Hydrogen and fuel cell technologies offer a pathway to enable the use of clean energy systems to reduce emissions, enhance energy security, and stimulate the global economy. As part of a portfolio of clean energy technologies, including energy efficiency, renewable energy and fuels, and battery-electric vehicles, employing hydrogen and fuel cells in the economy will help us to achieve these goals. A decade of sustained global research, development and demonstration (RD&D) is now producing the necessary technological breakthroughs for hydrogen and fuel cells to compete in the market. This report offers examples of real-world applications around the world and technical progress of hydrogen and fuel cell technologies, including policies adopted by countries to increase technology development and commercialization.

Hydrogen and fuel cell (HFC) technologies can use diverse domestic renewable and low-carbon resources and address multiple applications across stationary, transportation, and portable power sectors. The challenges facing full commercialization of hydrogen and fuel cell technologies can be addressed through both policy mechanisms and technology improvements, which require consistent and focused international collaboration to increase the incorporation of these technologies in the global energy portfolio.

COMMERCIAL ACTIVITIES

Demonstration projects help to address user acceptance issues and can accelerate the transition to widespread consumer uses. The most dramatic growth in market application of HFC technology has been in several areas including: stationary backup power, the use of fuel cells on forklift trucks, hydrogen production and transportation. Fuel cells are beginning to emerge as a viable, commercially demonstrated option for providing reliable power during natural disasters such as hurricanes, earthquakes, or when electricity grids unexpectedly go offline. Early HFC deployments in materials handling applications reflect the benefit of displacing conventional fossil fuels or batteries for special applications, which leads to longer term performance and shorter down time for refueling. For example, it can take 8 hours to recharge a battery, but it only takes 3 minutes to refuel a fuel cell forklift. This results in greater productivity and a reduced need for additional batteries.

The following are 2012 highlights of commercial deployment of HFC technologies.

Power Generation & Electric Grid Support

The world’s largest fuel cell power plant was opened in Daegu City, South Korea. The 11.2 MW facility will sell electricity to an electric utility and high-grade heat to the local municipality for their wastewater treatment plant under long term power purchase agreements.

More than 50 MW of stationary fuel cells were either installed or purchased in the United States since April 2010, according to a new report, State of the States: Fuel Cells in America 2011, by Fuel Cells 2000, a non-profit fuel cell information resource.
Fuel Cell Energy (USA) and the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) recently launched their joint venture for the Fuel Cell Energy Solution in Germany.

Ballard Power Systems of Canada partnered with GS Platech, a subsidiary of GS Caltex, one of South Korea’s largest petroleum refiners, to demonstrate waste-to-energy power generation using zero-emission fuel cells and hydrogen produced from processing of municipal solid waste.

Also in the European Union, waste-to-energy power generation together with hydrogen production for transport applications is supported by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

Transportation

Around the world, a number of automotive OEMs have publicly committed to introducing commercial Fuel Cell Electric Vehicles (FCEVs) to the market in the 2015+ time frame including: Daimler (Mercedes-Benz), Hyundai/Kia, Toyota, Honda, Ford, Nissan and GM.

In Canada, a 20-bus fleet powered by fuel cells produced by Ballard Power Systems and operated by British Columbia Transit in the resort town of Whistler surpassed 2.5 million Kms of service by the end of September 2012. This is currently the largest fuel cell bus fleet in the world.

In the European Union, several of the 26 buses of the CHIC project have been commissioned for daily public transport operations and bus routes in some of the five identified locations across Europe – Aargau (Switzerland), Bolzano/Bozen (Italy), London (UK), Milan (Italy), and Oslo (Norway). High VLo-City, another FCH JU project, intends to increase the fleet of hydrogen powered busses (14) and the number of hydrogen refueling stations (3) in three European regions (Flanders (BE), Liguria (IT) and Scotland (UK)). HyTransit, with six fuel cell buses and the corresponding refueling infrastructure (powered by wind) has a similar objective in Scotland.

In the United Kingdom (UK)-based Intelligent Energy provides an example of the market potential for fuel cell companies – they were listed 33rd in the Deloitte Technology Fast 50 List for 2012, the only energy and green technology company to feature in this listing. Rankings are based on revenue growth over five years, and during this period Intelligent Energy grew by 679 per cent.

