Biweekly Report 004 Sep/19

Research on Fuel Cell Vehicle Industry Development

Sep. 2016

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SMM
Shanghai Metals Market

The following terms are used in this report

Acronym	Definition
FCEV / FCV	Fuel cell electric vehicles / fuel cell vehicles
BEV	Battery electric vehicles
PHEV	Plug-in hybrid electric vehicles
PEMFC	Proton exchange membrane fuel cell
DMFC	Direct methanol fuel cell
SOFC	Solid oxide fuel cell
AFC	Alkaline fuel cell
MCFCI	Fusion carbonate fuel cell
PAFC	Phosphoric acid fuel cell
PFSA	Perfluorinated sulfonic acid
PEM	Proton exchange membrane

1

Toyota's Hydrogen Fuel Cell Mirai at the Chengdu Car Exhibition

Sep. 2, 2016 *Source: powerlife.com*

Toyota brought its Mirai hydrogen fuel cell vehicle to the 2016 Chengdu car exhibition, which had been on the 2015 Shanghai car exhibition but it still received a lot of attention.

The car can fill up an empty hydrogen tank in 3-5 minutes, with endurance reaching 600km, which are almost the same as ordinary petrol car. In contrast, charging fully may take at least 1-2 hours for Battery Electric Vehicles (BEV), and the maximum endurance is about 300 km.

2

Over 200 of China's Fuel Cell Electric Vehicles Entered Demonstration Operation

Sep. 5, 2016 *Source: Yangzi River Daily*

The 2016 Taiwan and China Mainland Summit Forum of Fuel Cell Technology & Industry Development was held recently in Wuhan Development Zone (Hannan District), which was co-sponsored by China Electrical Equipment Industry Fuel Cell Branch and Taiwan Institute of Economic Research Fuel Cell Promoting Office.

Many international leaders like Audi, Toyota and Nissan all keep investing and making breakthroughs in the research of fuel cell vehicle industry and try to improve its degree of commercialization, as well as companies at home. Over 200 fuel cell electric vehicles were put into operation, which serviced the Beijing Olympic Games and Shanghai World Expo, with travelling distance over 100,000 km.

Abstracts

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1 Fuel Cell Vehicles are Major Users of Hydrogen Fuel Cell

- Currently **the proton exchange membrane fuel cell (PEMFC)** is widely used in fuel cell vehicles, which uses pure hydrogen as fuel, also known as hydrogen fuel cell
- In comparison with lithium battery vehicles, fuel cell electric vehicles **have longer endurance and shorter charging time**. **The cost of fuel cell electric vehicles is the lowest** compared to diesel vehicles and Battery Electric Vehicles

2 China's Fuel Cell Vehicle Market is in Its Introduction Period, and Fuel Cell System, Hydrogen Production, Storage and Refueling Station are Its Key Parts

- **Fuel cell system represents 63% of total cost.** China's fuel cell technology is still immature compared to foreign countries
- China's hydrogen production is still **in the exploratory stage**, and cost is expected to fall further
- Hydrogen storage bottle is decisive for endurance. **China has mastered technology for 35Mpa hydrogen storage bottle, but using 70Mpa bottle is the industry trend**
- **Hydrogen refueling stations are scarce in China**, and core device still relies on import

3 Development of China's Fuel Cell Industry is Still Restricted as Technology for Key Parts is 5-10 Years Backward than Foreign Countries

- **Fuel cell pile, air circulation system and hydrogen air circulation system** account for 91% of total cost of fuel cell system. Such cost is still high in China due to weak key technology
- Fuel cell pile consists of **proton exchange membrane, bipolar plate and catalyst**. In China, proton exchange membrane almost realized industrialization, and graphite bipolar plate technology is relatively mature, but metal bipolar plate is the industry trend. The catalyst relies heavily on platinum, which is expensive, and there is small-scale production in China, and emphasis is put on the research of ultra-low platinum catalyst or platinum-free catalyst
- Main technology of air circulation system's **air compressor** is helical-lobe compressor and scroll compressor. In China, no mature product has been developed yet.
- **Hydrogen circulating device** has been put into utilization in foreign countries, but it remains being developed in China, and there has been no mature product yet.

4 Subsidy Policy Keep Supporting Fuel Cell Vehicle Industry

- China's Fiscal Support Policy for New Energy Vehicle Promotion 2016-2020 **stipulates RMB 200,000-500,000 subsidy for the fuel cell vehicle industry**, which is much higher than battery electric vehicles and plug-in hybrid electric vehicle
- There are also additional policy supports the fuel cell vehicle industry and development of technology for key parts

Contents

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6 Types of Main Fuel Cell in the Market, and 2 Types of Vehicle Fuel Cell

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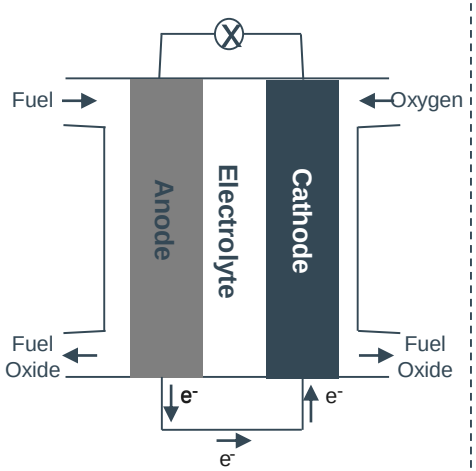
Definition and Principles of Fuel Cell

1. Definition

- Consisting of anode, cathode and ionic conduction electrolyte
- **A power generation device which converts chemical energy in fuel and oxidizing agent into electric**
- Fuel cell ≠ storage battery. Fuel cell generates electric, while storage battery stores electric

2. Principle



Classifications of Fuel Cell

1. Six Main Types in the Market

Battery System	1. PEMFC	2. DMFC	3. SOFC	4. AFC	5. MCFC	6. PAFC
Fuel	High purity hydrogen	Hydrogen or liquid methyl alcohol	Gas, methane	High purity hydrogen	Gas, methane	Mainly hydrogen
Catalyst	Platinum	Platinum-ruthenium	Low reliance on platinum	Non precious metals Normally nickel	Precious metals	Platinum
Operating Temperature	60-100	100	1000-1200	100	500-800	60-200
Catalyst	Solid/ PFSA polymer film	Solid/polymer film	Solid/zirconium dioxide ceramic material	Liquid/aqueous potassium hydroxide solvent	Liquid/carbonate carbonate solvent	Liquid/phosphoric acid solvent
Application Fields	Automobile	Consumer electronics, material transporters	Large and small power generation station	Aerospace	Large power generation station	100-400KW fixed power generation station, large vehicles

