Go/NoGo® Assessment Report

Methanol to Hydrogen Generation Technology for Stationary Fuel Cell Power Systems

May 29, 2013

Developer's NAIC: 325120 Hydrogen manufacturing

Science/Technology Fields: Fuel cell electric power generation

Arena NAIC: 325120 Hydrogen manufacturing
335999 Fuel cells, electrochemical generators, manufacturing

Technology Type: Product and Process system design

Supply Chain: Processing tools and techniques

International Patent Classification: H01M4/90; H01M8/10; H01B1/12

Geographic Region: Global

Project Number NUV0001GN
NuVant Systems, Inc.
was
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Recommendation and Findings

The function of the Go/NoGo® is to identify potential showstoppers for a technology. We will look at four areas — products, patents, research projects, and commercialization strategy considerations. We also provide an overall recommendation based on the factors outlined in the individual sections of the report.

Our recommendation is based on a cursory examination of:

- The material provided by NuVant Systems, Inc. (NuVant);
- Patents listed on the Thomson Innovation Express and Free Patents Online servers;
- R&D found via Web searches;
- Products found via Web and literature searches; and
- Targets found via the Thomas Register and Web searches.

Recommendation: Foresight recommends a **GO** because the Subject Technology Readiness Level is appropriate for continued R&D efforts. A relevant published patent is already assigned to NuVant. A competitive and growing market already exists for the Subject Technology. No intellectual property was found that appears to conflict with or replaces the Subject Technology (please consult with qualified counsel). A relatively large number of international articles were found using very specific search criteria relating to the relevant field of technology. With continued government incentives, it appears likely that the U.S. fuel cell industry will become self-sustaining within a decade. The U.S. stationary fuel cell market is projected to grow at a CAGR of 35% to $3.2 billion by 2016 and the European market is expected to grow at a CAGR of 53% to $175 million by 2018. Examples of potential targets are identified for partnerships, collaboration and commercialization.

We caution that the technologies of potential competitors and target companies are proprietary, patent applications of competing technologies may not be published, and commercial research and development projects are generally not published. If a patent application or a patent is published, protection against infringement may be difficult given the imbedded nature of the technology in finished products. Significant market research will be required to identify target companies, relevant products, customer requirements and key decision personnel. Since fuel cell power generator manufacturers have specification limits and require controlled manufacturing conditions for highly specialized applications, the advantages of utilizing the patented Subject Technology for other applications is unknown.

The key findings are:

1. **Technology's Maturity Level**: Technology Readiness Level is TRL 3. Proof of concept is validated and active research and development has been initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Demonstrations of technical feasibility using breadboard implementations are exercised with representative data.

2. **Intellectual Property**: US Patent 7923165, entitled "Electrolyte components for use in fuel cells," published April 12, 2011 is assigned to NuVant Systems, LLC (Honolulu, HI).

3. **Possible Competing Products**: Stationary fuel cells currently cover a number of market segments, including megawatt-scale prime power plants, uninterruptable power supplies, and combined heat and power. They also exceed all other market segments in terms of annual megawatts shipped, with US companies such as FuelCell Energy, UTC Power, and more recently Bloom Energy accounting for the dominant share of shipped capacity. Methanol is becoming increasingly popular as a source of hydrogen for systems based on PEM fuel cells, because it is stable, has low volatility, and remains liquid over a broad temperature range, covering all conditions in which fuel cells operate. It can also be reformed either internally or externally for use in fuel cells.

4. **Possible Competing Patents**: No patent or patent application was found that appeared to conflict with or replace the Subject Technology claimed under NuVant Patent US7923165. In some cases it appears that the technologies described in the search results could be used in conjunction with the Subject Technology.

5. **Possible Competing R&D**: A relatively large number of international articles were found using very specific search criteria relating to the relevant field of technology. The search results indicate a high level of scientific interest in the development technology relevant to commercialization of the Subject Technology. In many cases this interest is driven by recent partnerships in collaboration with current manufacturers of fuel cells for power generation.

6. **Market Barriers**: Continuing or expanding government incentives is essential to sustaining the U.S. fuel cell industry through its transformation period. If progress can be continued, even at slower rates than in the past, it appears likely that the U.S fuel cell industry will become self-sustaining within a decade.

7. **Commercialization Strategy Considerations**: Office buildings, hospitals, and military applications are some of the largest potential markets for fuel cell technology. Fuel cells for back-up power will reduce energy consumption, energy costs and green house gas emissions. The stationary fuel cell UPS and backup power market is experiencing double digit annual growth. Direct methanol fuel cells are becoming increasingly popular as a source of hydrogen for systems based on proton exchange membrane fuel cells. The U.S. stationary fuel cells market is projected to grow at a CAGR of 35% from $1.3 billion in 2013 to $3.2 billion by 2016 and the European market is expected to grow at a CAGR of 53% from $21 million in 2013 to $175 million by 2016.

8. **Examples of Potential Targets**: Eleven potential targets are identified with the name, location, description, website and points of contact for senior technology executives. The potential targets include Hy9, Altergy Systems, Dantherm Power, Ida Tech, Electro Power Systems, Ballard Power Systems, BASF Fuel Cell, Avalence, Proton Energy Systems, ReliOn, and Bayer Material Science. Five websites linking to other potential targets are also listed.

The following individual has been designated as a point of contact at NuVant: Eugene Smotkin, Chairman & CEO, e.smotkin@neu.edu or esmotkin@gmail.com, Boston: (617) 373-7526, Crown Point: (219) 644-3231, Cell: (787) 587-3748, Puerto Rico: (787) 723-7222.

Brief Non-Proprietary Description of Technology

The technology is a Process and Product design.

