Hydrogen & Fuel Cell Vehicles

June 2018

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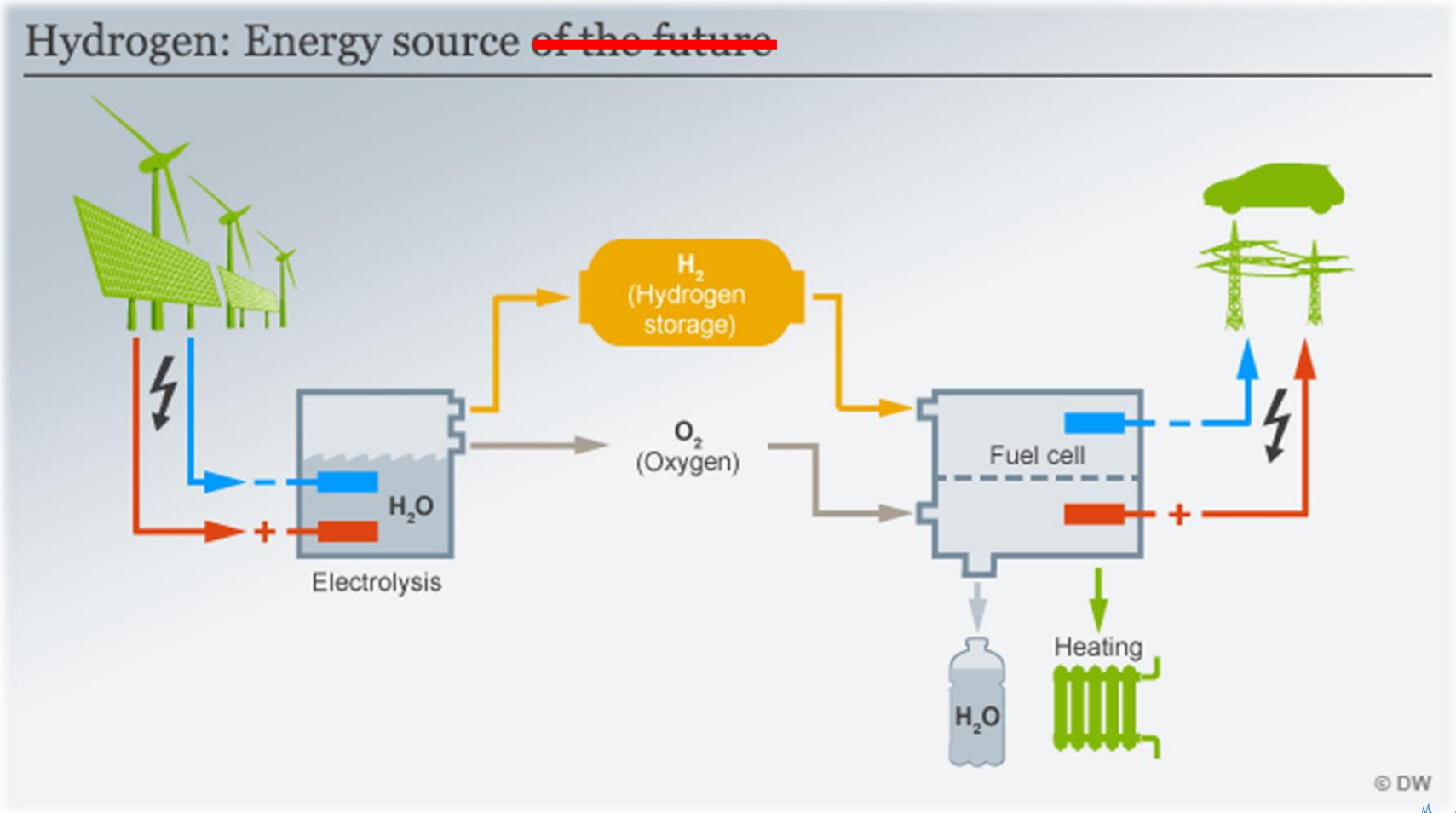
Hydrogen Cycle

"World oil refineries and chemical plants today have a demand for hydrogen which exceeds the US nuclear output in thermal terms"
(Wold Nuclear Association)



