Université d'ORLÉANS
POLYTECH ORLÉANS

# DESIGN OF AN ULTRA-LOW CARBON FOOTPRINT VEHICLE FOR PEOPLE WITH REDUCED MOBILITY

bertrandt

## INTRODUCTION

### What ?

Design of a vehicle-embedded hydrogen generator (L6-A quadricycle)

### Innovation ?

Use of a reversible fuel cell (**PEM-FC/EC** : **P**roton **E**xchange **M**embrane - **F**uell **C**ell / **E**le**C**trolyzer)

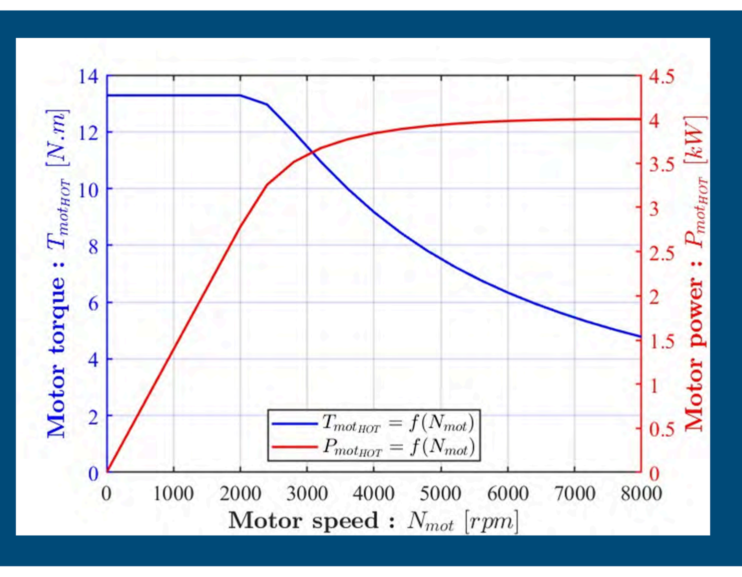
### How ?

SC AME

Powertrain sizing and control with advanced numerical simulations on WLTC class 1 cycle

### Specifications & Standards

- $650\ kg\ (GWV)$
- $P_{motor_{max}} \leq 4\ kW$
- $v_{max} = 50\ km/h$
- $Range \geq 100\ km$
- $Reversible\ fuel\ cell$



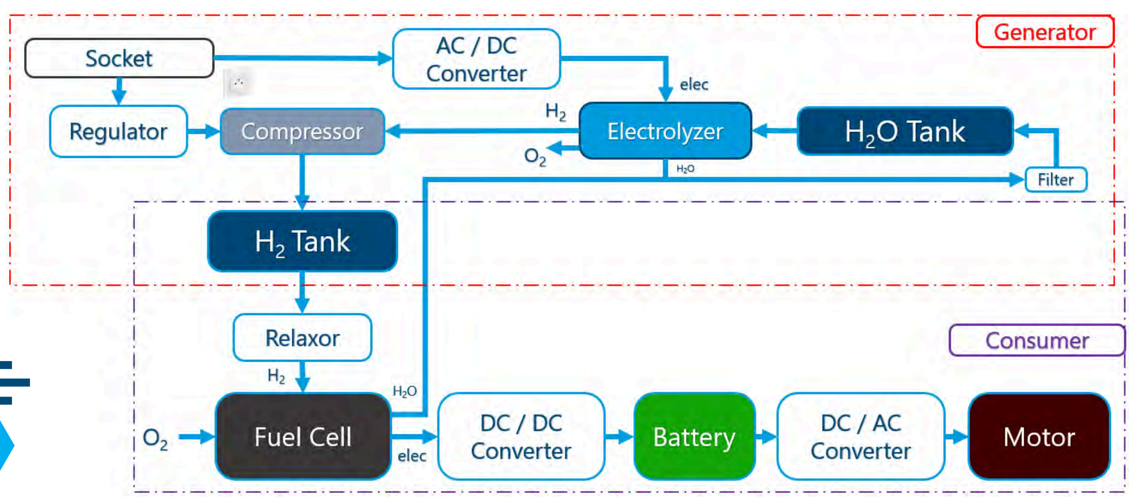

| Distance : d [km] | Comsumption : E [kW.h] |
|---|---|
| 6.648 | 0.2 |
| 100 | 3 |

### Hydrogen mass production ?

- Initial estimation :
  - $\eta_{PEM-FC} \approx 0{,}4$ (based on real FC)
  - $coef\,f_{safe} \approx 10\ \%$ (dispersions, aging, etc.)
  - $\rightarrow E_{PEM-FC} = \frac{1}{\eta_{PEM-FC}} * (1 + coef\,f_{safe}) * E_{100km} = 7.4\ kW.h$
- Amount of $H_2$ to produce 7.4 kW.h :
  - $LHV_{H_2} = 120\ 000\ kJ/kg = 0{,}0333\ kWh/g$
  - $m_{H_2} = \frac{E_{100km}}{LHV_{H_2}} = \frac{7{,}4}{0{,}0333} = 222\ g$

## 1 FUNCTIONAL DIAGRAM OF THE PROPOSED SOLUTION

- Composed of 2 parts (**Generator** and **Consumer**)
- Linked by an $H_2$ tank
- Hydrogen production when plug-in at home
- Electricity production when driving



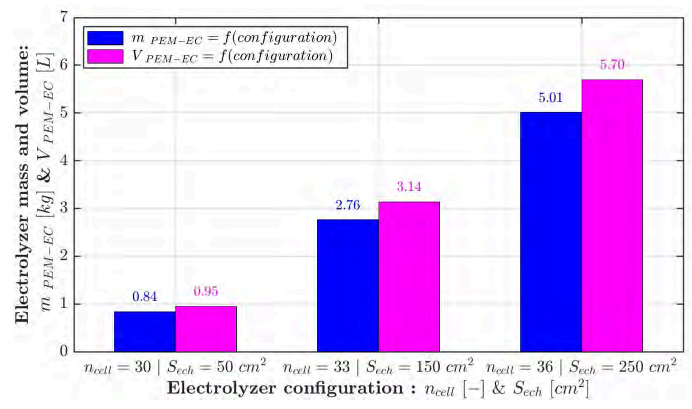

## 2 ELECTROLYSER SIZING STUDY (PEM-EC)

**Differents sizes of electrolyser were studied,** by varying two parameters :

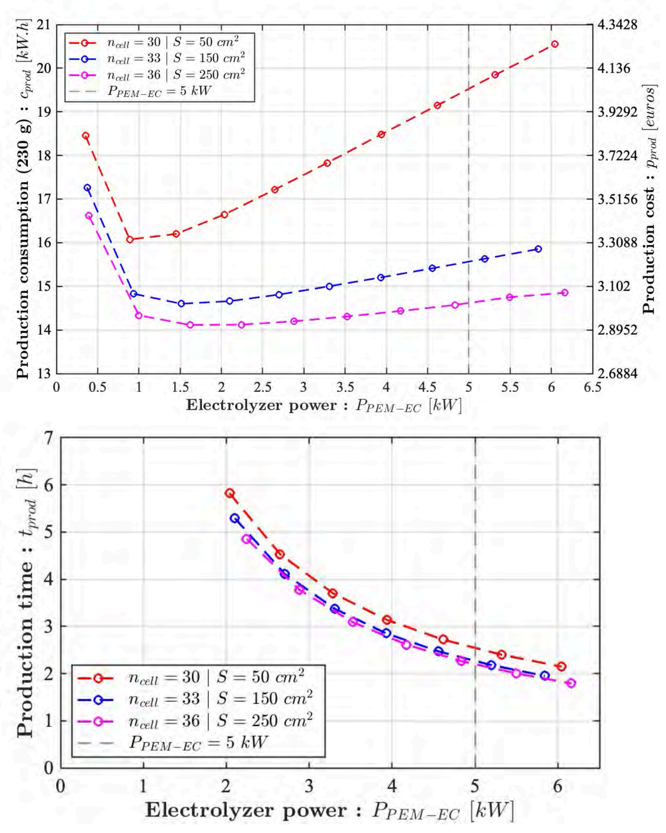
- The **number of cells**
- The **active surface area** of the component.

The study focused on three sizes of electrolyser :

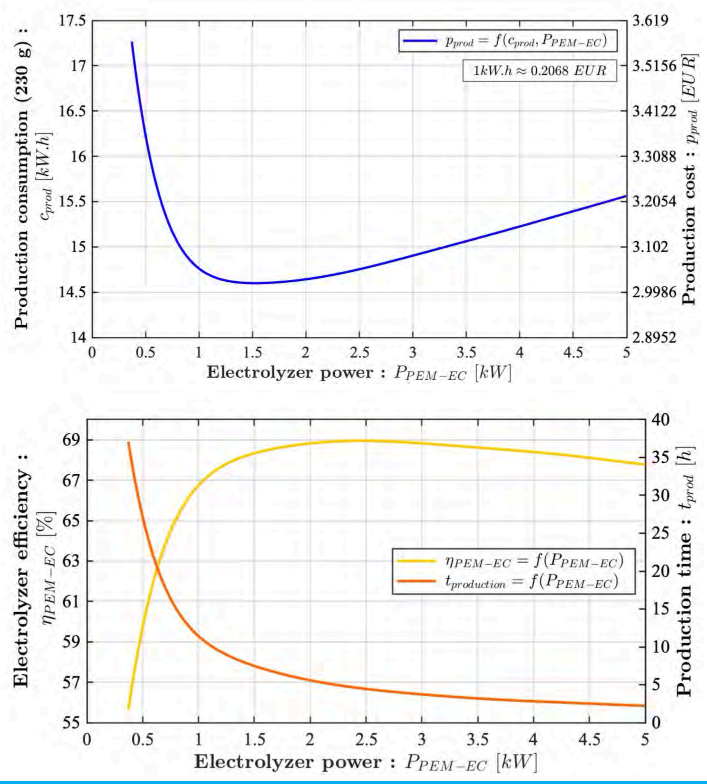
- **A large model**
- **A small model**
- **A compromise**




Study comparisons




Results of the choosen model




## 3 COMPRESSION SOLUTIONS

| Pressure | | Volume density (Molecule : *Dihydrogen* ($H_2$)) | | Storage volume | |
|---|---|---|---|---|---|
| $p\ [MPa]$ | $p\ [bar]$ | $\rho\ [kg/m^3]$ | $\rho\ [g/L]$ | $V\ [m^3]$ | $V\ [L]$ |
| 0.1 | 1 | 0.0827 | 0.0827 | 2.8 | 2781 |
| 1 | 10 | 0.82219 | 0.82219 | 0.28 | 280 |
| 10 | 100 | 7.7965 | 7.7965 | 0.030 | 30 |
| 25 | 250 | 17.863 | 17.863 | 0.013 | 13 |
| 35 | 350 | 23.65 | 23.65 | 0.0097 | 9.7 |
| 50 | 500 | 31.218 | 31.218 | 0.0074 | 7.4 |
| 70 | 700 | 39.692 | 39.692 | 0.0058 | 5.8 |

What to compress ?

230 g of $H_2$

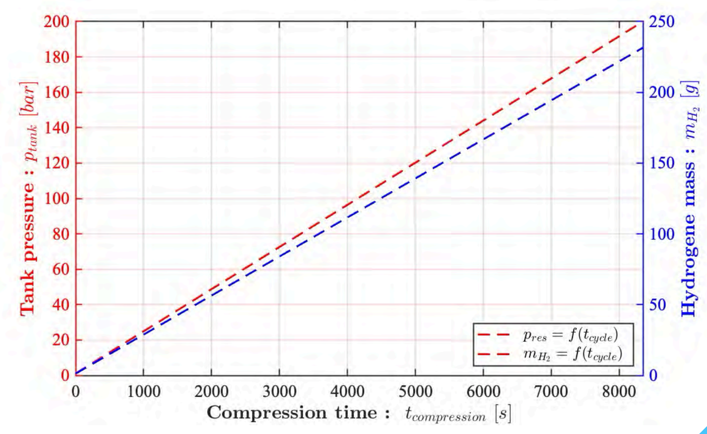
How ?

Using a compressor up to 200 bars

**Result compression and confirmation**

- Totality of the 230 g of hydrogen compressed at 200 bars.
- In 2 hours and 20 minutes
- Compression at the same time as production.
- Representing a volume of 14 L in the $H_2$ tank.

