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# Is Hydrogen Becoming Increasingly Popular?

*by Larry Plachno*

**Although it got off to a slower start, hydrogen fuel cell power seems to be coming from behind and becoming increasingly popular as an alternative fuel. Currently available in transit buses, hydrogen fuel cell power is moving into coaches where it shows an advantage in range. Shown here is an Irizar i6 coach with hydrogen fuel cell power that has a range of more than 600 miles.** IRIZAR.

For more than two years the bus people in Europe have been telling us to watch for an increase in interest in hydrogen fuel cell power. To some extent it has been long overdue. Although introduced in the United States more than two decades ago, hydrogen failed to keep pace with developments in battery-electric power. One reason is that battery-electric power was pushed along by engineering in the automotive industry who were developing this same power system. Another, and possibly lesser known, problem was concerns over different "colors" or ways of generating hydrogen.

It appears that interest in hydrogen has effectively exploded in recent months. In Europe, production of hydrogen fuel cell buses had been increasing slowly over the past decade and then, like other buses, suffered a decline following the pandemic. However, the recent Busworld event in Brussels introduced several hydrogen bus models including coaches with respectable ranges. Here in the United States, President Biden has announced the development of seven new hydrogen hubs around the nation that will develop hydrogen for transportation and other purposes.

In order to tell the entire story, we will go back two decades to the introduction of hydrogen fuel cell technology to transit in California. From there we will move into current developments in Europe and in the United States. Then, we can look at how a hydrogen fuel cell works in providing transportation. Finally, we can compare the advantages and disadvantages of hydrogen while explaining about the "colors" of hydrogen.

**Early History**

Arguably, the event that initially got hydrogen fuel cell transit in the public eye came when AC Transit in California put full-size hydrogen buses in regular transit service. It all started in 1999 when some of the AC Transit staff attended the American Public Transportation Association (APTA) show in Orlando and became fascinated by the Ballard fuel cell bus on display. This resulted in AC Transit joining the California Fuel Cell Partnership in early 2000.

Making the decision to move ahead with hydrogen fuel cell power, AC transit developed a small hydrogen energy station in conjunction with the California Fuel Cell Partnership and Stuart Energy. Located at AC Transit's Richmond Division in Richmond, California, it became operational in October of 2002. It generated hydrogen from the electrolysis of water and stored it for use in buses and other vehicles.

Anxious to get started with fuel cell power, AC Transit was able to lease a 30-foot bus from Thor Industries. UTC provided the fuel cell while ISE supplied power control software and systems. The bus was put in service in 2003 as well as 2004 and was fueled at the Richmond Energy Station. AC Transit also tested hydrogen autos and light-duty vehicles that were also fueled at the same location. The results of this initial program were encouraging since they showed that the hydrogen bus averaged the equivalent of 7.5 miles per gallon and 83 percent availability.

Deciding to move ahead with hydrogen fuel cell power, AC Transit worked with Chevron to develop a second hydrogen station at their Seminary Division in Oakland. This one was about six times as big as the original station at Richmond and used a steam reformer to develop hydrogen from natural gas. It had two dispensers so two buses could be fueled at the same time. This facility was able to refuel up to nine Hyundai Tucson fuel cell light-duty vehicles as a participant in the U.S. Department of Energy's Validation Project. It also had a stationary fuel cell that could use excess hydrogen to generate electricity for the facility.

By this time AC Transit was developing its new San Pablo Bus Rapid Service to provide better transportation on San Pablo Avenue, a major artery in the East Bay communities. After looking at several alternatives, AC Transit decided to purchase 131 diesel-powered Belgian-built Van Hool A330 40-foot, low-floor transit buses plus 57 diesel-powered Van Hool AG300 60-foot articulated, low-floor transit buses. [see the

October, 2004 issue of National Bus Trader]

Looking for a way to expand their hydrogen fuel cell project to full-size transit buses, AC Transit made the decision to order three additional new 40-foot Van Hool A330 buses and equip them with hydrogen fuel cell power. Since this request was so revolutionary, it prompted some questions in the hallowed halls of the Van Hool plant in Belgium. As a result, a small group of Van Hool staff, including resident mechanical wizard Francis Stevens, made their way to AC Transit in California to look into the hydrogen fuel cell project. The Van Hool group was satisfied with what they saw. As a result, Van Hool built three specially modified A330 low-floor transit buses without drive trains for the AC Transit's fuel cell project. The three as-yet-unpowered buses came to be called "gliders."

