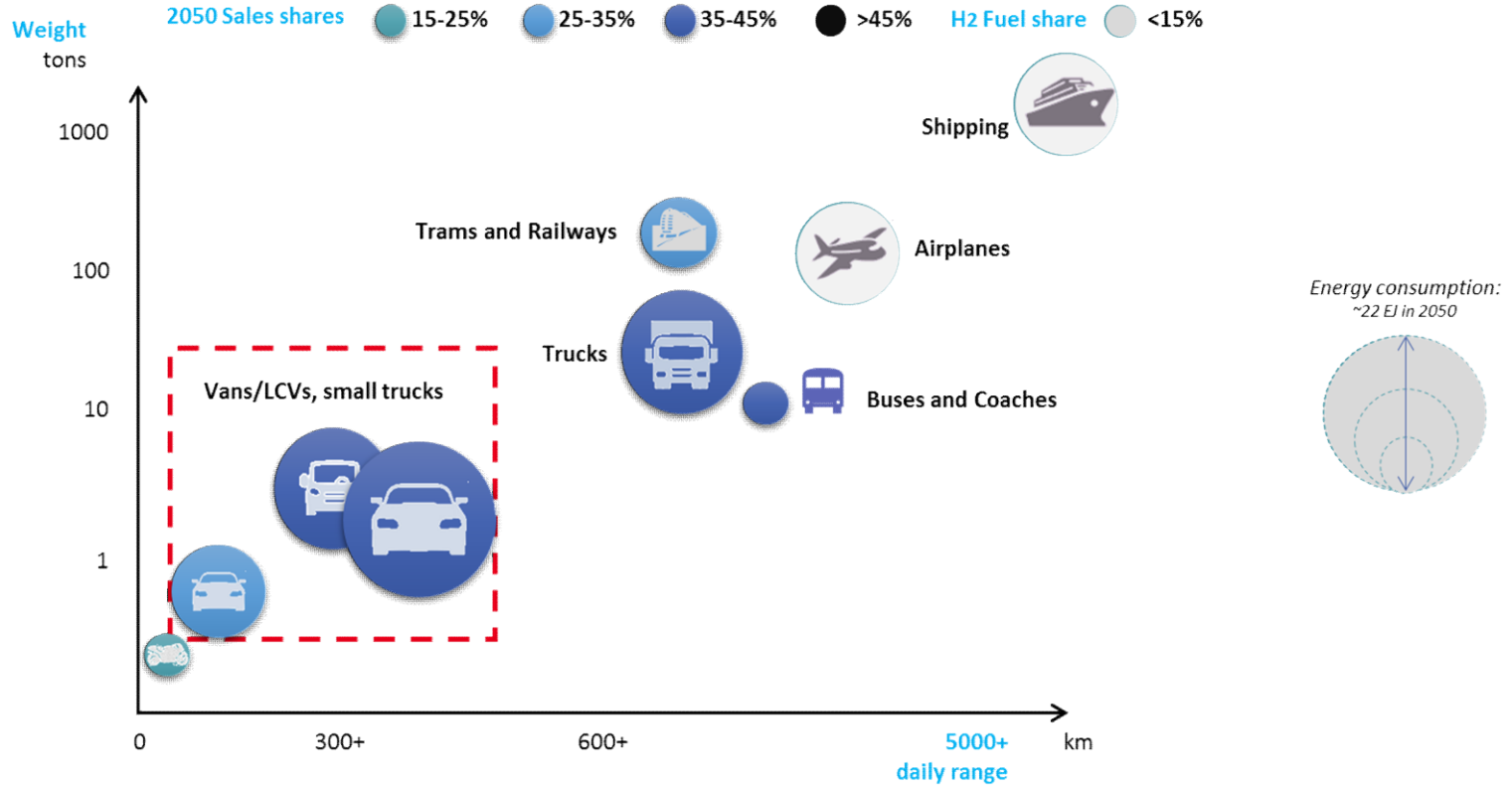




Source : Hydrogen Council 2017 study

1: Aviation, shipping, rail, material handling

ROLE OF HYDROGEN TO DECARBONIZE DIFFERENT SEGMENTS OF TRANSPORT AND MOBILITY



Forecast of energy consumption and market share (% sales) in 2050

Source : IEA ETP, HIS, Hydrogen Council 2017

TECHNOLOGIES TO COMPLY WITH CO_2 REGULATIONS

- Improvement of ICE
- Hybrid Vehicle (MHEV, HEV)
- Plug-in Hybrid Vehicle (PHEV)
- Battery Electric Vehicle (BEV)
- Fuel Cell Electric Vehicle (FCEV)
- **FCEV & BEV are complementary !**

Actual PSA's strategy

- ✓ 15 new electrified vehicles between 2019 and 2021 (Opel included)
- ✓ 100% of the range electrified by 2025

Launch of the new Euro 6d temp engines

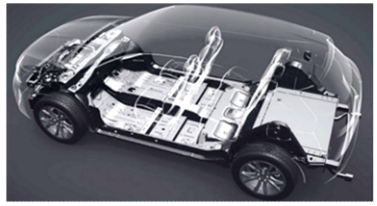
✓ Reduced emissions and fuel consumption:

✓ Pure Tech petrol engine (3 cyl.)

✓ 1.5L BlueHDi diesel engine (4 cyl.)

2 MULTI-ENERGY PLATFORMS
(PETROL, DIESEL, ELECTRIC OR HYBRID)

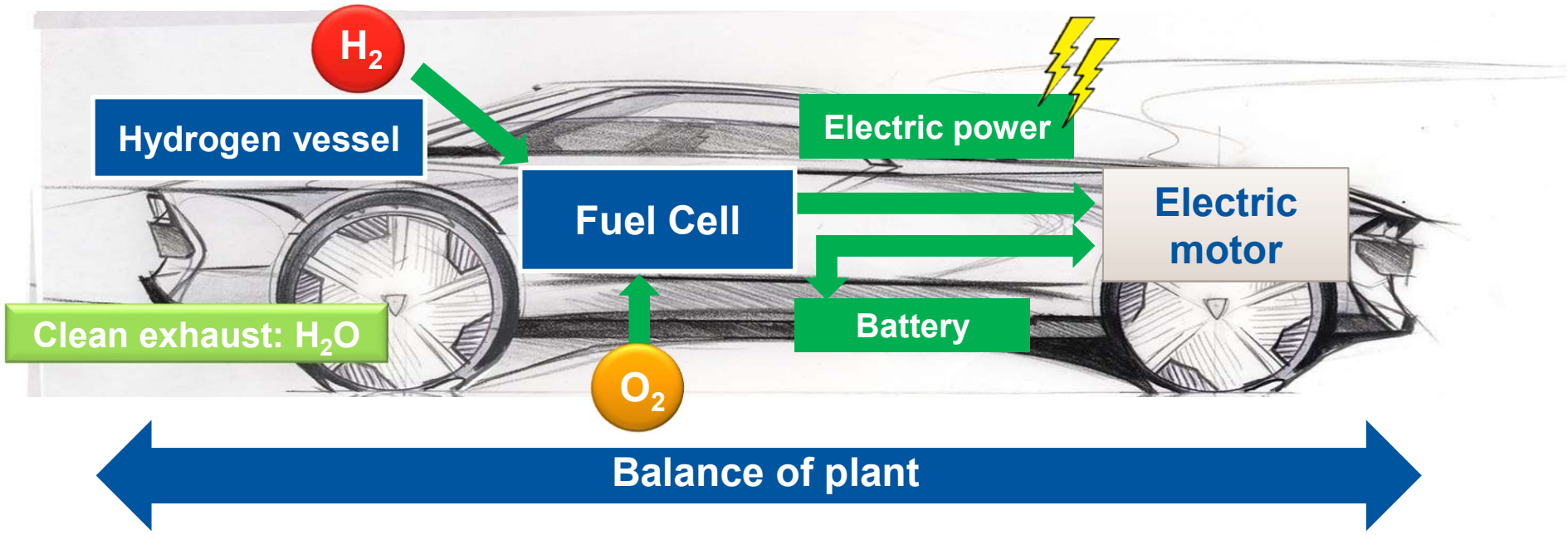
CMP | **EMP2**



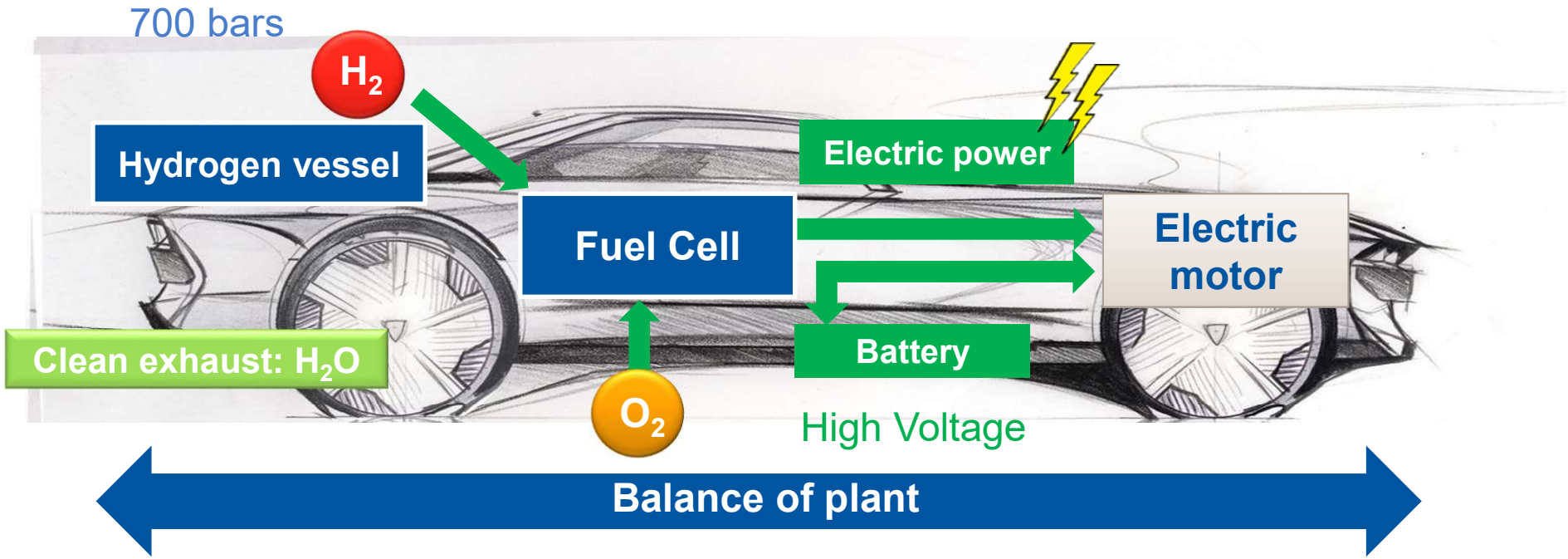
B & C segments
BEV from 2019

C & D segments
PHEV from 2019

What is a Fuel Cell Vehicle?

