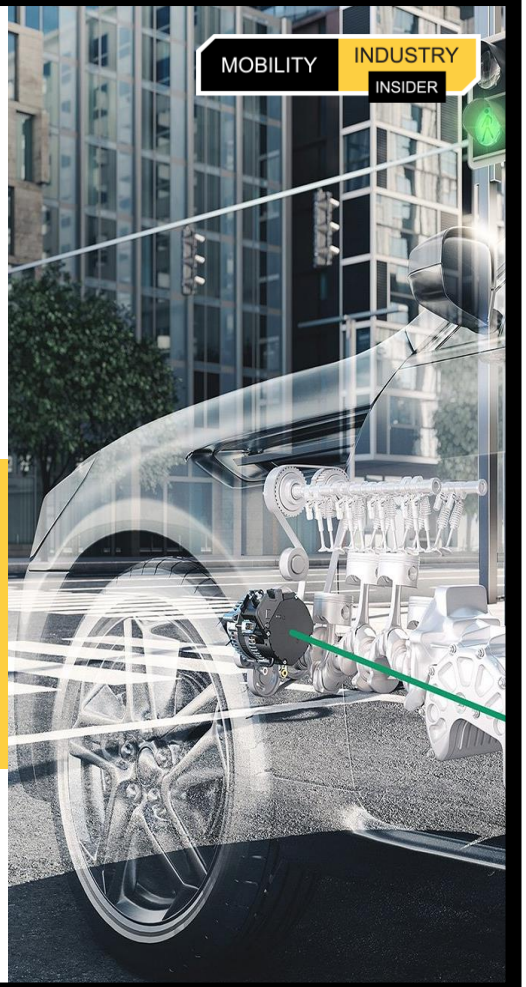
FutureBridge



Q2 2020 | **PULSE 2.0**

48V SYSTEMS

What's new in Pulse 2.0 ?

- Deeper coverage on commercial vehicle 48V systems and role of regulation
- Expansion of mild-hybrid portfolio by major German and Korean OEMs

CONTENTS

01

48V SYSTEMS

Upcoming Trend

- Heavy-duty powertrain concepts are moving towards high voltage electrification and fuel cell architectures to comply with the 2025 and 2030 GHG regulations. But these technologies require massive changes in the current powertrain architectures, and thecost involved is high. 48V systems provide better cost-effective solutions to meet the upcoming regulations and OEMs, and Tier-1s are evaluating this mild-hybrid solution

Players in our coverage

What do we see happening

- As electrification grows in many heavy-duty vehicle segments, it is also creating uncertainty regarding the future of componentry such as those used in conventional drivetrainsystems
- As electric power sources like batteries have evolved and dropped in price, it has become easier to incorporate them into various machine systems for commercial applications
- Drivetrain systems and components are anticipated to see many changes regarding size, packaging and gearing as electrification continues toincrease

CO_2 emission regulation targets (2025 -15%, 2030 -30% compared to 2019 baseline) are very challenging for OEMs and violation penalties are too high

Overview of CO2 regulation framework

Source: European Union, FEV , icct >>

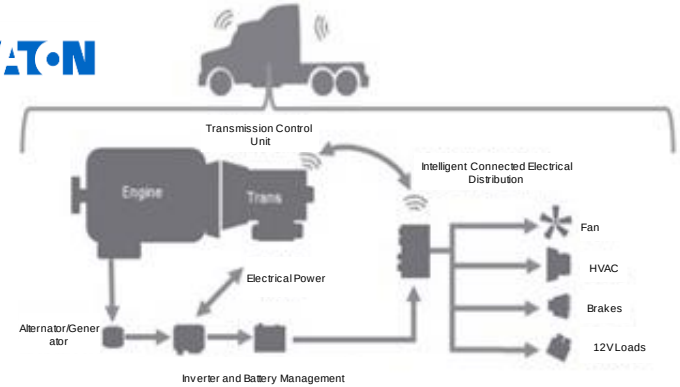
Regulation Target (Regulation (EU) 2019/631)	▪ 2025: 15% lower CO_2 emissions than 2019 baseline ▪ 2030: 30% lower CO_2 emissions than 2019 baseline (subject to revision in 2022)
Penalties	▪ 2025: 4,250€/g CO_2/tkm ▪ 2030: 6,800€/g CO_2/tkm

