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Technology Watch Report

ERTRAC - H2 ICE RESEARCH WORKSHOP

28 OCTOBRE 2022

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Interreg Grande Région | Großregion PAE

Budgetverantwortliche Partner / Partenaires financeurs

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DESCRIPTION

- **Objet :** Report on the participation to the H2 ICE research workshop
- **Location:** Brussels – Belgium + online
- **Date:** 20 October 2022
- **Web site:** https://www.ertrac.org/index.php?mact=CGCalendar,cntnt01,default,0&cntnt01event_id=131&cntnt01display=event&cntnt01returnid=91
- **Participant:** Anthony Auert, Cluster Manager – AutoMobility, Luxinnovation
- **Report version:** version #1

OBJECTIVES

- Increase knowledge about latest development done on Internal Combustion Engine (ICE) working with hydrogen.
- Understand the economic benefits that H2 ICE can bring to the Greater Region automotive ecosystem.
- Discuss R&D challenges for the next years, leading to possible collaborative research activity with the Greater Region automotive ecosystem.
- Networking, meet the leading companies developing cutting edge H2 ICE.

SUMMARY

The workshop draw a lot of attention since it was attended by more than 160 participants willing to increase their knowledge around Internal Combustion Engine (ICE) fed by hydrogen. The audience was composed by OEM like Hyundai, Volvo and MAN as well as TierX suppliers like BorgWarner, Bosch, FEV or IAV.
Four main axes were discussed:

- Engine Technology: State of the Art and Outlook
- Efficiency and emissions
- Infrastructure-Energy Carrier
- Impact Assessment

KEY LARNINGS:

- H2 ICE offers Diesel like performance with extremely low emissions.
- The segment of on road and off road commercial applications is highly diversified. The H2 engine is an efficient and complementary solution for dedicated use cases.
- In terms of robustness, readiness, material availability and cost, the H2 engine represents a very attractive sustainable powertrain technology.
- The H2 engine offers ideal conditions to meet current and future air quality targets.
- One challenge for hydrogen engines are NOx emissions which can be tackle with appropriate SCR technology.
- Carbonaceous compounds (HC, CO) and particulates originating mostly from the lubricant (although at very low levels) can be tackled by Oxidation catalysts and Particulate filters.

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ABOUT ERTRAC

The European Road Transport Research Advisory Council (ERTRAC) is the European Technology Platform (ETP) for Road Transport. Luxinnovation is member of ERTRAC who is recognized and supported by the European Commission[1].

The tasks of ERTRAC are to:

- Provide a strategic vision for road transport research and innovation in Europe.
- Define strategies and roadmaps to achieve this vision through the definition and update of a Strategic Research Agenda (SRA) and implementation research roadmaps.
- Stimulate effective public and private investment in road transport research and innovation.
- Contribute to improving coordination between the European, national, regional public and private R&D activities on road transport.
- Enhance the networking and clustering of Europe's research and innovation capacities.
- Promote European commitment to Research and technological development, ensuring that Europe remains an attractive region for researchers, and enhancing the global competitiveness of the transport industries.
- Support the implementation of Horizon Europe, the European Framework Programme for Research and Innovation

[1]ERTRAC is supported by FUTURE HORIZON, a coordinated action financed by the European Commission.

ATTENDED PRESENTATIONS

1. HYDROGEN INTERNAL COMBUSTION ENGINE - A VIABLE TECHNOLOGY FOR CARBON NEUTRALITY?

- **Speakers:**
  Stefan Hoffman, Hyundai
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - Series production 1.6 ℓ gasoline T-GDI engine is converted to operate with hydrogen as fuel to assess its potential as a viable strategy to comply with upcoming green house gas and emission regulations.
  - Extensive design front loading is done by visualization and CFD simulation to pre-optimize injector configuration, improve volumetric efficiency and mixture homogeneity.
  - With 2-stage boosting system (48V electric supercharger + VGT turbocharger), required excess air ratio was achieved throughout hybrid operating area and a maximum brake thermal efficiency over 40% was reached.
  - Extremely low NOx emission below 15 ppm was demonstrated at HEV operating area; traceable HC and CO emission below 1 ppm was measured with comparable pressure rise rate to gasoline engine.
  - Up to 3000 rpm, same full load performance as base 1.6 ℓ gasoline T-GDI engine is achieved.
  - At 4000 rpm, full load torque is reduced by about 20 Nm due to pre-ignition. Pre-ignition is suspected to be avoided by VGT with bigger compressor and higher Lambdas (assessed as next step).
  - Efficiency and emission potential confirmed at main operating area and comparable full load performance with base gasoline T-GDI engine indicates that H2ICE can be an important complementary technology to BEV and FCEV.

