Charging Ahead with Electric Buses

by Larry Plachno

The pressure to move to electric buses is substantial. In addition to the obvious reduction in pollution, electric buses are generally less expensive to operate, easier to maintain, liked by passengers and reduce our use of fossil fuels. Some battery electric buses have been operating in Europe for more than three years. Shown here is the i2e model from Irizar. IRIZAR.

In recent months we have seen an increasing interest in electric buses from our readers and a very strong movement in the industry towards this direction. We put off researching and writing this article until after the Busworld show in Europe because we expected to see some substantial progress with electric buses in Europe. We were not disappointed. Irizar is building a factory just for electric buses while VDL has had electric buses in operation for more than three years. Numerous European cities are making plans to eliminate pollution from their transit systems by going electric or at least alternative fuels by specific dates. As we have said for years, it is increasingly obvious that the bus industry is moving in the direction of electric vehicles although there still may be some technology limitations.

As somewhat of a transportation historian, I feel obligated to point out that this is the second electric revolution for the transit industry. While several people were developing electric transportation systems, it was Frank J. Sprague who electrified the Richmond Union Passenger Railway in 1888 and led the movement to electric transit in the following years. Bear in mind that the horsecars, mulecars and even cable cars of that time were not only slow but limited in range. The electric streetcars and interurbans solved both those problems in that era but, ironically, range is now a concern with our newer battery electric transit revolution.

There is substantial pressure to move to electric buses for a number of reasons including reducing pollution, renewable energy, lower maintenance costs, lower operating costs and a better ride for passengers. At least 25 cities have already pledged to buy only non-polluting buses in the future. Twelve cities have specifically said that they will only buy electric buses starting in 2025. These 12 cities include: London, Paris, Los Angeles, Copenhagen, Barcelona, Quito, Vancouver, Mexico City, Milan, Seattle, Auckland and Capetown.

An all-inclusive report on electric bus developments would be impossible because of so much recent activity throughout the world. What I will attempt to do is to cover electric bus developments in three different areas. The first will mention some of the basic information on electric buses such as pros and cons on operations as well as developments and alternatives on the mechanical and technical end. Next, I will go through some of the electric bus advancements in Europe which seem to be leading other areas with electric buses. Finally, we will try to cover some of the developments with electric buses in the United States and Canada. Please note that we were unable to obtain information from some electric bus manufacturers and did not look beyond the basic European and American markets. Hence, this report is more representative than comprehensive.

Pros and Cons

Much of the industry pressure to move to electric buses comes from the fact that they are clean and non-polluting in operation. Some people will argue that the new diesel buses are very clean and that not all electric power is generated without pollution. However, clean electric power is a

marvelous selling point for both riders and taxpayers.

Less obvious but equally important is the fact that electric buses are easier and less expensive to maintain. The dirtiest parts of diesel bus maintenance, the oil and fuel filters, are gone. Instead of using block heaters on cold mornings, you start with a simple switch. In addition, most electric buses will have longer brake life because of regenerative braking. People like IndyGo in Indianapolis, who operate the CCW ZEPS electric buses alongside convention diesel buses, will tell you that the maintenance on the electric buses is easier and less expensive. We have seen several studies that show that the electric buses are more economical after having looked at both operating and maintenance costs.

There are several other positive features of electric buses. Passengers tend to like electric buses because they offer a smoother and quieter ride. Technicians like electric buses because they are more reliable and easier to keep running. Yes, you will still have to replace tires, but most of the stuff in the engine compartment that causes problems is replaced by an electric motor and wires that require minimal attention. Another major advantage of electric buses is that regenerative braking puts power back into the battery pack. There is no diesel bus that puts fuel back into the fuel tank when braking.

The single major negative of battery electric buses is the lack of battery capacity given today's technology. On-route charging reduces this problem but is not practical for long distance service. I will stick my neck out and say that this battery capacity issue is essentially the major reason holding back a wholesale conversion to electric buses. Most cars and buses use standard lead acid batteries for starting, but they can be damaged by losing their charge and are not good for electric bus applications. Hence, most of these electric buses use lithium ion batteries.

The Europeans have also developed what are known as "tram buses" that combine some of the features of high-capacity trams with the ease of bus operations. They do very well when operated on dedicated lanes or roadways. Shown here is an electric version of the Van Hool ExquiCity model that was built for Hamburg, Germany. VAN HOOL.

