EXPERT PANEL FOR POLLUTING EMISSIONS REDUCTION
EXPAPER

Experimental Investigation of Powertrain Components and Energy Flow Analysis of a Fuel Cell Electric Passenger Car

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European Commission Joint Research Centre

Consiglio Nazionale delle Ricerche
STEMS

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AGENDA

- INTRODUCTION
- TEST PROTOCOL
- FUEL CELL STACK EFFICIENCY
- POWERTRAIN CHARACTERIZATION
- CONCLUSIONS

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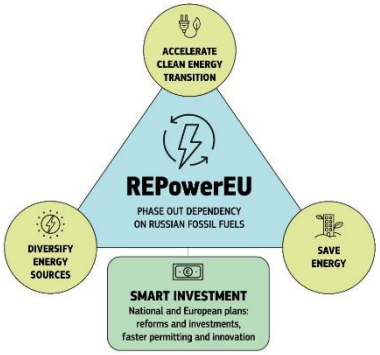
INTRODUCTION
Background

2019 **2020** **2021** **2022**



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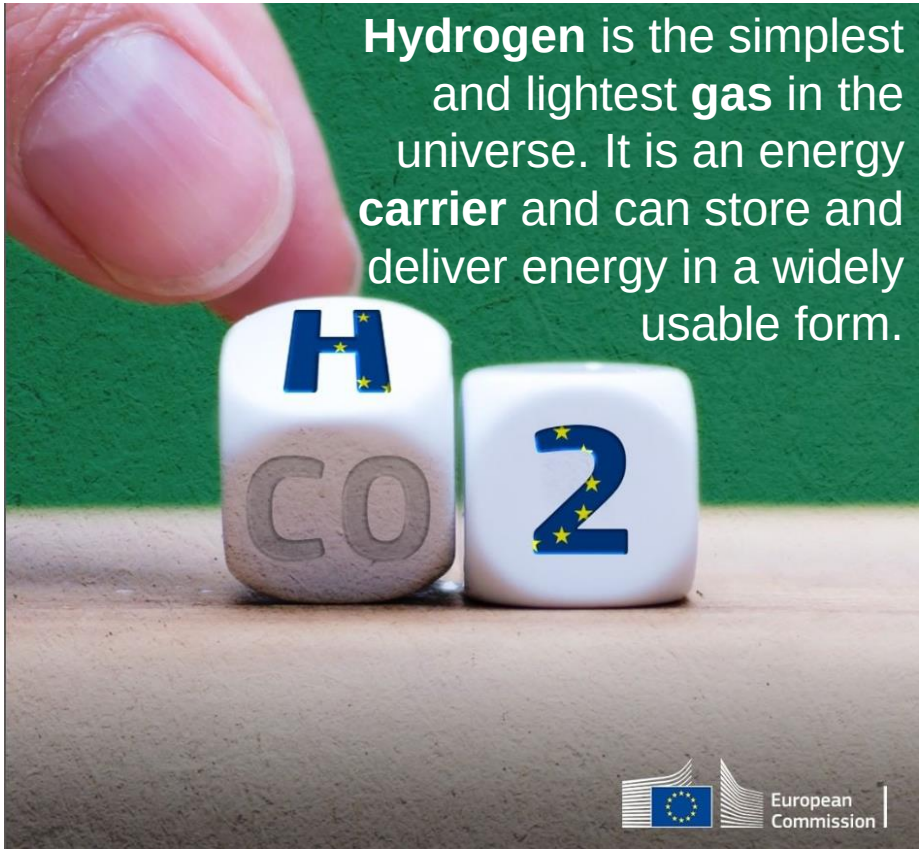
INTRODUCTION
Background



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What do we do in sustainable transport unit @ JRC?