2.Two Types of Vehicle Fuel Cell

- Two main types of **fuel cell are suitable for transportation**: Proton Exchange Membrane Fuel Cell (PEMFC) & Direct Methanol Fuel Cell (DMFC)
- The reason why they are suitable is that their operating temperature and relatively rapid dynamic response as vehicle energy source meet vehicle's requirement
- Currently **the proton exchange membrane fuel cell (PEMFC)** is widely used in fuel cell vehicles, which uses pure hydrogen as fuel, also known as **hydrogen fuel cell**

Hydrogen Fuel Cell-The Main Type of Fuel Vehicles Power in the Future

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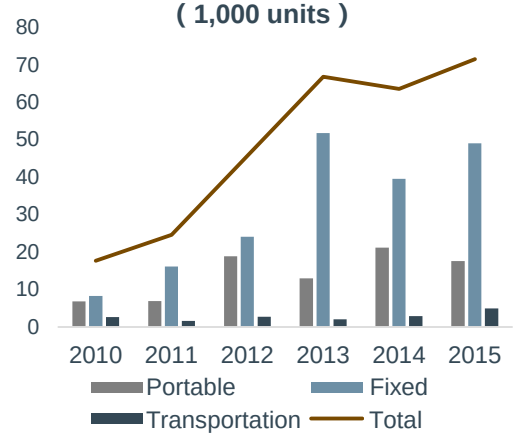
Application Fields

Shipments in Different Application Fields (1,000 units)

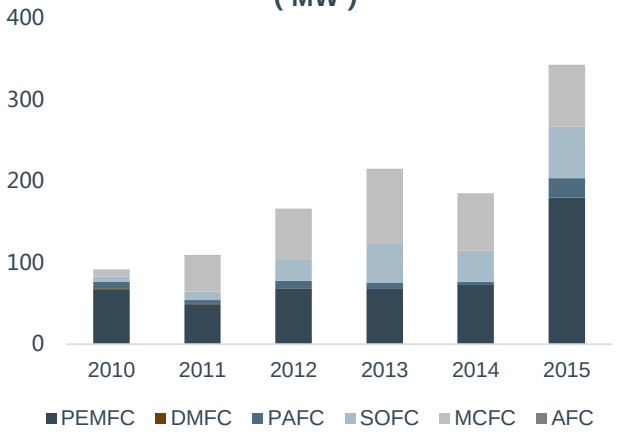


Sources:E4tech， Essence Securities ，SMM

- Global fuel cell shipments were 71,500 units in 2015, up nearly 304% from 2010, but the level was still far from large-scale commercialization
- Shipments to transportation field only took a small proportion during 2010-2015, but **nearly doubled in 2015**
- **Utilization in the transportation field has great potential**

Market Requirement

Annual Shipments of Different types of Cell (MW)



Sources: E4tech， Essence Securities，SMM

- Demand for **PEMFC, SOFC and MCFC is relevant strong**
- **Shipments of PEMFC surged 147.04% YoY in** 2015 due to strong demand from the transportation industry

Driving Factor

Environmental Protection Requirement

- The maximum **energy efficiency conversion ration exceeds 60%:** hydrogen cell directly converts chemical energy of hydrogen and oxidizing agent into electric energy
- **Environmental friendly**: continuous electricity generation and main product of the reaction between hydrogen and oxygen are water, which can achieve zero emissions

Performance Optimization Requirement

- **High energy density:** nearly 120-fold of lithium battery
- Advantage in charging time and endurance : can achieve hundreds of kilometers endurance in a few minutes' charging

Note: fuel cell is mainly used in fixed power source, portable power source and transportation fields.

Contents

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Main Technical Proposal for Fuel Cell Vehicle is Mixed Type of Fuel Cell and Storage Battery

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Technical proposal	Feature	
Fuel Cell Engine Driven Only	• High power and high cost • Power changes with load. Efficiency of fuel cell system is low when vehicle is low loading • Slow dynamic response, which will affect accelerating ability • No regenerative brake	Abandoned by most companies
Mixed Type of Fuel Cell & Storage Battery (Full Power Type)	• Fuel cell is major energy source • Storage battery is unable to meet requirement of driving with no load • Have advantages when keep high-power output for a long time • No need for circumscribed charging unit	International Main technical proposal
Mixed Type of Fuel Cell & Storage Battery (Plug-in Type)	• Relatively low battery power rating • Storage battery can meet demand for a pure-electric-driving drive in certain distance • Circumscribed charging	Used by SAIC
Fuel Cell Engine + Super Capacitor	• Fuel cell is major energy source and super capacitor provides peak power • Super capacitor has good instant charging and discharging ability, long cycle life and low cost. But storage capacity is limited, with big voltage fluctuation	Used by Volkswagen's HY.POWER
Fuel Cell Engine +Storage Battery + Super Capacitor	• Lower requirements for power of fuel cell and storage battery • Super capacitor has high current discharge ability when the temperature is low • Longer service life of battery	Both Structure and Operation are Complicated

Main

Note: Super capacitor is a new type of energy storage device, with high power density and short charging time

Fuel Cell Vehicles may be More Economical & Convenient

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	Lithium Battery Electric Vehicle	Fuel Cell Electric Vehicle
Similarity	• Zero fuel consumption, zero release and low noise	• Zero fuel consumption, zero release and low noise
Performance comparison	• **Endurance**: 400km • **Charging Time**: 30 minutes for fast charge，8 hours for trickle charge • **Performance at Low Temperature:** Weakens significantly • **Energy Exchange Efficiency:** High • **Safety:** Overcharging, fire at high temperatures	• **Endurance:** Above 500km • **Charging Time:** 3 minutes • **Performance at Low Temperature:** Still good • **Energy Exchange Efficiency:** Over 60% • **Safety:** Risk of leakage during hydrogenation
Cost comparison	• **Purchase Cost**: For vehicles made in china, below RMB 300,000/vehicle, a RMB 30,000-55,000 subsidy can be set off • **Working Cost**: Tesla model s 60（battery capacity 60kwh，endurance 390km），RMB 0.075/km providing electricity prices during third level of low demand period in shanghai	• **Purchase Cost**: For vehicles made in china, above RMB 600,000/vehicle， a RMB 200,000 subsidy can be set off • **Working Cost**: Toyota Mirai， hydrogenation cost JPY 5000 once, supporting endurance 500km, which means RMB 0.65/km（based on exchange rate of 0.65）
Infrastructure construction comparison	• **Charging Station**: 81,780 public chargers has constructed as of H1 2016 in China, and aims to complete 4.80 million chargers by 2020	• **Hydrogen Refueling Station**: There are only three which are all at demonstration stage at home, located in Beijing, shanghai and Zhengzhou, and there remains no clear government construction plan now

Note: Red words denote advantage

Compared to Lithium Battery Electric Vehicles, Fuel Cell Vehicles may be More Convenient

Cost per 100 kilometers

Vehicle model	Fuel cost	Consumption	Cost
Diesel Vehicle	RMB 2.04/kWh	9.2L/ 100km	RMB 47/100km
BEV	RMB 1.16/kWh	23kWh/ 100km	RMB 26.7/100km
Hydrogen Fuel Cell Vehicle	RMB 0.96/kWh	23kWh/ 100km	RMB 22/100km

