advanced propulsion News Special Report

Environmental Highlights of the 2008 Geneva Motor Show

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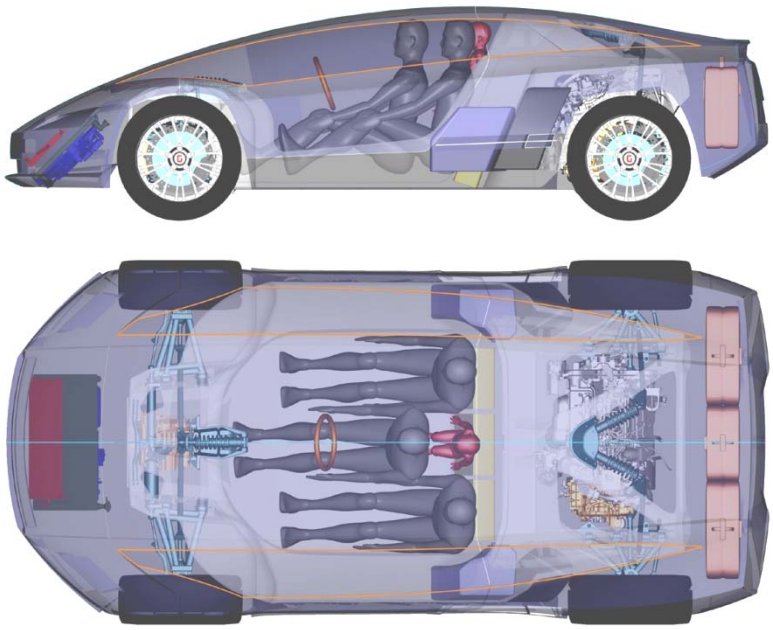
Salon de l' Auto Genève has always been a showcase of style for the leading European design houses and this year was no exception. However, the choices of propulsion systems for the vehicle design studies (by such icons as Guigiaro and Pininfarina) were very green – reflecting the environmental interest of the public and their clients, the automotive manufacturers.



Geneva also reflected the mix of reality and imagination inherent in the automotive business and the introduction of new technologies; this report attempts to separate serious developments from distractions.

REAL - Interest in diesel hybrids has certainly increased since Peugeot and Citroen showed their concepts last year. BMW, Mercedes-Benz and SsangYong all showed diesel HEV concepts; SsangYong justified theirs by saying that it had equivalent fuel consumption to a fuel cell vehicle. And SMART showed their new micro hybrid petrol variant as well as "the most efficient vehicle in series production", the **fortwo cdi** (3.3 l diesel/100 km on the NEDC).

Magna Steyr displayed several hybrid/alternative fuel components in production, including an integrated Li-ion battery system (using A123 cells), hydrogen and CNG storage plus a concept vehicle that put it all together.

TH!NK apparently will expand their EV product line with a 5-door, 5-passenger vehicle as well as additional battery options that include the Zebra sodium or Li-ion batteries from Enerdel or A123.

And small engine developments should not be ignored. Though not considered 'alternative', they will have a much greater environmental impact globally than hybrids in the foreseeable future. 'Small' engine technology ($\leq$ 1 liter displacement) could be the single most important factor in the environmental impact of the explosive growth of the vehicle market in India and China. Developments such as Honda's NOx reduction catalyst (introduced in Geneva in the new Accord for Europe) could be extremely important. And performance-oriented developments, such as two-stage turbocharging, could have a positive environmental impact when applied to small engines.

HOW REAL? – This category includes ventures that are more risky than most due to their high level of technical innovation and/or eccentricity. Perhaps the most extreme example is the Rinspeed EV that can operate on land or underwater like a submarine (obviously not for the typical EV user). Another is the Assystem hybrid, with zero-turn capability for maneuvering in the city (but they really could have used one of the Italian design houses).

MCE-5 Development (of Lyon) is about to publish the results of their variable compression engine development claiming a 30-35% fuel consumption improvement over standard SI engines and they will have vehicles to test by the end of the year. Developed outside the auto industry with a combination of private and public funding, it has had (and will have) a hard time being seriously considered by traditional vehicle manufacturers.

DESIGN – The styling is incredible though impractical for the mass market, but Fioravanti, Fornascari, Guigiaro and Pininfarina certainly attracted attention by wrapping their hottest new bodies around hybrid and fuel cell

technology. Morgan departed from the (modern) Italian design approach with a caricature of their classic design – surprisingly built around their own fuel cell technology.

