

# IMMORTAL

IMproved lifetiMe stacks fOR heavy duty  
Trucks through ultrA-durable components

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RESEARCH DAYS

15-16 NOVEMBER

**IMMORTAL**



Co-funded by  
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# Project Overview

## Project partners

- CNRS, JM, Bosch, FPT Industrial, IMTEK, AVL, Pretexo

## Total project budget and Clean Hydrogen JU contribution

- 3 825 927 €

## Project dates and stage of implementation

- 1st January 2021 - 31st December 2023 / M33 of 36 (90%)

## Call topic

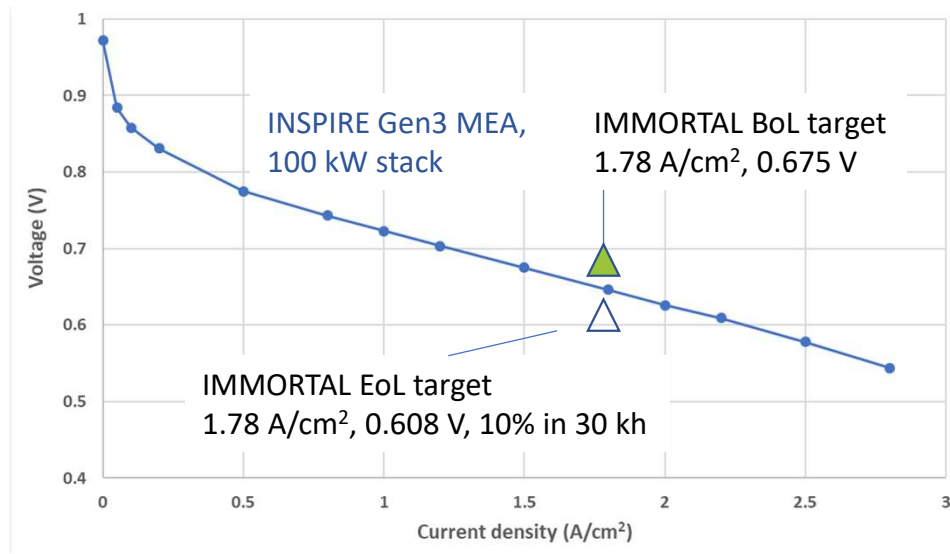
1.2 Durability-Lifetime of Stacks for Heavy Duty Trucks

## Call year

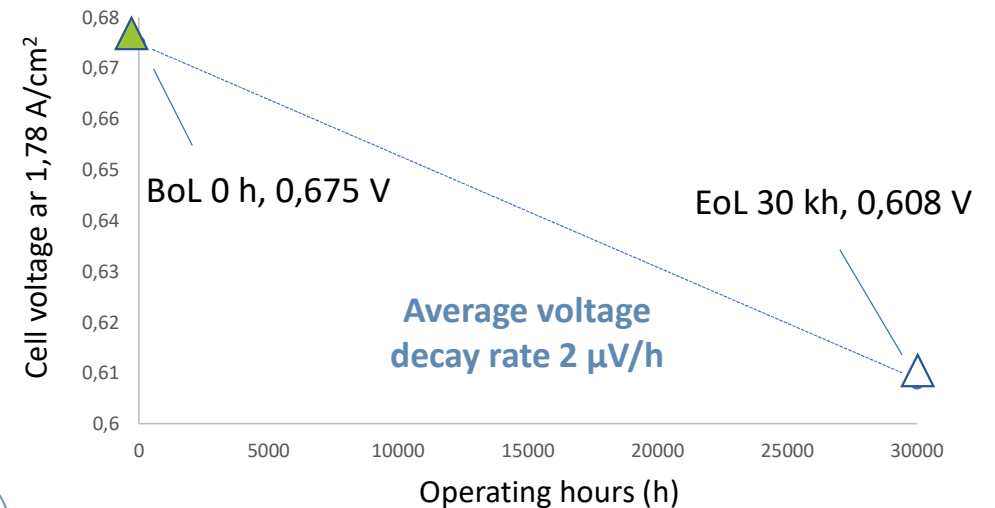
- 2020



# Heavy duty transport application requires high efficiency and durability



- IMMORTAL performance target of 1.2 W/cm<sup>2</sup> is lower than that of recent automotive projects INSPIRE, VOLUMETRIQ, GAIA, but at higher cell voltage, 0.675 V
- 30,000 hours lifetime requires a very low degradation rate