Source: SMM

Compared to Diesel Vehicle & BEV, fuel cell vehicles may be more economical

Fuel Cell Vehicle Industry is in Introduction Period, Restricted by Backward Key Part Technology

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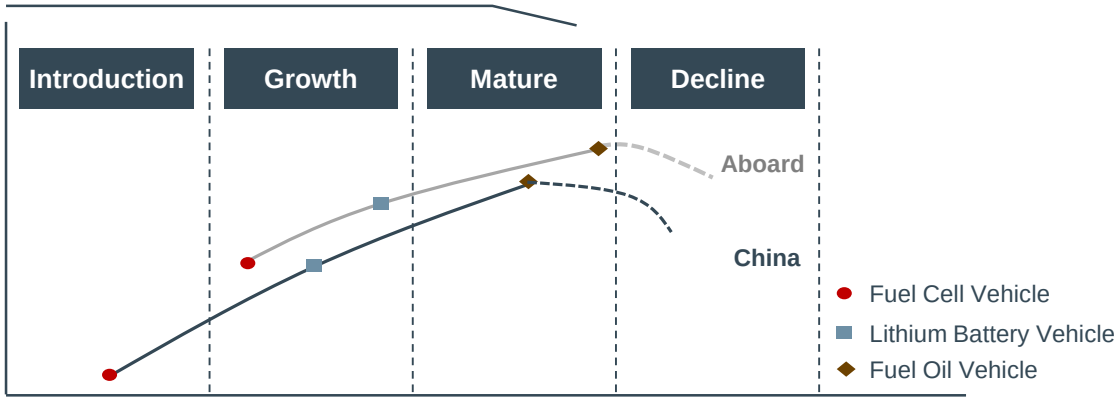
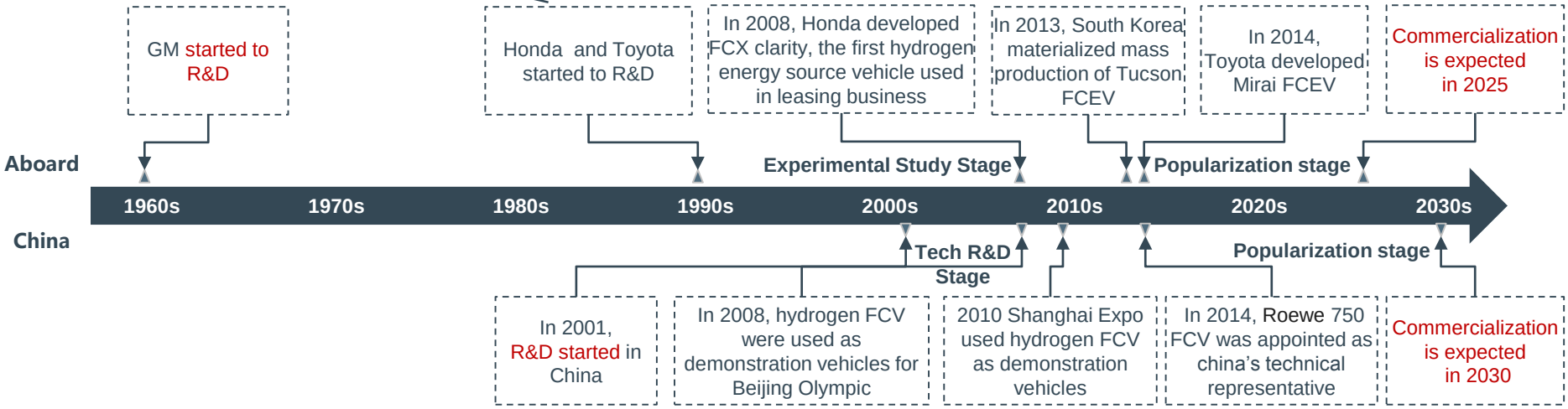
1.Development Stage of Major Vehicle Types at Home and Aboard



FCV industry aboard has entered initial stage of commercialization

FCV industry in China remains in introduction stage. Only 10 out of the 330,000 EVs sold in 2015 were hydrogen FCV

2.Development Stage of Hydrogen Fuel Cell Vehicles at Home and Aboard



Overall, hydrogen FCV at home is 5-10 years backward than aboard

Government Accelerates Fuel Cell Vehicle Development(1): Policy

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Policy type	Time	Document Name	Main content
Planning Target	2001	863 Plan-Major Special Projects for Electric Vehicle	FCV, BEV and PHEV were included in the "Three Horizontal and Three Vertical“
	2015	Made in China 2025	Three-step development for fuel cell vehicle
	2016	Guidance Directory of major Products and Services of Strategic Emerging Industries	Introduction of fuel cell system and core parts, FCV, hydrogen charging & storage facility
Technology Guidance	2014	Plan for electric vehicle in the 13th Five-Year Plan Period	Improving surface modification technology for metal bipolar plate and durability technology for vehicle fuel cell, and pushing hydrogen refueling station construction and FCV demonstration operation works in the next few years
	2016	Action Plan for Energy Technology Revolution Innovation (2016-2030)	Mastering efficient hydrogen preparation, purification, storage and transportation technology, realizing utilization of hydrogen energy and fuel cell technology in energy and hydrogen refueling station fields
Tax Preference	2011	China Vehicle and Vessel Tax Law	Vehicle and vessel tax is exempt for fuel cell vehicle
	2014	Notice Regarding Exemption of Purchase Tax for New Entergy Vehicle	Purchase tax for new energy vehicle was exempted during September 1, 2014 and December 31, 2017.12
Fiscal Subsidies	2009	Provisional Regulations on Fiscal Subsidy Funds for Energy-Saving & New Energy Demonstration Vehicle	Zero release electric and fuel cell vehicles enjoy RMB 60,000-600,000 fiscal subsidy
	2014	Charging Facility for New Energy Vehicle	Newly manufactured FCV hydrogen refueling stations that meet national standard and with daily hydrogenation capacity no less than 200 kg enjoy RMB 4 million award
	2015	Guidance Directory of Major Products and Services of Strategic Emerging Industries	Fuel cell passenger vehicles will enjoy RMB 200,000 subsidy during 2016-2020, with RMB 300,000-500,000 for commercial vehicles

Made in China 2025- Development Strategy for FCV

Strategy	Goal
Step 1: Domestication of **Key Material And Parts**	By 2020, realizing security of quality in mass production for fuel cell key materials
Step 2: Increasing **Performance** of Fuel Cell and Cell Pile	By 2020, service life of fuel cell will reach 5,000 hours, with power density over 2.5kw/L, endurance reaching 500km, charging time below 3minutes, and minimum starting temperature below -30℃
Step 3: Expanding **FCV Operation Scale**	By 2020, producing 1000 FCVs by and improving hydrogen production and hydrogenation facility

