FuelCellToday
The leading authority on fuel cells

# Fuel Cells and Hydrogen in China 2012

## Acknowledgements

Fuel Cell Today gratefully acknowledges the contribution of many individuals and companies in providing information for and assistance with the compilation of this report.

This report is based upon information from face-to-face interviews conducted in November/December 2011 during Fuel Cell Today's visit to China.

# Contents



Exchange rate used in this report RMB 6.31820 = $1 (US), correct on 9th Jan 2012.

## Summary and Conclusions

Fuel cells are not a new technology to China. Its universities have been developing the technology for many decades and the country hosts a number of well established commercial fuel cell companies.

The opportunities for fuel cells to contribute to a low carbon economy in the country are clear. China relies heavily upon coal-fired power for electricity generation; is the leading emitter of greenhouse gases (measured in absolute terms); has the largest domestic automobile manufacturing industry in the world; and is home to the largest and most rapidly expanding mobile telecommunications network on the planet.

Projects are underway to increase the contribution of renewable energy to China's electricity mix. This must be approached carefully in any country because the variability of renewables can cause grid instability. Balancing the grid is key to avoiding power cuts and fuel cells can contribute here. Excess electricity can be channelled into hydrogen production, which in turn can be used in fuel cell vehicles. Integrating a low-carbon transport solution as a means to facilitate decarbonisation of the energy grid would be an elegant solution.

With its ever growing automotive industry, China is well placed to be a dominant force in this sector. Plans for commercial deployment of fuel cells mirror those of other regions and virtually all major fuel cell demonstration projects thus far have involved transport fuel cells, either for cars, buses or multi-person sightseeing vehicles. The necessary hydrogen refuelling infrastructure is being developed alongside the vehicle demonstrations, with both permanent and mobile hydrogen refuelling stations currently in operation.

China has three mobile telecommunications providers, all of which rank in the top 21 in the world, measured by number of subscribers. The benefits of fuel cell uninterruptible power systems in this industry are recognised around the world and test systems have been operated in China for the past few years. Batteries currently dominate this industry, but with the cost of fuel cells decreasing and the added benefit of longer runtimes (a key attribute in areas with unreliable grid power) telecoms backup fuel cells are well poised for growth.

Financial support from the Chinese government is strong with fuel cells identified as a key future technology and funded accordingly. Chinese companies throughout the supply chain from catalysts to membranes and system integrators to end users are all driving fuel cell adoption leading China to become an international competitor.


The Pudong district of Shanghai at dusk. Image source: Dan Carter

## Snapshot

Capital: Beijing.

Population: 1.3 billion; urbanisation 47%.

Oil: Net importer since 1993, second largest globally since 2009.

Electricity generation: 80% from coal, 19% hydro, 1% others.

Vehicle production: >18 million (light and heavy duty) has been number one in the world since 2008.

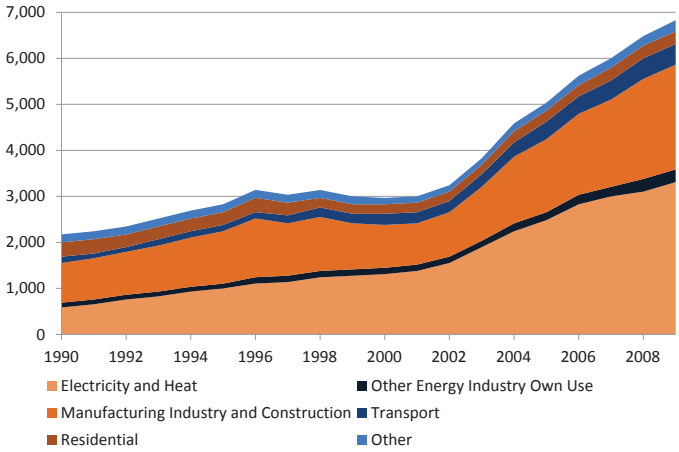
Mobile phone subscribers: 951 million (world's number one) with three mobile network providers in the top 21 globally.

