Zero-impact emissions from a gasoline car with advanced emission controls and e-fuels

J. Demuynck, D. Bosteels
Euro 6d significantly reduced impact on air quality

- RDE procedure with PEMS for NOx and PN
- Evolution in emission control systems
  - LD diesel - combination of deNOx technologies
  - LD Gasoline - introduction of particulate filter
- Several reports about improved air quality
- Example of NO₂ in Brussels

Source: CurieuzenAir report on air quality in Brussels, 2022

2015 vs 2021
Further contribute to air quality improvement with advanced emission control systems
- New WHO guidelines, published in September 2021
- The EU Ambient Air Quality Directive is being reviewed

Key elements from the Euro 7 proposal for light-duty vehicles
- Fuel-neutral pollutant emission limits at lowest Euro 6 level
- Introduction of limit for NH₃
- Cold-start budget for trips < 10 km
- Extension of RDE test conditions
  - Any trip composition
  - New parameter for driving dynamics in first 2 kms after an initial cold-start
- Extension of durability requirements

Adoption of Euro 7 expected within Q1 of 2024

Emission legislation evolution expected towards Euro 7

23rd Stuttgart Int. Symposium – 5 July 2023
Reduction of ICE CO$_2$ emissions to mitigate climate change

- Increase in efficiency and level of electrification for new vehicles
- Wider usage of sustainable renewable fuels to reduce Well-to-Wheel and lifecycle emissions
  - Immediate reductions for the existing fleet in addition to new vehicles
  - Production is a reality, further investments depending on the policy framework
  - Proposal is expected from EU Commission for vehicles running exclusively on CO$_2$-neutral fuels

Sythetic diesel and gasoline
Source: Aramco (2021)

Haru Oni pilot plant: wind power to e-fuel
Source: Siemens Energy (2020)
LD gasoline demonstrator concept

- Base vehicle
  - C-segment
  - 1.5l engine with 4 cylinders
  - Variable valve train and cylinder deactivation
  - 48V mild-hybrid (belt-driven, P0 configuration)
  - Euro 6d

- Instrumentation
  - Chassis dyno: 3x standard sampling points, 2x FTIR and tailpipe PN10
  - Road: prototype PEMS to measure CO$_2$, NOx, CO, THC, PN10, NH$_3$ and N$_2$O
LD gasoline demonstrator concept

- Euro 6d baseline: cc cGPF + uf TWC
- AECC emission control system
  - Phase 1: cc TWC, uf cGPF+TWC+ASC
  - Phase 2: cc EHC|TWC, uf cGPF+TWC+ASC
  - Bench aged components targeting 160k km

Implementation of electrically heated catalyst (EHC)

- Reduce the remaining initial cold-start emissions
- Operation strategy
  - Pre-heating in combination with post-heating
  - 60s pre-heating as outlook to advanced hybrids
  - Secondary air in exhaust manifold to enhance heat transfer within catalyst during pre-heating phase
- There is further potential due to certain constraints within this project, for example
  - Flow distribution not uniform, 90° bend at inlet
  - The part was not insulated
Testing focused on initial cold-start emissions

- RDE aggressive test is conducted on the chassis dyno
  - At Euro 6 RDE boundary for $v_{xa_{pos}}$
  - 3s of idling between key-on and drive-off
  - First acceleration immediately to 60 km/h
  - At ambient temperature of 23 °C and -10 °C
  - Maximum average wheel power during first 2 kilometers after the initial cold-start is ~15%
Gaseous emissions are mainly from initial cold-start

- The highest cold-start NOx peak measured is below the proposed Euro 7 emission budget limit
- Near-zero emissions under warm operation

![Graph showing cumulative NOx emissions over distance with emission budget and warm operation lines.]

RDE aggressive test
- Euro 6d -10 °C
- ctTWC 23 °C
- ctTWC -10 °C
- cECHC|TWC 8 s pre-heat -10 °C
- cECHC|TWC 60 s pre-heat -10 °C
- Euro 7 proposal

Note: 1.6 divider applied to data at -10 °C
Gaseous emissions are mainly from initial cold-start

- The highest cold-start NOx peak measured is below the proposed Euro 7 emission budget limit
- Near-zero emissions under warm operation

Note: RDE aggressive test results, 1.6 divider applied to data at -10 °C
Gaseous emissions are mainly from initial cold-start

Tests are significantly below the proposed Euro 7 limits for THC, CO and NH₃

**Emission budget**

- THC emission budget (mg at 10 km)
- CO emission budget (mg at 10 km)
- NH₃ emission budget (mg at 10 km)

**Total test result**

- THC total test (mg/km)
- CO total test (mg/km)
- NH₃ total test (mg/km)

Note: RDE aggressive test results, 1.6 divider applied to data at -10 °C
Particulate emissions are mainly from initial cold-start

- Most data is measured with aged GPF
  - Ash and soot accumulation supports filtration efficiency
  - Test with ccEHC at -10 °C repeated with fresh GPF
- All PN10 data remains below the proposed Euro 7 limit

Note: RDE aggressive test results, 1.6 divider applied to data at -10 °C; the fresh GPF test is not a valid test according to the Euro 7 proposal
30 s or 150 m to near-zero emissions

More videos available on YouTube (AECC eu): https://www.youtube.com/channel/UCbPS9op5ztLqrv6zIMH_IcQ
LD gasoline demonstrator with sustainable renewable fuels

Ultra-low pollutant emissions confirmed on Blue Gasoline and 2 e-gasoline samples

RDE aggressive test, $T_{\text{amb}} = 23 \, ^\circ\text{C}$

AECC cc comp. (EHC + TWC) + aged GPF, 8 s pre-heating, w/o secondary air

- RON95 E10
- Blue Gasoline
- E-gasoline 1
- E-gasoline 2

Ageing info: Engine bench aged targeting 160,000 km, EHC thermally aged


LD gasoline demonstrator with sustainable renewable fuels

- Blue Gasoline already offers today significant reduction of -17% WtW CO₂ emissions
- E-gasoline has the potential to nearly eliminate WtW CO₂ emissions

Advanced emission control system was integrated in a 48 V mild-hybrid gasoline demonstrator vehicle:
- Close-coupled TWC substrate with high cell density
- Active thermal management with EHC
- Ammonia Slip Catalyst in addition to improved lambda control

Towards zero-impact emission level:
- Significant reduction of initial cold-start peak compared to already low Euro 6d level
- Near-zero emissions after initial cold-start peak
- Sustainable renewable fuels to nearly eliminate WtW CO₂ emissions
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THANK YOU!