The building of these three hydrogen fuel cell buses caused a great deal of interest in the bus industry. First, because they are full-size transit buses to be placed in true high capacity transit service. Second, because this is not a stock "off-the-shelf" package but a unique set of components designed specifically for a bus application. The fuel cell selected was the 102 KW Pure Motion™ power system manufactured by UTC Fuel Cells of Connecticut. Included in the buses were three zebra nickel sodium chloride batteries that could capture energy from regenerative braking. Electric motors came from Siemens and had their ELFA drive. ISE in San Diego was responsible for integrating the various components around their own power control software and systems.

An interesting side note is that Sunline Transit in Thousand Oaks, California was very impressed with what they saw. They asked for a fourth set of fuel cell equipment be put together for them. ISE complied with their request although a different type of bus was used.

While there were other hydrogen fuel cell experiments and operations at this time, it was the AC Transit operation that caught the eye of the bus industry and received a great deal of publicity [See the article in the September, 2005 National Bus Trader]. The AC transit operation was different in two ways. One is that it was specifically a bus operation. The second is that it involved full-size transit buses operating on a heavy transit route. Among other things, this AC Transit operation showed that hydrogen fuel cell power was perfectly capable of being used to power full-size, heavy-duty transit bus operations.

The staff from Van Hool was impressed enough that they began working on similar technology in Europe. This is not necessarily surprising since Van Hool has had a reputation for offering a number of alternative


**It was the early hydrogen fuel cell transit operation at AC Transit in the East Bay area that showed that hydrogen was practical for bus operations. AC Transit developed its own hydrogen energy station in 2002 and then put their first hydrogen bus in operation in 2003. Shown here is that first hydrogen bus using a bus from Thor Industris, a fuel cell from UTC and power control software ISE.** AC TRANSIT.

power sources. However, hydrogen fuel cell power seemed to languish in the United States. One reason could have been a concern over how the hydrogen is produced, resulting in hydrogen of different "colors." We will cover this in more detail later.

Industry experts suggest that much of the reason for the lack of interest in hydrogen is that the battery-electric bus industry was helped along by the work, engineering and sales going into battery-electric cars. In comparison, there has not been much of a hydrogen fuel cell automobile industry. What we have been able to find is that there may only be 17,000 hydrogen fuel cell automobiles in the United States and virtually all would be in California where 50 hydrogen fuel cell stations are located.

Hydrogen fuel cell buses slowly began to catch on in Europe, but numbers built

**AC Transit acquired three 40-foot A330 buses without engines from Van Hool that were called gliders. They were then equipped with hydrogen fuel cells from UTC, electric motors from Siemens and power controls from ISE. These buses operated successfully in heavy-duty transit service that proved that hydrogen was perfectly capable of becoming a viable alternative fuel.** AC TRANSIT.

were lower than electric, CNG and hybrid. It was not surprising that Van Hool was a pioneer in this area and remained a major player in this market. Expectedly, hydrogen fuel cell bus sales dropped dramatically after the pandemic hit as with all of the other buses. However, two things changed recently which prompted us to start work on this article. One was increasing interest in hydrogen buses and displays at the recent Busworld Europe in Brussels in early October. Noteworthy was the introduction of hydrogen-powered coaches with an impressive range. The second event was President Biden's October 13 announcement to develop seven new hydrogen hubs around the United States to encourage the use of hydrogen in vehicles and other applications.

## Recent Events

### Increasing Hydrogen Fuel Cell Buses in Europe

Interest in hydrogen fuel cell buses has been increasing in Europe for nearly a decade. Here are a few of the more interesting examples. Van Hool of Belgium, who was somewhat of a pioneer in this area, received an order in late 2015 from Transport for London. It covered hydrogen fuel cell buses based on the Van Hool A330 12-meter (39-foot) bus. They had Ballard fuel cells and only needed 30 kilograms of hydrogen to cover a daily distance of 300 kilometers.

In 2018 Van Hool was building 40 hydrogen fuel cell buses for Germany; 30 buses for Köln and 10 for Wuppertal. At that time this was the largest order to date for fuel cell buses in Europe. They are the Van Hool A330 model, approximately 39 feet long with Ballard fuel cells. Deliveries started in the spring of 2019. It was noted that Köln (Cologne) had been operating two Van Hool hydrogen fuel cell buses since 2014 and was pleased with them.