## Introduction

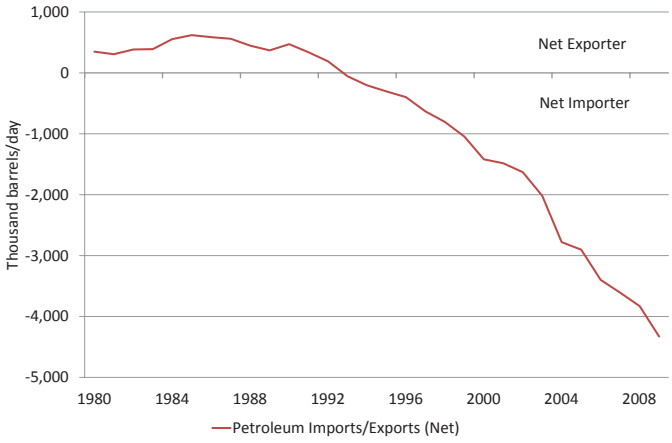
China is the largest country in Asia and the second largest in the world, covering 9.6 million square kilometres[1]; it also has the highest population in the world, with more than 1.3 billion citizens.[1] Both the large population and sheer scale of the country present numerous challenges in terms of energy provision, pollution management and energy security. Providing heat and power to so many citizens across such a vast area is not a simple task, and historically has come at a significant environmental cost. The most abundant natural resource in China is coal, from which greater than 80% of its electricity is generated[2] and, in remote regions, coal is also burned for heating and cooking. These emissions contributed to China's elevation to the top of the world's $CO_2$ emitters (in absolute terms) in 2007, overtaking the USA[3]. The government is well aware of this issue and for the past few years has been a world leader in installing renewable energy capacity and investing in carbon capture and storage (CCS) technology.

The delivery of electricity to meet demand relies upon a stable national grid structure. Increasing electricity production using fossil fuels or hydro power offers a fairly predictable supply, but comes at a significant cost in terms of air pollution, or the need to flood vast areas of land. While China has impressive potential for renewable energy generation, with wind power available in the north and rich solar opportunities in the west, increasing the percentage of renewables is not a straightforward task. Due to the intermittent nature of renewable energy sources, such as wind and solar power, integrating a large percentage of these energy types can make grid balancing a serious issue. The problem of transmitting electricity to where it is needed, generally in the eastern coastal areas, also places additional strain on an already fragile grid.

Electricity generation is not the sole emissions problem for the nation either, with a significant percentage of emissions coming from the manufacturing sector and smaller contributions from the transport and residential sectors. With the increasing number of people gaining the income levels required to support car ownership, urban air quality management is a key concern for the government. Energy security must also be taken into consideration, with China the second biggest net importer of oil in the world, currently importing more oil than




$CO_2$ emissions by sector, source: IEA 2011




Chinese net petroleum imports/exports, source US EIA

it produces per year;[1] reliance on imported oil is beginning to shape the direction of government policy. The country became a net oil importer in 1993 and, in 2009, overtook Japan as the world's second largest importer of oil next to the USA.

## History of Fuel Cell Development in China

Fuel cells are not a new technology to China, but in fact have been researched and developed since the 1970s, when a prototype alkaline fuel cell was developed for use in its domestic space programme. This unit never left the confines of the laboratory, but the interest in fuel cells remained with PEMFC technology emerging as the dominant technology. Through the 1990s research focused on automotive applications, but attempts to gain interest from commercial partners proved fruitless. Around 1999, the government extended the electric vehicle R&D investment to include fuel cell technology, and since 2000, a number of demonstration programmes have taken place raising the profile of fuel cells in the eyes of both the government and the public. Current academic and commercial interest in fuel cells ranges from very small portable units for powering torches and consumer electronics, through larger stationary systems for backup power and all the way up to fuel cell electric vehicles and fuel cell buses.

## Government Policy

The majority of fuel cell and hydrogen related research in China is done using government funding made available through two main programmes: the 863 National High Technology Research and Development Program, (which began in March 1986) and the 973 National Basic Research Program (similarly named after the project start date in March 1997).

The Ministry of Science and Technology (MOST) sets the development targets and funding levels for the various projects. The current MOST minister, Wan Gang, has a wealth of experience working in the automotive sector on future powertrains and is a strong believer in fuel cell technology. Targets set by MOST form the generic basis of Chinese research in terms of improving lifetimes, lowering costs etc., but it is the research centres themselves that write proposals for how they intend to meet those targets.

Project planning by Chinese government departments runs in a cycle of five year blocks, known as "five-year plans for the National Economic and Social Development of the People's Republic of China". The previous four five-year plans have all supported fuel cell and hydrogen technology to differing extents, due to the different overall aims of each plan. In the ninth five-year plan (1996-2000), RMB 30 million ($4.75 million) was provided from the 973 Program and RMB 0.38 million ($60,143) from the 863 Program.

The 10th five-year plan (2001-2005) saw an additional RMB 30 million ($4.75 million) invested, alongside RMB 22 million ($3.48 million) into generating hydrogen from solar power. Also during the 10th five-year plan MOST approved a RMB 880 million ($139 million) R&D programme to develop advanced hydrogen technology, hybrid-electric drives and fuel cell vehicles.

