

Edited by **Darlene Fritz**

Siemens VDO focuses on CO₂ reduction



Klaus Egger, the Siemens VDO Automotive AG Member of the Managing Board responsible for powertrain technologies, leads a team of more than 1400 engineers.

The **European Commission's** push for lower CO₂ emissions from new passenger car fleets meant that low-CO₂ productions and concept cars were front and center in the main halls at the recent Frankfurt Motor Show. But suppliers in the show's less glamorous buildings were also displaying their solutions.

Many systems suppliers want to be seen as key resources for OEM customers that are working to meet CO₂-reduction goals. Advanced combustion and electrical powertrain technologies will be key enablers. **Siemens VDO Automotive** was one of the many companies touting its know-how.

"When you look on the three domains—diesel, gasoline, hybridization—we have everything in our portfolio, either in production or in development," said Klaus Egger, the Siemens VDO Automotive AG Member of the Managing Board responsible for powertrain technologies.

Diesel engines have been the main workhorse for the European industry's recent reductions in vehicle fleet-wide emissions. But the time for easy reductions through the use of diesel engines may have passed, and there will now be more pressure on the emissions side. And Egger concedes that cost has become an issue with the latest clean diesels.

"It [will be] more of a challenge on the emissions side with Euro 6 and U.S. legislation with acceptable costs," he said. To meet U.S. regulations in all 50 U.S. states, he said, injector systems will have to be optimized with increased functionality, multiple injection strategies, and increased pressures (2000 bar or more). However, improved combustion systems will have to be supplemented with aftertreatment technologies such as SCR (selective catalytic reduction) for NO_x reduction and state-of-the-art particulate filters.

Egger and his team of more than 1400 engineers in the Siemens powertrain business unit are working on these and many other next-generation powertrain technologies.

Though the company does not produce engines, for its engine systems solutions the engineering team keeps up on the latest technology through in-house projects such as combined combustion, more commonly referred to as HCCI (homogeneous-charge compression ignition). HCCI combines the advantages of a gasoline engine's low emissions and a diesel's efficiency in one optimized engine.

"We are not designing engines, but we have to understand the interface with the injection system and design our components and systems in the right way," said Egger. He expects HCCI to make production around 2012, but challenges remain—especially for transient operation, when the engine needs to switch from one mode to another. Making running prototypes that run on engine test benches is now possible, but making an HCCI engine operate "in all conditions, temperatures, and driving modes is the challenge," he said.

At its Frankfurt Motor Show display, Siemens VDO unveiled other, more near-term solutions aimed at reducing CO₂.


The company has engineered its own turbocharger concept for gasoline engines. When paired with direct injection, the turbocharger offers "downsizing" opportunities. The use of smaller, more fuel-efficient gasoline engines with otherwise-identical performance characteristics makes it possible to reduce CO₂ emissions by more than 15%, according to Siemens VDO, bringing gasoline engines nearly to a comparable level with modern diesel engines.

"We analyzed the market and we clearly see that, on the gasoline side, downsizing combined with turbocharging and DI [direct injection] will come and be a major step forward to reach our goals," said Egger. This is not a new concept, **Volkswagen** being one of the main proponents, but he expects the solution to really catch on.

"We really want to be in this market because there will be a significant amount of turbochargers out in a few



Siemens is developing its own turbocharger with integrated sensors and actuators (shown) to be paired with gasoline direct injection to offer engine "downsizing" opportunities and CO₂ emissions reductions of more than 15%.



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Siemens is working with Lotus Engineering and Emitec on a low-CO₂ demonstration vehicle that should be running by the end of the year.

years, and we have the possibility of integrating our turbocharger into the overall system—to take a systematic approach to optimize not only functionality but also cost,” he said. “We have started development, and for the first time we are showing a prototype here which is already on the test stand. It is our design, with new ideas, new innovations, new patents, and some know-how from **Siemens AG**, which is experienced in material research and on the product side with gas turbines.”

The development team has created fully functional turbocharger prototypes, with the first generation having in-house electronics, sensors and actuators, and turbines. Solutions will be available for production on vehicles beginning in 2010.

