Fuel Cells, Heavy-Duty Mobility's Apex Solution for Complete Decarbonization

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On April 20th, 2010, in the Gulf of Mexico on the Deepwater Horizon platform, a methane leak exploded upwards from the ocean floor into the oil drilling unit, ultimately causing it to sink. Eleven people were killed, numerous others were injured, and it would take 87 days of environmental damage before BP and associated companies were able to seal the well and stop the stream of oil from continuing to gush into the ocean. By 2021 BP's estimated costs associated with the event were about $70B.

That 2010 disaster made it clear beyond a shadow of a doubt that fossil fuel extraction and use results in prohibitive human, environmental, and currency costs.

After the Deepwater Horizon event various energy firms globally went searching for alternative ways to power the global economy. Firms like Tesla and Volkswagen believe that battery electric vehicles (BEVs) are the best way to decarbonize the heavy and light-duty mobility sectors. However, while BEVs do have positive attributes, they require that all BEV owners have access to an electric station to recharge a vehicle's battery. For people on the light-duty side who live in densely populated areas, the ability to plug-in to recharge a BEV is awkward and expensive.

For fleet operators of Class 8 vehicles BEVs are also not an option simply because even a small BEV fleet would require megawatt charging capacity, and that is something electric utilities are unable to offer to every heavy-duty mobility operator.

Consequently, an innovative firms have prudently concluded that fuel cell electric vehicles (FCEVs) are the best way to decarbonize the heavy-duty mobility sector. FCEVs use hydrogen to power an electric motor, and relying on hydrogen has many benefits. Hydrogen is the most abundant element in the universe, it can be extracted from numerous sources like garbage and water, it can be transported using converted natural gas pipe networks, and, for heavy-duty fleet operators, the transition to FCEVs can be nearly seamless.

FCEVs also have the additional significant benefit of being an apex technology. Once a fleet operator upgrades its entire fleet to using FCEVs, then it need not upgrade to a newer technology for the foreseeable future. In one move Class 8 operators can essentially completely de-couple the mobility side of their operations from the painful volatility and danger of fossil fuels, obtain hydrogen at a parity price point with diesel, secure a level price for hydrogen for years to come, and transition to a zero emission fleet. Thereafter the FCEV fleet would, in all probability, require no further upgrades for the remainder of the century. There is simply no other pinnacle technology that comes with all those same benefits.

The conversion to using FCEVs can begin for any firm globally TODAY. Welcome to the revolutionary apex world of hydrogen fuel cell technology.

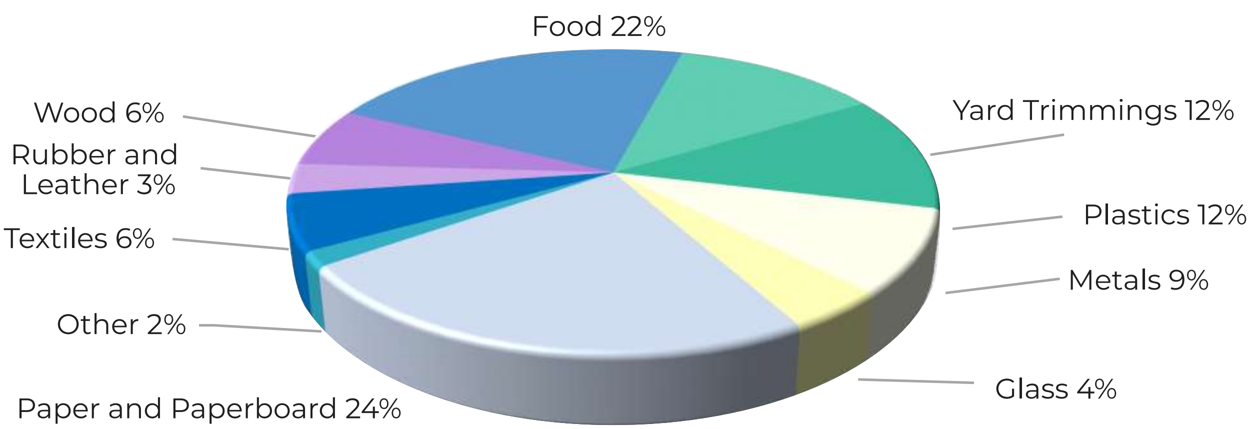
Let us be very clear on this point where heavy-duty trucking and fossil fuels are concerned: **there is no future in which the price of diesel or gasoline drops to an average cost of $3 per gallon or lower and then stays there for years at a time**. A major component of this fact is driven by the cost of profitably producing a barrel of oil. For Algeria, Kuwait, Saudi Arabia and other oil-exporting countries the fiscal break-even oil price is currently higher than $50 per barrel.(1) However, another reason for this fact involves geo-politics. For example, the U.S. Crude Oil First Purchase Price of a barrel of oil was at $3.39 in 1971, and by 1979 it was at $12.64.(2) At the heart of that rise was the economic backlash brought on by geo-politics. Put another way, the San Francisco branch of the U.S. Federal Reserve noted in a 2008 report that, "five of the last seven U.S. recessions were preceded by considerable increases in oil prices."(3) Simply put, reliance on gasoline or diesel will only get more expensive, it will continue to cause price instability to rise, and it will make reasonable profitability virtually impossible for firms that operate heavy-duty vehicles. Yet, given how embedded into the global economy fossil fuels are at this moment, it is reasonable to question what any future alternative power source would look like. After all, if a heavy-duty vehicle does not run on a fossil fuel, then where could an alternative solution come from? The answer, of course, begins with garbage.

