



GKN Driveline technical solutions for hybrids and electric vehicles

- based on ingenuity and experience
- with 200,000 vehicles already on-the-road

By Rob Rickell
Global Engineering Director, GKN Driveline

The well-known challenge to the automobile industry to reduce consumption of petroleum fuels is complicated by the realities of the marketplace, in which many customers are reluctant to spend more money for powertrain efficiency. The challenge for GKN Driveline, as a global supplier to the industry, is to engineer components that reduce emissions of CO₂ while offering benefits to the final consumer.

For the mass market of internal combustion vehicles, GKN Driveline continues to engineer more efficient sideshafts and transmissions. Although internal combustion engines (ICEs) will dominate the market for decades, automakers have clearly identified electric drive as one long-term solution to individual mobility. Vehicle manufacturers propose two basic solutions: adding electric drive to ICE vehicles to make hybrids, and driving electric vehicles (EVs) only by electric motors, sometimes in combination with an ICE / generator as a range extender.

GKN Driveline has developed driveline technologies for each solution that provide value to final consumers. GKN Driveline has a competitive advantage with the global engineering and manufacturing footprint, and has vehicles coming into production in North America, Asia and Europe for three **eAxles** that provide secondary propulsion in hybrids and for two **eTransmissions** that provide primary propulsion in EVs. GKN Driveline is pursuing some 36 hybrid and EV opportunities world-wide that would result in more than one million vehicles in 2015 if automakers reach their projected targets.

eDrive for hybrids

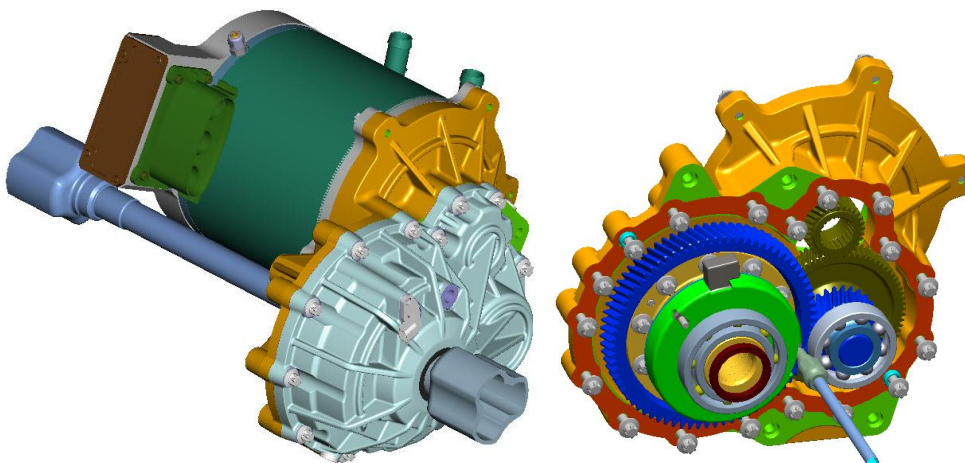
Adding electric propulsion to the front axle in a front-wheel-drive (FWD) vehicle creates problems of packaging. In addition, the final customer of such a vehicle is being asked to pay the on-cost of electric drive for the sole reward of improved efficiency. By adding electric drive to the rear axle of a FWD vehicle, customers receive not only improved efficiency but also the improved traction and dynamics of four wheel drive (4WD). Because there is no propeller shaft and transfer case, the 4WD system is already downsized from mechanical systems, and by using existing FWD platforms, the approach provides development and manufacturing efficiencies that result in lower cost.



Peugeot Citroën chose GKN Driveline to work at the expert stage to develop the industry's first diesel hybrid, which will arrive in the marketplace in 2011. In Europe, Peugeot Citroën has announced its plans to manufacture HYbrid4 versions of the Peugeot 3008, Peugeot 508 and Citroën DS5, using an electrically powered rear axle with a patented disconnect feature from GKN Driveline. The Peugeot 3008 HYbrid4 will have a 2.0-litre HDi engine of 120 kW and an electric motor with maximum output of 27 kW, for a total of 147 kW of power in 4WD. The Peugeot 3008 HYbrid4 will also be able to travel short distances on electricity alone – in zero-emission mode. In use, powertrain control software will transfer torque to the appropriate wheels. Fuel consumption of 3.8 l/100 km offers a reduction of 35 percent, according to Peugeot, compared to conventional ICE vehicles of this size and performance.