ZLEV's definition and incentives	▪ ZEV: < 1gCO_2/km
	▪ LEV: < half the sub-groups reference emissions in gCO2/km (varying across sub-groups)
	▪ Accounting system:
	  • Until 2024: Super-credits system (bonus only)
	  • 2025+: benchmarking system(bonus only, no malus) starting from a minimum quota
	▪ Directly impacting the final CO2/tkm amount for each manufacturer, up to 3% reduction
	▪ Vehicles included: all CV> 3.5 tons, incl.vocational, excl.buses,coaches; unregulated categories can account for maximum 1.5% (included in the overall maximum of 3%)
	▪ Benchmark quotas:
	  • 2025: 2% of newly registered heavy-duty trucks
	  • 2030: currently defined as 2% but likely to be reviewed and updated in 2022

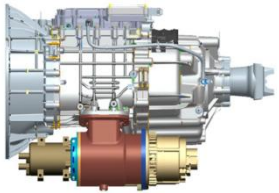
Miscellaneous	▪ Post-2030 targets to be proposed during 2022 revision ▪ Data will be obtained also through on-board devices, which monitor the actual fuel and energy consumption of heavy-duty vehicles ▪ Up to 2 tonnes additional weight allowance for zero-emissions and alternative fuels trucks ▪ Between 2025 and 2029, a banking system is used to account for credits and debts

Mild Hybrid Technology for Commercial Vehicles

the 48V vehicle electrical system is often regarded as bridging technology until a sufficiently large HV (high-voltage) BEV fleet has established itself worldwide to comply with the CO_2 regulations. However, 48V technology offers far more potential than just bridging the gap to pure BEV vehicles.



Component Details



- Alternator/Generator
- Inverter and Battery Management
- Fan
- HVAC
- Brakes
- 12V Loads

Eaton 48-volt regenerative accessory drive

Eaton has introduced a 48-volt mild hybrid electrically regenerative accessory drive that charges the vehicle's batteries, efficiently runs the air conditioner and other accessories, and replaces the alternator in line haul commercial vehicles >>

Market Scenario

Large trucks and buses are **unlikely to be 48V**, due to high voltage systems being already used in those segments. However, there is **potential for implementation in Delivery Vans and Small Trucks**. Examples have been found that uses P0 architecture, which uses belt integrated starter electric motor for engine start-stop that supports AC of the vehicle when the engine shuts off or is in a coasting mode. Over-the-road line haul truck sector may see an increased number of mild hybrid systems being deployed as efficiency standards tighten.

Recent Developments

- **Apr 20:** Kubota Debuts Micro-Hybrid System to North American Market. The Kubota Engines Micro-Hybrid system pairs a 48V motor generator with an engine to offer a 10 kW power boost. >>
- **Mar 20:** FPT's F28 Hybrid pairs a 74 hp engine with an e-flywheel (flywheel coupled with 48V motor) which can provide 40 hp of peak power, and is optimized for Start & Stop capabilities. >>
- **Feb 20:** Omega Seiki launches electric cargo three-wheelers: Swappable 48V battery and 100 km range. With Li-ion 48V battery and max torque of 80 Nm, models offer 45 km/h and 60 km/h of top speed, respectively. >>
- **June 20:** Ford has expanded its Transit range with the introduction of new variants including the off-road-focused Transit Trail. 2.0-litre four-cylinder turbo diesel engine paired with 48V system (P0) >>

Towards 2025 European legislation - CO_2 improvement measures that could be adopted by heavy-duty vehicles

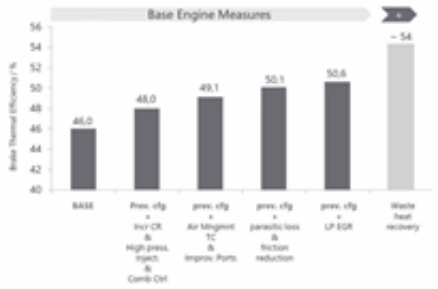
Following are the various efficiency improvements that can be adopted by heavy-duty vehicles with existing architectures and cost benefits

1 VEHICLE EFFICIENCY

Improvement ~ 6%

- Aerodynamic drag reduction
  - Weight& Dimension legislation
  - Use of extended front end, fairing, mirror cams
- Transmission efficiency
- Low rolling resistance tires
- Vehicle mass reduction