In Germany, the Federal Minister for Transport, Building and Urban Development, Dr. Peter Ramsauer announced plans to deploy 50 hydrogen refueling stations (HRS) by 2015. With respect to the existing 15 HRS, an additional 35 HRS will be built. The construction of the coming 35 HRS requires an overall investment of €40 M, funded within the National Innovation Programme (NIP).

The acceptance of the publicly funded NaBuZ project offers the opportunity to install 7 new fuel cell buses into the Hamburger Hochbahn fleet in the coming years. The entire Clean Energy Partnership (CEP) fleet provides up to 100 cars and 11 busses.

The CEP welcomes new partners—the EnBW Energy Baden-Württemberg AG will join the CEP along with 15 associated partners. The aim is to enhance the usage of renewable energies in the transportation sector and to strengthen hydrogen infrastructure. Within an already accepted project, funded by the NIP, EnBW will establish a hydrogen refueling station with on-site hydrogen production in Stuttgart.

Moreover, in September 2012 Siemens also joined the CEP. Siemens announced plans to equip HRS with a proton exchange membrane electrolyzer within the framework of the CEP.

In the UK, Ricardo, an engineering consultancy, and Intelligent Energy, developer of proton exchange membrane fuel cells, announced that they are forming a partnership to apply their respective expertise to providing customers with a fully integrated design, engineering and implementation capability for FCEVs.

Also in the UK, ITM Power, an energy storage and clean fuel company, is participating in a collaborative project supported by the Technology Strategy Board to build and integrate a hydrogen energy storage and vehicle refueling system on the Isle of Wight. The project will allow the electrolyzer to act as demand side management load to enable zero-carbon hydrogen to be produced for use as a vehicle fuel.

Combined Heat and Power (CHP)

Japanese residential fuel cell CHP market is rapidly growing. Under the government-funded demonstration project from 2005 to 2008, more than 3,300 residential fuel cell units were installed. Starting from 2009, several manufacturers, such as Panasonic, Toshiba and ENEOS CELLTECH, are supplying commercial systems, under the common name “ENE-FARM”. With the government incentives for installation, more than 40,000 systems are operated in Japan as of May 2013. Also in Japan, residential SOFC systems named “ENE-FARM type S” were released from JX Nippon Oil and Energy (formerly Nippon Oil) in 2011, followed by Aishin in 2012.
In the European Union, the project Ene-field, echoing the Japanese programme Ene-Farm, was launched in 2012. It involves nine fuel cell system manufacturers and almost 1,000 micro-CHP units across twelve EU member states. These will run for at least three years in demonstration, with the project ending in 2017.

Germany NOW’s lighthouse project CALLUX deployed 270 CHP systems to supply energy to homes. The third phase of the project has just started with the goal to operate 520 CHP systems during the three phases.

An Australian company formed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Ceramic Fuel Cells Limited, has commercialized a domestic combined heat and power system that can use natural gas or hydrogen, which is currently being evaluated in a trial program run by Ausgrid in the Hunter region.

In June 2011, the world’s first “tri-generation” fuel cell and hydrogen energy station began operating in Orange County, California, United States. This combined heat, hydrogen and power joint demonstration project between Air Products, FuelCell Energy, the State of California, and the U.S. Department of Energy (DOE) expects to operate until May 2014. The system can generate 250kWh of electricity and ~100 kg of hydrogen a day, and uses anaerobic digester gas from the Orange County Municipal wastewater system.

Fuel cell backup power system for base station of China Mobile (above)

Back-up and Remote Power Generation

In the United States, more than 1,350 backup fuel cells were deployed primarily by Relion and Altergy, including 806 as a result of Recovery Act funding. Of these, more than 370 were used as backup power for communication towers.

Nedstack shipped a 1MW PEM fuel cell power plant to a Solvay chlorine plant in Belgium, and ACAL Energy installed a 1kW backup power system using its redox cathode technology at another Solvay plant in the UK.

Another 1 MW fuel cell system is presently under construction and will be operating at a demonstration site in Hungary under the European FCH JU project called ClearGen.

A hydrogen PEM fuel cell system from Heliocentris has been installed in Meiningen, Germany, to provide backup power to the city’s council offices. Additionally, 116 fuel cell systems, funded by the NOW, will be deployed in the federal state of Brandenburg for the power supply of the digital radio communication of the public authorities.

