BRIEFING PAPER

GLOBAL COMMERCIAL VEHICLE DRIVE TO ZERO™

Thematic Deep Dive Series 2: Zero-Emission Medium-and Heavy-duty Vehicle Infrastructure

Bill Van Amburg, Strategic Advisor to CALSTART
Owen MacDonnell, CALSTART
Cristiano Façanha PhD., CALSTART

July 2022

This Infrastructure Briefing Paper has been developed to support the Multi-country Action Plan development process of countries who have signed the Global Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-duty Vehicles (ZE-MHDVs). In short form, it is intended to inform and provide guidance and resources to governments on strategies they can undertake to drive rapid deployment of ZE-MHDV infrastructure.

Key Takeaways

- Zero-Emission Medium- and Heavy-duty Vehicles (ZE-MHDVs) are ready for greatly expanded deployments in all regional applications and emerging longer range routes.
- Infrastructure is a critical enabling capability and potential limiter that must keep pace with and anticipate the rapid growth of ZE-MHDVs or risk slowing the market.
- Do not delay policy adoption and vehicle implementation because of either/or technology choices; battery electric and fuel cell electric systems are complementary.
- Governments can take specific actions to ensure that infrastructure growth accelerates at the pace of the ZE-MHDV market. These actions include:
  - Creating a regulatory structure directing utility investment in ZE-MHDV infrastructure;
  - Establishing competitive price rate structures for fuel suited to the commercial transportation market;
  - Creating road maps to project and anticipate infrastructure demand and identify priority deployment locations; and
  - Spurring early markets with incentives, investments, industry engagement, user education and workforce training.

Urgency for Action on Infrastructure

Infrastructure is the Key Barrier to Zero Emissions. Rapid expansion of medium- and heavy-duty Zero-Emission Medium- and Heavy-duty Vehicles (ZE-MHDVs) is underway. It is a critical pathway for achieving the significant climate reductions needed in transportation[1] and can concurrently provide air quality improvements especially in communities disproportionately overburdened by transportation emissions. Thousands of these vehicles are on the road today and expanding. But where government's initial focus on zero emission infrastructure has been mostly supporting passenger cars, it must now include commercial vehicles or risk delaying this critical market growth.

ZE-MHDVs are having their first successes in urban and regional applications, but their ability to carry heavy weight cargos and drive longer distances is expanding rapidly. Heavy zero emission tractor-trailer freight trucks now being sold have ranges of over 275 miles[2] (440 kilometers) and by 2023 the first long range trucks in Europe will be able to drive for multiple hours between recharging along freight corridors.[3] The timing is urgent. By regulating, investing in and incentivizing the deployment of electric charging and hydrogen fueling infrastructure for ZE-MHDVs, governments can help spur technology adoption, create jobs, promote prosperous and healthy communities, and support the faster transition to a zero-emission transportation system.

1 https://www.ipcc.ch/report/ar6/wg2/resources/press/press-release

2 https://www.volvogroup.com/en/news-and-media/news/2022/jan/news-4158927.html

3 https://www.scania.com/group/en/home/newsroom/news/2021/Scanias-electrification-roadmap.html

ZE-MHDV Infrastructure Types, Location and Timing

Infrastructure can have many definitions. For purposes of this discussion, infrastructure means the equipment, systems, and controls for providing electric charging or hydrogen fueling to commercial vehicles.

Two ZE-MHDV Fuel Types. There are two complementary technology and energy systems to support ZE-MHDVs: battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV). The primary power trains of these vehicles are exactly the same. The main differences are how the electricity is provided to the powertrain: via electrical energy stored in and delivered from a rechargeable battery; or via energy stored as hydrogen in on-board tanks and used to generate electricity via a fuel cell.

Because of the recent and rapid improvement of battery technology and their relative simplicity of design, the bulk of current Zero-Emission Medium- and Heavy-duty Vehicles worldwide are BEVs. Fuel cell vehicles are not yet as far along in development. Nonetheless, they promise the potential to fill possible application gaps (such as longer range or longer driving times before refueling) that can ensure zero emission options can fill all commercial vehicle uses.

