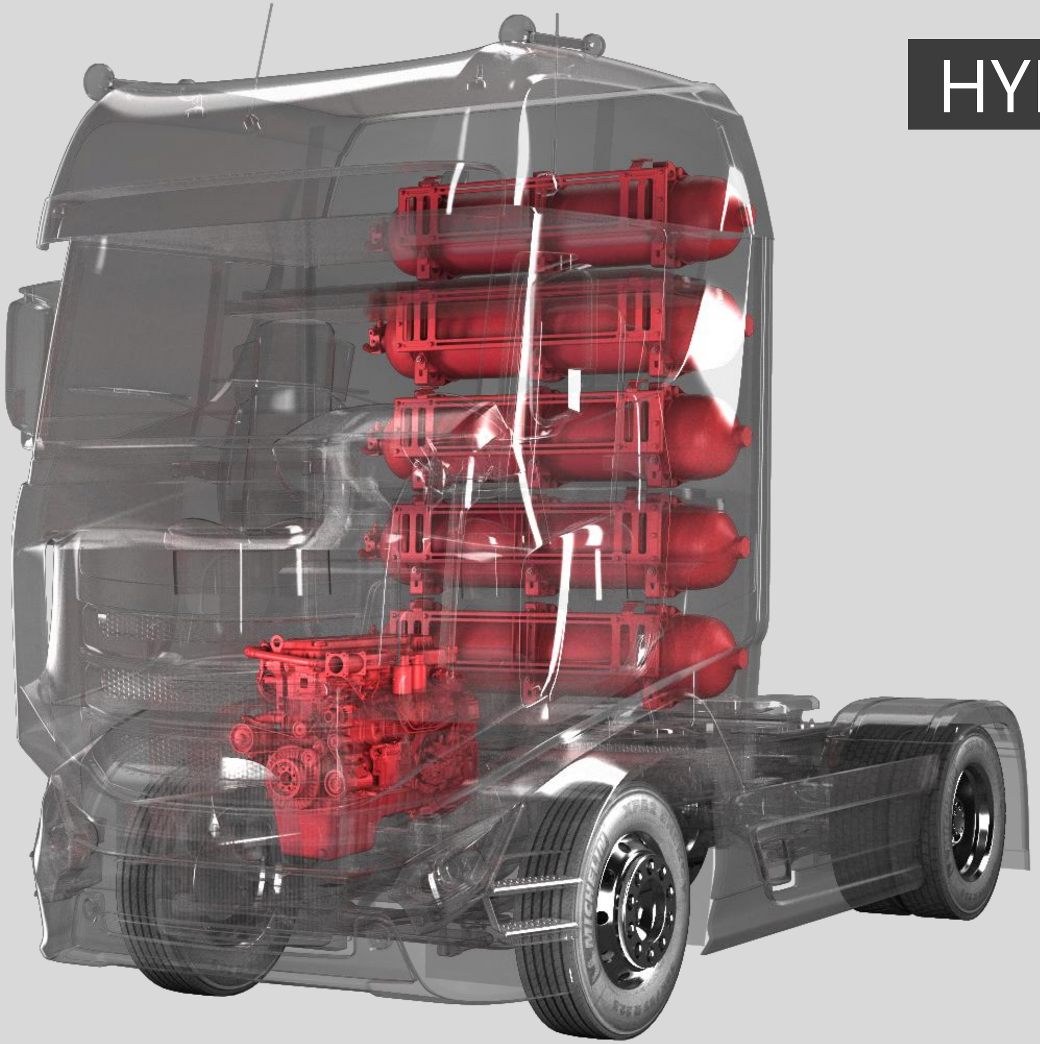