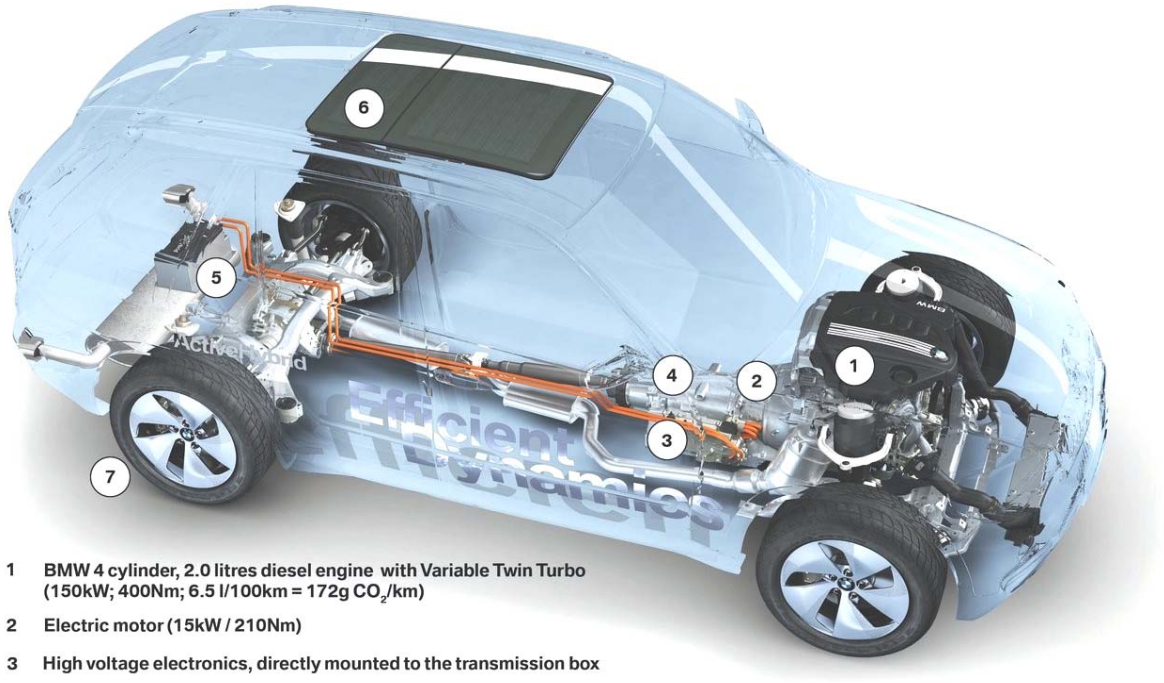
ETC. – Porsche confirmed their intent to purchase a controlling interest in VW and they (finally) showed the components of their hybrid SUV as well as the layout drawing of the 4-passenger hybrid car that is planned.

And though they were certainly not the sexiest or the most impressive vehicles at the show, the Tata Nanos (and the CEO) were almost smashed by the swarm of journalists.

An overview of the report contents (covering only premieres at this venue) …

BMW	*X5 Diesel HEV Concept*	*2 liter, twin turbo diesel mild hybrid with 100 bhp/liter, 6.5 l/100 km*
HONDA	*New Accord*	*Latest diesel engine with innovative NOx reduction comes to Europe in new Accords; CR-Z 'performance hybrid' later*
Mercedes-Benz	*GLK Vision HEV Concept*	*BLUETEC hybrid in new small SUV*
PORSCHE	*Cayenne HEV Cutaway* *Panamera HEV Layout*	*SUV and 4-door passenger car HEVs on the way*
smart	*New fortwo 'MHD' and 'CDI'*	*Micro-hybrid drive with stop-start; new small diesel engine technology*
SSANGYONG	*Diesel HEV Concept*	*Powertrain display only, but development vehicles running in Korea*
TATA	*New Nano*	*The 'people's car' offered in India for 100,000 Rp ~ $2500*
THINK	*th!nk^{Ox} 5-pass EV Concept*	*Plus GE investment and supplier agreement with A123*
FIORAVANTI	*Hidra FCV Concept*	*"Designed for" direct hydrogen fuel cell system*
FURNASARI	*R600 EV Concept*	*4WD EV by high-performance, luxury off-road vehicle builder*
GIUGIARO	*Quaranta HEV Concept*	*Toyota Hybrid Synergy Drive in a mid-engine configuration*
MORGAN MOTOR COMPANY	*LifeCar FCV Concept*	*Modern version of the classic with their own fuel cell system*
pininfarina	*Sintesi FCV Concept*	*Built around Nuvera fuel cell, reformer and electric drive system*
RINSPEED	*SQuba EV Concept*	*EV/submarine based on Lotus Elise*
MAGNA STEYR	*Mila Alpin HEV Concept*	*CNG hybrid with Li-ion battery*
ASSYSTEM	*City car Concept*	*Rear engine, front electric HEV with mid axle for maneuverability*
ESPACE Développement	*X80 Concept*	*2-cylinder turbo with stop-start to meet 80 gCO_2/km*
MCE-5	*Var. Comp. SI Engine*	*Claim 30-35% improved fuel consumption for same performance*

Improved efficiency without compromising performance is the basic idea of BMW's 'EfficientDynamics' strategy and their latest concept, the X5 ActiveHybrid with a diesel engine, appears to support the strategy. Combining a 2-liter, twin-turbocharged diesel ("… the world's first diesel with a specific power output of over 100 bhp per liter"), an automatic 8-speed transmission, a 15 kW motor and a Li-ion battery results in fuel consumption of 6.5 liters/100 km (or 36 mpg). The contributions of the additional gadgets on this vehicle, i.e., the solar transmission fluid warmer or turbulence-reducing wheels, were not explicitly addressed.