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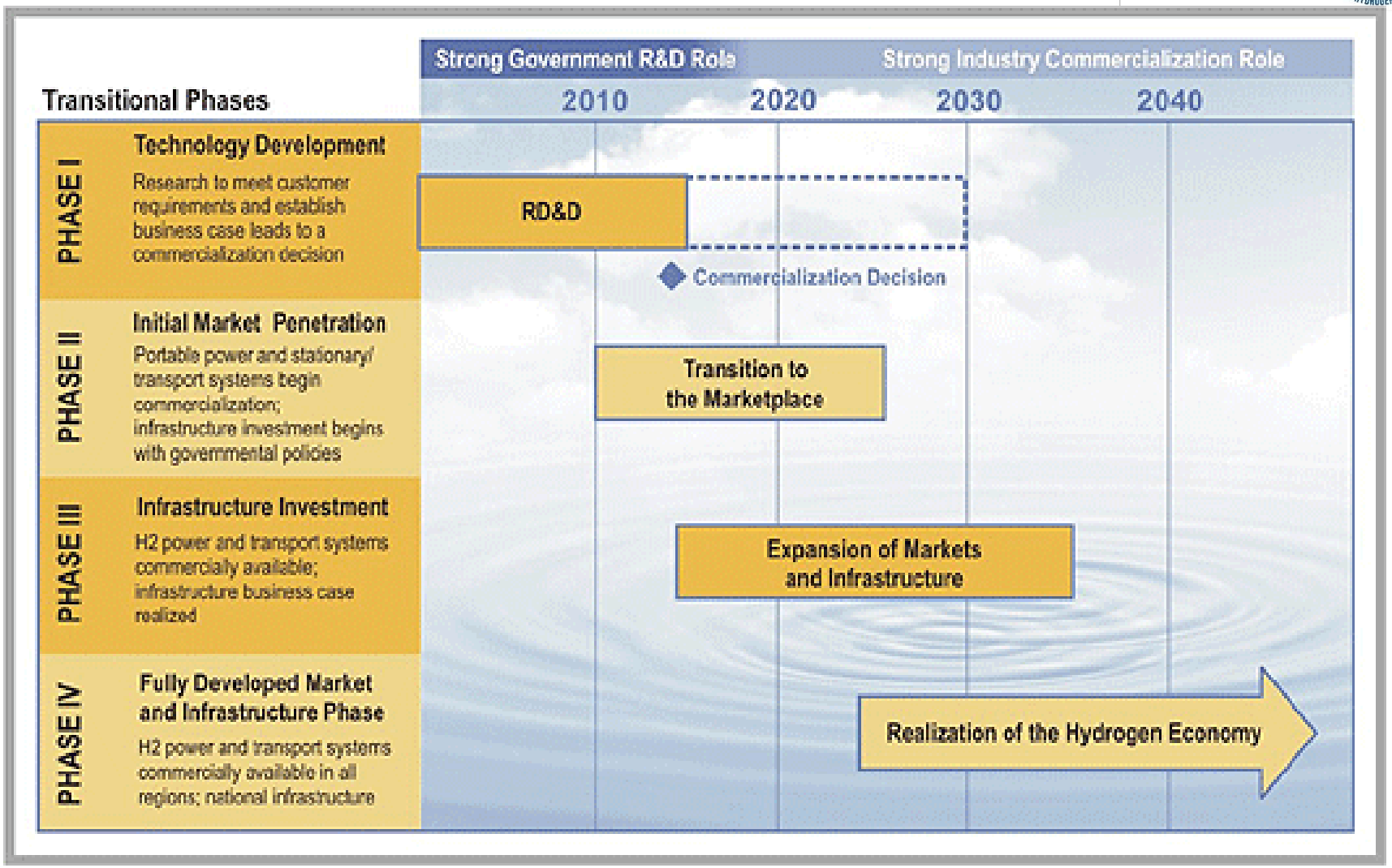
Hydrogen Economy



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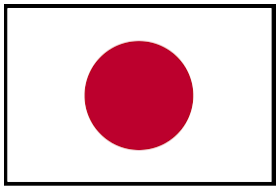
FCEV Global Market

'Do hydrogen cars have a future?' *(AutoExpress 2018)*
FCEVs = 10s
H2 refuelling stations <10

Germany to have 400 refuelling stations by 2023

FCEBs = 100s?
H2 refuelling Stations 10s?