FirstEnergy completed its project deploying a 1MW fuel cell developed by Canada based Ballard Power Systems that can provide peak power and load management to utilities when and where it’s needed. Similar power generation systems have been developed and deployed by another Canadian company, Hydrogenics Corporation.
Material Handling Equipment

The United States deployed over 725 fuel cell powered lift trucks as a result of Recovery Act and programmatic funding. The planned deployment by Recovery Act partners (without additional government funding) is over 2,700 additional fuel cell lift trucks. There are now more than 3,500 such trucks deployed or on order in the United States at firms such as FedEx, Coca-Cola, Wegmans, and Whole Foods.

In Germany six international airports are working together to establish a publicly funded project for fuel cell powered baggage tow cars and ground power units.

In Canada Walmart deployed hydrogen powered Plug Power GenDrive fork lifts, with fuel cells from Ballard Power Systems, in their new Balzac, Alberta Distribution Centre. During the initial four month trial, the units logged 18,000 hours of use, 2,100 indoor hydrogen fuelings and achieved a 3.5% increase in productivity over comparable battery-powered forklifts. Operating cost savings are expected to be $2M over a 7 year period and GHG emission savings of 530 tonnes of CO₂ per year.

In the European Union, 200 fuel cell material handling vehicles and associated refueling infrastructure will be tested in 10 to 20 sites as part of the project HyLIFT-EUROPE, making it the largest European trial of hydrogen fuel cell material handling vehicles so far and the world’s first large scale demonstration of airport tow tractors. This will continue efforts of the ongoing FCH JU supported HyLIFT-DEMO project.

Energy Storage

ITM Power, in the UK, has been awarded a grant by the Department of Energy and Climate Change (DECC) to undertake a £100k, 12-month engineering feasibility, as part of the £20m Carbon Capture and Storage Innovation Competition.

ITM Power is leading a consortium in an investigation of the technological, financial and operational feasibility of producing synthetic methane using carbon dioxide from industrial processes and hydrogen produced by electrolysis. The process will convert waste carbon dioxide and renewable hydrogen to produce pure methane for injection into the gas grid and other natural gas substitution applications.

In Canada Hydrogenics Corporation, a leading manufacturer of hydrogen generation & fuel cell products, entered into an agreement with Enbridge Inc, Canada’s largest natural gas distributor and a leader in clean energy solutions, to jointly develop utility scale energy storage in North America. This “power to gas” solution will enable hydrogen produced during periods of excess renewable energy generation to be injected into existing natural gas pipeline networks proportionally increasing the renewable energy content in natural gas pipelines.
In the European Union, a consortium of seven partners including Italy’s largest electricity distributor ENEL, the electrolyzer manufacturer Hydrogenics and the French hydrogen storage specialist McPhy will join forces to install a 1.2 MW electrolyzer with 1 ton of hydrogen storage for smart grid balancing in Puglia, Italy.

In China, two top telecommunications operators, China Mobile and China Telecom, started to test fuel cell backup power systems in their telecommunications network beginning in 2011. This is potentially an extremely lucrative market for fuel cells, and has attracted many international and domestic fuel cell companies, such as Dantherm Power, VN Tech, FutureE, Palcan and Foresight Energy. According to preliminary statistics, more than 66 fuel cell units are deployed for test trials. Successful trial activity is expected to lead to commercial deployments of fuel cell systems in the telecommunications network.

**POLICY DEVELOPMENT AND PROGRAMS**

As hydrogen and fuel cells begin to play a greater role in meeting the energy needs of the world, safety related to using hydrogen as a fuel remains a high priority.

In the European Union, the European Commission announced in January of 2013 an ambitious package of measures to ensure the build-up of alternative fuel infrastructure across Europe with common standards. For hydrogen, the Commission is proposing binding targets on Member States where such activities have already been developed for a minimum level of refueling stations, corresponding to a maximum distance between stations of 300km, to be built by 2020. The Commission proposal will now be discussed at the European Parliament and the European Council.

The European Union is also preparing its future research program on fuel cells and hydrogen, which will be part of the 2014-2020 Framework Program ‘Horizon 2020’. A decision on its format and budget is expected in 2013, the renewal of the Fuel Cells and Hydrogen Joint Undertaking is considered.

