

HydroGen4 – The First Year of Operation in Europe

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HydroGen4 – The First Year of Operation in Europe

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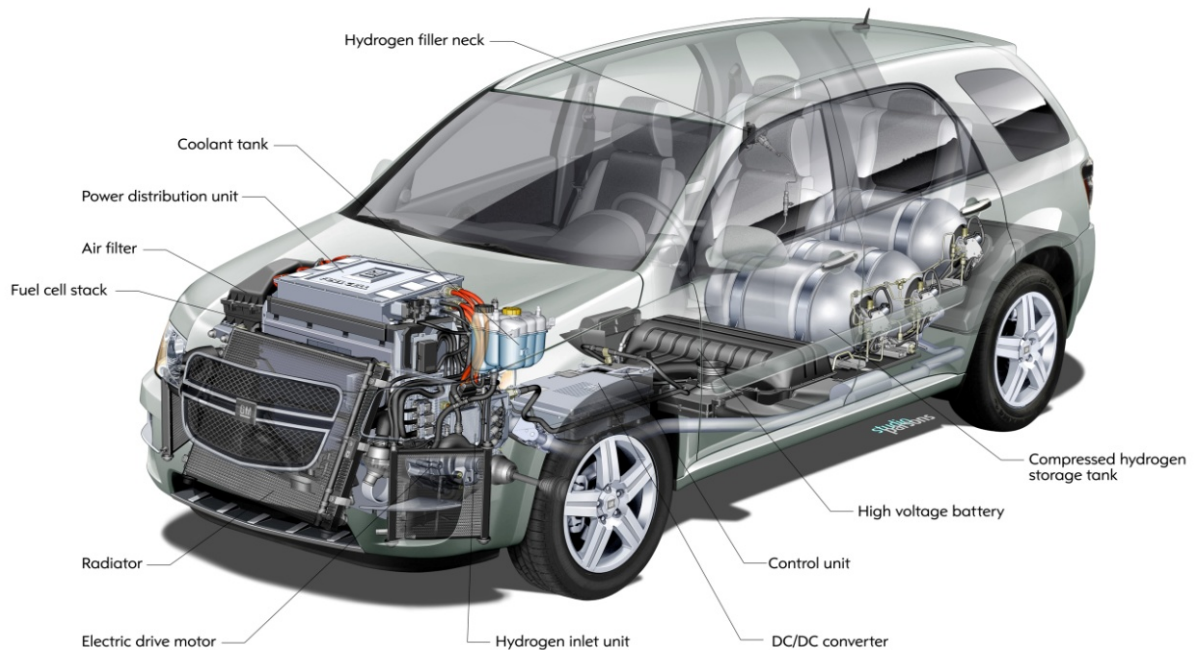


Figure 1: Opel HydroGen4 fuel cell electric vehicle.

1 The Opel HydroGen4

HydroGen4 is Opel's fourth generation fuel cell electric vehicle (FCEV) (Figure 1). It features improvements in everyday usability, performance and durability compared to its predecessor. The fuel cell stack comprises 440 single cells and provides the power for the 73 kW synchronous electric motor, delivering zero to 100 km/h acceleration in around 12 seconds (Table 1). Opel has opted for fueling with compressed hydrogen, thus avoiding the boil-off phenomenon occurring when hydrogen in cryogenic liquid form is used. HydroGen4's three carbon-fiber composite tanks hold 4.2 kg of hydrogen at a pressure of 700 bar, sufficient for an operating range of 320 kilometers. The vehicle is fitted with a 1.8 kWh high-power buffer battery to cover peak electrical loads during acceleration and to store energy from its regenerative braking system in order to enhance overall efficiency. The fuel cell system can start and run at sub-zero temperatures down to -25°C , a considerable advance over its predecessor and an important benefit for everyday usability. The HydroGen4 was designed to be as safe as conventional vehicles resulting in unique hydrogen safety features in each of its major systems.

Table 1: Opel HydroGen4, technical data.