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# IMMORTAL is a Clean Hydrogen Partnership funded project for the development of heavy duty truck MEAs

## IMproved lifetiMe stacks fOR heavy duty Trucks through ultra-durable components

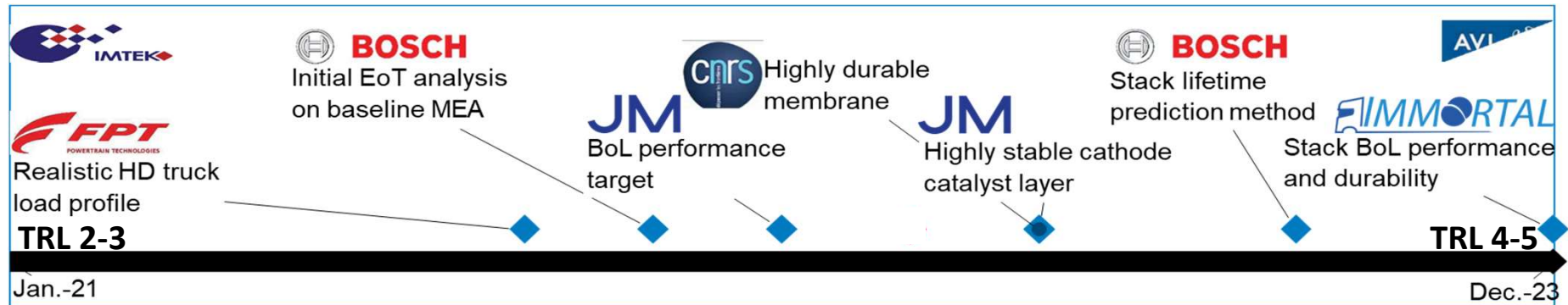
Develop load profile tests (LPT) for heavy duty membrane electrode assemblies (MEAs) performance and durability assessment

Develop high performance and high durability MEAs specifically designed for heavy-duty truck application