1 BMW 4 cylinder, 2.0 litres diesel engine with Variable Twin Turbo (150kW; 400Nm; 6.5 l/100km = 172g CO_2/km)

2 Electric motor (15kW / 210Nm)

3 High voltage electronics, directly mounted to the transmission box

4 8 gear automatic transmission

5 Lithium-ion battery (120 Volts)

6 Solar roof for pre-warming of transmission fluid

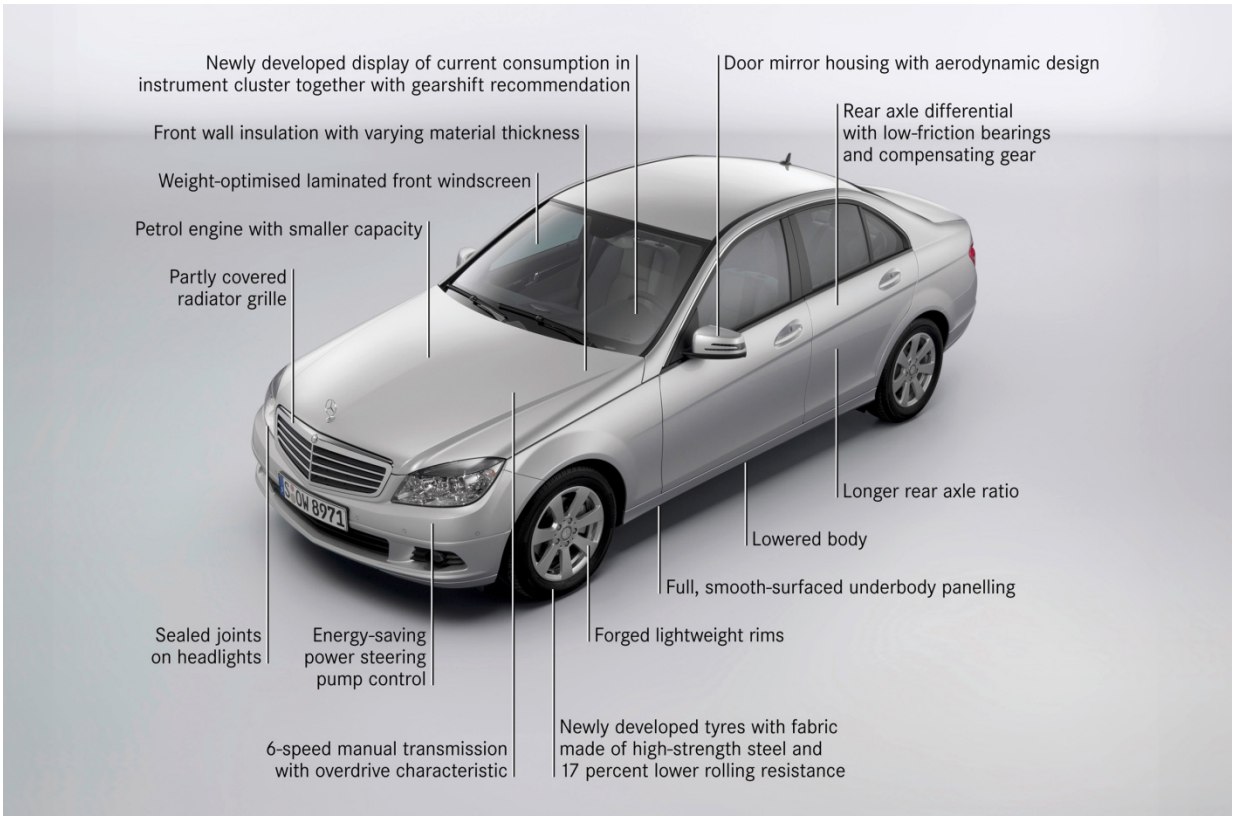
7 Rims with special aerodynamic effect for less turbulences

Last year the Honda Small Hybrid Sports Concept was revealed in Geneva (covered in the Frankfurt '07 report) and this year CEO Takeo Fukui confirmed that the next generation CR-Z Hybrid Sports model (below right, introduced in Tokyo '07) is on its way – in addition to the new hybrid that will be introduced in Japan, the U.S. and Europe in 2009. He also reminded the press that the FCX 'Clarity' fuel cell vehicle (introduced in LA) was to begin lease sales in the U.S. this summer (in Japan in fall). But the environmental message was a prelude to the introduction of the new Accord with three engines (all meet Euro 5), including 2.0- and 2.4-liter petrol plus the new 2.2-liter i-DTEC diesel with their unique NOx reduction technology.