Systems expertise is also being applied to the Siemens VDO Low-CO₂ demonstration vehicle being jointly developed with partners including **Lotus Engineering** and **Emitec** in an effort to achieve lower emissions in future gasoline-fueled vehicles.

“We want to show our customers what can be done by combining different technologies,” said Egger.

In advance of the full unveiling of the low-CO₂ engine in a demonstrator vehicle by the end of the year, Siemens VDO showed the final cylinder head design with a number of integrated technologies.

The primary objectives of the project are to deliver greatly reduced emissions while maintaining an engaging driving experience from an affordable set of

technologies. The cleverly integrated set of powertrain systems within a low-mass, downsized overall package ultimately will be used by both Siemens and Lotus to support automakers’ efforts to reduce fleet-average CO₂ emissions in next-generation products.

Siemens VDO is supplying the project’s engine control unit, hybrid drive, fuel-injection components, as well as sensors and actuators. Lotus Engineering is contributing its powertrain design, downsizing, and systems-integration expertise, along with a number of advanced technologies. Exhaust-gas aftertreatment and catalytic converter technology was contributed by Emitec, a joint venture of Siemens VDO and **GKN**. Tires of very low rolling resistance also contribute to lower emissions. The project is sponsored by the **Energy Saving Trust**, a nonprofit organization funded by the UK Government’s **Department for Transport**.

Key features include a newly designed supercharged 1.5-L three-cylinder gasoline engine and hybrid-electric system for the downsized powertrain. The display included Lotus’ unique integrated exhaust manifold design and cam profile switching system, and also featured Siemens VDO’s new high-pressure fuel pump and centrally mounted gasoline injectors.

Kevin Jost

ACEA OK with tough European emissions requirements if reasonable lead times provided

What could be a big enough issue to bring the European auto manufacturer CEOs together on one platform? Not surprisingly, it’s the environment—or more accurately, carbon-dioxide emissions. Like other governments, the European Union has plans for tight restrictions in the amount of carbon dioxide emitted by new vehicles.

Speaking at the Frankfurt Motor Show on behalf of the **ACEA** (European Automobile Manufacturers’ Association), **Fiat** Group CEO Sergio Marchionne, also Chairman of ACEA, expressed the Association’s view that the targets should not be met by powertrain technology alone. He was flanked on the platform by **Renault** CEO Carlos Ghosn, **GM Europe**

President Carl-Peter Forster, **Daimler** Chairman Dieter Zetsche, **PSA Peugeot Citroën** CEO Christian Streiff, **Ford of Europe** Chairman Lewis Booth, **BMW** CEO Norbert Reithofer, **Volkswagen** Board Member with Responsibility for Technical Development Ulrich Hackenberg, and ACEA Secretary General Ivan Hodac.

In February of this year, the European Union proposed a 120-g/km (193-g/mi) limit for average carbon-dioxide emissions from autos by 2012, but the proposal was rapidly withdrawn after fierce opposition from the European manufacturers. A proposal raising the limit to 130 g/km (209 g/mi) was tabled in its place. European auto manufacturers have al-

ready made voluntary commitments to reduce average carbon-dioxide emissions to 140 g/km (225 g/mi) by 2008.

“Car manufacturers support the 120 g/km average,” said Marchionne, “but only through an integrated approach. Vehicle technology is up to ten times more expensive than other measures.” He also expressed ACEA’s view that there is no single solution to the issue.

“The type of legislation is decisive,” he continued, “and an appropriate lead time is needed.” Marchionne gave the example of Japan, which has given its manufacturers until 2015 to reach an average of 138 g/km (222 g/mi). “A minimum of six to seven years is needed for lead time,” he said.

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If the EU introduces legislation in 2009, this would signal that ACEA would hope for the implementation date to move from 2012 to 2015-16.

Cost is clearly an issue for an industry that has seen its operating margins severely eroded. ACEA quotes research from the European Climate Change Program by the **Netherlands Organization for Applied Scientific Research (TNO)** in 2006. TNO assessed the costs and potential for reducing carbon-dioxide emissions from measures such as vehicle technology, bio-fuels, and infrastructure. Using engine technology to move toward a 120-g/km (193-g/mi) average emissions figure by 2012 would add an average of €3600 per vehicle, according to TNO, while reaching 130 g/km (209 g/km) would add some €2500 per vehicle. These figures, warns ACEA, would cause automotive manufac-



"European auto manufacturers support a 120-g/km carbon dioxide emissions target only through an integrated approach," said ACEA Chairman and Fiat Group CEO Sergio Marchionne.

turers to consider transferring manufacture to lower-cost areas outside the European Union.