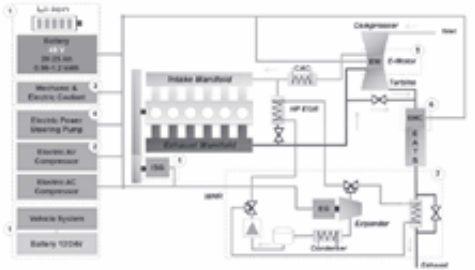
2 POWERTRAIN EFFICIENCY



Improvement ~ 5%

- Combustion efficiency increase
  - Compression and fuel injection control
- Air management improvements
  - High efficiency EGR& Turbo charging
- Parasitic loss reduction
  - Piston & liner system
  - Variable auxiliaries

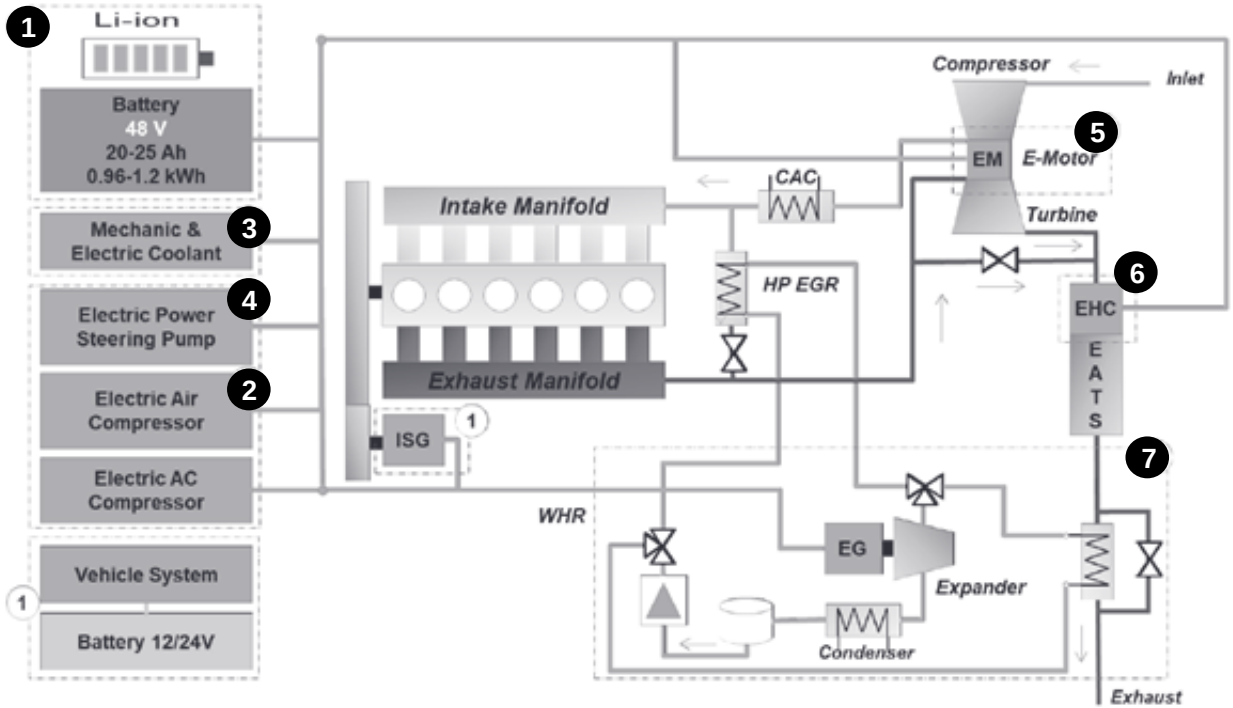
3 VEHICLE USAGE



Improvement ~ 8%

- Decentralized supervisory control
  - Predictive mission, energy, power and aftertreatment management
- Waste Heat Recovery (WHR)
- Modular 48V mild-hybrid system
  - Low costs
  - Minimal adaptation effort for current vehicles

A modular 48V mild-hybrid system offers a cost-effective, easy-to-integrate solution with extended electrification options for commercial vehicles



