

FCEB Webinar Series 2024: #1 – The Fundamentals of Fuel Cell Electric Bus Deployment

Question & Answer Session:

Q. I have many clients at small and mid-sized transit agencies interested in hydrogen, but there aren't any cutaway/shuttle bus or transit van options for them. Can you provide any insight you may have on upcoming options?

A. Manufacturers of cutaways and shuttle buses are responding to market demand, so it's important for transit agencies that need zero emissions and more capability than batteries tell their suppliers that they want fuel cell options. Bus OEMs will engage in development of a new platform only when they see market appetite.

Q. How do fuel cell electric buses (FCEB) compare to battery electric buses (BEB) and diesel buses for availability and uptime?

A. One of the most current and thorough studies done by bus operators is the AC Transit series of studies, comparing BEB to FCEB to diesel and diesel hybrid, in actual operations. You can find all four volumes [here](#).

Q. If possible, please describe maintenance training/education options for our frontline mechanics and technicians. The current US LowNo grant requires an education/training element, plus we need to know how to maintain, troubleshoot, and repair this technology.

A. Please attend our upcoming webinar on March 28th focused on maintenance, fueling and cold weather operation. There we will describe our on-site fuel cell module training, as well as training equipment available from Ballard that has been successfully applied to LowNo grant applications.

Q. Is there anything in the industry pointing to a reduction in the cost of hydrogen over the coming years?

A. The purpose of the seven DOE hydrogen hubs, each with about \$1B of federal funding, is to create economies of scale to drive down hydrogen

prices. These projects won't begin production until 2027 or so, however in the more immediate term the industry is looking to the IRS production tax credit, which provide up to \$3/kg of tax incentive, which is almost 1/3rd of the price being paid by transit today for delivered hydrogen. Most major clean hydrogen production projects which could drive down the price are waiting for final guidance on this tax credit.

Q. What about retrofitting an existing bus?

A. We are interested in supplying fuel cell modules to experienced bus retrofitters, as we would to any commercial bus OEM, however Ballard's scope of supply is the fuel cell module itself.

Q. I've had many colleagues voice concern about hydrogen because they see it as either dangerous, or more often say that hydrogen is just another way for gas/oil companies to stay relevant. I'm curious if you have run into these comments or something similar, and how you have addressed them?

A. We have! We have found that education is almost always the cure for such skepticism, except for those whose opinions are locked-in by self-interests. A great site for a wealth of FCEB information is from the [California Hydrogen Business Council](#) or ask them to attend or view recordings of our webinars!

Q. How much of a difference is there in battery requirement between BEB and FCEB?

A. The New Flyer Xcelsior Charge FC has 140kWh of battery, which is about a quarter of the battery of the smallest 40' BEB transit buses.

Q. What is the volumetric power density of a heavy-duty fuel cell? Is it a fuel cell dominant or battery dominant system?

A. You can figure the power density of the module from our spec sheet for the [FCmove®-HD+ 100kW module](#). The questions of "dominance" of either fuel cell or battery is entirely subjective – the control systems can draw upon either or both energy sources to drive the motor and can direct fuel cell power to the motor or to charge the batteries. Certainly, from an energy perspective all FCEBs are fuel cell-dominant as 100% of the energy comes

from hydrogen, but from a power perspective it's more subjective, and may not be the best term to describe a hybridized battery fuel cell electric powertrain.

Q. What percentage of the hydrogen is produced from electrolysis?

A. Hydrogen sources are customer decisions and vary from site to site. Delivered hydrogen in California is mandated to be made from at least 40% renewable sources, being either electrolysis or reformed natural gas (RNG). The electrolyzer in Champaign Urbana provides 100% electrolyzed hydrogen from a dedicated PV system for their FCEBs. The hydrogen dispensed at SARTA comes from RNG. The carbon content of hydrogen varies as widely as the carbon content of the electrical grid – however most transit customers choose to source their hydrogen from low-carbon hydrogen suppliers when they are available.

Q. Will there be any other Bus suppliers working with Ballard outside of New Flyer?

A. In Europe, Ballard works with several transit bus OEM customers today, including Solaris, Wrightbus and Van Hool. In the U.S., New Flyer is the only present supplier, although Ballard has supplied ElDorado National for the fuel cell buses they have produced in the past.

Q. Can BEB convert to fuel cell?

A. Yes – at a high level, most of the propulsion batteries must be removed, a hydrogen fuel storage system must be installed, as well as a fuel cell module and dedicated radiators, and the control system revised. Conversions of different powertrains to FCEB have been accomplished in the past by companies that do transit bus conversions, such as Complete Coach Works – for more information, we recommend speaking to them directly.

Q. What grade/color hydrogen goes into the buses?

A. Like electricity, hydrogen has no color – the hydrogen color rainbow is perpetuated by opponents of hydrogen, who wish to portray hydrogen in a

certain light. The U.S. hydrogen industry is converging on carbon intensity as a metric.

Q. Is either Ballard or NFI working with ammonia as a fuel for fuel cells, or as a source of hydrogen for the cells?

A. Our fuel cells operate on pure hydrogen only, so any carrier for the hydrogen such as ammonia would have to be reformed before use in our system. Such an ammonia “cracker” for use directly on a transit bus is likely to be costly and complex, so is not likely to be of interest for a bus OEM but could be for on-site fueling infrastructure.