Another major step forward came in 2019 when the new Bus Rapid Transit service was opened in Pau in the south of France. What made this innovative is that the eight buses were articulated, 18-meters (59 feet) long and built by Van Hool. Powered by hydrogen fuel cells, the buses run on dedicated lanes that are six kilometers long with 14 stations in the center of Pau. Keolis provided technical assistance for the route.

In 2021, Alexander Dennis introduced a next generation double-deck hydrogen fuel cell bus with a range of 300 miles. The new buses use Ballard fuel cells and Voith electrical drive systems. ADL President and Managing Director Paul Davies suggested the hydrogen power will be a milestone for zero emission technology with unrivaled efficiency that gives it a class-leading edge. He went on to say that hydrogen fuel cell power was perfect for high mileage routes that battery technology does not cover.

Activity seemed to increase in 2022. Italy joined the hydrogen club when Rampini of Italy introduced its new Hydron hydrogen fuel cell bus. Although only eight meters (26 feet) in length, it can transport up to 48 passengers. What makes the Rampini Hydron model interesting is that it uses an Energy Balance System that communicates with all on-board systems to achieve maximum performance. As a result, the hydrogen tank with a capacity of 10.8 kilograms gives the Hydron a range of 450 kilometers (280 miles) that is within the range of many transit applications.

What really caught everyone's attention in the hydrogen world was the hydrogen coach displayed at the IAA show in Hanover, Germany in September of 2022. Marcopolo from Brazil showed their Audace 1050 model powered by a hydrogen fuel cell drive. Although built with only two axles, it was a full-size coach with a length of about 39 feet and seating for 53 passengers. It had four hydrogen tanks, ZF axles plus Knorr air suspension and brakes. This same model was also available in both shorter and longer

**Like battery-electric power, hydrogen fuel cell power is much cleaner than diesel engines. Diesel fuel as well as most other lubricants and fluids are not needed. This photo shows a fuel cell being lifted into the engine compartment of one of the AC Transit Van Hool buses.** AC TRANSIT.


**After their involvement with the pioneering AC Transit fuel cell buses, Van Hool became an early leader in hydrogen fuel cell buses in Europe. In 2018 Van Hool built 40 hydrogen fuel cell buses for Germany including 30 for Köln and 10 for Wuppertal. Köln had previous experience operating two Van Hool fuel cell buses.** VAN HOOL.

lengths. Marcopolo said it had an operating range of 600 kilometers (about 370 miles).

More recently, the Busworld Europe show in October in Brussels, Belgium, showed some amazing hydrogen developments. Marcopolo again displayed their hydrogen-powered Audace 1050 coach, but the real show-stopper was the hydrogen-powered Irizar i6S Efficient that made its debut at this event. This is a modified version of the i6 that Irizar sells in the United States. In Europe it is available in lengths of up to 48 feet. The coach has a range of 1,000 kilometers or about 620 miles, bringing it into the range of many coach charter and shuttle applications. It can be refueled in 20 minutes. In addition, it can also be run as a battery-electric coach for short periods if necessary. This is somewhat turning heads in suggesting that hydrogen may be a better option for coaches.

Although there were several hydrogen-powered transit buses at Busworld, one that was particularly interesting was the introduction of the Midibus Hydron from Rampini in Italy. This new version of the Hydron can operate purely as a battery-electric bus, purely as a hydrogen fuel cell bus or a custom hybrid version to suit the customer's specific needs to extend the range of the bus. In the past we had hybrid diesel-electric power, but Rampini may have brought up a new concept that could see various power systems combined for the specific needs of the bus operator.

**The most recent development that is turning heads is the new i6 hydrogen-powered coach from Irizar. This coach has a range of more than 60 miles and can be refueled in 20 minutes. It can also run as a battery-electric coach for short periods.** IRIZAR.

**America's New Hydrogen Hubs**

The day after Busworld Europe ended in Brussels, President Biden was in Philadelphia announcing a $7 billion dollar program to build seven new hydrogen hubs in the United States. The announcement was somewhat of a surprise to many who had seen the current administration pushing heavily for battery-electric power as the answer to going green. Apparently the program had been underway for quite some time since the seven locations selected were picked from 79 proposed by private-public partnerships to the Department of Energy.