(1) International Monetary Fund Regional Economic Outlook Middle East and Central Asia, October 2019
(2) https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=F000000__3&f=A
(3) https://www.frbsf.org/education/publications/doctor-econ/2007/november/oil-prices-impact-economy/

Essentially every village, town, and city in the U.S. produces garbage that is taken to a landfill and disposed of. In fact, in 2018 292.4 million tons of municipal solid waste was generated in the U.S. alone.(4) That figure does not include the additional waste that is generated from "construction and demolition (C&D) debris, municipal wastewater sludge, and other non-hazardous industrial wastes."(5) Of that 292.4 figure 23.05% was for paper and paperboard, 12.20% for plastics, 12.11% for yard trimmings, and 21.59% for food. Together that equates to 68.95% or approximately 201,756,000 tons. That number is important because of a company called Raven SR. It has created a non-combustion process whereby it can take those kinds of feedstock, break all of that down into a syngas, and then extract hydrogen from that. Any sulfides and other waste not converted to hydrogen ends up being turned into bio-carbon in the extraction process. Raven SR is currently deploying its first commercial hydrogen production facility in Richmond, California, and it is expecting to be able to initially produce 4,500kg of hydrogen each day. As the hydrogen generation process at the facility matures, Raven SR is expecting to ramp up production to 20,000kg per day.(6) Depending on the class of truck, about 400 trucks each day could be fueled by the hydrogen Raven SR produces in Richmond alone. Noteworthy is the fact that Raven is simultaneously building another facility in San Jose, California that will be able to produce even more hydrogen.

Total MSW Generated by Material, 2018

292.4 Million Tons



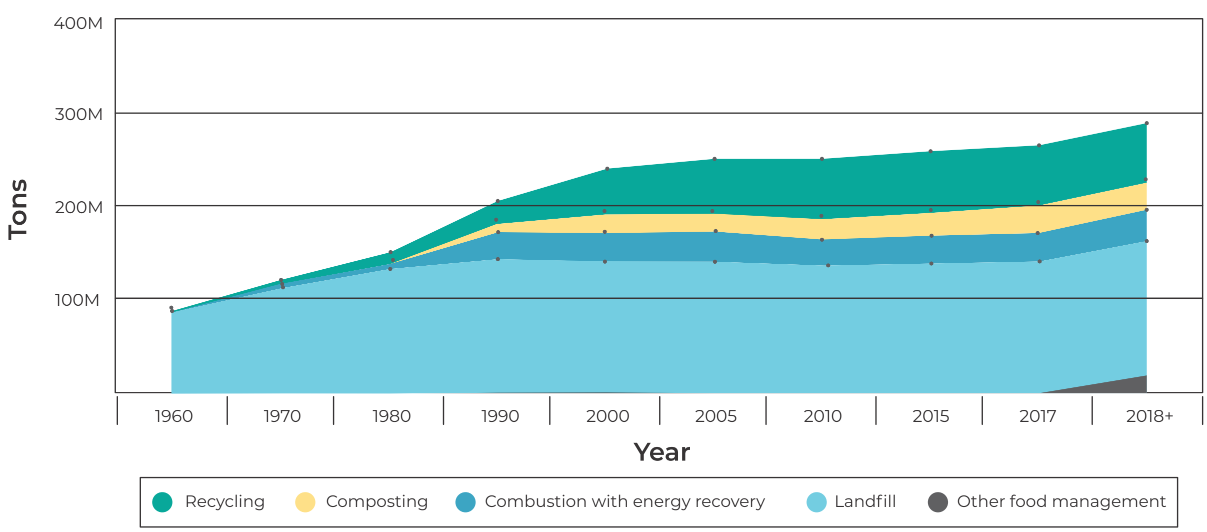
Source: EPA, Facts and Figures about Materials, Waste and Recycling

(4) https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials
(5) https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials
(6) https://fuelcellsworks.com/news/fuel-cells-works-interviews-raven-srs-ceo-matt-murdock/

This conversion of waste to hydrogen is not only good for Raven SR, but it is also good because it is exactly what companies that operate on a back-to-base model need in order to operate the FCEVs (fuel cell electric vehicles) that Hyzon and others produce. The back-to-base, or return-to-base, model is the most widely adopted operating model globally for companies that operate medium to heavy-duty vehicles, because it creates a central location from which to serve a wide area of clients. This maximizes profits while minimizing costs for fuel, maintenance, and other operating costs. Costco, DHL, Laid Law, and Republic Services are just a few of the many organizations that rely on the back-to-base model at this time.