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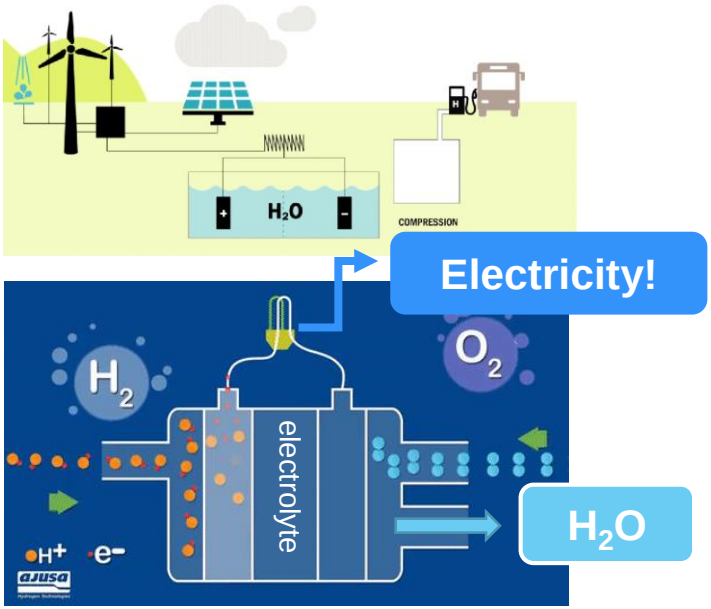
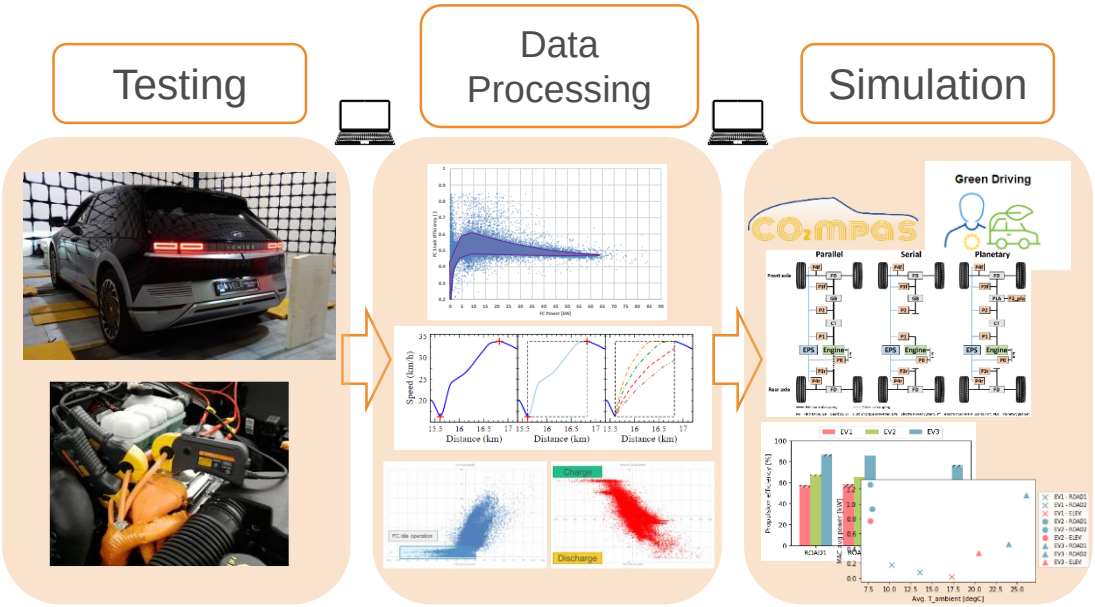
INTRODUCTION
Aim of the Work

- Very few **FCEVs** available in the **European market**
- Lack of **public** and **independent data** on modern FC tested vehicles
- Testing methodology to **characterize** FCEV powertrains, improve the internal **know-how** and have input for vehicle **modelling**