FCEVs on the road 6th June 2018 = 4,819
FCEBs = 21
H2 refuelling stations = 35 (100 by 2020)
(Caifornia Fuel cell partnership)



'The government set a target of fuel cell cars in Japan to 40,000 by March 2021'. *(engadget)* … 'to incorporate hydrogen stations into Japan's existing 31,000 gas stations'. *(asia Nikkei)*

Producing 10,000s of FCEVs for the rest of the World, Seoul plans to supply about 15,000 hydrogen vehicles and 310 charging stations nationwide by 2022 *(Electrive)*

PLUG POWER

GOLD MEDAL in PASSENGER VEHICLES

Hyundai Motors announced NEXO, their next gen Fuel Cell Electric Vehicle (FCEV) SUV, at CES in January 2018. They recently drove 190km from Seoul to PyeongChang with five self-driven FCEVs[1].

GOLD MEDAL in MASS TRANSIT

Hyundai Motors provided clean hydrogen fuel cell electric buses to transport Olympic athletes and visitors around PyeongChang during the games[2].

GOLD MEDAL in POWER PLANTS

- FuelCell Energy, working with POSCO, installed the world's largest fuel cell power plant (59MW), which has been operating since 2014 in Hwasung City[3].
- Bloom Energy has been awarded a contract to install 8.35MW for Korea South-East Power Co. at their Bundang Power Plant. It will be the first solid oxide fuel cell plant installed in South Korea and will operate using natural gas[4].

GOLD MEDAL in ENERGY TRANSFORMATION

The Hydrogen Council's latest study - *Hydrogen, scaling up* - identified Korea as leading world-wide adoption of hydrogen-powered fuel cell vehicles, alongside Germany, Japan and California. By 2030, hydrogen-powered passenger cars could make up close to 3% of new vehicle sales - meaning in Korea almost every 12th car sold could be fueled by hydrogen[6]. The Korean government has also announced ambitious plans to reduce overall CO2 output by 37% until 2030 compared to business as usual, a goal which goes hand in hand with the announcement of increased investments in hydrogen refueling stations – with a target of 310 by 2022[7].

GOLD MEDAL in POLICY

In South Korea, all power companies with more than 500MW of generation capacity are obligated to produce a certain percentage of electricity by renewable and new energy sources, including fuel cells, under the Renewable Portfolio Standard (RPS) system. Korea's deep subsidies are shaping the opportunity for large power generation in the hydrogen economy there[5].

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Microcab company overview

UK SME, founded 2004

- Designing fuel cell vehicles since 2000 (in previous company)
- Coventry University 20% shareholder
- 6-7 employees
- Supported by Coventry University team (up to 6 people)
- Annual turnover approx. £250,000 (2017)

Mission statement

The Microcab vision foresees a ‘New Mobility’ where alternate ownership models allow vehicle platforms to be designed within the paradigm of a continuous economy. This shift will bring together new business models, lean weight design, zero emission powertrains, connected and autonomous control architecture, coming together to give flexible, clean and integrated mobility with the user at its centre.

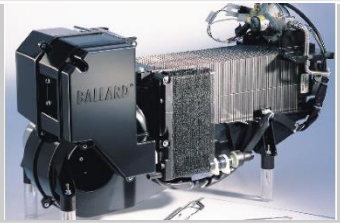
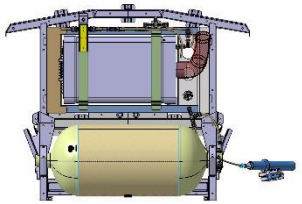
R&D: UK and EU grants

Portfolio of grant funded programs from 2001: Blue = Running

- *2001 (DTI) SMART award £65,000: fuel cell chassis on H3 EV*
- *2004 DTI R&D grant £145,000: Development of H4 quadricycle*
- *2007 HFCCAT project. BIS and DECC funded £1.3M project: 5 H4 cars*
- *2010 Niche Vehicle Network £185,000 grant:*
- *2011 CABLED project £700,000 grant: Build of 8 H2EV for hydrogen trial*
- *2012 FP7 Mu-Tool 1.2M Euro: novel ceramic tools for composites*
- *2012 SWARM project FCH-JU 7M Euro: fuel cell vehicle demo. - 2018*
- *2013 LREV TSB. £50,000 Solid state hydrogen storage system*
- *2014 Fuel Cell Recovery, TSB, £450,000 project*
- *2015 NVN £40,000 Demountable Fuel Cell*
- *2016 APC/NVN DISCUS £166,000 Integrate new Motor Drive*
- *2016 APC/NVN Smart Electric Drivetrain £250,000 project*
- *2017 EcoBulk H2020 12.3M Euro Circular Economy materials - 2021*
- *2017 NVN TracPac £30,000 New traction battery design – 2018*