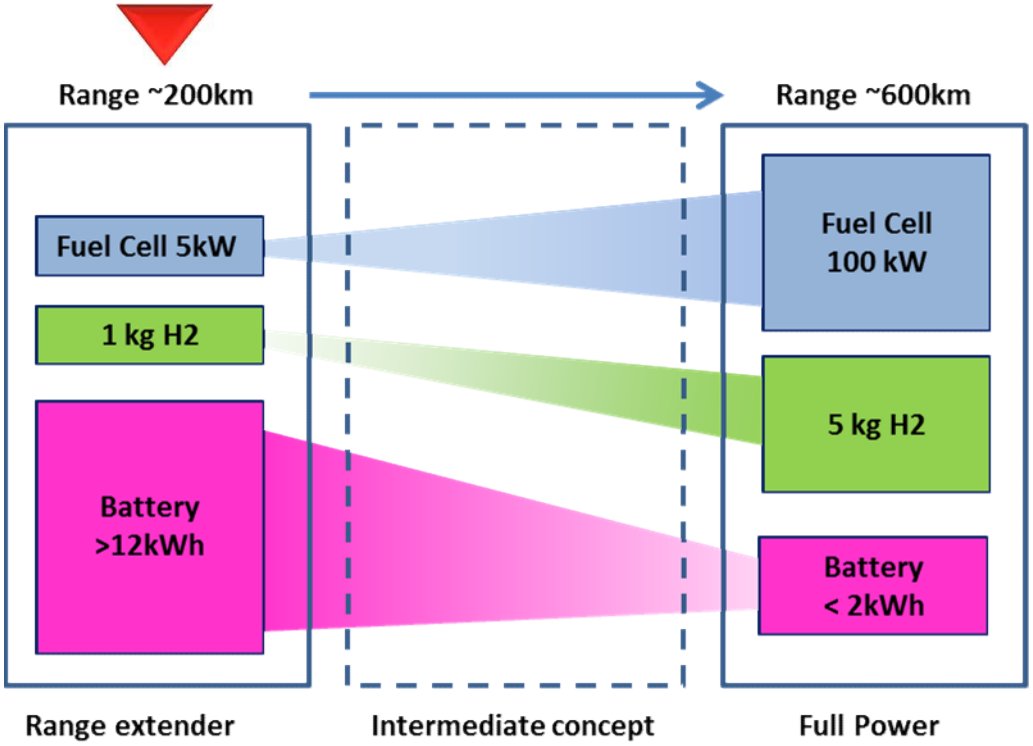


What is a Fuel Cell Vehicle?



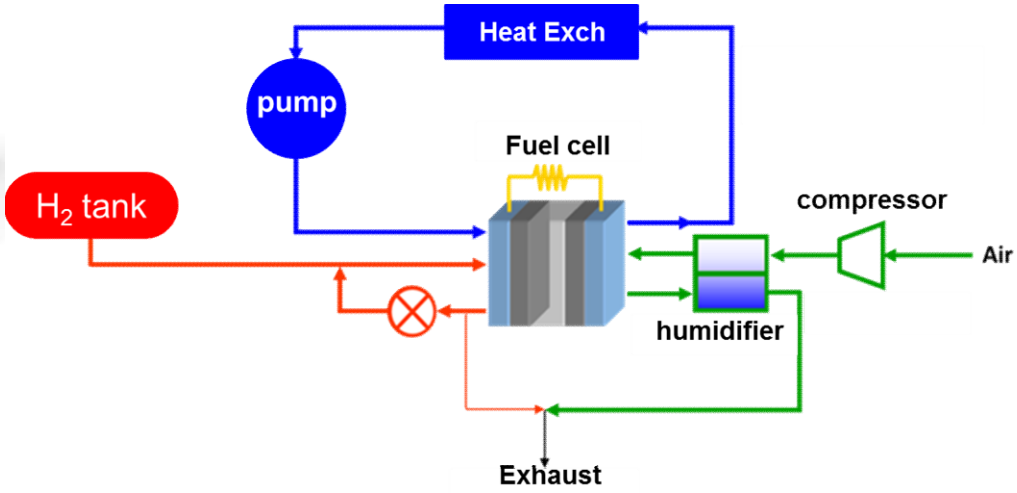
DIFFERENT TYPES OF FCEVS ARE POSSIBLE

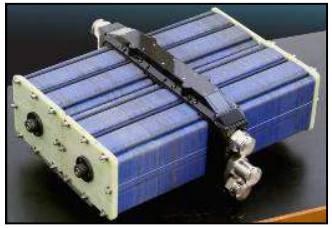
> An Electric Vehicle is based on a hybridization of the Electric Power Supply

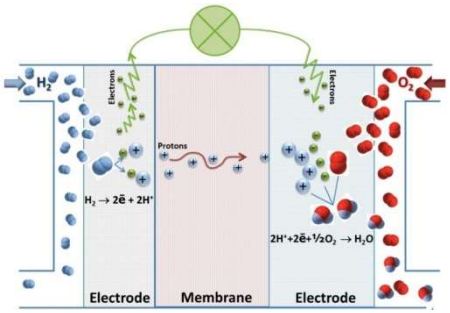


DIFFERENT TYPES OF FCEVS ARE POSSIBLE

- How does a Fuel cell work?
- The full system comprizes the Fuel cell and surrounding peripherals: the Balance of plant
- The heart of the system: the Fuel cell stack
- The hydrogen storage: composite pressurized vessels

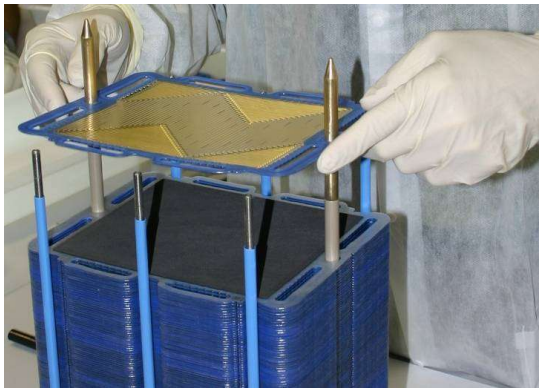


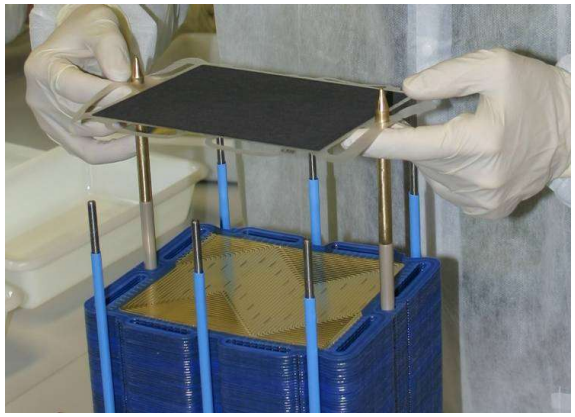


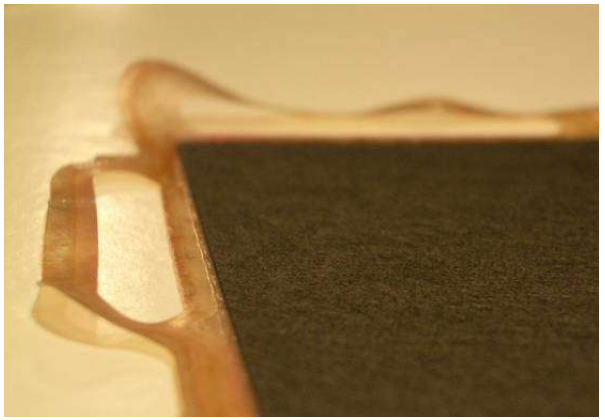


WHAT IS A FUEL CELL STACK

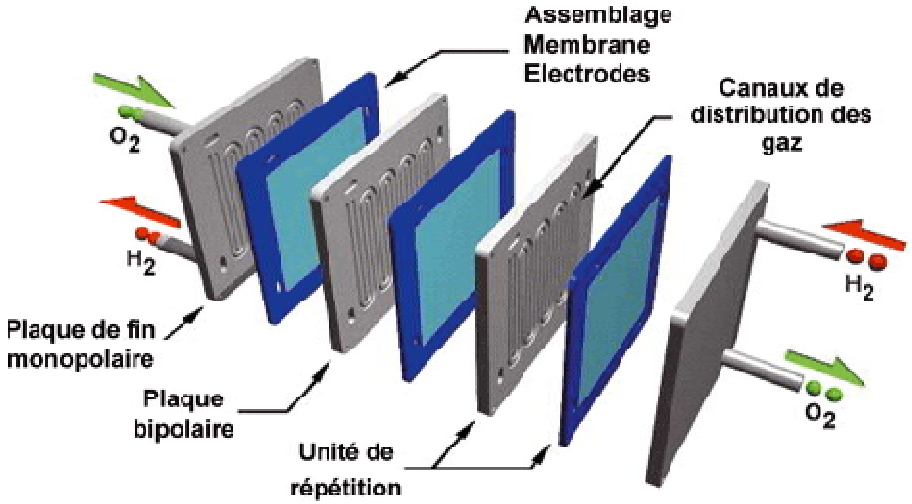
- Bipolar plate
- Membrane Assembly Electrode
- Fuel Cell Stack