Modularity

M1 - Generator and Battery

M2 - Electric air compressor

M3 - Electrically driven auxiliaries

M4 - Electric Power steering

M5 - Electrical EATS heating

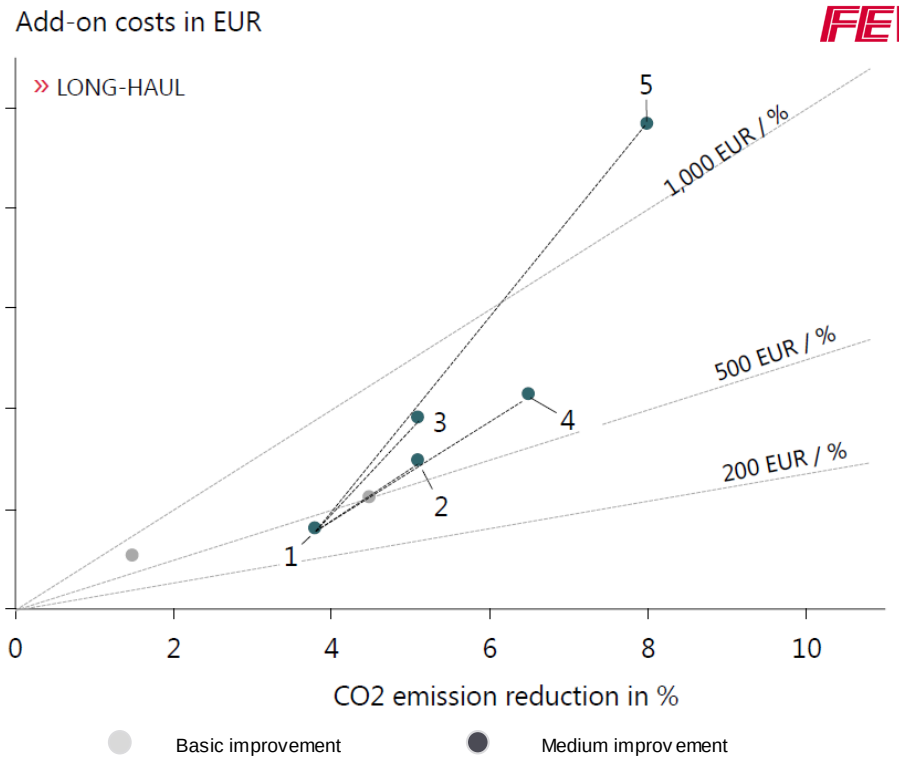
M7 - e-WHR system

Implementation

- Possible on existing commercial vehicle architectures
- Modularity based on vehicle usage and application

48V powertrain electrification including e-turbo and electrified auxiliaries shows the best cost efficiency among the technology packages available for heavy-duty vehicles

Cost effectiveness of diesel engine CO_2 reduction technologies



Technology Package Combinations (Engine size: 13L)

- **1: Only Engine Package**
- **2: Engine Package + Miller cycle**
- **3: Engine Package + Turbo compound**
- **4: Engine Package + 48V e-Turbo and 48V auxiliaries**
- **5: Engine Package + WHR and 48V auxiliaries**

Key takeaways

- A study conducted by FEV shows that all combinations except the ones with WHR have add-on costs below 1,000EUR/%CO_2 (48V system used for the study was 25kW peak power and P0 architecture)
- Compared to 48V add-ons, a WHR system exhibits a significantly worse cost/improvement ratio
- Cost advantage compared to purely electric or plug-in hybrid vehicles, the lower development effort and the immediate CO_2 reduction potential for the vehicle fleet are the specific reasons for 48V (P0-P1) system adoption in commercial vehicles
- The availability of highly decarbonized fuels in the market is also a parameter that could influence the deployment of electrified drivetrains and achieving the regulation targets

02

48V SYSTEMS

Upcoming Trend

- Despite the COVID pandemic, The German and Korean OEMs have continued to expand their mild-hybrid portfolio. A target value of 95 g/km of CO2 for 2020 for the new car fleet is set in Europe. However, there is a one-year phase-in period, requiring 95 percent of new car sales to comply with the target in 2020 and 100 percent from the end of 2020 onwards. Effectively, the 95 g/km target, therefore, applies from 2021 onwards. Ford is also accelerating its mild-hybridization strategy to achieve this regulatory requirement and gain the majority of share in the European market. Geographical coverage considered for this trend is Europe

Players in our coverage

What do we see happening

- Worthwhile reductions, but it's clear mild hybrids don't have the spectacular CO2 and fuel-economy figures of plug-in hybrid electric vehicles (PHEVs). But the mild-hybrid is an 'always on' technology and doesn't rely on user behaviour to deliver the promised benefits.
- Technology and market growth indicates that we will soon see 48V batteries used in full as well as mild-hybrid vehicles. These full-hybrid 48V cars will be much cheaper than today's full hybrids, achieving 70% of an engine-dominant high-voltage hybrid's benefits at 30% of the powertrain cost.