Perhaps the easiest way to understand the model is to visualize the humble refuse truck. At the beginning of the day refuse trucks all start out at a landfill and, from there, they are deployed to the locations of businesses and homes within an assigned area. After collecting the available garbage the trucks return to the landfill, drop off their loads, and then are made ready for the next day by being refueled. That the vehicles start and end their days at the same location allows for them to be refueled in one place. Hydrogen further increases this efficiency and the cost effectiveness of that setup. Because it removes many of the painful economic swings of fossil fuels from the equation, but it also brings the source of the fuel production much closer to where it is also used. **Furthermore, hydrogen removes the need to rely on petroleum products without a loss in driving range.**

Municipal Solid Waste Management 1960-2018



Source: EPA, Facts and Figures about Materials, Waste and Recycling

A fuel cell stack

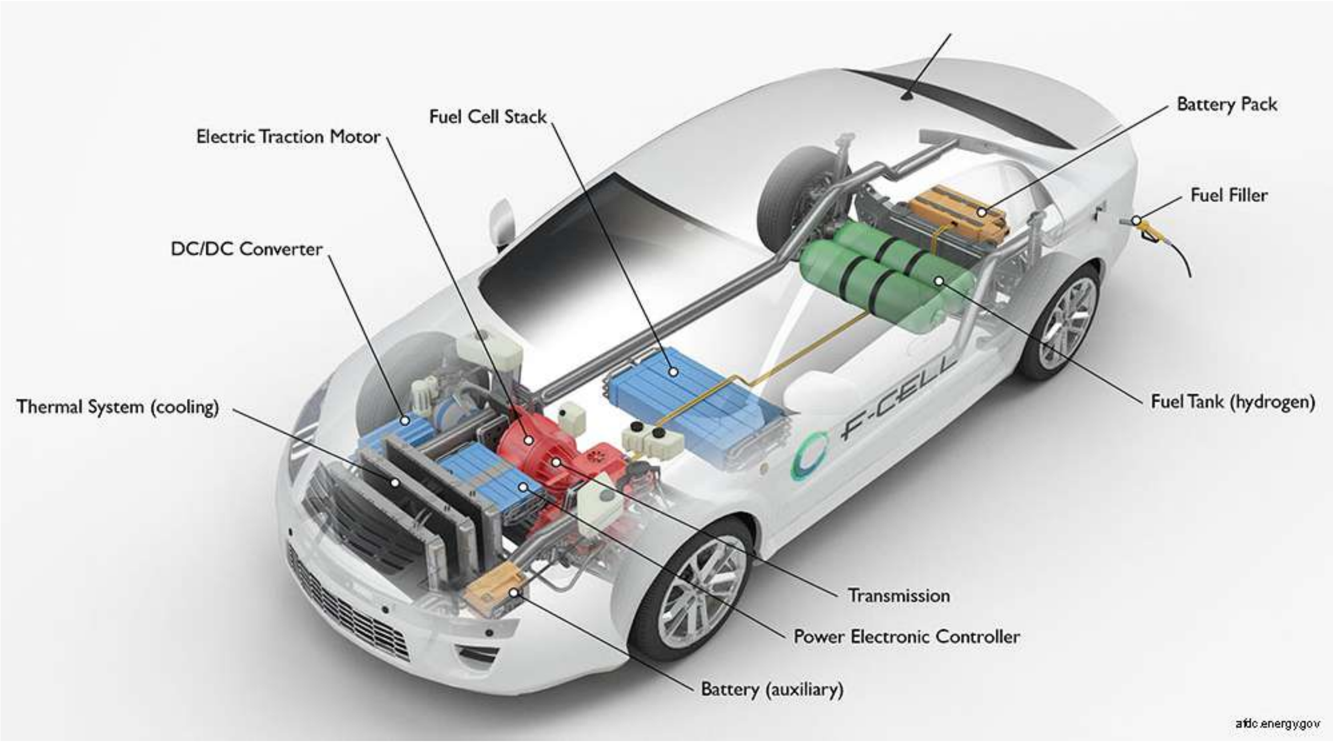
Source: Hyzon motors

FCEVs and traditional diesel or gasoline vehicles have similar characteristics. They all go to fueling stations, have very similar refuel times, have storage tanks for fuel, and possess a powerhouse. In the case of a diesel or gasoline vehicle, fuel is taken from the tank and pumped into an internal combustion engine. From there the fuel is burned which produces some energy that is then shunted to the transmission and wheels of the vehicle in order to propel it forward or backward. In the process harmful pollution gets expelled through the tailpipe. However, in a FCEV, the hydrogen flows from the storage tanks to the fuel cell stack where the electrons from the hydrogen atoms are peeled off and sent to power an electric motor. Meanwhile the protons from the hydrogen atoms pass through the fuel cell stack and, on the other side by way of a chemical process, combine with oxygen. The resulting "emissions" are heat and water vapor **Crucially, FCEVs do not create any pollution. Because hydrogen has nearly 3x the power of diesel, FCEVs are able to maintain a highly effective power-to-weight ratio** translating into heavy-duty FCEVs having a similar or better driving range than vehicles which run on diesel.

It is worthwhile to note that **FCEVs can**

come in any form factor, from regular passenger vehicles all the way up to Class 8 trucks, which brings us back to the return-to-base model. Commu nities develop in patterns which, depending on population density, can be categorized as rural, suburban, or urban. In time, the areas come to be subdivided into residential, commercial, and industrial zones. Within the zones large, medium, and small sized vehicles roam to support the needs of the populace. All of them have the ability to use hydrogen as a fuel which means that, just through the back-to-base model, most of the vehicular pollution can be eliminated.