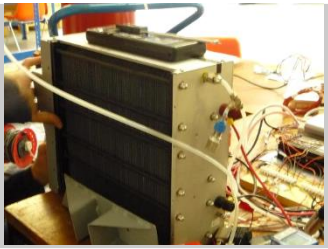
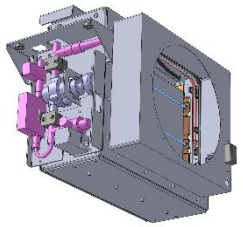
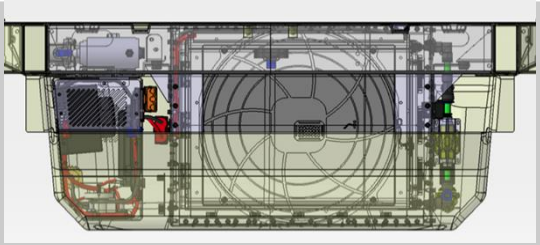
Over 26M Euro in grant funded projects!

Technology:

Fuel cell system history	
2001 H3 Intelligent Energy LTPEM 650w Built in DC/DC	
2005 H4 V1 Intelligent Energy LTPEM 1.1kw Built in DC/DC	
2007 H4 V2 Ballard Nexa LTPEM 1.2kW Zahn DC/DC 24v to 48v	
2011 H2EV V1 Serenergy HTPEM 3.0 kW Zahn (modified) DC/DC 170v to 80v	 

*Low temp PEM approx. 60C
*High temp PEM approx. 150C

Technology:

Fuel cell system history	
2013 H2EV V2 Horizon LTPEM 3.0 kW	
2015 H2EV V3 Ballard AC 70 cell 3.0kW	 
2016-2017 H2EV V3.5 Ballard AC 80 cell 3.3kW	
2018 onwards Integrate Ballard 10kW water cooled system	

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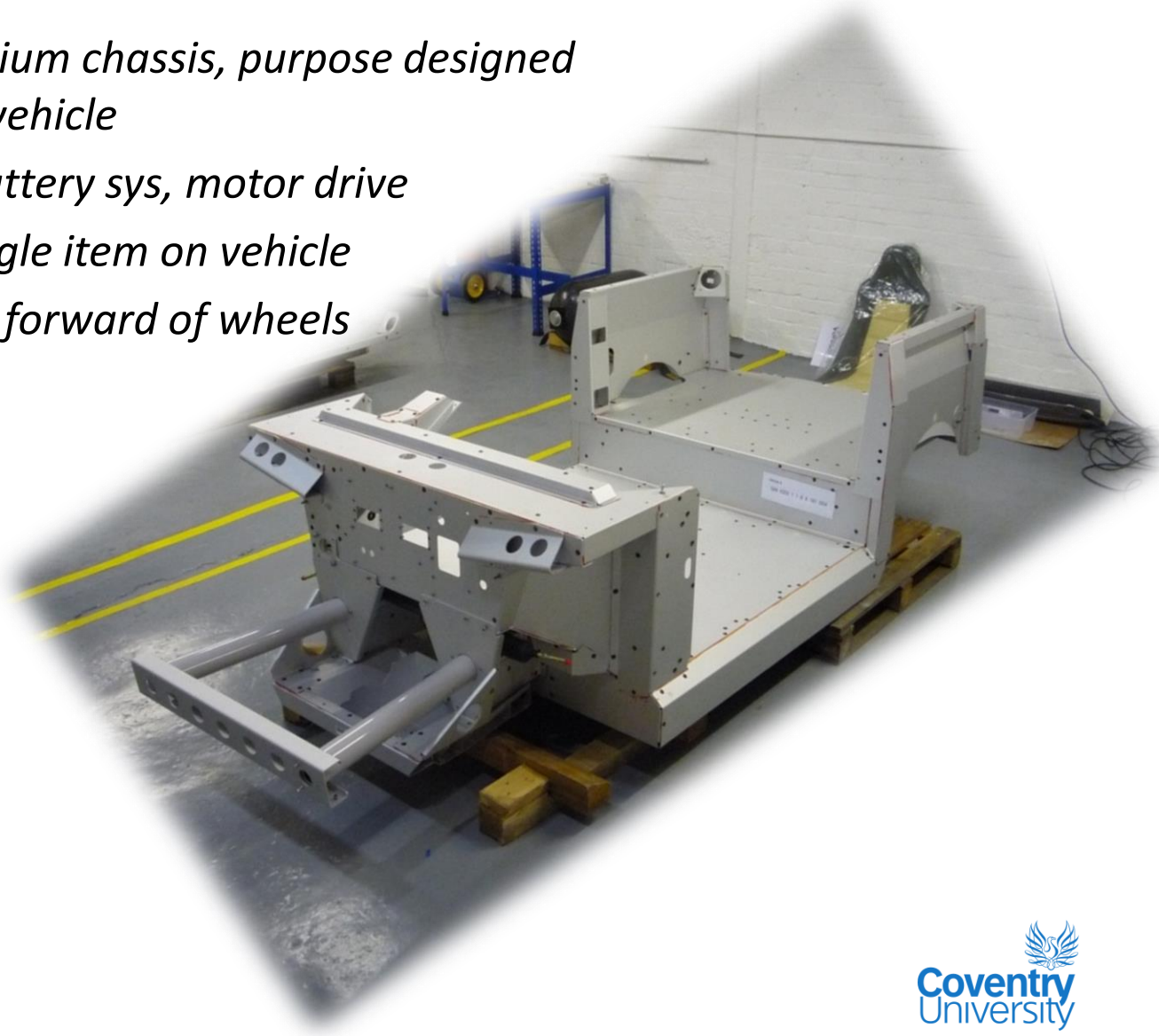
Technology: H2EV Chassis