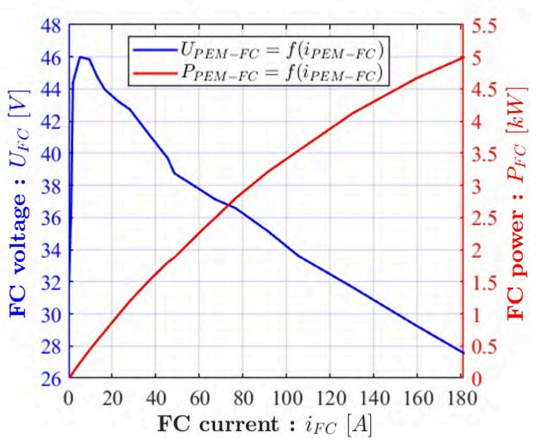
- **2 h 20 min** → generation/compression for 100 km
- **Cost : 3.20 €** (15.5 kW.h) → full recharge




## 4 FUEL CELL SIZING STUDY (PEM-FC)

$$U_{battery_{min}} \approx U_{min_{PEM-FC}} = n_{cell} \times U_{cell_{min_{PEM-FC}}} \approx 30\ V$$

$$U_{battery_{max}} \approx U_{max_{PEM-FC}} = n_{cell} \times U_{cell_{max_{PEM-FC}}} \approx 46\ V$$

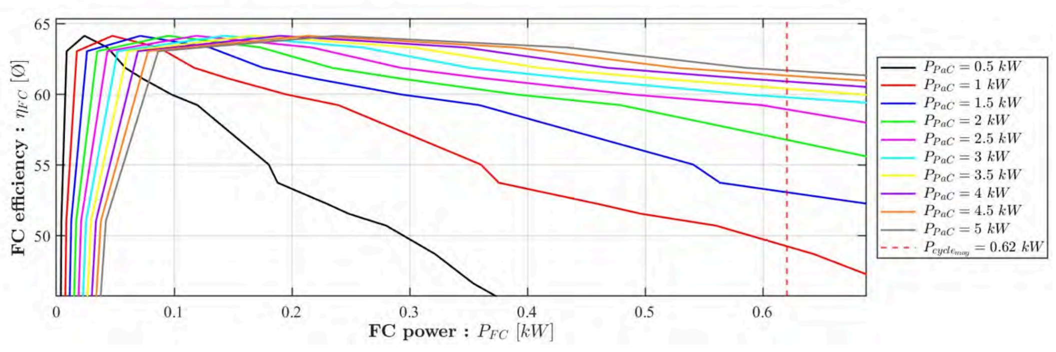



Efficiency

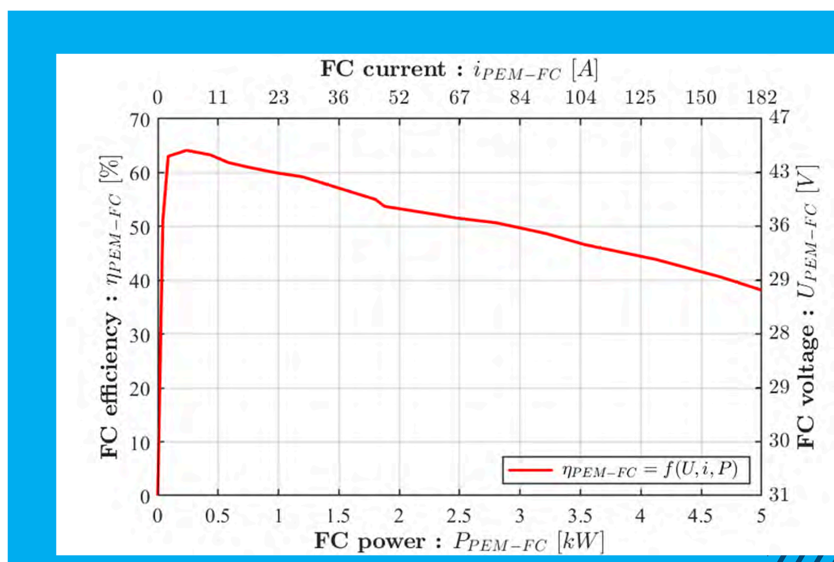
- Voltage : $U\ [V]$
- Current : $i\ [A]$
- Mass flow rate : $\dot{m}_{H_2}\,[g/s]$

$$\eta_{FC} = \frac{P_{FC}}{LHV_{H_2} \times \dot{m}_{H_{2FC}}}$$

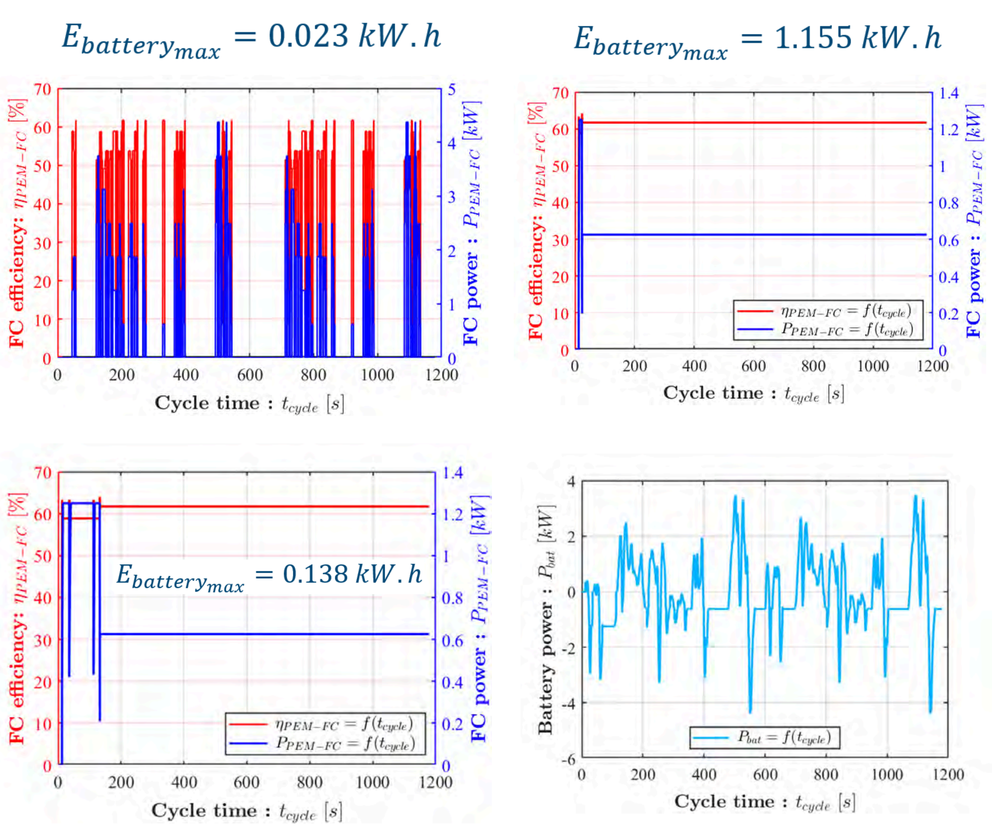
Study comparisons



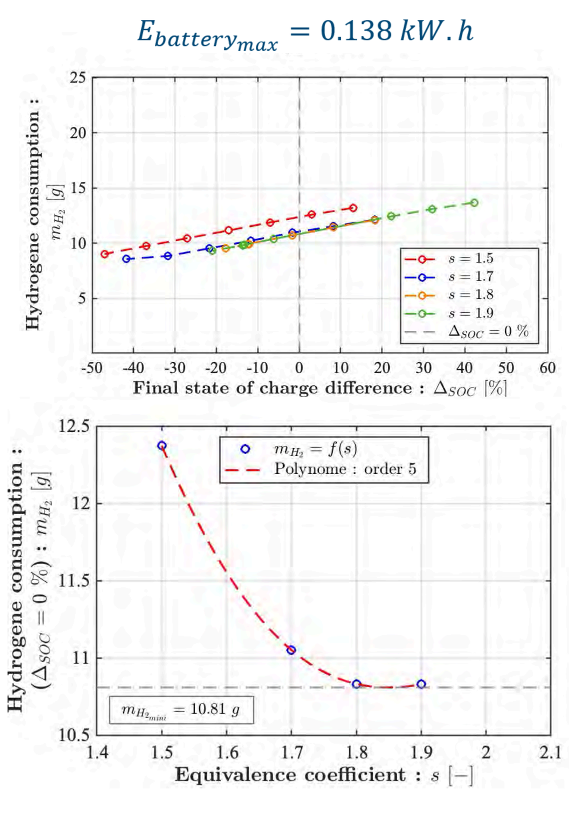

Results of the choosen model




## 5 BATTERY SIZING STUDY (PEM-FC)




## 6 ENERGY MANAGEMENT STRATEGY




- Based on Equivalent Consumption Minimisation Strategy (ECMS)
- Finding the equivalence coefficient "**s**" for minimum hydrogen consumption over the cycle with zero difference in battery state-of-charge.

## CONCLUSION

- Design and dimensioning of **each individual components** (battery, reversible fuel cell, motor, etc.).
- The concept at the research stage **makes sense**, and simulations show the **feasibility** of the project.
- **Next steps :** test bench, a trainee takes over project, ...

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# Eco Design of a Battery Electric Vehicle

Quentin P., Bérénice M., Bouchra A., Matthieu C., Daniel C.D.S, Ouafae E.G.M., El Hadj M.

## 1

## Reducing the environmental and economic impacts of EVs requires better design tools

**Want more range ?**
You'll need a bigger battery - and more emissions

**Want a cheaper car ?**
You might reduce motor size - and lose efficiency

We've created 3 simulation tools to guide eco-design from start

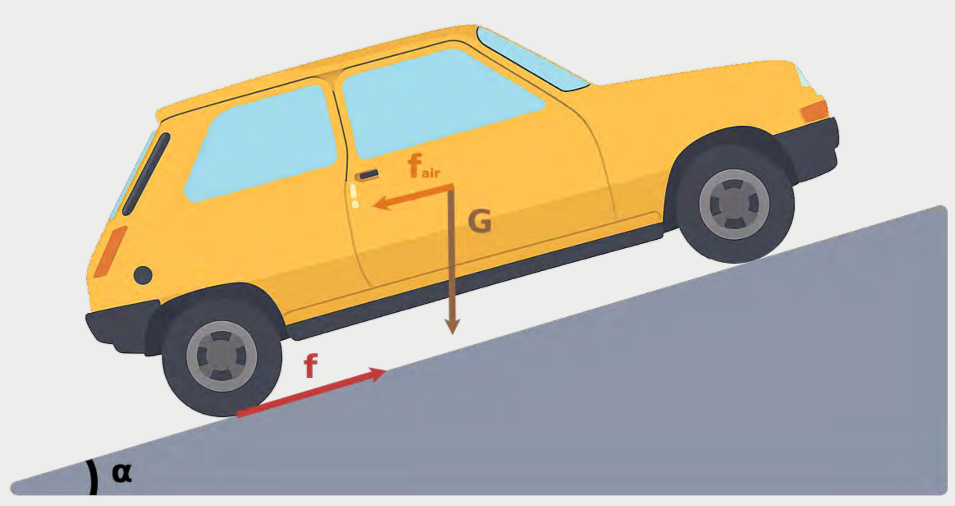
Throughout this paper, we have assumed an urban driving cycle for our tests, and all prices are given as averages for Europe.