In the United States, the Investment Tax Credit of $3,000/kW or 30% of installation costs for fuel cells, which is set to expire in 2016, continues to stimulate the market and enable several hundred deployments.

Germany’s NOW has accompanied the development of an EU-Stationary Coalition Position Paper which is focused on a technology introduction strategy and program primarily for CHP and uninterruptible power units.

China’s Ministry of Finance announced in Dec, 2011 that a total of 49 domestically made electric and fuel cell passenger vehicle models will be exempted from sales taxes, including 7 FCV models produced by SAIC, FAW, Shanghai Volkswagen, Chery and Changan. In March 2012, the tax cut policy for energy-saving and new-energy vehicles were announced, and according to the new policy, half the vehicle tax is to be collected on four types of fuel cell buses.

The development of hydrogen energy in Russia is viewed as a priority to lead to the technological modernization of the national economy and is referred to as a Critical Technology at the Federal level. R&D in hydrogen and fuel cells is carried out within two Federal Targeted Programs.

There is an ongoing need to develop national and international safety codes and standards for such items as tank life cycle testing and leak detection.

**TECHNICAL DEVELOPMENTS**

Significant progress in a variety of HFC technologies was made in the last year. Fuel cell markets for stationary generation, backup power, and material-handling applications continued to expand as the operational effectiveness and efficiency of HFC technologies increased. Fuel Cell Today anticipates the global fuel cell market to ship about 78,000 units in 2012, which is more than triple the number of shipments in 2012. Automotive applications progressed as RD&D programs lowered the cost of fuel cells and validated performance and durability in real-world applications. Global automakers continue to work toward a 2015 timeframe for introducing fuel cell electric passenger vehicles into the commercial market.

In Vancouver Canada Mercedes-Benz (Daimler) opened the world’s first dedicated and automated fuel cell stack manufacturing facility in June 2012. The plant has a 20,000 unit capacity per year and is Daimler global center of excellence in FC stack manufacturing.

There have also been advances in the production, delivery, and storage potential of hydrogen. For example, in the United States the delivered cost of hydrogen was further decreased, with hydrogen from steam reforming of methane now in the price-range of gasoline on a per mile basis.

Some HFC technologies must continue to improve performance and reduce cost to be competitive with the capabilities and cost of incumbent technologies.
Hydrogen Infrastructure

The cost to produce and deliver clean hydrogen to end users must be further reduced and include construction of hydrogen fueling stations for consumer use. There is also a need to improve emission-free methods of hydrogen production.

In the United States, to be competitive with existing technologies, the cost of high-volume hydrogen production must be within the range of $2–$4 per gallon gasoline equivalent (gge). The use of distributed natural gas reforming at high volume is projected to be in that range now, but the use of electrolysis or biomass still has about a factor of two to go, even at high volume.

The world’s first tri-generation (combined hydrogen, heat and power or CHHP) fuel cell and hydrogen energy station opened at the Orange County Sanitation District’s wastewater treatment plant in Fountain Valley, California, in the United States and was co-funded by DOE. The system, which is capable of producing hydrogen, heat, and power from wastewater treatment plant gas has been providing hydrogen to a public fueling station since March 2011 and has achieved 54% efficiency (power + hydrogen).

The growth of successful hydrogen distribution systems in both stationary and vehicle applications is impressive, especially in fleet applications where there are now over 50 stations in the United States and more than 220 worldwide. While the cost of delivering hydrogen for remote backup power systems remains high, there has been considerable progress in their deployment.

In the European Union, the Hydrogen Infrastructure for Transport (HIT) project aims at developing a Synchronized Implementation Plan for hydrogen refueling stations roll-out along a 1,000 km Trans-European Network corridor from Gothenburg (Sweden) to Rotterdam (Netherlands) and at demonstrating the state of the art refueling technology through the construction of three pilot stations in the Netherlands and Denmark.

The UK’s first public hydrogen vehicle refueling station opened at Honda’s manufacturing facility in Swindon, and the first 700 bar hydrogen refueling station opened in Holstebro, Denmark.

