

Introduction

Hydrogen has received increased attention as a renewable and environmentally-friendly option to help meet today's energy needs. The road leading to an understanding of hydrogen's energy potential presents a fascinating tour through scientific discovery and industrial ingenuity.

1766 Hydrogen was first identified as a distinct element by British scientist Henry Cavendish after he evolved hydrogen gas by reacting zinc metal with hydrochloric acid. In a demonstration to the Royal Society of London, Cavendish applied a spark to hydrogen gas yielding water. This discovery led to his later finding that water (H₂O) is made of hydrogen and oxygen.



1783 Jacques Alexander Cesar Charles, a French physicist, launched the first hydrogen balloon flight. Known as "Charliere," the unmanned balloon flew to an altitude of three kilometers. Only three months later, Charles himself flew in his first manned hydrogen balloon.



1788 Building on the discoveries of Cavendish, French chemist Antoine Lavoisier gave hydrogen its name, which was derived from the Greek words—"hydro" and "genes," meaning "water" and "born of."

1800 English scientists William Nicholson and Sir Anthony Carlisle discovered that applying electric current to water produced hydrogen and oxygen gases. This process was later termed "electrolysis."

1838 The fuel cell effect, combining hydrogen and oxygen gases to produce water and an electric current, was discovered by Swiss chemist Christian Friedrich Schoenbein.

1845 Sir William Grove, an English scientist and judge, demonstrated Schoenbein's discovery on a practical scale by creating a "gas battery." He earned the title "Father of the Fuel Cell" for his achievement.



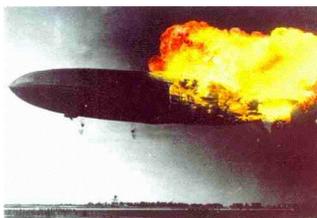
1874 Jules Verne, an English author, prophetically examined the potential use of hydrogen as a fuel in his popular work of fiction entitled *The Mysterious Island*.

"I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable."

Jules Verne,
The Mysterious Island (1874)



- 1889 Ludwig Mond and Charles Langer attempted to build the first fuel cell device using air and industrial coal gas. They named the device a fuel cell.
- 1920s German engineer, Rudolf Erren, converted the internal combustion engines of trucks, buses, and submarines to use hydrogen or hydrogen mixtures. British scientist and Marxist writer, J.B.S. Haldane, introduced the concept of renewable hydrogen in his paper *Science and the Future* by proposing that “there will be great power stations where during windy weather the surplus power will be used for the electrolytic decomposition of water into oxygen and hydrogen.”
- 1937 After ten successful trans-Atlantic flights from Germany to the United States, the Hindenburg, a dirigible inflated with hydrogen gas, crashed upon landing in Lake-wood, New Jersey. The mystery of the crash was solved in 1997. A study concluded that the explosion was not due to the hydrogen gas, but rather to a weather-related static electric discharge which ignited the airship’s silver-colored, canvas exterior covering which had been treated with the key ingredients of solid rocket fuel.
- 1958 The United States formed the National Aeronautics and Space Administration (NASA). NASA’s space program currently uses the most liquid hydrogen worldwide, primarily for rocket propulsion and as a fuel for fuel cells.
- 1959 Francis T. Bacon of Cambridge University in England built the first practical hydrogen-air fuel cell. The 5-kilowatt (kW) system powered a welding machine. He named his fuel cell design the “Bacon Cell.” Later that year, Harry Karl Ihrig, an engineer for the Allis—Chalmers Manufacturing Company, demonstrated the first fuel cell vehicle: a 20-horsepower tractor. Hydrogen fuel cells, based upon Francis T. Bacon’s design, have been used to generate on-board electricity, heat, and water for astronauts aboard the famous Apollo spacecraft and all subsequent space shuttle missions.
- 1970 Electrochemist John O’M. Bockris coined the term “hydrogen economy” during a discussion at the General Motors (GM) Technical Center in Warren, Michigan. He later published *Energy: the Solar-Hydrogen Alternative*, describing his envisioned hydrogen economy where cities in the United States could be supplied with energy derived from the sun.
- 1972 The 1972 Gremlin, modified by the University of California at Los Angeles, entered the 1972 Urban Vehicle Design Competition and won first prize for the lowest tail-pipe emissions. Students converted the Gremlin’s internal combustion engine to run on hydrogen supplied from an onboard tank.
- 1973 The OPEC oil embargo and the resulting supply shock suggested that the era of cheap petroleum had ended and that the world needed alternative fuels. The development of hydrogen fuel cells for conventional commercial applications began.