Hydrogen Fuel Cells Vehicle



Source: US Departament of Energy

Moreover, as more bases begin to use hydrogen thereafter as fuel, an organization that operates long-haul trucks, like UPS, will gain the infrastructure necessary to support FCEVs as they move about the country. A truck that leaves the Los Angeles, California hub can refuel in Sacramento, California, and then it can continue onto Portland, Oregon, and beyond. This has the added benefit of also creating a regional and then a national supply network for light-duty FCEVs. For example, a dairy may find it produces more fuel than its delivery trucks need, and it can setup a dispensing station for the general public to use. A company, like Verizon, may find it convenient to offset the cost of hydrogen fuel by allowing the public to use its hydrogen dispensing stations. Additionally, if hydrogen can be brought to or created at a distribution center, like those that national club store operations use, then some of that hydrogen can also be transported to the fueling stations that are operated at the individual club stores, which then gives light-duty FCEVs another way to obtain the hydrogen they require

Hydrogen filling stations California

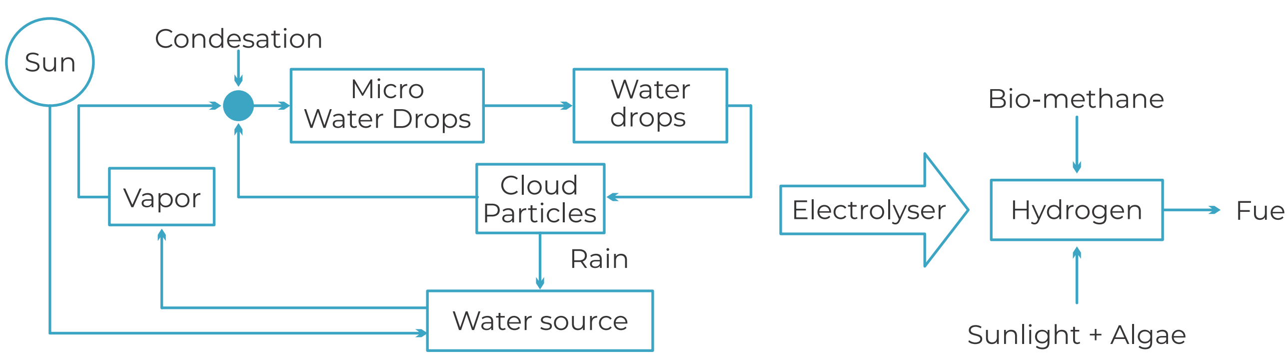
Source: REUTERS/Alex Gallardo

Converting garbage to hydrogen can serve as the foundation for establishing a system of national hydrogen production centers and getting national hydrogen refueling networks off the ground through the back-to-base model. Hydrogen production can also play to the strength(s) of any geographical region which is important in order to provide enough hydrogen to also support light-duty vehicles.

For instance, each day water flows into the ocean from rivers across the U.S. While that water ultimately gets recycled through natural Earth processes, some of it could instead be diverted into electrolyzer facilities and be converted into hydrogen. Areas that have dairies can use bio-methane and convert it to hydrogen. The northeastern part of the U.S. can also tap into the Great Lakes and convert some of the water there into hydrogen. Even the southwestern part of the U.S. can take advantage of algae to produce hydrogen, thanks to copious amounts of available sunlight. Ultimately there will be some areas like the Great Lakes region and the northwestern part of the U.S. that can produce more hydrogen than they need. Extra hydrogen can be taken advantage of by converting the existing natural gas pipeline system to transport hydrogen instead of natural gas. In 2021 Hydrogen Europe published the "Hydrogen Act," and in that paper it noted that natural gas pipes could carry 10-20 times more energy than electrical wires when converted to transporting hydrogen. Utilizing geographical strengths and using gas pipes to move hydrogen around will result in **a stable hydrogen supply while maintaining, to a high degree, the benefit of hydrogen production with short supply lines.**

Using refuse, bio-methane, and similar feedstock also has the added benefit of helping to bring the price of hydrogen

Water Cycle Schematic Diagram



to parity with diesel. **Raven SR is able to take something that society generally regards as having no value and turns it into useful hydrogen, which enables it to pay one of the lowest prices for feedstock**. Its non-combustion process helps to maintain a low cost due to a light permitting load since it vents no particulates or other pollution into the air. Additionally, by creating and transporting the hydrogen from a landfill to return-to-base operators in a local community, this process ensures that transportation costs are also kept to a minimum. When Raven SR's Richmond facility begins to produce hydrogen in 2023, the above advantages will translate into a per-kilogram of hydrogen cost at or below $8. Moreover, as more back-to-base operators convert to using FCEVs, the cost of the FCEVs will decrease as will the cost of hydrogen, because economies of scale and competitive market mechanics will come into play at that point. Those factors ultimately will reduce the time it takes for low-carbon intensity hydrogen production to reach price parity with diesel. Currently this is projected by the Hydrogen Council to occur in 2030.(7)

(7) Hydrogen Council Hydrogen Insights report February 2021

An active oil well in Southern California.