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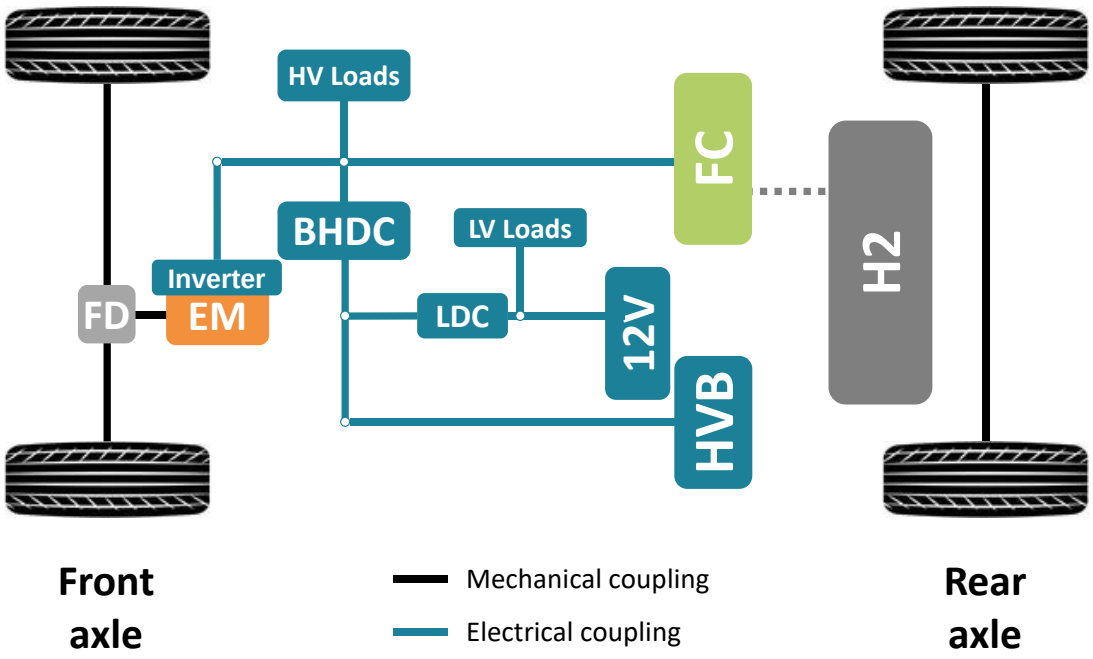
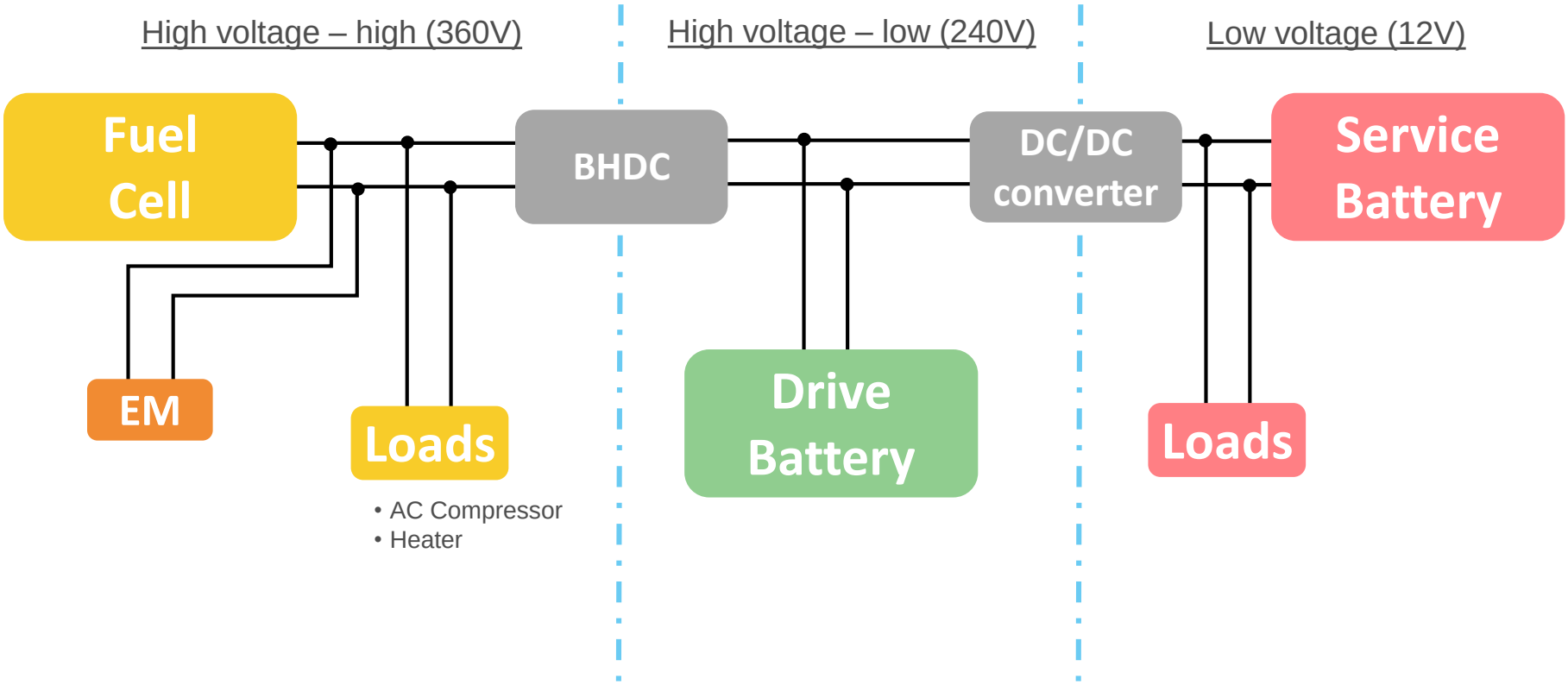
INTRODUCTION
Tested Vehicle



Fuel Cell Stack (FCS)	
Cell Type	Proton exchange membrane (PEM)
Output Voltage	250 – 450V
Max output	95kW
Hydrogen Tank	156.6 liters
Power Electronics (PE)	
Inverter	250 – 450V
BHDC	160 – 275.2V Input
	250 – 450V Output
LDC	250 – 450V Input
	12.8 – 13.9 Output
Vehicle	
Curb Weight	1814 kg
FCEV System Power	135kW combined
Electric Motor (EM)	
Type	PM Synchronous motor
Max Power / Max Torque	120 kW / 395 Nm
Final Drive (FD)	Single-speed 7.981
High Voltage Battery	
Type	Lithium-ion Polymer
Rated Voltage	240V
Capacity	1.56kWh / 6.5Ah