Validate MEA performance and durability using AST and LPT protocols

Develop robust algorithm for lifetime prediction to 30,000 hours of operation

Satisfy the project target in terms of performance, stack cost, and efficiency



# IMMORTAL materials for HD transport MEAs - membrane

Status at month 33 of a 36 months project at date 01/11/2023



Durable membrane

15  $\mu\text{m}$   
90,000 AST cycles

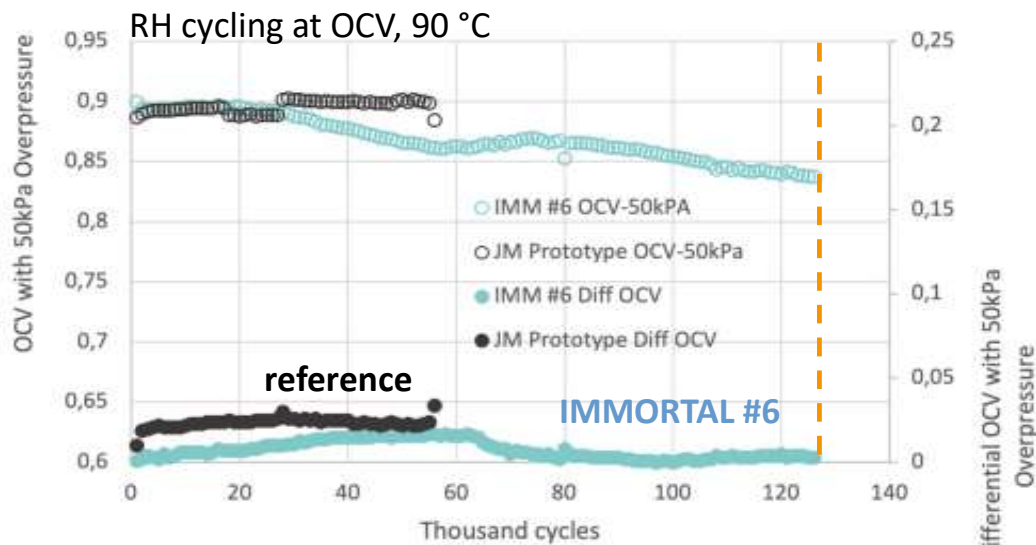


10  $\mu\text{m}$   
120,000 AST cycles

25%

50%

75%



- Combined mechanical/chemical accelerated stress test at 90 C on latest generation of nanofiber reinforced PFSA membrane, 10  $\mu\text{m}$  thickness
- 120,000 AST cycles, i.e. around 2,100 hours AST, to end of test with no rupture failure
- Surpassed previous generations and reference membranes in MEAs of otherwise identical construction

# IMMORTAL MEAs - performance and Pt thrifting

Status at month 33 of a 36 months project at date 01/11/2023



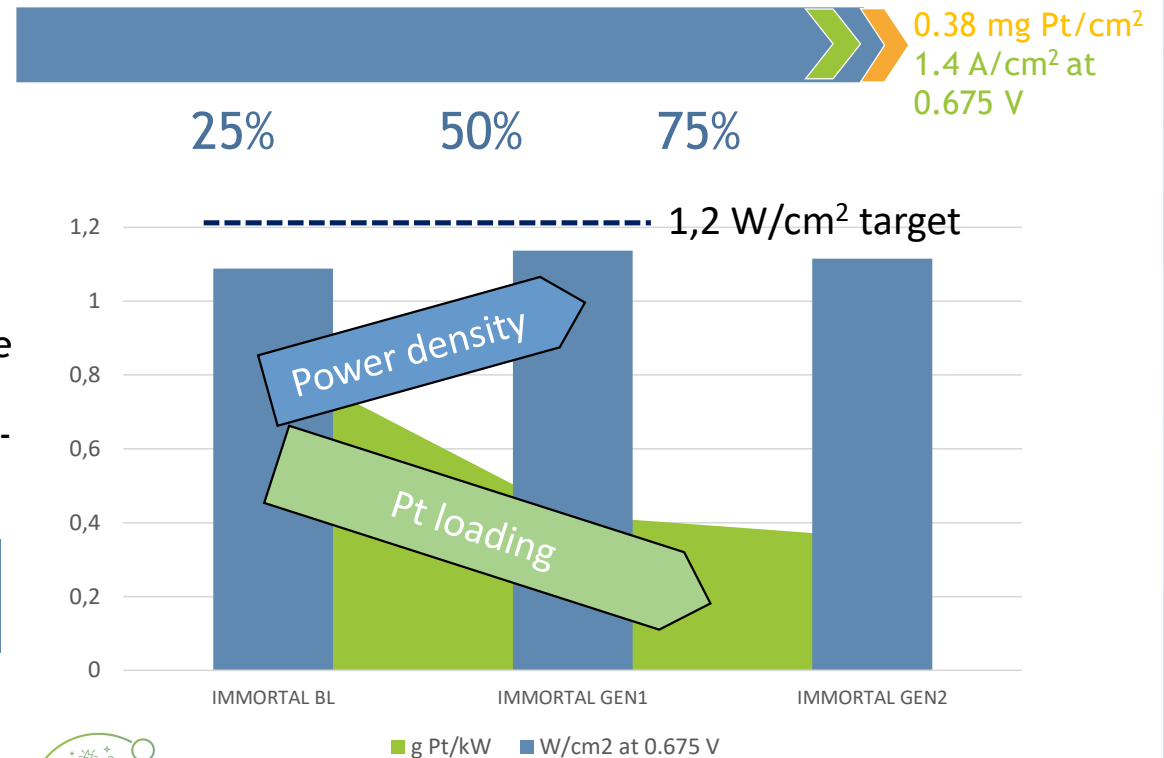
SRIA Pt loading and 95% power density targets achieved