Executive Summary – Geographical coverage - EU

EU

Stricter European CO2 emission legislation might cause severe penalty payments and reputation loss. Half of the automotive manufacturers are facing penalty payments of 0.4bn€ in 2020 and 3.3bn€ in 2021

A Steady increase in demand and supply for mild-hybrid engines – It is predicted that more than one-third of newly registered passenger cars in the EU will be electric or hybrid vehicles by 2026

CO2 emissions, on average, 23% higher under WLTP – complexity, and pressure for OEMs increase with a change in reporting of CO2 emissions according to WLTP test procedure in 2021

SUV trend continues – OEMs bet on electrification with over-operational growth in hybrid and electric engines in SUVs compared to smaller car types

Electric and hybrid vehicles as the biggest CO2 lever – OEMs are shifting their portfolio from conventional to more electric and hybrid vehicles

Emission target met at the European level in 2020 while application of flexibilities as super-credits and phase-in helps to avert €7.3 billion in penalty payments

Daimler and BMW could face fines of 997 million euros and 754 million, respectively if they don't reduce emissions from current levels. The legislation relies on average fleet CO2 emissions of the OEMs. The mix of the fleet sold determines the required reduction in CO2 emissions. This is the main point based on which OEMs are introducing more mild-hybrid models and bringing specific technology packages to be applied based on reduction requirements. However, technology cost and total cost of ownership determine the individual development directions in the market

Major launches by German and Korean OEMs in Europe

BMW is expanding its range of mild-hybrid powertrain by adding it in 3 series, X3 and X4 >>

Apr 1, 2020

BMW is in the final stages of development of its redesigned 4-Series and is planning to launch range-topping M440i with a mild-hybrid powertrain. >>

Apr 28, 2020

Fifth-gen **Mercedes** C-class to feature plug-in and mild-hybrid powertrains. A detuned version of their existing 48V architecture (P0) from the CLS53 AMG is expected to be used in C53 >>

May 7, 2020

Kia Motors unveils mid-cycle facelift for the fourth-generation Kia Rio with mild-hybrid petrol >>

May 28, 2020

Ford is replacing the existing 1.5-litre Ecoboost petrol engine in Ford Focus with the mild-hybrid (P0) 1.0-litre Ecoboost unit. >>

Jun 22, 2020

Apr 21, 2020

Audi has launched a new generation A3 sedan with a 48-volt mild-hybrid system in its powertrain along with S-Tronic dual-clutch transmission >>

May 6, 2020

Kia has updated the Sportage by adding a new mild-hybrid diesel powertrain and new trim level for 2020. >>

May 14, 2019

Updated 2021 **BMW** 5 Series Gains Mild Hybrid System >>

Jun 08, 2020

Ford is expanding its range of mild-hybrids with the launch of mild-hybrid Ford Fiesta. >>

Mild-hybrid Technology Comparison

Comparative study of mild-hybrid technology of the top four OEMs in Europe. Mercedes and Audi tops the competition as they have relatively wider adoption and technology edge

Parameters selected for competitive analysis	Mercedes-Benz	BMW	Audi	Ford
Available mild-hybrid architecture in the market	P0, P1	P0	P0	P0
Additional Power/Torque from 48V system	10 kW (14 hp) to 15 kW (20 hp)	8 kW / 11 hp electric boost	Up to 50 N·m	Up to 20 Nm
Impact on Fuel Efficiency	15% improvement in fuel economy	Cut fuel consumption by 0.3 litters per 100 km covered on average.	Reduces fuel consumption by up to 0.7 litters per 100 kilometres.	The technology contributes to fuel efficiency from 4.1 l/100 km (6% improvement)
Impact on CO_2 emissions	Reduced by 7 to 12 g/km	Reduced by up to 70 percent >>	Reduced to 101 – 96 g/km	93 g/km NEDC
Future outlook	Mercedes-Benz To Launch 20 PHEVs By The End Of 2020 >>	The company mentioned it will cut emissions by 20 percent this year compared to 2019 >>	Audi only uses mild hybrid currently for engines with six or more cylinders	Ford plans to bring in more mild-hybrid models to its commercial vehicle line-up and passenger cars >>