BEV – electrical charging – primary pathway While there are multiple ways of recharging a battery electric vehicle, in practice there is a primary pathway already well established – conductive - with global standards in place. Complementing the conductive system is the inductive – or wireless – connection, which some operators use based on preference or when a completely hands-free solution is required.

Conductive: Conductive charging is the preferred charging method used worldwide due to its ease of use, high reliability, and efficiency. It involves a physical connection, via cable, between the energy system and the vehicle. Global standards for safety, interoperability and communication allow all vehicle types to use these systems. Standards currently support charging rates for depots and hubs (J1772 and Combined Charging System – CCS[4]), as well as the first corridors. A new global Megawatt Charging System (MCS)[5] is being approved for extremely high-rate fast charging to enable extensive long haul freight operations.

Inductive: Inductive, or wireless, charging involves the transfer of electricity through magnetic induction. No direct connection with the vehicle is required. What is needed is installation of an in-ground system to provide the power and an on-vehicle system to receive the power. Such systems are less efficient and currently expensive and require careful placement of the vehicle over the system. Development work is also on-going for dynamic electric vehicle charging (or DEVC) technology which can wirelessly provide charging power to a compatible electric vehicle traveling across it at highway speeds. Significant inductive infrastructure and road construction would be needed to implement.

Other potential BEV infrastructure pathways

Battery Swap: This system is based on the mechanical replacement of a battery pack

4 https://en.wikipedia.org/wiki/Combined_Charging_System

5 https://www.charin.global/technology/mcs

when it is depleted with a fully charged pack. It requires fully standardized battery pack sizes across vehicle makers, consistent operational voltages and chemistries, a common under-vehicle frame and mounting to facilitate the swapping, a battery storage and charging facility and a mechanical replacement system. It has to date proven too complex for multiple vehicle types and public operations. Some systems are in operation in industrial applications such as ports,[6] and it has been implemented in transit systems in China, which is now exploring its use for passenger cars.[7]

Catenary: The catenary is an old and well-known system that is being evaluated for possible broader use in transportation. A catenary is at its simplest an overhead electrical power connection that a vehicle can attach to via a pantograph to power its electric motor. It is commonly used in railway and urban trolley systems; it has also been in declining use in some urban transit bus systems and is used in some mining operations. While well proven it would be very expensive to implement along an entire freight movement system and would require all vehicles to carry the connecting pantograph and power conversion systems, which add weight and cost.

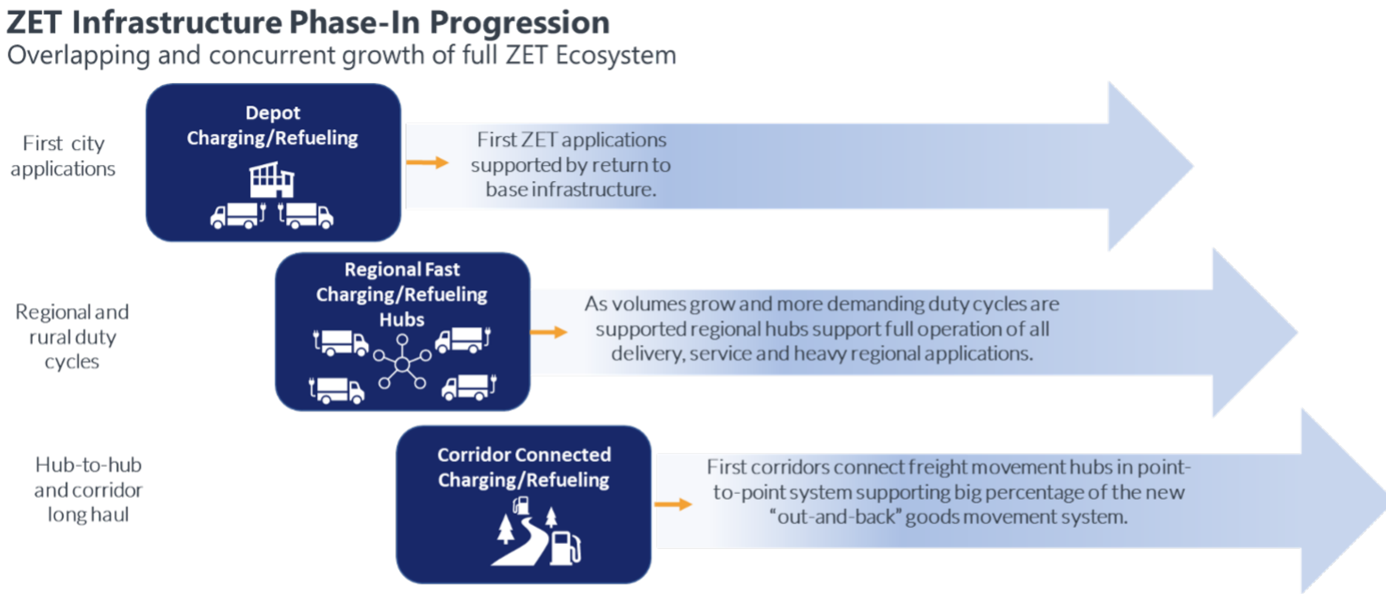
FCEV – hydrogen fueling: Hydrogen can be stored and distributed as a gas or a liquid. Hydrogen for transportation is typically stored and dispensed as a high-pressure gas which is then transferred to tanks on board fuel cell powered electric vehicles. Storage pressures range from 350-700 bar (5,000 – 10,000 PSI). The higher-pressure tanks are most common for transport because they provide more storage per volume. Hydrogen fueling stations therefore require a bank of storage tanks, compressors and high-pressure dispensers to transfer the fuel to the vehicle. Because hydrogen fuel cost increases significantly if it needs to be transported long distances from where it is generated, many large-scale hydrogen stations may benefit from co-located hydrogen production facilities. Electrolysis from renewable energy is the preferred method of splitting water into hydrogen and oxygen gasses. Other methods include steam-reformed methane and as a byproduct of petroleum production.