INTRODUCTION
Vehicle Electric System



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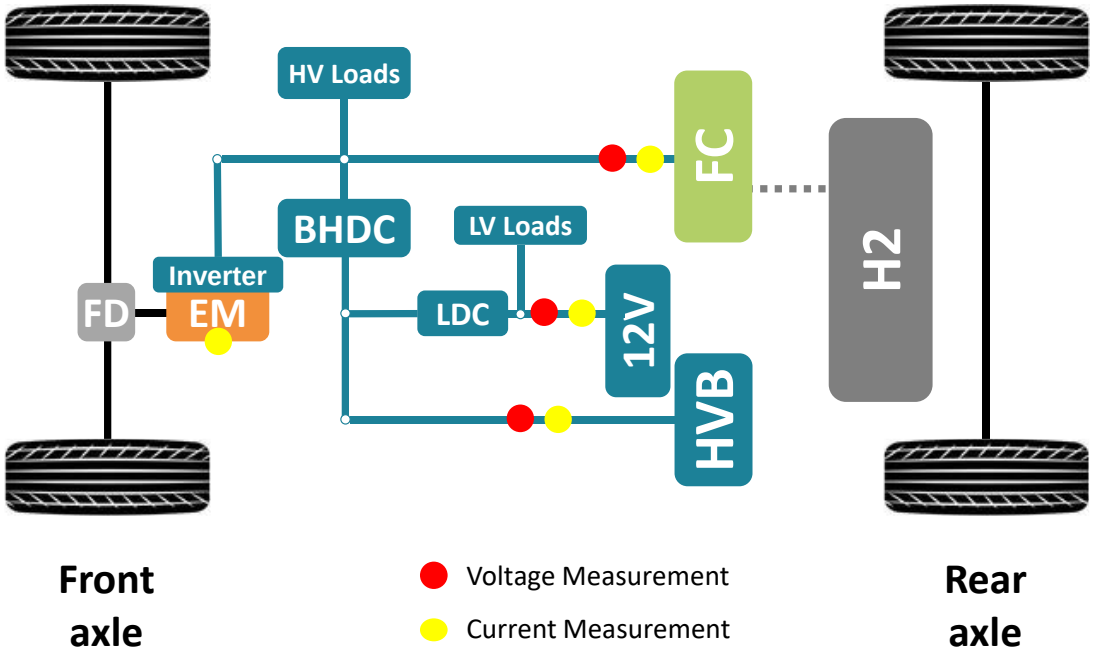
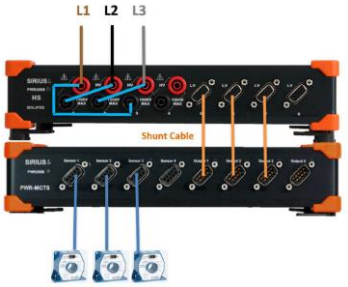
TEST PROTOCOL
Vehicle Instrumentation





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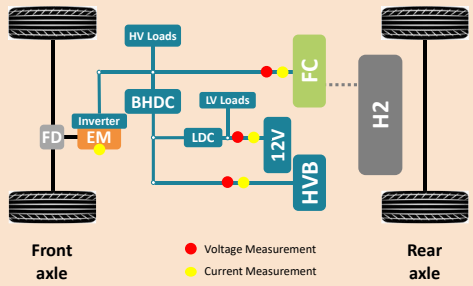
TEST PROTOCOL
Vehicle Instrumentation

1. Voltage & Current Measurements



Electrical components characterization

2. OBD + Powertrain CAN

Signals from vehicle communication system

3. Chassis-dyno Installation

Variable	Unit	Value
Test Mass	Kg	2030
F0	N	178.7
F1	N/(km/h)	0.9190
F2	N/(km/h)^2	0.04037

JRC's VELA lab

Current/Voltage of the BHDC
H_2 fuel rate
HV battery SOC
EM speed and torque

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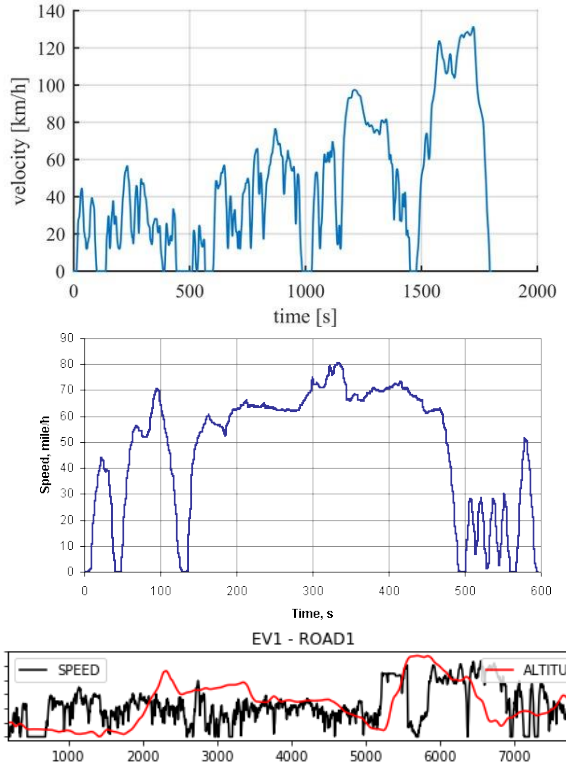
TEST PROTOCOL
Lab Experimental Campaign

DYNO TEST	SPECIFICATIONS	SCOPE
WLTP x 10	23.3 km	Explore average operating points
	1800 s	
	avg. vel 46.5 km/h	
US06 x 2	12.8 km	Reach higher speed and acceleration
	596 s	
	avg. vel 77.9 km/h	
RDE x 2	27.9 km	Explore real-world operating points
	1854 s	
	avg. vel 55.1 km/h	