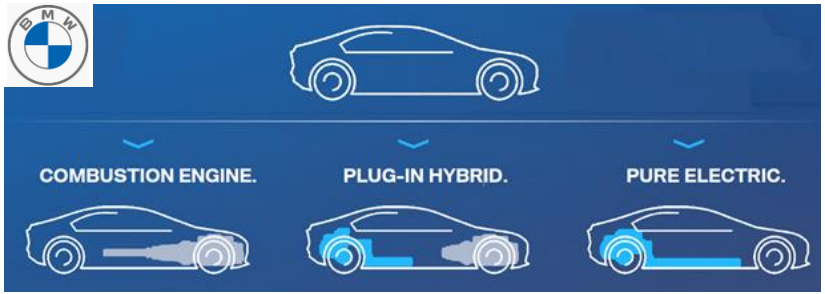
Strong capability/advanced technology

Low capability/ technology is relatively inferior

BMW conducted its 100th annual general meeting in Munich on 14th May. Oliver Zipse, Chairman of the board of management, delivered the keynote speech reflecting on BMW's future endeavors, electrification strategy, and impact of COVID pandemic. Here are some of the highlights of the annual meeting

"What is our priority right now? The best restart possible for your company. This is how my Board of Management team and I are approaching the situation. We are adopting a realistic view. Taking actions that are controlled, but highly consistent. And switching course quickly when circumstances change. This applies to all three phases of dealing with the coronavirus pandemic: lockdown, reopening and a gradual return to normal business. In Phase I, we protected our employees worldwide, while at all times maintaining our operational capabilities. We always kept the BMW Group running. In production, we continued to implement everything that was urgently needed. In non-production areas, many people worked from home. In Phase II, we began, and will continue with, a structured, phased ramp up of our global production network: Starting in mid-February with the joint venture plants in China and our components plants – including here in Germany. In Phase III, we will gradually resume all production and sales activities, under stricter standards, as we continue to protect our employees' health." >>

- **Oliver Zipse**, Chairman of the board of management BMW AG



• By 2021 BMW plans to have only one platform for its combustion engine, PHEVs and pure EVs. >>

- BMW plans to expand its second-generation mild-hybrid electrification technology to 37 new models. Thus, the line-up of models fitted with standard 48-volt starter-generator will extend to **51 models**.
- BMW second-gen 48-volt mild-hybrid technology offers a saving up to nine grams of CO2 per kilometre
- BMW targets a quarter of the vehicles sold in Europe to have an electric drive train by 2021 a third in 2025 and half in 2030.

Pure EVs

PHEVs and MHEVs

Ford Electrification Strategy in Europe - Ford targets Europe to be among the first Ford regions to become carbon neutral before global target

48V Mild-Hybrids from Ford

High Voltage Full Hybrids and PHEVs

PHEVs

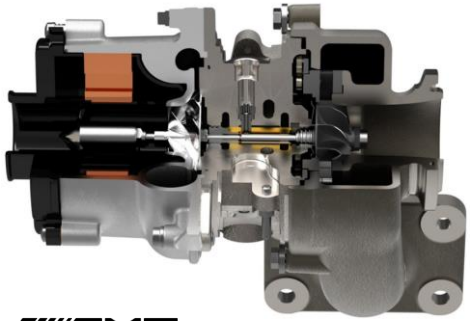
Full-electric under development

- Ford is investing more than $11.5 billion in electric vehicles through 2022 and committed to offering an electrified version of every passenger vehicle it brings to market in Europe where it will grow its range of electrified vehicles on sale to 18 before the end of 2021, including mild hybrid, full hybrid, plug-in hybrid, and battery electric vehicles
- Ford targets Europe to be among the first Ford regions to become carbon neutral before the global target
- Ford significantly accelerated its plan for electric vehicles during 2019, unveiling the all-electric Mustang Mach-E that will be available in Europe in early 2021 with a targeted EPA-estimated range of up to 600 kilometres under Worldwide Harmonised Light Vehicles Test Procedure (WLTP) regulations >>

