



Energy research Centre of the Netherlands

Trends Hydrogen Cars

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Presented at the IEA HIA Task 18 meeting, Oslo, Norway on 6-8 May 2009

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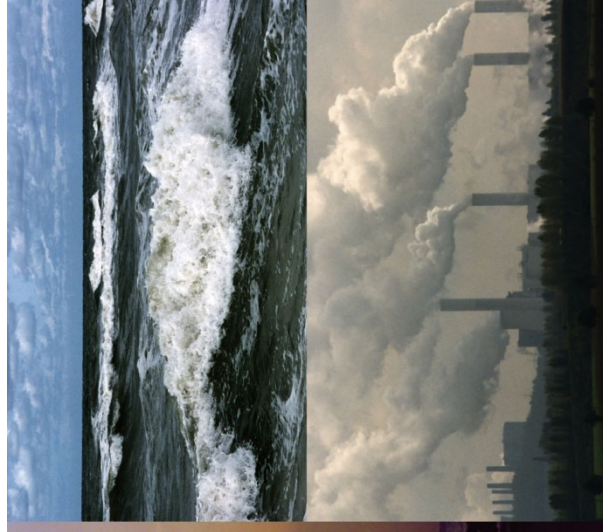
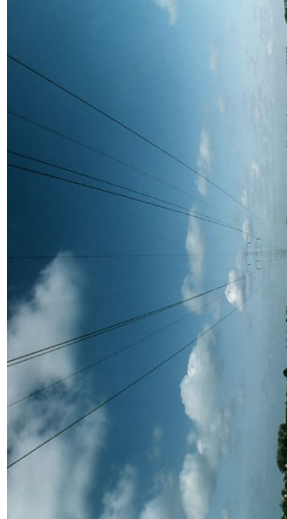
ECN

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Sources

- www.H2mobility.org
- Roads2HyCom, Feed-back and Feed-Forward from WP5 and Demonstration Activities, Deliverable 6.1-2, July 2007
- NREL, Learning Demonstration, Progress Report – Spring 2008, Technical report NREL/TP-560-42986, April 2008
- I. Bunzeck, Market perspectives of H₂ vehicles, Analysis of current status and requirements, March 2009
- 2008 Light Duty Vehicle survey, Fuel Cells Today
- Other ... presentations

Trends

- Gradual improvement of performance:
 - Fuel usage
 - Range (result of improvement efficiency and increase pressure)
 - Reliability – decrease in failure rates
- From prototypes ... to small series
- From hand made ... to semi automated production
- Car manufacturers start (commercial) leasing out cars
- Hydrogen gradually becomes part of regulations (Type approval H₂ vehicles)

Current car testing and planned market introduction

- Main players:
 - Honda
 - Daimler
 - GM - Chevrolet/Opel
 - Ford (FCV and ICE)
 - Hyundai-Kia
 - Toyota
 - Nissan
 - Volkswagen (GE, China)
 - BMW (ICE-bifuel)
 - Mazda (ICE-bifuel)

Segment	Currently testing		Planned market introduction
	Europe	US	
A-Micro			
B-Sub compact			
C-Compact	Daimler F-cell		2009, small series 2014/15, 100,000 units
D-Mid-size		Honda Clarity	Not known
		FCX	FCX
		Nissan	2014
E-Full size	Ford Focus	Ford Focus	Not known
			2012
F-Luxury			
MPV	Mazda RE	Premacy	Not known
SUV	GM HydroGen 4	GM Equinox	Not known
		Toyota FCVH	2015

Achievements and projected performances

- Number of cars
 - More than 200 FCV on public roads (July 2007)
 - About 500 hydrogen cars in 2009 (based on 10x Toyota Prius is 2% of total H₂ cars on the road; Statoil presentation joint IEA HIA 18/23 meeting, 6 May 2009))
 - Order of magnitude production light duty vehicles 2007 was 300 units
 - OOM 2008 close to 2008 (2008 Light duty vehicle survey; Fuel Cell Today)

- Accumulated mileage:
 - US validation and demonstration project: >1,750,000 km (about 60-70 cars)
 - Daimler A-class F-Cell (>60 cars): >1,500,000 km by 2007 (Daimler FCV experience >4 mln km accumulated mileage, EVS24, Stavanger, 2009)
 - Canada (5 Ford Focus): 270,000 km
 - CEP (phase I, about 20-25 cars): 374,000 km
 - JHFC (about 60 cars)
 - Korea, China, ...