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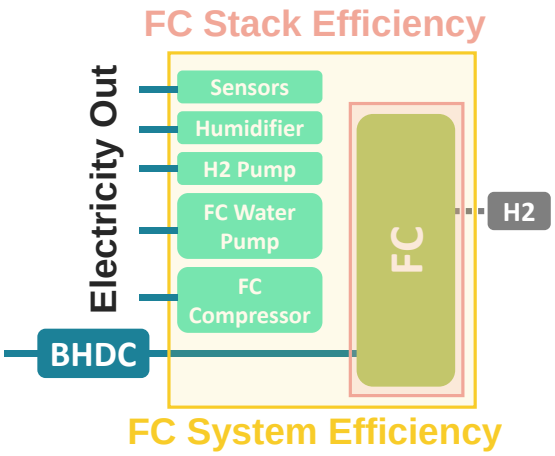
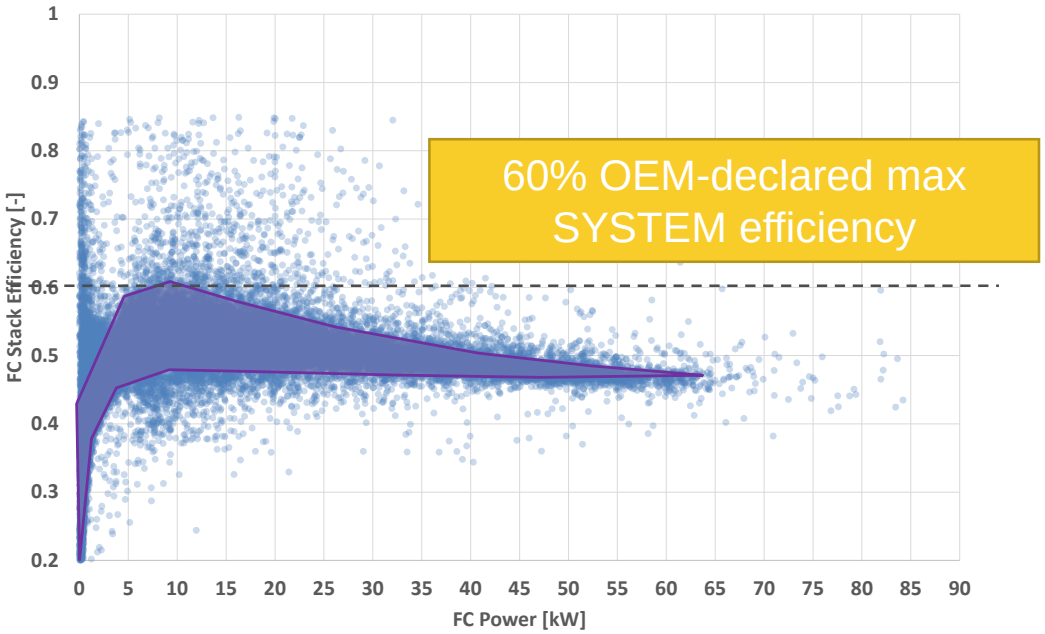
FUEL CELL STACK EFFICIENCY Measurement

FC System Efficiency and FC Stack Efficiency

The electrical system efficiency calculations include many individual components: fuel processors, humidifiers, fuel cell stacks, power conditioners, and controls.



$$\eta_{FC} = \frac{\int_{t_0}^{t_f} V_{FC}(t) \times I_{FC}(t)\, dt}{\int_{t_0}^{t_f} \dot{m}_{H_2}(t) \times LHV\, dt}$$