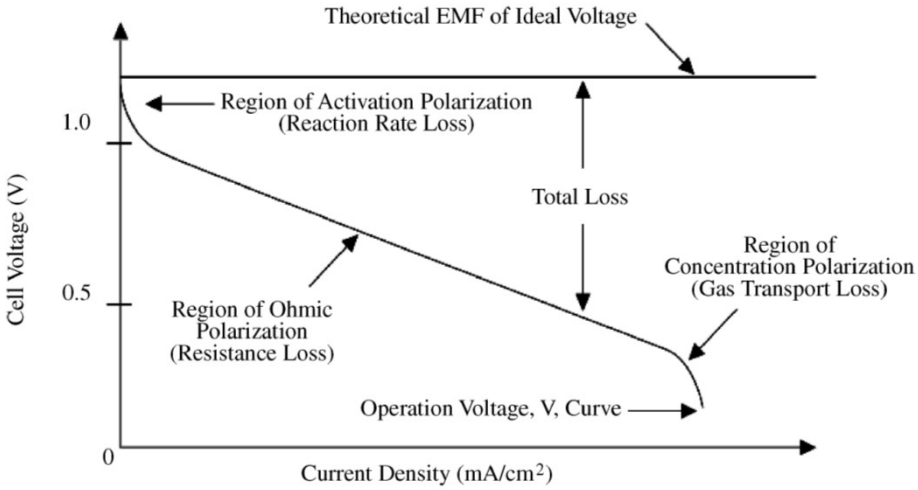




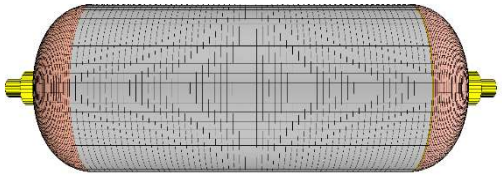


HOW DOES IT WORK?

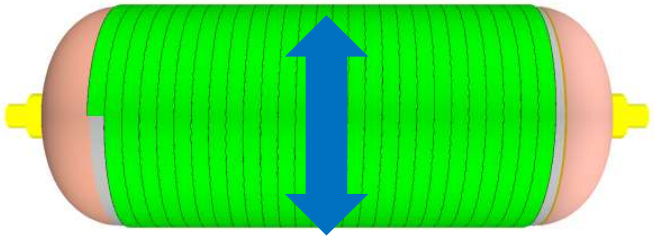




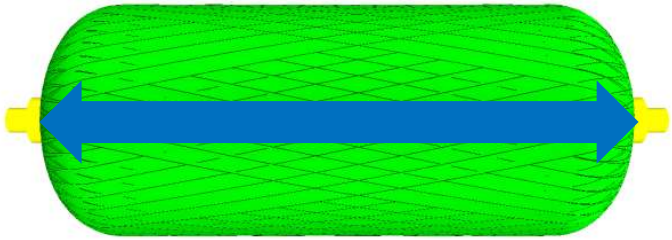
MANUFACTURING OF COMPOSITE PRESSURIZED VESSELS: AN AUTOMATIZED PROCESS FROM SIMULATION TO PRODUCTION

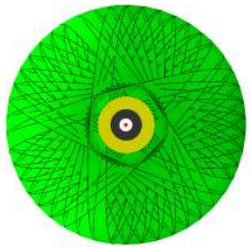


Hoops = resist to radial expansion



Helicoils = Resist to axial expansion



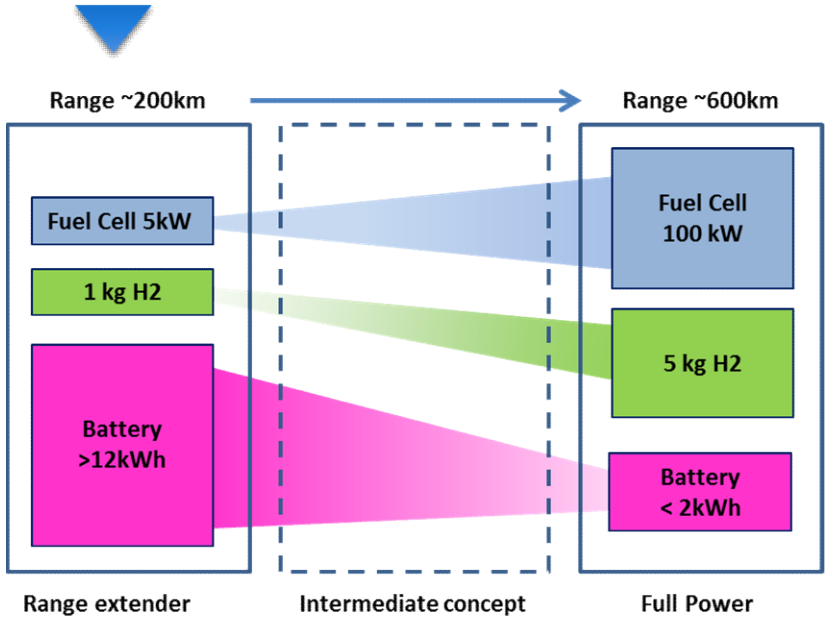


What does a winding process look like?

DIFFERENT ARCHITECTURE OF FUEL CELL SYSTEMS

> An Electric Vehicle based on the hybridization of the Power Supply for Urban / Suburban use: daily range ~200km.

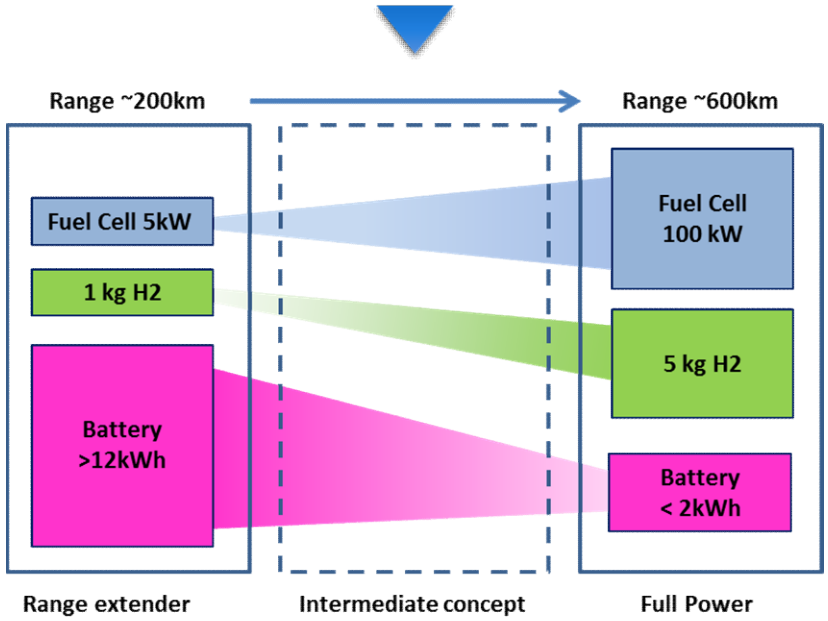
> Range Extender
- HV Battery : >12kWh
- Fuel Cell System : <10kW
- Hydrogen Storage System : 1-2kg H_2
- E-drive : ~70kW



DIFFERENT TYPES OF FCEVS ARE POSSIBLE

> An Electric Vehicle based on the hybridization of the Power Supply for versatile use: daily range ~400km.

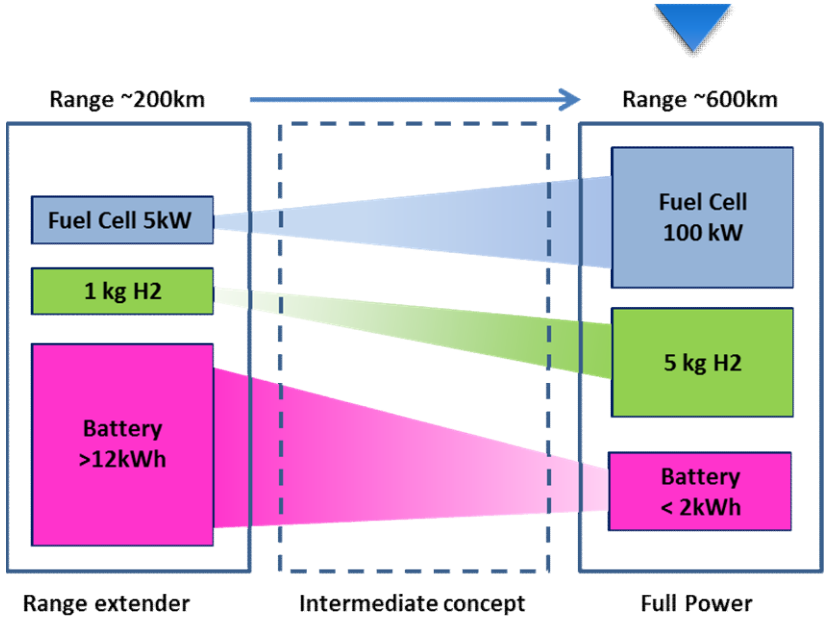
> Intermediate Concept
- HV Battery : ~8-9kWh
- Fuel Cell System : ~20 à 100kW
- Hydrogen Storage System : 3-4kg H_2
- E-drive : ~100kW



DIFFERENT TYPES OF FCEVS ARE POSSIBLE

> An Electric Vehicle based on the hybridization of the Power Supply for versatile and equivalent to today's vehicles: daily range ~600km.