Note:

- Chinese government has already planned to develop FCV as early as 2001. “863 Plan-Major Special Projects for Electric Vehicle” identified "Three Vertical and Three Horizontal" , "three vertical” includes BEV,PGEV and FCV
- In 2015, "Made in China 2025" Plan issued, proposed a three-step FCV development strategy
- By 2020, achieving the target that producing 1,000 FCVs and carrying out the demonstration operation

Government Accelerates Fuel Cell Vehicle Development(2): Subsidy

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1. Subsidy for Fuel Cell Vehicles 2016-2020

FCV Types	Subsidy (RMB 10,000/vehicle)
Passenger Vehicles	20
Light Bus and Truck	30
Large and Medium-Sized Bus, Medium and Heavy Truck	50

Subsidy for FCV is up to 20-50 per vehicle, which shows the national policy strong support for the development of FCVs

2. Subsidy Comparison for New Energy Passenger Vehicle 2016-2019

Type	Mileage (km)	2013	2014	2015	2016	2017	2018	2019
BEV	2013-2015 (80≤R<150)	3.5	3.325	3.15	-	-	-	-
	2016-2020 (100≤R<150)	-	-	-	2.5	2	2	1.5
	150≤R<250	5	4.75	4.5	4.5	3.6	3.6	2.7
	R≥250	6	5.7	5.4	5.5	4.4	4.4	3.3
PHEV	R≥50	3.5	3.325	3.15	3	2.4	2.4	1.8
FCV	-	20	19	18	20	20	20	20

Subsidy for both BEV and PHEV will decrease during 2016-2019

Subsidy for FCV will not fall during 2016-2019 and is much higher than it for BEV and PHEV

The Key to the Fuel Cell System

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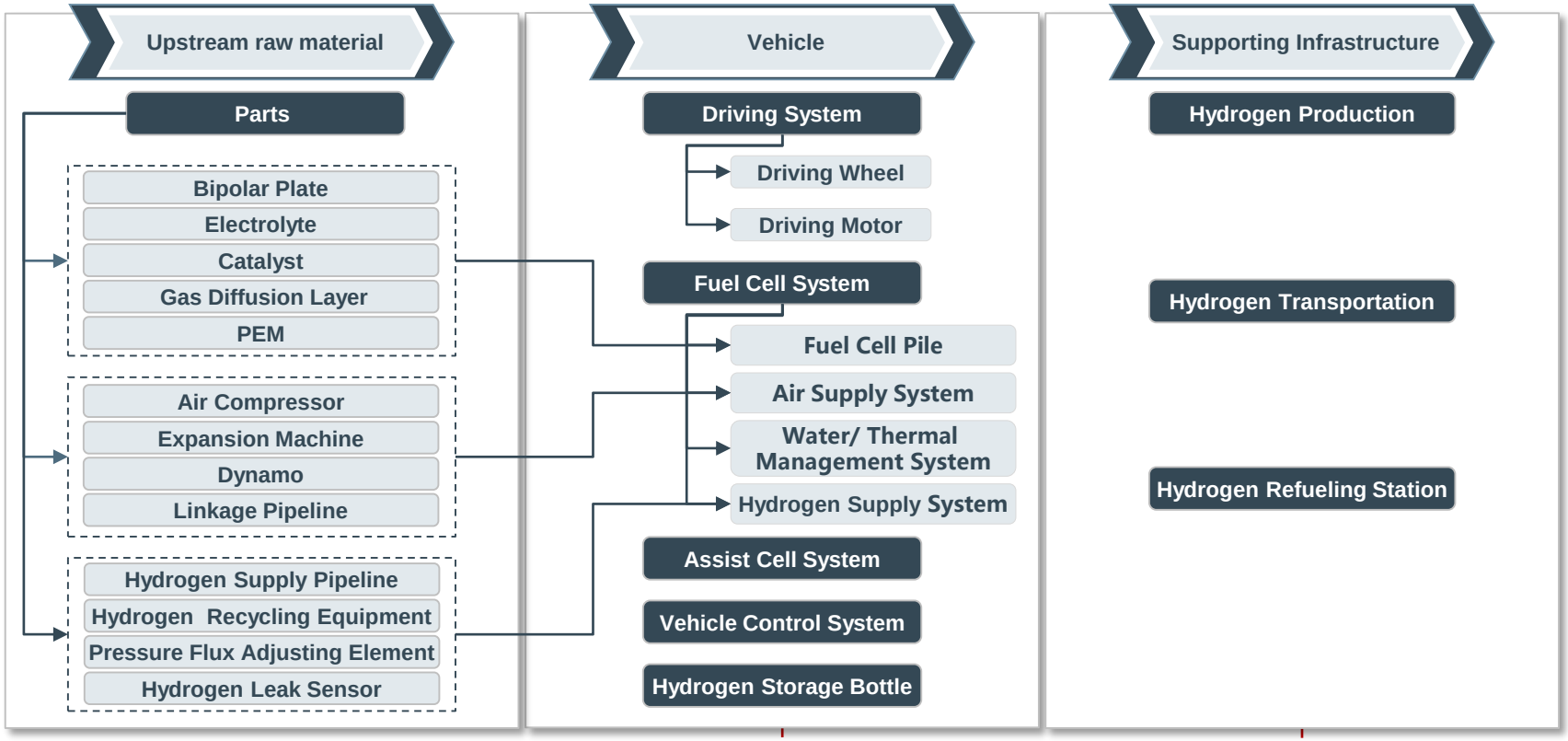
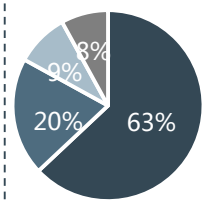


FCV cost structure



- Fuel Cell System
- Other Parts
- Motor System+ Assist Cell
- Hydrogen Storage System

Sources: science & technology review, 51report.com

Key: Fuel Cell System, Hydrogen Storage Bottle

- Big gap between domestic and overseas technology
- Weak key part technology restricts localization
- Requirements for producing hydrogen storage bottle are high

Key: Hydrogen Production, Hydrogen Refueling Station

- Immature hydrogen production technology in China
- Scarce hydrogen refueling stations

Note: Assist cell system means motive cell and flywheel energy accumulator, or motive cell and super capacitor. Traditional hydrogen transportation is widely used in FCV industry

China Fuel Cell Technology Remains Immature

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1. Target And Status Quo Of Fuel Cell Technology

Technical Indicator	International Status in 2015	DOE Target in 2020	DOE Long-Term Target	Made In China 2025 Target
Fuel cell system				
Power density (W/L)	640	650	850	-
Specific power (W/kg)	659	650	650	-
Cost for annual production of 500,000 units ($ /kw)	53	40	30	-
Life (hours)	5000	5000	8000	-
Non-assist cold boot temperature (℃)	-30	-30	-30	≤-30
Fuel cell pile				
Pile power density (W/L)	3100	2250	2500	2500
Specific power (w/kg)	(Toyota)	2000	2000	-
Cost for annual production of 500,000 units ($/kw)	2100	20	15	-
Durability (hours)	(Nissan)	5000	8000	5000
	26			
	3900			

