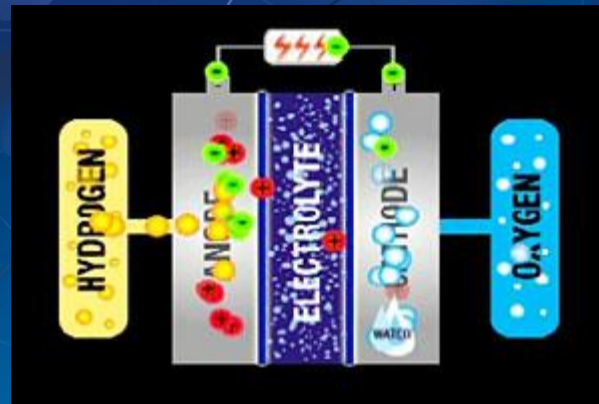


Advanced Manufacturing Technology (TechVision)

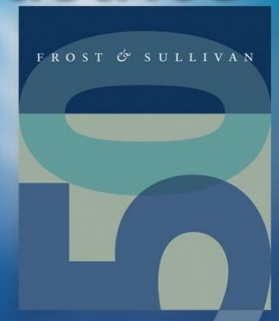


Fuel Cell Power for Manufacturing Industries

Providing sustainable energy for manufacturing industries

D718-TV

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Fuel Cell Power– An Introduction

Fuel Cell Power— An Overview

What are Fuel Cells?

- *Fuel cells are essentially power generation systems that use hydrogen and oxygen to produce electricity.*
- *Fuel cells produce energy that can be called as 'ultra-clean' as they use gases that are available in abundance in nature.*
- *During the functioning of the fuel cell, hydrogen is sent to the anode and oxygen is channeled to the cathode side of the fuel cell.*

Importance of Fuel Cells in Industries

- *Industries are on a constant look out for solutions to improve their energy efficiency as a solution to reduce their carbon footprint.*
- *As the world is moving towards a low-carbon future, industries are looking to obtain more energy from clean (environment friendly) sources. Fuel cells offer ultra-clean energy at a cost on par with other clean energy sources.*

Market Drivers

- *Increase in usage of clean energy in industrial manufacturing*
- *Sustainability*
- *Energy savings*
- *Suitable for various industries*
- *Faster return on investment*

Market Challenges

- *Cost factor*
- *Initial Investment*
- *Integration to industrial power supply systems*
- *Maintenance*

Innovations in Fuel Cell Power for Manufacturing Industries

Alkammonia Fuel Cell

AFC Energy, UK

Tech Profile

Alkammonia fuel cells is the most reliable fuel cells that are existent over a long period of time. Alkammonia fuel cells are highly efficient and forms an ideal source for industrial power generation. Moreover, hydrogen cells for these cells can be fed by recycling some waste products from petroleum and gas industries.

Innovation attributes

- Cost-effective and efficient alkaline fuel cell system
- Advanced fuel processing system
- High-tech ammonia fuel system
- CO₂ emissions reduced
- High-performance energy carrier



Competing Aspects

- Highly modular
- Competitive costs
- Emission-free
- Occupies less space
- Decreases operational costs
- Clean-up setup not required

Company Profile

Incorporated in 2006, AFC Energy is now the world's leading player in manufacturing low-cost alkaline fuel cell technology. This company aims at designing technology that provides clean energy on-demand to oil and gas, natural gas and petrochemical industries.

Impact & Opportunities

Wide-scale Adoption

Less emissions, modular and reduced operational costs would tend to be a very attractive factor in implementing the usage of this fuel system across all the industries. Another important factor for adoption in oil and gas industry is that some waste generated in this industry can be recycled by feeding as hydrogen source for Alkammonia fuel cells

Market Opportunity

With the rising fuel prices and the subsequent increase in the operational cost, advanced fuel systems like ALKAMMONIA would enable cutting cost considerably and operate efficiently. This would pave the way for adopting this technology in various fields.

Technology Convergence

As the fuel cells are very economical and efficient, it can be used as a power source for various stand-alone applications that are not grid connected. It can also prove to be a very good source of power for remote and inaccessible locations like metal mines and coal mines and remote manufacturing facilities.

Freedom Power™ Systems

Alteryg Systems, USA

Tech Profile

Freedom Power™ Systems come in sizes from 500 W to 7.5 kW. And provides grid-free and battery free clean energy solutions for industries and household that can act as standalone power sources or back up power sources.

Competing Aspects

- Compact
- Rugged
- High efficiency
- Power at point of use
- Reliable
- Effective distributed power generation

Company Profile

Alteryg is one of the market leaders in manufacturing proton exchange membrane fuel cells. Alteryg also holds a prominent position in the telecom and infrastructure market.