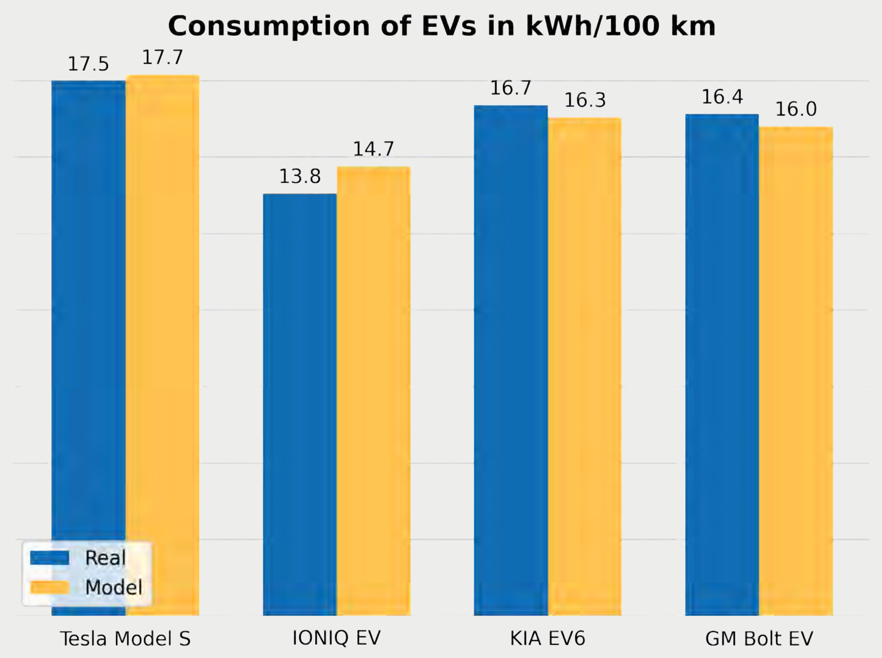
## 2

## A dynamic energy model accurately estimates EV energy use

Our model predicts how much energy an EV uses on real roads

**Inputs :**
- Road slope
- Speed
- Weight
- Transmission ..



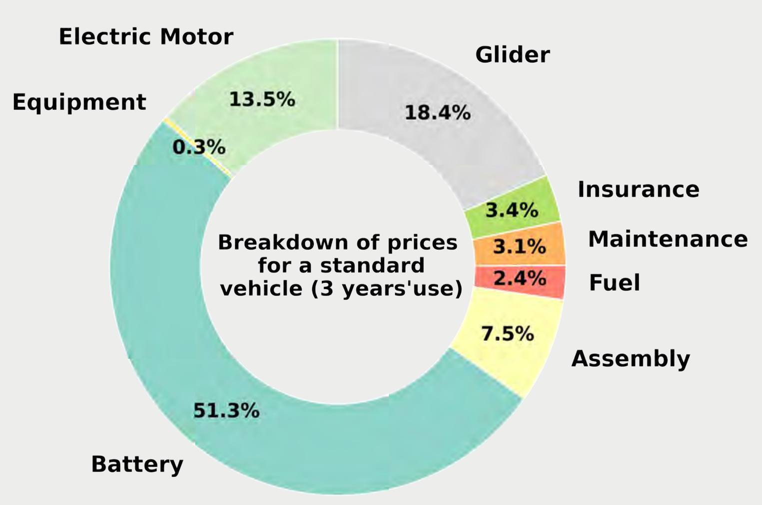

Based on +20 vehicles

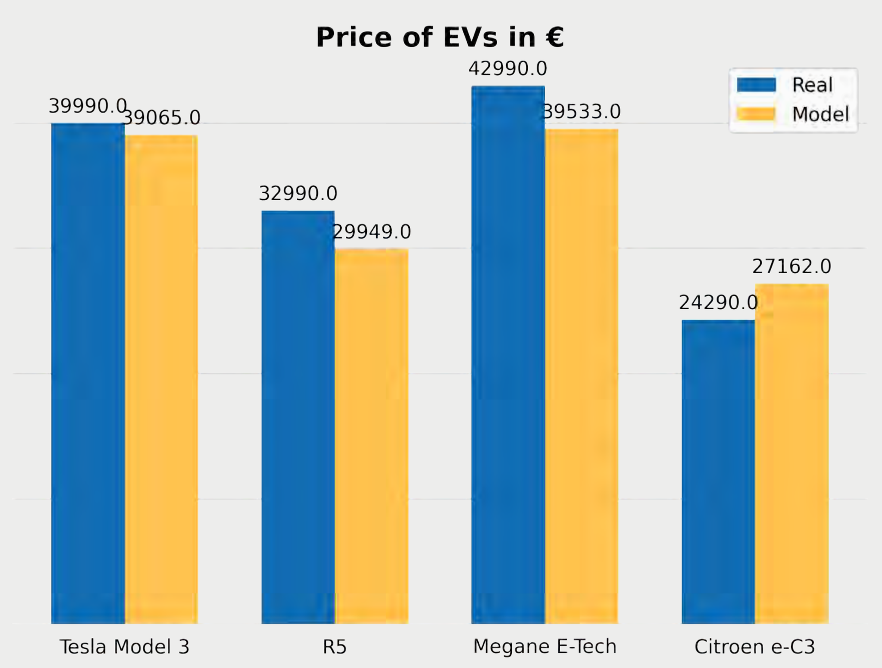
**6%** Estimation error

## 3

## A Total Cost of Ownership model evaluates EV affordability

- Includes glider, battery, motor, VAT, repairs, insurance ...
- Helps assess trade-offs during early design




Based on +20 vehicles

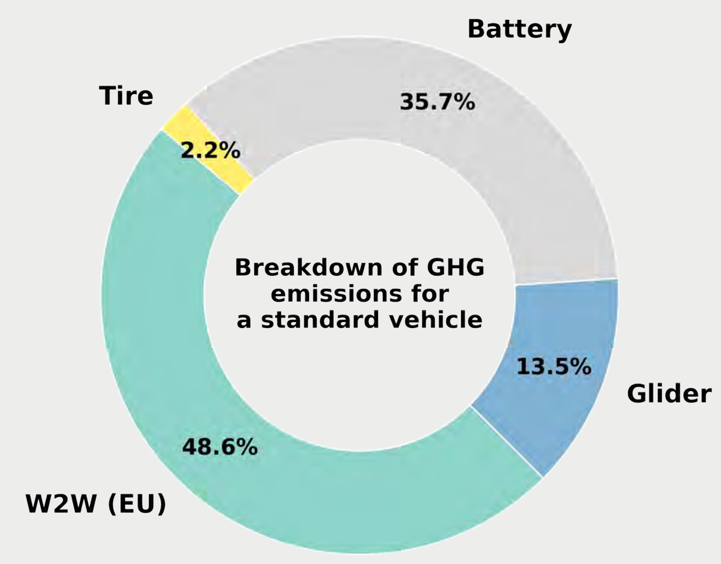
**8.3%** Estimation error

## 4

## A life cycle assesment model quantifies emissions from production, use and recycling of EVs

Emissions don't stop at the factory. We track them from start to end. There are **3 mains stages** :

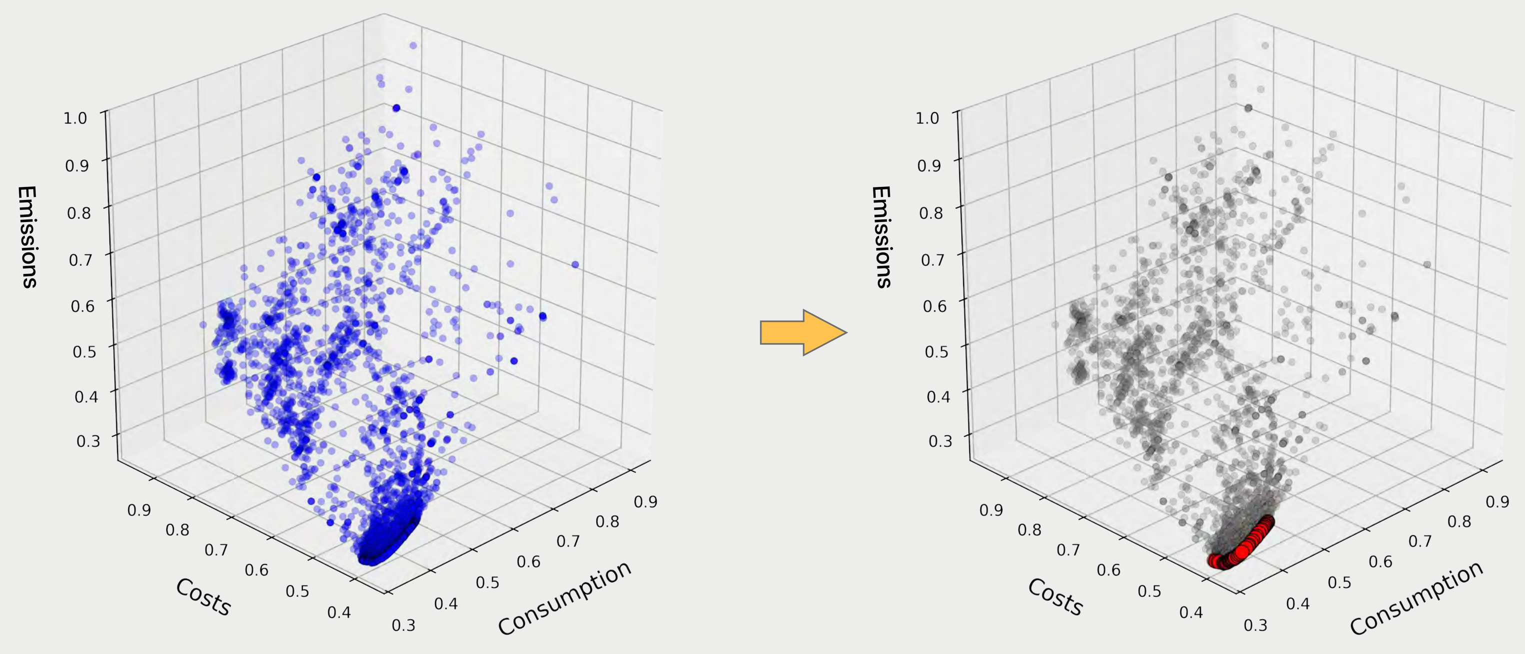
- Production
- Use
- Recycling




## 5

## A Pareto optimization identifies powertrain configurations that balance energy consumption, cost and carbon footprint

We conducted **hundreds of thousands of simulations** using the PSO algorithm and applied the Pareto algorithm to identify **167 optimal solutions.** All values have been normalized.




By choosing **equivalent ratio** between the three parameters, it gives us this optimal configuration :

| 80 kW | 225 Nm | 18 kWh | 249s1p | 7 Gtr |
|---|---|---|---|---|

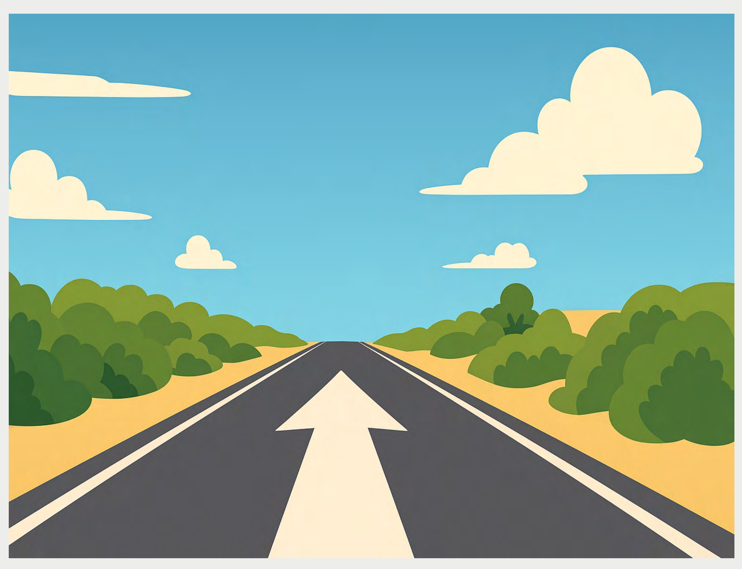
**12.2** kWh/100 km - **19 480** € - **17.4** tCO2eq

## 6

## New simulations tools enable more sustainable EV designs, but further refinements are needed to match market and technical realities

**Future actions to improve accuracy of the models**

- Regional energy grids
- Geographic cost variability
- Quantity cost variability
- Behavior based usage scenarios
- More advanced battery model

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# Conversion of a versatile single-cylinder gasoline engine to $H_2$

Arthur GRANDON - Corentin LEPEZ - Axel SANSON

## Introduction

In a world where reducing pollutant emissions and our carbon footprint is at the heart of the debate, the subject of single-cylinder conversion to hydrogen fits perfectly into this ecological transition. In this study, we present our market study and our final choice of single-cylinder to convert. We'll also explain the calculations and engine modifications we made to optimize its operation on H2.

## Benchmark

**Main criteria :**

- Versatility
- Displacement
- Reliability

**Versatility :**

- Presence in different markets
- Various modes of use (tools, generators, etc.)

**Displacement :**

- Most popular displacement: ~300 cc

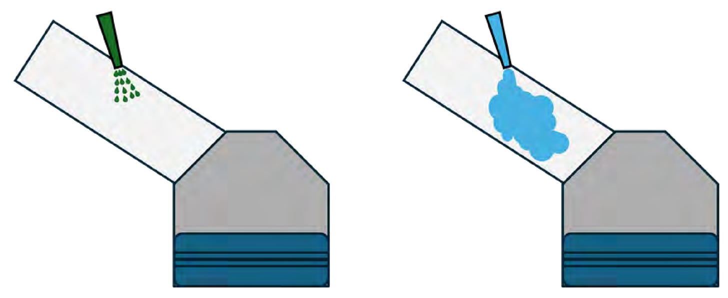
**Reliability :**

- Robust engine, no after-sales returns: HONDA

**Conclusion :**

Single-cylinder HONDA GX270 (in gasoline)

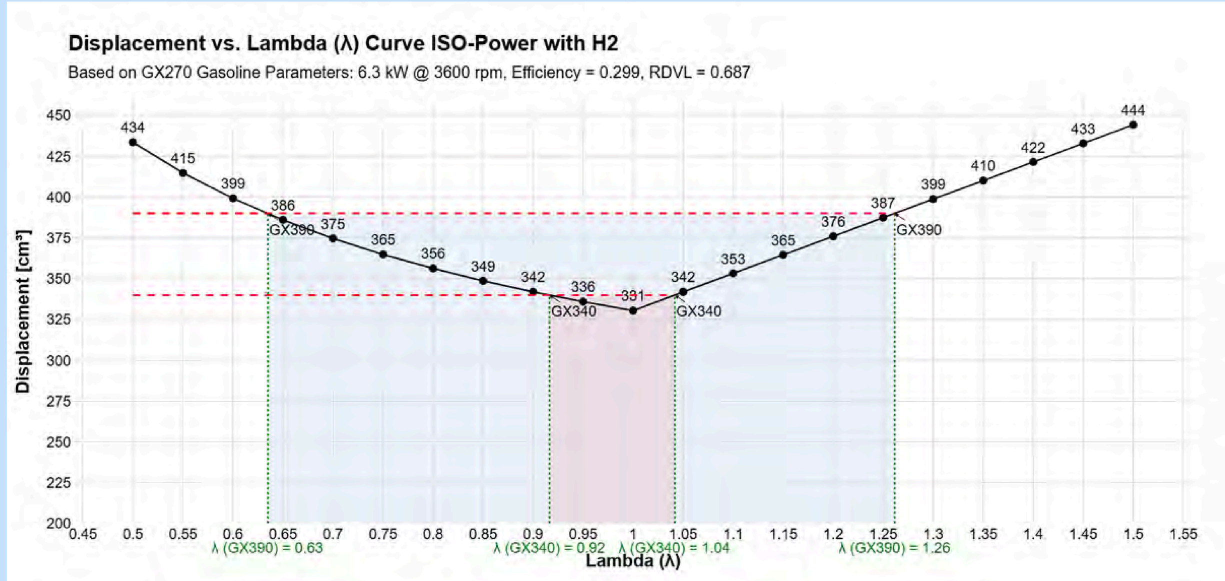
## Final Choice



- **Hydrogen Vs Gasoline specs. :**

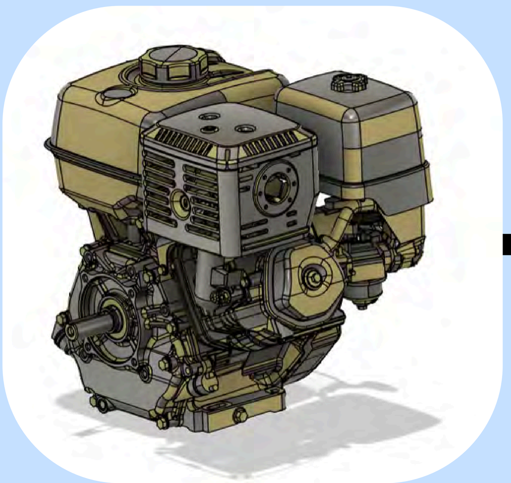
| Parameters | Gasoline | Hydrogen | Remarks |
|---|---|---|---|
| LHV | 42,5 MJ/kg | 120 MJ/kg | $H_2$ PCI ~3x |
| PCO | 14,48 | 34,46 | LHV/PCO: 1,18 |
| Fuel mass/cycle | 15,17 mg/cyc | 5,37 mg/cyc | Less $H_2$ mass required (LHV) |
| Fuel volume/cycle | 0,02 mL/cyc (liquid) | 65,0 mL/cyc (gas @ 1 atm) | Very high volume required for $H_2$ (Density 0.0827 kg/L) |
| Air volumic flow rate | 0,17 L/int | 0,14 L/int | −18% for $H_2$ (Consistent with LHV/PCO) |
| Total volumic flow rate | | 0,208 L/int | +22 % |