- **Overseas key technology has almost reached or exceeded the target value**
- **Parts of the key technology still lacks clear development plan in China**

Note: DOE means US department of energy

Sources: DOE multi-year research, development, and demonstration plan 2016 , made-in-china 2025 , SMM

2. Comparison of Key Indicators in China and Overseas

Representatives	Power Density (kw/L)	Endurance (km)	Cold Boot Temperature (℃)	Hydrogen Storage Capacity(kg)
Overseas (Japan: Toyota Mirai)	3.1	>500	-37	5.0
Overseas (Germany: Daimler F125)	-	1000	-25	7.5
Domestic (Roewe 950 Fuel Cell)	<1	400	-20	4.18

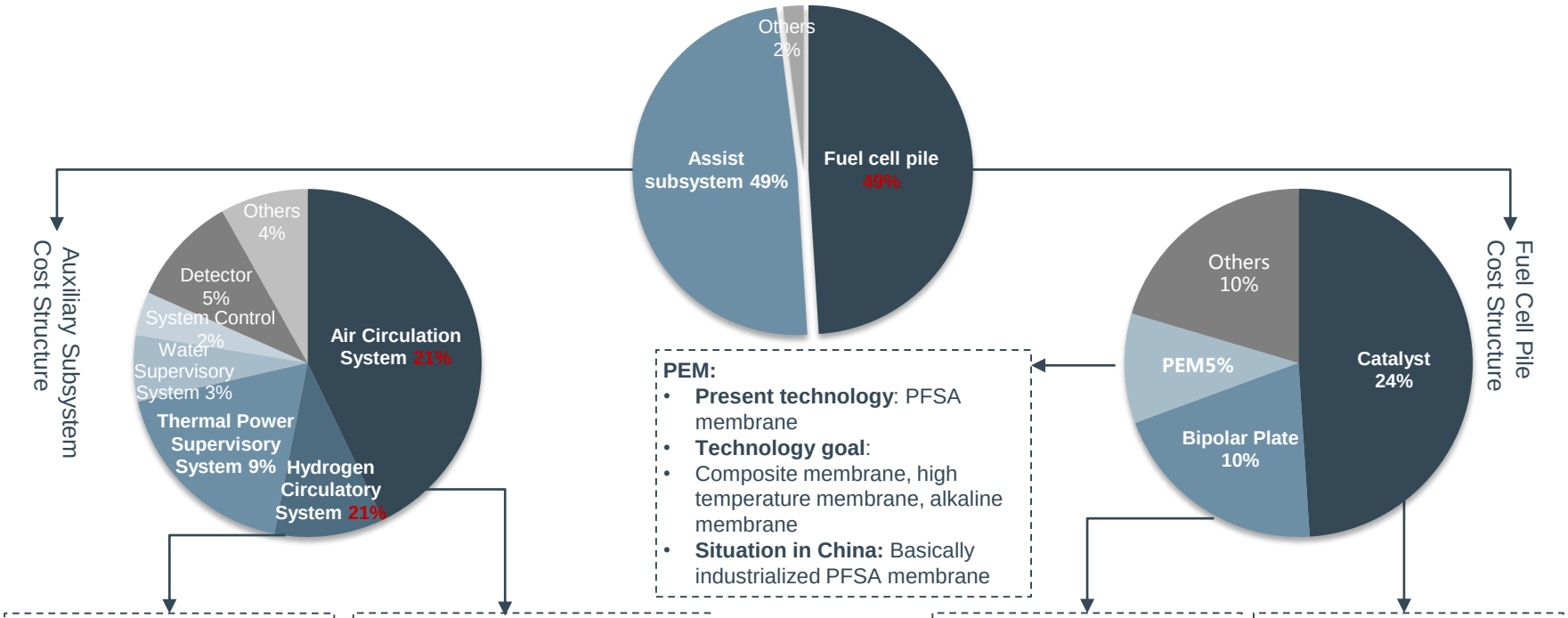
- **The representative FCVs in China performs obviously not as good as FCVs overseas in many key indicators, such as power density, endurance, cold boot temperatures and hydrogen storage capacity**

Sources: evdays.com , diandong.com , SMM

Lack of Key Part Technology Restricts Fuel Cell Localization in China

- Lack of key technology on fuel cell pile, air circulation system and hydrogen circulatory system is the current situation in China , which account for most of the fuel cell system cost

Fuel cell system cost structure



PEM:
- **Present technology**: PFSA membrane
- **Technology goal**:
- Composite membrane, high temperature membrane, alkaline membrane
- **Situation in China:** Basically industrialized PFSA membrane

Hydrogen Circulatory System:
- Have been put into operation aboard
- It remains to be at R&D stage in China

Air Circulation System:
- **Present technology:** Industry compressor
- **Technology goal:** Turbine air compressor, screw turbine air compressor
- **Situation in China:** High technical barriers and overseas companies have core technology

Bipolar Plate
- **Present technology:** Graphite bipolar plate
- **Technology goal:** Metal bipolar plate
- **Situation in China:** Metal bipolar plate remains to be at R&D stage

Catalyst:
- **Present technology:** Pt/C catalyst is expensive due to platinum tightness
- **Technology goal:** ultra-low platinum or platinum free
- **Situation in China:** Only a few producers have small capacity, with high cost.

Note: PEMFC mainly uses Pt/C catalyst, which consists of pt particles (3-5nm) and active carbon with large specific surface area which support the particles

Hydrogen Production Technology is at R&D Stage and its Cost is Expected to Decrease Further

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- Hydrogen as a raw material of fuel cell is an important part of the industry, but nature of hydrogen is very rare. So hydrogen production technology needs to take factors into consideration, like environment, economics and practicality

Current Technology

1 Short-term

Process Route	Hydrogen Cost	Applicable Scale	
Natural Gas Conversion (Including Refinery Gas)	RMB 0.8-1.5/Nm^3	200-20×104	Low cost, wide application, but polluting
Naphtha Conversion (Including Liquefied Gas)	RMB 0.7-1.6/Nm^3	500-20×104	
Coal Gasification (Including Coke)	RMB 0.6-1.2/Nm^3	1000-20×104	High cost, immature technology, most environmental friendly
Liquid Ammonia Decomposition	RMB 2.0-2.5/Nm^3	10-200	
Methanol Decomposition	RMB 1.8-2.5/Nm^3	50-500	
Water Electrolysis	RMB 3.0-4.0/Nm^3	10-200	