In the 11th five-year plan (2006-2010), hydrogen and fuel cell technology research was awarded RMB 182.5 million ($28.88 million) out of a total advanced energy technology fund of RMB 634.3 million ($100.39 million). Funding totalling RMB 413 million ($65.37 million) was also provided for energy-saving and new energy vehicles, of which fuel cell vehicles were awarded RMB 150 million ($23.74 million).

China's Renewable Energy law, introduced in 2006, saw a RMB 0.25/kWh ($0.04/kWh) premium for biomass generated electricity fed into the grid. This premium is added to province-specific prices of coal power generation and is applicable for fifteen years. In 2010, the National Development and Reform Commission superseded this with a new national feed-in tariff for biomass power of RMB 0.75/kWh ($0.12/kWh).

The current 12th five-year plan, which runs from 2011 to 2015, is targeting economic growth, innovation, competitiveness and social developments such as access to education. Economic growth is the main objective, but

specific emphasis is placed on green development, environmental protection and energy conservation. The 12th five-year plan includes binding global energy targets, with non-fossil fuel resources to reach 11.4% of primary energy consumption by 2015, energy consumption per unit of GDP to decrease by 16% and $CO_2$ emissions per unit of GDP to fall by 17% by the same time.

The current plan also includes specific deployment targets for renewable energies. China plans to construct 120 GW of hydro power and build 70 GW of wind capacity, in six onshore and two large coastal and offshore wind power bases, by 2015. China is also planning to install 5 GW of solar energy power stations, located mainly in the west of the country (Tibet, Inner Mongolia, Gansu, Ningxia, Qinghai, Xinjiang and Yunnan provinces). The five-year plan also aims to support the development of new energy industries, such as large wind power generating sets and parts; new, more efficient solar power generation and heat utilisation, and biomass energy conversion and utilization technologies. In support of this, the Chinese government published an installed capacity target for biomass generation of 30 GW by 2020.[4] The feed-in tariffs and capacity targets could provide attractive incentives to encourage the introduction of bio-methane fired fuel cells.

Despite these ambitious targets, the majority of electricity generated in China still comes from coal, and will do for the foreseeable future as the needs of the population must be met. Hydro-electric power capacity is increasing too, mostly as a result of the completion of the Three Gorges Dam project. The reservoir reached full capacity in 2011 and when fully operational the turbines generate around 80 TWh per year. Planning for this project began in the 1930s and underscores China's ability to support long-term energy projects.

In June 2011, 40 top scientists from around China met in Beijing for a three day round table discussion about hydrogen and fuel cells. The meeting was an opportunity for information exchange between academics and was financially supported by the government. The output was to be a written memo updating the government on the state of the technologies in China. The main conclusion of the event was to ask the government to support hydrogen and fuel cell research in advance of the 2015 commercialisation for FCEV and also to suggest a hydrogen highway be built between Beijing and Shanghai to attract these vehicles. The construction of a hydrogen highway is likely to be a contentious issue, because it will travel through a number of provinces and therefore getting agreement from all parties involved could prove difficult.

2011 is the first year of the 12th five-year plan with RMB 0.1 billion ($15.8 million) available for hydrogen and fuel cell projects starting this year; these funds are part of the 863 project. This money does not include funds for the commercial development of FCEV, but is specifically for fuel cell and hydrogen research. In addition, the 973 project has RMB 70 million ($11.1 million) of fuel cell funding available split into two parts: the first for solid oxide fuel cell (SOFC) research and the second for platinum-free fuel cells. This money is split roughly 50/50 between the two projects.

## Research and Development

China has a strong research base, with all of its top-tier universities conducting fuel cell research. Virtually all of the commercial projects to date demonstrating fuel cell technologies have involved local universities. Tsinghua and TongJi Universities are two of the most prominent in terms of the vehicle developments for the projects discussed below. Some connections are stronger than others however, with Wuhan University of Technology (WUT) having particularly strong links with MEA manufacturer Wuhan New Energy Co Ltd. and the Dalian Institute of Chemical Physics (DICP) also working closely with its spin-off company Sunrise Power Co Ltd. Close collaborations like these provide both a unique route to market for the researcher's technologies and at the same time offer the commercial enterprises access to state of the art research and technology.

| Patents | Applications | Granted |
|---|---|---|
| 2000 | 0 | 0 |
| 2005 | 21 | 0 |
| 2010 | 14 | 8 |

International patent applications and grants with China as priority country

International fuel cell patent activity from China is low compared to the rest of the world, but it is growing and something we expect to increase further in the future. Looking back over the past ten years, no international activity was seen

in 2000, with applications being logged in 2005 but none granted. In 2010, application activity continued and we began to see international patents being granted with China as the priority country. A number of Chinese companies hold IP in the fuel cell field: Sunrise Power Co Ltd has one of the largest holdings with more than 200 patents, JS Power (formed in 2010) has six and Horizon Fuel Cell Technologies also holds patents for its MEA technology.