Several people involved have suggested that this new and expensive program is a federal attempt to kick start a brand new industry that can help America go green. Hence, it will require a great deal of effort to point it in the right direction and make sure it develops properly. Plans include substantial infrastructure, pipelines and tanks. There will be a long road of funding and permitting ahead. In addition to the $7 billion for the new hydrogen hubs, an additional $1 billion has been allocated for supporting demand, which will include hydrogen fuel cell-powered vehicles.

**Rampini from Italy joined the hydrogen fuel cell market in 2022 with their Hydron hydrogen fuel cell midi-bus. Eight meters long, the bus had a range of 280 miles. Since then, Rampini has offered models that combine battery-electric and hydrogen fuel cell power into one bus.** RAMPINI.

The seven hydrogen hubs named include the Mid-Atlantic Hydrogen Hub that covers Pennsylvania, Delaware and southern New Jersey. An Appalachian Hydrogen Hub will be located in West Virginia, Ohio and Pennsylvania. California's Hydrogen Hub will look at heavy-duty trucking and port operations. In the South, a Gulf Coast Hydrogen Hub will be centered around the Houston, Texas area. In the North, the Heartland Hydrogen Hub will cover Minnesota, North Dakota and South Dakota. The new Midwest Hydrogen Hub will be located in Illinois, Indiana and Michigan. Finally, the Pacific Northwest Hydrogen Hub will cover Washington, Oregon and Montana.

Expectedly, there are groups that are both positive and negative on these new hydrogen hubs. The Biden administration suggests that moving to hydrogen could reduce 25 percent of climate emissions by 2050. Proponents of hydrogen power suggest that it is more versatile than battery-electric power. While battery-electric power has already proven itself in the field of transportation, it has been pointed out that hydrogen power could be more appropriate for numerous other applications including stationary fuel needs, manufacturing and even cell phones

and remote power applications. While hydrogen might not be the best alternative in each situation, it is versatile enough to be used for most energy needs.

There are several concerns on the negative side. One is that since the administration is effectively jump-starting an entirely new industry, it needs to be carefully guided in the right direction. Most of the hydrogen produced today comes from fossil fuels so some people caution allowing the oil and gas industry to control the new hydrogen venture. Another possible problem area is that it would be very easy to spend too much money or cause excess pollution elsewhere to generate hydrogen. If you produce hydrogen using electricity, would the hydrogen produced have more energy than the electricity used? Again, there is also the concern with the different "colors" of hydrogen based on how it was produced.

Hydrogen is like electricity in that both can be generated from different sources with different results. For example, electricity itself is "clean" in application but can be "dirty" if generated from unclean coal or some other polluting source. While hydrogen is the most popular element in our universe, it is never found by itself in nature. In order to make pure hydrogen for fuel, it must be taken from elements that may have varying degrees of concern or pollution. This is where the colors of hydrogen come from.

There are eight colors of hydrogen that we know of. Considered the cleanest is *Green Hydrogen* which splits water into hydrogen and oxygen during renewable energy like solar and wind power. *Pink Hydrogen* is made from electrolysis powered by nuclear energy. *White Hydrogen* comes from geological deposits. Another example is *Turquoise Hydrogen* that comes from natural gas but eliminates $CO_2$ emissions by using the pyrolysis method.

The dirtiest methods include *Brown Hydrogen* that comes from lignite and *Black Hydrogen* that is made from bituminous coal. Currently, the most common and cheapest way to produce hydrogen, *Gray Hydrogen*, uses steam-reforming on methane. Somewhat better is the *Blue Hydrogen* method that improves on Grey Hydrogen by capturing the $CO_2$ emissions during the process. Hence, in dealing with hydrogen, a great deal of thought goes into how the hydrogen is produced.

### How a Hydrogen Fuel Cell Works

A hydrogen fuel cell is simpler and has considerably fewer moving parts than a diesel engine. Some might say that it is less mechanical and more chemistry. Unlike a bus engine that moves the drive line mechanically, the fuel cell generates electricity that is put into a battery. That electricity is then controlled by the driver and used to power an electric motor that in turn is connected to the drive line and makes the bus move.


**One of the biggest advantages of hydrogen fuel cell power is that refueling is not that much different than diesel fuel. While the connection needs to be more secure, you can fuel a hydrogen bus or coach in about 20 minutes. This, combined with a range of more than 600 miles, suggests that hydrogen may become more practical with coaches than battery-electric power.** AC TRANSIT.