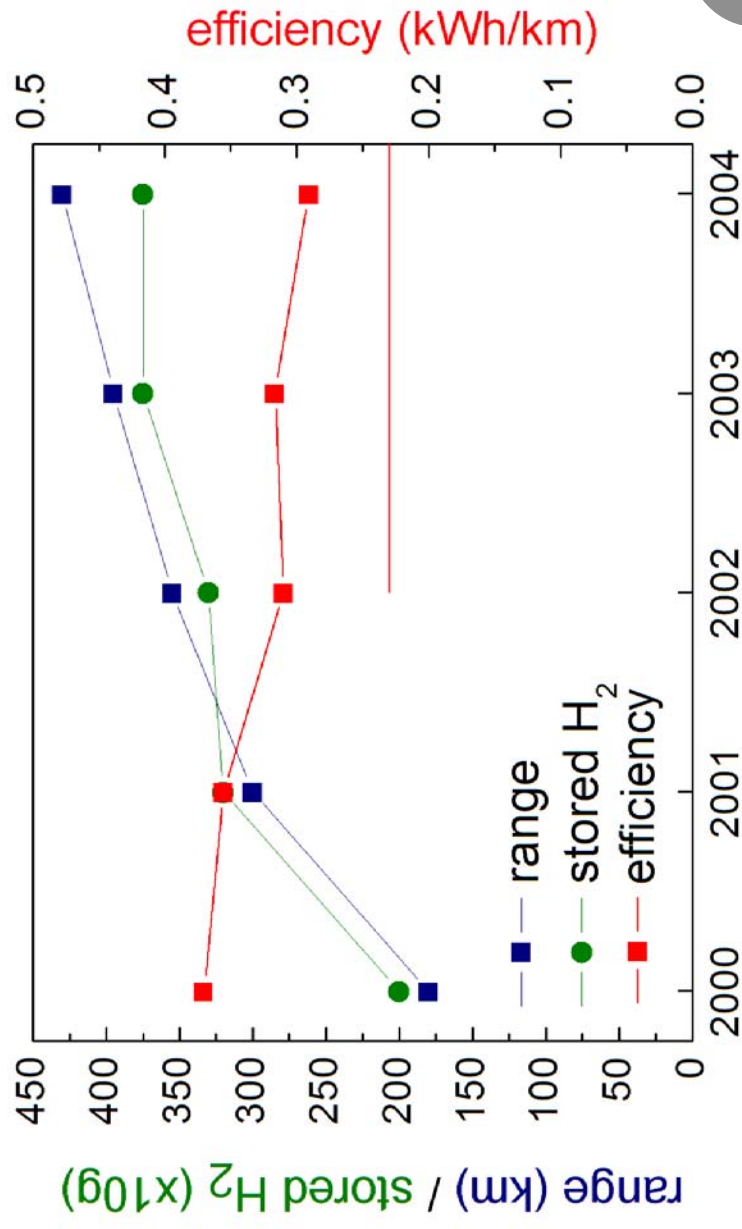
Achievements and projected performances

- Fuel usage:
 - Daimler A-class F-Cell: 4.8 l DE/100 km calculated NEDC
3.6 l DE/100 km calculated (0.36 kWh/km)
3.8 - 6.0 l DE/100 km in practice
 - US project: 3.7 - 4.9 l DE/100 km calculated
4.6 - 6.9 l DE/100 km in practice

- Range
 - 190 - 350 km calculated (4 car models)
130 - 260 km from operation data

- Reliability:
 - January 2007 first F-Cell >100,000 km
 - January 2007 first F-Cell 2000 hr without significant performance loss
 - First car accumulated >1000 hr in real world operation without repair
 - Average projected time to a 10% voltage degradation is about 1,200 hr
 - Daimler Citaro FC-Bus: lifetime FC-system up to 4000 hr average (EVS24, 2009)

Fuel cell vehicle development: from prototypes ...



Honda FCX



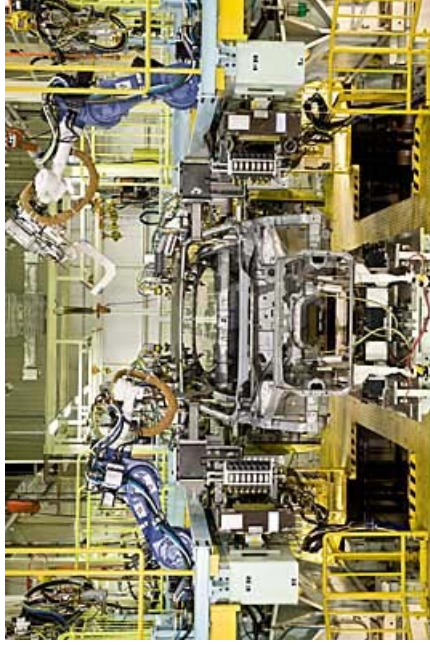
... to small series



Vehicle	Honda	FCX Clarity
Status	2008	Small Series
Propulsion	Fuel Cell Battery Electric Motor	100 kW (57 liter, 67 kg) Li-ion battery 100 kW (torque 256 Nm)
Storage	CGH ₂	35 MPa (171 l)
Performance	Range Top speed	~430 km 160 km/h (limited)

