PEM Fuel Cells
Status, Developments and Future Drivers

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About Intelligent Energy

A fuel cell engineering company focused on the development and commercialisation of its PEM fuel cell technologies for a range of markets including automotive, stationary power and UAVs.

We are headquartered in the UK, with additional offices and representation in the US, Japan, India, and China.
Our Sectors

A wide range of sectors and applications

**UAVs**
- Our technology provides a unique solution
- Fuel cells offer extended flight times and quick refuelling
- Fuel cells are a natural solution for UAV manufacturers moving into larger UAVs with heavier payloads

**Motive**
- Our expertise opens up a range of opportunities in the motive sector, for range extenders and prime power

**Stationary Power**
- Back-up power and diesel replacement, for telecom towers, construction and a range of other sectors
- Field proven in India, with a tower uptime of close to 100%
Milestones in Hydrogen Fuel Cell Technology

- **2005**: 1st fuel cell motorbike
- **2008**: First manned fuel cell aircraft with Boeing
- **2010**: First PEM fuel cell taxi
- **2011**: First fully road approved fuel cell scooter
- **2012**: Fuel cell taxis London Olympics
- **2015**: High power system
- **2016**: Fuel cell power for UAVs
- **2018**: Fuel cell scooter fleet trial

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Fuel Cell Electric Vehicles into the Mainstream

- FCEVs and their refuelling infrastructure are in the early stages of market ramp-up. A mature market is expected in the 2020s with expected sales of 10,000s of vehicles per annum.

- Major automotive OEMs have begun launching serial production cars with specific recent activity from Toyota, Honda, Daimler and Hyundai.
Automotive Move to FCEVs

• Sales of the Toyota Mirai exceed 3,000 in California, FCEV sales over 5,000 worldwide
• Toyota have announced plans for mass production plant for the Mirai, aims for 30,000 per year by 2020
• New Hyundai Nexo FCEV unveiled in early 2018
• Audi and Hyundai form partnership to develop fuel cell technology in June 2018
• SAIC recently launched two FCEVs
• Great Wall Motor plans to commercialise FCEVs by 2022
Fuel Cell Bus Commercialisation

Worldwide introduction of fuel cell bus fleets underway

• Fuel cell buses operating in London since 2004, eight now operating on route RV1
• California has 21 fuel cell buses in operation with more than 15 years of service. In the next few years, it will more than double its fleet
• JIVE 2 will deploy 152 fuel cell buses across 14 European cities, including London, Birmingham and Aberdeen, supported by a €25 million from FCH JU.
• Toyota began sales of its Sora fuel cell bus in early 2018, 100 buses will be in operation at the 2020 Tokyo Olympics
• Korea aims to fund 1000 fuel cell buses by 2022
• In China, Yutong the biggest bus manufacturer, is to build 100 FC Buses, 300 fuel cell buses are to be deployed in Foshan and Yunfu cities and a factory will be built in Zhangjiakou Hebei province with capacity to build 2,000 buses per year
Fuel Cell Trucks

• In China, Youngman Automobile Group has produced 400 fuel cell trucks and plans to launch 800 vehicles in Xian
• Dongfeng forecast to build up to 1000 fuel cell trucks in 2018
• In the US Anheuser-Busch have ordered 800 fuel cell trucks from Nikola Motor Company
• Nikola has struck deal with NEL ASA, to provide network of hydrogen fuelling stations in the US, providing renewably produced hydrogen
• Toyota unveiled its 2nd Generation fuel cell truck in July 2018
Hydrogen Fuel Cells for Rail Transport

New Age of Steam!

• UK Government has called for removal of all diesel rolling stock by 2040
• Hydrogen fuel cells provide a cleaner alternative to diesel on non-electrified lines
• Alstom to covert fleet of existing electric trains to hydrogen fuel cells in North West England
• November 2017, Alstom and the local transport authority of Lower Saxony signed a contract for the delivery of 14 hydrogen fuel cell trains
• The world’s first hydrogen fuel cell passenger train was granted approval by the German Railway Office in July 2018 for passenger service in Germany
ZERE Project and Metropolitan Police Scooter Trial

- APC funded £11m, 3.5 year programme with Suzuki, Intelligent Energy and Cenex
- Development a 4kW fuel cell system based on Intelligent Energy’s air cooled architecture
- Fleet trial of seven fuel cell scooters with the Metropolitan Police
- Scooters based at Alperton (North West Traffic Unit), for the use of Police Community Support Officers within the Roads and Transport Policing Command
- Trial endorsed by Greater London Authority, running from Sept 2017 for 18 months
Focus on Advancing Manufacturing

FCEVs are now entering the mainstream, but to drive continued adoption need to ensure fuel cell stacks are robustly productionised and remain cost competitive in the future.