**Analysis**: The entire filling deficit is compensated by increased displacement.

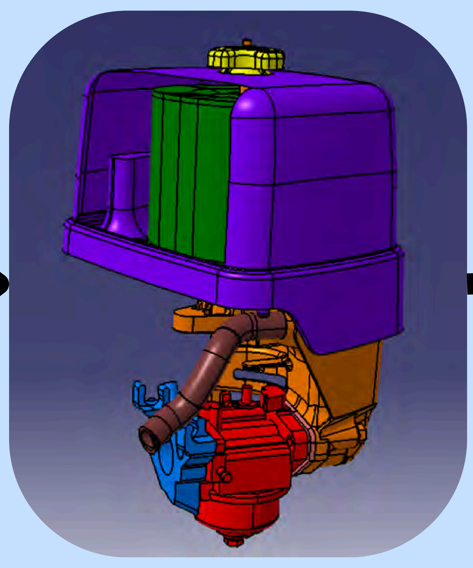



- Minimum required displacement with H2: 331 cc
- In the Honda GX line up, the GX390 model (390 cc) enables operation over a wider lambda range.
- **Final Choice: Honda GX390**

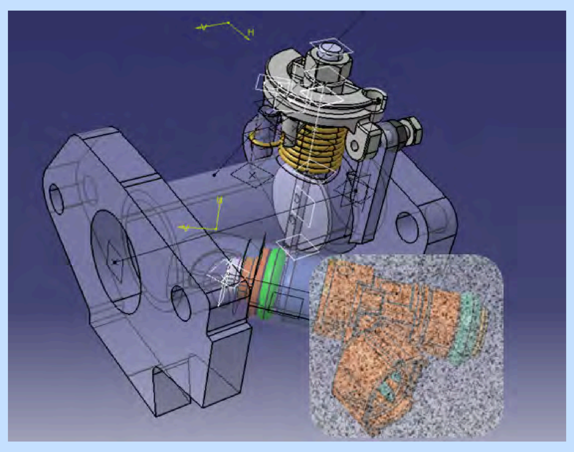
## Adaptation to H2 fuel



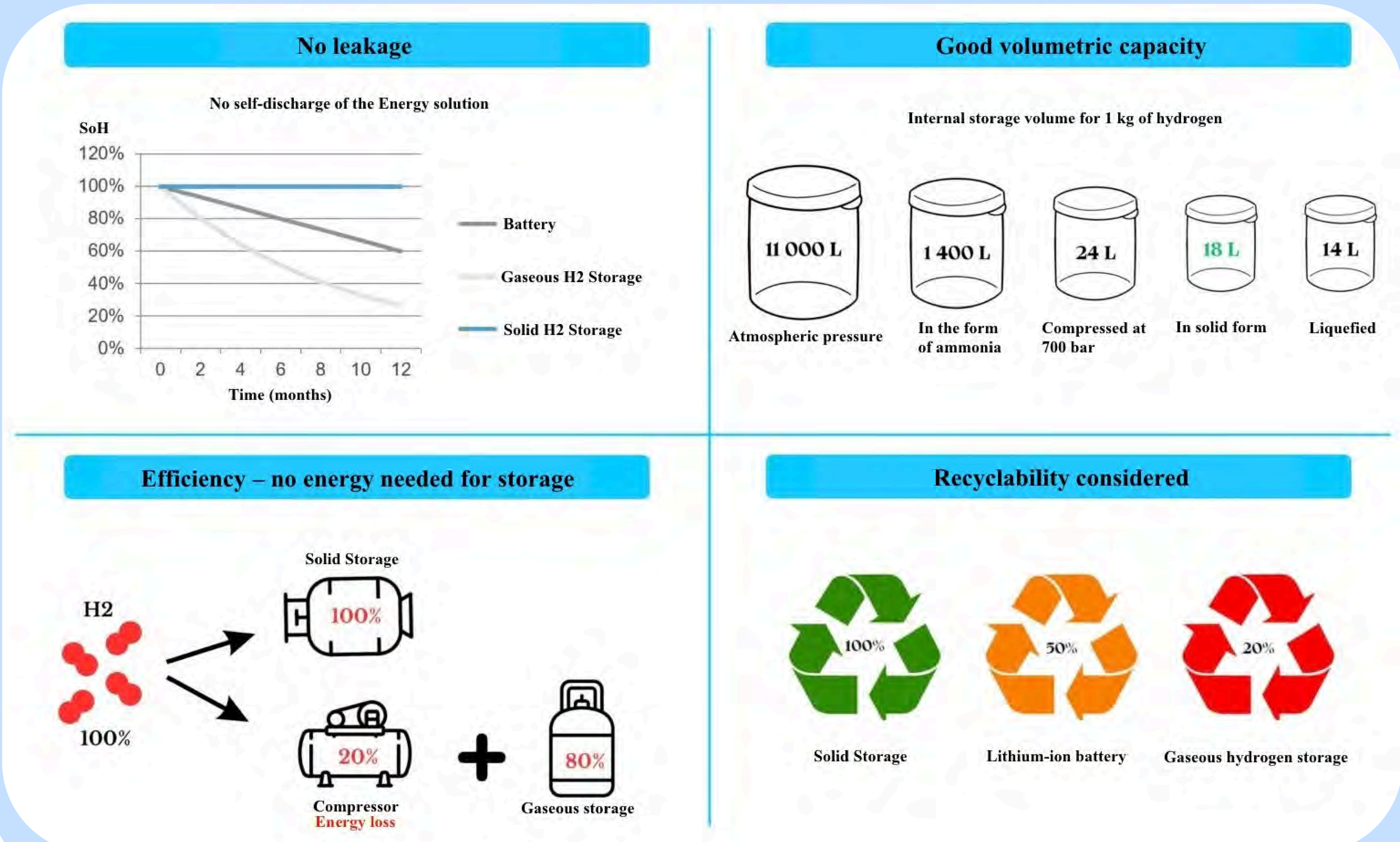
**Complet CAD GX390**



**Intake with carburator GX390**

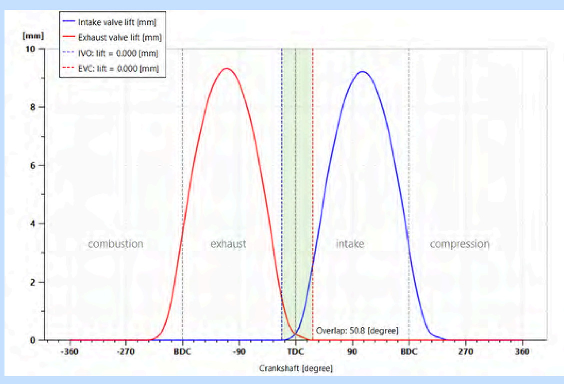


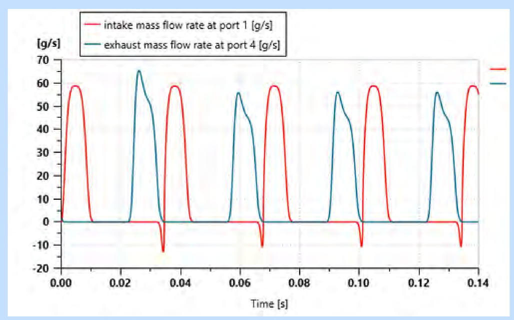
**PFI Admission GX390**

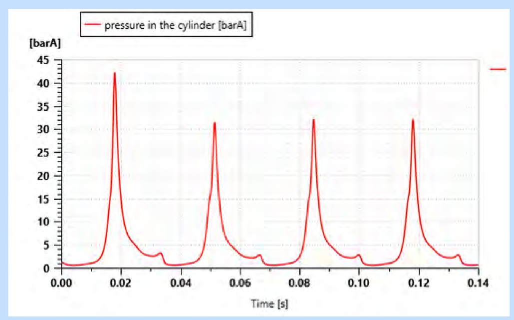



## Simulation results

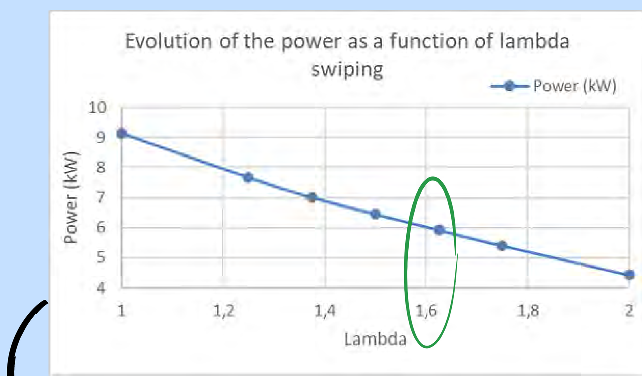
**Data matching of our Amesim model with the GX390 data found. Calibration of the Pmax (8.7 kW @ 3600rpm) OP in gasoline.**

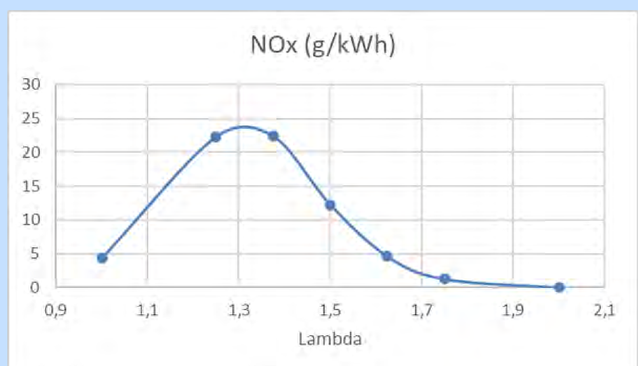




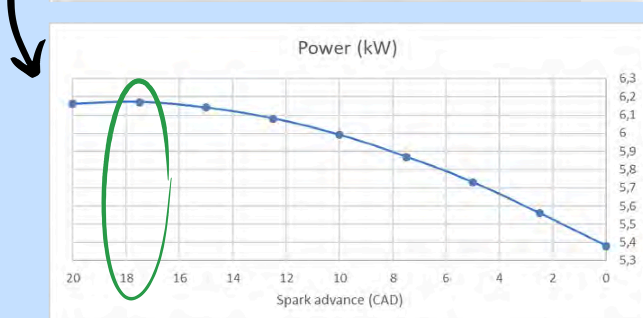


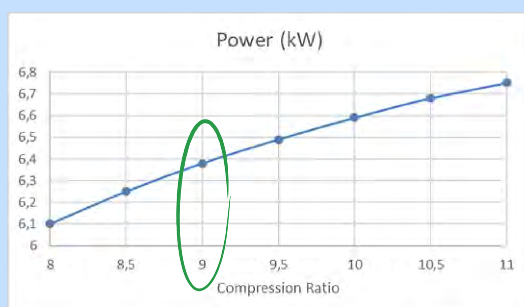
**Switch to H2, recalibration of our model to obtain the same perfo as GX270 (6.3 kW @ 3600rpm), and optimization of efficiency.**




With this lambda swiping, we were able to highlight the importance of running lean to reduce NOx. It seems that the best NOx/perfo compromise target is lambda = 1.6.




After optimizing the spark advance (17.5 CAD) and the compression ratio (9) parameters, we managed to obtain the GX270's target perfo P = 6.38 kW.

D'autres paramètres comme le SOI, et l'arbre à came seront aussi à optimiser.

## Next Steps

1. Implement remaining technical enhancements on the GX390 (Start of Injection, camshaft, injection system) to boost engine efficiency.
2. Complete design and fabrication of the injector body for conversion from carburetor to Port Fuel Injection (PFI).
3. Develop and size the fuel system components.
4. Conduct performance validation through dyno testing.

## Conclusion

- The choice to adapt an engine instead of engineering one from scratch was made, justified by the existence of a large number of reliable and adaptable engine bases.
- The adaptation of this type of engine to hydrogen allows for a local reduction in emissions as well as the optimization of performance by taking advantage of the characteristics of this gas.
- However, many challenges related to ease of use are at stake due to large and/or costly storage and safety concerns.