48V Systems – Technology developments from Mercedes and Audi

Both German OEMs are currently working on using 48V systems beyond propulsion assistance, such as active anti-roll bars and active suspension systems

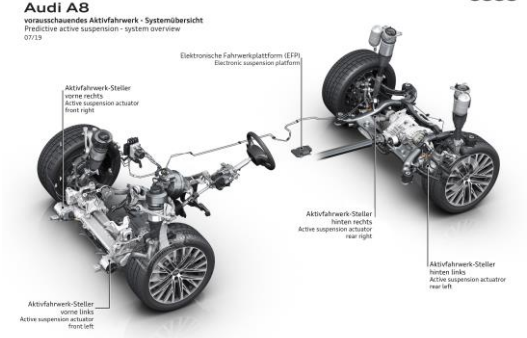
48V e-Turbo



Mercedes-Benz AMG

- Mercedes-AMG has teamed up with Garrett to deliver a new electric turbo solution powered from the on-board 48V mild hybrid system for its upcoming models >>
- The electric turbocharge technology is usually used by the company for its Formula One cars and is now making way into Mercedes passenger vehicles as well
- The highlight of the innovative solution is the 4 cm electric motor integrated directly to the turbocharger shaft and, the turbo could run up to 170,000rpm

Predictive Active suspension powered by 48V system >>



- There are compact electric motors located close to each of the Audi A8's wheels, running off the car's 48-volt primary electrical system and governed by power electronics
- A belt drive and a compact harmonic drive step up the electric motor's torque almost 200-fold to 1,100 Nm and apply it to a steel rotary tube. The latter is permanently attached to a preloaded titanium rod located inside it and capable of turning through more than 20 degrees
- From the end of the rotary tube, the force is transmitted to the suspension via a lever and coupling rod – at the front suspension it acts on the spring strut, and at the rear suspension on the transverse link >>
- Audi is now offering predictive active suspension for the Audi A8 luxury sedan

Future outlook and Takeaways

- The 2025 emission targets are achievable with more conventional measures such as P0, P1 mild-hybrid architectures, as exhibited by some of the OEMs. However, the 2030 emission regulations requires more radical measures and technology advancements such as high power density 48V battery could be the way forward

- At the beginning of 2021, OEMs must convert their specific NEDC-based emission target into a corresponding WLTP-based target. As the new WLTP procedure is based on more realistic driving conditions and considers equipment variants and weight classes, there could be an increase in emissions recorded by all OEMs

- The EU allows certain special regulation flexibilities, which reduce the CO_2 emissions taken into account by the EU commission. Vehicles emitting less than 50gCO_2/km are counted 2x in 2020,1.67x in 2021 and 1.33x in 2022, and only 95% of each manufacturer's newly registered passenger cars in 2020 are taken into account. If car manufacturers exceed the specific yearly emission target they must pay 95€ per excess gram multiplied by the number of newly registered passenger cars in the current calendar year

- To reduce the high penalty payments, within the next two years, the majority of car manufactures will have to initiate short term countermeasures that combine steering dimensions profitability, volume, and regulatory compliance

- There is a significant growth in the mild-hybridization of mass-produced hatchbacks and smaller SUVs, as indicated by the latest launches. The price difference between a mild-hybrid variant and a pure IC engine variant is considerably low in these segments which helps in shifting customer preference towards mild-hybrids

- The higher voltage of the 48-volt network opens up new possibilities. Audi, for example, uses electrically driven compressors. They sit in the intake manifold and compress the air before the turbochargers engage. The cars respond more spontaneously, thus improving acceleration and reducing exhaust emissions. As cost comes down for these components we could see these technologies in mass-produced vehicles

- In the SUV segment, the 48-volt network for roll compensation. The stabilizers contain electric motors that tension the chassis in the opposite direction to the curve. The body rolls less and stays straight in fast hairpin bends.

Upcoming topics in our next deliverables

01	Assessment of more than 50+ players for automotive 48V systems which includes funding, techno-commercial details etc
02	Competitor benchmarking, latest academia, break-through technologies, latest technology innovations
03	Any specific interest topics areas of your interest. Reach out to the relationship manager

H1'20 Deep Dive coming July 2020

Do you want to learn more?

Submit a BO

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