Technology Overview of Future Powertrains

Matteo DE CESARE
MM - PWT Innovation

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Magneti Marelli Company Overview

AUTOMOTIVE LIGHTING
(Headlamp, Rearlamp, Lighting and Body Electronics)

POWERTRAIN
(Gasoline and Diesel engine control, Electric Motor, Inverter and Transmission)

ELECTRONICS
(Instrument Clusters, Infotainment & Telematics)

SUSPENSION SYSTEMS AND SHOCK ABSORBERS
(Suspension Systems, Shock Absorbers and Dynamic Systems)

EXHAUST SYSTEMS
(Manifolds, Catalytic converter, Diesel Particulate Filter and Mufflers)

PLASTIC COMPONENTS AND MODULES
(Bumper, Dashboard, Central Console, Pedals, Hand Brake Levers and Fuel System)

AFTERMARKET PARTS & SERVICES
(Mechanical, Body Work, Electrics and Electronic and Consumables)

MOTORSPORT
(Injection Systems, Electronic Control Units, Hybrid Systems, Telemetry Systems, Electric Actuators)
Automotive Market Trends

<table>
<thead>
<tr>
<th>Autonomous driving</th>
<th>Cruise control</th>
<th>Conditionally autonomous</th>
<th>Fully autonomous</th>
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</thead>
<tbody>
<tr>
<td>Electrical vehicles</td>
<td>Hybrid</td>
<td>Pure electric (Premium brands)</td>
<td>Pure electric (availability in popular consumer models)</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Bluetooth</td>
<td>Connected drive</td>
<td>Different Layers</td>
</tr>
<tr>
<td>CO2 Environmental Sustainability</td>
<td>EU 130 g/km</td>
<td>EU 95 g/km EU 75÷68 g/km</td>
<td>USA 97 g/km EU 75÷68 g/km</td>
</tr>
<tr>
<td></td>
<td>EU6d</td>
<td>EU WLTC, RDE</td>
<td>USA EU 7</td>
</tr>
<tr>
<td>Pollution</td>
<td></td>
<td></td>
<td>Zero Emission</td>
</tr>
<tr>
<td>Sharing Mobility</td>
<td>Car Sharing</td>
<td>Private Car disappear</td>
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**WLTC:** Worldwide Harmonized Light duty driving Test Cycle  
**RDE:** Real Driving Emissions
The Powertrain Evolution Challenge

At the same time

Autonomous Vehicle

End user expectations

Regulation

Easy to use

Performance

Fun to drive

Driving comfort

Powertrain

Evolutions

Cost containment

Cyber security

OBD

Emission standards

Safety

Fuel economy

CO₂ Reduction

Fuel Economy Reduction

Local Pollution Reduction

Cost Containment
What is the Powertrain Prospective?
Many Powertrain Technologies to Reduce Fuel Consumption & CO₂ Emission → No clear winners?

- Powertrain Efficiency Increasing (TTW)
- Reduce Carbon in Fuel
- Low Carbon Vehicle

- Conventional Vehicle
- Powertrain Efficiency Increasing (TTW)
- Reduce Carbon in Fuel

- Natural Gas/Biogas
- Renewable Fuels
- Plug – In Hybrid (Low Carbon Electricity)
- Battery Electric Propulsion (Low Carbon Electricity)

- Downsized Engines
- Downspeeding/Gear Increase
- Thermal Management
- Friction Reduction
- Combustion Control
- Hybrid Powertrain
- Advanced Combustions
- Heat Recovery

TTW= Tank-to-Wheel
| Vehicles below 2020 EU CO2 Limits = 95 g/km (C-Segment) |
Impact of New Test Cycles on Powertrain Solutions

WLTC, downsized ICE and HEV reduce the benefit for CO2
RDE, for Diesel expected impact on NOx emission control
RDE, for GDI Gasoline, expected impact on Soot emission control (PN limit)
RDE, for HEV and PHEV reduced electric autonomy and CO2 benefit
CO2 in Real Use vs. Powertrain Solutions

CO2 Emission gap between Real Use and Type Approval (NEDC)

Source: FROM LABORATORY TO ROAD - A 2015 update of official and “real-world” fuel consumption and CO2 values for passenger cars in Europe, ICCT September 2015
The Short Term Trend (2020+)

Main Technologies:
- More Efficient Internal Combustion Engines (ICEs)
- Engine Aftertreatment improvements
- AMT/DCT/AT diffusion with Gears Increasing
- Powertrain Electrification depending on Vehicle Class
MM Technologies Portfolio for GDI Engines