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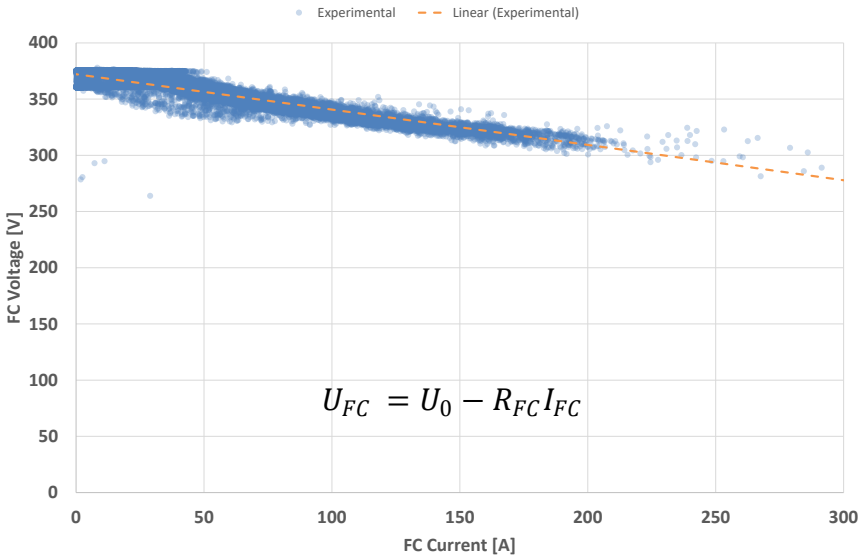
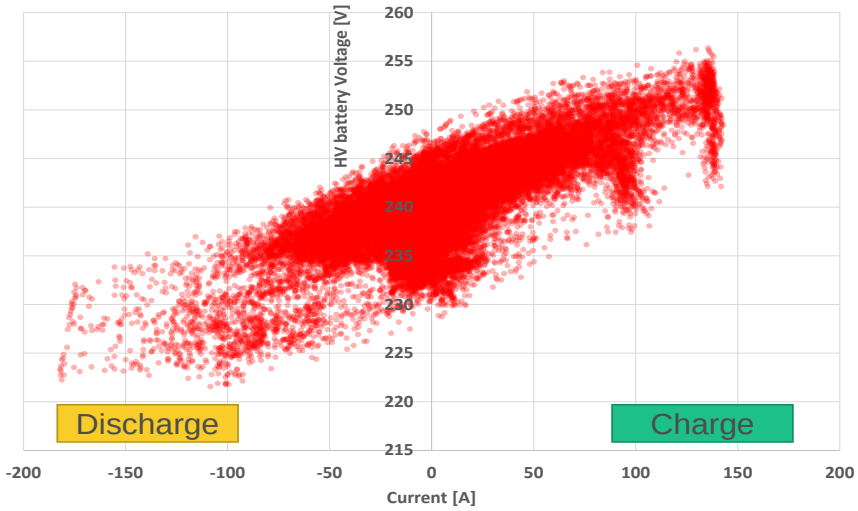
Powertrain Characterization
Polarization Curves

Fuel Cell



U_0	R_{FC}
372.12 V	0.3142 Ω

HV Battery



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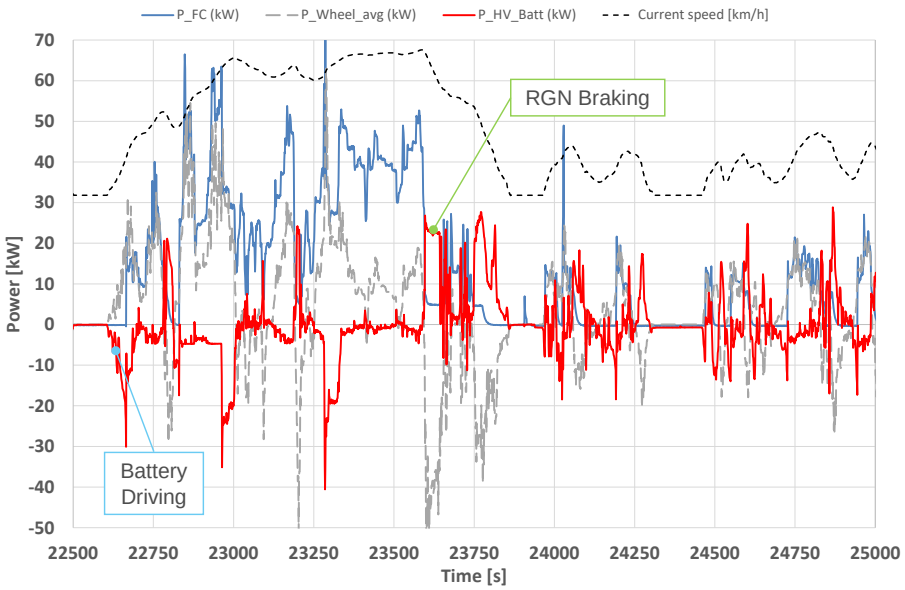
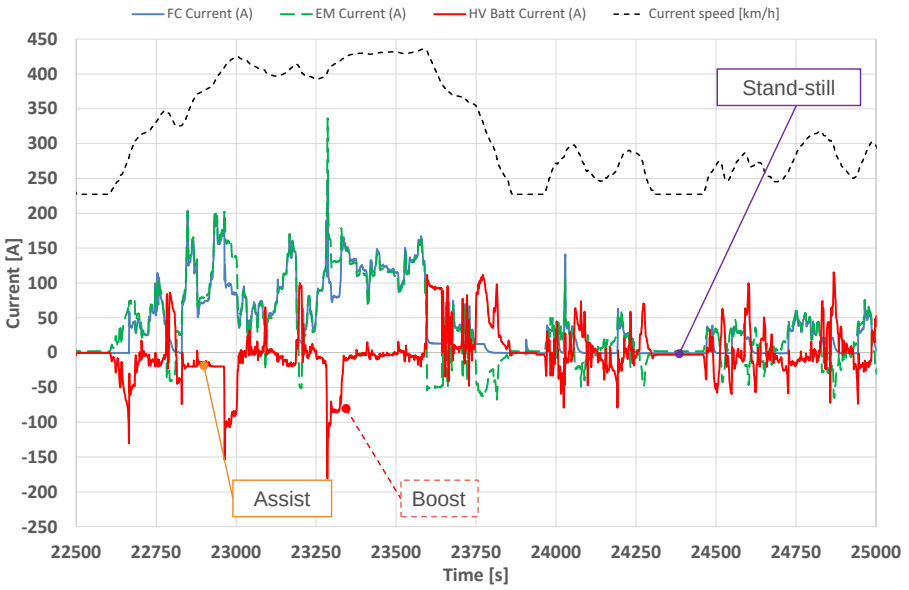
Powertrain Characterization
Driving Event Analysis