> Full power concept
- Batterie HT : < 2kWh
- Fuel Cell System : ~100kW
- Hydrogen Storage System : 5-6kg H_2
- E-drive : ~100kW



FCEVs ALREADY COMMERCIALLY AVAILABLE IN 2019

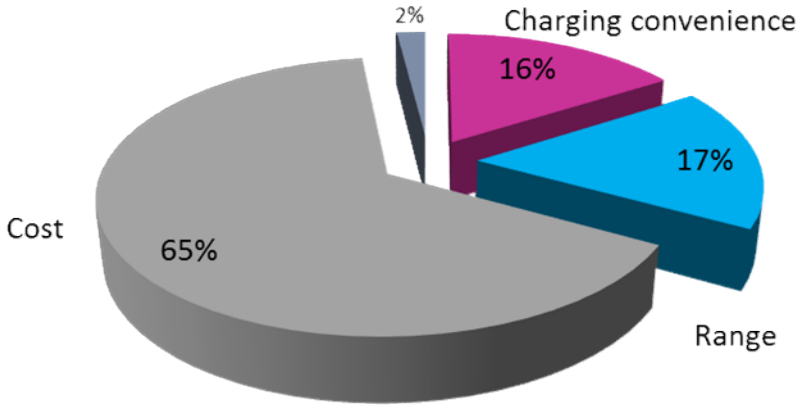
- Available FCEVs concepts are fully functional and validated (durability, safety).
- FCEVs are Zero Emission Vehicles, only emiting vapor water.
- FCEVs offer fast recovery of autonomy (H_2 refueling within ~ 3-5 minutes).
- Only limited number of models are proposed today by some car makers.




~ 1/3 OF CUSTOMERS VALUE RANGE AND CHARGING MORE THAN COST AND DON'T CONSIDER FAST CHARGING SUFFICIENT

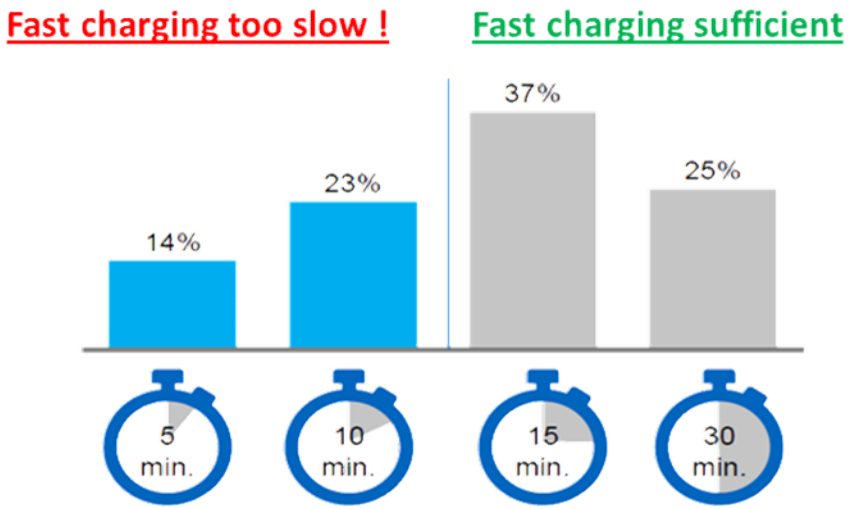
Top factor when chossing a new car

Share of respondents



Maximum acceptable time for charging

Percentage of respondents



Source : customers survey 2018 held by Mc Kinsey.

WHY DON'T WE FIND MORE FCEVS ON THE ROADS THEN?

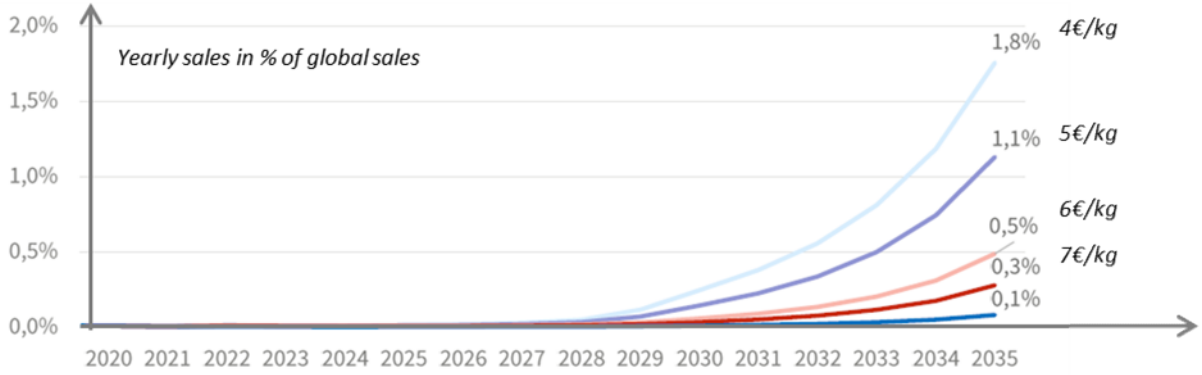
> Some challenges & questions about Hydrogen & FCEVs remain

- Are FCEVs really green vehicles? ...
- How to produce hydrogen? ...
- What about CO_2 total emissions? ...
- What is the effective Energy performance? ...
- How do we manage the system integration? ...
- What is the real cost of the technology? ...
- What about the refueling infrastructure? ...
- Is it a really safe technology? ...

DEPLOYMENT SCENARIO: SEVERAL DRIVERS AFFECT THE MARKET OF FCEV

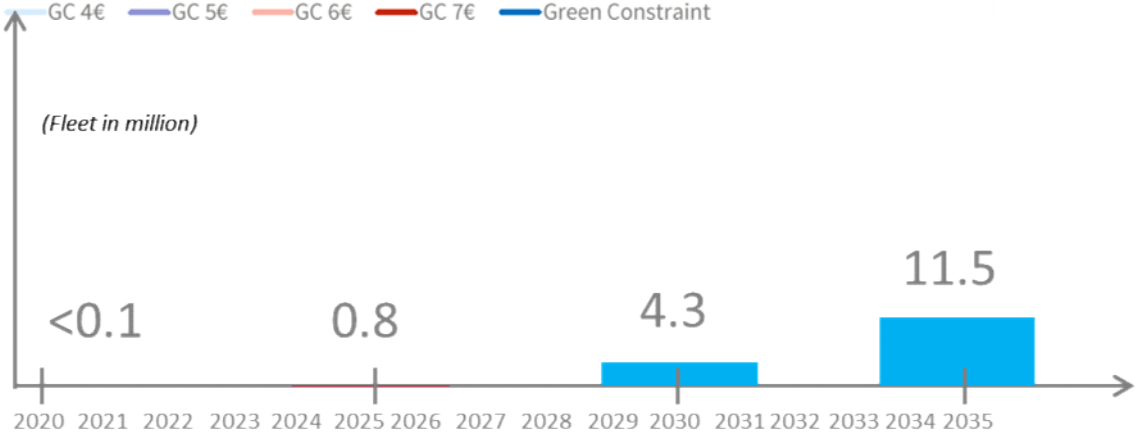
Etude de sensibilité au prix de l'hydrogène à la pompe