## Demonstration Programmes

A number of fuel cell and hydrogen demonstration programmes have been conducted during the past six years, tending to coincide with high-profile public events. The main focus of these demonstrations has been transportation, with a range of fuel cell vehicles from small golf buggy sized, to larger FCEV and fuel cell buses. Key demonstrations are highlighted below.

### Fuel Cell Bus Demonstration

This project was launched by the Chinese government in March 2003 in collaboration with the Global Environmental Facility (GEF) and the United Nations Development Programme (UNDP). The first phase took place between June 2006 and October 2007, with three Daimler-Chrysler fuel cell buses in operation for use by the Beijing public. These buses carried nearly 57,000 passengers a total distance of more than 92,000 km during their service with an availability of 90%. The second phase took place in Shanghai and was launched in November 2007. Running until the World Expo in 2010, this phase ran a fleet of six SAIC (Shanghai Automotive Industry Corporation (Group)) fuel cell buses, three powered by Ballard stacks and the other three by domestic suppliers.

### Beijing Olympics 2008

600 hybrid vehicles, battery electric vehicles and fuel cell electric vehicles were used during the 2008 Olympic Games in Beijing. The vehicles were used as support cars for the marathon and to transport the organisers, special guests and the press. As part of this green fleet, twenty VW Passat Lingyu FCEV covered a total distance of more than 100,000 km without any major incidents, each car having a theoretical range of 235 km per tank of hydrogen.

After the Olympics, sixteen VW Passat Lingyu Fuel Cell vehicles were sent to California for fleet demonstrations at the California Fuel Cell Partnership (CAFCP). Here, the fleet covered an additional 37,000 km between February and June 2009.

Fuel cell vehicles in Beijing, source: Foton

### 1,000+ Green Vehicles in 10+ Cities.

In February 2009, a demonstration project began to promote new energy vehicles in thirteen cities. The government made funds available in the form of a one-off subsidy for the purchase of these vehicles, which will initially target vehicles for public use, such as taxis and buses. The project hopes to have more than 60,000 clean cars and buses on the road in these cities by 2012.

| Vehicle type | | Subsidy | |
|---|---|---|---|
| | | RMB | US$ |
| Passenger cars and light commercial | Hybrid | 50,000 | 7,900 |
| | Electric | 60,000 | 9,500 |
| | Fuel Cell Electric | 250,000 | 39,500 |
| Buses | Hybrid | 420,000 | 66,500 |
| | Electric | 500,000 | 79,000 |
| | Fuel Cell Electric | 600,000 | 95,000 |

Vehicle purchase subsidies

### World Expo 2010.

During the 2010 World Expo, a total of 1,017 clean energy vehicles were in use transporting visitors, including 90 fuel cell cars, six fuel cell buses and 100 sightseeing cars. Hydrogen was brought to the Expo refuelling station and the Anting* hydrogen station on tube trailers from a by-product hydrogen purification plant; two mobile

* Anting is a town located in the Jiading district of Shanghai and home to SAIC Motor Company

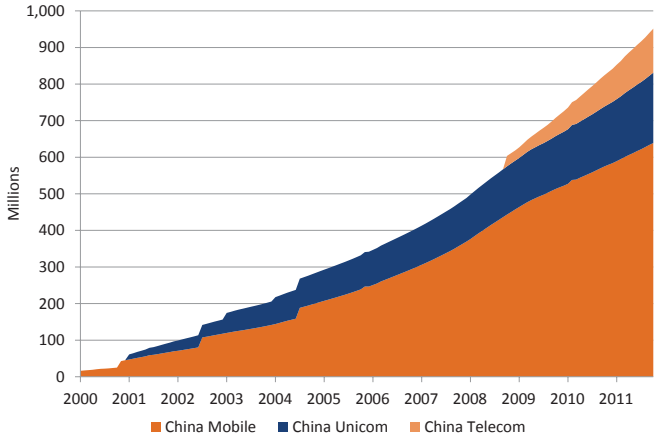
hydrogen refuelling stations were also in use. The mobile refuelling stations each had a hydrogen storage capacity of 80 kg and could dispense at 35 MPa. The FCEV were manufactured by SAIC, GM, Shanghai Volkswagen, FAW-Volkswagen, Chang'an Motors and Chery.

