Light-duty hybrids expected to grow

Annual hybrids sold forecasted to increase in the next 10 years: ~32 m by 2025

Electrification mix unclear after 2023 as OEMs adjust to meet stringent regulatory targets

Source: IHS August 2018

Millions
Electrification: Combining functions to reduce size & cost

Propulsion inverter

DC-to-DC Converter

CIDD (Combined Inverter DC/DC)

- Eliminates extra DC cables and separate DC/DC housing
- Eliminates extra liquid cooling lines
- Fewer components to install in vehicle
Design for High Pressure
Multi-hole Injector M16 for 500+ bar Pressures

**Multec 16 – 500+ bar**

- 500+ bar customized elastomer interface
- Optimized:
  - internal fuel routing
  - magnetic performance
  - materials
- Decoupled armature-pintle assembly
- 6mm lower housing with machined seat

**Benefits**

- Optimized injector fueling
- Noise reduction
- Drive wave form energy reduction

**Status**

- Advanced development validation completed

**Multec 16 with up to 600 bar system pressure capability**
48V eDSF: Demonstrated Benefits

- 15+% CO₂ REDUCTION
- INCREASED LOW-END TORQUE
- 20%+ IMPROVED ACCELERATION (0-30 KPH)
- INCREASED CHARGING DURING DECELERATION
- SEAMLESS START-STOP PERFORMANCE

Realizing the system synergies of powertrain technologies and capabilities
ARPA-E NEXTCAR Project
48V eDSF with Intelligent Driving

Connected & ADAS systems
- Radar and Camera modules
- Navigation system
- V2X

Powertrain systems
- 48V mild hybrid
- Dynamic Skip Fire
- Powertrain controls

20%+ fuel economy improvement goal: 48V eDSF with connected data
ARPA-E NEXTCAR Project
48V eDSF with Intelligent Driving: Target Benefits

1%-2% improvement estimated for FTP City test cycle

Connected Technologies:
V2X sensors and ADAS systems: topography, surrounding environment and traffic conditions

Cloud Computing: Synergistically merge route information with powertrain control to minimize fuel consumption

~7% Fuel Savings

~4% Additional Fuel Savings

Intelligent driving targeting 10%+ real-world fuel efficiency improvement
Simulation results comparing
• Driver model
• Intelligent Driving controls

• **Driver Model results**: represent variation in model parameters.
• **Intelligent Driving results**: represent variation of aggressiveness parameter between Travel Time and Fuel Consumed.

Simulated Fuel Consumption Reduction for Route Scenario 19
- 23%
- 11%

Simulated Intelligent Driving Controls Demonstrate Significant Potential Benefit
NEXTCAR Project: Fuel Economy Evaluation

Fuel Consumption Evaluation on Test Track with NEXTCAR Development Vehicle
Summary

- Electrification penetration increasing rapidly to complement advanced internal combustion engines
- Connected and Automated Vehicle Systems provide new opportunities for propulsion system optimization
- Software, controls & system integration expertise critical for best value solutions

Driven to make a difference