0.68 mg Pt/cm<sup>2</sup>  
1.2 A/cm<sup>2</sup> at 0.675 V

0.38 mg Pt/cm<sup>2</sup>  
1.4 A/cm<sup>2</sup> at 0.675 V

- Over the course of the project, IMMORTAL MEAs:
- Provided increased power density at 0.675 V while reducing the Pt loading/kW by 60%
  - Showed BoL performance of 0.642 V at 1.77 A/cm<sup>2</sup> - within 5% of the target

IMMORTAL MEAs achieve the SRIA 2024 target for HDV: 1.2 W/cm<sup>2</sup> at 0.65 V with 0.36 mg Pt/cm<sup>2</sup>



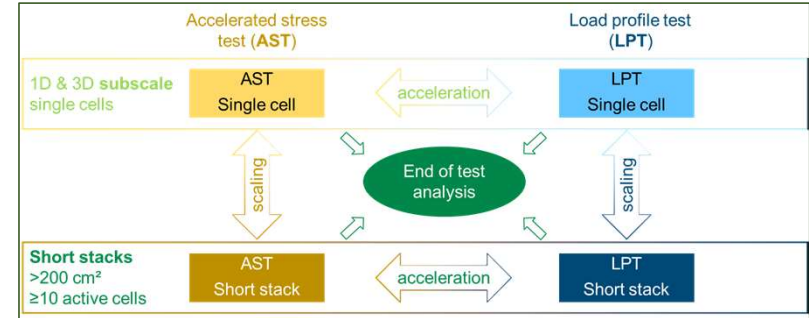
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# HDV load profile test development

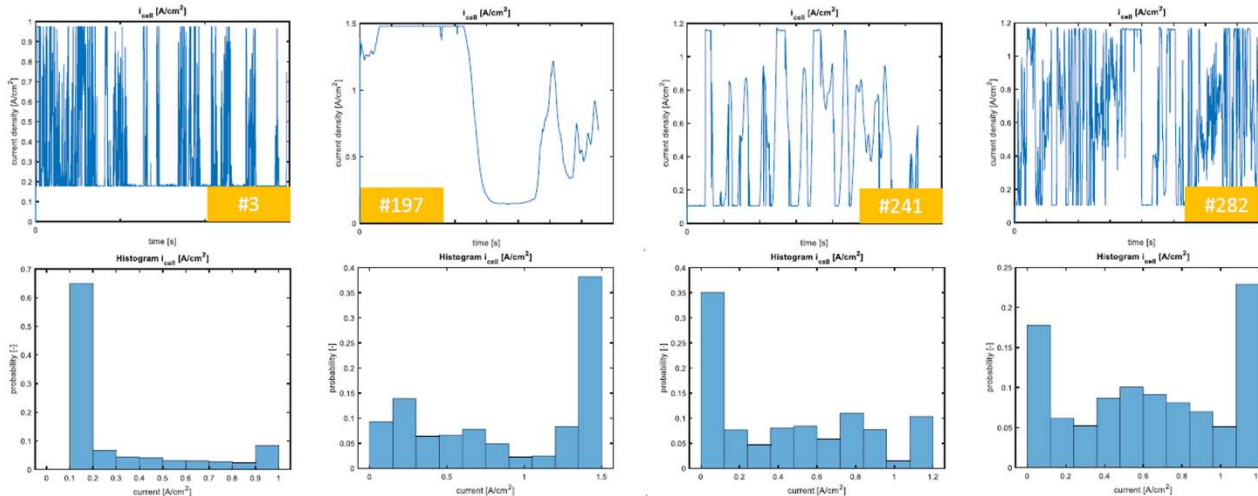
AST and LPT  
on single cells  
and short  
stacks

