48-volt and automotive electrification – systems, performance and opportunity

2nd edition

By Alistair Hill
About the author

Alistair Hill

Alistair Hill started his career in production and project management having graduated as a metallurgist from the University of Aston in Birmingham. He then moved into industrial market analysis and senior marketing roles within the truck industry supply sector. He became a consultant for Knibb Gormezano & Partners in the mid-1990s and began a long history of automotive and commercial vehicle sector analysis working for a wide range of clients including OEMs, suppliers and analytical companies. He has spoken on a wide range of technical subjects at conferences around the world and is actively involved in science and technology development in his adopted country of New Zealand. Alistair gained an MBA from Huddersfield University in 1994 whilst working senior management at the world’s leading friction materials manufacturer and is now reading for a PhD at Otago University.

About the editor

Soren Sarstrup, Managing Editor

Soren Sarstrup has spent most of his career working in the automotive intelligence industry.

As founder and Managing Editor of Autelligence Ltd., he contributes extensive editorial and publishing experience, a global network of contacts on both the OEM and supplier side, in-depth understanding of the industry and the markets it operates in, hands-on sales and marketing experience, and, last but not least, a long-standing passion for all things automotive.
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**3.1.1 Fuel economy and CO₂ emissions**

International CO₂ reduction commitments from Europe, the US and Asia, coupled with the promulgation of legislation have forced vehicle manufacturers to produce cost-efficient alternatives whilst driving markets toward increasing environmental consciousness. While the environmental problem is seen as global, the solutions are being managed in a variety of different ways within each of the vanguard triad jurisdictions. However, overall the global CO₂ target range is beginning to converge.

Figure 17: Comparison of global CO₂ regulations for passenger cars, in terms of NEDC gCO₂/km.

![Comparison of global CO₂ regulations for passenger cars, in terms of NEDC gCO₂/km.](image)

Source: ICCT

The movement to set fuel economy standards was launched by the US following the first OPEC oil shock of the early 1970s, although the Corporate Average Fuel Economy (CAFE) standards that were introduced in 1975 were increased gradually for a few years and then allowed to relax once the global oil price stabilised. However, since the end of the twentieth century, the EU and Japan have also developed fuel economy standards for the new light vehicle fleet.

The EU opted to use grams of CO₂ emissions per kilometre (g/km) as a unit of measure, Japan adopting kilometres per litre (km/l) of fuel and the US retaining miles per gallon (mpg) using the US gallon (3.7854 litres). China has also now set standards that are expressed in litres per 100km (l/100km).

**3.1.2 The European Union**

Following the development of the Kyoto Protocol in 1998, the European Automobile Manufacturers Association (ACEA) and the European Commission (EC) signed a commitment in order to help achieve the EU Community’s Kyoto goals. Its most highlighted feature was the agreement to reduce CO₂ emissions from
The stringency of the US and EU standards as well as the German proposal can be compared in another manner. From 2012 to 2025, the US standards aim to reduce car GHG emissions annually by 4.8%. The European Commission proposal targeted a 4% annual reduction. In contrast, the German proposal would amount to a 2.7% annual reduction in new vehicle CO₂ emissions.

The Chairman of the European Parliament Committee on the Environment, Matthias Groote, rejected Germany’s proposal, saying “A deal is a deal.” However, as the EU tries to reconcile its ambitions to fight climate change with efforts to help economic recovery, the German proposal gained significant support. It now seems unlikely that the industry will be allowed to use this route to curtail its risk of severe financial penalties, but as Germany bought forward these proposals and they appear to have failed to gain sufficient traction the motivations for a speedy introduction of 48-volt as a lower cost alternative to high voltage hybrids become yet more pronounced.

From a consumer perspective how much motivation is there for 48-volt, even if it is differentiated as a choice? This depends very much on cost and running costs, which necessarily depends on the dynamics of fuel pricing.

Figure 29: Additional costs entailed by tougher European CO₂ legislation for a vehicle with emissions of 161g/km

This is an area that regulation can also affect significantly and Europe has a long history of taxing consumers to promote fuel efficiency. With an aging vehicle fleet and increased annual mileage, the concept of an ‘emissions tax’ still hovers over the EU with up to as many as 11 member states introducing into their taxation systems, elements based on a vehicle’s CO₂ emissions and/or fuel consumption.
Based on work carried out by engineering consultancy FEV, the different stop-start systems listed above can be evaluated using a decision matrix (Figure 41) based on a spider diagram helps to understand the complex dependencies. The spider diagram is based on FEV’s experience from past and on-going projects.