Description of Technology
The Subject Technology is a hydrogen generation system design for stationary fuel cell power systems. A key advantage of the design is the use of a methanol fuel reformer to generate up to 99.9999% pure hydrogen in the flow field entering the fuel cell or in a mode where the fuel cell receives fuel from an external methanol fuel reformer.

Proton exchange membrane (PEM) fuel cell backup power systems have numerous advantages versus traditional stand-alone battery or diesel generators. In addition to those benefits, reformer technology solves hydrogen siting issues providing virtually unlimited fuel cell backup power. In the comparison between liquid fuel and hydrogen bottles, 60 gallons of a methanol/water fuel mixture and a fuel reformer will provide the same amount of power for the same length of time as 36 hydrogen cylinders. Existing solutions using fuel cell and reforming technology are commercially available today for mission critical and remote sites.[1]

Decentralized hydrogen production from methanol would greatly benefit from high catalyst selectivity towards hydrogen and carbon dioxide at the lowest possible temperature. Formation of carbon monoxide has to be avoided as much as possible, because it acts as a strong poison for almost all fuel cell catalysts.[2] This statement is of particular importance because it is quoted from a current scientific publication and the Subject Technology directly addresses these concerns.

The Subject Technology includes the following nonproprietary advantages.

- Very high purity 99.999% to 99.9999% hydrogen is produced by the methanol fuel reformer.
- Methanol is becoming popular as a source of hydrogen for systems based on PEM fuel cells
- Hydrogen can be generated in the flow entering the fuel cell or from an external reformer.
- The membrane electrolyte assembly can operate in a temperature range of 175-550° C.

Supplemental Proprietary Information

The invention summary described in NuVant US Patent 7923165 states that: “Additional advantages of this invention would become readily apparent to those skilled in this art from the detailed description, wherein only the preferred embodiments of this invention are shown and described.” NuVant plans to file several more patents as the state of the art advances during phases one and two of the NSF grant process.

[1] Bill Shank, Vice-President of North American Sales, IdaTech, “Extended run fuel cell backup power: Solving the hydrogen problem,” April 3, 2007, *The Battcon Archive Papers 1997 through 2013*, Battcon website, http://www.battcon.com/PapersFinal2007/ShankPaper2007.pdf (accessed May 24, 2013).

[2] Kusche, M., et al., “Enhanced Activity and Selectivity in Catalytic Methanol Steam Reforming by Basic Alkali Metal Salt Coatings,” *Angewandte Chemie International Edition*, Vol. 52, No. 19, pp 5028–5032, April 3, 2013, http://www.greencarcongress.com/2013/04/meoh-20130419.html (accessed May 24, 2013).

Product Search

We searched Google, HighBeam Research, Hoovers and Frost & Sullivan for relevant products using the following terms and their stemming derivatives: methanol reformer stationary hydrogen "fuel cell" (power OR generator) for the period from January 1, 2010 to May 14, 2013. Fuelcells.org has an informative listing of the fuel cell industry top 200 companies organized by company name, location and type of technology. Some of these companies with hydrogen reformer technology are listed below.[3]

Examples of Relevant Products/Services Identified

Product Name	***Manufacturer***	***Relevance***	***Web site/Phone #***
HG Series Hydrogen Generator	Hy9 Corporation Hopkinton, MA	HGS-M hydrogen generators joined with fuel cell power systems such as Altergy, ReliOn, and CommScope, and running on methanol fuel are superior to diesel generators in terms of operating cost, cleanliness, weight, noise & vibration; batteries in terms of performance, maintenance and ownership cost; and hydrogen cylinders in terms of cost, safety requirements and logistics.	http://www.hy9.com/ 508-435-3742 George Roberts Vice President of Engineering
ElectraGen-ME systems	Ballard Power Systems, Inc. Burnaby, BC Canada	ElectraGen™-ME systems, which run on reformed methanol fuel, are particularly well suited for 'extended duration runtime' telecom backup power requirements. These systems are designed for high reliability, long life and minimal ongoing maintenance. Available in 2.5 and 5 kW configurations, the ElectraGen-ME system includes a fuel reformer that converts HydroPlus (a methanol-water liquid fuel mixture) into hydrogen gas to power the fuel cell system.	http://www.ballard.com/ 604-454-0900 Christopher Guzy Vice President and Chief Technology Officer
Celtec®-P membrane electrode assemblies	BASF Fuel Cell, Inc. Somerset, NJ	BASF Fuel Cell, Inc. produces the Celtec® high temperature membrane electrode assembly used in systems for micro combined heat and power, backup power, and auxiliary power. Celtec®-P membrane electrode assemblies operate at 120°C to 180°C, do not require additional humidification, and are compatible with reformer streams with 1-2% CO.	http://www.basf-fuelcell.com 732-545-5100 Emory S. De Castro, Ph.D. Executive Vice President emory.decastro@basf.com 732-545-5100 (ext. 4114)
Hydrofiller high-pressure electrolytic hydrogen fuel generators	Avālence, LLC Milford, CT	The Hydrofiller is a particularly good fit in environments where high pressure hydrogen is required such as commercial and automotive transportation, a variety of manufacturing applications, and for use with back-up and renewable power systems.	http://www.avalence.com Nancy Selman VP, Business Development ncs@avalence.com 203-701-0052

[3] "Fuel Cell Industry Top 200 Companies," http://www.fuelcells.org/top_200.cgim?slug= (accessed May 14, 2013).