- *Lotus bonded aluminium chassis, purpose designed for hydrogen hybrid vehicle*
- *Space for fuel cell, battery sys, motor drive*
- *H2 tank is largest single item on vehicle*
- *Mounted under rear, forward of wheels*



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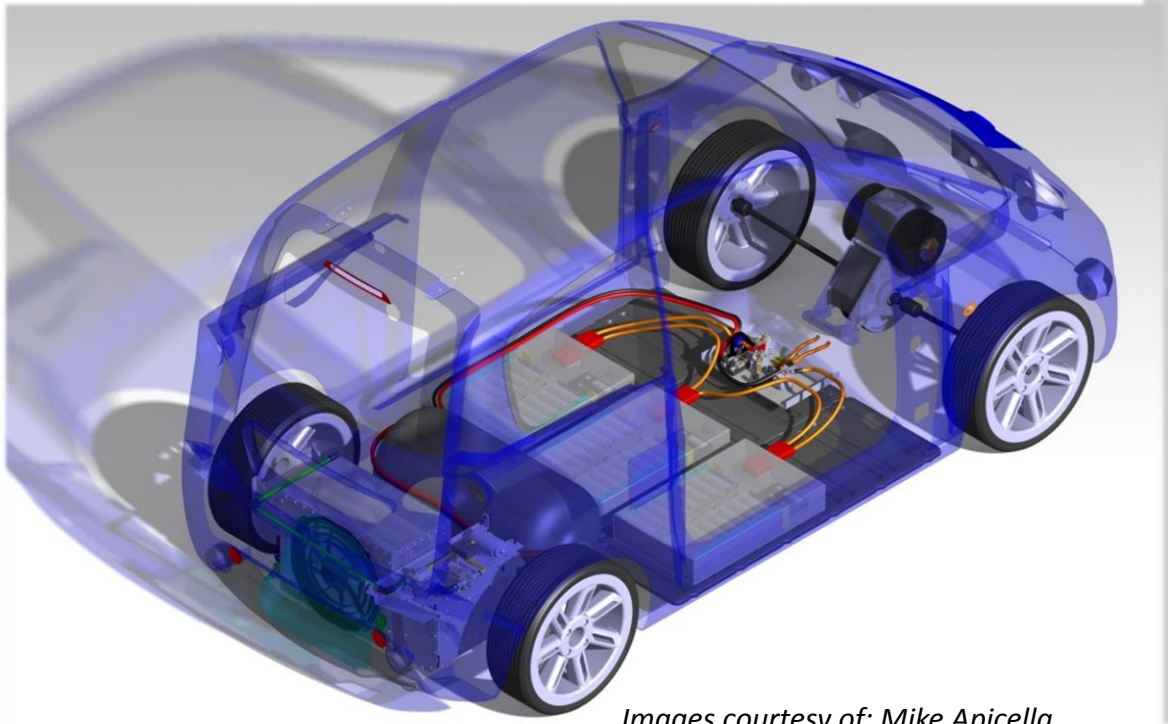
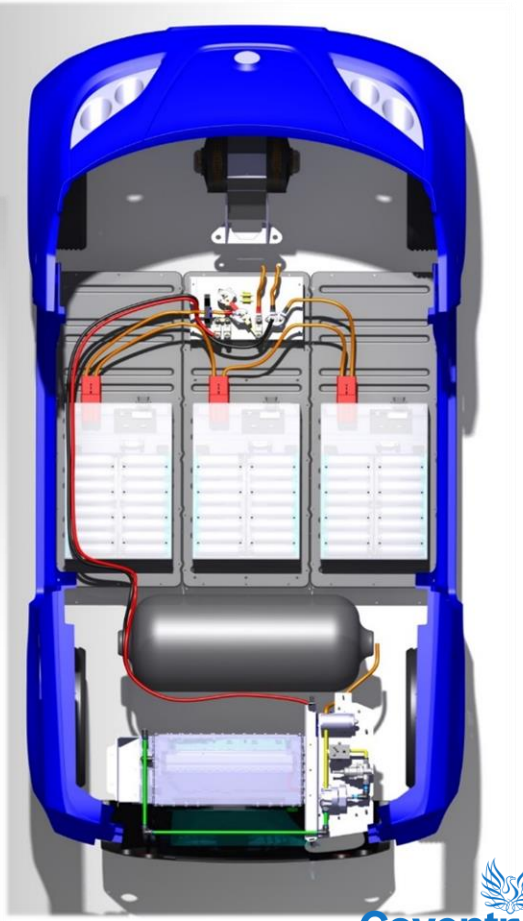
Generation 3 Developments