Even with lithium ion batteries you have problems. One is that they are costly. The second is while they will better withstand deep charge cycles, they do have a finite life. A third is that, even though they are better than most other batteries, they simply cannot hold enough of an electrical charge. If you increase the size of your batteries to get more charge, you also increase costs and the weight of your bus.

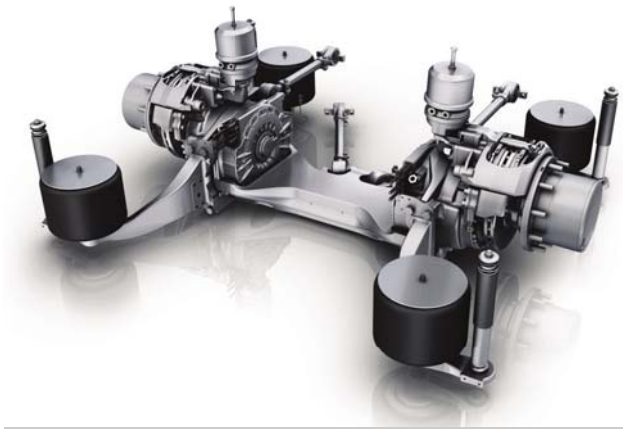
What this means with current technology is that electrical buses are often limited to an operating range of about 150 miles. This is usually workable for transit buses, particularly if they can get some additional charging along the route. This range tends to limit coaches to commuter or shuttle services. What is interesting is that some electric bus manufacturers provide different ranges depending on whether the air conditioning is on or off. There are also some electric bus manufacturers who optionally provide a fuel-fired heater to limit the electrical draw in the cold winter months.

Among the engine manufacturers, Volvo is a leader in electric buses. In 2015, they introduced an electric version of their popular transit bus that is called the 7900e. This photo shows the option of charging the bus by cable or by an overhead connection at the end of the route.

How They Work

With the exception of the propulsion system, batteries, electric motor or any related control equipment, a battery-powered bus is not that much different than a diesel-powered bus. In fact, there is very little difference between driving an electric bus and a diesel bus. However, lighter weight is an obvious advantage for a bus powered by batteries.

While there may be some variations, I only know of two basic ways to get power to the wheels on an electric bus. One of these is to put the electric motors in the axles. This has a couple of significant advantages. One is that it eliminates the



The AVE 130 axle from ZF has been available for several years as a way of powering electric buses. Electric motors are built into the axles so there is no need to use space inside the engine compartment. ZF.

Recently introduced by ZF, their CeTrax electric motor can be connected to a conventional bus drive line. This will enable virtually any bus manufacturer to easily offer a diesel bus model as an electric. ZF.

need for an electric motor in the bus body, thus providing more free space. A second advantage is that you can design the axle to work with a low-floor bus.

This is actually not revolutionary since both streetcars and diesel-electric locomotives have electric motors either mounted on or connected to their axles. The concept has worked well for many years and the motors tend to survive well. For several years ZF has offered their AVE 130 axle with electric motors for this application. I have driven electric buses with these ZF axles and found them very responsive and easy to drive.

Another approach is the electric motor that can be attached to a relatively conventional drive line. Although originally designed for high-floor buses, this could conceivably also be used on low-floor buses. ZF calls their electric motor CeTrax and I have heard that Cummins recently introduced a similar motor. This has the advantage in that the electric motor will effectively replace the diesel or other engine in the engine compartment and connect to the drive line. It is desirable in many cases because it can be used with buses designed for traditional engines and drive lines, although it would require some changes.

I could write a lot on batteries, but the batteries most typically used in electric buses at this time are lithium ion or something similar. They tend to be expensive and in many cases may warrant changing after a few years. Right now, the range for a fully-charged electric bus is probably somewhere around 150 miles. A lot of effort is going into the search for a battery that can hold more of a charge with less weight. Anyone who invents something like that will make a fortune.

What appears to be the single biggest factor holding back electric bus development is the lack of battery capacity. One solution to this is to top off the electric charge along the route using a system in the pavement or an overhead device as illustrated by this New Flyer bus. Several manufacturers have been working to standardize electric connections. NEW FLYER.

There are three popular ways to charge an electric bus. What might be called the most traditional would be an overnight charge in the bus garage using a cable. There are two advantages to this system. One is that electric power is the least expensive in the middle of the night. The second is that a long, slow charge usually does the least to wear out the battery or other components. The negative aspect of this is that the electrical charge is limited to what the bus battery can hold and may not be enough for some routes or applications.