ACEA believes that a cost-effective solution can be introduced that incorporates bio-fuels, improved infrastructure, carbon-dioxide-based car taxes, and "Eco-Driving." Eco-Driving involves a series of measures to persuade drivers to improve their driving standards and in the process reduce the amount of fuel consumed.

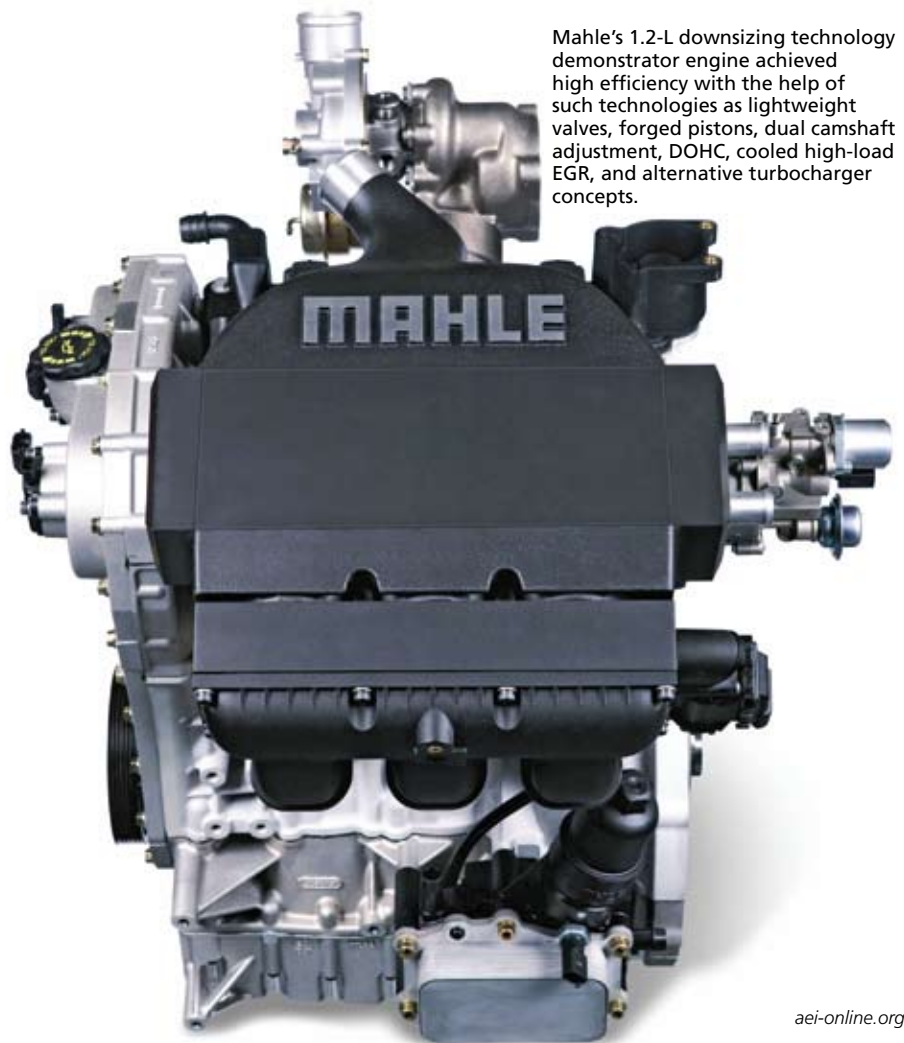
"Addressing climate change is a key issue," said Marchionne. "We need coherent, consistent, cost-effective action. We will continue working with the European Commission to find a way forward. The exact date is irrelevant—we need sufficient lead time. 120 g/km is only possible with other parties involved."