A new £7.5 million (USD $12.1 million) demonstration program in the UK will help further accelerate the adoption of HFC technologies for everyday use. There is increasing interest in using existing gas pipeline infrastructure in the United States and Canada to deliver hydrogen-rich gas to end-use points. A notable example is the Hawaiian Hydrogen Initiative between the Departments of Defense and Energy, General Motors on Oahu, and Hawai‘i Gas. In this initiative, Hawai‘i Gas is assessing the feasibility of using the hydrogen produced as a by-product from its synthetic natural gas production process to distribute hydrogen-rich gas blends into its 1,100-mile natural gas pipeline system at key locations to be used in FCEVs.

The first pipeline-fed hydrogen fueling station opened in Torrance, California, United States. This station has two fueling islands and four dispensers, enabling up to four vehicles to fill at the same time.

Proton OnSite has been awarded a $1.7 million second-phase contract with the United States Army’s Tank-Automotive Research Development and Engineering Center to produce a large-capacity hydrogen refueling station in Hawaii that will fuel 16 GM Equinox vehicles.

Fuel Cell Vehicles

In the United States there has been a major reduction in the cost of polymer electrolyte membrane (PEM) fuel cells produced at high volume over the last decade (more than 80% since 2002, more than 35% since 2008). The 2012 analysis of this cost showed a projected decrease to $47/kW, within range of the $30/kW target. Although auto manufacturers have not revealed their anticipated production costs, the fact that supply chains are being activated in anticipation of 2015 first generation consumer market introductions suggests that they are confident that it is feasible to commercialize the technology.

Significant progress continues to be made in the United States to lower the platinum group metal (PGM) content from more than 1g/kW to less than 0.2g/kW and is well on its way to the goal of 0.125g/kW. In addition, progress continues on developing...
platinum-free technologies. However, as PGM loading and costs decrease, durability becomes more challenging.

**Fuel Cell Cars and Buses**

Auto manufacturers in the United States continue to expand their HFC demonstration fleets as they move toward their 2015 commercialization date. Currently, Toyota has 100 demonstration vehicles on the road, Honda 200, GM 115, Daimler 100 and Hyundai, and other auto manufacturers are ramping up.

The cost of safe, lightweight, low-volume hydrogen storage systems must come down, although automakers are preparing to incorporate current high-pressure tanks in their 2015 vehicle introductions.

In the United States, the world’s largest single FCEV demo was completed with 183 FCEVs, 25 fueling stations, and more than 3.6 million miles driven as part of the DOE technology validation effort.

- Hyundai Motor Company unveiled a third-generation FCEV with a 100 kW fuel cell, 700 bar storage, -25°C start capability, and a 400-mile range. Forty-eight of these vehicles were added to the Hyundai test fleet in 2011.

- In 2011, Mercedes began leasing the B-Class fuel cell vehicle to customers in Orange County and Los Angeles, California.

Opel, a German automobile company, announced that its HydroGen4 vehicle fleet had passed the 2.4 million mile mark as part of the GM global fleet test.

In the UK, five fuel cell-powered taxis were used to transport VIPs during the period of the London Olympics. The vehicles were supplied by the London Taxi Company and the fuel cell systems by Intelligent Energy. The vehicles were refueled at the Heathrow hydrogen refueling station provided by Air Products. The project was supported by the European Hydrogen Transport for European Cities (HyTEC) project.

In the European Union, the project H2movesScandinavia was completed, with approximately 20 FCEVs (manufactured by Daimler, Hyundai, Honda and Toyota) having driven more than 70,000Kms since 2011.

Thirteen Japanese companies announced plans to install 100 hydrogen fueling stations by 2015 as part of a previously announced commitment to introduce FCEVs to consumers by 2015.

**Technical and Economic Analysis**

Recent studies from the United States National Renewable Energy Laboratory have shown that there is a factor of 1.8 to 2.4 greater fuel economy of hydrogen fuel cell buses than the fuel economy of diesel and compressed natural gas buses.

In Germany, the study “Integration of Wind Hydrogen Systems in the Energy System” investigates the future amount of surplus wind power that cannot be fed into the electricity grid, but can be converted into hydrogen instead. It emerges that wind hydrogen can satisfy most of the demand for fuel cell vehicles in Germany and be economically viable. Another study, “Hy-NOW: Evaluation of the processes and technologies for hydrogen provision based on biomass” evaluates the potential of hydrogen production from biomass in Germany and identifies promising conversion technologies. Both studies will be published in 2013.