A second alternative is an overhead charging system, usually placed at the end of the bus line. Poles or a device on the bus roof will raise up and make contact with the charging device. This system is typically used to extend the range of the bus by increasing the charge already in the batteries. The positive aspect is that it allows the bus to increase its battery charge without having to return to the garage. The negative is that if the bus is running late, there may be a conflict between getting a charge or remaining on schedule. A similar system is used on a light rail line in Japan where the train charges a little at each station but there is no wire over the rest of the track.

A third type of charging system is embedded in the pavement. The bus parks over the area and receives a charge when standing still. One brand, known as the WAVE system, has been used effectively with CCW's ZEPS buses. Like the overhead contactor, this kind of system is more typically used to top off a charge at the end of a line and has the same shortcoming as the

overhead charging devices in that the bus must be parked to use it.

European Electric Buses

There are reasons why we have elected to include some of the recent developments in European electric buses. One of the most obvious is that Europe has become a leader in this area with electric buses in operation for more than three years. Several European cities have made commitments to move to electric or at least non-polluting transit by specific dates. While not directly related to electric buses, I might note that Europe is also producing what they call "Tram Buses" that are articulated and offer more capacity in order to provide Bus Rapid Transit (BRT) service on heavier routes.

As an interesting side note, I observe that some of the European bus builders who also build diesel engines have been significantly slower in offering electric power than many of the bus builders who do not have their own engines. Volvo has been a significant exception to this with their 7900 electric bus. Here, very briefly, are some of the electric bus developments in Europe that are worth noting.

Based in the Netherlands and Belgium, VDL is credited with having the most electric buses operating in Western Europe – nearly 300 by the end of 2017. They offer both conventional 10- and 12-meter buses with electric power as well as a lighter bus slightly shorter than 10 meters. Also available is this 18.1-meter Citea electric articulated with BRT design. VDL.

Irizar in Spain has had conventional electric buses running for quite some time in both 12-meter and 18-meter lengths. Just introduced at Busworld in late 2017 is their new 18-meter Tram bus with BRT design shown here. Irizar is well along with constructing a new facility in Spain that will specialize in building electric buses. IRIZAR.

VDL has the most battery electric buses operating in Western Europe. They originally started in 2013 with a 12-meter battery electric bus, added an 18-meter articulated two years ago and a shorter 10-meter bus last year. By late 2017 they had nearly 300 electric buses operational in Western Europe. They are now offering a low-floor, 18.1-meter Citea model with modern BRT design.

Another leader in this area is Irizar. Their i2e electric bus has been on the road for three years. Originally offered in a length of 12 meters, the product line was later expanded with an 18-meter articulated version. At the recent Busworld in Kortrijk, Irizar introduced their new ie bus as well as an impressive 18-meter articulated ie Tram bus with BRT design. It is noteworthy that Irizar has invested in a new factory south of San Sebastian, Spain that will be dedicated to electric bus production.

Volvo deserves special credit for being one of the first diesel engine builders to embrace electric bus technology. Their popular 7900 transit model was originally introduced in 2011, and was soon expanded into additional models including hybrid power and a longer articulated version. June of 2015 saw the introduction of an electric version known as the 7900e. This model was featured at the recent 2017 Busworld show in Belgium where their Opportunity Charging System was shown that allowed the buses to be charged at the end of the line from overhead equipment as well as overnight in the garage.

Now building in both Belgium and Macedonia, Van Hool has developed a wide range of power options on its buses. Working with AC Transit in the United States, they built some of the first fuel cell buses in 2009. Current power offerings include diesel, CNG, fuel cell, hybrid, trolley electric and battery electric. Their ExquiCity Tram Bus is available in lengths of 18 and 24 meters (double-articulated) and has been built with most of these power options. Van Hool is also developing an electric coach for the North American market based on their CX45 and CX35 diesel coach designs.

The leading bus builder in Turkey, Temsa, has been involved in electric buses for a while. Their MD9 electriCITY bus was introduced in 2015. It is a shorter transit bus with up to three doors, a capacity of about 26 seated passengers and a two-hour charging time. Making a debut at this recent Busworld event in Belgium was the new Temsa Avenue Electron. This is a more conventional 12-meter electric transit bus with an extended range of

Temsa from Turkey offered their first electric bus in 2015, the MD9 ElectriCITY. At the recent Busworld in Belgium they introduced their new 12-meter Avenue Electron electric bus. NBT.