Source : BiPE 9.2018

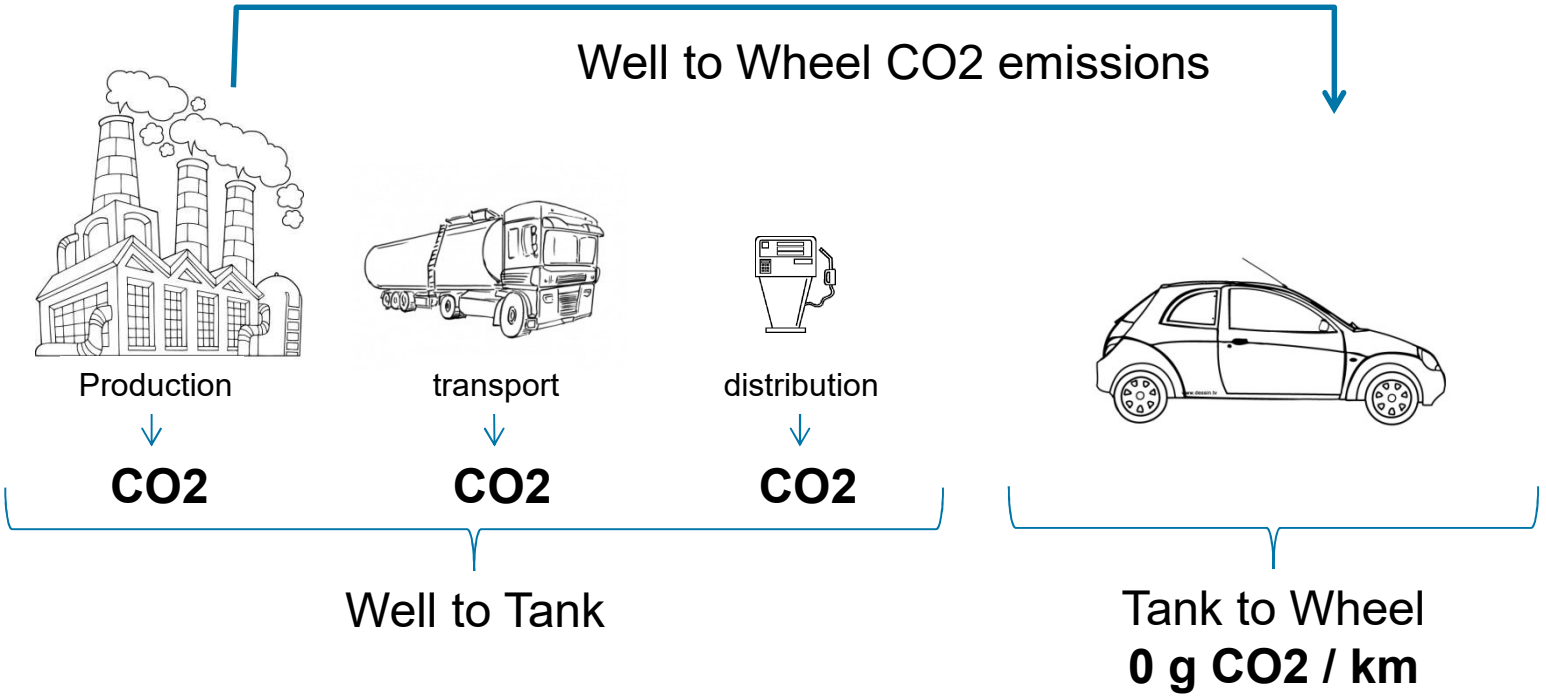


Ambitious Scenario "acceleration of H2 deployment"

Source : Hydrogen Council 11.2017



> Yes but …

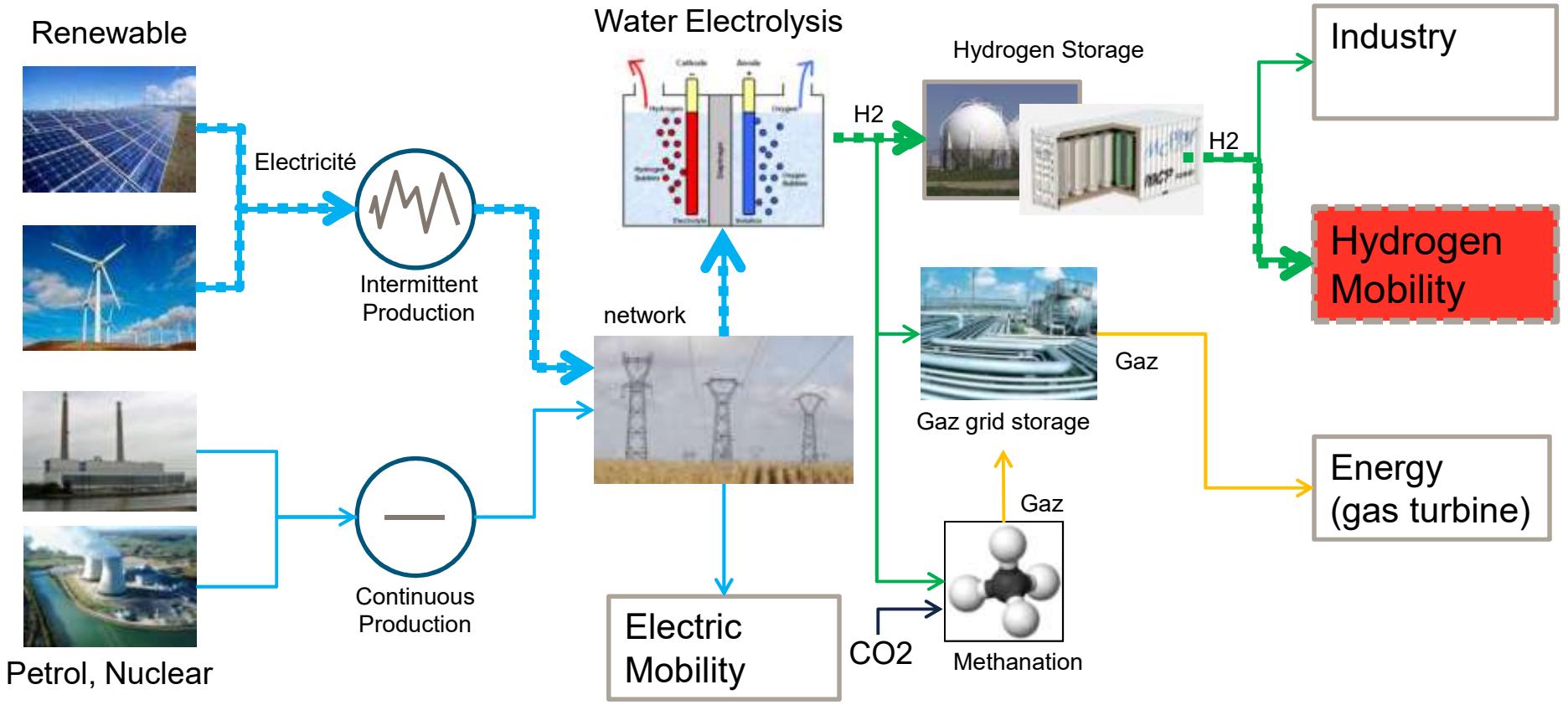

Well to Wheel CO2 emissions
Production
transport
distribution
CO2
CO2
CO2
Well to Tank
Tank to Wheel
0 g CO2 / km

> How to produce hydrogen?

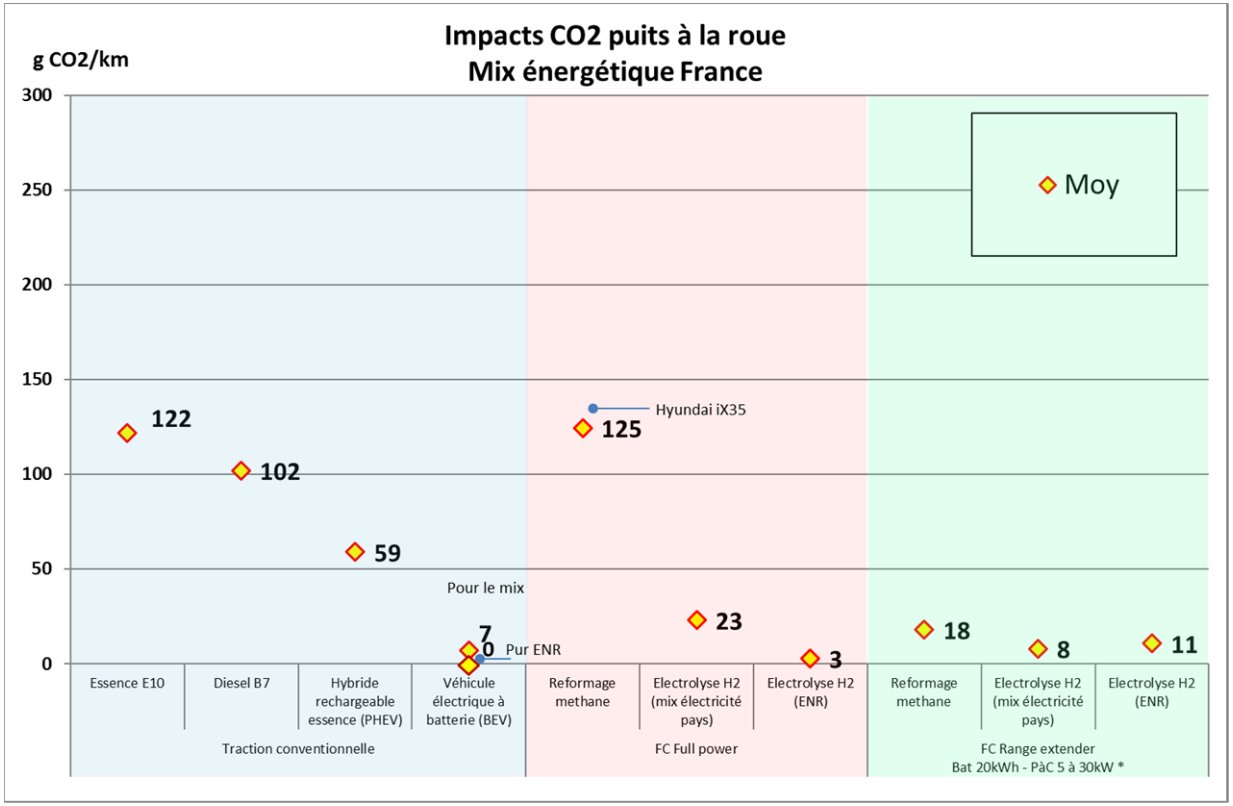
- Main way: use of carbon compound to produce hydrogen
  - Steam reforming of natural gaz (SMR)
  - 1kg H_2 produced by SMR = emission of ~10kg CO_2