Q. Will FC120 still be battery-dominant technology? I see 140 KWH battery for the drive to get the range.

A. Battery or fuel cell “dominant” is not useful terminology from our perspective. New Flyer has sized these components for maximum efficiency as well as maximum overall range and maximum range at peak power output.

Q. As we pivot more towards nuclear power and a broad range of renewables, electricity should get cheaper – meaning that the production of hydrogen will get cheaper?

A. We see a lot of excitement and common interests from the nuclear industry in using hydrogen production to maintain continuous rated output from nuclear power, enabling more economic operation of these facilities, particularly with high renewables penetration on the grid.

Q. How much does high altitude affect the fuel cell's power output?

A. Our operation remains unchallenged up to 8000ft of elevation. For sites higher than this, some power derating may be required due to thinner air for reacting hydrogen and for cooling.

Q. What is latest estimates for next-gen FCEVs on miles per kg?

A. In the absence of a detailed study, we see >10 mi/kg in some applications! In general, we hang in the 6-8 mi/kg range.

Questions for New Flyer:

Q. Does NFI expect lead times for bus orders to inflate over the next 5-10 years? At what point does NFI expect economies of scale to reduce or plateau the cost of these FCEBs?

A. Re: lead times, we expect them to go down, hopefully soon. The longer lead times we see now are still part of the post-pandemic supply chain hangover and are unfortunately still lingering, and OEMs are still playing catch-up. We expect to align with customer expectations eventually. This is a pain point.

Re: cost reduction, this is controlled a little more on the component supplier side than the end-product OEM side. In transit, unfortunately our market influence on e.g. the global battery market is negligible compared to truck and especially personal automotive and personal devices, so the transit manufacturing industry is in a bit of a "wait and see" for market factors that we cannot influence to make an impact on price. Certainly, the build out of "gigafactories" for these components coming to fruition and adoption of EVs in other sectors will make a difference, and they're coming, but they are behind where we are in transit. We agree that the sticker shock is real at this point, and we share your eagerness for the costs to come down so we can really get some work done.

Q. Would NFI consider producing its own hydrogen right next to where it is going to be used?

A. We are not planning to own hydrogen production assets but rather assist with transit organizations' plans for infrastructure. In this sector, it is typical for transit entities to have significant on-site supply delivered, or even produced, so yes – this is already the case and could continue to proliferate. With transit being one of the few examples of having hydrogen vehicles deployed and thus having a source to fuel them, centering supply and even production around their facilities makes sense and we expect them to be the center of many hydrogen hubs as they're built out for that exact reason.

Q. What about improving the batteries for the current BEB fleets?

A. We continue to monitor the market for the constantly, incrementally improving battery technology that is being commercialized and incorporating them into our products. Last Fall, we announced the onboarding of our [partnership with American Battery Solutions](#), which brings our 40' BEB from 520 kWh to 660 kWh, and along with our [new enhanced pack validation](#) also announced last fall, brings our 60' BEB from 520 kWh to 880 kWh! We have an ongoing technology vetting & validation process for batteries occurring in the background ensuring we have the best new tech coming down the pipe, years out.

Q. Are there plans to improve reporting on Connect 360?

A. Yes, Connect 360 is in constant evolution and is updated frequently with the latest and greatest measurement and calculation techniques. We recognize there's work to be done in automation and accuracy of reports and this is top of mind for our Smart Bus team dedicated to building this tech offering.

Q. Has New Flyer manufacturing facility in Anniston built a H2 operational fueling station infrastructure, not just H2 fuel transfer tanker? New H2 buses need maximum full fuel testing before delivery to customers.

A. We currently only have a transfer-fill style at the Anniston plant. We are taking steps to ensure our Quality team continuously improves fuel system operation and leakage before delivery and recognize there have been problems recently as we are now delivering FCEBs on mass. Thanks for your patience with the process and helping in the journey with pain points along the way – this is the bleeding edge! We understand and agree we can and should be doing better here.

Q. Does NFI infrastructure have extra precautions to avoid any possible hydrogen leakage though the course of wear and tear operations?

A. Yes – the safety systems described during Mike McDonald's presentation monitor and detect unexpected gas system pressure drops and can even identify the approximate location by 'zone' (the system consists of

independent segments).

Q. Any consideration for using LFP batteries in your FCEBs?

A. There are no official plans at this time although we recognize this technology is getting better and could be a good fit for a FCEB that utilizes the batteries in the way we do, where we view them as contributing significant energy to the overall ESS along with hydrogen. We are engaging with the battery supply world, and it very well may turn out that as we expand or potentially change supply that LFP will be in scope for non-high range, all-battery applications.

Q. Has NFI considered storing hydrogen at 700bar for longer range?

A. Not seriously, at least yet. We are developing added capacity options but still at 350, simply due to reducing complexity and weight of the tanks and accompanying balance of plant for the fuel system. [Read more here](#).

This will get us to 5kg on a 40ft and good for easily over 400 miles – good enough for nearly 100% of all North American use cases, even including cabin heating requirements in cold climates. So, there's not really a need to go to 700. When we do a fuel cell MCI coach, that could be a different story.