- New triple pack (3 x 24v) traction battery system
- New integrated 80 cell Ballard 3.3kW AC stack
- New brushless AC motor and gearbox
- New VCU with active intelligent power management
- Fuel cell stack has Cell Voltage Monitoring (CVM) system
- CVM system operates on vehicle, on road at all times





Images courtesy of: Mike Apicella

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Green House Gas Emissions

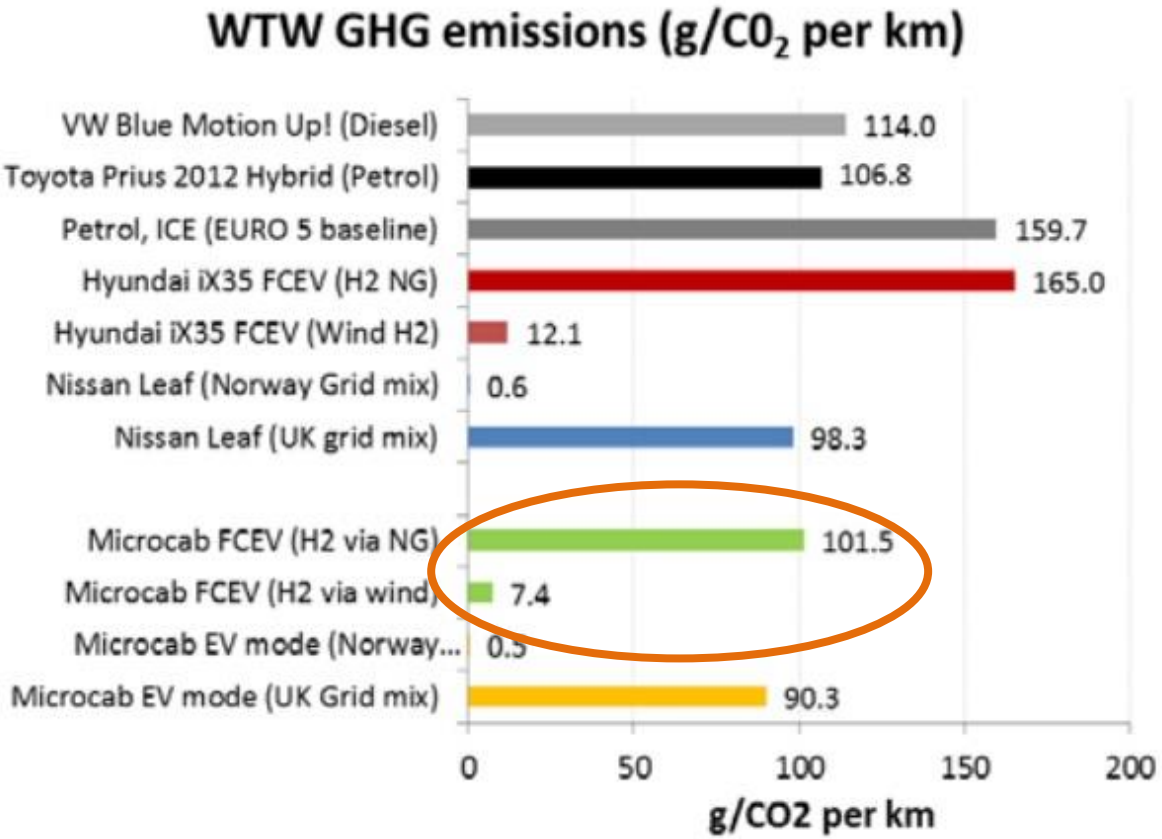

Figure 14: WTW GHG emissions for various vehicles, depending on electricity and H_2 sources

FEV (Forschungsgesellschaft für Energietechnik und Verbrennungsmotoren)