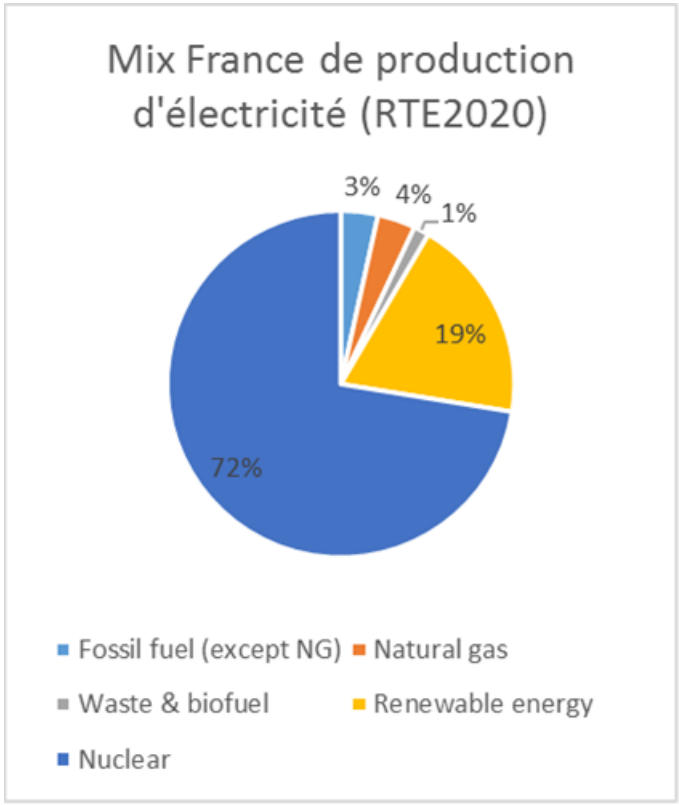
- But new processes can help to decrease CO_2 emissions
  - Water Electrolysis but required electricity from renewable
  - Carbon Capture & Sequestration (CCS) combined with SMR