Infrastructure Locations. This infrastructure will be needed at multiple locations depending on the use profiles of the ZE-MHDVs being supported. Each has a slightly different need in terms of power or fuel delivered as well as costs to install and business models to support. Infrastructure can be provided:

- At a vehicle's main or supporting base of operations (Depots);
- At multi-vehicle sites distributed throughout a city or region (Hubs); or
- At muti-vehicle sites placed along longer distance freight routes connecting cities or regions (Corridors).

6 https://www.p2sinc.com/projects/port-of-long-beach-pier-e-terminal-south-battery-exchange-building

7 https://www.reuters.com/business/autos-transportation/inside-chinas-electric-drive-swappable-car-batteries-2022-03-24/



Return-to-base depot charging is the first tier of this system. Most early market ZE-MHDVs will be local or regional vehicles that travel known distances and return to their main base at night. But these infrastructure locations will not emerge only in a strictly sequential, linear fashion. There will be parallel and overlapping waves of installation. Already in most regions that have ZE-MHDV deployments the need for regional fast-charge hubs has been identified and the first locations established.[8] Concurrently, fleets and manufacturers are identifying their first priority corridors that will need infrastructure to connect key freight regions. These corridor plans are already being developed in some regions.[9]

Government Role. Governments can provide different forms of support at each of these location types. Depots, which will be a large percentage of the first deployments, are primarily privately maintained sites. Governments should ensure utility and other stakeholders are encouraged to invest. Some incentives funds in the early years can reduce risk for adopters. Fast charge hubs and corridor charging and refueling facilities will likely be available to multiple fleets and users. In these cases, government can provide early support funding to "seed" the establishment of networks, ensure interoperability for all vehicles and sustain sites in early years when utilization rates will be low.

Avoid Delay. From a policy makers perspective, there is no need to delay action. Both technologies will play a role in a complementary ZE-MHDV and energy ecosystem. In the near term, BEV charging infrastructure requires immediate attention, support and deployment. As this deployment happens, policy makers and governments should monitor and plan for the extension of a complementary, and in some cases, co-located, hydrogen fueling infrastructure system.