- 1974 National Science Foundation transfers the Federal Hydrogen R&D Program to the U.S. Department of Energy. Professor T. Nejat Veziroglu of the University of Miami, FL, organized The Hydrogen Economy Miami Energy Conference (THEME), the first international conference held to discuss hydrogen energy. Following the conference, the scientists and engineers who attended the THEME conference formed the International Association for Hydrogen Energy (IAHE).
- 1974 International Energy Agency (IEA) was established in response to global oil market disruptions. IEA activities included the research and development of hydrogen energy technologies.
- 1988 The Soviet Union Tupolev Design Bureau successfully converted a 164-passenger TU-154 commercial jet to operate one of the jet's three engines on liquid hydrogen. The maiden flight lasted 21 minutes.
- 1989 The National Hydrogen Association (NHA) formed in the United States with ten members. Today, the NHA has nearly 100 members, including representatives from the automobile and aerospace industries, federal, state, and local governments, and energy providers. The International Organization for Standardization's Technical Committee for Hydrogen Technologies was also created.
- 1990 The world's first solar-powered hydrogen production plant at Solar-Wasserstoff-Bayern, a research and testing facility in southern Germany, became operational. The U.S. Congress passed the Spark M. Matsunaga Hydrogen, Research, Development and Demonstration Act (PL 101-566), which prescribed the formulation of a 5-year management and implementation plan for hydrogen research and development in the United States.
- The Hydrogen Technical Advisory Panel (HTAP) was mandated by the Matsunaga Act to ensure consultation on and coordination of hydrogen research. Work on a methanol-fueled 10-kilowatt (kW) Proton Exchange Membrane (PEM) fuel cell began through a partnership including GM, Los Alamos National Laboratory, the Dow Chemical Company, and Canadian fuel cell developer, Ballard Power Systems.
- 1994 Daimler Benz demonstrated its first NECAR I (New Electric CAR) fuel cell vehicle at a press conference in Ulm, Germany.
- 1997 Retired NASA engineer, Addison Bain, challenged the belief that hydrogen caused the Hindenburg accident. The hydrogen, Bain demonstrated, did not cause the catastrophic fire but rather the combination of static electricity and highly flammable material on the skin of the airship. German car manufacturer Daimler-Benz and Ballard Power Systems announced a \$300-million research collaboration on hydrogen fuel cells for transportation.
- 1998 Iceland unveiled a plan to create the first hydrogen economy by 2030 with Daimler-Benz and Ballard Power Systems.



Interested in Learning More?

U.S. Department of Energy
www.eere.energy.gov/hydrogenandfuelcells

National Hydrogen Association
www.hydrogenassociation.org

U.S. Fuel Cell Council
www.usfcc.com

International Partnership for the Hydrogen Economy (IPHE)
www.iphe.net

New York State Energy Research and Development Authority

17 Columbia Circle
 Albany, NY 12203-6399
 toll free: 1-866-NYSERDA
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 fax: (518) 862-1091

www.nyserda.org

1999 The Royal Dutch/Shell Company committed to a hydrogen future by forming a hydrogen division. Europe's first hydrogen fueling stations were opened in the German cities of Hamburg and Munich.

A consortium of Icelandic institutions, headed by the financial group New Business Venture Fund, partnered with Royal Dutch/Shell Group, DaimlerChrysler (a merger of Daimler Benz and Chrysler), and Norsk Hydro to form the Icelandic Hydrogen and Fuel Cell Company, Ltd. to further the hydrogen economy in Iceland.



2000 Ballard Power Systems presented the world's first production-ready PEM fuel cell for automotive applications at the Detroit Auto Show.

2003 President George W. Bush announced in his 2003 State of the Union Address a \$1.2 billion hydrogen fuel initiative to develop the technology for commercially viable hydrogen-powered fuel cells, such that "the first car driven by a child born today could be powered by fuel cells."



2004 U.S. Energy Secretary Spencer Abraham announced over \$350-million devoted to hydrogen research and vehicle demonstration projects. This appropriation represented nearly one-third of President Bush's \$1.2 billion commitment to research in hydrogen and fuel cell technologies. The funding encompasses over 30 lead organizations and more than 100 partners selected through a competitive review process.



2004 The world's first fuel cell-powered submarine undergoes deepwater trials (Germany navy).

2005 Twenty-three states in the U.S. have hydrogen initiatives in place.

Today-2050 Future Vision

In the future, water will replace fossil fuels as the primary resource for hydrogen. Hydrogen will be distributed via national networks of hydrogen transport pipelines and fueling stations. Hydrogen energy and fuel cell power will be clean, abundant, reliable, affordable and an integral part of all sectors of the economy in all regions of the U.S.