General:	
Vehicle type:	5-door, front-wheel-drive vehicle
Seating capacity:	4
Dimensions:	
Length/Width/Height:	4796/1814/1760 mm
Wheelbase:	2858 mm
Cargo volume:	906 liters
Curb weight:	2010 kg
Payload:	340 kg
Fuel storage system:	Carbon fiber composite (3 vessels)
Service pressure:	700 bar
Storage capacity:	4.2 kg
Fuel cell system:	Polymer Electrolyte Membrane (PEM)
Number of cells:	440
Power:	93 kW
Battery system:	NiMH high-power battery; regenerative braking
Power:	35 kW
Energy content:	1.8 kWh
Electric traction system:	3-phase synchronous electric motor, with integrated power electronics and planetary gear
Power:	73 kW continuous, 94 kW maximum
Torque:	320 Nm
Performance:	
Top speed:	160 km/h
Acceleration 0-100 km/h	12 sec
Operating range:	320 km
Operating temperature:	-25°C to +45°C
Safety:	Driver and passenger frontal air bags and roof rail side-impact air bags; ABS, traction control, StabiliTrak (ESP)

2 The HydroGen4 Fleet in Berlin

In November 2008, ten HydroGen4 were deployed in Berlin as part of the Clean Energy Partnership (CEP) demonstration project. The CEP is *the* European lighthouse project aiming to prove the everyday suitability of FCEV technology and hydrogen as a fuel for transportation [1] [2]. It is funded by the German Ministry for Transport, Building and Urban Development (BMVBS). Two vehicles out of the fleet are used by Opel, while the others are operated by business partners (B2B) since early 2009 (Figure 2). In the following, the first year of this customer operation is being reviewed, including vehicle operation data, customers' feedback as well as learnings for the next generation of FCEVs.

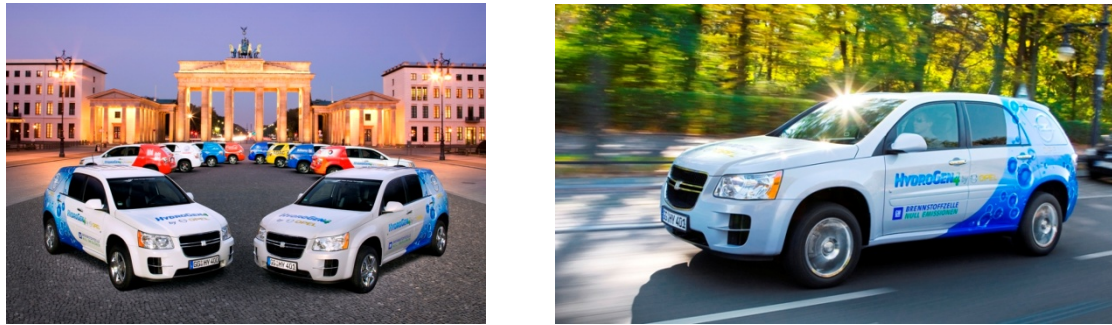


Figure 2: European HydroGen4 fleet (left), HydroGen4 running on Berlin roads (right).

ADAC, Allianz, Axel Springer AG, Coca-Cola, Hilton, Linde, Schindler, Total, and Veolia were the first business partners to test drive a HydroGen4 over a period of several months. The usage and driving patterns of these companies are as different as their businesses. While some of the partners operate the HydroGen4 in the same way as all the other cars of their fleet, other companies use the vehicle in a unique way, e.g. providing shuttle services for VIP guests. The toughest requirements, however, can be associated with the usage pattern of the HydroGen4 operated by the ADAC providing regular road assistance services. In order to achieve this, the HydroGen4 has been modified in the same way as ordinary ADAC cars, including the installation of yellow flash lights as well as the ADAC driver information display and tool box system. In addition, the fuel cell system of the car has been adjusted to enable recharging of the on-board starter batteries used by the ADAC driver to offer jump start assistance for stranded cars.

3 Vehicle Operation Data and Customer Feedback

Although ADAC operates the vehicle under toughest conditions, it did show an outstanding reliability during the first year of operation with just two days out of service due to unplanned maintenance of the propulsion system. But also the other nine HydroGen4 cars performed well with altogether only 17 days of unplanned service. Since HydroGen4 was the first FCEV within the CEP to offer full cold start capability, the vehicles were operable throughout two hard winters. From first customer deployment in early 2009 until the end of February 2010, the entire fleet achieved an operation time of over 3,500 hours, corresponding to a driven distance of more than 83,000 kilometers. The distribution of operating hours and associated distances driven per vehicle are shown in Figure 3 (left) and Figure 4 (right). The velocity distribution of the whole fleet (Figure 3, right) clearly indicates that the vehicles were mostly operated in urban traffic with about 37% share of idle mode alone. The average speed ranges from 14 km/h (ADAC) to 33 km/h (Axel Springer AG) and is an indicator for the very different driving profiles of the B2B partners. These differences are important to gain as much learnings as possible from the demonstration project.