# Current Opportunities for Fuel Cells in China

## Stationary Systems

The market for stationary power has huge potential in China and in the backup sector for telecommunications power it is beginning to gather momentum. China is home to the world's most rapidly expanding mobile phone network, but at the same time does not have an integrated national grid system. China's disjointed, and in some areas unreliable, grid system is composed of power clusters spread across eight regions and controlled by three main companies. Backup power cannot therefore be guaranteed and so battery backup is widely used in the telecommunications industry. There are 30 to 50 billion RMB ($4.7 to $7.9 billion) of battery sales per year in China for the telecoms industry alone, and currently more than one million cell sites in the country. Growth of new cell sites currently runs at ten to twenty thousand per year.


Electricity grid system in China. Source IEA 2011




Domestic mobile phone subscribers, source: China Mobile, China Unicom and China Telecom

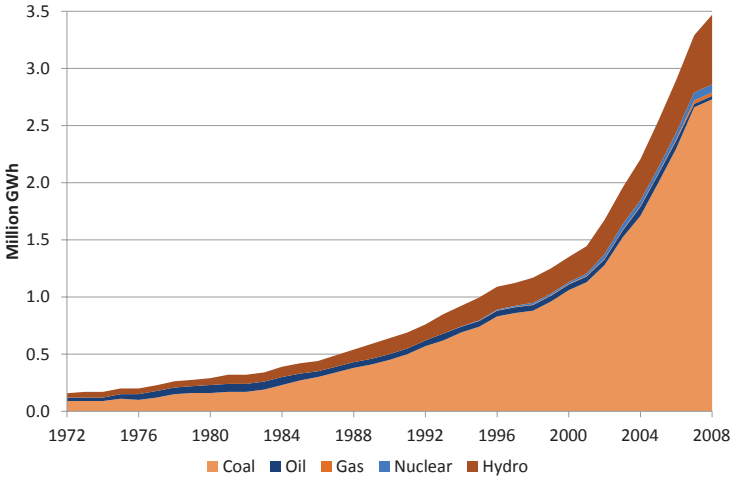
China has three main mobile phone network operators: China Mobile is the biggest network operator in the world by number of subscribers, with China Unicom (#11) and China Telecom (#21) also high in the world rankings. These companies work with infrastructure providers, such as Huawei and ZTE, to plan and source the backup power solutions. Fuel cell companies enter the supply chain at this point, competing with incumbent battery technology, but fuel cells need buy-in from the network operators who ultimately foot the bill and charge their subscribers. The telecoms industry is looking for government subsidies in order to speed up adoption of this technology. Currently the government funds research projects in this area through the 863 project, but this central government funding is predominantly for research; if projects are successful, then companies have to apply for funding elsewhere.

Demonstration projects are underway and international telecoms backup fuel cell companies such as ReliOn have previously tested units in China. Domestic company WUT New Energy Co. Ltd. has been demonstrating a telecoms backup power unit (shown on the following page) since 2009 with no recorded problems in operation. Pearl Hydrogen Technology Co Ltd. is also involved in this field and is targeting 100 h/year and a ten-year lifetime for its systems; Pearl Hydrogen also currently has a small number of fuel cell prototypes in operation


WUT New Energy Co stationary fuel cell system
Source: WUT New Energy Co Ltd

for evaluation purposes. Shanghai Everpower Technologies Ltd. has around 6 kW of backup power units currently undergoing tests and Sunrise Power Co Ltd is also in discussions with the big three network providers about fuel cell deployment.

While ultimately these companies are targeting a global market, reducing cost is currently the main priority so the fuel cell systems can achieve parity with battery technology. Fuel cell back-up systems are currently cost-comparable with lithium-ion or lead-acid batteries when operated continuously for more than eight hours, shorter operation results in less favourable costs. The availability of lead-acid batteries could become an issue in the future due to a clampdown by the Chinese government on factories producing the technology in a polluting manner. Towards the end of 2011 the government closed more than half of the industry for inspection, with very few of these manufacturers surviving to re-open. The lack of availability of lead-acid batteries in certain applications could accelerate a transition to lithium-ion technology, which is significantly more expensive; closer in price to fuel cell technology in this industry.