Proton OnSite regenerative fuel cell (RFC) systems	Proton Energy Systems, Inc. Wallingford, CT	Hydrogen, generated onsite from water, is stored safely and efficiently without mechanical compressors using proton exchange membrane (PEM) electrolyzers. By integrating PEM fuel cells with high pressure PEM electrolyzers and hydrogen storage subsystems, Proton RFC systems deliver a predictable and uninterrupted source of backup power for businesses.	http://www.protonenergy.com http://www.protononsite.com/ Robert Friedland President 203-678-2000
Stationary hydrogen fuel cells	ReliOn, Inc. Spokane, WA	ReliOn claims to be the world's leading developer and marketer of modular, cartridge-based, proton exchange membrane fuel cell technology. ReliOn markets a range of stationary fuel cells for emergency and backup power systems, uninterruptible power supplies, digital power needs and a range of off grid power requirements.	http://www.relion-inc.com/ William A Fuglevand Vice President Research And Development 509-228-6500

According to ZoomInfo, Hy9 Corporation, founded in 1992, has 20-50 employees located in Hopkinton, MA. Annual sales are estimated at $20-50 million. On its website, Hy9 claims its H2Pur palladium membrane hydrogen purifiers, incorporated in its HGS-M hydrogen generator, produce hydrogen of purity greater than 99.9999%. Its hydrogen generators are said to be designed for fuel cell backup power applications requiring extended runtime hydrogen supply. On November 20, 2012, Hy9 and Altergy Systems (Folsom, CA) announced an agreement to integrate and optimize Hy9's HGS platform with Altergy's Freedom Power PEM fuel cell systems.[4] On January 10, 2013, Hy9 and Sankosha Corporation (Tokyo, Japan), announced an agreement to develop the Asian market for reformer based fuel cell powered telecommunications systems which operate on methanol as fuel.[5] The Patent Search section of this report cites the most recently published US patent assigned to Hy9 as a representative IP example.

According to Hoovers, Ballard Power Systems, Inc. (Ballard) headquartered in Burnaby, BC Canada was founded in 1989 and has 395 employees. Its 2012 sales were $43.7 million, down 43% from 2011. Ballard has yet to become profitable. No information is available on the selling price of its equipment. On its website, Ballard states that the ElectraGen-ME system is available in 2.5 kW and 5 kW low emission configurations including a fuel reformer that converts a methanol-water liquid fuel mixture into hydrogen gas to power the fuel cell system. Ballard has shipped over 2,000 fuel cell systems to telecom customers, equivalent to 7,800 kW of backup electric power for ‘short duration runtime’ and ‘extended duration runtime’ requirements. Its fuel cells are said to provide a highly reliable and cost-competitive power source for backup power in wireless telecom networks worldwide. The Patent Search section of this report cites the most recently published US patent assigned to Ballard as a representative IP example.

[4] “Altergy and Hy9 Announce a Collaboration to Develop an Integrated Methanol Reformer with Altergy Systems Fuel Cells,” Yahoo Finance website, November 20, 2012. http://finance.yahoo.com/news/altergy-hy9-announce-collaboration-develop-070000609.html (accessed May 27, 2013).
[5] “Sankosha and Hy9 Establish Strategic Partnership to Meet Telecom Backup Power Needs in Asia,” Yahoo Finance website, January 10, 2013. http://finance.yahoo.com/news/sankosha-hy9-establish-strategic-partnership-130000475.html (accessed May 27, 2013).

According to Hoovers, BASF Fuel Cell, Inc. (BASF), a subsidiary of BASF Catalysts LLC, has 45 employees located at a 5,000 sq. ft. facility in Somerset, NJ. On its website BASF states that based on its competencies in polymer membranes, catalysts and electrochemistry, it is developing sophisticated MEAs for high temperature PEM fuel cells. Most customers combine the high temperature PEM fuel cell system with a fuel processor using hydrocarbons such as methanol, diesel or natural gas. The tolerance of the fuel cell against carbon monoxide and sulfur, and the thermal integration of stack and fuel processor increase the robustness and efficiency of the system significantly. In a 2012 interview with Dr. De Castro, he commented that PEM is expected to be the dominant technology for most fuel cell applications, except high power generation, through 2020.[6]

According to Hoovers, Avalence, LLC (Avalence) was founded in 1996 and has 19 employees located at a 17,000 sq. ft. facility in Milford, CT. Its 2012 sales were $2.3 million. Thomas Jackson is its Chief Technology Officer and is a co-founder of Avalence. On its website Avalence states that it produces emission-free, reliable and cost-efficient hydrogen-generating equipment. The Avalence Hydrofiller generates ultra-high-pressure hydrogen fuel without a costly compressor and cuts the costs of point-of-use hydrogen production by up to 50%. The near-term market focus of Avālence is to produce hydrogen fuel for energy storage, industrial, commercial, academic and research use. Avalence forms strategic alliances and creates teaming arrangements with companies involved in the hydrogen infrastructure, renewable energy use and fuel cell markets.

According to Hoovers, Proton Energy Systems, Inc. (d/b/a Proton OnSite) was founded in 1996 and has 77 employees located at a 98,000 sq. ft. facility in Wallingford, CT. Its 2012 sales were $18.8 million. On its website Proton Onsite states that it designs and manufactures proton exchange membrane (PEM) electrochemical systems to make hydrogen from water producing safe, pure, reliable onsite hydrogen to meet global hydrogen requirements ranging from grid-level support for energy storage to turbine generator cooling in power plants. Proton OnSite is a partner to the U.S. military, aerospace, fueling and renewable energy industries. For laboratory and scientific needs, hydrogen is used as an ultra high purity fuel and reducing agent. HOGEN hydrogen generation systems provide ultra high purity hydrogen as a carrier gas with consistent composition and predictable low levels of oxygen and nitrogen.