8 https://www.truckinginfo.com/10170433/wattev-to-build-electric-truck-charging-stations-at-port-of-long-beach

9 https://www.acea.auto/publication/european-electric-vehicle-charging-infrastructure-masterplan

Key Infrastructure Issues and Considerations for Policy Makers

Create a utility investment regulatory framework. Governments have a critical role to encourage and require utilities to plan for, invest in and take an active role in transportation electrification that is inclusive of installing ZE-MHDV infrastructure at the pace required to meet rapid market growth. Government has a primary role to set the direction for society, through agreements, executive orders, regulations, and supportive policies. In most cases, utility investment and cost recovery is regulated by government agencies or boards. Importantly, from a public policy perspective, the demand increase from ZE-MHDVs can be highly beneficial to utility rate payers as it will eventually spread fixed costs across a much larger customer base.[10]

Utilities ideally need to plan for and quickly implement:

- Distribution grid improvements to accommodate commercial vehicle charging loads at depots and public charging stations;
- "Make ready" electrical connections between the distribution grid and the customer charging locations;
- Distributed Energy Resource (DER) assets that may be needed to support grid resiliency, such as battery storage to harvest renewable energy while it is available and reduce the strain on the distribution grid;
- Fast interconnect timing to reduce the delay between fleet customer decision to purchase ZE-MHDVs and when fueling will be ready; and
- Customer support in terms of site planning, energy needs assessment and ultimate build out of the site.

Examples:

- Charge Ready Transport Program, Southern California Edison: https://crt.sce.com/overview
- EV Make-Ready Program, Joint Utilities of New York: https://jointutilitiesofny.org/ev/make-ready

Develop a competitive ZE-MHDV utility rate structure. Governments must encourage and require utilities and power providers to design and provide competitive and conducive rate structures to users of Zero-Emission Medium- and Heavy-duty Vehicles. Mobile customers are different than stationary customers in time of use, peak demand variability and other issues. Stationary (built environment) rate structures are not well designed to encourage electricity as a vehicle fuel. Most EV rates that have been established for vehicles are aimed at passenger cars (light duty), not the larger battery sizes and co-located vehicle fleet structures of commercial vehicles. Addressing electrical rate cost, time of day considerations, demand charges and other utility rate design structures and refining them for commercial vehicle success is critical.

As an example, in many utility jurisdictions, there are multiple costs for service, including "demand" charge, which is the normal peak electrical load or demand a site will make on the electrical grid. As commercial vehicle charging is added to a site, this demand peak can be exceeded, often leading to significant price increases. It can completely negate the positive business case of electricity as fuel. Several

10 https://www.forbes.com/sites/jeffmcmahon/2019/02/01/electric-vehicles-benefit-all-utility-customers-as-much-as-their-own-ers/?sh=563f14244fe5

utilities are experimenting with waiving demand charges during this growth stage of the industry or setting more flexible "subscription" levels that replace demand charges and reduce costs.

This and other reasons are also why government incentives should allow and encourage use of smart charging software that can manage charge loads and costs.

Examples:

- Best Practices for Commercial and Industrial EV Rates: https://www.nrdc.org/sites/default/files/media-uploads/best-practices-commercial-industrial-ev-rates_0.pdf
- Business Electric Vehicle Rate Plans, PG&E: https://www.pge.com/en_US/small-medium-business/energy-alternatives/clean-vehicles/ev-charge-network/electric-vehicle-rate-plans.page

Conduct road mapping and anticipate emerging demand. Governments can have a highly valuable role, either through internal or contractor-led studies, in establishing strong ZE-MHDV market demand roadmaps to assist utilities, transport ministries, municipalities and industry in preparing for and anticipating demand for charging and refueling assets needed to accommodate the rapid growth of ZE-MHDVs. These future demand assessments can include fleet depot charging, the needs for regional fast charge networks and for determining fast charge locations along freight corridors between regions. Ideally such activities will model demand growth and develop "heat maps" highlighting expected areas of vehicle charging concentration. Together with this, creating an overlay of utility distribution grid capacity showing where stronger and weaker zones for energy delivery exist will highlight areas that can accommodate immediate demand and those needing capacity expansion investments.

Partners in road mapping activities should certainly include government, utility and fuel provider stakeholders in the regions being studied. They can also benefit from input from manufacturers on expected production volumes and from fleet users on expected demand timing, volumes and priority routes needing infrastructure. It is vital to include input from a broad set of stakeholders, such as existing truck fueling and service providers, whose locations can serve as potential sites for co-locating electric charging and hydrogen fueling systems. Importantly, the planning should prioritize the needs of communities situated along freight routes and around freight terminals and distribution sites. These communities have borne the health burden of heavy-duty transportation emissions. Reducing those emissions via targeted ZE-MHDV deployments needs to be a priority.