China electricity generation by fuel type
Source: IEA Energy Statistics

The majority of China's electricity is produced from coal,[2] since it is a large domestic resource. Up until 2008, China was a net exporter of coal, but demand has since outstripped supply and in 2010 China imported 172 million tonnes contributing to a total consumption of 3.7 billion tonnes versus domestic production of 3.5 billion tonnes. Aside from coal-fired power, China has been a world leader for the installation of renewables, including hydro, wind and solar power. With this rapidly increasing percentage of variable renewable energy sources in China, the lack of grid interconnectedness is becoming more of an issue, leading to grid instability. China subsidises electricity prices, which retail at around 40% of the global market price, leaving little incentive for users to reduce consumption – a key load levelling strategy for grid management in other countries. Generation of power from renewables is also highly localised, with wind resources in the north of the country, solar resources in the west and large pumped-hydro facilities concentrated in the south. The consumers of energy are mainly in the southeast coastal areas, where the economy is the most developed. Therefore there are disconnects between the areas where renewable power is being installed and where electricity is being consumed. There is potential to use this localised variable electricity supply to generate hydrogen which could be channelled for use in regional fleets of fuel cell vehicles. Maximising the utilisation of these variable renewables will allow the country's clean energy targets to be met, while at the same time reducing its dependence on imported oil and reducing emissions.

## Transportation Fuel Cells

Automotive fuel cells for light duty vehicles and buses have formed the main focus of government-funded demonstration projects to date, and have resulted in domestically produced vehicles which have not only operated

at high-profile domestic events, such as the 2008 Olympics, but have also been demonstrated as far afield as California, where sixteen FCEV were tested with the backing of the California Fuel Cell Partnership.

The number of vehicles on China's roads is increasing at a rate of more than ten percent per year, a trend which is likely to continue. While tailpipe emissions legislation is tightening, pollution from the automotive industry and its future effects is of concern to the government.

As such the government has funded a significant amount of research and development into FCEV but more needs to be done before the technology can reach commercialisation. Demonstration projects to date have been carried out by Sunrise Power and Shanghai Shen-Li High Tech, who have worked with automotive companies, such as the joint venture between Volkswagen and SAIC to produce vehicles. Direction for the future is now needed to drive commercialisation of the technology, and improvements are needed in performance and lifetime of the fuel cells before they can be introduced to consumers. In line with automakers in other countries, SAIC intends to begin pre-production of its FCEV for use in internal tests as early as 2013, with only twenty to thirty vehicles. From 2015 commercial production plans are to produce upwards of a thousand vehicles per year.

A number of Chinese fuel cell companies are targeting the electric bike (e-bike) market as a potential opportunity for fuel cells. E-bikes are becoming increasingly popular in the country, but are facing a number of problems. The availability of lead-acid batteries mentioned earlier is one issue, which could drive sales towards more expensive lithium-ion or fuel cell options. The longer run time provided by fuel cells could be attractive both in terms of range and also in allowing users to power lights. Currently a large number of e-bike riders do not use their lights when it is dark for fear of losing range. Another obstacle facing e-bikes, which would affect fuel cells as much as batteries, are blanket bans, which also include motorcycles, coming into force in certain cities and districts. We didn't see much evidence of this in Shanghai and Beijing during our trip and would hope that fuel cells would eventually be exempt from these bans as the government already recognises their green credentials in other transportation fields.

## Portable Fuel Cells

There is interest in developing portable fuel cells from a number of companies in China. JS Power has a 2 W fuel cell charger and is interested in supplying this to the Chinese military for use in the field. Its patented solid state hydrogen technology can be provided in an easy to use bag which can produce 99.999% pure hydrogen when in contact with any type of water, regardless of its purity. One fuel pouch contains 12 g of powder and can produce 12 l of hydrogen, equivalent to five hours' running time.

Singaporean company Horizon Fuel Cell Technologies also has fuel cell manufacturing interests in China and in the near future will be targeting a slightly different audience for its MiniPak portable electronics charger. It is interested in the wider consumer electronics market and is in the process of finalising marketing agreements with major telecommunications providers for the supply of its hydrogen powered fuel cell unit. Working with cartridges of solid state hydrogen which resemble large batteries, Horizon's fuel cell can be recharged at home with its proprietary home refuelling station, where one cartridge can be refuelled in around 30 minutes. One cartridge can provide enough power for two charges of an iPhone 4, so a couple of these could provide off-grid power for up to a week.

Both of these units will be sold complete with a USB torch and, with this in mind, additional applications of these fuel cells for both commercial and recreational underground activities, such as mining and caving can easily be envisaged. With the recent launch of the Powertrekk fuel cell charger at the 2012 Consumer Electronic Show, and Aquafairy targeting the Japanese consumer electronics market, fuel cells for consumer electronics charging look to finally have arrived.