John Kendall

Mahle technologies boost engine efficiency

"The combustion engine will have to make one of the important individual contributions to bringing down CO₂ emissions," Heinz K. Junker, Chairman of the **Mahle** Management Board, said during an interview with *AEI* at the Frankfurt Motor Show. To demonstrate the influence combustion engine components and systems can have on overall engine efficiency, the supplier has applied its entire range of state-of-the-art technology to a technology demonstrator engine that was developed and constructed at Mahle Powertrain in the U.K. This 1.2-L three-cylinder gasoline engine pushes out up to 120 kW (160 hp) per liter. According to Mahle, this would be sufficient for a 1.6-tonne vehicle—a vehicle class that would typically be powered by a 2.5-L engine. Reducing the capacity by half would result in more than 20% higher fuel efficiency, according to the supplier. "The future lies in downsizing," Junker said.

As turbocharging technology is key for this kind of downsizing, Mahle will start to manufacture turbochargers by 2010. Current development includes gasoline-engine wastegate turbochargers for engines with up to 200 kW (268 hp) output, and variable-flow turbochargers for diesel engines with up to 150 kW (201 hp) output. The first prototypes were shown at Frankfurt.



Mahle's 1.2-L downsizing technology demonstrator engine achieved high efficiency with the help of such technologies as lightweight valves, forged pistons, dual camshaft adjustment, DOHC, cooled high-load EGR, and alternative turbocharger concepts.



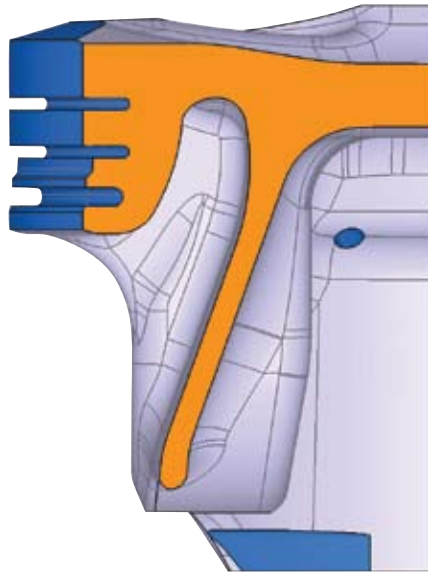
The new lightweight valves with internal sodium cooling have an extended operating range that is 50 to 100°C (90 to 180°F) greater than that of conventional valves.

The demonstrator engine's high efficiency owes to a long list of innovative technologies that includes two alternative turbocharging concepts, forged pistons, DOHC, and direct injection with injector-tip cooling. Additional technology applications include an air-water intercooler, cooled high-load exhaust gas recirculation, dual camshaft adjustment, and lightweight valves.

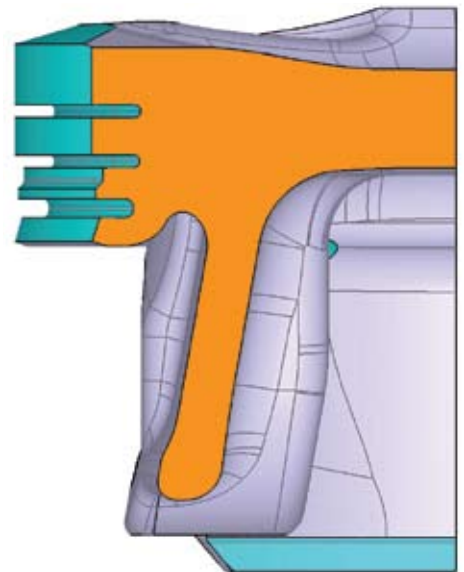
Mahle's core development targets were to cut total mass by reducing component weight and minimizing internal friction in the engine. One-third of the engine's friction losses can be attributed to the tribological system of rings and pistons, according to the supplier. To help reduce this effect, the demonstrator engine's piston pins were coated with a diamond-like carbon coating, cylinder running surfaces were coated with Nikasil, and the piston rings were PVD-coated. The supplier also uses PVD (physical vapor deposition) technology for its Flex Fuel engine piston rings, as they require a much higher wear and fretting resistance than piston rings for conventional-fuel engines.

When it comes to reducing the friction of bearings in the engine, Mahle is also considering the replacement of plain bearings with roller bearings, according to Junker.