Source: galaxy securities

- **Hydrogen can be produced and separated out** during the manufacturing of synthesis ammonia, synthesis methyl alcohol and petroleum
- **Cost of hydrogen is lower than gasoline,** calculated based on daily fuel charge. Based on oil corporation's liquid hydrogen prices in Japan, it costs JPY 5000 to fill up Toyota Mirai's 5kg hydrogen tank, or RMB 298. Prices are **below RMB 0.5/km**, with endurance of 650km. Regular 2.0T gasoline vehicle will cost RMB 0.7-0.8/km. If hydrogen production cost decrease in the future, marginal cost of FCV consumers will fall more obviously

Technology Target

2 Medium-term

- **Technology trend:** Hydrogen production technology is based on **renewable resources** such as biomass, which is a kind of important renewable energy
- **Technical difficulties: Low quality density and energy density, and high tar content after biomass gasification** are two major problems

3 Long-term

- **Technology trend: Zero-emission hydrogen production technology based on solar energy** is likely to be realized in the long term. Percent conversion of the technology is still low, but the technology has been used by Japanese producers in solar energy hydrogen refueling station, which serves as provisional and complementary hydrogen fuel replenishment method
- **Technical difficulties:** Solar energy hydrogen production technology has **low percent conversion**, with research emphasis on photocatalysis and the composition of efficient and long-life photocatalyst.

Note: Nm^3 means normal cubic meter, which is gas volume unit with 0 degree centigrade and 1 standard atmospheric pressure

Hydrogen Storage Bottle Technology Has Large Room to Improve

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- Hydrogen storage bottle is decisive for endurance, and the industry tend is 70mpa hydrogen storage bottle

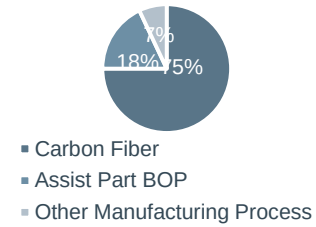
Comparison of Hydrogen Storage Technology

	High Pressure Gaseous Hydrogen Storage	Liquid State Hydrogen Storage	Hydrogen Storage Material Hydrogen Storage	
			Ti Hydrogen Storage Alloy	Carbon Nano Tube
Safety	low	low	high	
Energy Utilization Rate	low	low	high	
Unit Hydrogen Storage Capacity/%	-	-	2	4
Unit Hydrogen Storage Capacity (kg/M^3)	31.5	71	61	160
Unit Energy Density (Kwh/Kg)	-	-	0.8	5.53
Unit Energy Density (Kwh/L)	1.24	2.8	2.4	6.32
Merit and Demerit	Convenient but high pressure is dangerous	High storage and transportation efficiency, but high energy consumption	Safe, easy to transport but high cost	

Key Technology Used by FCV

Current Technology

1 Hydrogen Storage Bottle Cost Structure



Sources: DOE, Huatai securities

2 International Advanced Level

- Technology of 70MPa hydrogen storage bottle is mature. FCVs that have realized or will reach mass production mostly use 70mpa hydrogen storage bottle
- Endurance of several FCVs is over **500km,** such as Hyundai ix35, Toyota Mirai and Honda clarity

3 Technology in China

- Key technology is mastered in China, but is still far from industrialization
- Vehicle-mounted **70MPa** hydrogen storage bottle has been developed. SAIC also mastered key technology for 70mpa high pressure hydrogen storage and fuel supply system, but is still weak in low-cost industrialization production technology and research of key materials. Key valve and sensor still rely on import

Technology Trend

1 Hydrogen Storage Bottle Requires High Efficiency and Safety

- **Efficiency:** Hydrogen storage bottles majorly use carbon fiber material, which accounts for 75% of total cost, and 60-70% of total weight. **Reducing use of fiber and carbon fiber cost** is major target for domestic and overseas technology development in the future
- Safety: Hydrogen storage bottles are required to use **coating with high density** or metal clad layer, so as to raise airtightness
- Trend: 70MPa hydrogen storage bottles meet DOE's 5.5% mass density requirement, with endurance reaching 500km, which will be the developing trend

2 Target For Vehicle-mounted Hydrogen Storage Facility Technology

Indicator	Unit	2020	Final
Quality hydrogen storage density	kWh/kg	1.8	2.5
	kg H_2/kg system	5.5%	7.5%
Volume hydrogen storage density	kWh/L	1.3	2.3
	kg H_2/L system	0.04	0.07
Unit costs	$/kWh net	10	8
	$/kg H_2 stored	333	266

Source: Data released by DOE may 2015

Few Hydrogen Refueling Station in China and Key Devices Still Rely on Import

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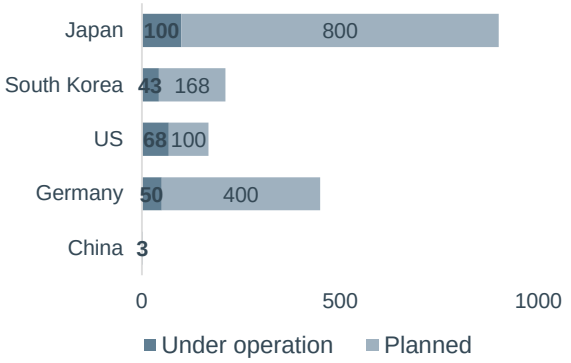
- The Ministry of Finance (MoF), Ministry of Industry & Information Technology (MIIT) and National Development & Reform Commission (NDRC) released the Notice Regarding Award to New Energy Vehicle Charging Facility Construction in November 2014, stipulating that each newly constructed fuel cell car hydrogen refueling station that meets national standard and with daily hydrogenation capacity **no less than 200kg** will **receive RMB 4 million** as an award during **2013~2015**

Comparison of Hydrogen Refueling Station Numbers in China and Overseas

Number of Hydrogen Refueling Station under Operation and Planned in Major Countries(unit)

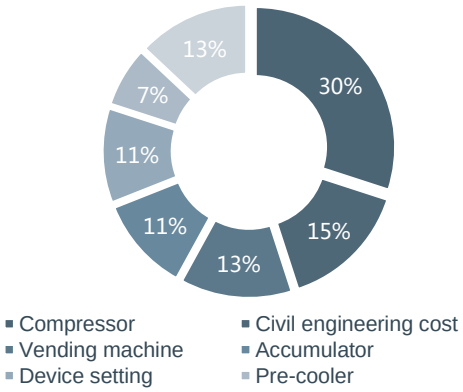


Source: SMM

- Development strategy has been made for fuel cell vehicle promotion and hydrogen refueling station infrastructure construction in Japan, US and Europe. However, there are only three which are **all at demonstration stage** at home, located in Beijing, shanghai and Zhengzhou, and there **remains no clear government construction plan now**

Cost Analysis

Hydrogen Refueling Station Cost Structure



Sources: GF Securities, SMM, July 2016

- Current Construction Model
  - **Direct Construction:** Cost above USD 4 million
  - **Gas Station Transform:** Adding hydrogenations, cost below USD 2 million
  - **Mobile Hydrogen Refueling Station:** Cost only 50% of direct construction.
- Government and automobile manufacturers are major constructers due to high cost, with government subsidy over 50%