Using a landfill, for example, as a production source for hydrogen to support organizations that operate on the back-to-base model has another distinct advantage over petroleum, which is supply. It does vary from location to location, but oil wells can last anywhere from 10 years to 40 years. U.S. oil drilling commenced in 1859 and, **as of 2018 in the U.S. alone, there were 2.6M abandoned oil wells,**(8) which shows the scale of how frequently oil wells reach the end of their useful lives.(9) However, humans produce refuse every day. In fact, "total annual MSW generation in the U.S. has increased by 93% since 1980, to 292 million tons per year in 2018."(10) **This means that essentially the supply of garbage that can be converted into hydrogen only increases each year, thus resulting in a reliable and constant amount of hydrogen for fuel.**

A stable year-after-year supply of hydrogen will also result in the price per kilogram of hydrogen continuing to decrease for the foreseeable future. Raven SR and a number of other firms are anticipating that the price of hydrogen will be less than the cost per gallon for diesel prior to 2030. When hydrogen achieves a lower price point than diesel, then the economics will clearly favor a hydrogen-based economy.

Additionally, a steady hydrogen supply also has the added benefit of simple availability. Overdrive Magazine did a

(8) Environmental Protection Agency Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018
(9) https://aoghs.org/petroleum-discoveries/
(10) https://css.umich.edu/factsheets/municipal-solid-waste-factsheet

Abandoned oil pumps

Credits: Antonio Solano

survey in the U.S. from May-November 2021 and found that, 49% of the time (11) during that period, truck drivers experienced at least once a limit to the amount of diesel that could be purchased at the fuel pump, with 21% of drivers experiencing such a situation on multiple occasions.(12)

Then, too, **unlike oil wells which also have an end-of-life capital cost between $20,000 and $40,000 for traditional wells and $300,000 for fracking wells,** (13) if they are responsibly plugged, **producing hydrogen would only require recycling the equipment because there is nothing that will need to be plugged nor any toxic chemicals cleansed.** Fuel cell stacks are similar in that regard as well because, when a stack reaches the end of its life, it is broken down into its elemental parts and recycled. Unlike internal combustion engines, **fuel cell stacks are a cradle-to-cradle technology.** It is also important to note that while stored gasoline and diesel can seep into the ground and cause environmental damage resulting in additional operating costs for a business, **hydrogen is non-toxic.** If hydrogen were to escape from a storage tank, then it would harmlessly dissipate. This fact can create overall lower operational costs for hydrogen dispensing sites, especially since there will not be a need to carry insurance to cover the costs related to hazardous material storage.

(11, 12) https://www.overdriveonline.com/business/article/15281294/diesel-fuel-shortages-a-mystery-to-fuel-haulers
(13) https://www.forbes.com/sites/energyinnovation/2020/09/21/plugging-abandoned-wells-the-green-new-deal-jobs-plan-republicans-and-democrats-love/?sh=585abf8b2e10

Worth noting as well, unlike diesel engines, fuel cell stacks give 100% of the available torque instantly when the propulsion pedal is pressed, which makes driving FCEVs easier when merging onto a highway or after stopping at an intersection governed by a stop light or stop sign. With no moving parts within the fuel cell stack, FCEVs are also able to typically operate with a lower noise pollution profile when compared with diesels. This, too, will enhance driver satisfaction for drivers of FCEVs.

Perhaps the strongest advantage of the back-to-base system are the instances that are least obvious. For instance, mining typically happens in remote regions where energy resources are scarce. Producing hydrogen on-site avoids complicated logistic supply chains, thereby reducing the environmental footprint of mining companies.

Hyzon Class 8 Fuel Cell Electric Truck

Source: Hyzon Motors

Total cost of ownership is perhaps the most tangible benefit of converting to an FCEV fleet in the heavy-duty mobility sector. According to the National Private Truck Council's 2021 annual benchmarking survey fleets replaced class-8 trucks ever 6.4 years in 2020 and those trucks had an average milage of 620,000. Those figures are in-line with similar ones from Bloomberg(14). That works out to a truck being driven about 100,000 miles each year. Oil changes are typically done in increments of 25,000 miles which results in a yearly cost for a diesel truck of about $800, since an oil change for a class-8 truck costs between $200-300. FCEVs have no oil to change enabling owners to save at least $800 per year. However, that $800 annual cost does not reflect the time it takes to free up a truck, get the oil change done, and then get it back on the road.