According to Hoovers, ReliOn, Inc. has sold and installed more than 2 MW of products with private and public entities in the energy, telecommunications, and transportation segments. Investors include Avista, Enterprise Partners Venture Capital, and Wall Street Technology Partners. ReliOn's products are available in the US and internationally for commercial and industrial backup applications in the 300 MW to 12kW range. By 2009 it had delivered products to more than 600 commercial customer sites in 18 countries. Expanding its product range, in 2009 the company launched the Eco-200 for smaller scale power applications. The product is a compact fuel cell system housed in a 3.5" tall rack-mountable package. ReliOn was founded in 1995 as Avista Laboratories, the fuel cell manufacturing and development subsidiary of Avista Corp. It was spun off in 2003 and became ReliOn in 2004. ReliOn was ranked number 148 on

[6] Emory S. De Castro, Ph.D., (Executive Vice President, BASF Fuel Cell, Inc., 848-209-9509) in a phone conversation with James W. Fraser on April 30. 2012.

Deloitte's Technology Fast 500, a ranking of the 500 fastest growing technology, media, telecommunications, life sciences and clean technology companies in North America.[7]

Based on our product search, we conclude that the Subject Technology is a GO for use as a hydrogen generation system design for stationary fuel cell power systems. Stationary fuel cells currently cover a number of market segments, including megawatt-scale prime power plants, uninterruptable power supplies, and combined heat and power. They also exceed all other market segments in terms of annual megawatts shipped, with US companies such as FuelCell Energy, UTC Power, and more recently Bloom Energy accounting for the dominant share of shipped capacity.[8] Methanol has not only inspired the development of the direct methanol fuel cell (DMFC) dedicated to its use, but is also becoming increasingly popular as a source of hydrogen for systems based on PEM fuel cells. Methanol is stable, has low volatility, and remains liquid over a broad temperature range, covering all conditions in which fuel cells operate. It can also be reformed either internally or externally for use in fuel cells.[9]

Patent Search

We search the following data sets: *INPADOC*, which contains patent family documents from 71 world patent signatories and legal status information from 42 patent offices; *WIPO PCT Publications*, which contains abstracts, full document images, and full text from over a hundred member countries of the Patent Cooperation Treaty; *European Patents and Applications* from the European Patent Office; and *US Patents and Applications* from the US Patent and Trademark Office. Searching these data sets simultaneously often does lead to multiple counts of the same patent, as both the application and patent may be retrieved or the item can show up in multiple databases. This procedure highlights applicants who file, pursue the patent, and protect it in multiple jurisdictions and the presumption is a patent protected in multiple jurisdictions is more important to its owners than one which is not.

Given this procedure, the following published US and WIPO patents and applications were found using the search string ("high temperature" MEA "fuel cell" reform stationary power) for the Patent Description. Overall, the string produced 194 hits for the most recent five year period.

The following patents and patent applications indicate kinds and range of technology that show up in the patent literature. We emphasize that we look at patents from the standpoint of market competition. We have no opinion on the patentability of your technology. Please consult with qualified legal counsel for opinions on NuVant's freedom to operate and extent of Intellectual Property protection. Material in quotes is from the patent abstract unless otherwise noted.

[7] "2011 Fuel Cell Technologies Market Report," DOE Energy Efficiency & Renewable Energy website, July 2012, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2011_market_report.pdf (accessed May 26, 2013).
[8] Ibid.
[9] "Methanol and Fuel Cells," Fuel Cell Today website, May 23, 2012, http://www.fuelcelltoday.com/analysis/analyst-views/2012/12-05-23-methanol-and-fuel-cells (accessed May 26, 2013).

Examples of Relevant Patents and Patent Applications Identified				
Patent or Patent Application #	***Patent Title***	***Date***	***Relevance***	***Assignee***
US Patent 7182917	Steam-reforming catalytic structure and pure hydrogen generator comprising the same and method of operation of same	February 27, 2007	A reactor/purifier for generating pure hydrogen in a stack or array of pairs of alternatingly connected high and low pressure reactor chambers. The catalyst-coated structure in each high pressure chamber is reacted with steam and hydrocarbon fuel, such as methane at a controlled temperature between 200° C. to 650° C. to produce pure hydrogen.	Hy9 Corporation (Woburn, MA)
US Patent 6696027	Reformation reactor with catalyst charging	February 24, 2004	A reformation reactor that can be used especially for steam reformation of methanol for generating hydrogen in motor vehicles operated by fuel cells. A gas stream to be reformed is conducted through a reaction chamber into which a charge of a catalyst material is added. A catalyst supply container connected with the reaction chamber is so arranged that the catalyst material is automatically added from the supply container to the reaction chamber.	Ballard Power Systems AG (Kirchheim/ Teck-Nabern, Germany)
US Patent 7910253	Reformer for fuel cell and fuel cell using the same	March 22, 2011	A reformer for a fuel cell includes a reforming reactor generating reformed gas having abundant hydrogen gas by reforming fuel and steam and a standing shape of a water gas shift reactor coupled to the reforming reactor for lowering the concentration of carbon monoxide contained in the reformed gas.	Samsung SDI Co., Ltd. (Korea)
WIPO Patent Application WO/2010/029431 US Patent Application 20100062293	Internal reforming alcohol high temperature PEM fuel cell	March 18, 2010 March 11, 2010	This invention refers to an Internal Reforming Alcohol Fuel Cell using polymer electrolyte membranes, which are functional at 190-220°C and alcohol fuel reforming catalysts for the production of CO-free hydrogen in the temperature range of high temperature PEM fuel cells.	Advent Technologies (Athens, GR)
US Patent Application 20100062293	Portable reformed fuel cell systems with water recovery	February 25, 2010	The system generates one or more exhaust streams from which water can be recovered. A water removal system contained in the portable fuel cell system package draws water from an exhaust stream; the exhaust may include a burner exhaust, a reformer exhaust, and/or a fuel cell exhaust. The water can then be provided to the incoming fuel.	Ultracell Corporation (Livermore, CA)

US Patent 8293416	Fuel cell system	October 23, 2012	A fuel cell system which includes a hydrogen generator with raw material to generate a fuel gas containing hydrogen; a humidifier supplied with the fuel gas generated in the hydrogen generator; and a fuel cell which is supplied with the humidified fuel gas and an oxidizing gas to generate electric power while discharging heat energy and off gas. The fuel cell system includes a condenser which cools down steam of the off gas discharged from the fuel cell, by heat exchange with a cooling medium to convert the steam into condensed water, and supplies the condensed water to the humidifier to humidify the fuel cell.	Panasonic Corporation (Osaka, JP)

U.S. Patent 7923165 relates to a composite electrolyte system for use in either stand alone intermediate temperature fuel cell systems or in fuel cell systems with methanol reforming catalysts within the anode compartment. The composite electrolyte system comprises a metal hydride support foil or gauze upon which are supported electronically insulating proton conductors on one or both sides of the support foil.