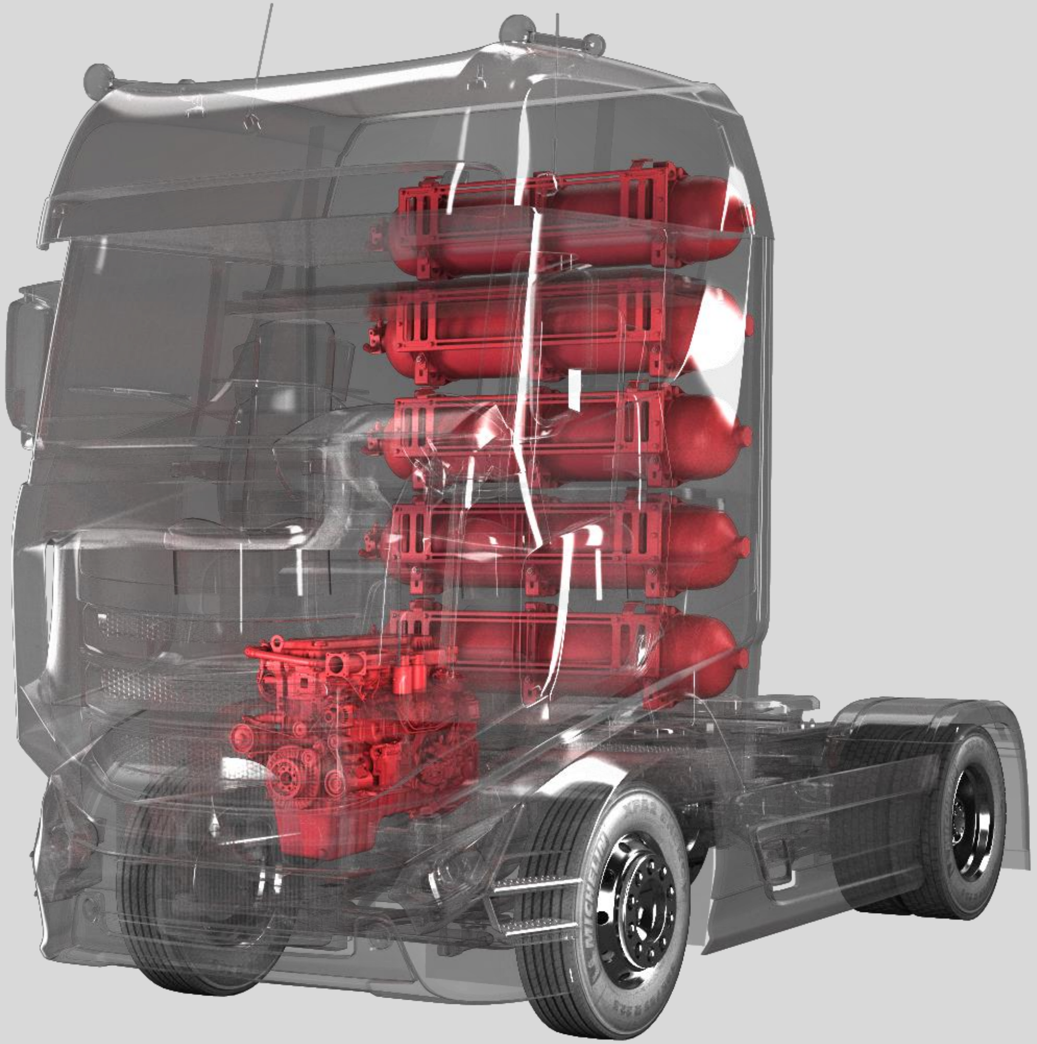
OCTOBER 5TH – 7TH, 2020