Among the component innovations shown at Frankfurt were lightweight intake and exhaust valves with internal cooling. These are made of formed sheet-metal parts. The valve has a hollow body, and the cone and disc are produced in a



The new asymmetrical Evotec piston (left) saves weight by reducing the box wall thickness even further in areas of less stress. The Mahle Evotec precursor, Ecoform (right), was already weight-optimized.



multistage metal-forming process. The stem is made of a steel pipe, and individual components are joined by means of high-precision laser welding. As a result, mechanical finishing is reduced by 25% compared to forged-steel valves. The hollow design allows the valves to be filled with sodium, enabling considerably higher combustion-chamber temperatures and an optimized engine operation with respect to fuel consumption.

"These lightweight valves can take temperatures that are between 50 and 100°C higher than is possible with other valves. Originally, we developed this valve type mainly to reduce the moving masses which have to be accelerated and decelerated at high frequency during operation. By doing this we increased the component strength in high-speed ranges while reducing wear and noise. Today, it becomes obvious that lightweight valves offer additional benefits for turbocharged lean-burn gasoline engines. We have embarked on three engine programs that are likely to result in [production of] lightweight valves."

Mahle's new gasoline-engine Evotec pistons also feature lower oscillating masses. The box walls of the piston thrust side are narrower than those on the anti-thrust side. This saves weight in areas subject to less stress. Compared to a standard piston version without recesses behind the ring zone above the bosses, the Evotec piston is approximately 20% lighter, according to Mahle. Improved engine responsiveness, lower fuel consumption, and lower exhaust-gas emis-

sions are the consequence, the supplier claims. To produce this asymmetrical shape, Mahle designed a new casting process. To increase the piston's service life and wear resistance, the Evotec piston is available with a ring carrier for the first ring groove.

For passenger-car diesel-engine aluminum pistons, the load limit may be near 200-bar (2900-psi) peak pressure and temperatures in excess of 400°C (750°F), Junker said. "When you take commercial engines as the role model, this was basically the load population when the change to steel pistons began. By 2012 or 2015 we might see the first diesel-passenger-car forged-steel piston applications. In particular, the identical heat rate of piston and cylinder will help to minimize blow-by and oil consumption."

High-strength and reduced-mass connecting rods made of forged steel are another element of lightweighting. The forging process results in a favorable fiber orientation. The new 36MnVS4 material provides a steel grade with a unique chemical composition. It has a fine-grained microstructure and its fatigue resistance is up to 30% greater than existing materials for fracture-split connecting rods.

Finally, Junker drew attention to another steel component: the piston pin. "By using shorter piston pins, we can take out another bit of weight of the total piston/conrod system."

Jörg Christoffel

Continental refines modular hybrid technologies

Currently **Continental Automotive Systems** (CAS) is supplying hybrid-drive solutions for two **General Motors** SUVs.

The supplier's series production of hybrid drives started in 2003. However, the company's R&D goes back to the early 1990s when the newly founded CAS (1994) developed integrated starter alternator (ISAD) technology. In 2005, the supplier reorganized its activities, centralizing the development of electric motors and electronics at the Berlin site. At that time, CAS also entered a strategic alliance with **ZF Friedrichshafen** that covers the transmission and powertrain integration of hybrid drive components. The target of this alliance is to facilitate a fuel efficiency progress of up to 25% via complete hybrid drive solutions.



Karlheinz Haupt, Member of the CAS Management Board and head of the electric drives business unit, expects to see the first European hybrid vehicles on the road by the end of 2008 or early 2009.

CAS is now working with several automobile manufacturers to push forward series production projects for hybrid vehicles. These projects include start-stop systems, mild hybrid drives that supply additional torque during acceleration and use regenerative braking, and full hybrid drives with the option of fully electric driving. The electric output can reach more than 150 kW (201 hp). The company uses a scalable principle for its power electronics solutions, a flexible modular concept that includes energy storage, a voltage transformer for the 14-volt on-board power supply, the electric motor, and the inverter.