U.S. Patent 7182917 relates to steam-reforming catalytic structures and hydrogen generation, particularly novel unitary catalytic structures and methods for generating hydrogen by reacting steam with a gaseous or gasified fossil hydrocarbon fuel at a moderately elevated temperature, using palladium-bearing membrane pure hydrogen generators comprising the same.

U.S. Patent 6696027 relates to a reformation reactor with a reaction chamber through which a gas stream to be reacted is conducted, and into which a charge of a catalyst material is loaded. Reformation reactors are known in a wide variety of versions, for example for steam reformation of methanol for obtaining hydrogen, which can be used, for example, as fuel for a fuel cell system.

U.S. Patent 7910253 relates to a reformer for a fuel cell. An aspect of the invention provides a new structure and shape of a water gas shift (WGS) reacting unit in a reformer in which a reforming reaction unit and WGS reacting unit are integrally manufactured in order to minimize the contact between catalyst and water in the WGS reacting unit.

WIPO Patent Application WO/2010/029431A2 relates to an Internal Reforming Alcohol Fuel Cell composed of a membrane electrode assembly comprising a high temperature proton-conducting electrolyte membrane sandwiched between the anodic fuel reforming catalyst for the production of CO-free hydrogen and the cathodic gas diffusion electrodes.

U.S. Patent Application 20100062293 relates to a portable fuel cell system for producing electrical energy included in a portable package has a fuel processor including a reformer configured to receive fuel and to output hydrogen and reformer exhaust, and a burner configured to receive fuel, to generate heat using the fuel, and to output burner exhaust. The package also has a fuel cell configured to produce electrical energy using hydrogen output by the reformer.

U.S. Patent 8293416 relates to a fuel cell system including a polymer electrolyte fuel cell which uses a fuel gas and an oxidizing gas to generate electric power. An object of the present invention is to provide a durable, reliable, and cheap fuel cell system capable of adequately humidifying the fuel gas supplied to the polymer electrolyte fuel cell by a simple configuration including the humidifier without disposing a particular exclusive auxiliary device.

The patents and applications cited above are not listed in any order of relevance to the Subject Technology. We emphasize that we are not patent attorneys and thus our analysis focuses on marketability. We strongly recommend you discuss patentability and freedom to operate with qualified patent counsel.

Based on our patent search, we conclude that the Subject Technology is a GO for use as a hydrogen generation system design for stationary fuel cell power systems. No patent or patent application was found that appeared to conflict with or replace the Subject Technology claimed under NuVant Patent US7923165. In some cases it appears that the technologies described in the search results could be used in conjunction with the Subject Technology.

R&D/Practices Search

A search of Google Scholar and HighBeam was conducted using the search string ("high temperature" MEA "fuel cell" methanol reform stationary power). A Google Scholar search using these terms was the most productive with 81 hits for the five year period from 2008 through 2013. We also examined the literature for R&D and practices via a Google Web search.

Examples of Relevant Projects Identified			
Project Title	***Performing Institution***	***Performance Period***	***Relevance***

Polybenzimidazole Acid Complexes as High-Temperature Membranes	NY State Center for Polymer Synthesis, Department of Chemistry and Chemical Biology, Rensselaer Polytechnic Institute Troy, NY	2008	Progress towards applying acid-doped polybenzimidazoles (PBIs) as polymer electrolyte membrane (PEM) fuel cell membranes from 1998 through 2008 is reviewed including the possible degradation modes of the commercially available products from BASF Fuel Cells.[10]
Comparative Study of Different Fuel Cell Technologies	Department of Electrical Engineering, University of Malaya Kuala Lumpur, Malaysia	2012	This paper includes a comparative study of basic design, working principle, applications, advantages and disadvantages of various technologies available for fuel cells. The results indicate that fuel cell systems have simple design, high reliability, noiseless operation, high efficiency and less environmental impact.[11]
Fuel Cell Systems Optimization Methods and Strategies	Department of Chemical Engineering, University College London London, UK	2011	This paper reviews the current state of modeling and optimization with regard to fuel cell systems design. The existing models for portable, stationary and transportation fuel cell systems are identified and characterized by approach, state, system boundary, spatial dimension and complexity or detail.[12]
Influence of Methanol Impurity in Hydrogen on PEMFC Performance	Department of Applied Chemistry, Sri Venkateswara College of Engineering Pennalur Tamil Nadu, India	2013	This paper presents the studies on the influence of methanol impurity in hydrogen for the PEM fuel cells. The effect of various parameters such as methanol concentration, cell voltage, current density, exposure time, reversibility, operating temperature, etc. on the cell performances was investigated using pure hydrogen. Various methods of methanol poisoning mitigation were also investigated.[13]
Concerns specifying materials for the components and housing materials of fuel cell technology	ReliOn, Inc. Spokane, WA Bayer Material Science Pittsburgh, PA	2011	ReliOn consulted with Bayer Material Science to choose the best material for proprietary components for its E-1100 hydrogen fuel cell. The evaluation considered mechanical, thermal, chemical and sustainability requirements.[14]