GKN Driveline was a development partner for the **eAxle** with Bosch and Peugeot Citroën. The key innovation from GKN Driveline is the electromagnetic disconnect in the rear drive unit that reduces friction losses by disengaging the e-motor and reduction gears when the vehicle is driven purely by the ICE on the front wheels.

The concept was patented by GKN Driveline in 2001 and used first in Japan, where engineers developed the first family **eAxle** for small front-wheel-drive cars in 2002. A 3.5 kW or 5 kW e- motor is powered by the belt-driven generator when front wheels slip. The additional torque to the rear wheels permits a small car to accelerate and climb in mountainous snow country. GKN Driveline has supplied more than 200,000 **eAxles** in Japan for the Nissan March, Nissan Cube and Nissan Note and the Mazda Demio and Mazda Verisa.



GKN Driveline Second Family eAxle

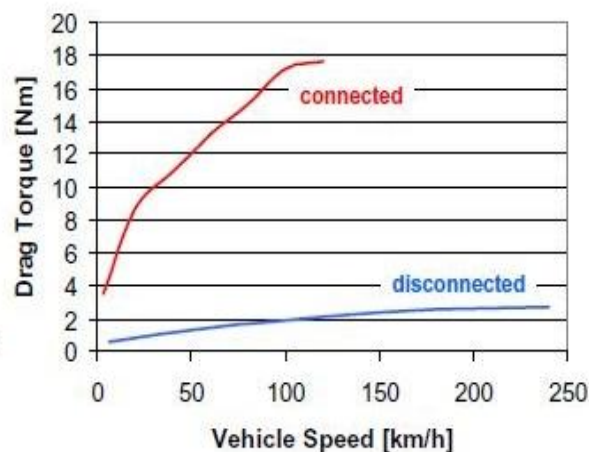


In the more powerful second family **eAxles**, the disconnect provides high efficiency at high speed for maximum CO₂-reduction, and high traction at lower speeds for maximum benefit of 4WD. The speed and power available from the e- motor defines the maximum speed at which the 4WD can be connected. For the early applications with a 3.5 kW and 5 kW motors, disconnect occurs at 27 km/h. Using a motor of 27 kW peak power connected to an **eAxle** like that developed for Peugeot Citroën, disconnect is at 120 km/h. This **eAxle** is designed to handle a nominal 1500 Nm of differential torque, and a peak of 2500 Nm. The maximum speed of the e- motor is 7,500 rpm. The gearbox efficiency in the transfer of power is 96%.

Drag torque on the **eAxle** when the electric motor is disconnected is in the 1-2 Nm range. When the motor and reduction gears are connected, drag torque rises with vehicle speed, from near 4 Nm at 10 km/h to near 18 Nm at 120 km/h. Thus, when the vehicle is being driven in FWD mode, the disconnect provides considerable savings.

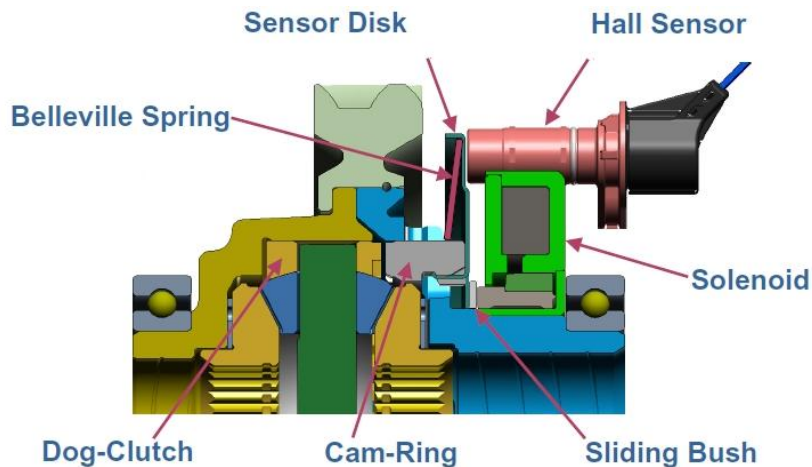
Disconnect provides:

- > high efficiency at high speed → maximum of CO₂-reduction
- > high traction at low speed
- > low weight because of optimized duty cycle



GKN Driveline eAxle Disconnect

The disconnect feature on the **eAxle** uses a software controlled dog clutch, which is simpler, more durable, smaller and less costly than a friction clutch. Within the disconnect device, a solenoid provides the actuation force on a sliding bush to couple the rotating parts. The sliding bush shifts a cam ring axially to mesh with the turning dog clutch. The software, guided by signals from a Hall sensor and sensor disk, accelerates the motor so that the cam ring matches the speed of the turning dog clutch. The teeth are then meshed, allowing torque from the e-motor to power the rear wheels.



GKN Driveline eAxle Disconnect Device

With no current to the solenoid, the **eAxle** is disconnected, which is the fail-safe position. Connection requires a maximum three amps to the solenoid, but less than 1 amp is sufficient to maintain the connection. The disconnect device engages in 100 milliseconds and disengages in less than 80 milliseconds.

GKN Driveline has optimised the **eAxle** for weight, packaging and efficiency, sizing of gears and bearings. One of the unique design elements is attaching the pinion gear directly to the electric motor's output shaft, saving components and package space. The **eAxle** weighs just 18kg. For Peugeot Citroën, GKN Driveline assembles the Bosch motor to the **eAxle** and delivers a tested module to the automaker's assembly line.

GKN Driveline is developing similar products for many vehicles in Asia-Pacific, the United States and Europe. This hybrid solution can be simply applied to the front axle of a rear wheel drive vehicle as well. The only difference to the rear axle design is tuning for the different ramp-up of torque. Typically a prototype can be delivered in three months, and industrialisation is in 18 months. Some new applications are being tested at GKN Driveline's facilities near the Arctic Circle in Sweden, and additional **eAxles** could reach the market in 2013-2015.



eTransmission for pure Electric Vehicles

GKN Driveline is contributing to the growth of the EV industry by reducing the cost and mass of **eTransmissions**.

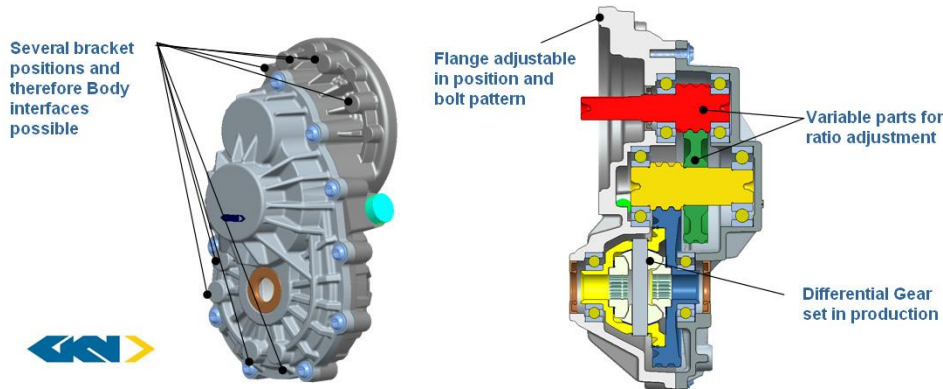
Battery-driven vehicles are essentially simple and operating costs per kilometre are lower than for ICE vehicles. The long-term trend is clear: petroleum fuel costs will rise and battery costs will decline. However, for the moment EV batteries are extremely expensive and provide limited driving range, which has led to a new model of automotive business case in which customers lease their battery.

For a small segment of the market, the total cost of ownership of an electric vehicle may already be less than for an ICE vehicle. In France, La Poste intends to order 10,000 light utility vehicles whose lifetime costs will be the same or lower than an ICE. Some governments provide significant purchase incentives, and operating and maintenance costs per kilometre are lower. Particularly in fleets with established routes, beneficial lifetime costs can be calculated for vehicles that can be recharged cheaply at night and that travel 20,000-25,000 kilometres per year without exceeding their daily limits of 100-160 km.

During the transition toward a mass EV market, supported by less expensive batteries and a widespread recharging infrastructure, automakers need to lower costs and improve efficiency of their EVs.