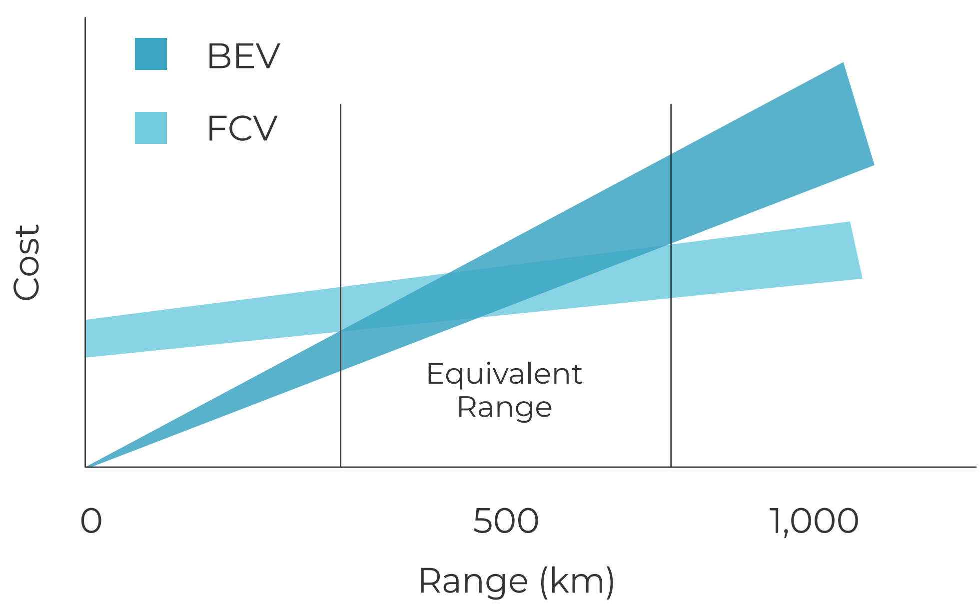
The total cost of ownership argument is further enhanced by a report that AC Transit published in 2021. In its report titled "Zero Emission Transit Bus Technology Analysis" it compared its diesel, new fuel cell, legacy fuel cell, and battery electric buses. While there is a lot of data in the report the comparison of the new and legacy fuel cell buses to battery electric and diesel buses revealed that "[o]perational Cost/Mile Totals (July 2020 – December 2020)" for the diesel buses maintenance was at .54 cents, the newer fuel cell buses (2019)

(14) https://www.bloomberg.com/news/articles/2021-11-15/electric-semi-trailers-are-next-step-in-greening-china-s-roads-kw0l4rzd?sref=dwySGKwS

were at .56 cents, and the legacy fuel cell buses (2010) were at $1.29(15). Not only does this show the tremendous work fuel cell manufacturers are doing to reduce the maintenance costs of FCEVs, but it also shows that newer fuel cell buses are reaching maintenance price parity with diesel buses. This strongly suggests that a bus produced with the latest fuel cell technology will almost certainly have a lower maintenance cost than diesel buses given that diesel bus manufacturers have very few options with which to lower that aspect of vehicle ownership. For fleet operators another important aspect of ownership is vehicle availability, and in the report the newer hydrogen buses had an up-time performance similar to diesel buses. Interestingly, battery electric buses were significantly inferior in their availability when compared to both the new and legacy fuel cell buses.16) The report also showed that while battery electric buses had a "refueling" time of 5.5 hours per charge, fuel cell buses had a 6.5-7.5 minute refuel time(17).

Part of the reason why FCEVs are reaching maintenance parity with diesels so quickly is that FCEV powertrains have less parts than diesel engines do. Yet, each additional part that a diesel engine has represents a potential extra repair cost and potential downtime for a truck. Overdrive Magazine reported last year

Cost vs Range in BEV and FCV



Source: Electrive; Hyundai's electric strategy – two prongs to success?

(15) AC Transit Zero Emission Transit Bus Technology Analysis Published June 23, 2021, Page 17
(16) AC Transit Zero Emission Transit Bus Technology Analysis Published June 23, 2021, Page 19
(17) AC Transit Zero Emission Transit Bus Technology Analysis Published June 23, 2021, Page 10

that even a basic item like Bulk 10w30 (engine oil) sometimes has been unavailable(18). If a part is not in-stock when it needs to be replaced, then that represents an increased downtime for a truck.

Additionally, in an accident it is common for diesel-based trucks to spill fuel onto the highway, which results in a first responder cost to contain and clean-up the diesel spill. Such containment efforts can lead to a bill of several thousands of dollars, or much more, being owed. The bill can increase if a truck driver does not report the spill within a time frame required by any applicable statute. While truck insurers typically pick up clean-up costs, a FCEV would not have a clean-up cost for any leaked hydrogen. This is because hydrogen would dissipate quickly into the air. While this makes hydrogen safer, it also introduces the tantalizing possibility of truck insurers charging lower rates for FCEVs, since accident remediation costs for FCEVs will be lower than those for diesel-based trucks.

As noted above, FCEVs will also enjoy a stable hydrogen supply and the price per kg of hydrogen is already approaching parity with that of diesel. Yet, hydrogen producers are working on continuing to decrease the cost of hydrogen and, within this decade, we will likely see a price per kg of hydrogen around $3. At that point hydrogen will be considerably cheaper than diesel, further reducing the total cost of ownership.

The aforementioned circumstances clearly lay out a situation where the total cost of ownership for a FCEV, including fuel, **is already on a trajectory to be at parity with diesels.** However, both fuel and maintenance costs for FCEVs are expected to continue to lower over the rest of the current decade, and this will ultimately result in a total cost of ownership for FCEVs that will be far less expensive than for diesels.