LEPEZ Corentin
IFP SCHOOL

# MATLAB/Simulink-Driven Thermal Modeling for High-Efficiency Hydrogen Fuel Cells

Sangyeop SONG [1] , Stephane VAUTRIN [1], Quentin SIMARD [1], Racha Bayzou [2], Mohand-Ouyahia Bousseksou [2], Guillaume Guilbert [2]

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## Overview of project

**A solution to climate challenges**

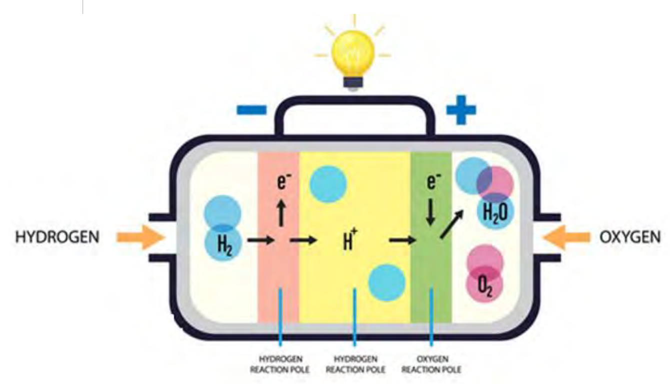
Hydrogen offers a sustainable alternative to fossil fuels, significantly reducing greenhouse gas emissions.

**A key application in the automotive industry**

In Proton Exchange Membrane Fuel Cells (PEMFCs), hydrogen powers vehicles while ensuring performance and range.

**Zero emissions, high efficiency**

PEMFCs convert hydrogen into electricity with high efficiency, emitting only water - a clean, forward-thinking energy solution.


**Managing heat for performance and durability**

PEM fuel cells generate considerable heat. Without efficient cooling, thermal gradients can degrade performance, shorten lifespan, and compromise system safety.

**A demanding automotive environment**

In vehicles, space is limited, and thermal loads vary with driving conditions. Cooling systems must be compact, responsive, and robust to ensure reliable operation.

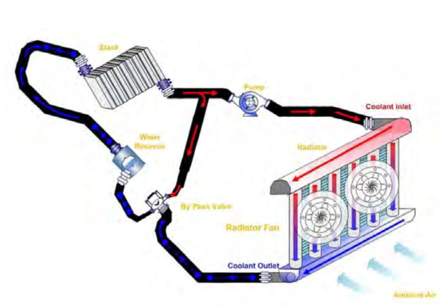
**Simulation-driven optimization with MATLAB/Simulink**

Thermal behavior is modeled and analyzed using MATLAB/Simulink, enabling precise testing of cooling strategies. This approach supports design decisions and reduces the need for costly physical prototyping

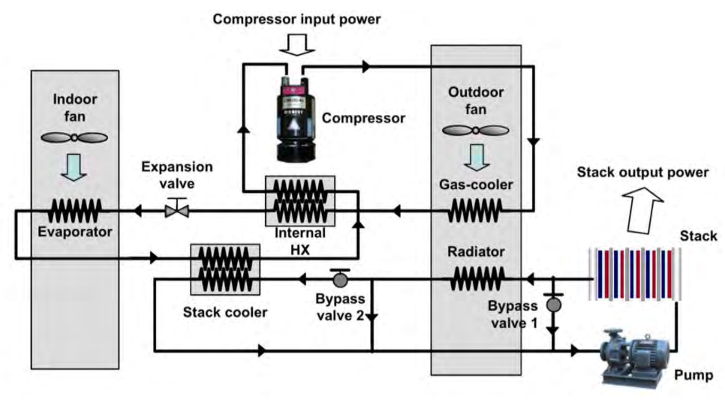
## Main approach – Input requirements

**Which type of cooling system ?**

**High thermal conductivity** → More efficient heat dissipation than air
**Essential for fuel cell temperature control** → Maintains optimal performance and durability
**Compact & quiet** → Better integration in vehicle design



**Which model Architecture ?**




**Why Matlab/Simulink Simulations?**

Fast, cost-effective system testing without physical prototypes.
Enables early design validation, reducing development time and expenses.

**What settings define the simulations?**

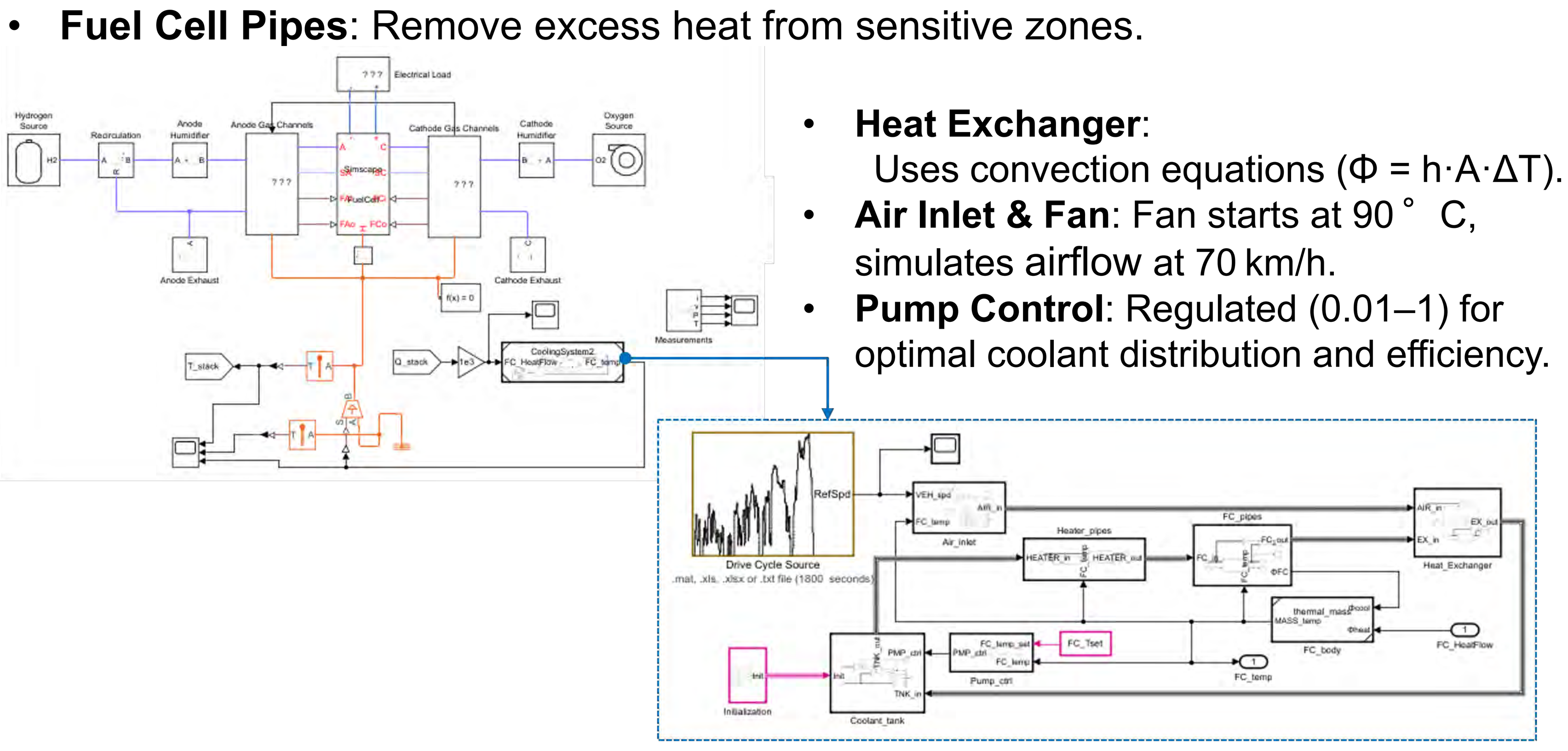
| | |
|---|---|
| Coolant circuit | • Mixture : Ethylene glycol / water<br>• Uniform fluid and optimal heat dissipation |
| Sensors | • Measure inlet and outlet coolant temperatures<br>• Strategically positioned for accurate reading |
| Thermal power and regulation | • Thermal power requirement : 10 kW<br>• Target fuel cell temperature 60°C to 80°C |

| | |
|---|---|
| Radiator | • Material : Aluminium<br>• Dimensions : 60 cm x 40 cm x 5 cm<br>• Thermal requirement : 10 kW to dissipate |
| Fan cooling | • Estimated capacity based on thermal requirements<br>• Ensure adequate heat dissipation<br>• Provides airlow for cooling the radiator |

## Model Description

The model is made up of connected blocks that represent key thermal components in the system. This helps simulate how heat moves and behaves in the fuel cell.

- **Initialization**: Sets initial temperature, pressure, and coolant flow. Includes coolant properties (Cp, ρ, total mass).
- **Heater Pipes**: Heat injected via 26 pipes;
- **Radiator**: 60 × 40 cm, 472 fins, 7.09 m² active surface.
- **Fuel Cell Pipes**: Remove excess heat from sensitive zones.

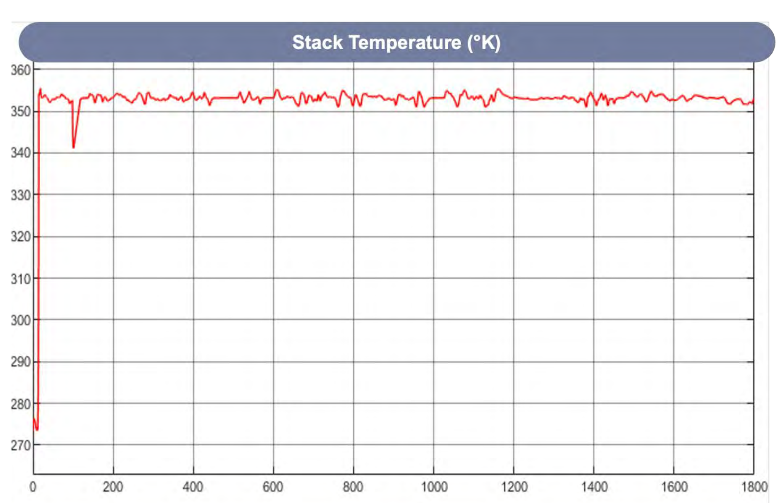


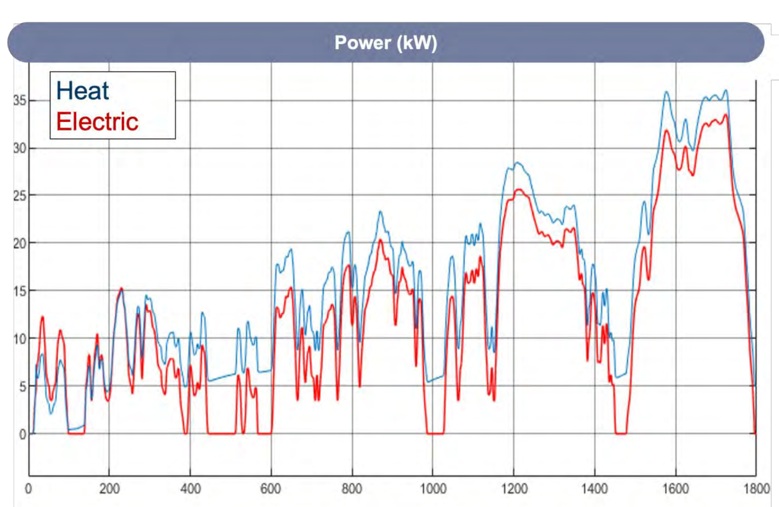
- **Heat Exchanger**: Uses convection equations ($\Phi = h \cdot A \cdot \Delta T$).
- **Air Inlet & Fan**: Fan starts at 90 ° C, simulates airflow at 70 km/h.
- **Pump Control**: Regulated (0.01–1) for optimal coolant distribution and efficiency.

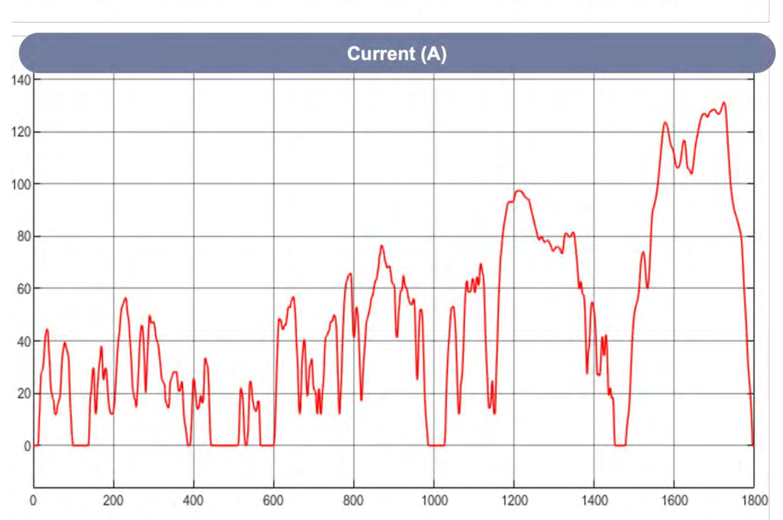
## Results & Analysis

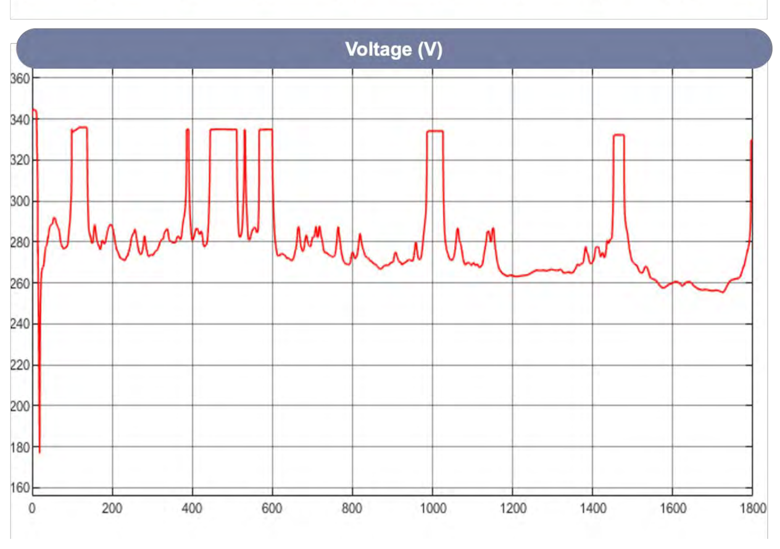
**Simulation scenario:** WLTP (Worldwide Harmonized Light Vehicles Test Procedure) cycle.