The **Vision GLK BLUETEC HYBRID** SUV concept was the centerpiece of the press conference, but it was only one of several vehicles revealed in Geneva as part of the 'Road to the Future' discussed in the Frankfurt '07 report. Their BlueEFFICIENCY strategy was demonstrated in C-Class passenger cars that were introduced with diesels and BLUETEC after-treatment as well as petrol engines with spray-guided direct injection – with as much as 12 percent lower fuel consumption than their predecessors.

The hybrid concept is based on the new compact SUV that is scheduled for launch this fall. It is equipped with a new 2.2-liter, 4-cylinder CDI engine with two-stage turbocharging, BLUETEC after-treatment, an electric motor packaged between the engine and automatic transmission and a JCS Li-ion battery. The system is capable of 165 kW (224 hp) and 560 Nm, with the motor providing up to 160 Nm to support acceleration and engine start-stop. The performance (0-100 km/h in 7.3 seconds) and NEDC fuel consumption (5.9 l/100 km or 40 mpg) are pretty good for the SUV segment. The GLK hybrid supposedly complies with BIN5 and EU6 regulations and they claim the CO_2 emissions of 157 g/km is the world's lowest for the segment.

The results of the BlueEFFICIENCY strategy will be demonstrated in the new C-Class vehicles to be launched this spring. It is a holistic approach, combining new engine technology, weight reduction, low rolling resistance tires and improved aerodynamics; the graphic below provides the overall perspective.



The BlueEFFICIENCY version of the 100 kW/136 hp **C 200 CDI** consumes 5.1 l/100 km (135 g CO_2/km), representing a savings of 0.9 l/100 km. The higher performance **C 180 KOMPRESSOR** BlueEFFICIENCY with 115 kW/156 hp improved by 0.6 l/100 km, resulting in measured consumption of 6.5 l/100 km of premium petrol (with 156 g CO_2/km). The **C 350 CGI** model, shown in Geneva with a 6-cylinder and spray-guided direct injection, uses 10% less petrol than the current V6 model.

The detailed contributions are interesting and too numerous for this report, but some of the more notable specifics within this array of improvements are listed below:

Weight savings ranged from 19 to 32 kg depending on the model:

- A newly developed laminated windscreen with an acoustically effective plastic membrane saves about 1.2 kg (from the Maybach).
- Optimizing the noise-insulating lining of the firewall saved about 20%; by varying the thickness of the sound-absorbing resinous foam, using new materials and computational methods.
- Forged lightweight wheels saved around 1.8 kg per wheel (and they incorporated a design to reduce aerodynamic turbulence).

Mercedes-Benz collaborated with Michelin to develop *lightweight, low rolling resistance tires*; and they will premiere in the C-Class. The belt of the tire contains a multi-layered mesh of high-strength steel for less deformation and it is lighter than conventional designs, saving about 1.7 kg per set. The secret, according to Mercedes, lies in the rubber compound used in the tread and side walls – reducing rolling resistance by 17 % while retaining good handling and braking characteristics.

Aerodynamic improvements resulted in a drag coefficient (Cd) of 0.25 for the C-Class. These included a series of details, such as tail lights with ventilation slits that reduce turbulence at the rear and replace the usual spoiler lips, lowering the suspension (15 mm), aerodynamic wheels that improve the airflow around the flanks and basically paying attention to all the joints and appendages (e.g., the mirror).

Energy management is key in the BlueEFFICIENCY models of the C-Class; the power steering system is controlled based on need – reducing the NEDC fuel consumption by 0.14 l/100 km (or 2.5%in the C 200 CDI).

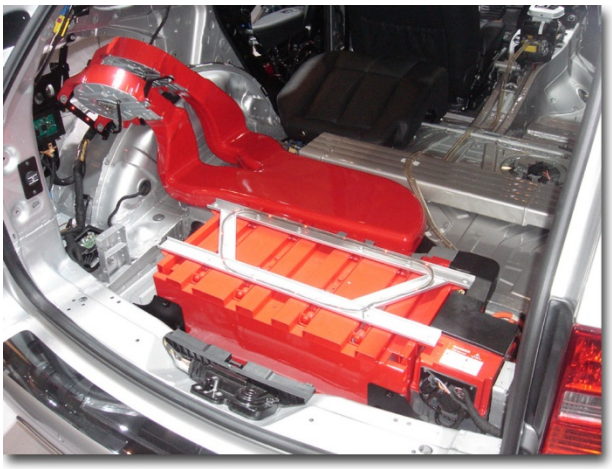
The BlueEFFICIENCY **C 180 KOMPRESSOR** and **C 200 CDI** models are equipped with a *newly developed final drive* featuring further-improved antifriction bearings, forged differential gears and lightweight construction – reducing drive losses in the transmission. The *longer final-drive ratios* also help to reduce fuel consumption (2.87:1 vs. 3.07:1 in the **C180 KOMPRESSOR** and 2.47:1 vs. 2.65:1 in the **C200 CDI**).

A *newly developed gearshift display* in the cockpit informs the driver when he should change gear to save fuel. The Mercedes-Benz "ECO Training" courses apparently have resulted in drivers that are able to average fuel savings of up to 15% without any loss of driving enjoyment.