In the European Union, the Fuel Cells and Hydrogen Joint Undertaking presented the conclusions of a study on the various powertrain technologies available for urban buses in Europe from 2012 to 2030 (fuel cells and others). Some 40 companies and government organizations participated in this study, which provides up-to-date comparative and...
well-to-wheels data of the sustainability aspects, performance and economics. A subsequent study on the development of a European urban fuel cell bus commercialization strategy is planned for 2013. In parallel, the European Electromobility Observatory (EEO) was launched in December 2012. The EEO will act as a European point of reference for electromobility, including fuel cell vehicles.

Also in the European Union, twelve European leading organisations have announced the launch of the 2-year duration HyUnder project, which will provide the first complete assessment (through 6 case studies) of the potentials for large scale storage of fluctuating renewable electricity in underground salt caverns for hydrogen, with specific focus on using synergies with its application as transport fuel and other markets.

RESEARCH PROGRESS

As shown by the number of successful HFC system demonstrations and commercial deployments, great strides have been made in all areas of hydrogen use. However, continued R&D is required to meet the long-term goals shown in Table 1 and further increase the use of this promising technology. In 2011 in the United States, DOE awarded $7 million to four independent studies to evaluate pathways for reducing both fuel cell and hydrogen storage system costs. Reducing system costs is a key to increase the value of these technologies and their widespread use. Following is an overview of HFC R&D conducted over the past year, organized into six research areas: hydrogen generation, storage, fuel cell development, stationary applications, compression, and research for enabling other renewable technologies.

Major efforts are made in the European Union to identify the degradation mechanisms of fuel cells and stacks and to increase their durability. This research leads to world durability records, notably achieved in Jülich. Another research topic of great interest at European level is the use of electrolyzers to generate hydrogen from excess renewable energy from wind turbines and solar panels.

Fuel Cells

It is possible to reduce fuel cell costs through continued R&D in targeted areas, such as reducing or replacing platinum catalyst (which represents close to half of high-volume PEM fuel cell stack cost), lowering membrane costs, as well as reducing the cost and improving the durability of balance-of-plant components.

In the UK, ITM Power is undertaking an eighteen month development program with the Carbon Trust to develop its high energy density membrane material for automotive applications. Three months into the program the material has outperformed all the targets against which it has been measured.

The UK’s Acal Energy has developed a proprietary liquid catalyst to eliminate most of the platinum used in conventional fuel cells. The company has benefitted from the Carbon Trust’s PEM Fuel Cell Challenge, and has successfully raised an additional £3.25m from existing investors in its latest funding round. This will help to bring forward the commercialization of Acal’s technology.

In the United States, Argonne National Laboratory, Brookhaven National Laboratory, and 3M have been developing innovative low and ultra-low platinum catalysts, while Los Alamos National Laboratory has been developing a non-platinum catalyst – many of which exhibit levels that exceed, or are projected to exceed, DOE targets.

In Canada, the Canadian government has invested in a national research network of academic institutions, a public research institute and industry aimed at reducing or eliminating the use of platinum in fuel cells. Complementary cost reduction investments have also been into application specific projects aimed at reducing the cost of fuel cell buses & cars.

Hydrogen Production and Distribution

Efforts to reduce the cost of delivered hydrogen focus on improving production pathways other than natural gas reforming. Pathways such as electrolysis and biomass still require a factor of two cost reduction at high volume to be competitive. Parallel efforts to reduce the accompanying greenhouse gas emissions for all methods continue.

Compression is a major cost component of hydrogen fueling infrastructure. HyET, a Dutch company, announced that its electrochemical compressor technology has achieved 800 bar (11,600 psi)
hydrogen compression from atmospheric pressure. In addition, the single-stage compressor has no moving parts, avoiding issues around friction and wear. The company is targeting applications for hydrogen filling stations. Air Products has demonstrated tube trailer delivery of hydrogen at high pressure to reduce the need for compression at the station. Linde has demonstrated cryo-pump technology with high efficiencies for compression.

A hybrid power plant in Prenzlau, Germany was put into operation by Enertrag and other companies in October 2011. It converts wind power into hydrogen and both stabilizes the electricity grid and provides fuel for FCEVs. Since 2012 wind hydrogen has been shipped from Prenzlau to Berlin to fuel the vehicles of the Clean Energy Partnership. Another wind-hydrogen-system by the company Wind-projekt will enter into operation shortly.