During the reorganization, CAS decided to focus on power electronics and brake-specific hybrid know-how. *Automotive Engineering International* spoke to Karlheinz Haupt, Member of the CAS Management Board and head of the electric drives business unit, about the current hybrid status quo at CAS. According to Haupt, one of the core challenges is to integrate power electronics within the existing powertrain installation space. "With the second generation of power electronics, we are targeting to achieve 5-L construction volume for the power electronics," he said. "This will allow us to install the power electronics in the space of the conventional generator." Through cooperation with ZF, a joint CAS/ZF solution was developed that can offer hybrid drive automatic transmissions complete with integrated electric motor.

For regenerative braking, CAS applies conventional braking system technologies to develop concepts with pedal-feel simu-

lation. A newly developed electric-hydraulic brake (EHC) designed for use in hybrid vehicles combines hydraulic front-axle braking with fully electric wheel brakes on the rear axle. It remains to be seen how CAS will use the electronic wedge brake (EWB) technology developed by **Siemens VDO**. So far, CAS has communicated a pro-hydraulics position that would appear to contradict the electronic solution that is now available to the newly merged CAS/Siemens VDO organization. As Karl-Thomas Neumann, President of CAS and Member of the Executive Board, is an electronics engineer himself and appears to be open to innovative approaches, the EWB may turn out to be a valuable dowry, despite CAS's dominant hydraulics tradition in braking.

In the lithium-ion battery field, CAS is cooperating with several partners to avoid prejudgment. "We find that each battery specialist tends to focus on just one type of chemistry," said Haupt. "In general, we expect to see dramatic development in battery technology in the future."

Asked about the oncoming development of different hybrid concepts—micro, mild, and full—Haupt said that this will also depend on political influence. "In California, for instance, the mild hybrid may have a slight advantage when it comes to earning credits for low-fuel-consumption technology. However, everything is in constant flow in the mild hybrid field, where we are talking about 10 to 15 kW of electric power. Even belt-driven solutions with low-cost batteries may be an option. The current phase is one of clarification and funneling.

"The hybrid start-stop function is a reality. The next step, particularly in Europe, is equipping luxury sedans, which need hybrid drive technology to achieve substantial fuel-consumption savings despite their typically powerful and dynamic driving characteristics. This is where hybrid-drive solutions will have to prove their potential."

By the end of 2008 or early 2009, Haupt expects to see the first European hybrid vehicles on the road. "And we will have a premium car solution on the road as well," he said.

Jörg Christoffel



CAS is approaching 5 L of volume with its second generation of power electronics.

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Green Diesel Platform develops off-the-shelf exhaust aftertreatment solution

Looming CO₂ legislation and mandatory rules on fuel economy provide the automotive industry continued pressure to bring down fuel consumption quickly. The time until strict rules will be in place is only six years in Europe (2014) and even less in the U.S. According to the **Green Diesel Platform**, this challenge means using existing, validated technologies to bring down CO₂ emissions quickly in conventional, mass-production cars. The diesel engine, with its high level of fuel efficiency, can help automakers meet the greenhouse gas legislation limits; however, the issues of particulate matter (PM) and oxides of nitrogen (NOx) emissions must also be addressed. The minimum target is to bring diesel's local pollution down to the same level as the gasoline engine's.

clean machine, it offers a potential for lowering carbon-dioxide fleet emissions. French carmaker **Peugeot** spearheaded the use of the diesel particulate filter (DPF) with an additive-based solution. Peugeot was the first company to equip its vehicles with DPFs in 2000 when the rest of the European car industry, particularly the German automakers, focused solely on bringing down engine-out emissions. The massive success Peugeot achieved by removing at least one of diesel's two "poison pills" forced the whole industry to review the situation. By now, the DPF is nearly standard in new diesel cars, though it will not be mandatory in the EU until the Euro 5 standard takes effect in 2009. The next step will be the installation of selective catalytic reduction (SCR) systems to achieve the NOx emis-