Aachen - 4800 employees worldwide

- Coventry University joint development with FEV
- New £30m institute under construction
- FEV have hydrogen and fuel cells on their road map

Below: FEV visit for ground breaking ceremony for new institute

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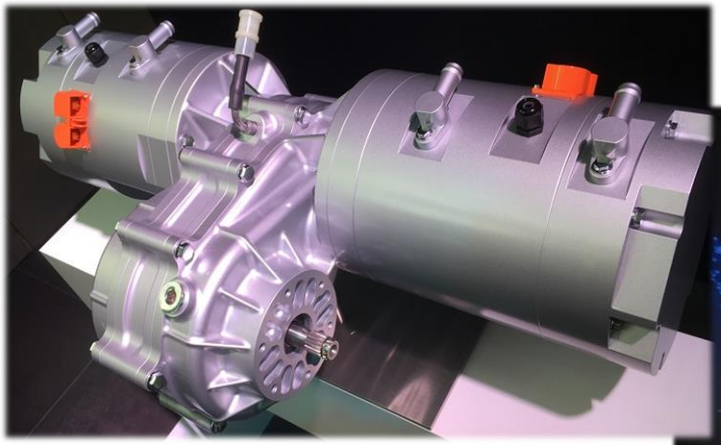
MAHLE

Driven by performance



MEET

Mahle Efficient Electric Transport

- 40-60kW
- peak performance
- motor drive
- 48v

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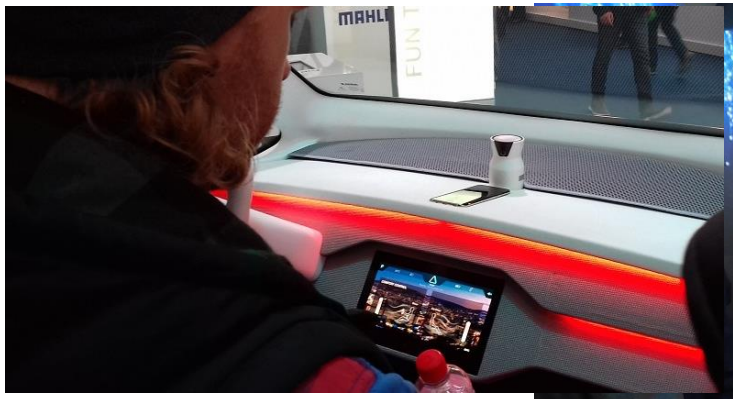
MEET