**Inputs:** Varying power loads corresponding to real-world driving conditions.




### Study Case : Toyota Mirai

| | |
|---|---|
| **Active Surface Area** | 400 cm² |
| **Membrane Thickness** | 117 µm |
| **Number of Cells** | 370 |

| | |
|---|---|
| **Physical Dimensions** | Length: 0.7 m<br>Width: 0.4 m<br>Height: 0.13 m |

- **Temperature Stability:** Adaptive pump control system significantly reduced temperature fluctuations, lowering overheating risks and improving system safety.
- **Cooling Fluid Performance:** Water-glycol mixture ensured optimal steady-state temperature maintenance under dynamic driving conditions.
- **Smart Flow Regulation:** Adaptive control optimized coolant distribution, balancing thermal performance and energy efficiency of the system.
- **Time Efficiency:** Simulated approach required less design and testing time than traditional experimental methods — speeding up development while cutting costs.

## Perspectives

- **AI-Driven Thermal Control**: Implement intelligent control algorithms to autonomously manage thermal loads and adapt to variable driving conditions.
- **Phase Change Materials (PCM)**: Introduce PCM-based modules to passively absorb and release heat during thermal peaks, enhancing system reliability.
- **Energy Efficiency Enhancement**: Combine adaptive pump and fan control with AI to reduce parasitic energy consumption while maintaining thermal stability.

MATLAB AI

References:
- Zhang et al., Int. J. Hydrogen Energy, 2019
- DOE Hydrogen Program, 2020
- Park et al., Applied Thermal Engineering, 2018
- Adzakpa et al., *J. Power Sources*, 179(1), 2008.
Aminudin et al., *Int. J. Hydrogen Energy*, 48(11), 2023.

Capgemini engineering

# Optimization of a Work Vessel Powertrain

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Tutors : Sébastien BERTHEBAUD - Sylvain LANNEAU

HYBA* HYBRIDE BRETAGNE ATLANTIQUE

*financed by *France Filière Pêche*

## Context

Fishing boats use **sub-optimized powertrain** to handle the worst navigation scenarios, leading to high fuel consumption, emissions, and costs. The **HYBA consortium** is developing an approach to analyze the cases and develop sustainable solutions.

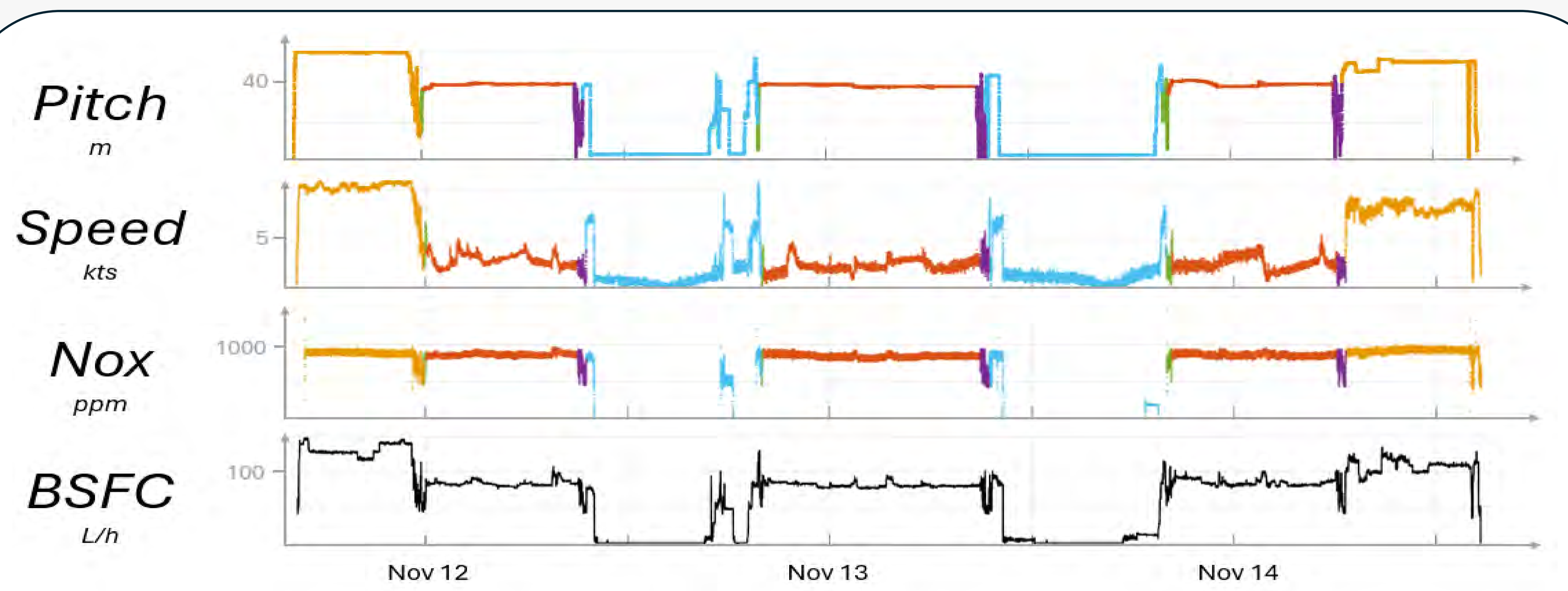

## Objectives

Contribute to the **HYBA consortium** by developing the **energy management system** to control and optimize the powertrain using a **parallel hybrid** configuration. This setup includes a **buffer battery,** a **variable-pitch propeller** and is based on real-world operating data.

## Methodology

### 1. Data Collection and Analysis

For one year, a Breton fishing boat was equipped with **80 onboard sensors**, providing signals at 10 Hz to record detailed data on navigation and usage.

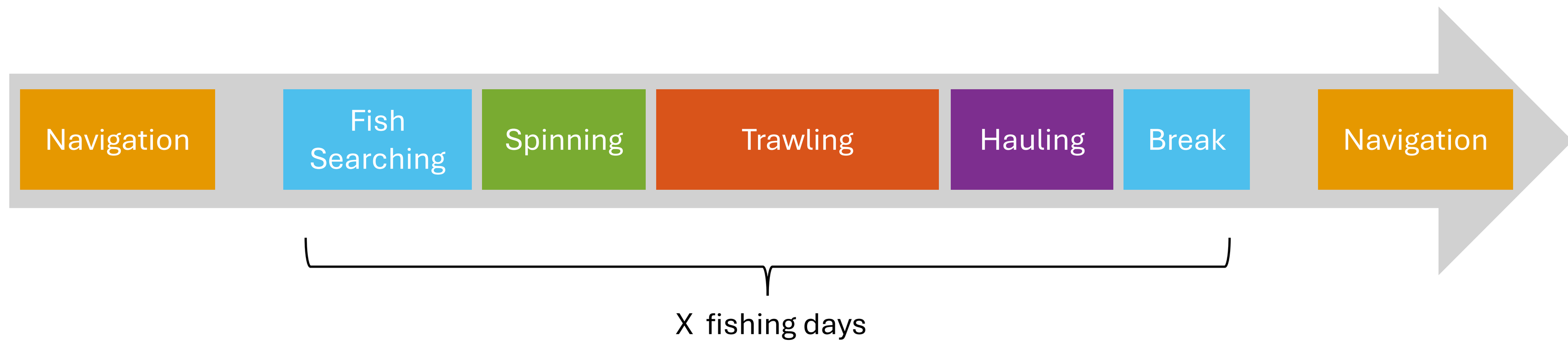



***Example of data over 3 days***

By plotting the data collected over a certain period, we analyze the different parameters according to the various usages.

### 2. Creation of Standard Scenarios

The data is analyzed to **create standard scenarios** based on fishing types. Each fisherman can **customize** their scenario.

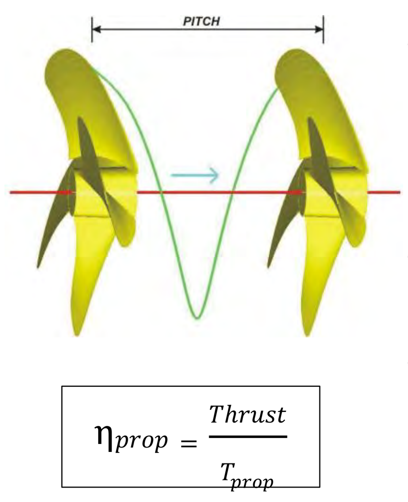



- We create **scenarios** tailored to each client, composed of combinations of the different modules mentioned above.
- There is **no standardized duty cycle for boats** (unlike the WLTP for automobiles). Each scenario will be specifically developed to reflect the vessel's actual operating profile.
- This scenario will serve as the **basis for the powertrain optimization**

### 3. Powertrain Optimization

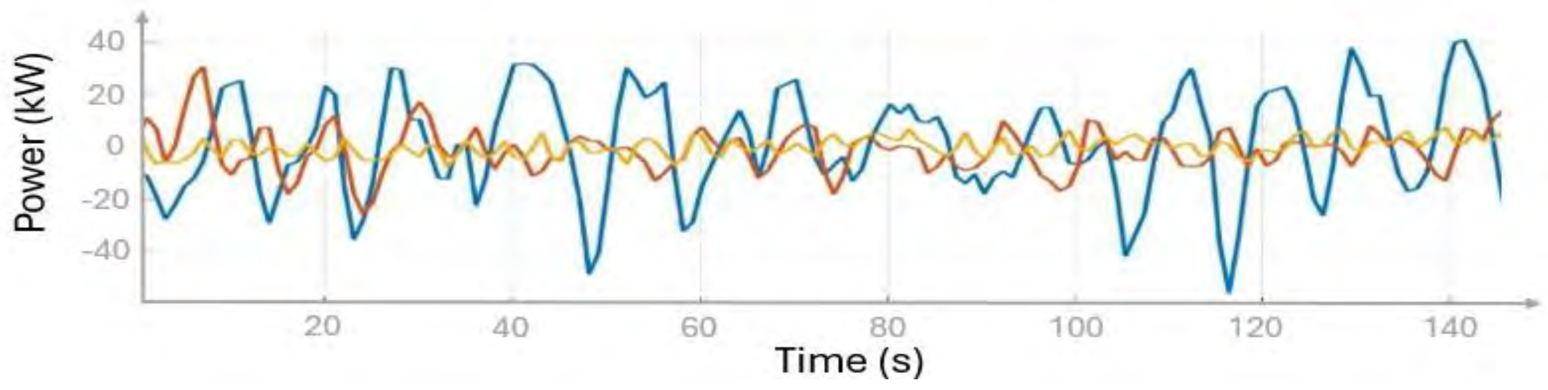
Based on the **customized scenario**, a **Hamiltonian approach** is used to optimize the powertrain and **reduce consumption**

#### Variable pitch propeller and ICE operating point



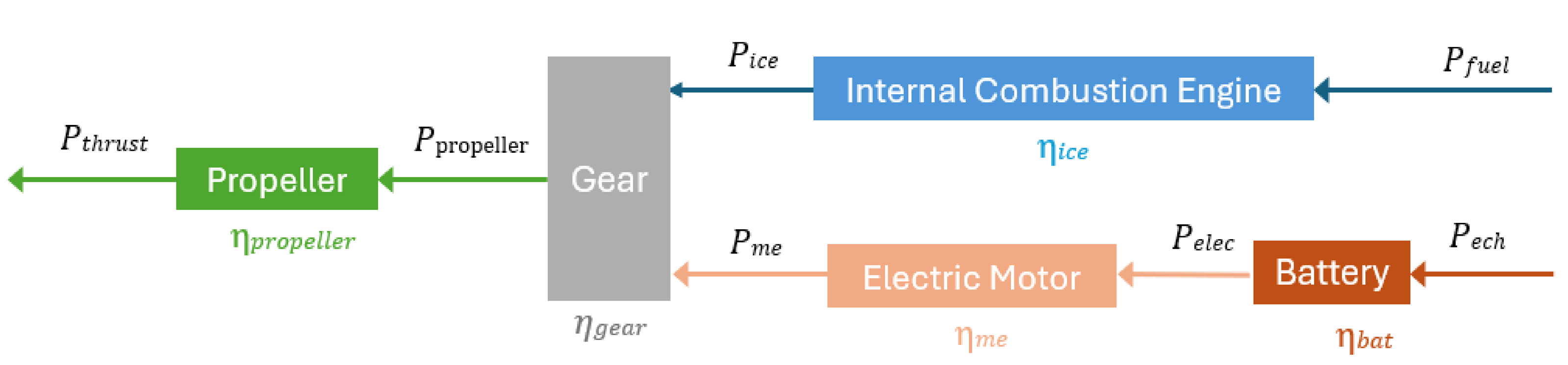

- Boats typically operate either with a **fixed pitch propeller (FPP)** and a **variable speed engine**, or a **fixed engine speed** and a **variable pitch propeller (CPP)**, adjusting components to match the desired **boat speed.**
- However, both the **efficiency of the propeller and the engine vary** depending on the pitch and speed.
- By adjusting the shaft speed for a given vessel speed, it is possible not only to optimize engine performance, but also to improve overall propulsion efficiency.