(18) https://www.overdriveonline.com/equipment/article/15066506/truck-parts-in-short-supply-2021s-rule-for-ownerop-repairs

For the heavy-duty machine segment there are organizations trying to transition to battery electric vehicles (BEVs) in the belief that this is a viable way to achieve a zero emission vehicle (ZEV) fleet. Unfortunately, this is an inefficient route to such a goal. Hydrogen has an energy efficiency 10x higher than that of lithium. This means that a BEV would be unable to carry the same load as a FCEV for an equal or greater number of miles. Additionally, even a small fleet of 10 heavy-duty BEVs would require a megawatt charging station, and the larger the fleet the greater chance it will require the same amount of electricity that a local electricity source, like a hydro-electric plant or solar farm, can generate. Furthermore, any BEV charging system for commercial application would require a massive battery backup system to prevent charging disruption should the station's connection to the electrical grid be disrupted, as has become more common in recently California, Oregon, Texas, and Washington. It is possible to get around the battery backup situation by buying extra batteries for the BEV fleet and switching out discharged batteries for fully charged ones, but this would add an additional capital expenditure to handle having more batteries, the storage of them, and extra technical resource cost. Switching out a battery instead of recharging it right away would require maintaining a database of each battery to track its maintenance history, its location at any given time, and its current charge level.

Furthermore, the greater electrical demand a BEV fleet will put on the power grid comes with associated costs from the energy company to provide a grid hook-up in support of the needed charging stations. **However, utility companies are unable to offer every fleet operator enough electricity** given the very finite amount of energy that is produced, which means that only some fleet operators will be able to deploy BEVs. In fact, in 2019 California borrowed 70.8MWh from adjacent states, which means that some states literally do not have enough power on their own to support BEV charging for light and heavy-duty applications. And if more states have to borrow electricity to support BEV networks, then the U.S. would reach a point where demand would exceed supply. This also does not even begin to address the resources needed if residential electric customers were to begin recharging light-duty BEVs in mass.

Another challenge to deploying BEVs are the additional capital costs from using a fast-charging system to rapidly recharge batteries, since that reduces the life expectancy of a battery more quickly. The faster a battery degrades, the less performance it has to offer! All of that only increases the frequency of buying new batteries which directly increases operational costs. Perhaps the most difficult part of BEVs in the heavy-duty sector is that, even with DC fast charging, it still will take about 45 minutes, on average, to charge the batteries of a Class 8 vehicle. That is about 30 minutes longer per vehicle as opposed to a Class 8 fuel cell truck which has a typical refuel time of 15 minutes. Even in a fleet of only 30 trucks that would result in, at best, several hours of productivity being lost to charging, and in a worse case it could be tens of hours lost each week.

Credits: Tania Malréchauffé

While this paper has used the U.S. as an example of how to produce and deploy hydrogen, every country can utilize and benefit from hydrogen usage. The back-to-base model is already used everywhere, landfills are a common sight in all parts of the world, each country has geographical resources that can be used to supplement hydrogen production from refuse, and hydrogen technology can be deployed everywhere. Unlike current internal combustion technology that has a dizzying array of laws that it must comply with as not every regulatory body has the same tolerances for pollution, hydrogen fuel cell technology is a zero emission technology! There is nothing to regulate in that regard. This ease of deployment is crucial considering that climate change is a challenge that every country is currently facing.

While the above consideration of total cost of ownership is useful, there is also a need to analyze a conversion to FCEVs in terms of a cost-benefit analysis. With hydrogen, organizations benefit from being near to a power supply source since with hydrogen it is possible to produce it on-site or from within local community. Thus, the diesel supply chain that reaches from an oil rig in the middle of an ocean to a tanker truck bringing the fuel to a firm's site half a world away entirely disappears. That physical supply chain reduction is bolstered by hydrogen as a power source forever removing the price uncertainty of diesel while creating a predictable and highly level fuel cost going forward. In all likelihood, a firm may start out paying $8 per kg and eventually see that price level out at $3-4 per kg. There is also no technology on the horizon that is equal or superior to that of fuel cells. BEVs have to overcome a number of challenges before they can rival fuel cells in every way. This means that once an organization upgrades to fuel cells, then no other future upgrades will be needed for at least the rest of this century. Fuel cells are also a green technology, and that benefit remains forever true. Cities in California have outlawed the installation of new natural gas lines, and Los Angeles County recently decided to phase out gas and oil drilling in unincorporated parts of the county. Part of the reason for the decision was that gas and oil drilling disproportionately impacts poorer communities. A firm that continues to rely on fossil fuels will face ever greater scrutiny and negative public relations, which is something the U.S. Navy is presently learning in Hawaii. Some people in Hawaii have arrived at the conclusion that they are less important to the federal government of the U.S. than other people are, which clearly