THE COMPLETE ECOSYTEM NEEDED FOR H_2 MOBILITY

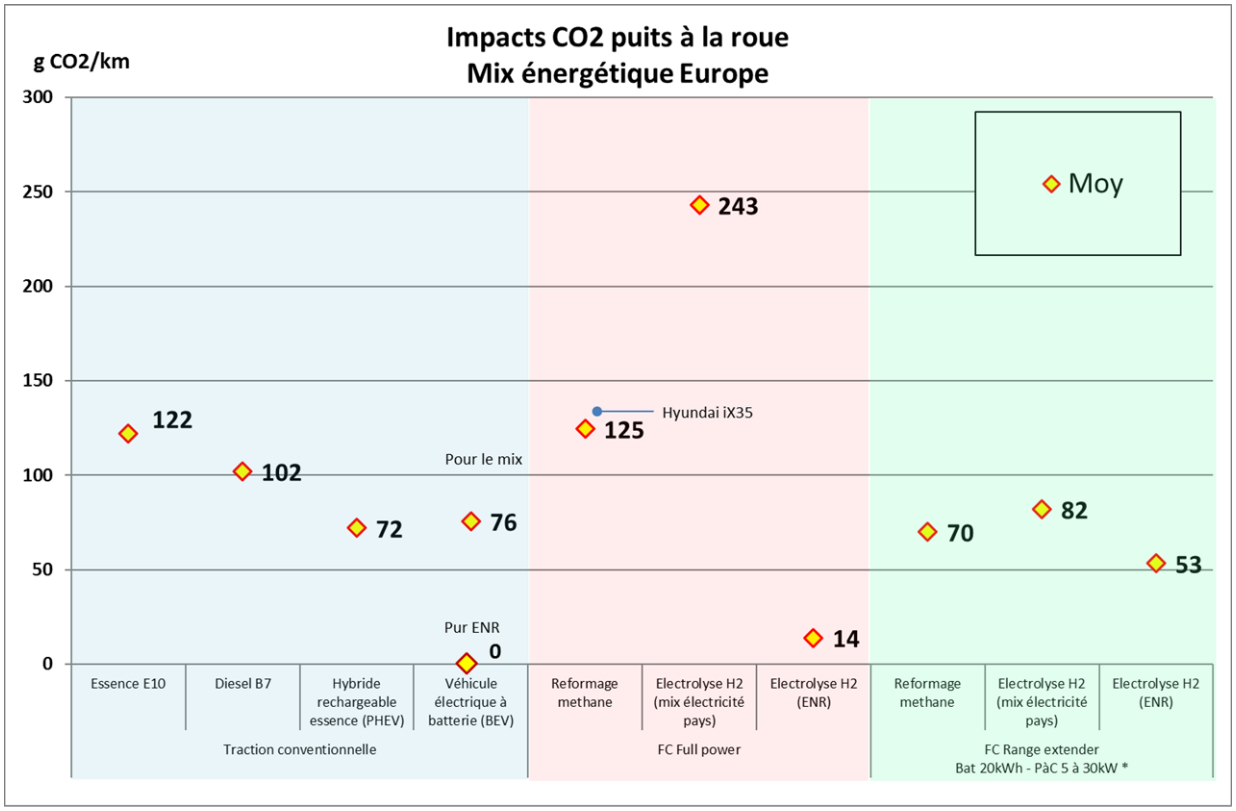


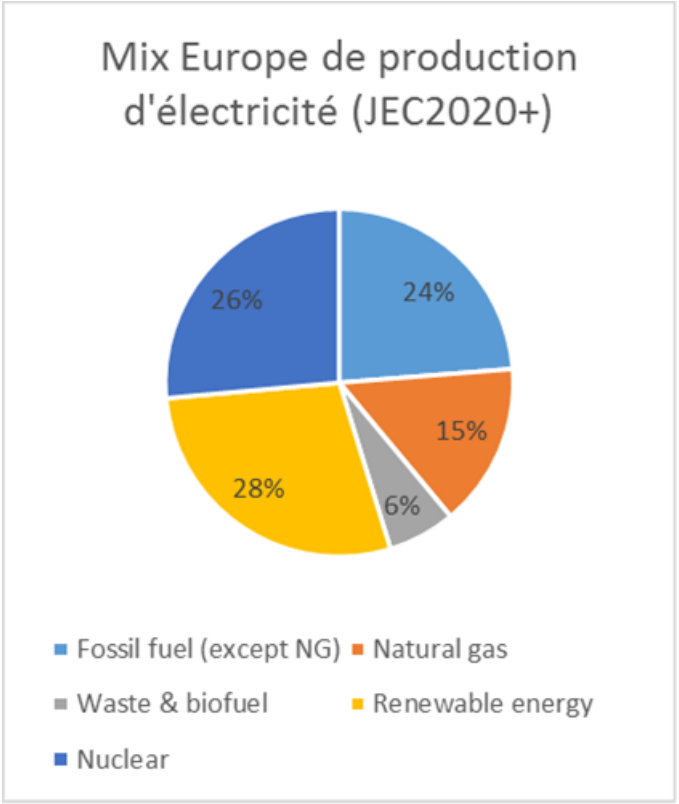
WELL TO WHEEL LIFE CYCLE ANALYSIS OF POWERTRAIN - FRANCE



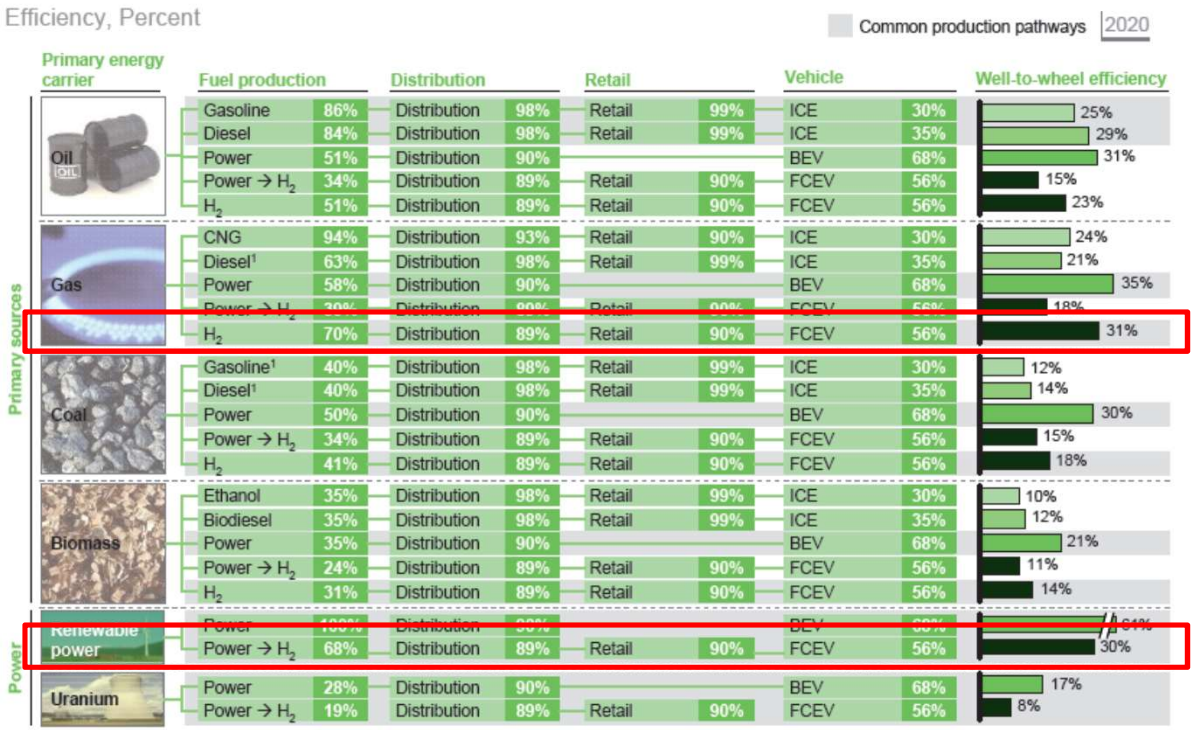


WELL TO WHEEL LIFE CYCLE ANALYSIS OF POWERTRAIN : EUROPE





WELL TO WHEEL EFFICIENCY OF DIFFERENT POWERTRAINS

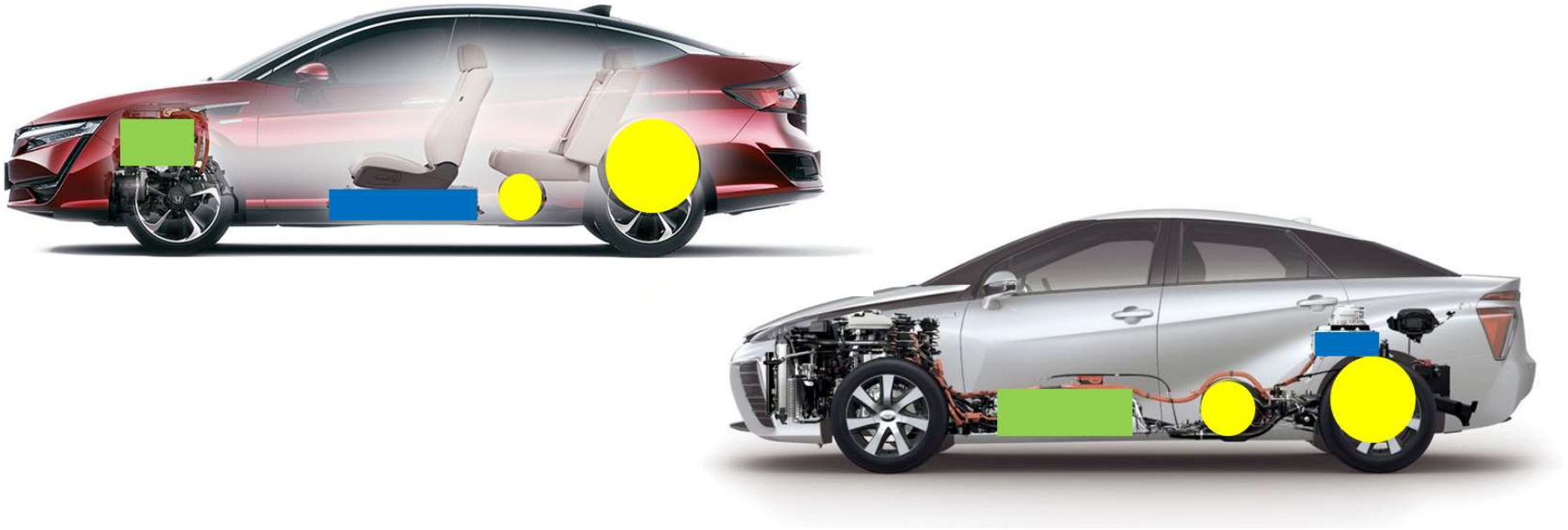


1 Gasoline and diesel production through Fischer-Tropsch process

SOURCE: CONCAWE-EUCAR JEC-WTW study; study analysis

- 8 to 31% WtW efficiency for FCV powertrain
- Same range of ICE efficiency
- BEV the leading powertrain
- Renewable power or gaz : efficient ways

> A complex system to integrate in a vehicle…



> … without safety issue, and without prejudice on livability

How is a Fuel cell integrated in the vehicle?

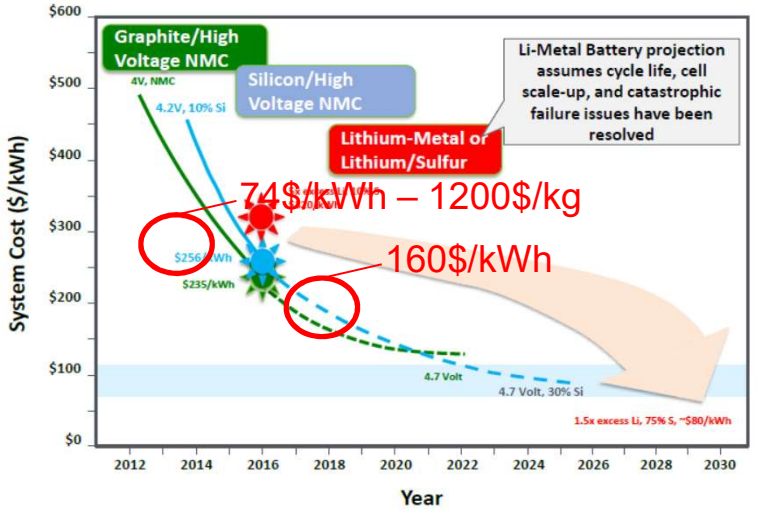
> A complex system to integrate in a vehicle… thermal management

> Fuel Cell System efficiency ~50%: high thermal energy to dissipate by the front heat exchanger

THE COST OF THE TECHNOLOGY NEEDS TO IMPROVE

Source : Department Of Energy

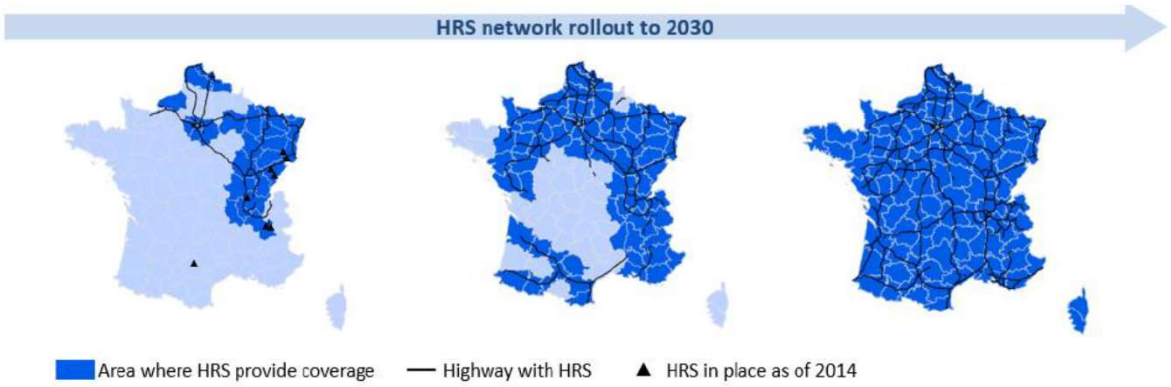
> An economical challenge … on the vehicle
- FCEVs cost ~ 70000€
- Fuel Cell System & Hydrogen Storage System competitivity are required for FCEVs mass production



> An economical challenge… on hydrogen cost (@ Hydrogen Refueling Station)
- Production, transport, retail
- From 8 to 15€/kg H_2 (today)

THE INFRASTRUCTURE HAS TO GROW

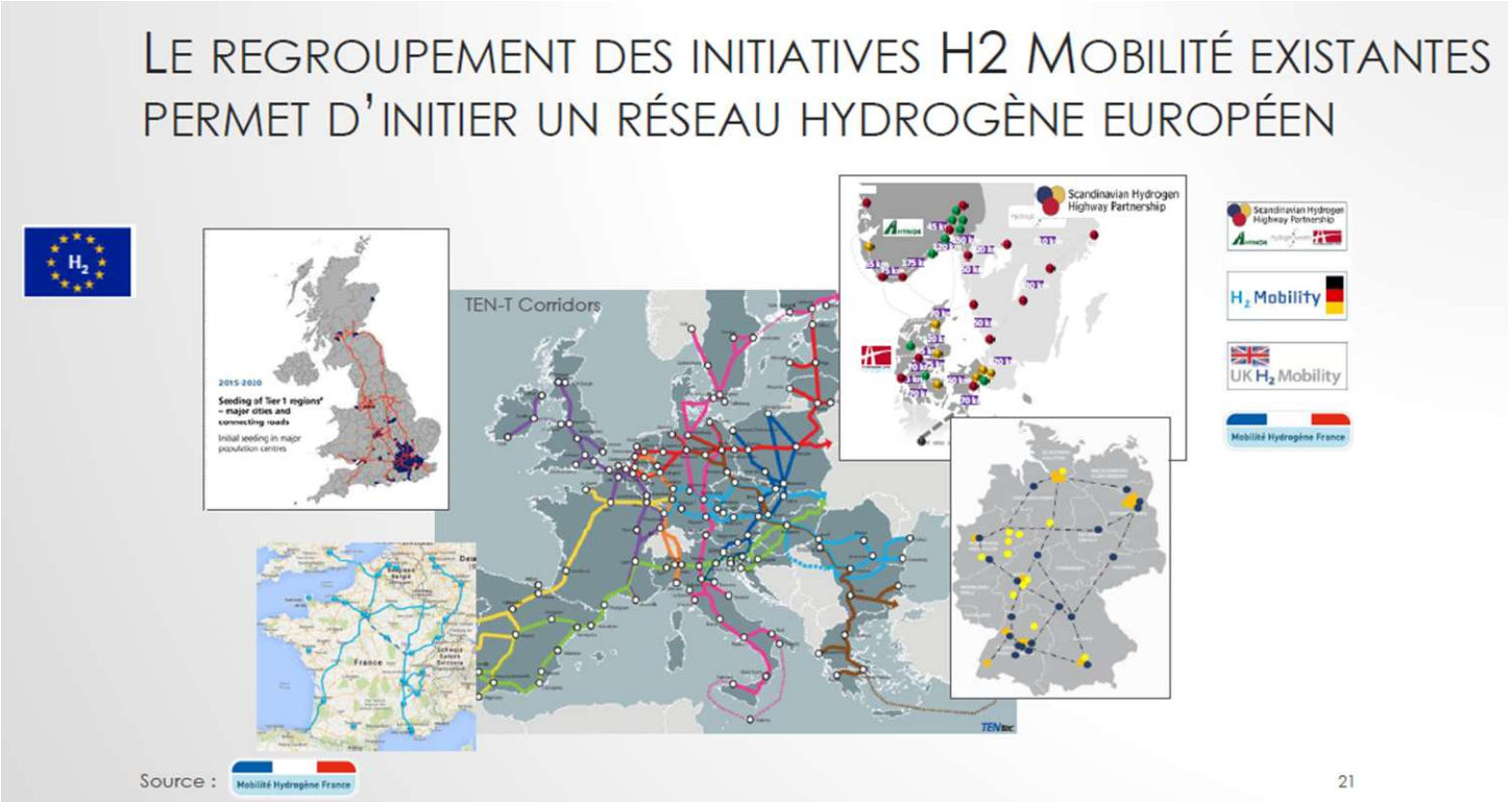
- H_2 mobilité France: to propose a risk limited deployment scenario of FCEVs using regional clusters:



H2MF strategy (2014): expansion of the HRS network up to 2030

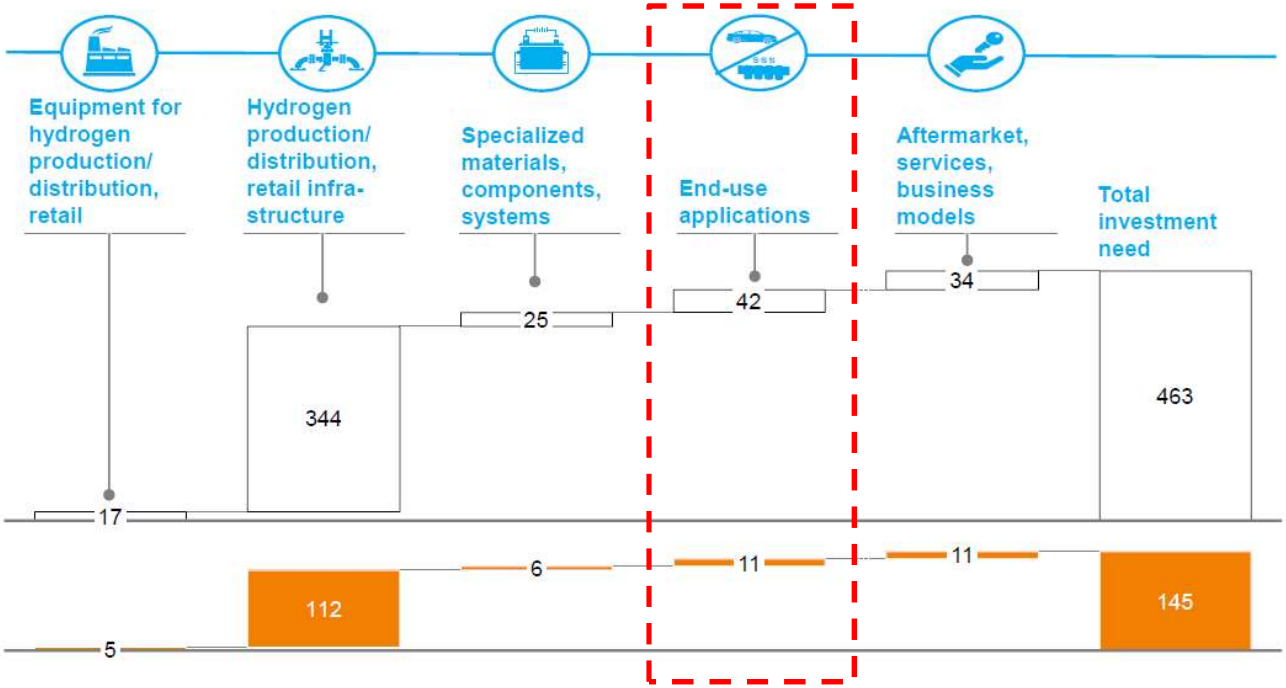
- New hydrogen refueling station arrive in France: the last one openned in Orly!
- National target for 2023: 100 hydrogen refueling station
- H_2 mobility Germany: already 400 hydrogen refueling station expected by 2023.

FROM NATIONAL TO EUROPEAN INFRASTRUCTURE EXPANSION



INVESTMENT NEEDS: IN TOTAL, INDUSTRY PLAYERS NEED TO INVEST BETWEEN 130 AND 450 BN EUR UNTIL 2050.

Total investment needs (estimation)
cumulative between 2018-2050, in EUR bn



Ambitious Scenario
"acceleration of H2 deployment"

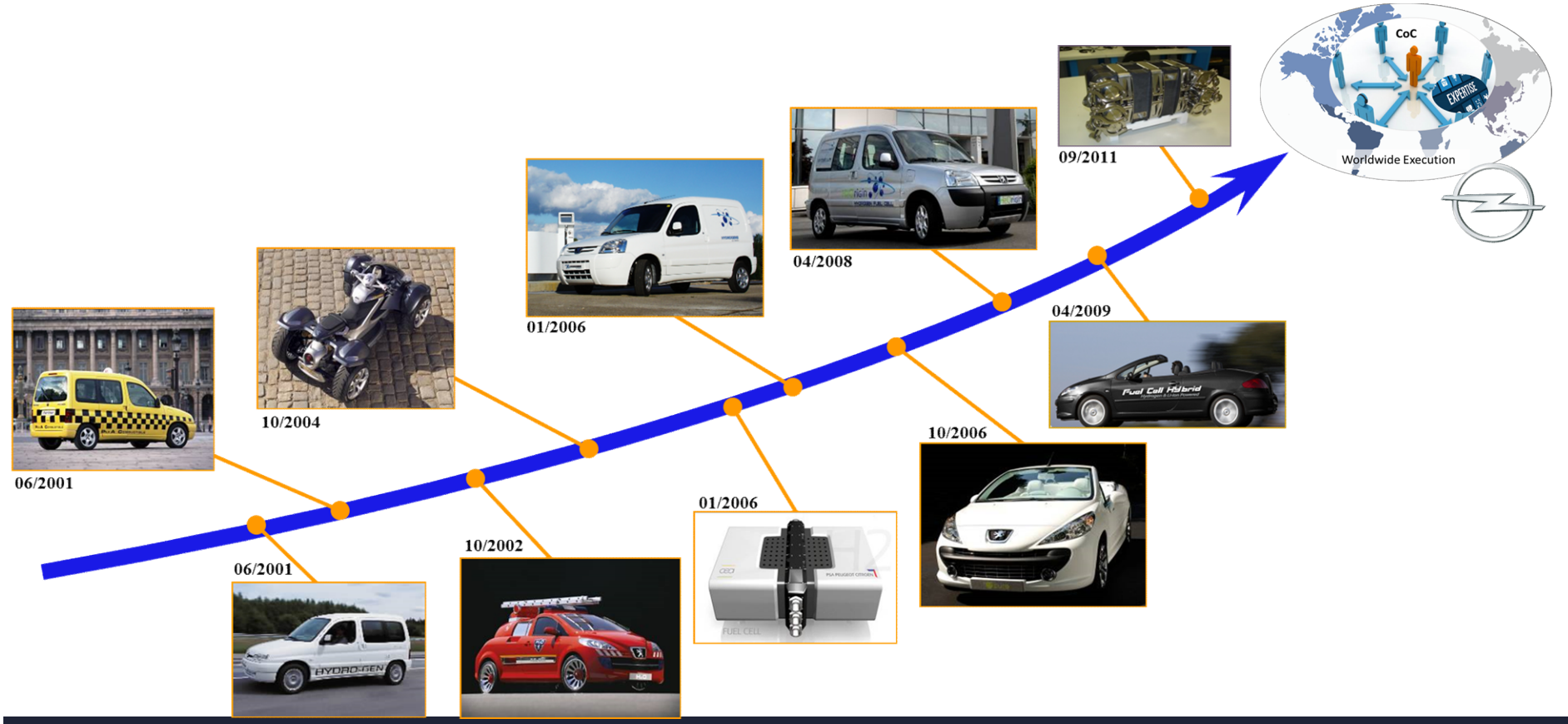
Business as usual

Source : Hydrogen Council 2017 study

How is France competing in the global H_2 economy?

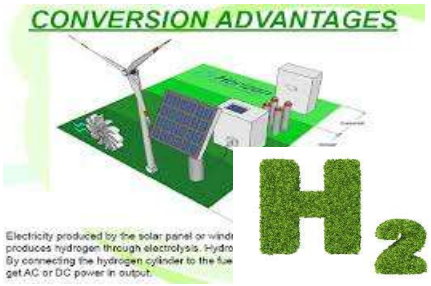
- **Fixing 10% Hydrogen share by 2023**
- **Engaging 100 M€ to support the first initiatives of the plan, under the umbrella of the ADEME agency.**
- **2018 and onwards new projects are labelled as "ECV" (Engagements pour la croissance verte), for the automotive and other industrial sectors.**

GROUPE PSA AND HYDROGEN : A LOT OF TECHNOLOGICAL DEMONSTRATOR SINCE 2001



WHAT HAS CHANGED FOR PSA SINCE 2011…

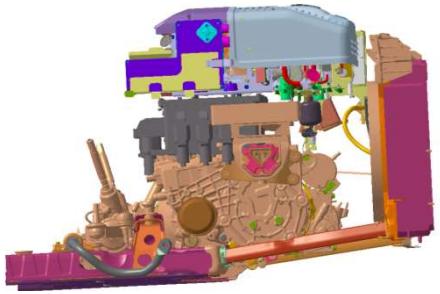
- **H2 production**



- **Costs**

- **H2 distribution**

- **H2 platform integration**



- Positive evolutions on the 4 identified roadblocks that confirm interest in re-opening opportunities on H2 activities

CONCLUSIONS

- **Hydrogen technologies are still in R&D phase with already available products in different segments of the market and some expanding fleet numbers.**
- **FCEV & BEV are complementary technologies**
- **The challenges of greenhouse gases and global warming make the use of hydrogen a necessity to decarbonize several areas of the industry, including mobility and transportation.**
- **Regulation authorities, politicians, OEMs and suppliers are preparing a number of initiatives and product launches to make Hydrogen become a reality for transportation.**
- **The key to succeed : R&D investment required from OEM & tier one suppliers to decrease technology cost (with industrial process).**
- **Need of a complete hydrogen ecosystem to propose a global service offering**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