[10] Jordan Mader, et al., "Polybenzimidazole/Acid Complexes as High-Temperature Membranes," *Advances in Polymer Science*, Vol. 216, 2008, Pages 63-124, http://link.springer.com/chapter/10.1007/12_2007_129 (accessed May 27, 2013).
[11] S. Mekhilef, et al., "Comparative Study of Different Fuel Cell Technologies," *Renewable and Sustainable Energy Reviews*, Vol. 16, January 2012, Pages 981-989, http://www.sciencedirect.com/science/article/pii/S1364032111004709 (accessed May 27, 2013).
[12] Sheila Mae C. Ang, et al., "Fuel Cell Systems Optimization Methods and Strategies," *International Journal of Hydrogen Energy*, Vol. 36, November 2011, Pages 14678-14703, http://www.sciencedirect.com/science/article/pii/S0360319911019720 (accessed May 27. 2013).
[13] N. Nachiappan, et al., "Influence of Methanol Impurity in Hydrogen on PEMFC Performance," *Ionics*, Vol. 19, March 2013, Pages 517-522, http://link.springer.com/article/10.1007/s11581-012-0770-4 (accessed May 27, 2013).
[14] Kim Ukura, "Fuel cells materialize: as fuel cell technology continues to develop, engineers face a number of concerns," *Product Design & Development*, September 1, 2011, http://www.highbeam.com/doc/1G1-268313457.html (accessed May 27, 2013).

Design of compact methanol reformer for hydrogen with low CO for the fuel cell power generation	Department of Chemical and Materials Engineering, Chang Gung University, Kweishang, Taiwan Green Hydrotec Inc. Kweishang, Taiwan	2011	A series of compact methanol reformers are designed and fabricated with the use of large reactor surface area in catalyst beds and high heat transfer constant to produce hydrogen with 2-4 ppm of CO for fuel cell power generation at a cost of $.20-.23 per cubic meter and $.196 cents per KWH.[15]
German researchers improve catalyst for steam reforming of methanol with salt coating; enabler for renewable energy storage systems	University of Erlangen Nurnberg, Germany	2013	A central problem of renewable energy technology lies in the intermittency of energy generated. One proposed solution is methanol-based hydrogen storage. In this scenario, excess renewable electricity can be used to electrolyze water to produce hydrogen. The hydrogen, in turn, is then reacted with carbon dioxide to make methanol and water, thus allowing it to be stored as a liquid. The hydrogen can be released from the methanol at a later time to power a fuel cell.[16]

The relatively large number of hits using very specific search criteria relating to high temperature MEA fuel cell technology to generate hydrogen from reformed methanol for electric power generation indicates a high level of recent international scientific interest in the development technology relevant to commercialization of the Subject Technology. In many cases this interest is driven by recent partnerships and collaboration with current manufacturers of fuel cells for power generation such as those listed in the Product Search section of this report.

Based on our R&D search, we conclude that the Subject Technology is a GO for use as a hydrogen generation system design for stationary fuel cell power systems. No publications were found that appeared to conflict with or replace the Subject Technology's primary claims at this early stage of development.

Commercialization Considerations

Key findings regarding the commercial potential for this technology are as follows:

[15] Harvey H.F. Wang, "Design of compact methanol reformer for hydrogen with low CO for the fuel cell power generation," *International Journal of Hydrogen Energy*, Vol. 37, May 2012, Pages 7487-7496, http://www.sciencedirect.com/science/article/pii/S0360319912001966?np=y (accessed May 27, 2013).
[16] M. Kusche, "Enhanced Activity and Selectivity in Catalytic Methanol Steam Reforming by Basic Alkali Metal Salt Coatings," *Angewandte Chemie International Edition*, Vol. 52, May 3, 2013, Pages 5028-5032, http://onlinelibrary.wiley.com/doi/10.1002/anie.201209758/abstract (accessed May 27, 2013).

Data Related to Market Potential	
Likely Markets and Basis for Feasibility	Office buildings, hospitals, and military applications are some of the largest potential markets for fuel cell technology. Currently, most buildings that require emergency power use inefficient and polluting combustion powered generators. Estimated at $6 billion, the back-up power market is well-established and growing. Fuel cells have the potential to be the front-running technology in this market.[17]
Possible Market Barrier(s)	Manufacturers are generally operating well below existing capacities and see scale economies as having major potential for cost reduction. OEMs have narrowed their product offerings to be more competitive. Manufacturers believe further cost reductions of 40% to 50% are necessary to compete with alternative technologies. In the current market, government incentives are critical to sustaining the U.S. fuel cell industry. This is likely to remain so for the next 5-10 years. Analyses using the non-automotive fuel cell market model indicate that continuing or expanding government incentives is essential to sustaining the U.S. fuel cell industry through its transformation period. If progress can be continued, even at slower rates than in the past, it appears likely that the U.S fuel cell industry will become self-sustaining within a decade.[18]
Possible Market Driver(s)	Switching to fuel cells for back-up power will reduce energy consumption, and energy costs. Like all fuel cells, back-up systems provide power while reducing green house gas emissions. A small fuel cell back-up generator can save one ton of CO_2 per kilowatt hour of fuel cell power compared to combustion generators. Fuel cell back-up power systems can be up to 99.9999% reliable, translating to about one minute of downtime over six years.[19]
Indicator(s) Suggesting How Big the Market Opportunity Might Be	The stationary fuel cell UPS and backup power market is experiencing double digit annual growth, from a low base. An increasing number of companies operating in the UPS and backup power markets have introduced fully certified products in geographies including Europe, America, China, Indonesia, and India. These certifications enable new companies to move quickly through the low volume, quasi-automated, production phase of market development.[20]
Product Opportunities	The direct methanol fuel cell is becoming increasingly popular as a source of hydrogen for systems based on proton exchange membrane fuel cells. Methanol can be generated in the flow entering the fuel cell or from an external reformer to produce hydrogen that is then fed to the fuel cell. An advantage of methanol is that it lends itself to this process, requiring no prior clean-up and only moderate conditions for the reforming process.[21]