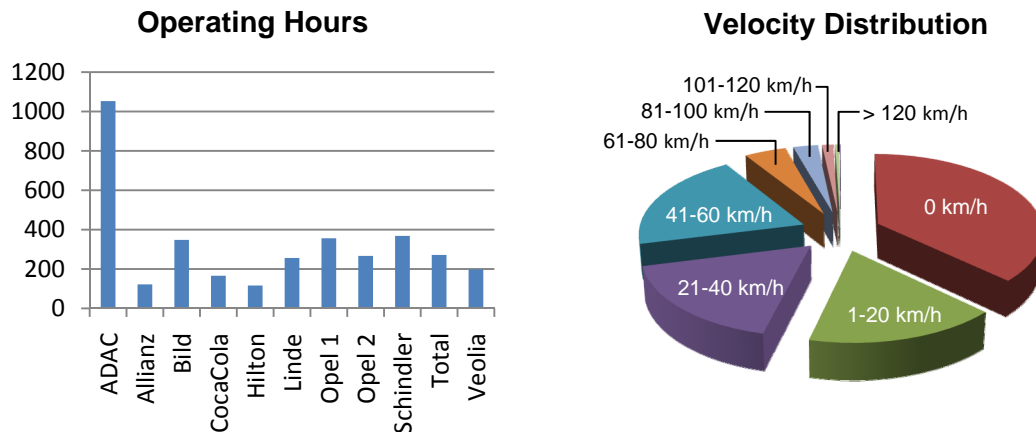


Figure 3: Operating hours since deployment per vehicle (left) and fleet average of velocity distribution (right).

So far, all the B2B customers provided a very positive feedback on their daily experience of driving and refueling the HydroGen4. In particular, they liked very much the acceleration behavior, as well as the low noise level inside and outside the car. Criticism only concerned conventional technology (e.g. missing parking distance control), not the fuel cell system.

4 Hydrogen Refueling Data and Customer Feedback

During the first year of operating the HydroGen4 vehicles in Berlin, three hydrogen fueling stations were principally available to our B2B customers [3]. The refueling process was considered as being rather easy and convenient. However, the drivers were not satisfied with the actual availability of the fueling stations. Since early 2009, our drivers have reported a total of 173 days when it was not possible for them to refuel at one of the hydrogen stations. In combination with the large distance between the stations, this caused severe inconveniences for the drivers in case there was not sufficient hydrogen left in the tank to reach another station. Hence, an effective information system is planned to be installed by the infrastructure providers of the CEP to inform the drivers when a station is out of service and when it is in operation again. In spite of the mentioned problems, a total of 778 refuelings was achieved since deployment. Figure 4 (left) shows the distribution of the number of refuelings per vehicle. Currently (April 2010), only one of the hydrogen stations in Berlin allows for fast refueling within 3 minutes at 700 bar, with hydrogen pre-cooled at -40°C. However, in order to provide an optimized refueling process with respect to refueling time and filling level at all stations, those to be built in the future should be designed according to SAE J2601.

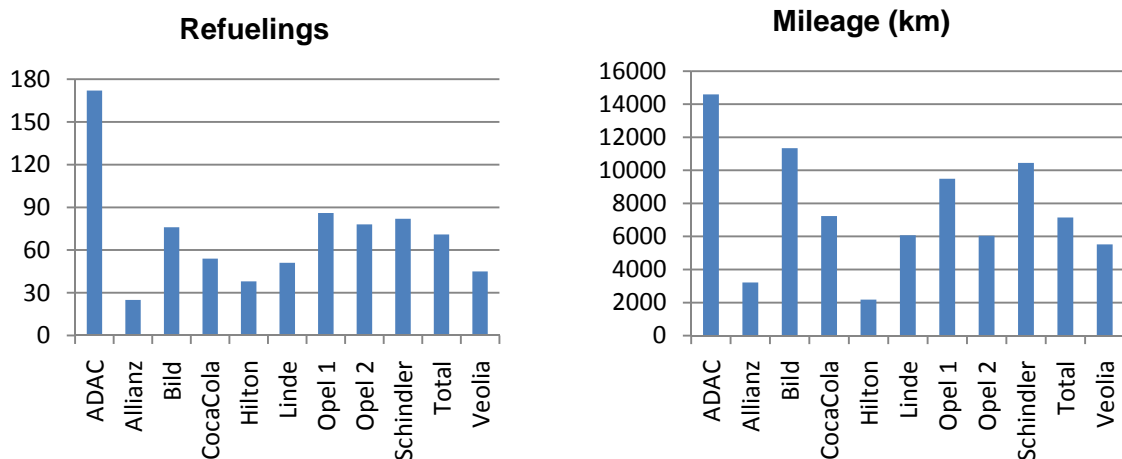


Figure 4: Number of refuelings since deployment (left) and driven kilometers since deployment (right) per vehicle.