Engine downsizing made possible by optimising the combustion chamber, mixture formation and engine friction saves 0.35 l/100 km. For example, the **C 180 KOMPRESSOR** reduced overall displacement from 1796 to 1597 cc while retaining the same output (115 kW/156 hp) and torque (230 Nm).

PORSCHE

This is not groundbreaking news, but the images were not contained in the press materials. The actual hybrid components in the **Cayenne** were finally shown – confirming the drawing (right) shown previously. The same mild hybrid configuration will be used in the 4-door **Panamera** passenger car – according to the layout drawing (below) which was displayed at the show. The battery is packaged below the rear floor and the visible components in the front are the power electronics.



More significant is the recent legal ruling that allows Porsche to exercise control over VW due to its 75% ownership, so we can expect common hybrid propulsion components over the next few years.

The **fortwo micro hybrid drive (mhd)** with stop/start functionality was introduced in Geneva; the engine is switched off below 8 km/h when the brake pedal is pressed and restarted when the brake pedal is released.

The fortwo mhd combines a 52 kW (71bhp) petrol engine, an automated manual transmission with slightly modified gear ratios, a belt-driven generator/starter and an AGM battery to reduce fuel consumption on the NEDC by about 8% – from 4.7 l/100 km to about 4.3 l/100 km. The corresponding reduction in average CO_2 emissions is 9 grams – to 103 g CO_2/km. Smart says that up to 19% fuel savings are possible in heavy slow traffic.

But they claim that the world's most economical production car is the direct-injection diesel engine variant, the **fortwo cdi.** The 3-cylinder, 33 kW/45 bhp engine consumes 3.3 l/100 km and emits 88 g CO_2 /km (NEDC). The new engine has common-rail direct injection that provides up to 1600 bar (previously 1350 bar) for fuel injection through new seven-hole injectors. Power and torque have improved by 10% and fuel consumption is reduced by 13%. Depending on the driving situation and engine load, EGR can be up to 60%. Like Mercedes-Benz CDI engines, a pilot injection precedes the main injection by a few milliseconds to ignite and preheat the cylinders – reducing combustion noise. A compact turbocharger (33 mm compressor wheel) in the exhaust manifold rotates up to 280,000 rpm and builds up a maximum charge pressure of 1200 mbar – at an engine speed as low as 1800 rpm. This results in torque of 85 Nm (75% of the maximum) being available at 1500 rpm.

SsangYong Motor's mild parallel (in-line) hybrid system was shown in an integrated component display (below) and combines a 30kW electric motor with a direct injection diesel engine and a 340V battery. And they made it very clear to the press that all of the components and controls (hardware and software) were developed domestically.

They reported results from a test vehicle during the 'initial development phase' that 'do not reflect driving strategies'. These results indicate that fuel efficiency has improved by around 25% compared to existing vehicles of the same class. In addition, they say that NOx is 10% lower while PM has decreased by 15%. They expect that their completed development program will yield a diesel hybrid car capable of at least 30% fuel efficiency improvement in addition to a 50% emissions benefit.

Though not directly relevant to DOE's electric or hybrid technology development activities, the newly announced **Nano** will strongly impact future vehicle designs (and the environment) in Asia.

The question being debated is whether or not this vehicle turns out to benefit the environment or not; by replacing more polluting vehicles or allowing someone that now uses public transport to drive their own vehicle and potentially producing more emissions overall. A question relevant to DOE (and industry in general) is whether an environmentally acceptable vehicle can be built this inexpensively. Most engines and emission control systems on typical US passenger cars cost more than the Nano, which is priced at 100,000 Rp (equivalent to €1700 or $2500).

There are no plans to offer the **Nano** for sale in Europe or the US, but we breathe the same air on a global basis and the exhaust emissions will be very important when these vehicles are produced in large numbers. And they are not likely efficient when loaded beyond recommended capacity (not unusual in some parts of the world).

Most readers are familiar with the original electric cars developed by Ford/Pivco. Since that time, TH!NK has relied on its own ingenuity and fundraising capability. Apparently GE is impressed and as part of its "efforts to enable global electrification of transportation" invested $4M in the company as well as $20M in A123 Systems. Concurrently, TH!NK signed a commercial supply agreement for A123 Li-ion batteries.

The **TH!NK city** has largely retained the appearance of the original EV, but the current (5th generation) vehicle offers battery choices that provide range up to 180 km per charge:

	Zebra Sodium	*A123 Li-ion*	*EnerDel Li-ion*
Capacity (kWh)	28	19	26
Range (km - UN Reg 101)	170	130	180
Nominal voltage (V)	370	370	370
Weight (kg)	245	260	260

To reduce battery worries, TH!NK offers a program called 'Mobility Pack', where they retain ownership and take full responsibility for the battery's performance. The customer pays a monthly 'mobility fee' ("typically €200" or about $300) which includes a full maintenance service agreement, carbon offset payments and, in some countries, all electricity and insurance.