Stressor sensitivity  
to operation  
parameters

Acceleration  
factor  
between AST  
and LPT



Real life mission profiles | Simulated drive cycles | Extraction of stack load profiles | Selection of load profiles for testing



Post-processing of load profiles | Synthesis of modal LPT | Load profile testing

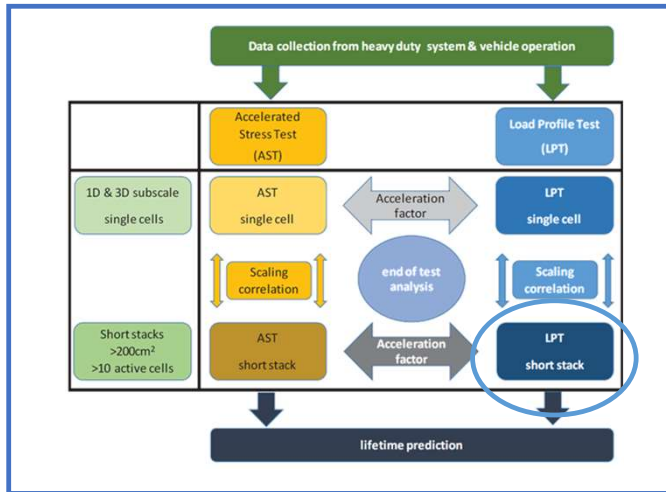
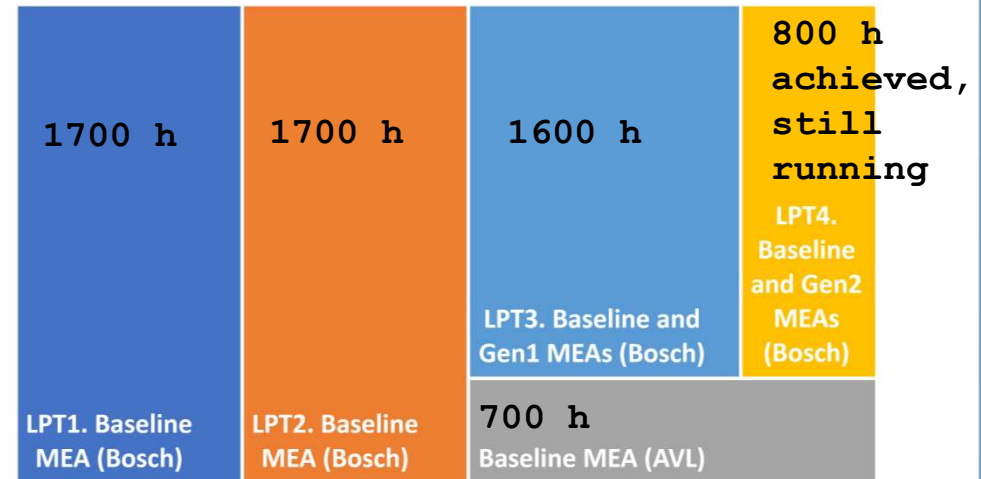