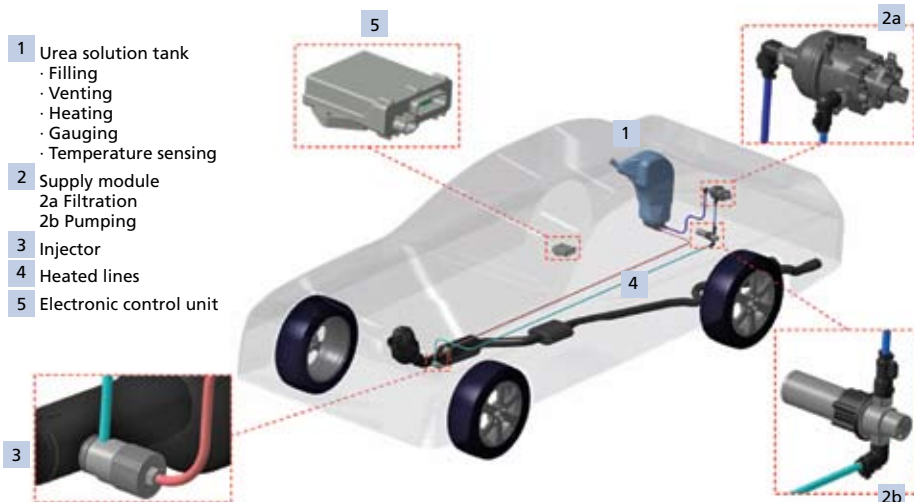
aftertreatment. Platform partners focus on supporting vehicle manufacturers, with the first Green Diesel Platform application—the **Audi Q7** diesel with SCR system—due in the U.S. in 2008.

Specialty chemicals group Rhodia contributes the additive know-how that is behind the Peugeot solution. Rhodia has refined the Eolys additive formula, which is now in its third generation and so highly concentrated that 2 L (0.5 gal) are enough to last for 240,000 km (150,000 mi) before the additive tank needs a refill.

Eolys is dosed to the diesel tank in a low-ppm (parts per million) concentration every time the car is refueled. The fuel-borne catalyst brings down the temperature level for DPF regeneration (the burning of soot) by 150 to 200°C (270 to 360°F), so regeneration can be accomplished in less than 5 min at 450 to 500°C (840 to 930°F), according to Rhodia. The new additive's high efficiency also means that regenerating the DPF has only a low impact on fuel consumption—a less-than-1% increase, according to Laurent Rocher, Sales & Market Development Manager for Rhodia. "This compares to around +5% with other technologies," Rocher added during a press briefing at the Frankfurt Motor Show.

Inergy, a plastic fuel tank system supplier, was founded in 2000 as a joint venture between **Plastic Omnium** and **Solvay**. The company brings to the platform the additive storage and urea system know-how for SCR systems. Urea storage and distribution is a challenge as SCR technology requires around 1 L (0.3 gal) of urea solution per 1000 km (620 mi). Inergy has developed tank solutions that hold 20 to 25 L (5.3 to 6.6 gal) to give the SCR system an acceptable reach. To accommodate the necessary installation space, this volume is often packaged in multiple, separately located tanks. Since the solution freezes at -12°C (10°F), the Inergy system incorporates a heating element to ensure that molten urea is available after 20 min at -30°C (-22°F). Tank, supply module, urea injector, heated lines, and electronic control are marketed under the name Dinox.

Jörg Christoffel



The Dinox liquid system for urea storage and dosage incorporates such functions as filling, venting, heating, and monitoring.

In Europe, where about 50% of all new cars are equipped with a diesel engine, much of the progress toward achieving the first **ACEA** target of 140 g of CO₂ per km (225 g/mi) by 2008 owes to the increasing share of downsized turbocharged diesel engines. Despite an increasing trend toward the use of powerful, large-capacity diesel engines for premium sedans and large SUVs, the same underlying logic still applies. Modern direct-injection, turbocharged diesel engines better a naturally aspirated gasoline engine's fuel efficiency by roughly 30%.

Once the diesel engine is turned into a

sions levels required by the currently debated Euro 6 standard, which will be implemented in 2014.

The growing international tendency to equip cars with diesel engines is the motivation for the Green Diesel Platform. Created in 2002, the platform brings together supplier skills in diesel exhaust aftertreatment. **Aaquis & Aaquis**, **Inergy**, and **Rhodia** are pooling their managerial, business, and technology know-how within the platform to adopt existing, off-the-shelf technology. The business rationale is to offer an integrated technology solution for diesel exhaust