Technology analysis

Main Technology

- **Home-Made Hydrogen Technology:**
  - **Water-Electrolytic Hydrogen Making: The technology is very mature**, and uses highly integrated shell device, which is easy to install and more automatic, and takes up less room
  - **Hydrogen making by natural gas reformation** is of **low cost**, but **initial investment is high**, and is polluting, widely used in **chemical industry**
- **External Hydrogen Supply:** Hydrogen deriving from industry

Comparison

- **Overseas:**
  - Europe, US and Japan: Technology totally mastered of hydrogen compressor, high pressure hydrogen storage bottle and hydrogen refueling machine, which are three core devices for hydrogen refueling station
  - **Europe:** Water-electrolytic hydrogen making technology is mainly used
- **China**:
  - Hydrogen refueling station devices mainly rely on import, which is expensive. Science & technology department is now supporting to construct a self-developed hydrogen refueling station
  - Shanghai's hydrogen refueling station mainly uses industrial hydrogen. Beijing uses pipeline hydrogen, reformed natural gas and water-electrolytic hydrogen in hydrogen refueling station

Contents

Overseas Representative: Toyota

Shanghai Metals Market

Development of FCV

1992	2012	2013	2014	2015	2020
Start to R&D of FCV	Toyota signed FCV memorandum of understanding	Jointly developing fuel cell system with BMW, and making breakthrough in PEMFC	**Launched FCV Mirai**	**Providing 5680 fuel cell system patents for free**	Planning to sell 10,000 vehicles of Mirai

Representative Products

Toyota Mirai (First Launch on December 15, 2014)

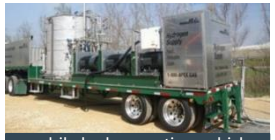
- Selling Price in Japan: JPY 6.70 million, with JPY 2 million government subsidy
- Fuel Storage Method: One large and one small high-pressure hydrogen storage tank with capacity of 122.4L, which can hold 5 kg of hydrogen and are three-decker structure
- Maximum Power Output :114kw
- **Hydrogenation Time:3 minutes**
- **Endurance: 650km**
- Max Speed: >160km/h
- Speed Acceleration: 9s/100km
- Output Plan: 700 vehicles(2015)→2000 vehicles (2016)→3000 vehicles(2017)

Technology

- Toyota put emphasis on development of hybrid power and fuel cell vehicles, as it saw limited growth in lithium battery vehicles. Electric vehicles' endurance will barely make breakthrough without reducing load
- Toyota strived to reduce platinum utilization by improving cladding technology, so as to lower production cost of fuel cell vehicles
- Toyota uses expanded graphite-contained fire-proof polyurethane sheet to protect impact resistance polyurethane sheet, so as to secure fire resistance

Hydrogenation Solution

- In response to government requirement, Toyota jointly invest JPY 6 billion with Honda and Nissan in July 2015 to support hydrogenation station project. Construction cost for each is expected to be USD 5 million, with 50% from government subsidy and 30% borne by the three companies
- Toyota cooperated with Air Products in December 2015 supplying hydrogen fuel with mobile hydrogenation vehicle before the newly constructed hydrogen refueling station in California was completed. Each device can meet the demand of over 30 vehicles, and fill half of Mirai's hydrogen storage tank each time



mobile hydrogenation vehicle

Upstream Partner

- **Fuel Cell Module:** TOYOTA BOSHOKU
- **Vehicle Assembling:** Factory at Toyota Motomachi

Note: Fuel cell memorandum of understanding (MOU): Toyota, Honda, Nissan and Hyundai signed the MOU in October 2012 in Copenhagen, Denmark, planning to introduce fuel cell vehicle to Norway, Norway, Iceland and Denmark during 2014 to 2017, and construct hydrogen refueling station
Three-decker high pressure hydrogen storage tank: inner layer is made of resin which seals hydrogen, middle layer is made of carbon fiber reinforced resin securing compression strength, and surface layer is made of fiberglass fortified resin which protects the surface

Domestic Representative (1): SAIC MOTOR

Shanghai Metals Market

Development of FCV

2001	2008	2009	2010	2011	2015
First generation FCV was developed	Jointly developing 20 FCVs with Tongji University which serviced the Beijing Olympics	Deciding technological path of EVs, and developing FCVs in the medium to long term	**Providing over 40 hydrogen FCVs for Shanghai World Expo**	**SAIC Motor's hydrogen cell did well in the Michelin Challenge Bibendum**	Only SAIC produced 10 FCVs in 2015. Roewe 950 Fuel Cell realized small scale production

Representative Products

Roewe 950 Fuel Cell(First Launch at Beijing auto show April 20, 2014)

- **Power:** Motive battery and hydrogen cell
- **Fuel Cell System:** Proton exchange membrane fuel cell(PEMFC)
- **Endurance:** 400km
- Fuel Storage: Two 70MPa hydrogen storage tank, with capacity of 4.18 kg
- Cold Boot Temperature: -20℃
- Max Speed:160km/h
- **Hydrogen Consumption:1kg/100 km**
- **Hydrogenation Time:3-5 minutes**

Technology

- Technological path of plug-in fuel cell: Fuel cell pile is equipped with a large electric driven engine to keep cost low, which is better for SAIC Motor's development
- SAIC Motor's fuel cell vehicles already materialize marketization, for its advancement, safety and durability and safety is the key technology focus

Hydrogenation Solution

- SAIC built the largest hydrogen refueling station in China, in 2011, which has been dismantled in **2011** due to projecting factor
- SAIC signed memorandum of understanding with AIR LIQUIDE in January 2015 on cooperation in hydrogen plant plan construction research, making of hydrogen plant standard and hydrogen fuel cell promotion

Upstream Partner

- **Roewe 950 Fuel Cell**: Using lithium iron phosphate batteries developed by 811th Research Institute, with fuel cell system jointly developed by SAIC and Sunrise Power
- **Roewe 950 Fuel Cell mounted air compressor** :APM140/90W air compressor produced by GSE

Note:

Michelin Challenge Bibendum: A summit on global sustainable development, and innovativeness think tank targeting at clean, safe, convenient and economic mobility

811th Research Institute: The Shanghai Institute of Space Power Sources

Sunrise Power: A fuel cell company, with a 34% stake held by SAIC, engaging in critical material, key parts and pile system of proton exchange membrane fuel cell engine system

Domestic Representative (2): Yutong

Shanghai Metals Market

Development of FCV

- **2009** — The first generation of FCV launched at the IAA
- **2013** — The second generation of FCV, using low floor, wheel edge motor drive technology and advanced communication bus technology
- **2014** — Joining china FCV technology innovation strategic alliance and passing examination of fuel cell bus production quality by the MIIT
- **2015** — **Meeting Entry requirement by the MIIT, and becoming the first producer qualified for fuel cell bus production in China**
- **2016** — Pushing the third generation of fuel cell bus, and signing letter of intent with Beijing Yihua in April on 100 FCVs
- **2018** — Planning to develop the fourth generation of fuel cell bus, with endurance expected to rise to 800km and lift rising to 10000h