- 50% increase of output density per volume (67% by mass) compared to previous FCX
- 20% increase of fuel economy (indicative fuel use 26-30 km/l g.e., latter eqv to 72 mi/kg H₂)
- Improved low temperature start-up capability: at -30°C
- Begin of limited retail marketing in summer 2008 in Southern California
- For three years lease term: \$600 per month including maintenance and insurance

Honda starts FCX Clarity production (16/6/2008)



FCX Clarity Vehicle Assembly at Honda New Model Center 2008.06.16



FCX Clarity Vehicle Assembly at Honda New Model Center 2008.06.16



Fuel Cell Stack Manufacturing at Honda Engineering 2008.06.16



Fuel Cell Stack Manufacturing at Honda Engineering 2008.06.16



Fuel Cell Stack Manufacturing at Honda Engineering 2008.06.16

Honda FCX Clarity

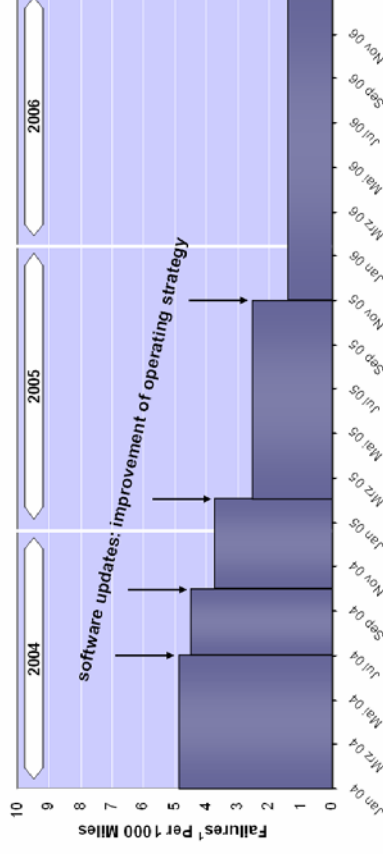


Daimler A-class FCV



Vehicle	Daimler	Mercedes A-Class
Status	Since 2002	> 60 vehicles in operation
Propulsion	Fuel Cell	85 kW
	Battery Electric Motor	65 kW
Storage	CGH ₂	35 MPa (350 bar)
Performance	Range	160 km
	Top speed	145 km/h

- 2007 accumulated mileage >1.5 mln km
- Accumulated operation >42,000 hr
- January 2007 first F-Cell >100,000 km and 2000 h without significant performance loss
- Overall availability >85%



Daimler is increasing the pressure (21/7/2008)




Vehicle	Daimler	Mercedes A-Class
Status	Since 2002	> 60 vehicles in operation
Propulsion	Fuel Cell	85 kW
	Battery Electric Motor	65 kW
Storage	CGH ₂	70 MPa (700 bar)
Performance	Range	270 km (from 160 km)
	Top speed	145 km/h

- By May 2009 accumulated range Daimler FCVs > 4 mln km (EVS24, Stavanger)
- Extended operating range for A-class FCV
- First A-class FCV “plus” with 70 MPa H₂ storage in everyday operation

Daimler B-class announced for 2010 (25/4/2008)



Vehicle	Daimler	Mercedes B-Class
Status	2010	Small series
Propulsion	Fuel Cell	80 kW
	Battery Electric Motor	Li-ion (1.4 kWh, ~30 kW) 100 kW
Storage	CGH ₂	70 MPa (700 bar)
Performance	Range	~400 km
	Top speed	180 km/h

- Stack size reduction by 40%
- Stack life anticipated >2000 hr
- Cold tests in Sweden (cold start capability -25°C)
- Fuel consumption target 2.9 l/100 km diesel eqv. 
- Market introduction 2015 – 2020?



General Motors Chevrolet Equinox



Vehicle	GM	Chevrolet Equinox
Status	2007	100 vehicles
Propulsion	Fuel Cell Battery Electric Motor	115 kW 35 kW NiMH
Storage	CGH ₂	70 MPa (700 bar, 4.5 kg)
Performance	Range Top speed Acceleration	320 km 145 km/h 0 – 100 km/h in 12 s

- Field test 100 vehicle in Los Angeles, Washington D.C. and New York
- Target: 1000 vehicles by 2010 and 100,000 vehicles by 2015

HydroGen4 hits the road in Europe (December 2009)



Vehicle	GM	HydroGen4
Status	2009	>100 test cars
Propulsion	ICE	? kW
	Battery Electric Motor	NiMH 1.8 kWh, 35 kW 73 kW
Storage	CGH ₂	70 MPa (4.2 kg)
Performance	Range	320 km
	Top speed	160 km/h