Innovation Attributes

- California Air Resources Board (CARB)-certified
- Zero emission
- Uniform power quality
- On-demand standby
- Capability to operate in stand alone and combined mode
- Easy interface with other systems

Market Opportunity

Freedom Power™ Systems (FPS) are launched in numerous models like FPS engines, power cabinets and fuel cabinets to suit the needs of various needs of industries like telecommunications and data centers. These model variations will serve as an attractive market opportunity for Alteryg Systems as it gives more benefits to customers.

Technology Convergence

Freedom Power™ Systems' ability to operate in tandem with stand-alone applications and with combined systems would enable them to have flexibility during working.

Wide scale Adoption

With the plug-and-play feature, these fuel cells have wide-scale adoption feasibilities in manufacturing industries of small and medium scale as a primary power source or back up power source.

Jupiter Fuel Cell Systems

Heliocentris Energy Solutions, Germany

Tech Profile

Jupiter Fuel Cell Systems are fuel cell power generation systems manufactured by Heliocentris Energy Solutions as an alternative to uninterrupted power supply (UPS) Jupiter Fuel Cell Systems are available in 19 and 23 inches fuel cell configurations.

Innovation Attributes

- Usage of industrial-grade hydrogen as fuel
- Attractive physical appearance
- Easily combines with other systems
- Capable of meeting on-site requirements

Competing Aspects

- Low complexity
- Easy operation
- Low maintenance
- Zero emissions
- Well packaged
- Available in 2 models
- Higher efficiency

Company Profile

Heliocentris Energy Solutions AG is one of the leading companies in energy management systems. It has also has expertise in developing hybrid power solutions for industries, educational, and research purposes.

Heliocentris

Impact & Opportunities

Wide-scale Adoption

Jupiter is not only a simple-to-use and smart collaborative fuel cell system, but also occupies less space and is highly configurable in different production environments in various industrial verticals. These advantages present very good scope for wide-scale adoption of Jupiter Fuel Cell Systems.

Market Opportunity

Due to its flexibility in size, Jupiter can be an exciting product for applications in manufacturing industries of various scale. Ideal for small scale and medium scale manufacturing industries, these power systems can be used as back up power systems in large manufacturing industries

Technology Convergence

Jupiter Fuel Cell Systems are scalable and involves various technologies like sensors and is available in 2 different form factors. Jupiter Fuel Cells works as a standalone unit and adds to the clean energy requirements of industries.

Ecobox MR-150

Horizon Fuel Cell Technologies, Singapore

Tech Profile

ECOBX-MR150 is the name of methanol reformer integrated fuel cell systems that are produced by Horizon Fuel Cell Technologies to supply clean electricity to industrial environments. Energy intense industries like cement, aluminum and food processing industries will be able to supply the clean energy generated by ECOBOX at various locations in their industries to cut their carbon footprint.

Competing Aspects

- Quick setup
- Low-cost industrial robot
- Wide range of application fields
- High precision
- Integration to computer/machine vision
- Highly sensitive force control system

Company Profile

Horizon is a global fuel cell manufacturer with competence in industries like defense, aerospace, telecom and automotive. Its products vary from micro-fuel cells to very dense industrial oriented grade systems.



- Less peripherals
- Effective off-grid industrial power solution

Innovation Attributes

- Lighter weight
- Easy to integrate
- Highly Flexible

Market Opportunity

Horizon Fuel Cell products are lightweight and offer a configurable operation in terms of its numerous products across various verticals, such as manufacturing and automobile assemblies. Over the time, they will see an increased adoption among electronics OEMs, electronics parts manufacturers and automobile assemblies.

Technology Convergence

Convergence of various technologies is central to industrial automation. Horizon's fuel cell systems efficiently combine various options such as stack modules and off-grid power extends the application potential of these systems to a wider range.