Representative Products

Yutong third generation of fuel cell bus ZK6125FCEVG2

- First Launch: May 23, 2016
- **40km/h Endurance: >600km**
- Hydrogen Storage System: 35mpa aluminum liner Carbon Fiber Enwinding
- Fuel Cell System: Active force, ordinary pressure, non-humidifying, preserved -40℃
- **Hydrogenation time: 10 minutes**
- Cost: Decreased by 50%
- **Life:5000h**
- Battery Management Technology: 睿控3.0

Technology

- Yutong new energy bus uses 睿控3.0 technic, motive cell management technic. When combined with inside and outside box structure and heat management system, temperatures of cell cabin can be controlled between 15℃-35℃
- Yutong bus uses efficient motive system technology, and integrated controller, with high pressure node down 55% and volume falling 63%, which helps reduce failure rate

Hydrogenation Solution

- Yutong constructed china's third hydrogen refueling station in Zhengzhou in 2015
- Hydrogen refueling station can meet the demand of 10 hydrogen cell buses, with capacity reaching 250 kg, which meet the demand of demonstration operation

Upstream Partner

- **Fuel Cell System Supplier**: Sunrise Power
- **Lithium Battery System Supplier**: Lithium Titanate Battery/Zhengzhou Yutong

Note: SINO HI-TECH(BEIJING) INTERNATIONAL EXPERIMENTAL TECHNOLOGY, China's leading hydrogen cell new energy vehicle industry core product supplier

睿控3.0: Yutong's exclusive new energy technology

Domestic Representative (3): Beiqi Foton

Shanghai Metals Market

Development of FCV

2006	2008	2013	2014	2016
Undertaking R&D of hydrogen FCVs with Tsinghua university and SINO HI-TECH(BEIJING) INTERNATIONAL EXPERIMENTAL TECHNOLOGY	Servicing Beijing Olympics marathon and running 801 route in Beijing for one year	Jointly R&D hydrogen fuel electric logistics vehicles with SINO HI-TECH(BEIJING) INTERNATIONAL EXPERIMENTAL TECHNOLOGY	Producing 5 second generation 12m developing hydrogen fuel electric buses and able to run commercial operation	Receiving 100 fuel cell vehicles order from URCar

Representative Products

AUV BJ6852
- First Launch: April 2016
- Length:8.5m
- Endurance:250~500km（ flexible module composition ）
- Endurance of Single Cell Module :50~60 km

- Application: Receiving 100 fuel cell vehicles order from URCar in May 2016, with 60 vehicles due for delivery before the end of 2016 and 40 due for delivery before late 2017

Three "First"

- The first producer signing global largest hydrogen fuel cell bus orders
- The first producer realizing major project of China's 863 plan, and research and manufacturing of hydrogen fuel electric bus
- The first producer materializing industrialization and commercialization of hydrogen fuel electric bus

Hydrogenation Solution

- Beiqi Foton undertook hydrogen fuel cell bus R & D project in national 863 plan with Tsinghua University and SINO HI-TECH(BEIJING) INTERNATIONAL EXPERIMENTAL TECHNOLOGY, the other two are responsible for R&D of hydrogen cell system and vehicle-mounted system, and Foton provided vehicle manufacturing technology
- Foton puts emphasis on R&D of hydrogen cell fundamentals, and the endurance of its AUV hydrogen cell bus reaches 600-700km, close to that of traditional diesel vehicles
- Founding AUV, AUMARK hydrogen fuel cell electric vehicle production base, and completing industry chain covering hydrogen fuel cell electric bus R&D, manufacturing and fuel supply

Upstream Partner

- **Fuel Cell System Supplier**: SINO HI-TECH(BEIJING) INTERNATIONAL EXPERIMENTAL TECHNOLOGY
- **Lithium Battery System Supplier** : Lithium Titanate Battery/ Beijing Keypower Technologies

Note: The 863 plan is national hi-tech R&D plan, which was put forward in March 1986
AUV *and AUMARK are Beiqi Foton's automobile brands*

Contents

Industry Opportunity Exploring

Key Parts of Industry Chain

Fuel Cell System (Key Technical Link Accounts for 63% of Total Cost)

1. **Fuel Cell Pile**
- PEM: PFSA membrane has realized industrialization
- Bipolar plate: graphite bipolar plate technology is relatively mature at home, but metal bipolar plate is the industry trend
- Catalyst: Relying heavily on platinum, which is very expensive. Super-Low Platinum And Platinum-free Is The Trend

2. **Air Circulation System:** Helical-lobe compressor and scroll compressor are key technology, but there remains no such mature products in China
3. **Hydrogen Circulation Device**: Being used overseas, but is still under R&D stage in China

Hydrogen Production (Fuel Source)

1. Hydrogen making by natural gas reformation is of low cost in China but initial investment is high, which is polluting and widely used
2. Water electrolysis hydrogen production is very mature, and is the most environmental friendly hydrogen production method. But its cost is high

Hydrogen FCV

Hydrogen Refueling Station (Core Supporting)

1. Few hydrogen refueling station in China, and core device relies on import
2. Government and automobile manufacturers are major producers of hydrogen refueling station due to high cost, with government subsidy over 50%

Hydrogen Storage Bottle (Regarding to Endurance and Safety)

1. High pressure gaseous hydrogen storage bottle is main technology used in fuel cell vehicles at present
2. Manufacturing technology of 35Mpa hydrogen storage bottle is generally mastered in China, and 70Mpa hydrogen storage bottle is the trend

Recommendation for Investment Target

1. **Fuel Cell Technology Companies**:
- **Sunrise Power**: the company was founded in April 2001, and is the first professional joint-stock company in china dealing with developing of fuel cell products. Sunrise power co., Ltd specialize in developing PEM fuel cell technology for vehicle power and backup power etc., And supplies solutions of PEM fuel cell stack components, FC stacks, FC
- **Shanghai Shen-li High Tech Co., Ltd.** :Founded in June 1998, Is one of the key private companies engaging in PEM fuel cell
- **SAIC** also produces fuel cell system for its own use

2. **Suppliers of Key Parts of Fuel Cell**
- **Snowman**: its holding compan**y OP**CON has air circulation system and helical-lobe compressor technologies
- **Jingcheng Machinery Electric Company**: it has 70mpa hydrogen storage bottle technology

3. **Technology Companies in Hydrogen Refueling Station Field**
- **Chengdu Huaqi Houpu Holdings:** A natural gas device manufacturer, which has successfully developed hydrogen refuel device and entered product test stage
- **Furui Special Equipment:** The company has begun technology development for hydrogen utilization equipment, and has water electrolysis hydrogen production technology and device

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