HYDROGEN AND FUEL CELLS ADVANTAGES

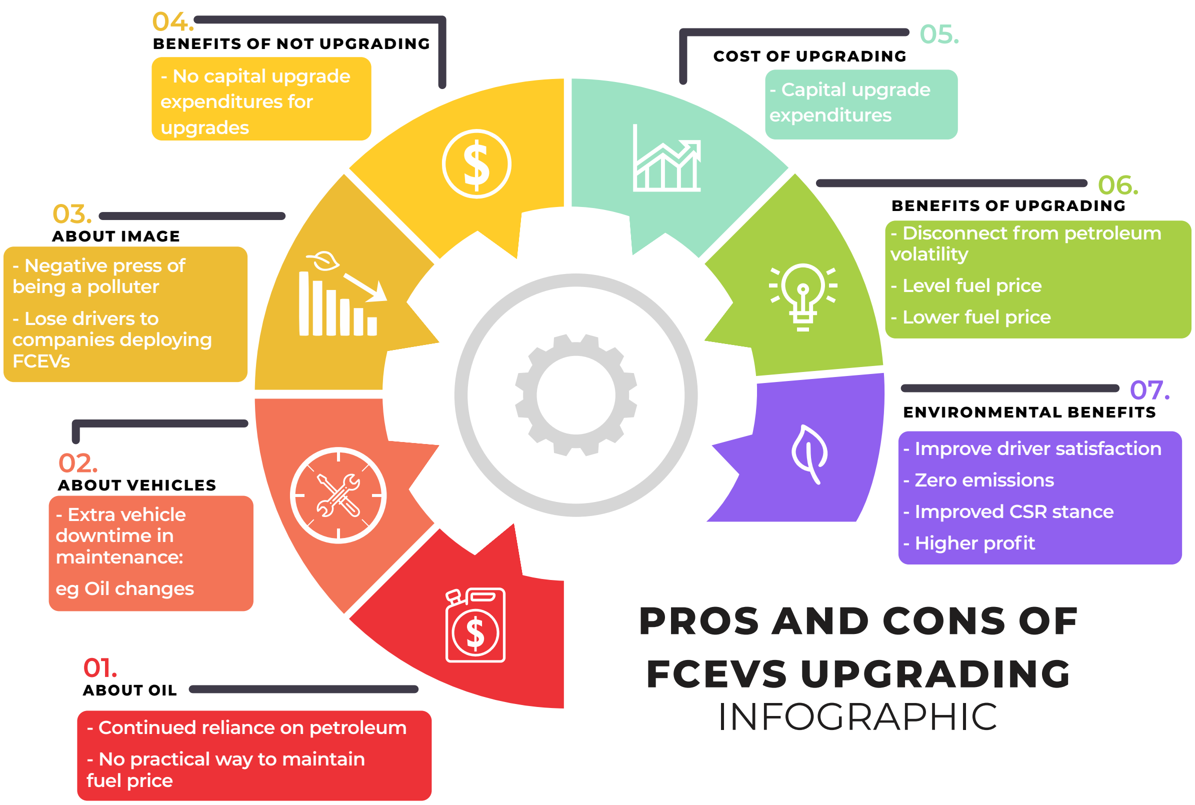
- Reduced greenhouse gas emissions
- High Reliability
- Flexibility in installation and operation
- Reduced demand for foreign oil
- Improved environmental quality

(19) https://www.bloomberg.com/news/articles/2021-09-21/l-a-county-drilling-ban-is-an-environmental-justice-feat?sref=dwySGKwS

demonstrates the public relations nightmare that relying on fossil fuels can bring to any organization.

This means, for example, that if a company spends $5M today to switch to hydrogen and fuel cells for heavy-duty mobility, it gains a resilient fuel supply chain, a stable fuel price, technological upgrade insulation in the long-term, a green image, and protection from negative associations with fossil fuels. A firm which continues to spend money on fossil fuel-based vehicles gains none of those benefits. Instead, it will continue to struggle each year with profitability because of geopolitics or because of the extra work of maintaining vehicles that have substantial downtime due to something as simple as an oil change **In a world of continuously increasing instability, hydrogen and fuel cells become the only mobility bargain to be had.**

As of the beginning of May the world has witnessed the significantly destructive consequences of relying on fossil fuels when war erupts. Russia's invasion of the Ukraine has caused damaging price fluctuations in the price of a barrel of oil, and it put the EU in a position of either giving Vladimir Putin victory in Ukraine or watching its fossil fuel supplies diminish. Certainly, Russia's war on the Ukraine has demonstrated that the cost of converting to a hydrogen economy outweighs the "benefit" of fossil fuels whatever their price.



Fossil fuels will only continue to drive global instability and reduce a heavy-duty mobility firm's ability to be reasonably profitable. Russia's war on the Ukraine in 2022 exemplifies this fact. It is also true that there is no guidebook that the world economy can turn to for a smooth transition from a reliance on fossil fuels to one depending on hydrogen. The only reasonable course of action is to create a playbook that has the highest chance of enabling a successful transition, and FCEVs will be core to the strategy in the most successful play-books. As organizations that operate on the back-to-base model embrace fuel cells, this will create regional, national, and then international hydrogen refueling networks. At the same time, it will also reduce a significant swath of the global economy's negative emissions. Where those processes occur, firms that embrace hydrogen will decouple almost entirely from petroleum volatility. With their new energy independence, heavy-duty mobility organizations will gain a stable hydrogen supply, a stable hydrogen price, and, best of all, by embracing an apex technology like fuel cells, they will be gaining technological upgrade protection. In a world where profits and the future are constantly shrouded by the uncertainty that comes from relying on petroleum, fuel cells offer the only clear and uncompromising path to a profitable zero emissions future.

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