2. APPLICATION OF H2 ICE TECHNOLOGY ON A LIGHT COMMERCIAL VEHICLE

- **Speakers:**
  Gavin Dober, BorgWarner Luxembourg
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - H2 ICE offers Diesel like performance with extremely low emissions.
  - H2ICE Outlook:
    - BorgWarner sees an economic and technical opportunity to deliver virtually zero CO2 mobility for many applications.
    - BorgWarner is developing the critical components including Fuel Injection, Turbo-Charger and Control systems.
    - BorgWarner and its partners have created a LCV demonstrator in order to develop the required system integration knowledge and showcase the technology potential.
  - H2 ICE Engine and Vehicle Performance:
    - A 2L Diesel engine has been adapted and calibrated for H2 operation:
      - It shows very low emissions (Only a small amount of NOx)
      - It has very similar energy consumption to the Diesel baseline
    - The engine has been installed in a LCV and is running on the road:
      - Calibration of the baseline Diesel after treatment system is ongoing

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- BorgWarner is confident to exceed “Euro7” tailpipe emissions targets as predicted by simulation

3. HYDROGEN ENGINE FOR COMMERCIAL VEHICLES

- **Speakers:**
  Stefan Bareiss, Bosch
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - H2 engine in general:
    - The segment of on-road and off-road commercial applications is highly diversified. The H2 engine is an efficient and complementary solution for dedicated use cases.
    - In terms of robustness, readiness, material availability and cost, the H2 engine represents a very attractive sustainable powertrain technology.
  - Technology:
    - Excellent emissions achieved @ WHTC with moderate application effort for PFI-HD engine.
    - Post injection @ DI H2-engine as enabler for Diesel-like performance and lowest emissions.
    - The H2-engine offers ideal conditions to meet current and future air quality targets.

4. CAN A HYDROGEN ENGINE CONTRIBUTE TO CREATE SUSTAINABLE TRANSPORT SOLUTIONS?

- **Speakers:**
  Lukas Virnich, FEV
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - Mature technology from diesel and natural gas engines suites as base newly combined it can create powerful and super-efficient hydrogen engines.
  - Three main output parameters performance, emissions and efficiency are mainly influenced by five major components: turbocharger, fuel Injection, base engine, compression ratio and ignition system.
  - Power level, engine efficiency and emissions of today´s engine can be improved by:
    - Avoiding abnormal combustion at high BMEP level
    - Crank Case Ventilation
    - Ignition system
    - Improved mixture homogeneity
    - Increased air fuel ratio
  - Its chemical properties make hydrogen vulnerable to combustion anomalies such as knocking combustion and pre-ignition.
  - Mature technology from Diesel and Natural Gas engines suites as base but it is not copy paste, hydrogen engines have specific requirements.
  - Mixture formation is key to high engine efficiency and low raw emissions.

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5. HYDROGEN INTERNAL COMBUSTION ENGINES: EMISSIONS AND EXHAUST AFTERTREATMENT SYSTEMS - A REVIEW

- **Speakers:**
  Prof. Zissis Samaras, LAT
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - ICEs have demonstrated potential to genuinely be zero-emission powertrains.
  - Main challenge for hydrogen engines → NOx emissions that could be tackled with:
    - In-cylinder strategies with some drawbacks on engine performance and efficiency
    - Dedicated EATS with main device the SCR
    - Further supported by combinations like NSC – NH3 SCR and H2 SCR – NH3 SCR which can operate efficiently at a wide range of exhaust temperatures
  - Carbonaceous compounds (HC, CO) and Particulates although at very low levels (originating mostly from the lubricant) should be tackled by Oxidation catalysts and Particulate filters.
  - Particles need special consideration due to very small diameter (below 10nm).
  - NH3 and N2O should also be carefully evaluated and accounted for.
  - PEMS are required to measure in high H2O content (up to or just above 20%). Special PEMS will be required for H2, or measurements in H2 ICEs in the lab only.