In addition to the influx of investment, they introduced a full-size EV, the **TH!NK Ox** 5-seater which is based on a space frame with the batteries centrally located in two compartments in the lower frame. The press material shows an MPV version as a taxi (with easy entry and exit as well as a large trunk) and the coupé/sports variant as the higher performance model (with more battery capacity). A future variant with extended range up to 450 km is mentioned in the press materials. The specifications are summarized in the table on the next page.

TH!NK Ox Dimensions	
L x W x H	4120 x 1814 x 1650 mm (w/o mirrors)
Wheelbase	2775 mm
Track	1500 mm
CD	0.2 – 0.34
Frontal area	2.43 m²
Turning diameter	12 m
Vehicle Description	-Aluminum space frame -Front wheel drive -US and EU safety standards (5 star crash rating)
Curb/Gross Weight	1500/1850 kg

Battery	
Types (packaging)	Zebra Sodium, (high stack; 2 compartments) A123 or EnerDel Li-ion (low stack; lower/upper frame)
Power (nominal/peak)	60/100 kW
Weight	350 kg
Charging	100% in 12 h (230V/16A) 80% in < 1 h (off-board fast charger)
Motor	
Type	Water-cooled PM synchronous
Power (nominal/peak)	60/100 kW
Performance	
Acceleration (0-100km/h)	8.5 sec
Range (US06)	200 km

The **TH!NK Ox** uses the same materials as the **TH!NK *city***, an unpainted and recyclable exterior and a 95% recyclable interior (using ABS and PP). A solar panel in the roof is intended to keep the interior cool when the engine is off or run the sound system. The car has extraordinary connectivity; as summarized from the press material:

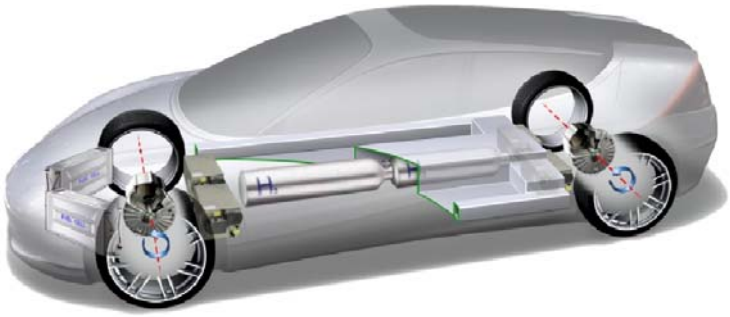
A key-less entry fob can set the desktop, music and display e-mails. Seats, mirrors and the steering wheel are adjusted. The 'DNA-key' gives charge status and can send messages for pre-heat or pre-cool options via GPRS.

The O^x has real time navigation, web, e-mail and open source interfaces, intelligent and sustainable driving and route calculations; connectivity may give drivers feedback on their driving behavior and guidance on optimizing energy. The navigation system will graphically display how far the car can go one-way, given the current battery charge level, how far the car can go round trip, and how much battery charge time is required to reach a specific destination. GPS and internet can provide available parking spaces and availability of charging stations. Battery performance is monitored and the system allows remote diagnostics at all times.

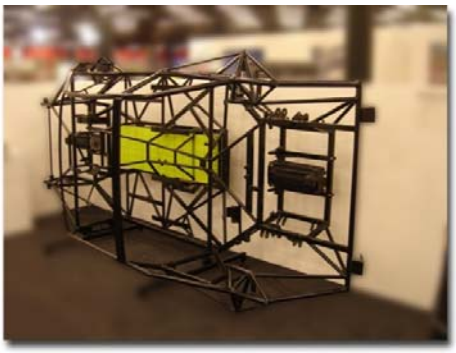
And in conjunction with selected utility partners, the system will enable "demand side management" by charging during off-peak times, or allowing the utility the option to modulate charging during peak hours.

It was recently announced that Volvo, Saab and TH!NK will participate with Test Site Sweden in a demonstration commencing this year, but the program has not been defined to date.

This Italian design studio outside Turin is not as well known as Guigiaro or Pininfarina, but it is led by Leonardo Fioravanti, who worked at the latter for over 20 years – on Ferrari designs including the Daytona, Dino, 512 Boxer, 288 GTO and 308 GTB. Based on the styling cues and (less subtle) Honda fuel cell stacks shown in the drawing in the press kit (below), the **Hidra** *appears to be* an idea developed for the Honda FCX Clarity or the Accord Tourer concepts. Irrespective of its origins, it has more design than technical significance; it is included because it was presented as a direct hydrogen fuel cell vehicle.



With the corporate tag line "Luxury runs fast", Fornasari is known for packaging Chevy V8s in bodies of their design and selling them as luxury off-road/desert racing vehicles, but they displayed the **R600 EV** concept in Geneva. After all, 'green racing' is en vogue and the Middle East is trying to save their resources as well.