THE AACHEN COLLOQUIUM
SUSTAINABLE MOBILITY

HYDROGEN ICE





- 2-Stage turbocharging offers possibility of lean air fuel ratio even at higher load points
- Engineering targets
  - Brake mean effective pressure ~ 20 bar
  - Effective engine efficiency > 42%
- Variation of
  - compression ratios
  - turbulence level
  - spark plug layout
  - to evaluate effect on engine efficiency and peak firing pressure for different air fuel rations

Hydrogen offers wide range of possible combustion system layouts in combination with different aftertreatment systems

HYDROGEN COMBUSTION ENGINES CAN BE EITHER WAY BASED ON DIESEL AND GASOLINE ENGINES

Base engine	Engine size	Combustion concept	Aftertreatment	Boosting/ Air control
Diesel	HD Engine Size ~13l	Mid/High pressure **DI SI** FL: Ultra Lean PL: Ultra Lean	None	1 or 2 stage / Wastegate VTG
	MD Engine Size ~8l	Low/Mid pressure **DI SI** FL: Lean PL: Ultra Lean	SCR Particle Filter	
	LCV Engine Size ~2-3l	Mid pressure **DI SI** FL: stoichiometric + EGR PL: Ultra Lean	TWC (+H_2 SCR) Particle Filter	NA or turbo charged Throttle valve Valve timing
	PC Engine Size ~2l			
Gasoline	REX Engine Size ~1l	Low pressure **PFI/DI SI** FL: stoichiometric (+EGR) PL: stoichiometric	TWC Particle Filter	

Low pressure < 30 bar, Mid pressure 40 – 60 bar, High pressure > 200 bar

For MD and HD vehicle class low/mid pressure in combination with lean full load and ultra lean part load operation seems most favorable

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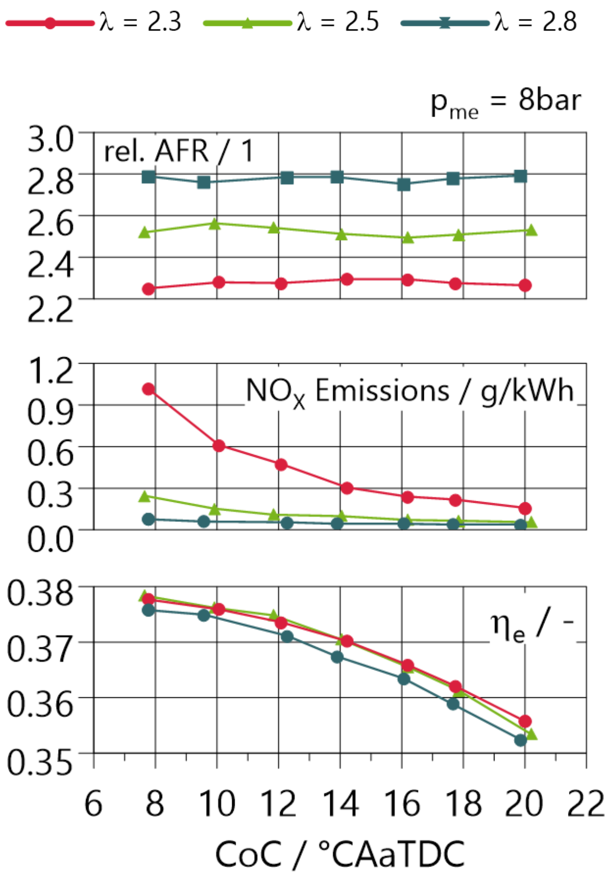
Gasoline (Temperature)		REX Engine Size ~1l	Low pressure **PFI/DI SI** FL: stoichiometric (+EGR) PL: stoichiometric	TWC Particle Filter	

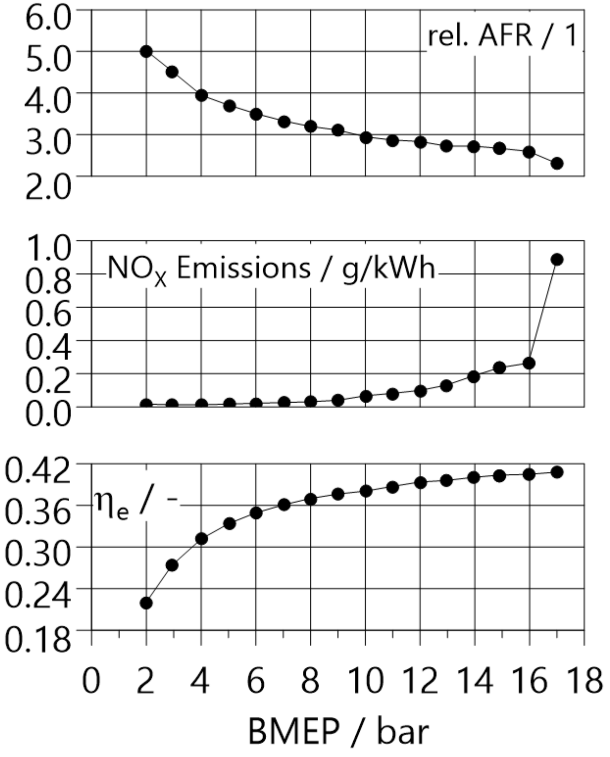
Low pressure < 30 bar, Mid pressure 40 – 60 bar, High pressure > 200 bar