# Heavy-duty stack degradation assessment

Load profile test hours

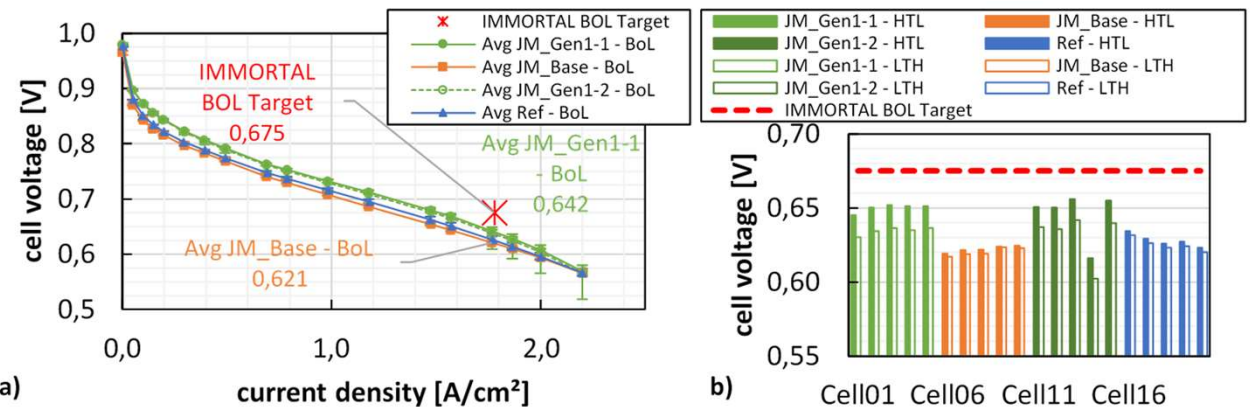
LPT1, LPT2 used initial test protocol

LPT3, LPT4 use improved test protocol



>6.5 kh load profile test hours on 5 short stacks

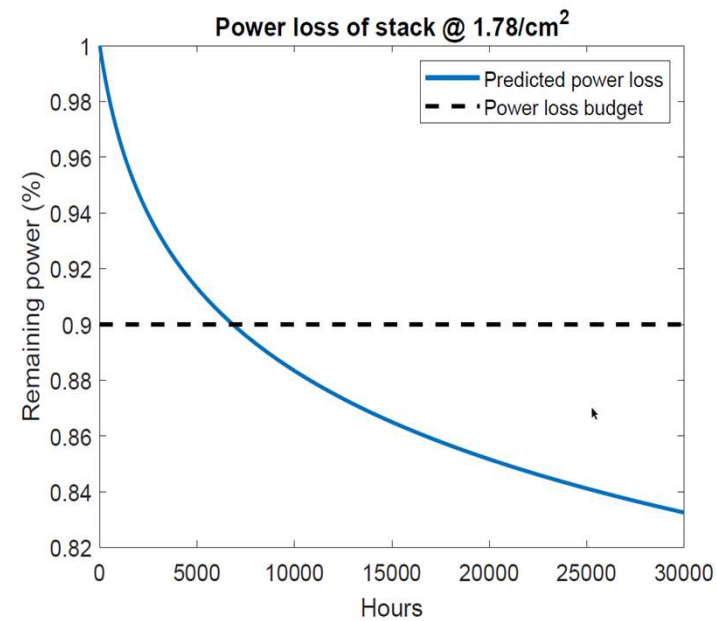
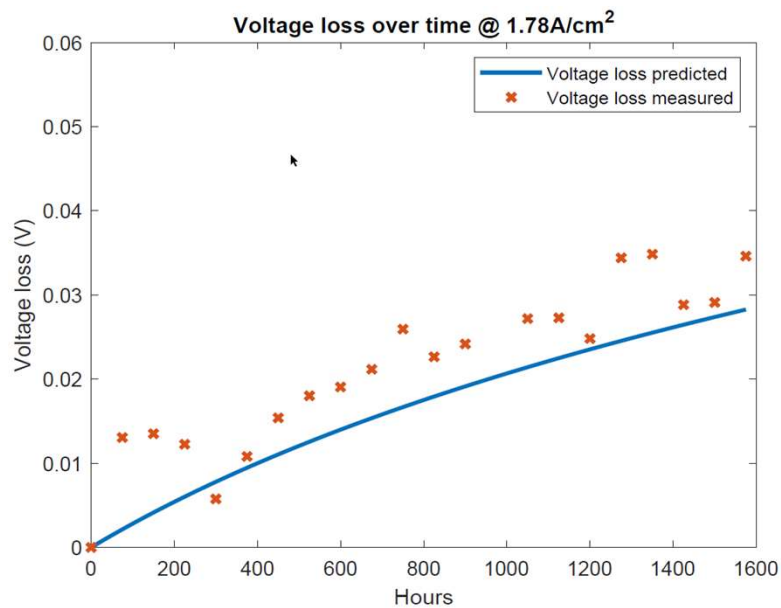
Initial and improved LPT protocols  
2 stack hardware types