Yutong from China introduced their new two-door ICe12 electric coach with traditional coach features for the European market at the recent Busworld. It has a range of up to 165 miles. NBT.

almost 250 miles. Charging times as low as eight minutes have been claimed.

Based in Poland, Solaris was founded as a Neoplan licensee named Neoplan Polska. They have subsequently developed their own line of transit buses under their Urbino model as well as a tram bus design. They are another bus builder moving ahead with electric buses. Their 18-meter articulated Urbino model was first introduced in 2014 and is now available as a battery electric with a capacity of 140 passengers. A more conventional 12-meter electric Urbino is also available as is a shorter 8.9 meter electric.

Some of the Chinese bus builders got an early start in electric buses. Pollution has been a concern in China while battery technology has been moving ahead at a steady pace. Yutong, the largest bus builder in China, introduced two new electric bus models at the recent Busworld show in Belgium. Their E12 is a relatively standard 12-meter electric bus with a range of 140 to 200 miles depending whether the air conditioning is on or off. Perhaps more interesting was their new ICe12 12-meter electric coach. It has a range of about 135 to 165 miles depending on whether the air conditioning is on or off. It does have most typical coach features including luggage compartments.

I would be remiss if I did not mention that in late 2017 we received word that Mercedes-Benz has been moving ahead with their electric Citaro bus. The first delivery of their electric Citaro will go to a German transit operator, Rhein Neckar Verkehr GmbH, in late 2018.

Complete Coach Works in California offers a remanufactured battery electric bus known as the ZEPS or Zero Emission Propulsion System. It combines a rebuilt and upgraded low-floor transit bus with new systems that has been repowered by an electric motor. It has the advantage of being highly compatible with buses already in the fleet. This example is one of 21 ZEPS buses operating for IndyGo in Indianapolis. COMPLETE COACH WORKS.

Remanufactured Electric Buses

There is only one company offering remanufactured electric buses and that is Complete Coach Works in California. They have three significant advantages. The first is that for transit operations seeking to try electric buses, this offers the most economical alternative. The second is that since the buses are highly compatible with their existing fleet, the transition on support and maintenance is minimal. The third follows up on the second advantage by offering operators an easy and accurate comparison between diesel and electric since the CCW electric buses are so similar to existing fleets.

What the engineers at Complete Coach Works did was to develop what they call their Zero Emission Propulsion System or ZEPS bus. It starts with a clean, low-floor transit bus that operated in service with diesel power. It is then stripped down to the frame and rebuilt with new components and systems. In many areas the bus is better and more modern than initially built. Emphasis is placed on lighter weight where possible. Instead of a diesel engine, the bus receives a clean electrical motor and drive line. This same procedure has also been used with other vehicles including trolley-themed buses and shorter buses.

ZEPS buses are in operation from coast to coast. In many locations they are the first electric buses in the fleet and are being evaluated prior to transit agencies moving to larger fleets of electric buses. Indygo, the transit operator in Indianapolis, has 21 ZEPS buses in operation. Their electric fleet has already put on substantial miles and has developed an excellent record in operations and maintenance.

United States and Canada

The United States and Canada have had less pressure to move towards electric buses. Among other things, EPA regulations have made diesel engines so clean that they have minimized the advantages of electric buses. Hence, by the end of 2017 there are only a few small electric bus operations although there are several bus operators experimenting with or testing electric buses. Noteworthy are the remanufactured ZEPS electric buses that are running in numerous communities. Indianapolis has a fleet of 21 that have compared very favorably with the equivalent diesel buses. Here is a list of some of the manufacturers who are bringing electric buses to the United States and Canadian market and have provided information.

Nova Bus is a major transit bus builder in the United States and Canada with manufacturing plants in both countries. As a subsidiary of Volvo and associated with Prevost, Nova Bus can draw upon the substantial bus building expertise of both organizations. The company has embarked on an Electro Mobility™ strategy building for the future. Volvo has had considerable experience with electric buses, particularly their 7900 battery electric transit bus that was introduced in 2015.