The multi-cylinder hydrogen commercial engine can be used in multiple operation modes – efficiency optimized as well as emission optimized

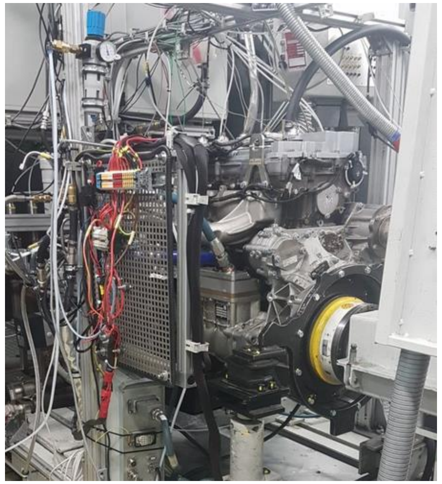
HYDROGEN HD APPLICATION REACHING EFFECTIVE EFFICIENCIES OF 42 %



MD-Engine 7.7l R6, Fuel: H_2, PFI
n = 1400 1/min, 2-Stage TC



- Engineering targets
  - BMEP ~ 20 bar
  - η_e > 42%
- 2-Stage turbocharging
  - lean air fuel ratio even at higher load points
- Steady state trade off
  - EGR vs. lean operation
  - Volumetric efficiency vs. turbulence level (burn duration)
  - NO_x emission level vs. exhaust gas temperature (best air fuel ratio)

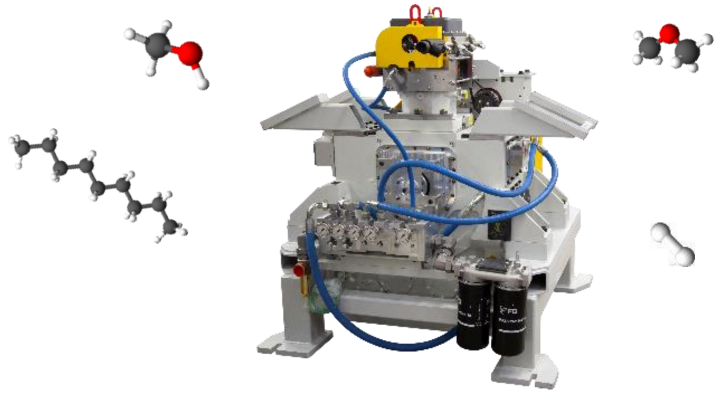


CoC: Center of Combustion

Leveraging our profound experience in the field of fuels research, we have set up a heavy-duty single cylinder engine suited for alternative fuels

HYDROGEN INVESTIGATION Q4/2020

- Investigation of injector vs. spark plug position
- Optimization of hydrogen nozzle using 3D CFD
- Dedicated piston design for hydrogen combustion