5 Learnings and Next Steps

During the first year of operation, we had a number of learnings from the daily customer operation under “real world” conditions. In Winter 2008/09, the cars performed without any problems even though ambient temperatures in Berlin stayed very low for a long time, reaching levels down to -20°C. This winter (2009/10), however, we were facing a freezing issue with a valve on the cathode side of the fuel cell system at these very low sub-freezing temperatures. The identified reason was that after implementation of a software update (in summer 2009), intruding moisture had caused the valve to freeze and impeded a system start. After several tries, however, the valve usually could be actuated; hence this issue was characterized as “customer inconvenience” only. The problem was successfully solved by the subsequent software update. Also, we were challenged with electrical contact difficulties concerning the high-voltage battery. These, however, could be sorted out by rewiring.

All technical issues as well as the customer feedback and the vehicle data were directly fed into the ongoing fuel cell propulsion system development, leading to reduced hydrogen consumption, as well as increased performance, reliability and durability. Thus, all the findings from the CEP project which is part of our global demonstration activities were of significant importance for further development and reinforced our confidence for fuel cell technology to be ready for volume production in the foreseeable future. The next step on this pathway towards commercialization of FCEVs will be our next generation fuel cell system providing standard automotive durability at reduced cost (Figure 5). Due to further improved system integration it will be half the weight and half the volume compared to the current generation. At the same time, technical advancements will reduce fuel cell degradation and thus enhance durability to reach levels that customers expect from a car. Due to a new electrode design with considerably lower platinum content and the use of knowledge from volume production of conventional propulsion technology, system cost will decrease significantly as well.

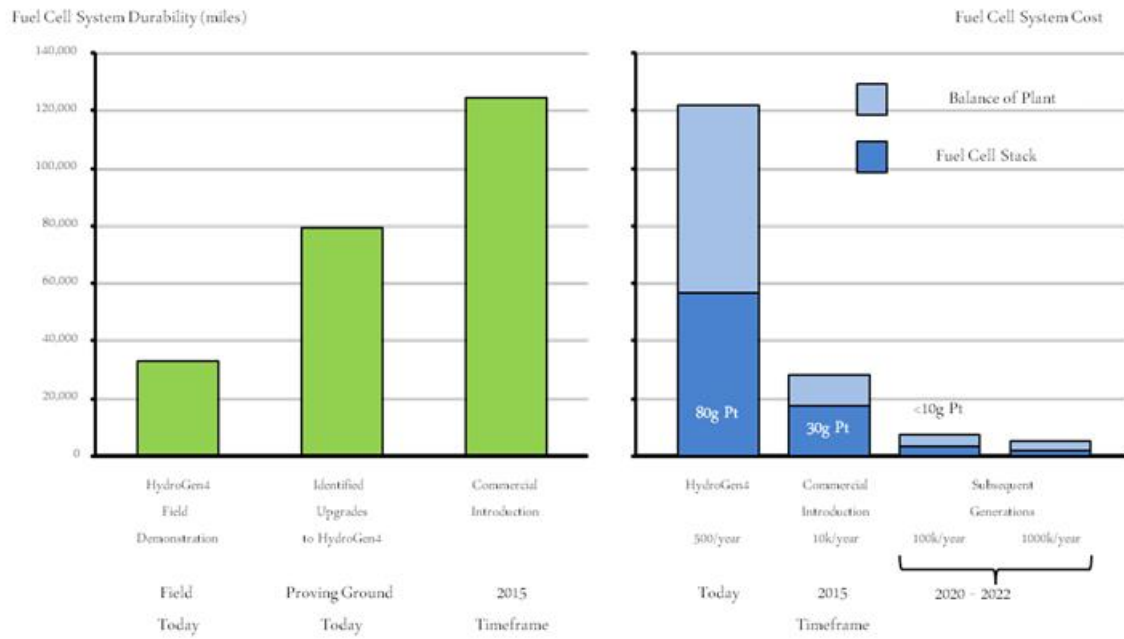


Figure 5: Fuel cell system durability progression and cost reduction.

References

- [1] <http://www.cleanenergypartnership.de/>
- [2] http://www.cleanenergypartnership.de/fileadmin/pdf/CEP_Report_2002-2007_en.pdf
- [3] <http://www.cleanenergypartnership.de/index.php?id=14&L=1>