The Navigant Research report referenced in the above table evaluated 13 of the leading UPS and backup power fuel cell developers and rates them on 12 criteria for strategy and execution, including go-to-market strategy, product portfolio, partnerships, innovation, reach, market share,

[17] "Back-up Power and Fuel Cells," Fuel Cell & Hydrogen Energy Association web site, March 4, 2011. http://www.fchea.org/core/import/PDFs/Back-up%20Power%20Fuel%20Cells%20Fact%20Sheet.pdf (accessed May 27, 2013).
[18] David L. Greene, Oak Ridge National Laboratory "Non-Automotive Fuel Cells: Market Assessment and Analysis of Impacts of Policies," Hydrogen.Energy.gov website, May 10, 2011. http://www.hydrogen.energy.gov/pdfs/review11/an015_greene_2011_o.pdf (accessed May 27, 2013).
[19] "Back-up Power and Fuel Cells," Fuel Cell & Hydrogen Energy Association web site, March 4, 2011. http://www.fchea.org/core/import/PDFs/Back-up%20Power%20Fuel%20Cells%20Fact%20Sheet.pdf (accessed May 27, 2013).
[20] Pike Pulse Report: UPS/Backup Power Stationary Fuel Cells, "Assessment of Strategy and Execution of 13 Leading UPS & Backup Power Fuel Cell System Manufacturers," Navigant Research website, December 2011. http://www.navigantresearch.com/research/pike-pulse-report-upsbackup-power-stationary-fuel-cells (accessed May 27, 2013).
[21] "Methanol and Fuel Cells," Fuel Cell Today website, May 23, 2012, http://www.fuelcelltoday.com/analysis/analyst-views/2012/12-05-23-methanol-and-fuel-cells (accessed May 27, 2013).

pricing, and staying power. The most recent annual revenues reported for the top six leaders and contenders of this group is, Dantherm Power ($50-100MM), Altergy ($1-5MM), Hydrogenics ($10-25MM), IdaTech ($10-25MM), EPS ($1-5MM) and ReliOn ($5-10MM). Assuming a compound annual growth rate (CAGR) of 30%, the total average revenue of these five companies would grow from $125 million in 2012 to $600 million by 2018.[22]

Frost & Sullivan projects that the U.S. stationary fuel cells market will grow at a CAGR of 35% from $1.3 billion in 2013 to $3.2 billion by 2016. Key market drivers over the next five years are expected to be: (1) government financial incentives and funding for research and development; (2) high and/or volatile energy costs; and (3) heightened environmental concerns and focus on sustainability. Key market restraints are expected to be: (1) high capital costs; (2) growing industry focus on traditional renewable technologies; and (3) significant research and development investment required by manufacturers.[23] Frost & Sullivan projects that the European PEM Fuel Cells Market will grow at a CAGR of 53% from $21 million in 2013 to $175 million by 2016. Key competitive factors are expected to be price, reliability, durability, and price to performance ratio.[24]

Based on our commercialization considerations, we conclude that the Subject Technology is a GO for use as a hydrogen generation system design for stationary fuel cell power systems. This assessment is based on findings that office buildings, hospitals, and military applications are some of the largest potential markets for fuel cell technology. Fuel cells for back-up power will reduce energy consumption, energy costs and green house gas emissions. The stationary fuel cell UPS and backup power market is experiencing double digit annual growth. Direct methanol fuel cells are becoming increasingly popular as a source of hydrogen for systems based on proton exchange membrane fuel cells. The U.S. stationary fuel cells market is projected to grow at a CAGR of 35% from $1.3 billion in 2013 to $3.2 billion by 2016 and the European market is expected to grow at a CAGR of 53% from $21 million in 2013 to $175 million by 2018.

Potential Targets

The following table lists examples of potential targets.

Examples of Potential Targets			
Target	***Reason for Inclusion***	***Web site***	***Point of Contact with Phone or E-mail***

[22] "Pike Pulse Report: UPS/Backup Power Stationary Fuel Cells," Navigant Research website, 4Q 2011. http://www.navigantresearch.com/research/pike-pulse-report-upsbackup-power-stationary-fuel-cells (accessed May 27, 2013).
[23] "Market Potential for Stationary Fuel Cells in the United States," Frost & Sullivan website, June 12, 2012. Subscription required. http://www.frost.com/prod/servlet/frost-home.pag (accessed May 27, 2013).
[24] "European Stationary Fuel Cells Markets," Frost & Sullivan website, December 2010. Subscription required. http://www.frost.com/prod/servlet/frost-home.pag (accessed May 27, 2013).