In Russia, to integrate renewable energies into the electric grid and to improve energy management the NRC “Kurchatov institute”, JSC “Red Star”, and Joint Institute for High Temperatures have been developing an innovative demonstration energy accumulation system based on hydrogen technologies. This system consists of a high pressure PEM electrolyzer (130 bar), two types of hydrogen storage systems and a PEM fuel cell.

For MW-scale applications, a 5 MW power unit was successfully tested by the Joint Institute for High Temperatures RAS and Voronezh “Khimavtomatika” Design Bureau which is a key element for future hydrogen energy management systems. Due to fast start-up, it is has a variety of applications such as fire extinguishing.

Australia’s CSIRO conducts research that covers a range of scientific capability and new technologies that are relevant to hydrogen; these include research into membrane and separation technologies and solar conversion of natural gas to syngas.

**Hydrogen Storage**

Safe, high-pressure vehicle fuel tanks have been proven, but their cost in the United States remains at least two times too high (roughly $2,700 produced at high volume). Efforts to develop new lightweight materials continue to be actively pursued for high-pressure storage on board vehicles. For solid-state storage, many different materials are showing promise.

In Germany, the need to integrate large volumes of fluctuating renewable energies into the wider energy system, places urgency on the matter of developing storage solutions. Thus, the federal government launched an “Energy Storage Funding Initiative” worth € 200 million, supporting R&D and demonstration of different storage technology options, including hydrogen storage systems and electrolyzer as key components. Private sector initiatives such as “Performing Energy - Wind Hydrogen Alliance” are working towards realizing large-scale hydrogen storage by fostering collaboration in demonstration projects carried out between companies and other organizations.

In Russia, an advanced storage system of cryo-compressed hydrogen in flexible glass capillaries has been developed in the NRC “Kurchatov institute.” The technical characteristics of the system will correspond to DOE 2015 targets for the gravimetric and volumetric capacity of mobile storage vessels.

**Regulations, Codes and Standards (RCS)**

Non-technical barriers to broader adoption must also be addressed, such as the public’s unfamiliarity with HFC systems and a prevailing misconception that hydrogen is unsafe and unreliable. Furthermore, current regulations and standards do not always reflect real-world use of HFC technologies and need to be standardized. A major advancement includes progress towards the Global Technical Regulation on hydrogen fuelled vehicles. This regulation will serve as the technical underpinning for the United States Federal Motor Vehicle Safety Standard.

**HYDROGEN AND FUEL CELLS IN THE GLOBAL ECONOMY**

There has been significant commercial adoption of hydrogen and fuel cell technologies in niche areas, such as fuel cell forklifts and backup power. Commercial passenger vehicle introductions are anticipated in the 2015 timeframe, but their success will be coupled to a commitment to build up fueling infrastructure. While limited hydrogen infrastructure networks are expanding in certain regions in the United States including California, Hawaii, and New York, more will be needed for large-volume commercial sales. However, this growth will not happen without continued support of RD&D from various venues.

Government support can ensure that the early markets for HFC technologies successfully “cross the chasm” that is so often associated with early technology adoption. This will further stimulate private investment in these products and technologies, which have already been shown to be assets in niche areas. With support, these technologies will play a vital, more widespread role in meeting the energy objectives of the IPHE Partners.
# BUDGET

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* Initial estimates, to be finalized in 2013

The members of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) have been coordinating activities since 2003 to accelerate the adoption of hydrogen and fuel cell technologies into the global economy. The four priority focus areas of the IPHE are: 1) Accelerating the market penetration and early adoption of hydrogen and fuel cell technologies and their supporting infrastructure; 2) Policy and regulatory actions to support widespread deployment; 3) Raising the profile with policy-makers and the public; and 4) Monitoring hydrogen, fuel cell and complementary technology developments. IPHE has 18 member governments, including: Australia, Brazil, Canada, China, the European Commission, France, Germany, Iceland, India, Italy, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, the Republic of South Africa, the United Kingdom and the United States. Together, members have a combined population of approximately 3.5 billion people, use three-quarters of all the electricity produced on the planet, and account for two-thirds of global energy consumption and CO$_2$ emissions.

To learn more about the IPHE and it’s members, please visit our website at [www.iphe.net](http://www.iphe.net).