In battery electric buses, Novabus currently offers their LFSe model. Based on their popular LFS design, this is a 40-foot, low-floor transit bus with a seating capacity of up to 41 seated passengers (loading capacity:71). Mechanically, it has four Volvo high voltage lithium-ion batteries in parallel. Two of the batteries are located on the roof while the other two are in the rear of the bus. Propulsion comes from a TM4 Sumo HD electric power-

Novabus builds in both Canada and the United States. As a subsidiary of Volvo, it has access to Volvo technology and support. They currently offer their LFSe model. This 40-foot electric transit bus is based on their popular low-floor LFS design and incorporates Volvo lithium-ion batteries and a TM4 electric powertrain. NOVABUS.

train. This is hooked up as a direct drive, without a gearbox.

For charging, Novabus is offering an overhead inverted pantograph that can be placed at the end of the line, garage or other appropriate locations. A superfast charge of less than five minutes gives the bus enough charge to operate for an hour. When the bus is fully charged, that gives the bus a range of up to 15 miles. This effectly allows the bus to operate continually with dedicated infrastructure.

New Flyer introduced their first electric bus prototype in 2012. In late 2017 they introduced their new generation of electric bus known as the CHARGE. They are being offered in lengths of 35, 40 and 50 feet. NEW FLYER.

Three LSF3 are running in Montreal, Canada, since May 2017 with excellent results. The passengers and drivers just love them.

New Flyer in Winnipeg is one of the oldest bus builders in the United States and Canada and most likely has the most experience building electric buses. In 1967, New Flyer rebuilt an electric trolley bus for Toronto that led to an order for 151 buses, the first new trolley buses in North America since 1955. In the following years the company has built thousands of electrically driven buses and today offers both fuel cell electric and battery electric as well as trolley buses.

Their battery-electric Xcelsior heavy-duty transit bus was announced in 2011, was unveiled as a prototype in 2012 and was first delivered in 2014. They utilized the popular heavy duty Xcelsior transit bus design and were tested at Altoona. In October of 2017, New Flyer introduced their new generation electric bus known as the Xcelsior CHARGE™. This battery-electric bus can now be built at either of New Flyer's manufacturing facilities, including Winnipeg, Manitoba; Anniston, Alabama; and Crookston and St. Cloud, Minnesota – available in lengths of 35 and 40 feet as well as an articulated 60-foot Bus Rapid Transit model.

The Xcelsior CHARGE uses a highly efficient electric motor from Siemens that is hooked up as a direct drive and requires no transmission. For the 60-foot version, it has a unique two-axle drive system for added traction and enhanced safety. An optional higher torque motor provides substantial hill climbing ability for cities such as San Francisco and Seattle. Electri-

cal storage is handled by lithium-ion batteries that are assembled in the United States. A sophisticated battery management system is provided. It suppliess three-phrase alternating current for the motor, AC current for the air compressor and air conditioning compressor and DC current for other accessories and lighting. Regenerative braking recovers energy back into the battery system when decelerating to increase range and efficiency.

Two different charging systems are available. Plug-in chargers can be used for overnight, mid-day and off-line battery charging. They provide a full charge in less than five hours that gives the bus an effective range of up to 284 miles (based on the Federal Transit Administration's duty cycle) on a single charge. However, the buses can also make use of on-route rapid chargers that can be placed at terminal points. They allow for additional charging while on a route and can keep the bus in operation 24 hours daily. To recharge, the bus stops underneath the charger and the pantograph makes contact with the charge bars. This system requires fewer on-board batteries.

New Flyer's new Xcelsior CHARGE battery-electric bus is already on order and in production. In October of 2017, the Los Angeles County Metropolitan Transportation Authority placed a firm order for thirty-five 60-foot articulated Xcelsior CHARGE electric buses with an option for 65 more. The Xcelsior CHARGE is even going into private bus service. In December of 2017, Academy Bus in Hoboken, New Jersey placed an order for six 40-foot Xcelsior CHARGE buses to be used for the Columbia University Intercampus Shuttle. They will operate between Manhattan, New Jersey and Rockland County.

In 2017, New Flyer opened a first of a kind vehicle Innovation Center (VIC) in Anniston, Alabama, dedicated to advancing bus and coach technology in America. Transit agencies are invited for hands-on experiences with the essentials of electric propulsion technology and infrastructure.

The 60-foot articulated version of the New Flyer CHARGE provides a unique two-axle drive system for added traction and safety. An optional higher-torque motor provides more hill climbing ability. It is a good choice for Bus Rapid Transit (BRT) applications. NEW FLYER.

Proterra is somewhat different that most other builders. They started with electric buses and never built a diesel bus. Their Catalyst model is amazingly light because it is built with carbon composite material. PROTERRA.