Hy9 Corporation Hopkinton, MA	Hy9 and Altergy Systems (Folsom, CA) have an agreement to integrate and optimize Hy9's HGS platform with Altergy's Freedom Power PEM fuel cell systems.[25] Hy9 and Sankosha Corporation (Tokyo, Japan), have an agreement to develop the Asian market for reformer based fuel cell powered telecommunications systems which operate on methanol as fuel.[26]	http://www.hy9.com/	George Roberts Vice President of Engineering 508-435-3742
Altergy Systems Folsom, CA	Altergy is cited by Navigant Research as a leading UPS and backup power fuel cell developer.[27]	http://www.altergysystems.com/	Mickey Oros Senior Vice President, Business Development oros@altergy.com 916-458-9412
Dantherm Power, Inc. Burnaby, BC Canada	Dantherm is cited by Navigant Research as the leading UPS and backup power fuel cell developer.[28]	http://www.dantherm-power.com/	Nina Caroline Hjorth Project Manager, Business Development nch@dantherm.com 458-843 5500
IdaTech, LLC Bend, OR	IdaTech is cited by Navigant Research as a leading UPS and backup power fuel cell developer.[29]	www.idatech.com	Kathy Schwiebert, Ph.D. Vice President of Engineering 541-322-1054
Electro Power Systems Torino, Italy	Electro Power Systems is cited by Navigant Research as a leading UPS and backup power fuel cell developer.[30]	http://www.electropowersystems.com/	Giuseppe Gianolio, Ph.D. Chief Technology Architect email@electropowersystems.com +39-011-225-8211
Ballard Power Systems, Inc. Burnaby, BC Canada	Ballard has shipped over 2,000 fuel cell systems to telecom customers, equivalent to 7,800 kW of backup electric power for 'short duration runtime' and 'extended duration runtime' requirements. Its fuel cells are said to provide a highly reliable and cost-competitive power source for backup power in wireless telecom networks worldwide.	http://www.ballard.com/	Christopher Guzy Vice President and Chief Technology Officer 604-454-0900

[25] "Altergy and Hy9 Announce a Collaboration to Develop an Integrated Methanol Reformer with Altergy Systems Fuel Cells," Yahoo Finance website, November 20, 2012. http://finance.yahoo.com/news/altergy-hy9-announce-collaboration-develop-070000609.html (accessed May 27, 2013).
[26] "Sankosha and Hy9 Establish Strategic Partnership to Meet Telecom Backup Power Needs in Asia," Yahoo Finance website, January 10, 2013. http://finance.yahoo.com/news/sankosha-hy9-establish-strategic-partnership-130000475.html (accessed May 27, 2013).
[27] "Pike Pulse Report: UPS/Backup Power Stationary Fuel Cells," Navigant Research website, 4Q 2011. http://www.navigantresearch.com/research/pike-pulse-report-upsbackup-power-stationary-fuel-cells (accessed May 27, 2013).
[28] Ibid.
[29] Ibid.
[30] Ibid.

BASF Fuel Cell, Inc. Somerset, NJ	Based on its competencies in polymer membranes, catalysts and electrochemistry, BASF is developing sophisticated MEAs for high temperature PEM fuel cells.	http://www.basf-fuelcell.com	Emory S. De Castro, Ph.D. Executive Vice President emory.decastro@basf.com 732-545-5100 (ext. 4114)
Avālence, LLC Milford, CT	Avālence products produce hydrogen fuel for energy storage, industrial, commercial, academic and research use. Avalence forms strategic alliances and creates teaming arrangements with companies involved in the hydrogen infrastructure, renewable energy use and fuel cell power.	http://www.avalence.com	Nancy Selman Vice President, Business Development ncs@avalence.com 203-701-0052
Proton Energy Systems, Inc. Wallingford, CT	Proton OnSite is a partner to the U.S. military, aerospace, fueling and renewable energy industries to meet global hydrogen requirements ranging from grid-level support for energy storage to turbine generator cooling in power plants.	http://www.protonenergy.com http://www.protononsite.com/	Robert Friedland President 203-678-2000
ReliOn, Inc. Spokane, WA	ReliOn markets a range of stationary fuel cells for emergency and backup power systems, uninterruptible power supplies, digital power needs and a range of off grid power requirements. ReliOn is consulting with Bayer Material Science to choose the best material for proprietary components for its E-1100 hydrogen fuel cell.[31]	http://www.relion-inc.com/	William A Fuglevand Vice President Research And Development 509-228-6500
Bayer Material Science, LLC Pittsburgh, PA	With 2007 sales of EUR 10.4 billion, Bayer Material Science is among the world's largest polymer companies.	http://www.MaterialScience .bayer.com/	Jerry MacCleary President 412-777-3012

Names of other potential targets may be found at the following Web sites.

Internet Sites Linking to Other Potential Targets	
Web site	***Reason for Listing***

[31] Kim Ukura, "Fuel cells materialize: as fuel cell technology continues to develop, engineers face a number of concerns," *Product Design & Development*, September 1, 2011, http://www.highbeam.com/doc/1G1-268313457.html (accessed May 27, 2013).

http://www.fuelcells.org/	The Fuel Cells website is a leading independent fuel cell resource. Its provides information relevant to fuel cells, hydrogen, industry and market resources. Fuelcells.org has an informative listing of the fuel cell industry top 200 companies organized by company name, location and type of technology.
http://www.fuelcells.org/top_200.cgim?slug=	A list of the fuel cell industry top 200 companies is available at this website. Fuel Cells 2000 believes these companies to be the most active players in the fuel cell industry, from developers to component manufacturers to hydrogen suppliers and system integrators. The list includes company by name, location and type. The companies can be grouped into separate categories such as, Components & Testing (23), Developer (39), Government (2), Hydrogen Supplier (11), NGO (11) and Service Provider (10).
http://www.fchea.org/index.php?id=2	The Fuel Cell and Hydrogen Energy Association (FCHEA) is the trade association for the fuel cell and hydrogen energy industry, and is dedicated to the commercialization of fuel cells and hydrogen energy technologies.
http://www.chfca.ca/	As the collective voice of the Canadian hydrogen and fuel cell sector, the Canadian Hydrogen and Fuel Cell Association (CHFCA) raises awareness of the many economic, environmental and social benefits of hydrogen and fuel cells.
http://www.hfc2013.com/	Hydrogen + Fuel Cells 2013 (HFC2013) is the sixth edition of its kind, a leading international conference for the hydrogen and fuel cell industry hosted by the Canadian Hydrogen and Fuel Cell Association.