Power



Current



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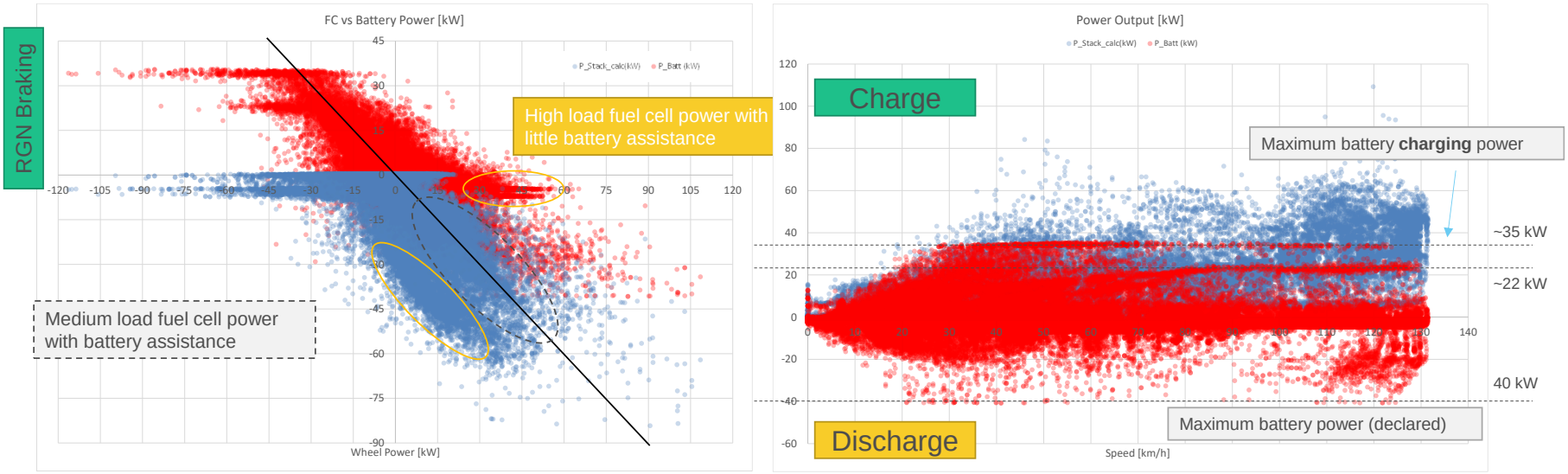
Powertrain Characterization
FC and HV Battery Usage



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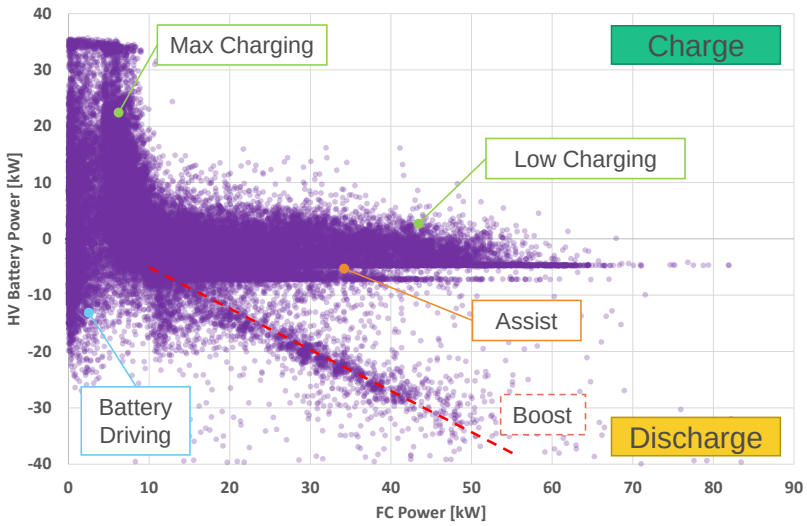
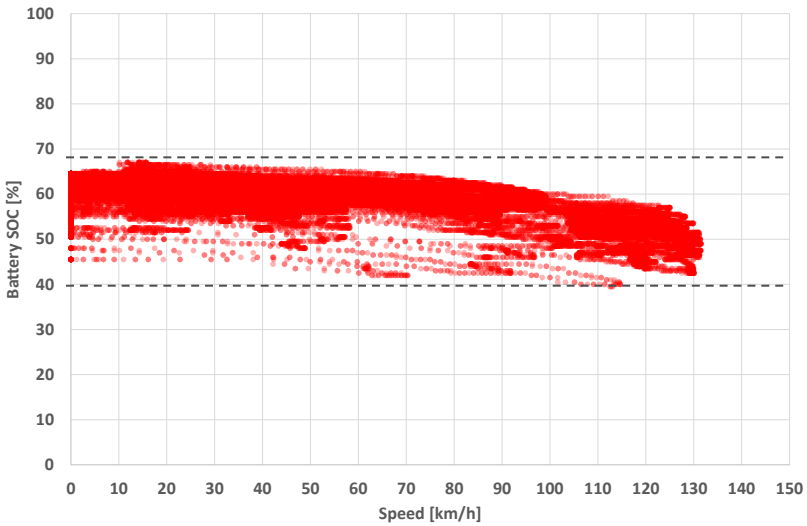
Powertrain Characterization
FC and HV Battery Usage