### Figure 41: Comparison between different stop-start systems

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Costs</th>
<th>Complexity/Package of Solution</th>
<th>Start Comfort</th>
<th>Fuel Consumption Benefit</th>
<th>Wear</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSG</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Enhanced starter</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Direct start</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>ISG</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Source: FEV

The two most competitive stop-start systems in near future are the BSG and the enhanced starter combined with an enhanced alternator for regenerative braking. As indicated in Figure 41 it is evident that both systems have similar advantages such as ease of packaging, fuel consumption benefits and comparable costs.

Compared to these systems the ISG is a high-cost solution but it gives many more possibilities for hybrid functionality.

A further advantage of the BSG is the possible option of leaving out the conventional starter in small engine applications. Retaining the existing layout of the system and comparable additional costs for integrating the stop-start system, a belt-driven starter generator with ability to boost might be the solution.

The SpeedStart system manufactured by Controlled Power Technologies in the UK is a BSG with all the control and power electronics in a single housing. It is liquid cooled and uses a switched reluctance machine, which provides additional benefits over conventional permanent magnet electric motors. It is designed to be applicable at both 12-volt and 48-volt. Figure 42 shows the performance improvements achieved in moving to the higher voltage version.
Aeristech claims that it overcomes the thermal management issues that can restrict other electric boosting devices currently available on the market to only transient operation by using permanent magnet motor technology in place of the more usual switched reluctance type. This has been made cost-effective by developing a patented control and switching technology that enables the use of many cost-competitive components.

Aeristech’s 48-volt eSupercharger has already been demonstrated by MAHLE Powertrain UK in a D-segment appraisal vehicle using its downsized turbocharged 1.2 litre, 3-cylinder gasoline engine. The engine achieved 32.9 bar BMEP at 2000rpm (+10% over base), delivering 313Nm (231 lb-ft) and a maximum power output of 193kW (259hp)—an increase of 61% over the base engine.

At low speed (1250rpm), the eSupercharger achieved 28.6 bar brake mean effective pressure (BMEP); an increase of 43% over the baseline 20 bar BMEP in the Mahle engine (Figure 55).

**Figure 55: Results from MAHLE tests Aeristech’s 48-volt electric supercharger**

Analysis of the power curve shows that the turbocharger run up line was complete by 3000 rpm, resulting in poor low-speed driveability. The addition of the eSupercharger re-instated the low-speed torque. In other words, combining the eSupercharger and the turbo resulted in a continuous torque curve through the complete engine operating range.

“By replacing the smaller turbo in a two-stage turbocharging arrangement with the eSupercharger, MAHLE Powertrain UK was able to increase the size of the main turbocharger without concerns over driveability and transient response. The eSupercharger can not only help increase specific output but is also much easier to accommodate within the engine compartment than a second stage turbocharger because it has greater layout flexibility”, says Bryn Richards, Aeristech CEO.
The converter uses silicon carbide devices that could operate at a higher frequency than silicon components. It also results in lower switching losses and smaller magnetic components, enabling the converter to achieve an efficiency of 98.7%, a gravimetric power density of 10.5kW/kg and a volumetric power density of 20kW/litre.

Therefore, it is likely that series production of this kind of multiport device will quickly align with the introduction of dual 12-volt/48-volt architecture vehicles in around 2016 enhancing the efficiency of handling multiple voltages, multiple energy storage devices and much more effective energy recuperation.

**Figure 74: Dual battery electrical architecture**

![Dual battery electrical architecture](image)

Source: Valeo

**Figure 75: Projected powertrain demand scenarios**

![Projected powertrain demand scenarios](image)

Source: Johnson Controls
7.1.2 Chassis and auxiliary systems improvements through 48-volt

- Enhanced efficiency in steering systems leading to a wholesale move to EPAS;
- Enhanced active chassis systems allowing improved vehicle dynamics;
- Enhanced operation of electro-mechanical braking and emergency brake assist;
- Improved auxiliary efficiency including window lifters, seat heaters, HVAC, infotainment and navigation systems.

7.1.3 Energy recuperation systems

- Dual 12-volt/48-volt battery systems and/or incorporation of ultracapacitors;
- Dual wiring harness configuration but with little weight penalty;
- Move to lithium-ion technology as available;
- Enhanced energy recuperation from stop-start system, transmission, thermal energy recovery, brake and suspension regeneration systems.