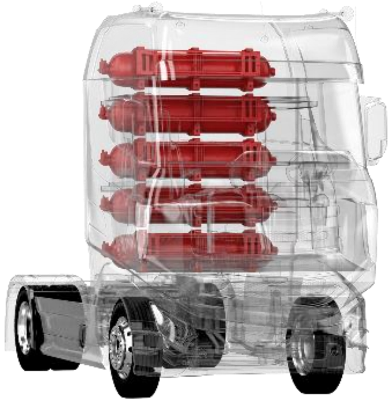


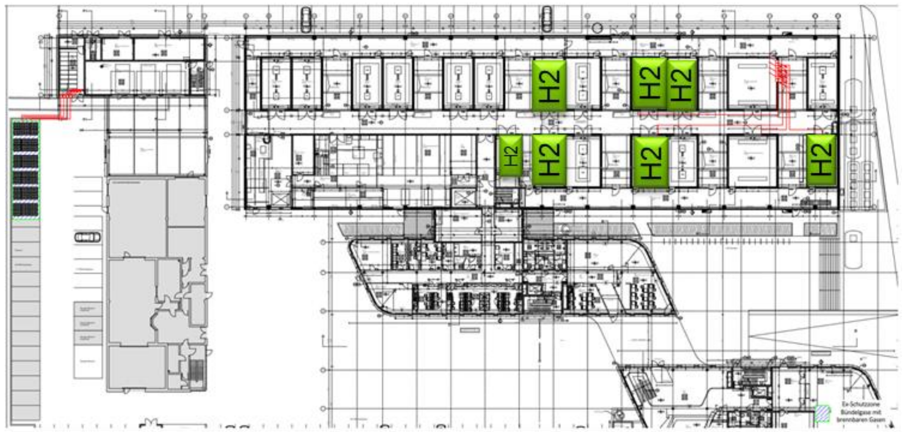
KEY FACTS

- Power unit based on Daimler OM 471
  - Bore: 132 mm, stroke: 156mm, V_H 2.13 dm^3
- Beyond state of the art combustion systems
  - Flexible cylinder head design **w/ alternative position for injector or spark plug**
  - CI / SI + **PFI/Direct Injection of alternative liquid or gaseous fuels**
  - **Boost pressure up to 8 bar** at full load
  - Peak firing pressure up to 300 bar
  - FIE: Fluids up to 3000 bar , digital rate shaping, dual fuel operation
- Infrastructure for gaseous and liquid fuels of all kind
  - **H_2**, DME, methanol, alkanes, OME, CNG

FEV’s test benches at the testing facility “European Technical Center” in Aachen are hydrogen ready – 7 test benches available today