#### Hybrid Strategy to Mitigate Ocean Swell Effects



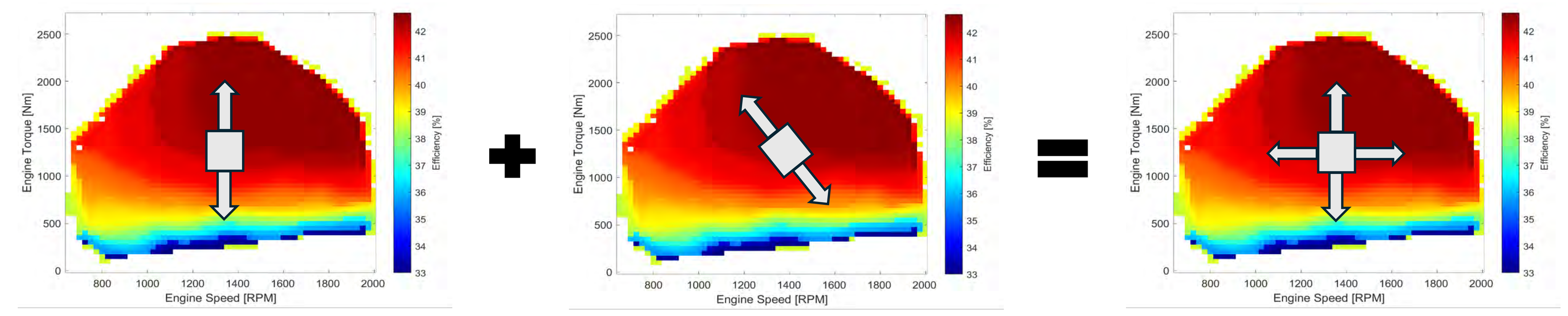

- Swell induces oscillations in ICE operating points due to variations in hull resistance and propeller load, resulting in transient fuel consumption.
- The primary impact of hybridization lies in **smoothing the swell-induced dynamics** through the **electric motor** and **buffer battery** (or supercapacitor).

#### Powertrain Architecture – Parallel Hybrid with Buffer Battery




- The vessel features a **parallel hybrid transmission** with an **ICE** and **EM** driving a **variable pitch propeller.**
- A **buffer battery** enables energy recovery and power assist.
- **Efficiency maps** are required for the ICE, EM, and propeller to optimize fuel consumption. For the ICE, the latter is **recalibrated from baseline** engine maps.

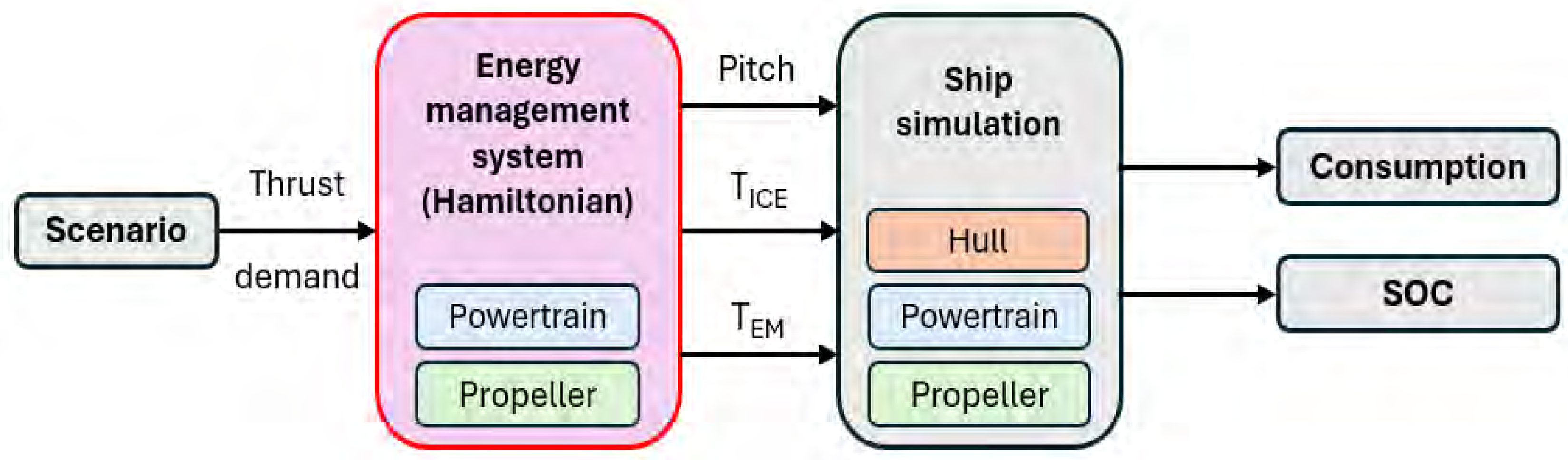
#### Degree of Freedom on ICE Efficiency Map



Hybrid : ICE + EM = 1 DoF | Variable pitch = 1 DoF | 2 DoF

- **The electric motor** adjusts ICE torque (vertical axis on the static efficiency map) to target high-efficiency zones - an **energy-driven strategy**, unlike wave smoothing which depends on **battery power for dynamic load variations**.
- **Variable pitch propeller** offers a second **degree of freedom (DoF)** changing simultaneously torque and rotational speed at iso thrust.
- These two independent means aim to **optimizing overall fuel efficiency.**

#### Hamiltonian Energy Management System (EMS)




- We focus on the development of the Energy Management System (EMS), while the rest of the ship simulation environment has been developed in the **HYBA Project** within EcoBoatTwin Saas Platform/Digital Twin. Dimensioning of the powertrain is also done in cooperation with the **HYBA consortium.**
- For a given scenario, the EMS selects the most fuel-efficient powertrain settings by **minimizing the Hamiltonian function** H, while ensuring that the battery's state of charge (SOC) respects the constraints. The tuning constant s0 allows control over battery usage, whether to enforce a **SOC-neutral strategy** or to allow a certain level of discharge.
- The **key breakthrough** of this project lies in optimizing the overall powertrain efficiency by **considering the combined efficiencies** of the propeller, ICE, and EM, rather than optimizing each component individually.

## Conclusion

Detailed analysis of actual navigation data enables the propulsion system of fishing boats to be adapted to the specific needs of each activity. Thanks to **Hamiltonian EMS** and the integration of **standard scenarios**, it is possible to optimize energy performance and reduce fuel consumption.

## Outlook - NOx

Due to the implementation of **NECA** (Nitrogen Emission Control Areas) zones in the North Sea and the English Channel, and **SECA** (Sulphur Emission Control Areas) designation in the Mediterranean Sea, stricter emission limits are being enforced. In this context, some works from the bibliography suggest modifying the Hamiltonian formulation to include NOx emissions alongside fuel consumption. This approach has been shown to **reduce NOx emissions by up to 40%,** with only a limited **increase in fuel consumption of only 5%.**

*Source : Energy management Strategies for Diesel Hybrid Electric Vehicle ; IFP Energies nouvelles*

Eduardo ROMBOLA | Gautier FONTAINE | Simon GARRIGUES

Supervisor : Florian CHIAPPINI

# Study of the viability of PHEVs Long Range in the European market

## *Objective : size lifelong filters for the engine of a PHEV Long Range*

## Life Cycle Analysis (LCA) and Total Cost of Ownership (TCO)

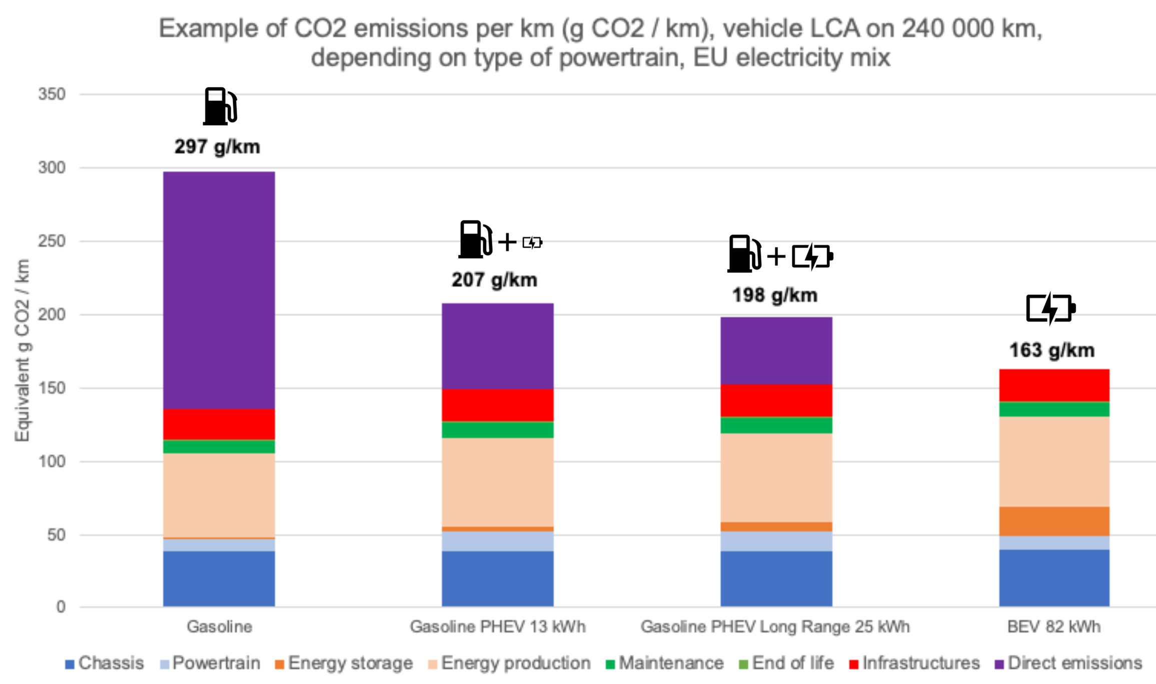
LCA analysis with Carculator tool (Paul Scherrer Institute, Switzerland).
When increasing the size of a PHEV car :
- Battery CO2 footprint increases
- Battery CO2 footprint for PHEV LR is greater than PHEV, but less important than BEV

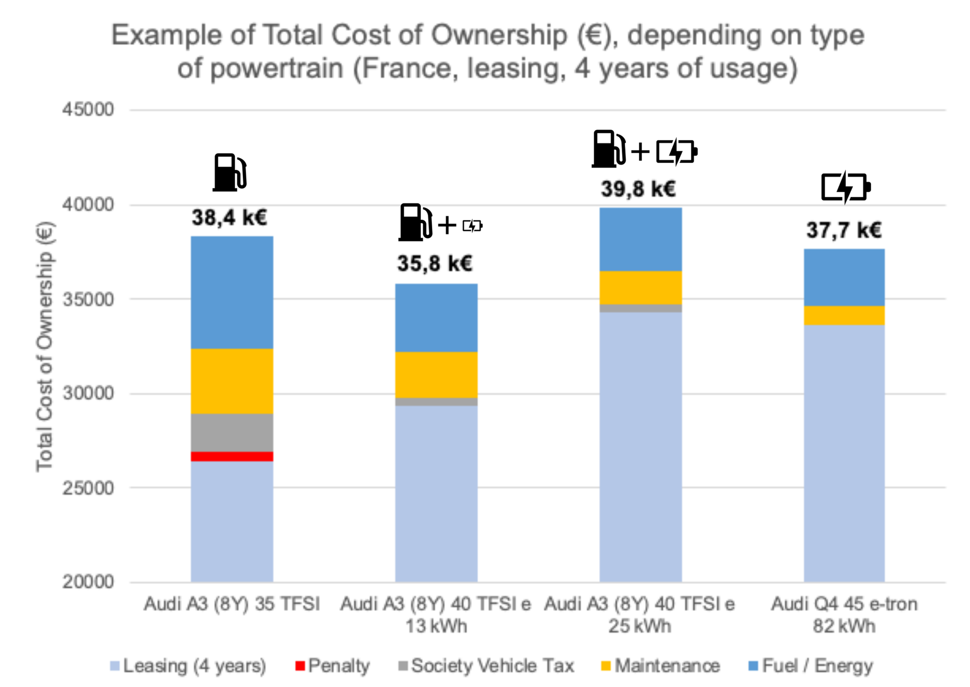
BUT :
- Mileage driven with BEV mode increases
- Direct emission (Tank To Wheel) CO2 footprint decreases
- Energy production (Well To Tank) CO2 footprint decreases

→ PHEV LR show a total CO2 footprint on LCA slightly less important
→ Can lifelong car filters reduce “maintenance” CO2 footprint ?