HV Battery vs. Fuel Cell



SOC vs. Speed



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Conclusions & Next Steps

- Preliminary study with a methodology applied on a state-of-the-art FCEV
- Contribute with independent experimental data on modern FC
- Perform powertrain characterization - Modelling

FOLLOW-UP

- Measure/analyze the consumption of the FC system Balance of Plant (BoP)
- Evaluate total FC system efficiency
- Include hot and cold testing for the thermal management and real-world driving

Thank you

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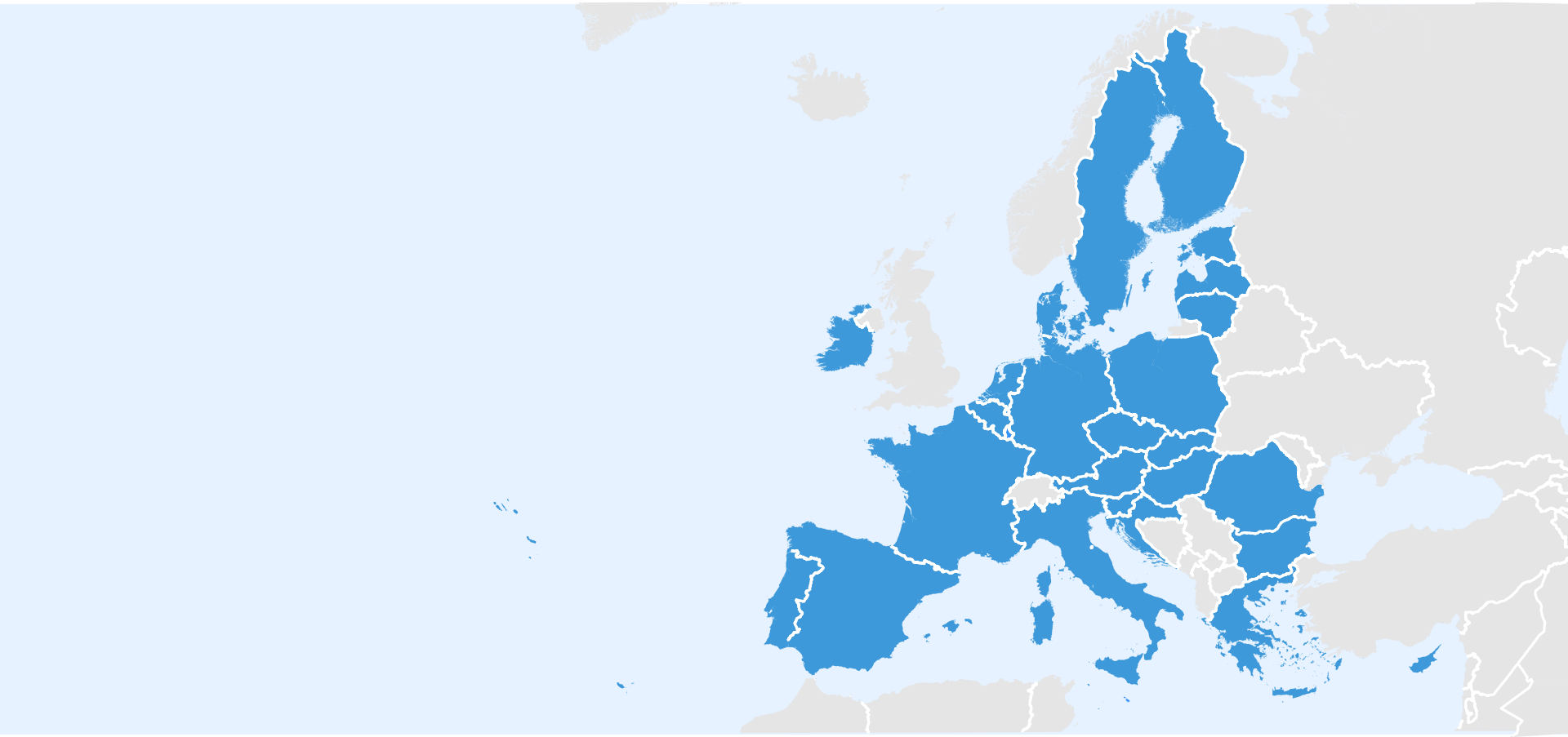
EU countries



0 250 500 1,000 Km

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