CENTER FOR MOBILE PROPULSION – HYDROGEN READY ICE AND FUEL CELL TEST BENCHES

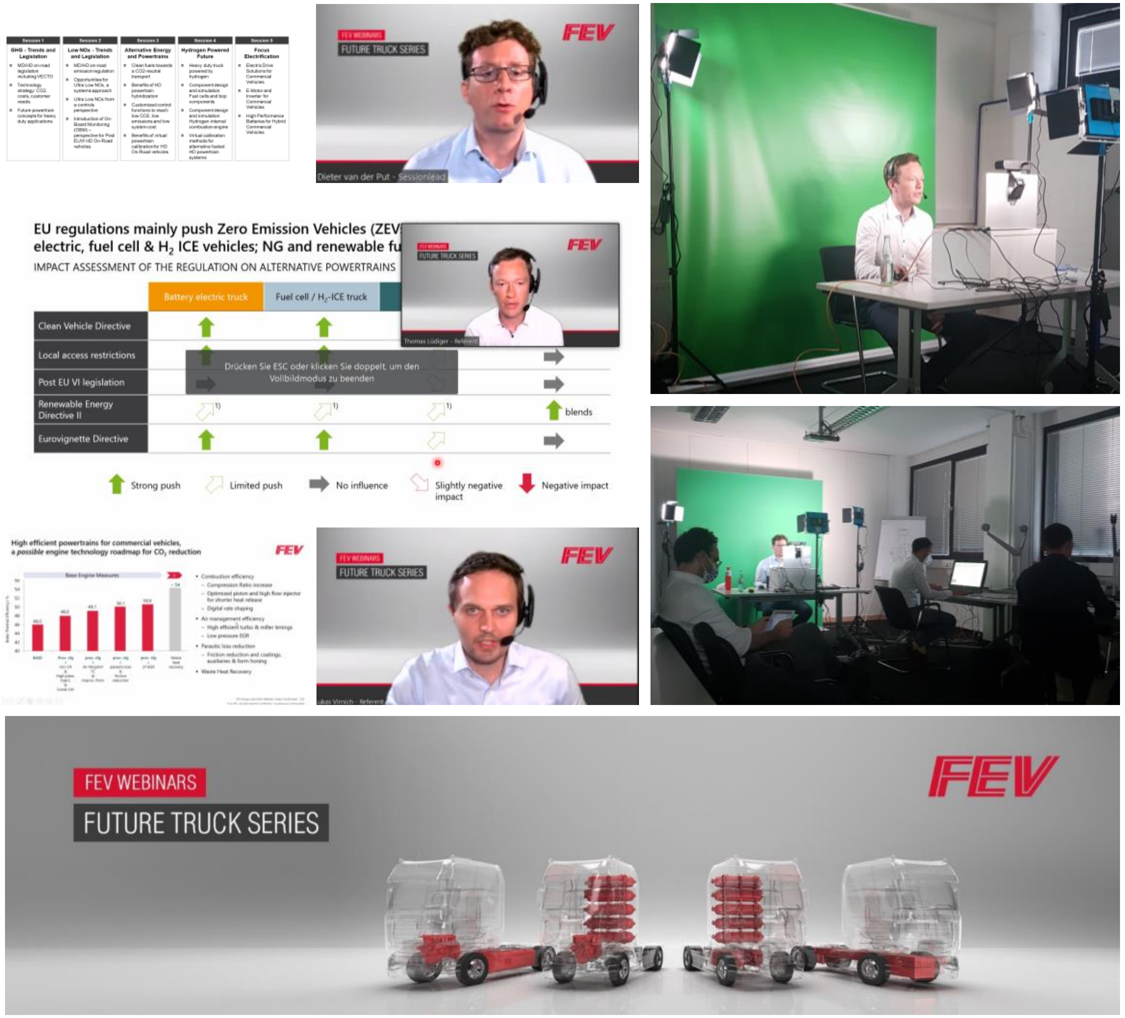




- Hydrogen specs:
  - 60 bar H_2 pressure upstream ICE/FC
  - 35 kg/h max. H_2 fuel flow
  - H_2 quality range from 3.0 … 8.0
- Bench features:
  - Full transient operation (WLTP, WHTC, WHSC, RDE-cycles, etc.)
  - Up to
    - 500 kW FC electrical power
    - 640 kW IC engine power
    - 4500 Nm IC engine torque
  - Flow measurement of H_2 and Air
  - FEV FEVER emission measurement

FEV FUTURE TRUCK SERIES

- Hydrogen Powered Future
  - Heavy duty truck powered by hydrogen
    - Infrastructure / TCO Analysis
  - Component design and simulation Fuel Cells
    - Challenges and solution approaches for fuel cell systems
    - Modelling and development framework for fuel cell vehicles, systems and BOP components
  - Component design and simulation H2 ICE
    - Combustion system layout
    - Turbocharger design
    - Aftertreatment system
    - Control Software
  - Virtual calibration methods for alternative fuels
    - Challenges of alternative powertrain development
    - FEV virtual powertrain development process
    - Virtual calibration



FEV Future Truck Series 2020 – Now available on demand
Contact us via chat to get further details

FEV

GHG – Trends and Legislation

- MD/HD on-road legislation including VECTO
- Technology strategy: CO2, costs, customer needs
- Future powertrain concepts for heavy duty applications

Low NOx – Trends and Legislation

- MD/HD on-road emission regulation
- Opportunities for Ultra Low NOx, a systems approach
- Ultra Low NOx from a controls perspective
- Introduction of On-Board Monitoring (OBM) – perspective for Post EUVI HD On-Road vehicles

Alternative Energy and Powertrains

- Clean fuels towards a CO2-neutral transport
- Benefits of HD powertrain hybridization
- Customized control functions to reach low CO2, low emissions and low system cost
- Benefits of virtual powertrain calibration for HD On-Road vehicles

Hydrogen Powered Future

- Heavy duty truck powered by hydrogen
- Component design and simulation: Fuel cells and bop components
- Component design and simulation: Hydrogen internal combustion engine
- Virtual calibration methods for alternative fueled HD powertrain systems

Focus Electrification

- Electric Drive Solutions for Commercial Vehicles
- E-Motor and Inverter for Commercial Vehicles
- High Performance Batteries for Hybrid Commercial Vehicles