Wide scale Adoption

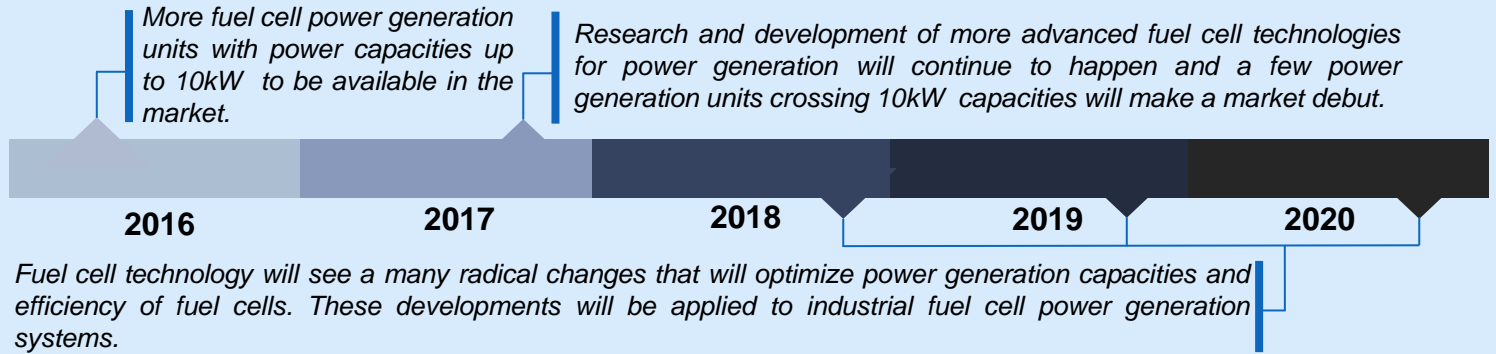
The number of application areas of H-series stacks and other products in electronics and automobile manufacturing promises wide-scale adoption in these industries.

Strategic Perspectives

Technology Roadmap and IP trends

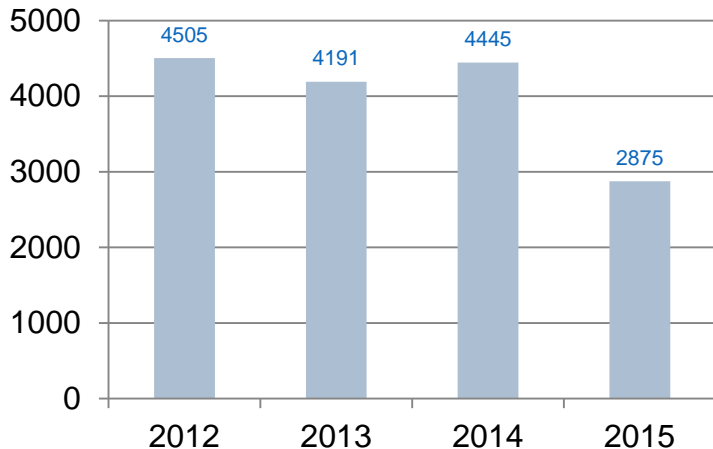
Technology Roadmap

Fuel cell power generation systems are gaining popularity among industries across the world. Technology availability and low cost is fuelling more adoption in Europe. More adoption can be seen in the forthcoming years across the globe.



Intellectual Property (IP)

No. of patents



- The patent filing trends in the last 4 years indicate that the intellectual property activities in fuel cell technology are intense.
- This highest IP activity can be attributed to the fact that fuel cell technology is a field of research that is capable of addressing an important global issue, that is, global warming
- Fuel cell technology has a fairly good amount of research and development activities going on in various universities on par with research in industries and national laboratories.
- Continuous research and focusing research on addressing current industry challenges will lead to more innovations and consequent IP activity in fuel cell technology.

Strategic Insights

The 2020 Scenario



- *In 2020, fuel cells will essentially see wider adoption among manufacturing industries across various industrial verticals.*
- *During this time, advance fuel cell power generation systems with performance tweaks and more intelligence will contribute to clean power in industries.*
- *In 2020, fuel cell power generation systems will be capable of providing at least 2 times more power than the current power generation systems .*

Growth Potential



- *The number of application areas and industries that fuel cell power generation technology will have an impact on are many. Several new industries adopting fuel cell power generation technology are increasing over time.*
- *Meanwhile, there is an increased need for clean energy in the industrial sector. Fuel cell power generation technology will certainly occupy a strategic position among other technologies in providing clean, perhaps ultra-clean energy to industries.*

Funding Focus



- *Funding support by government and venture capitalists is expected to accelerate the commercialization of prototypes and products. Technology developers would be able to bring innovative ideas to the market with financial support.*
- *While venture capital firms and other funding agencies continue to fund collaborative start-ups, government grants and loans are helping more research and product development in universities and industries across the globe.*

R&D Focus Areas



Research and development is key to propel the growth of any technology. Fuel cell technology being no exception to this fact sees few shortcomings in the R&D area. Some areas of research that require more attention are

- *Power generation efficiency*
- *Low cost fuel cells*
- *Integration to power grid*
- *Advanced materials for power generation optimization*