JS Power 4 W portable fuel cell charger
Source: JS Power

## Fuel and Infrastructure

The leading fuel cell technology type in China is PEMFC. While some research institutions have historically conducted research into DMFC and SOFC technology, hydrogen is the dominant fuel required to power fuel cells in the country. In 2007 China's first hydrogen station opened in Anting, a suburb of Shanghai. Built by Shanghai Sunwise Energy Systems Co. Ltd., this station is still in operation. Sunwise has developed several mobile refuelling stations, the first was in 2004 and dispenses hydrogen at 350 bar; this station was upgraded in 2006. The company also built two refuelling units for the World Expo station, which were used to refuel the sightseeing vehicles. The second mobile station for the expo has finished its required use now and will be moved to Jiading district and split into two fuelling stations. It will join the Anting station and enable dual pressure fuelling at 700 bar as well as 350 bar. The Jiading district is an international demonstration area for all electric vehicles. Fuel cell vehicles (cars and buses) are also in use at Jiading.

In China there are four permanent hydrogen stations and five mobile refuelling stations with all the mobile units being located in Shanghai. In Shanghai, the hydrogen is brought in using tube trailers, and we understand by-product hydrogen is used. In Shanghai, maximising use of the by-product hydrogen from the steel-making and chemicals industries alone could fuel up to 10,000 FCEV. In Beijing, one of the stations receives hydrogen from a variety of different sources including tube trailers, on-site steam methane reforming and water electrolysis; the second station has an electrolyser only.

There are no clear plans for a hydrogen highway infrastructure in China. At a government sponsored conference in 2011 a proposal was made to build a hydrogen highway between Beijing and Shanghai. Discussion is currently between scientists and industrialists, but the first stage of any project like this is to build clusters, which then get connected to from the highway. The hydrogen for the highway will be generated using wind, solar and by-product hydrogen. Apparently electricity companies are not keen on integrating wind and solar power into the grid because the variable renewables cause too much instability for the electricity grid. There are discussions around converting these renewable energy sources directly to hydrogen for use in vehicles but there are no real projects on this at the moment.

In general, China develops projects in line with ISO standards, so any development is likely to follow international standards; especially because nozzles etc. are all imported from foreign companies. More information on hydrogen refuelling stations in China can be found by visiting the website www.china-hydrogen.org, a website run by Shanghai Sunwise Energy Systems Co. Ltd.


Anting Hydrogen Station. Photo source, Dan Carter, Fuel Cell Today.

# Appendix I: Companies Visited

### Dalian Institute of Chemical Physics (DICP)

| | |
|---|---|
| Company | Location, Dalian; established 1949; 100 permanent fuel cell staff (plus 100 students) |
| Fuel Cell Interests | Researching key materials and system integration for PEMFC; DICP also has DMFC and SOFC research interests. Developed China's first AFC system for the space program |
| Website | http://www.english.dicp.ac.cn/ |

### Shanghai Everpower Technologies Ltd

| | |
|---|---|
| Company | Location, Shanghai; established June 2009; 40 employees, plans to expand in 2012 |
| Fuel Cell Interests | Developing small PEMFC systems up to 5 kW for backup power and small vehicles. Staff have 15-20 years fuel cell experience gained at fuel cell companies such as Ballard |
| Website | http://en.hjpower.com/index.html |

### Horizon Fuel Cell Technologies

| | |
|---|---|
| Company | Shanghai (Headquartered in Singapore); established 2003; 130 staff (~15 in Singapore) |
| Fuel Cell Interests | PEMFC technology for portable power and small transportation applications. Scaling up its units for telecoms backup power, consumer electronics charging and city-vehicles |
| Website | http://www.horizonfuelcell.com/ |

### Hydrogen God Fuel Cell Ltd

| | |
|---|---|
| Company | Location, Tianjin; established March 2011; 6 employees |
| Fuel Cell Interests | Focussing on sub-1 kW PEMFC for emergency power and small fuel cells for e-bikes. Once established intends to develop larger units for UPS and transport applications |
| Website | Under Development |

### JS Power

| | |
|---|---|
| Company | Location, Zhenjiang; established 2010; 60 employees but plans to expand in 2012 |
| Fuel Cell Interests | Focussing on $H_2$ production and storage. Has its own powdered $H_2$ production technology. Has a range of PEMFC products from a 4 W portable charger up to a 5 kW system |
| Website | http://www.jspowerinc.com |

### Palcan Energy Corp.

| | |
|---|---|
| Company | Location, Suzhou, Headquartered in Canada; established 1998; 30 employees |
| Fuel Cell Interests | Integrates PEMFC technology for backup power, portable and e-bike applications. Developed a proprietary $H_2$ production system using powdered hydride and water |
| Website | http://www.palcan.com/ |

### Pearl Hydrogen Technology Co. Ltd.

| | |
|---|---|
| Company | Location, Shanghai; established January 2006; 35 staff (50% in manufacturing) |
| Fuel Cell Interests | Focussed on commercialisation of PEM fuel cells for telecoms backup and light vehicles targeting greater lifetime and lower cost. Manufacturing capacity: 2 MW / year |
| Website | http://www.pearlhydrogen.com/ |