- **HP GDI Injectors**
- **HP GDI Pump**
- **GDI Engine Control Unit with VVA Management**
- **Turbo Electric Actuator**
- **Engine Calibration**
- **Control & SW**
- **Air Intake Manifold with Water Air Cooler**
- **LP EGR Valve**

Magneti Marelli - Proprietary & Confidential
Magneti Marelli HEV/BEV Product Range

- 48V SYSTEMS
  - BSG
- 48V TRACTION SYSTEMS
- HV MOTORS
- HV INVERTERS
- POWERTRAIN ELECTRIFICATION
- ENERGY MANAGEMENT (DC/DC, BMS, BMC)
- e-TURBO

Low Voltage (48V)

High Voltage

LV & HV
MM PERFET® (Performing and Efficient Transmission)

Low Voltage (48V) Hybrid architecture, 70% of the benefit of the plug-in hybrid systems for just 30% of the costs.

- MM 48V Parallel Hybrid architecture with integrated e-motor and inverter technology

Full Hybrid Functions
Low speed EV mode
AMT Torque Gap Filling

- A very attractive solution is to connect electric motor to the gearbox output shaft: the motor can supply torque directly to the wheels.

- Up to 22% of CO2 reduction compared to S&S and AMT vehicle in production
Paths of CO2 reduction for Gasoline C-segment Vehicle

- 2020 EU Limit 95 g/km
- 2025 EU Limit 75 g/km

GDI = Gasoline Direct Injection
CR= Compression Ratio
TC= Turbocharger
WI= Water Injection
S&S= Stop & Starts
MT= Manual Transmission
DCT= Dual Clutch Transmission
BSG= Belt Starter Generator 48V
eSC= Electric Supercharger

<70 g/km
+ Full Hybrid
High Voltage
The Medium-Long Term Trend (2025+)

Main Technologies:

- Advanced Combustion Engine
- Renewable Fuels
- Heat Recovery Systems
- High Level of Powertrain Electrification
Powertrain Electrification Trend

Long term outlook

Bloomberg, 2016
Life Cycle Assessment of Various Powertrains

C-Segment, over 200 kkm in the WLTC, EU -27


Lower local pollution

Cost decreasing (@ same performance)
A Sustainable Powertrain with Renewable Fuels

Various renewable fuels with different powertrain architectures

Renewable energy + Water + CO₂ / residual materials >> Audi e-fuels

Audi e-gas® g-tron
Audi e-power e-tron
Audi e-hydrogen® n-tron
Audi e-diesel® TDI
Audi e-gasoline® TFSI

Source: The new Audi 2.0l g-tron - another step for the sustainable mobility of the future
Evolution of Spark Ignition Engine Efficiency (TTW)

- **Waste Heat Recovery**
- **Low Temperature Comb.**

**Graph Details:**
- **Vertical Axis:** Maximum Thermal Efficiency (%)
- **Time Period:** 1990 to 2030
- **Trends:**
  - **NA Improvement**
  - **Boosted EGR**
  - **Boosted Lean**
  - **T/C EGR boosted**
  - **Miller cycle**

Legend:
- Green Circle: NA
- Green Square: DST
Application Fields and Powertrain Architectures

- **City**
  - Limited Range (<100 Km)
  - Low average speed (~ 10 Km/h)
  - Frequent regenerative braking

- **Urban + Suburban**
  - Wide Range (> 500 Km)
  - High average speed (>100 km/h)
  - Limited regenerative braking

- **High Way**
  - Wide Range (> 500 Km)
  - High average speed (>100 km/h)
  - Limited regenerative braking

- **Internal Combustion Engine Vehicle (ICEV)**
- **Hybrid Electric Vehicle (HEV)**
- **Plug-in HEV (P-HEV)**
- **BEV**
- **Range Extender Electric Vehicles (FCEV or E-REV)**

Synthetic fuels (liquid and gaseous) mainly from Renewable Electricity
Conclusions

- New technologies can improve ICE Tank-to-Wheel Efficiency
- Considering CO2 LCA, synthetic renewable fuels from renewable electricity lead to the ICEVs to be comparable with BEVs
- However Powertrain Electrification is key to reduce local pollution and to improve Tank-to-Wheel Efficiency of ICEs in city use
- Electric Hybrid powertrain architecture E-REV can be a “smart general purpose solution”, summing ICEVs and BEVs advantages
Thank you for the attention