6. HIGH EFFICIENCY HYDROGEN ICE, CARBON FREE POWERTRAIN FOR PASSENGER CARS AND COMMERCIAL VEHICLES

- **Speakers:**
  Maximilian Brauer, IAV
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - H2 ICE is important for transition to sustainable energy applications and mobility.
  - IAV observes high interest in H2 ICE on a global scale: EU, Japan, China and US.
  - CO2 emission target of CO2 < 1 g/kWh can be met only when CO2 contained in the admitted fresh air intake is subtracted. Same for FCEV.
  - CO2 from lubricant HC and CO oxidation is insignificant.
  - With “moderate” AdBlue (NH3) dosing strategy CO2 emission < 1 g/kWh can be reached.
  - H2 ICEs should be “ZEV capable” in case of a CO2 target of CO2 < 1 g/kWh.

7. ENGINE LUBRICANT: AN ENABLER FOR SUSTAINABLE H2-ICE MOBILITY?

- **Speakers:**
  Nicolas Obrecht, TotalEnergies
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - Particle emissions can exceed Euro VI limit for hydrogen combustion engine without specific lubrication system design (on a PN10 basis).
  - Engine oil composition can significantly impact particle emissions in H2 –ICE.
  - Significant impact of engine oil composition on pre-ignition frequency in H2-ICE.
  - Lubricant formulation solutions for LSPI mitigation in gasoline SI engines not as efficient in H2 engines → need to develop new lubricant solutions?
  - Lubricant role in CO2 emissions, particle emissions and pre-ignition seems to be associated to different attributes. Further investigation is required to better understand underlying mechanisms.

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- Hydrogen diffusion in oil film doesn't seem to impact lubricant performances.
- Engine calibration strategies can strongly impact oil degradation process through nitro-oxidation → need to adjust oil performance depending on application target.
- Collaborations between oil industry and OEMs can foster synergistic solutions.

8. H2 PRODUCTION AND INFRASTRUCTURE FOR ICE

- **Speakers:**
  Sasa Marinic, TotalEnergies
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - Three regions are leading the global adoption of hydrogen in mobility: Asia (China, Japan and South Korea), the United States (mainly California) and (Northwest) Europe. These regions are TotalEnergies' focus for hydrogen in mobility activities.
  - Hydrogen in mobility activities is predominantly driven by strong public support (regulation and subsidies).
  - TotalEnergies has the ambition by 2030 to operate directly or indirectly up to 150 hydrogen refueling stations in Germany, the Netherlands, Belgium, Luxemburg and France.
  - TotalEnergies has the capacity to provide complete hydrogen refuelling solutions: design, financing, installation, supply, operation & maintenance.
  - H2 project development requires partnerships across the value chain.

9. ENVIRONMENTAL IMPACT ASSESSMENT (FOCUS ON GHG) AND ECONOMIC ANALYSIS (EXTRACT OF RESULTS OF FVV FUELS STUDY IV AND IVB)

- **Speakers:**
  Dr. Ulrich Kramer, Ford, FVV
- **Link to presentation material:** click here
- **Summary (presentation extract):**
  - Factors of required installed power generation capacity 2050:
    - H2-FCEV international / BEV domestic » 1.5
    - H2-ICEV international / BEV domestic » 1.7
  - Highest costs (NPV) for BEV (4,500 … 5,300 bil. €) followed by FCEV (3,900 … 4,500 bil. €).
  - Lowest costs (NPV) are for ICEV (+ e-fuels) with continued 2020 vehicle technology:
    - It is more cost efficient to build additional power generation and energy/fuel distribution infrastructure, than to maximise efficiency measures (at high cost) on vehicle level
    - H2-ICEV: lower total costs than BEV & FCEV, but higher costs than "Hydrocarbon E-Fuels"
    - H2-ICEV: oncosts driven by vehicle tank system (700 bar)
  - Many single technology scenarios cannot achieve GHG neutrality* by 2050 (e.g., BEV limited to 76% defossilisation rate, mainly by ramp-up of the electric supply network).
  - Single technology scenarios (without e-fuel usage in the for existing fleet) yield to considerably higher cumulated GHG in 2050 (e.g., BEV: +39 % à further GHG emissions after 2050 until 100% defossilisation rate achieved).
  - Single tech. scenario H2-ICEV can achieve GHG neutrality by 2050 (+18% GHG, +1% costs).