- European equivalent of Chevrolet Equinox

Ford FCV fleet exceeds expectations (5/9/2008)



Vehicle	Ford	Ford Focus
Status	2002	30 vehicles
Propulsion	Fuel Cell	85 kW
	Battery Electric Motor	68 kW
Storage		35 MPa (178 l, 4.5 kg H ₂)
Performance	Range	320 km
	Top speed	

- Fleet exceeded accumulated 1.4 million km without significant maintenance issues
- Vehicles already lasted 3x longer than targeted with virtually no degradation in performance
- Test program extended with 24 months,... but Ford recently announced to stop the program

Toyota starts leasing of its advanced FCHV (9/9/2008)



Vehicle	Toyota	Toyota Highlander
Status	2008	From demo to field test
Propulsion	Fuel Cell Battery Electric Motor	90 kW Hybrid with NiMH battery 80 kW (Torque 260 Nm)
Storage	CGH ₂	70 MPa (700 bar, 156 l)
Performance	Range Top speed	580 km (real test) 155 km/h

- Advanced FCHV 25% more fuel efficient than earlier version
- 70 MPa hydrogen storage instead of previous 35 MPa
- Long distance road test from Osaka to Tokyo (580 km) on a single fueling of hydrogen
- Fuel efficiency for 1880 kg SUV is 4.2 l/100 km (23.7 km/l g.e.)
- FCHV to cost 5,500 €/month for 30 months

Mazda begins commercial leasing of another H₂ model (30/4/2009)



Vehicle	Mazda	Premacy H ₂ RE Hybrid
Status	2009	Small series
Propulsion	ICE (Rotary) Battery Electric Motor	110 kW Hybrid with Li-ion battery 30 kW
Storage	CGH ₂	35 MPa (110 l, 2.4 kg)
Performance	Range Top speed	200 km ~200 km/h

- Hybrid system increases max. output by 40% to 110 kW compared to RX-8 Hydrogen RE
- Dual-Fuel: the Premacy Hydrogen RE Hybrid can also run on gasoline (60 liter petrol tank onboard, ICE power on petrol 154 kW)
- First units will be delivered to local government authorities and energy-related companies in the course of 2009

... and there is much more

- Hyundai with new platform concept towards commercialisation (23/4/2008)

- Purpose built platform
- Third generation fuel cell stack



- Nissan doubles power density of next generation fuel cell stack (25/8/2008)

- 35% cost reduction achieved
- Platinum requirement halved
- Power output increased 1.4 times from 90 to 130 kW
- Stack size reduced by 25% from 90 l tot 68 l




- Type approvals for hydrogen vehicles approved (16/9/2008)

- European Parliament adopts hydrogen vehicle type approval

EU publishes new regulation (4/02/2009): Type approval of Hydrogen-powered motor vehicles

- <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:035:0032:0046:EN:PDF>
- Regulation (EC) no. 79/2009

L 35/32  Official Journal of the European Union 4.2.2009

REGULATION (EC) No 79/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 14 January 2009
on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission,

After consulting the Economic and Social Committee (1),

Acting in accordance with the procedure laid down in Article 251 of the Treaty (2),

Whereas

(1) The internal market can raise an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured. To that end, a comprehensive Community type-approval system for motor vehicles is in place. The technical requirements for the type-approval of motor vehicles should be harmonised to avoid the introduction of different requirements in different Member States and to ensure the proper functioning of the internal market with a view to attaining a high level of environmental protection and public safety.

(2) This Regulation is a separate regulation for the purposes of the Community type-approval procedure provided for by Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles, their components and of systems, components and separate technical units intended for such vehicles (framework Directive) (3). Therefore, Annexes IV, VI and XI to that Directive should be amended accordingly.

(1) Opinion delivered on 9 July 2008.
(2) Council Decision of 18 December 2006 (not published in the Official Journal) and Council Decision of 18 December 2008.
(3) OJ L 263, 9.10.2007, p. 1.

(4) OJ L 184, 17.7.1999, p. 21.

Nissan prototypes SOFC for automobiles (30/4/2009)

- Plans to implement SOFC in a hybrid powertrain
- So far SOFC have not been the fuel cell technology of choice for vehicle powertrains, because of the high operating temperature
- It takes 15 minutes to start up the SOFC
- A 1000 kg vehicle that has a motor output of several tens of kW would be charged with a 4 kW SOFC

- Prototype with a 5-cell stack and a gross output of 54 W using hydrogen as fuel
- Output translates to an output density of 0.37 kW/l
- The prototype was strong enough to endure the temperature change from room temperature to 600 °C in 60 min and a heavy load operation of 1 kW/l for 30 minutes