# Lifetime prediction

- Lifetime prediction method established
- Parameterised aging model used to simulate voltage loss and compared with actual voltage loss during 1800 hours of LPT for the IMMORTAL baseline MEA
- 17% power loss after 30,000 hours



# Risks, Challenges and Lessons Learned

Risks, Challenges	Lessons learned - Measures taken
Catalyst developments not sufficiently mature to carry through to upscale and use in IMMORTAL MEAs	New understanding developed on structural changes occurring in Pt alloy catalysts under electrochemical bias
Risk to use a catalyst providing performance at the expense of durability ?	Lessons learned to be carried forward into other work on MEAs for HDV
Only two MEA generations during the project lifetime	Limited by cost, but at least one other MEA iteration required to make use of the learning from test results on Gen2

Lessons learned to be carried forward into other on-going & future work on MEAs for HDV

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# Communication & Dissemination Activities

## IMMORTAL communication channels:

- [www.immortal-fuelcell.eu](http://www.immortal-fuelcell.eu)
- Project brochure
- Newsletters at M12, M24
- Presentations at the iDWG International Durability Working Group meetings with DOE funded Million Miles Fuel Cell Truck Consortium (M2FCT) and NEDO FC-Platform
- Presentation at recent MoreLife workshop

## IMMORTAL dissemination:

- 4 publications in scientific journals
- 3 invited talks and 1 plenary
- 4 contributed talks and poster presentations at international conferences
- Public summaries of all deliverables are accessible through the IMMORTAL website

PRETEXO



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# Synergies With Other Projects And Programmes

Interactions with projects funded under EU programmes

- HIGHLANDER: IMMORTAL LPT to be used in HIGHLANDER



Interactions with national and international-level projects and initiatives

- IMMORTAL participates in the international Durability Working Group discussions with the Million Mile Fuel Cell Truck Consortium (M2FCT, DOE) and FC-Platform (NEDO) gathering around 60 participants around topical presentations on HD testing protocols, modelling, materials developments for HD application



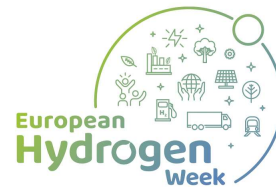
# Exploitation plan / impact

Exploitation Plan Item	Partner	Exploitation Activity / Impact
Methodology standardisation - Load profile test for HD trucks	Bosch, JM	Standard methodology for HDV test protocols and data analysis. Use in future HD stack testing
Lifetime prediction algorithm	Bosch	Apply to future HD MEA/stack developments
Use of components in next generation HD MEA products	JM	Introduce IMMORTAL components and manufacturing processes in next generation HD MEAs
Data-based lifetime prediction tools	FPT	FC system & vehicle durability assessments Higher durability e-powertrain architecture and power management
Simulation methodology	FPT	Improved fuel cell stack → system → e-powertrain → vehicle modelling methodology
Further R&D	CNRS, IMTEK, JM, Bosch, FPT	Continue the development and improvement of new MEA materials, their testing against IMMORTAL AST and LPT protocols and development of mathematical models to predict stack durability and for load profile creation



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