Proterra represents a different type of electric bus manufacturer. The company is relatively young, has limited bus production to only battery electric buses, uses lightweight construction, and has been somewhat of a pioneer in American battery electric buses. It was founded in 2004 by people with prior experience in building CNG buses and aluminum dump trailers. Originally based in Golden, Colorado, the company moved its headquarters and manufacturing plant to Greenville, South Carolina in 2011 to be adjacent to the Clemson University International Center for Automotive Research.

In 2014, Ryan Popple from Tesla Motors took over as CEO. The following year saw the company receive a grant from the State of California to develop an electric bus in the City of Industry, California where they now have a production facility. Later that year the company headquarters moved from South Carolina to Burlingame, California although the production facility in Greenville, South Carolina continues.

Early history includes working with Foothills Transit in Pomona, California on a demonstration project that started in October, 2010. Three Proterra battery electric buses were placed in service and evaluated. That worked out so well that in 2014, Foothills Transit purchased 12 battery electric buses from Proterra.

Early production centered around the EcoRide BE35 model, a 35-foot battery electric bus that carries 37 seated passengers and has a total capacity of about 60 riders. This model completed the 12-year/500,000-mile Altoona test in March of 2012 and was reported to be the first full-size, heavy-duty battery electric transit bus to do so.

In 2014, Proterra introduced its new Catalyst model, a fast-charge 100 percent electric bus to replace the BE35. Improvements included a longer, lighter and more fuel efficient bus. It was initially offered with a length of 40 feet but only weighed 27,000 pounds, less than any other 40-foot transit bus on the market. Much of the weight reduction is due to using durable carbon composite material for construction. A similar 35-foot model was made available in October of 2015.

The Catalyst uses a lithium battery that can be charged at a bus stop in five to 10 minutes. For charging, overhead terminals are connected to a charging station while stopped at a bus stop. This does not require driver involvement. In June, 2016, Proterra granted royalty-free access to the patents covering their overhead charging system. By 2017, Proterra has sold more than 375 buses with major orders going to Foothill Transit, King County Metro in Seattle and the Transit Authority of River City in Louisville.

Two of the more interesting developments in American electric buses are electric coaches from MCI. MCI's connection with New Flyer gives the company access to 50 years of electric bus construction and recent developments in this area. MCI's J4500, the most popular coach in the industry, will soon be available as a battery-electric coach. The first demo unit will be testing in early 2018 and additional details will be available in the near future.

In addition, MCI will be offering a battery electric version of its new D45 CRT LE Commuter Coach. Introduced in late 2017, the D45 CRT LE is a new concept in improving transportation for those with mobility concerns. It is based on the traditional and durable MCI "D" model Commuter Coach with some updates and improvements. Looking for ways to make boarding easier for those with mobility devices, MCI came up with a low entry that is much easier to use than a wheelchair lift. The coach has a traditional front door for ambulatory passengers, but it also has a center door at curb level leading into a lower section of the coach. Those with mobility devices can enter or leave the coach easily and quickly using only a simple ramp.

MCI's new D45 CRT LE Commuter Coach offers all of the traditional MCI features but has added a middle door and ramp to a lower level area to make entry and exit easier for those with mobility devices. It will soon be available as a battery electric coach with a Siemens electric motor and a battery system that can be charged in less than three hours. Orders will be taken in 2018. MCI.

A 100 percent electric version of this coach will be available in the near future. It will be powered by a Siemens 2130 LB FT electric drive system and will use a battery thermal management system driving its motor and control systems. The battery system can be charged in less than three hours and will have sufficient range for long distance commuter operations. Orders will be taken in 2018.

In the fourth quarter of 2017, Van Hool announced that it had selected Proterra to provide the battery platforms for electric coaches that will be sold on the American market. The coaches will use the E2 battery technology developed by Proterra. Two models will be available, both based on existing diesel coaches in the Van Hool product line. The 45-foot CX45E is based on the existing popular CX45 model while the 35-foot CX35E is based on the recently-introduced CX35 model. The electric coaches will be highly compatible with the diesel coaches in some of the parts and maintenance. The new electric coaches will be introduced to the American market in early 2019. ❑

Van Hool will soon be offering an electric coach to the United States market. It will be based on their popular 45-foot CX45 model and new 35-foot CX35 model. It will be on the market in 2019 and sales will be handled by ABC Companies. ABC.

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