### SAIC Motor Corporation Ltd

| | |
|---|---|
| Company | Location, Shanghai; domestic market share ~20%; >100,000 employees |
| Fuel Cell Interests | Involved in all major domestic FCEV and fuel cell bus demonstrations to date. Plans to manufacture 22 FCEV for employees by 2013 and >1,000 for commercial sale from 2015. Controls 34.5% of Dalian-based fuel cell company Sunrise Power Company Ltd. |
| Website | http://www.saicgroup.com/english/index.shtml |

### Shanghai Shen-Li High Tech Co. Ltd

| | |
|---|---|
| Company | Location, Shanghai; established June 1998; |
| Fuel Cell Interests | PEMFC development and transport fuel cell demonstration are main focuses. Also has a 10 kW hydrogen fuelled stationary product and a 100-300 W portable system |
| Website | http://www.sl-power.com/index_en.html |

### Space power

| | |
|---|---|
| Company | Location, Shanghai; part of the China Aerospace Science and Technology Corporation |
| Fuel Cell Interests | Has developed PEMFC for transport applications, collaborates with universities and automotive companies. Also has 1 kW DMFC system for portable power. |

### Sunrise Power Company Ltd

| | |
|---|---|
| Company | Location, Dalian; established 2001, a spin-off from DICP; 140 staff (~50 academic) |
| Fuel Cell Interests | Full spectrum of research from catalysts to fuel cell systems, offers technical support and owns 200-300 fuel cell patents. Co-located with the National Engineering Research Center of Fuel Cell & Hydrogen Technology |
| Website | http://www.fuelcell.com.cn/english/index.html |

### Shanghai Sunwise Energy Systems Company Ltd

| | |
|---|---|
| Company | Location, Shanghai; established 2004; |
| Fuel Cell Interests | Develops hydrogen refuelling stations, including the permanent installation at Anting and a number of mobile units. Developing on-board storage of hydrogen for FCEV. |
| Website | http://www.sunwise.sh.cn/ also runs: http://www.china-hydrogen.org/ |

### Tsinghua University

| | |
|---|---|
| Company | Location, Beijing; major fuel cell research centre; 10 staff plus 30 postgraduate students |
| Fuel Cell Interests | Focus is on PEMFC and DMFC but also researching low temperature ($500^0$C) SOFC |
| Website | http://www.tsinghua.edu.cn/publish/then/index.html |

### Wuhan University of Technology

| | |
|---|---|
| Company | Location, Wuhan; established 2000 with the amalgamation three universities. Can trace its original roots back to the Ziqiang Institute in 1893 |
| Fuel Cell Interests | PEMFC modelling and development. Researching fuel cell engines with DongFeng. Channels development work and IP through partner WUT New Energy Co. Ltd. |
| Website | http://w3.whu.edu.cn/en/ |

### WUT New Energy Co Ltd

| | |
|---|---|
| Company | Location, Wuhan; established May 2006, a spin-off from Wuhan University of Technology; 50 staff (20 academic) plus >100 students |
| Fuel Cell Interests | PEMFC only. Catalysts, membrane electrode assemblies, recent investment in semi-automated MEA production. MEA Capacity 5,000 $m^2$/year |
| Website | http://www.wutenergy.com/index.asp |

# Appendix II: References

1. CIA, The World Factbook: China

2. IEA Energy Statistics

3. Union of Concerned Scientists: http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html

4. IEA Global Renewable Energy, Policies and Measures

# Appendix III: Glossary

CCS –Carbon Capture and Storage
$CO_2$ – Carbon dioxide
DMFC – Direct Methanol Fuel Cell
FCEV – Fuel Cell Electric Vehicle
GDP – Gross Domestic Product
GEF – Global Environment Facility
GW – Gigawatt ($1x10^9$ Watts)
IEA – International Energy Association
ISO – International Organisation for Standardization
kW – Kilowatt ($1x10^3$ Watts)
MEA – Membrane Electrode Assembly
MOST –Ministry of Science and Technology
MPa – Megapascal
MW – Megawatt ($1x10^6$ Watts)
PEMFC – Proton Exchange Membrane Fuel Cell
R&D –Research and Development
RMB– Chinese currency
SOFC – Solid Oxide Fuel Cell
TWh – TeraWatt hour
UNDP – United Nations Development Programme
US EIA – United States Energy Information Administration

FuelCellToday
The leading authority on fuel cells

Fuel Cell Today, Gate 2, Orchard Road
Royston, SG8 5HE, Hertfordshire, UK
www.fuelcelltoday.com