In operation, hydrogen (H2) is fed into one side of the fuel cell. Oxygen from the air (O2) is fed into the other side of the fuel cell. The hydrogen and oxygen then combine into water (H2O). This is then generally exhausted as harmless water vapor. What happens is that as the hydrogen and oxygen combine into water, electricity is produced. This electricity is then fed into the battery system to provide power for the electric

**This photo shows the engineless compartment of a Marcopolo hydrogen fuel cell bus. The most obvious first impression is that it is much cleaner than a diesel-powered bus. In addition to the lack of fuel, the hydrogen fuel cell has less need for lubricants and other fluids.** MARCOPOLO.

motor. If it sounds simple, it actually is. Moreover, this operation is much cleaner than a diesel engine.

### Comparisons

Right now we are in an era of comparing the various forms of energy, particularly in regard to transportation. These might include gasoline, diesel fuel, hydrid, overhead wires or third rail, propane, natural gas, battery-electric and now hydrogen. There actually are others. For example, Toyota is offering an ammonia-powered engine and several other propulsion methods have been used over the years including steam, naphtha, compressed air and flywheels. For now, we can eliminate these other propulsion methods from consideration.

How do you compare these different forms of power? There are several different criteria being considered including cleanliness, flammability, cost, range and ease of use. As a general rule, the industry is moving away from fossil fuels and more towards clean and renewable fuels. Here are some general thoughts, but industry leaders are looking at this from several different aspects.

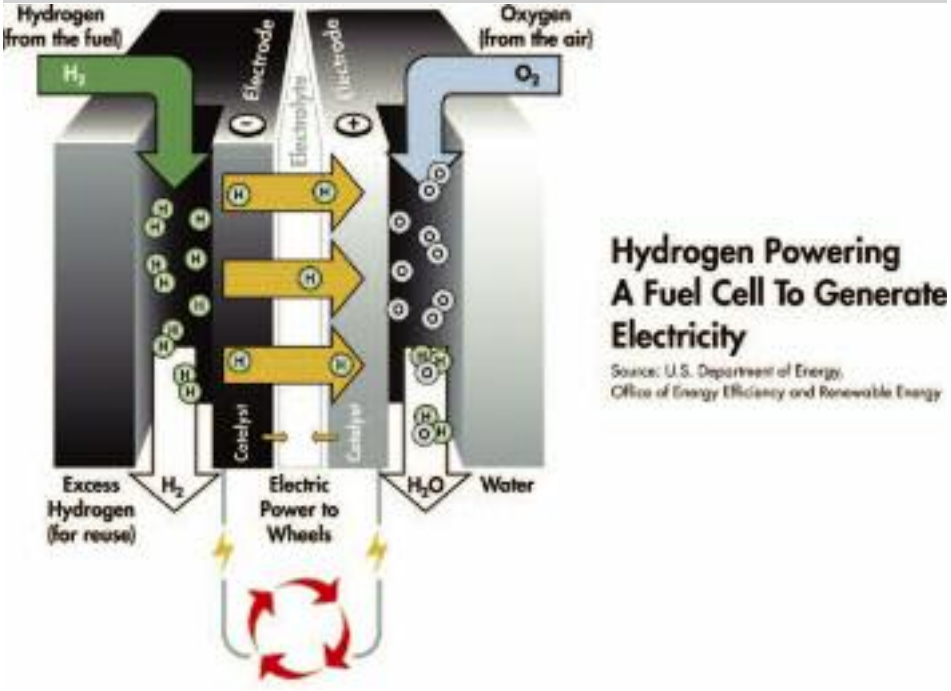

**The hydrogen fuel cell industry has progressed to the point where you can actually buy a kit to convert a diesel bus to hydrogen. In early June of 2023, SAFRA from France introduced their H2PACK® hydrogen retrofit kit at the Public Transit Summit in Barcelona. The Mercedes-Benz coach on display is one of 15 that SAFRA was retrofitting with hydrogen power for the Occitanie Region in France.** SAFRA.

**Flammability**

By and large, the most flammable fuel has been gasoline. While diesel fuel occasionally is mentioned, it is less likely to catch fire. Bus engine compartments can now be fitted with fire suppression systems to further reduce the possibility of a fire. While propane, natural gas and hydrogen are flammable, they have not caused a substantial number of fires. The tanks are relatively rupture-proof and unless there is a source of ignition, these gasses will dissipate in the air quickly. Hydrogen, being lighter than air, will disappear very quickly if let loose.