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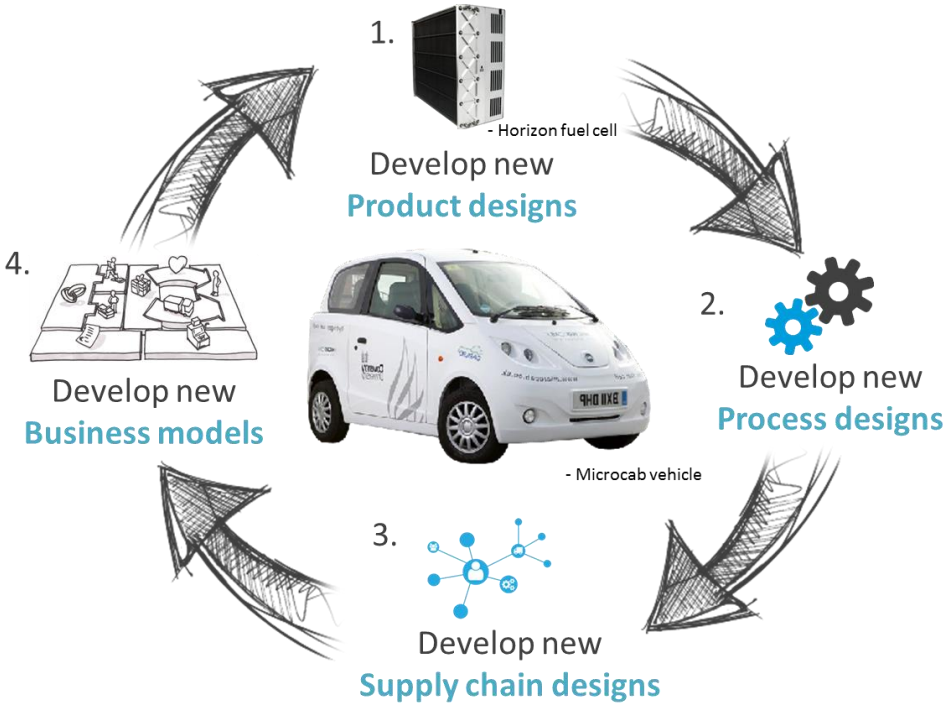
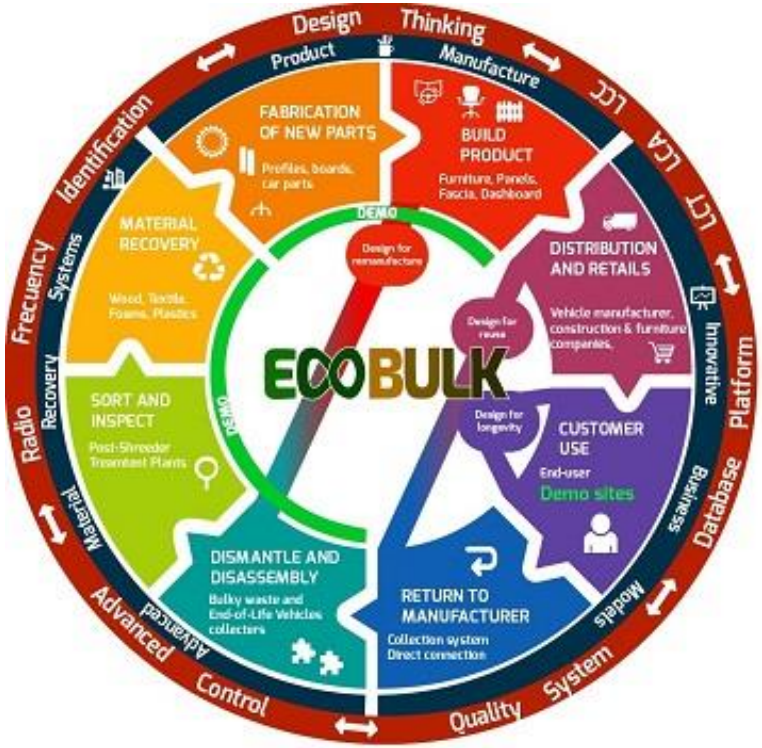
New interior design

- Working in framework of Ecobulk – Horizon 2020
- Circular Economy
- Using material from waste streams for manufacture
- Previous InnovateUK project – fuel cell recovery





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Mahle investment allows Left Hand Drive vehicle

- 2 LHD Fuel cell vehicles in build
- Part of FCH-JU SWARM project
- SWARM Microcab fleet now @ 12,000km
- New interior design for LHD

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Automotive Sector

UK Labour Party leader, giving his Brexit speech February, NTDC Coventry

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Photo: Mike Sewell

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Conclusion

We are looking to councils and governments to support this area of change, to promote local industry, to create sustainable jobs, and to give us all cleaner air in our towns and cities.

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