Appendix

Key Patents– World

No.	Patent No.	Publication Date	Title	Assignee
1	WO/2016/013728	28.01.2016	FLAT-TUBE TYPE SEGMENT SOLID OXIDE FUEL CELL AND MANUFACTURING METHOD THEREFOR	KOREA INSTITUTE OF ENERGY RESEARCH
	<p>A method for manufacturing a flat-tube type segment solid oxide fuel cell, according to one embodiment of the technical concept of the present invention, can comprise: mixing NiO and Sc₂O₃-CeO₂-ZrO₂ powder; adding ethanol to the mixed powder, adding a zirconia ball thereto, and then proceeding with wet ball milling; proceeding with the wet ball milling, drying the mixed powder in a dryer, and then forming fine mixed powder; quantifying the mixed powder, adding a solvent (-terpineol) and a dispersing agent, and then mixing the mixed powder by using a high-speed centrifugal mixer (planetary centrifugal mixer, ARM-310); mixing a binder (organic binder) (ethyle cellulose-cp50) and the solvent (-terpineol), and then mixing the mixture by using the high-speed centrifugal mixer; mixing the mixed powder slurry and the binder and then producing paste by using the high-speed centrifugal mixer; repeatedly milling the paste with a three-roll mill; and forming an anode from the milled paste by using a screen mask.</p>			
2	WO/2016/013320	28.01.2016	FUEL CELL SYSTEM AND FUEL CELL SYSTEM PRESSURE LOSS ESTIMATION METHOD	NISSAN MOTOR CO., Ltd.
	<p>The fuel cell system comprises a fuel cell stack, a compressor for supplying a cathode gas to the fuel cell stack, an airflow sensor for detecting the flow rate of the cathode gas supplied by the compressor, a humidifier provided on the cathode gas supply passage between the compressor and the fuel cell stack, and a controller for estimating, based on the flow rate detected by the airflow sensor, a loss in the cathode gas pressure occurring between the compressor and the fuel cell stack. When the flow rate is greater than a predetermined flow rate, the controller determines the pressure loss to be a predetermined value.</p>			

Key Patents– Energy generation

No.	Patent No.	Publication Date	Title	Assignee
3	WO/2016/012728	28.01.2016	ENERGY GENERATION SYSTEM COMBINING A FUEL CELL AND A RECHARGEABLE BATTERY AND METHODS IMPLEMENTING SUCH A SYSTEM	GDF SUEZ
	<p>The present invention relates to a system (1) for generating low-power energy including a fuel cell (71) supplied by a gas network (2) and a rechargeable energy storage system (72). The present invention also relates to an energy generation method and to an energy management method implementing such an energy generation system.</p>			
4	WO/2015/198780	30.12.2015	FUEL CELL SYSTEM AND FUEL CELL SYSTEM CONTROL METHOD	TOYOTA JIDOSHA KABUSHIKI KAISHA
	<p>This fuel cell system comprises: a fuel cell stack which is installed in a vehicle; an oxidation gas supply device; an exhaust gas circulation device; an electricity consuming device; a collision possibility detection device, and a control device which executes, when the possibility of a collision is detected by the collision possibility detection device, an oxidation gas supply stopping process for controlling the oxidation gas supply device so as to stop the supply of the oxidation gas to the cathode, an exhaust gas circulation process for controlling the exhaust gas circulation device so as to start the circulation of the exhaust gas to the cathode, and an electricity consuming process for controlling the electricity consuming device so as to start the consumption of electricity from the fuel cell stack.</p>			

Key Patents– Fuel Cell Components

No.	Patent No.	Publication Date	Title	Assignee
5	WO/2016/014578	28.01.2016	COMPOSITION FOR FUEL CELL ELECTRODE	LG FUEL CELL SYSTEMS, INC.
	<p>In some examples, a fuel cell including an anode; electrolyte; and cathode separated from the anode by the electrolyte, wherein the cathode includes a Pr-nickelate based material with $(Pr_{1-x}A_x)_{n+1}(Ni_{1-y}B_y)_nO_{3n+1+\delta}$ as a general formula, where n is 1 as an integer, A is an A-site dopant including of a metal of a group formed by one or more lanthanides, and B is a B-site dopant including of a metal of a group formed by one or more transition metals, wherein the A and B-site dopants are provided such that there is an increase in phase-stability and reduction in degradation of the Pr-nickelate based material, and A is at least one metal cation of lanthanides, La, Nd, Sm, or Gd, B is at least one metal cation of transition metals, Cu, Co, Mn, Zn, or Cr, where: 0</p>			
6	WO/2016/013321	28.01.2016	ANODE SYSTEM FOR FUEL CELLS	NISSAN MOTOR CO., Ltd.
	<p>This anode system for fuel cells is provided with: a fuel cell stack; a circulation circuit that introduces a gas, which is discharged from an anode-side outlet of the fuel cell stack, into an anode-side inlet of the fuel cell stack; and a gas-liquid separator which is provided in the circulation circuit and separates the moisture content from an anode off-gas. The gas-liquid separator is provided with a holding part that is provided in a flow path for a gas within the gas-liquid separator and holds a liquid.</p>			

Industry Interactions

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