As potential demand approached, GKN Driveline began working on an **eTransmission** that would transfer torque from an electric motor to the drive wheels. From the first sketch engineers developed a modular approach, following the same principle used for standard driveshaft families that can be tailored to individual vehicle requirements. For EVs, we designed a family of three pre-engineered **eTransmissions** that can be quickly and simply adjusted to different vehicle manufacturer requirements. This is done by changing two gears inside the standard, pre-developed case for which tooling has already been developed. The mass of the **eTransmissions** is minimal, as weight is a main driver of EV cost and range, and they are quiet. Working with Peugeot Citroën on the 3008 HYbrid4, we learned how to reduce the gear noise that becomes apparent in zero-emission mode, and we have applied that knowledge to the **eTransmissions**.

	Typical use	Gear range	Max motor	Wheel torque
First family	Small cars	i=1:6 to 1:14	15 kW	1500 – 2500 Nm
Second family	Family cars	i=1:9.5 to 1:12.5	50 kW	2500-3500 Nm
Second family / 2 speed	Family cars	i=1:6 and 1:12	50 kW	2500-3500 Nm
Third family / 2 speed	Large cars / SUVs	i=1:6 and 1:12	<300 kW	<3500 Nm



GKN Driveline Family 1 eTransmission

The modular advantage is clear. A manufacturer might specify that they have a 15 kW motor that will turn at 8,000 rpm and have 1,000 rpm at the wheel, and another might specify 12 kW at 14,000 rpm, with an 800 rpm wheel speed (about 93 km/h with 185/65R15 tires, for example). The Family 1 module can fit either of these by changing two components inside the gearbox to adjust it to match the requirements.

This flexible approach gives GKN Driveline the competitive advantage of speed as well as low cost. Developing a gearbox housing can require six to eight months lead time, while our product is already available, ready to use with an electric motor from any supplier.

GKN Driveline's experience in partnership with other suppliers addresses another aspect of speed to market. Some vehicle manufacturers that are developing EVs in addition to their traditional vehicles are requesting turn-key solutions for EVs, and GKN Driveline is in a position to respond to such requests. Engineers are developing close relationships with a number of emotor and power electronic companies so that GKN Driveline can quickly respond to requests for proposals.

In December, a domestic Chinese car manufacturer produced a demonstration electric car with a GKN Driveline **eTransmission** connected to a motor from Leroy Somer of France and power electronics from Valeo.

Those same three companies, along with Johnson Controls-Saft, Michelin and Leoni, presented a concept electric car on the Valeo stand at the 2010 *Mondial de l'Automobile* in Paris. Today, GKN Driveline is developing **eTransmissions** for 15 vehicles in global markets aimed for launch in 2012-2015 and has confirmed orders for three.



About GKN Driveline

GKN Driveline is the world's leading supplier of automotive driveline systems and solutions. As a global business serving the leading vehicle manufacturers, GKN Driveline develops, builds and supplies an extensive range of automotive driveline systems – for use in the smallest ultra low-cost car to the most sophisticated premium vehicle demanding the most complex driving dynamics.

GKN Driveline is a leading global producer of CVJ systems, AWD systems, Trans Axle solutions and eDrive systems.

www.gkndriveline.com

About GKN Group

GKN plc is a global engineering business serving mainly the automotive, aerospace and land systems markets. It has operations in more than 30 countries, around 38,000 employees in subsidiaries and joint ventures and had sales of £5.4 billion in the year to 31 December 2010. GKN plc is listed on the London Stock Exchange (LSE: GKN)

www.gkn.com

Company Contact:

Paul Dinwiddy
Global Communication Director
GKN Driveline
Tel: + 44 1527 533 646
Mobile: + 44 7801 077 523
Email: paul.dinwiddy@gkndriveline.com

Media Contact – Americas:

Larry Weis or Craig Miner
AutoCom Associates
Tel: + 1 248 647 8621
Mobile: + 1 248 705 4448
Email: lweis@usautocom.com or
cminer@usautocom.com

Media Contact – Germany:

Peter Richter
AutoCom Deutschland
Tel: + 49 2224 919 8091
Mobile: + 49 160 9020 3282
Email: peter.richter@autocom-deutschland.de

Media Contact – Europe:

Simon Pearson
Tel: + 44 207 861 3158
Mobile: + 44 7836 744 192
Email: simon@s-pearson.com