The single biggest concern in recent years has been the lithium batteries used in vehicles as well as other things. If they catch fire from damage or overheating, they are difficult to extinguish. Both the post office and airlines have restrictions on them. The New York City Fire Department has indicated that lithium batteries have replaced cigarettes as the leading cause of fires. Unlike other fires, lithium fires are very difficult to extinguish and require special equipment and procedures. As a result, this is starting to become a negative feature of battery-electric vehicles.

**A hydrogen fuel cell has considerably fewer moving parts than a diesel engine. Hydrogen is fed from one side while oxygen from the air comes from the other side. When they meet, they produce electricity to run the bus as well as some water vapor.** AC TRANSIT.




**Cost**

The cost of alternative fuels is difficult to compare because it can vary so much from one place to the next. For example, places that have hydroelectric power have an advantage with trolley or battery-electric buses. Some places may have economical electrical power while others may have an advantage with other fuels. One concern that is emerging is that some of the processes used to generate electricity or hydrogen may actually use more energy than is generated. What I suspect may happen is that different areas may favor different types of power and that increased use of hydrogen may change the balance in the years ahead.

**Range**

Range has become an increasing concern in certain applications such as coaches and trucks. The hands-down leader in this area would be overhead electric wires or third rail because they allow operation without carrying fuel or a need to stop to refuel. Obviously, both gasoline and diesel fuel are small and light enough to provide a decent vehicle range. Battery-electric has progressed to the point where it is suitable for most transit operations, and can be extended with chargers at the end of the bus line.

Hydrogen is starting to emerge as a contender for better range on coaches and trucks. Irizar already has a coach with a range of more than 600 miles and a refueling time of 20 minutes. While the tanks require more space than diesel fuel tanks, this does provide some possibility for the future. The interesting question is that now the administration is developing hydrogen hubs, will we see hydrogen become more popular in vehicles including automobiles?

**Going Green and Clean**

Unfortunately, this is not an easy question to answer. In recent years, the people watching for pollution have taken this task to multiple levels. The first and most obvious one is at the application. Both electric and hydrogen offer no real pollution while operating. Electric motors may produce a little ozone and hydrogen fuel cells may release some water vapor, neither of which is a concern.

However, more interest is being shown on how the electricity and hydrogen are generated. Is this process clean? Does it create pollution in any way? The problem here is that while renewable options like solar and wind power may be the most desirable, others may object to nuclear power. Hence, in the move to going green, we may end up taking a closer look at how our electricity is generated. A side note is that there are increasing concerns that our electrical grid is already overtaxed and we either need to improve it or look for power elsewhere.

In addition to the above, there are people pointing out that some of the manufacturing may not be the cleanest. Increasingly coming under fire are the lithium batteries for electric vehicles. The lithium and other materials need to be mined and shipped, which is not a clean operation. Battery production is traditionally not a clean operation, which is why China has been a leader in this area. In addition, the used lithium batteries can create a disposal problem. Although battery production is going domestic, there are concerns that they may be a negative factor in going green.

**In September of 2022 Marcopolo showed its hydrogen fuel cell bus at the IAA show in Hanover, Germany. It had a length of about 39 feet, seated 53 passengers and came with ZF axles as well as Knorr air suspension and brakes. This early model offered an operating range of about 370 miles.** MARCOPOLO.

**Future?**

At this point the crystal ball for the future of transportation energy is somewhat clouded. This article was primarily put together to get readers up to speed on recent developments with hydrogen power. However, a great deal is going on and the administration's new hydrogen hubs are very much still in their infancy. In addition, hydrogen is initially showing some positive trends towards providing greater range for coaches and trucks. We will try our best to keep up with developments and get them to our readers in future issues. ❑


**Hydrogen fuel cell power is now starting to make increasing inroads in the United States. Shown here is one of two new hydrogen fuel cell buses from New Flyer that were recently delivered to RTC in Las Vegas. Presumably, additional transit and coach operators will be tempted to try hydrogen power in the near future.**

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9698 W. Judson Road • Polo, Illinois 61064

Ph: (815) 946-2341

Fx: (815) 946-2347

www.busmag.com