Cutaway drawings of the **Quaranta HEV** concept were shown in the introduction of this report to characterize how new technology is wrapped in a sexy body to attract attention. As such, this vehicle has little technical significance, but it certainly turns heads and supports the latest trend toward sporty hybrids – from both marketing and performance perspectives. Guigiaro took a more practical approach than the fuel cell or all-electric drive – choosing to package Toyota's Hybrid Synergy Drive in a mid-engine location and adding an electric front axle for higher performance. Though the overall utility may be lacking for the typical family, it could carry three adults and a child.

The Brits departed substantially from their norm with the **LifeCar**, a fuel cell concept vehicle based on the Morgan Aero Eight. The fuel cell provided by QinetiQ (the defense contractor) provides power for cruising while ultra capacitors store regenerative energy and supply peak power.

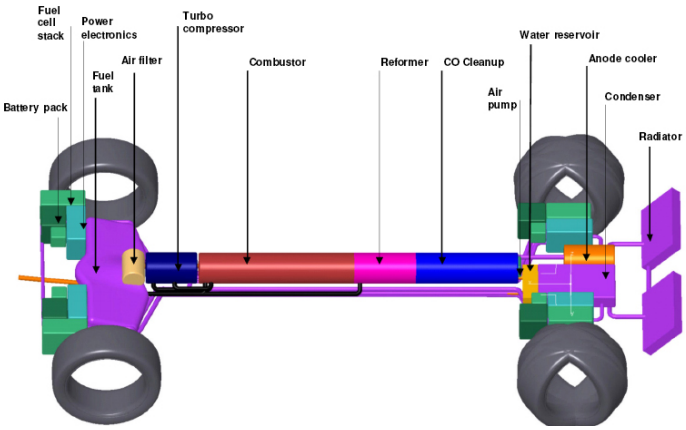
The 22 kW fuel cell (claimed to be 45% energy efficient overall) is built up from four 6 kW sub-stacks – reportedly for lower maintenance cost, automated assembly and broader market applications. Each sub-stack is made up of over 50 plates with etched structured grooves to control the flow of hydrogen, air and water within the stack. The grooves are described as mimicking growth patterns in nature to promote better flow and increased efficiencies. The stack materials appear to be standard, including graphite bi-polar plates, polymer membranes, carbon composite end plates and titanium.

Four separate (axle-mounted) electric motors provide 4WD and, in combination with the ultra capacitors rated at 1000 A discharge/charge capability, return up to 50% of the kinetic energy (with up to 0.7g retardation). The motor technology and system control were provided by the Oxford and Cranfield Universities, respectively.

Theoretically the vehicle can accelerate 0-62 mph in under 7 sec, it has a top speed of 80-85 mph, a range of 250 miles and consumes fuel equivalent to 150 mpg on petrol.

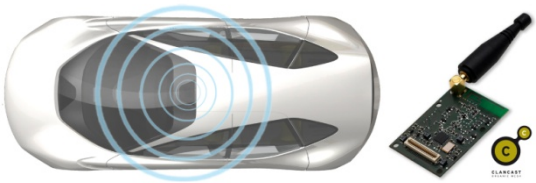
The **Sintesi** FCV relies on Nuvera technology for hydrogen generation, conversion and electric propulsion. The concept has a power module at each wheel, consisting of a 20 kW_{MAX} fuel cell, Li-ion battery and power electronics, combining to provide 110 kW intermittently and up to 180 kW transients.

Nuvera uses their Andromeda™ fuel cell and STAR™ hydrogen generator technologies. The so-called Quadrivium™ Drive is designed to combine the efficiency of fuel cells with fuel flexibility (i.e., conventional and bio-fuels) and high performance. Though optimized for high performance, fuel consumption on the NEDC combined is reportedly 5 l/100km (or 48 mpg) and CO_2 emissions are as low as78 g/km (likely predictions).



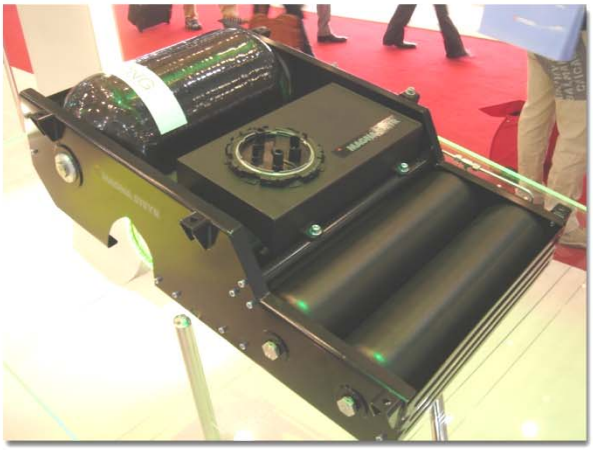
Concept	*Central H^2 generator; 4 power modules*
Fuel Cell Stack	*Andromeda PEM (one per wheel)*
Output (kW)	*80 kW continuous (20 kW_{MAX} x 4)*
Battery Pack	*Lithium Ion (one per wheel)*
Output (kW)	*80 kW_{MAX} (20 kW_{MAX} x 4)*
H2 Generator	*STAR multi-fuel processor*
Fuel Storage	*40 liter liquid tank*
Motor Type	*Brushless DC PM, integrated brake*
Max Power	*68 kW each*
Max Torque	*910 Nm each*
Transmission	*2.8:1 integrated gear set*