Examples:

- West Coast Clean Transit Corridor Initiative: https://westcoastcleantransit.com
- Alternative Fuel Infrastructure Corridor Coalition: https://www.westcoastcollaborative.org/files/sector-fuels/wcc-aficc-mhd-infrastructure-development-plan-2020-03-12.pdf

Spur Early Markets and Investments. Governments have an important role to play in supporting the initial market for ZE-MHDV infrastructure and in establishing attractive conditions for private investment and capital to quickly scale these markets and assume their primary role in funding this expansion. This can take many forms, including:

- Incentives and/or grant programs to reduce early adopter risk and "seed" first large scale deployments;

- Risk mitigation programs for investors, such as lending rate guarantees, first-loss protection[11] or longer concession/contract time periods for public contracts;
- Regulatory flexibility, such as allowing resale of electricity as a service; and
- Streamlining and accelerating permitting for charging/fueling sites is also critical.

The wind and solar industries have become fully cost competitive with conventional power generation in almost all areas of the world due to such policy and investment mechanisms. Their lessons can be highly beneficial to adapt for the expansion of ZE-MHDVs. Often these approaches have involved innovative finance structures that can be adapted to transportation. These mechanisms include extending the payback periods for infrastructure investments and even turning them into lease or service offerings (Charging as a Service – CaaS), as well combining vehicle, infrastructure, service and even fuel costs into one subscription package (Transport as a Service – TaaS). Government's roles could involve guaranteeing or reducing interest rates or setting minimal performance standards for those offering services.

Government can also provide, or support:

- Outreach and training to early infrastructure adopters on best practices;
- Technical assistance to those planning installations; and
- Workforce training and job creation programs to ensure an adequate skilled workforce is prepared for the scale.

Examples:

- Energy Infrastructure Incentives for Zero Emission Commercial Vehicles (EnergIIZE): https://www.energiize.org
- Infrastructure Readiness Center: https://www.energiize.org/irc

Actions and Next Steps for Governments

For governments ready to act on supporting ZE-MHDV infrastructure deployment, or who are already active but wanting to go the "next step", there are several discrete actions that can be implemented. Which one's governments choose will depend on where they are in the process.

- **Engage.** Engage industry and government stakeholders to assess the timing and need for the kinds of infrastructure outlined in this document.
- **Educate.** Implement educational workshops to explore best approaches and context to address the topics explored above.
- **Guide.** Provide templates for and encourage regions to develop ZE-MHDV infrastructure deployment plans.
- **Establish.** Assess case studies for smart EV utility rate and investment programs and policies and work to implement those structures as soon as possible.
- **Support.** Review best practices for developing and implementing ZE-MHDV infrastructure incentives and establish the most effective structure depending on national and regional context.

Conclusions

The informed and rapid deployment of safe and reliable ZE-MHDV charging and hydrogen refueling in all regional and corridor markets will facilitate the continuous expansion of ZE-MHDVs at a critical point in the climate battle. All recent

11 https://globaldrivetozero.org/publication/taking-commercial-fleet-electrification-to-scale-financing-barriers-and-solutions

climate change data points to the urgency of accelerating the replacement of fossil fuel commercial vehicles as rapidly as possible – and making significant progress over the next five years.

The foundation for this success rests on understanding the current reality of Zero-Emission Medium- and Heavy-duty Vehicles, the rapid pace of their market expansion and their viability to perform a significant percentage of commercial vehicle duties today.

Governments can and must play a strong and central role in supporting this transformation. As ZE-MHDVs move rapidly from initial depot charging and fueling to needing regional fast charge and fueling hub networks as well as corridor-based charging and fueling, governments should understand where gaps exist in electricity and fuel capacity. They should determine what actions can encourage private investment and require and encourage utilities and fuel providers to fund infrastructure installation and develop and provide simplified and competitive fuel rate structures.

Most importantly, governments can send strong signals and directions to the market of society's priorities for transportation, envision and support the growth of a new and complementary energy ecosystem to enable these priorities, and provide targeted regulations, investments and incentives to spur the early market and launch its growth at the pace needed to contain and eventually reduce the worst impacts to our damaged planet.