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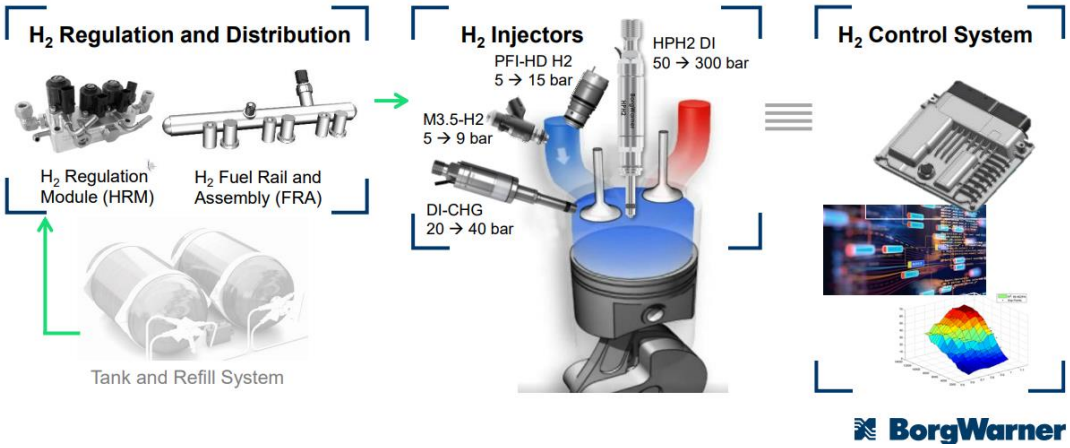
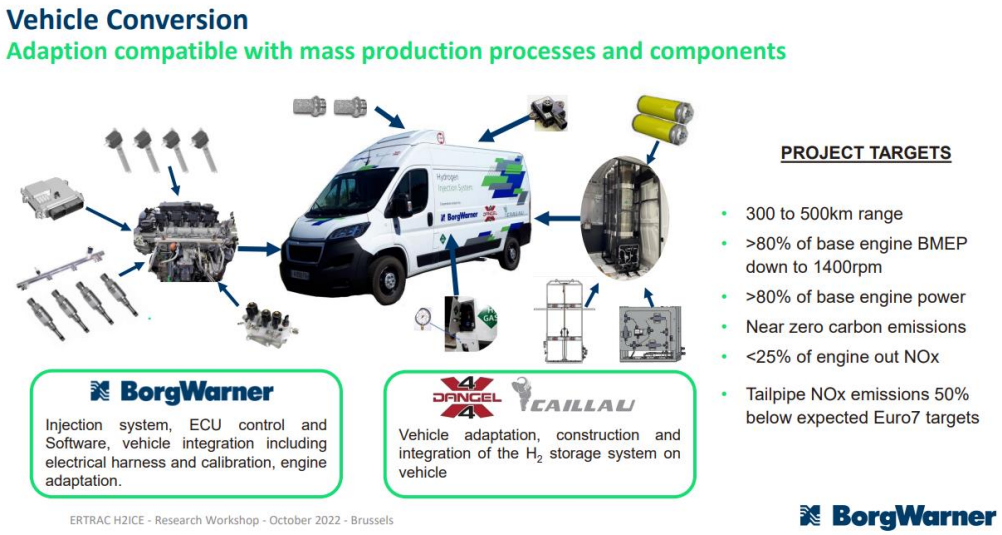
LUXEMBOURG PRESENCE

1. BORGWARNER (TECHNICAL PRESENTATION: APPLICATION OF H2 ICE TECHNOLOGY ON A LIGHT COMMERCIAL VEHICLE)

- **Offering:**
  Whether in a highly efficient combustion engine, an intelligent hybrid system or the very latest electric drive, BorgWarner is driving mobility for today and tomorrow. As the product leader with more than 130 years of experience in the field of powertrain systems, BorgWarner is supporting the automotive industry in realizing clean propulsion and efficient technology solutions for light-, medium- and heavy-duty vehicles as well as off-highway applications.
  https://www.borgwarner.com/home

- **BorgWarner is offering the complete hydrogen fuel injection system:**





VEHICLE CONVERSION VIDEO