LCA analysis assumptions :
- European electricity mix
- French driving habits, population driving long journeys (executive jobs population)

TCO assumptions :
- 4 years leasing, executive jobs population
- French penalties and corporate taxation
- PHEVs use 100% BEV mode when they can
- PHEVs use 100% ICE on highway
- BEV shows higher consumption and uses more expensive electricity on highway




## BYD Seal U DM-i Design

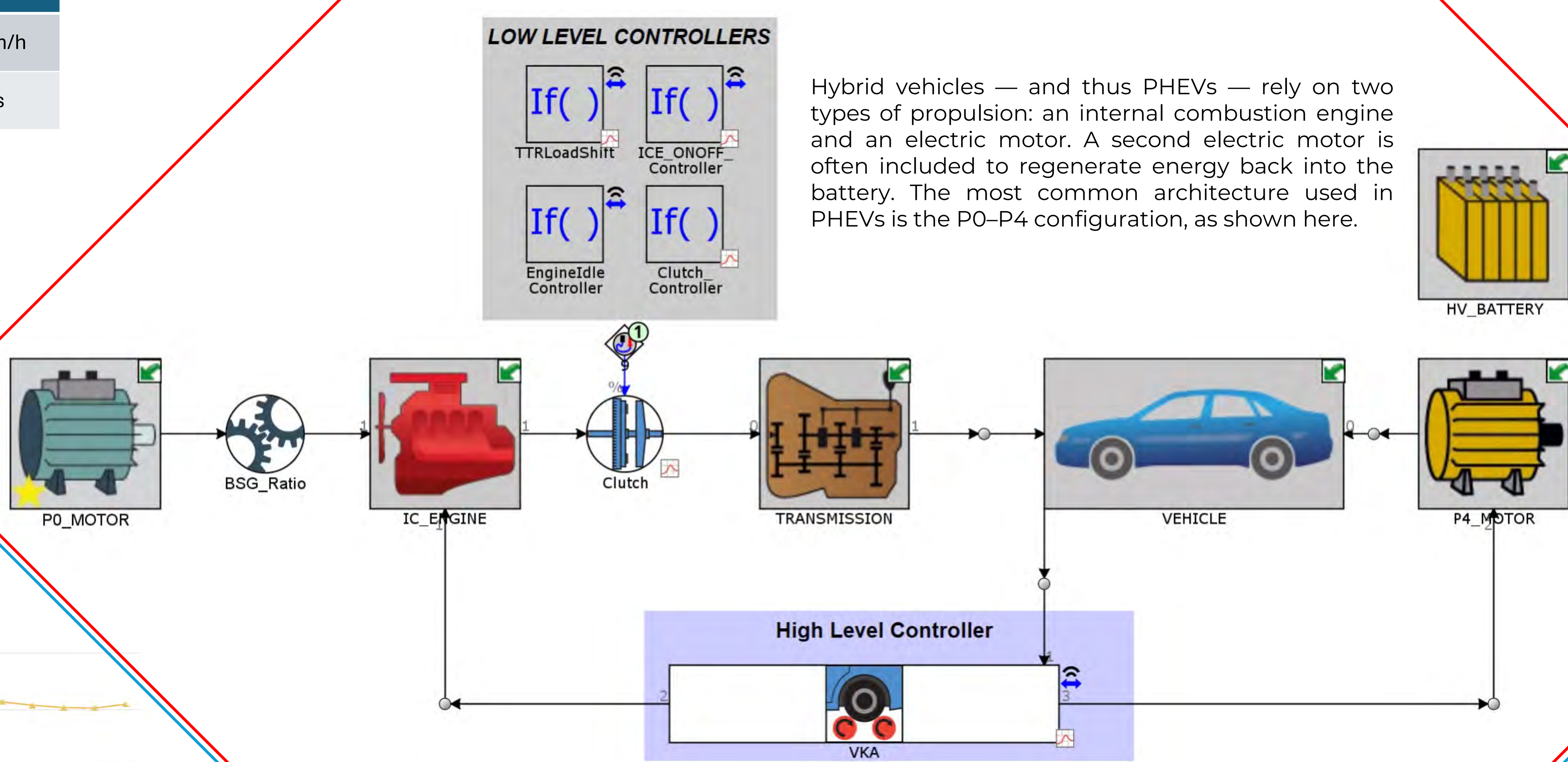
| | |
|---|---|
| Range WLTP | 70 km (EV) – 870 km (Total) |
| Consumption | 23,5 kWh/100km (EV)<br>7,4 L/100km (Hybrid mode) |
| Battery Capacity | 18,3 kWh |
| Combustion Engine | 1,5 L - 96 kW – 220 Nm |
| Two Electric Motors | 150 kW – 300 Nm |
| | 120 kW – 250 Nm |

| Performances | |
|---|---|
| Maximum speed | 180 km/h |
| Acceleration 0 – 100 km/h | 5,9 s |

| Charging times | |
|---|---|
| AC 15 % - 100 % | 120 min |
| DC 30 % - 80 % | 35 min |

## PHEV

Hybrid vehicles — and thus PHEVs — rely on two types of propulsion: an internal combustion engine and an electric motor. A second electric motor is often included to regenerate energy back into the battery. The most common architecture used in PHEVs is the P0–P4 configuration, as shown here.




| Driving mode | ICE | P0 | P4 |
|---|---|---|---|
| Electric | ✗ | ✗ | ✓ |
| Hybrid | ✓ | ✗ | ✓ |
| Regenerative braking | ✗ | ✓ | ✓ |
| Engine-only | ✓ | ✗ | ✗ |

Motors used depending on driving mode

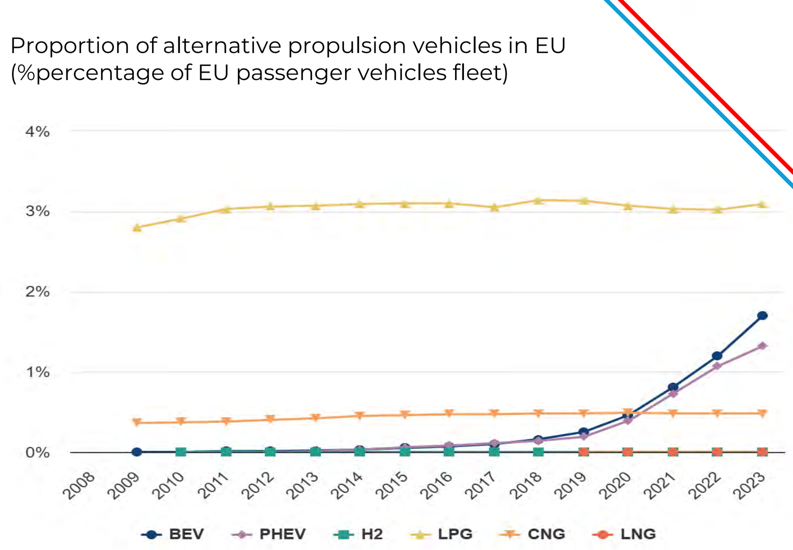
## Lynk & Co 08

| | |
|---|---|
| Range WLTP | 205 km (EV) – 1100 km (Total) |
| Consumption | 20,4 kWh/100km (EV)<br>5,5 L/100km (Hybrid mode) |
| Battery Capacity | 39,8 kWh |
| Combustion Engine | 1,5 L - 120 kW – 255 Nm |
| Two Electric Motors | 160 kW – 350 Nm |
| | 155 kW – 290 Nm |

| Performances | |
|---|---|
| Maximum speed | 200 km/h |
| Acceleration 0 – 100 km/h | 4,6 s |

| Charging times | |
|---|---|
| AC 25 % - 100 % | 160 min |
| DC 10 % - 80 % | 33 min |

## European market / standards

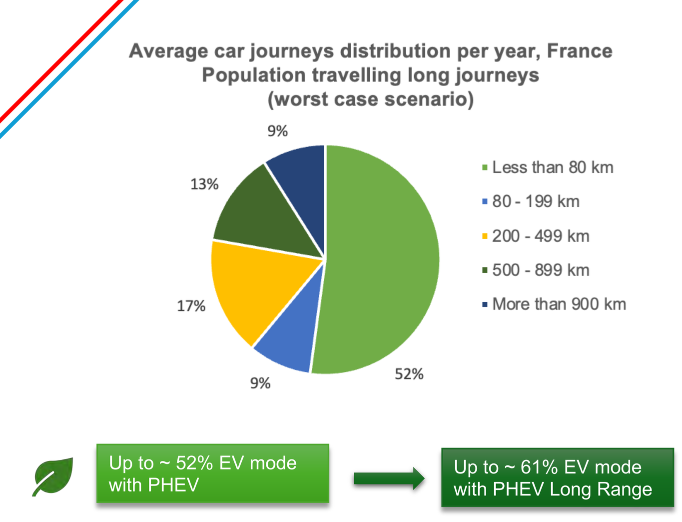



| Euro 7 Emission Standards – Summary for Passenger Cars | | |
|---|---|---|
| Category | Euro 6 | Euro 7 |
| $NO_x$ Limit | Petrol: 60 mg/km<br>Diesel: 80 mg/km | **60 mg/km for all**<br>(petrol & diesel unified) |
| Particulate Number PN)<br>(Carbon Monoxide) | $6\times10^{11}$ #/km<br>(includes pa 123 nm) | **$6\times10^{11}$ #/km,**<br>includes particles ≥10 **nm*** |
| CO (Carbon Monoxide) | Petrol: 1000 mg/km<br>Diesel: 500 mg/km | **No change** |
| Emission Compliance Duration | Not regulated | Brake particle limits +<br>tyre abrasion monitoring |
| Brake & Tyre Emissions (PHEV/EV) | Not regulated | Minimum performance required over 5 years or |
| Real Driving Emission (RDE) | Already applied | **Expanded***:<br>includes extremes (hot/col |

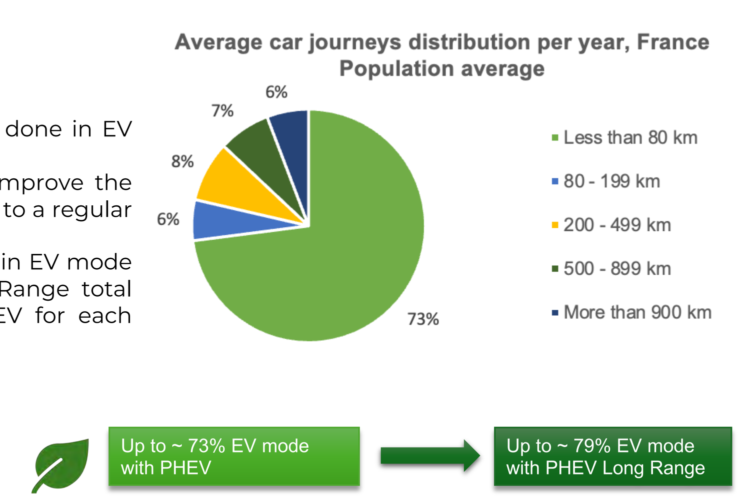
EU releases standards to encourage the use of alternative propulsion vehicles. Their number tends to increase over the next years.

This tends to develop the market for these kinds of vehicles and therefore for PHEVs.

## Driving Habits




Challenges:
- How many of these journeys can be done in EV mode for each population?
- How much will PHEV Long Range improve the mileage spent in EV mode compared to a regular PHEV?
- What can be the total mileage spent in EV mode and ICE mode for the PHEV Long Range total lifetime compared to a regular PHEV for each population?

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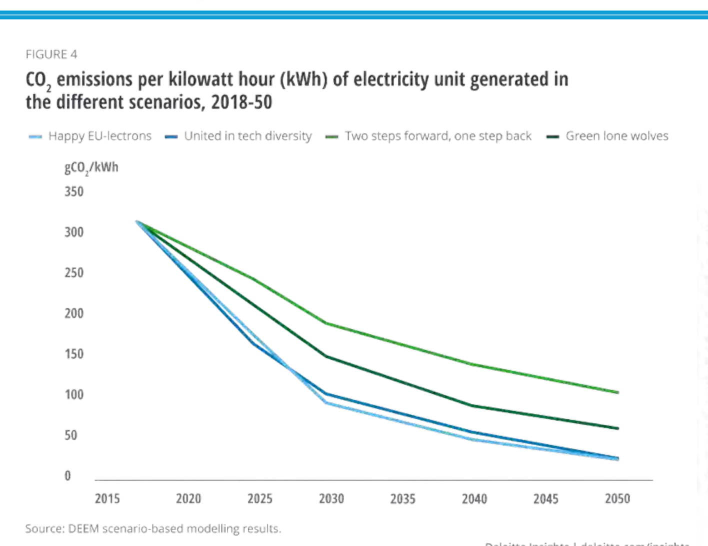
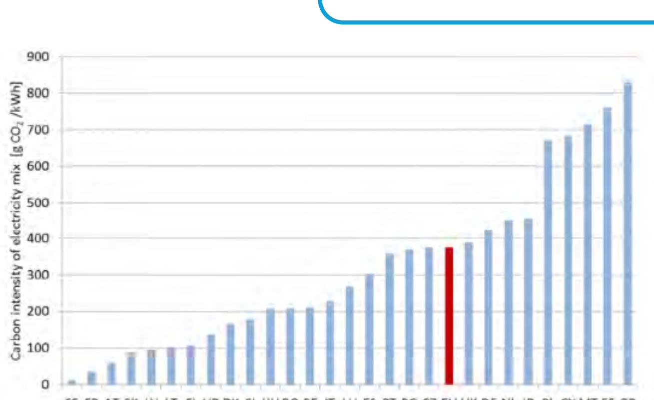
## European electricity mix



Europe tends to decrease its electricity carbon footprint by decreasing the generated CO2/kWh of electricity produced. Hence, this will help PHEVs to develop as they appear as a low carbon transportation solution that overcomes the main issue of the BEV : the range.