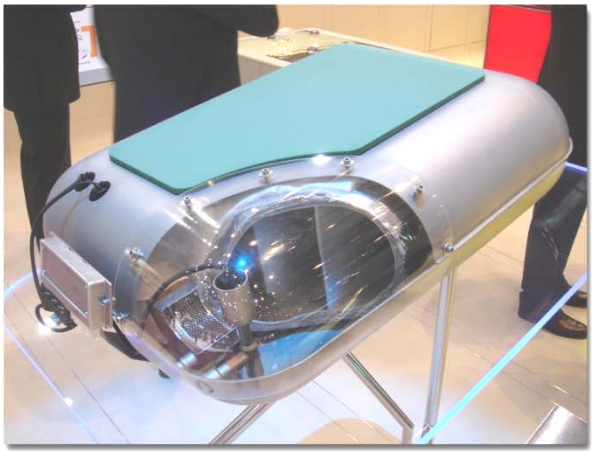
The **Sintesi** also has some interesting electronics (using Clancast® technology developed by Reicom) that provides vehicle-to-vehicle communication; completely decentralized data-transmission networks by means of stacks, communication protocols and a new generation of radio devices capable of reconfiguring themselves (even at the hardware level) in order to adjust to the surroundings.



A prize for the smallest niche market vehicle would go to the **SQuba** EV concept (just edging out Fornasari's off-road EV), which is designed to operate on road or as an open submarine. 'Nuff said – additional images and a video (with a James Bond theme, no less) are available.

As a large Tier 1 supplier and vehicle manufacturer for DaimlerChrysler (in Graz), Magna Steyr has developed notable systems engineering and integration capabilities. Of particular interest were their subsystems currently in series production for alternative fueled vehicles, including hydrogen and natural gas storage systems as well as Li-ion battery systems for heavy duty applications. They demonstrated their vehicle integration capabilities in a concept vehicle, the **MILA Alpin**, with several propulsion options including a CNG hybrid with Li-ion batteries (their BMS and packaging of A123 cells); a comparison of the options is summarized in the table.



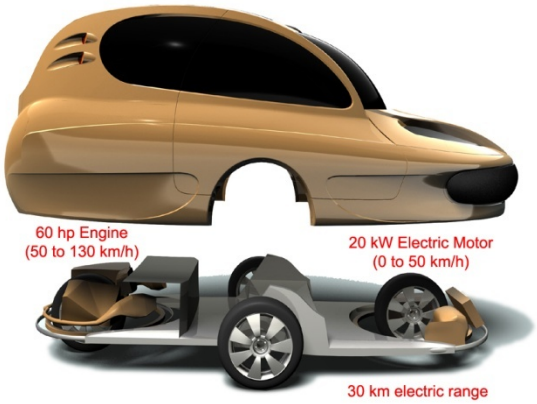


	Mila Alpin Pure (petrol)	**Mila Alpin CNG Hybrid**
Engine	3-cylinder, 1-liter, turbocharged	3-cylinder, 1-liter, turbocharged
Electric Motor		20 kW (27 hp)
Powertrain	AWD, 5-speed manual	AWD, automated 5-speed
Performance		
Acceleration (0-100 km/h)	< 11.5 sec	< 11.5 sec
Top Speed	> 140 km/h	> 140 km/h
Fuel Consumption		
Combined	5.8 l/100 km	5.45 l/100 km
CO_2	137 g/km	99 g/km

Assystem is a consulting company and this vehicle was developed to demonstrate its ability to provide solutions for its clients with respect to reduced fuel consumption and emissions (obviously not styling).

The 'Assystem City Car' has two autonomous propulsion units:
- an electric motor, with a 30 km range, propels the car up to 50 km/h
- a thermal engine takes over at 50 km/h and recharges the battery

The vehicle is obviously peculiar, but has the positive features of being a 'through-the-road' hybrid with autonomous operational capability and zero-turn capability (yes, like commercial mowers) due to the ability to revolve around the middle axle.



This company is trying to attract investors to the **X80**, a mild hybrid designed to meet the 80g CO_2/km standard. It is constructed around a 2-cylinder, 750 cc engine and reportedly consumes only 3.5 l/100 km (70 mpg).

MCE-5 Development claims their variable compression engine reduces fuel consumption 30-35% compared to standard SI engines and they will have vehicles to test by the end of this year. In addition to efficiency improvements, they say the 1.5 liter MCE-5 engine has the same power as a 3-liter V-6.

The first prototypes will be installed in Peugeot 407s by the end of this year for testing. Dynamometer development is underway and improvements will be incorporated by the end of 2009, targeting a specific design for pre-production by 2013. They estimate that mass production could begin in 2015.