Must be able to mass manufacture and produce in volume

Key Drivers
- Reliability
- Durability
- Cost
- Efficiency
- Scalability
Cost Down Manufacture Required

• Need to develop next generation automated assembly processes, capable of scaling to mass production capacity

• Integrate digital manufacturing techniques with advanced automated production technology to check and ensure the quality of production

• **DIGIMAN = DIGItal MANufacturing and Proof-of-Process for Automotive Fuel Cells**
Hydrogen Roadmap

Hydrogen Council Roadmap – Hydrogen, Scaling Up

• Deployed at scale, hydrogen could account for 1/5th of global energy consumption by 2050, and contribute 20% of the reduction in carbon emissions required to stay below 2°C warming, has the potential to develop $2.5 trillion of business and could create more than 30 million jobs by 2050

Hydrogen and Fuel Cells are Critical to Decarbonize Transportation:

• Hydrogen Council Milestones 2030
  ➢ 1 in 12 cars in Germany, Japan, South Korea, and California powered by hydrogen
  ➢ Globally 10 to 15 million cars and 500,000 trucks powered by hydrogen
  ➢ Deployment of hydrogen-powered trains and passenger ships

• Hydrogen Council Target Picture 2050
  ➢ Up to 400 million passenger vehicles (~25%), 5 million trucks (~30%), and more than 15 million buses (~25%) running on hydrogen
  ➢ 20% of today’s diesel trains replaced with hydrogen-powered trains
  ➢ 20 million barrels of oil replaced per day, 3.2 Gt CO2 abated per year
Refuelling Infrastructure

• UK H2Mobility and a £23 million fund to accelerate the take up of hydrogen vehicles and rollout infrastructure announced in March 2017
• H2ME will deploy 49 Hydrogen Refuelling Stations (HRS) across 8 European countries by 2022
• Germany H2Mobility, 100 hydrogen refuelling stations by 2020, 400 by 2030
• The USA has 40 hydrogen stations, 36 of them in California’s Hydrogen Highway
• Korea plans 310 new hydrogen filling stations by 2022
• Japan has 90 hydrogen stations, aims to have 160 by 2021 and 900 by 2030
• China has 18 hydrogen stations in operation, plans for 100 by 2020, 1000 by 2030
Japan – Towards a Hydrogen Society

- Tokyo Metropolitan Government has set up a ¥40 billion (£270 million) fund to promote the use of hydrogen energy ahead of the 2020 Olympic Games.
- Tokyo 2020 Olympic Games, will leave a “Hydrogen Society” as its legacy
- Japan wants to have 160 hydrogen stations and 40,000 FCVs on the country’s roads by March 2021. By 2030, it aims to have 900 stations to service some 800,000 FCVs, buses and forklifts.
- Beyond automotive, Japan is aiming for over 1.4 million residential fuel cells by 2020 and over 5 million by 2030
- Japan is aiming to establish a liquid hydrogen supply chain by the 2030s. Led by Kawasaki Heavy Industries, demonstrating the viability of producing hydrogen from coal in Australia and renewable hydrogen from Norway and shipping to Japan.
- Totally CO₂ free hydrogen system by 2040
Spotlight on Fuel Cell Vehicle Activity in China

Fuel Cells are a “Defined Technology” under China’s 13th 5 Year Plan

- Yutong, China’s biggest bus manufacturer to build 100 FC Buses
- 300 fuel cell buses to be deployed in Foshan and Yunfu cities
- Factory built in Zhangjiakou Hebei province with capacity to build 2,000 buses per year
- Youngman Automobile Group has produced 400 fuel cell trucks and plans to launch 800 vehicles in Xian
- Dongfeng forecast to build up to 1000 FC trucks in 2018
- Wuhan, capital China’s Hubei Province, will build itself into a "hydrogen city" with up to 20 hydrogen fueling stations from 2018 to 2020 to support 3,000 FCEVs
- Reported in August 2018 that Shandong Heavy Industry to develop and implement 2,000 hydrogen fuel cell buses in Shandong Province
- China aiming for 10 million FCEVs by 2050
Summary

• FCEVs are now entering the mainstream, with major automotive OEMs launching serial production vehicles, and trains, buses, trucks and two-wheeled vehicles all showing great potential

• Advanced Manufacturing processes are required and being developed to further drive cost reduction and commercialisation

• Hydrogen has been identified as a major mitigator against climate change and an enabler of the decarbonisation of transport

• Hydrogen refuelling infrastructure expected to grow rapidly particularly in China, Japan, Korea and Europe

• Continued government support still required to accelerate pace of infrastructure roll-out and FCEV adoption
Thank you