Submission No 27

INFRASTRUCTURE FOR ELECTRIC AND ALTERNATIVE ENERGY SOURCE VEHICLES IN NSW

Organisation: CALSTART Drive to Zero

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Submission to the Committee on Infrastructure for Electric and Alternative Energy Source Vehicles in New South Wales

Submitted by: CALSTART / Drive to Zero

1. Introduction

CALSTART/Drive to Zero is a mission-driven, non-profit consortium working to accelerate the deployment of zero-emission medium- and heavy-duty vehicles (ZE-MHDVs) around the world. We envision a future where people and goods move sustainably, equitably, and without pollution, supporting global climate goals while enabling economic growth.

At COP26 in 2021, CALSTART and the Government of the Netherlands launched the Global Memorandum of Understanding (Global MOU) on ZE-MHDVs. This MOU sets a global goal of 100% new ZE-MHDV sales by 2040, with an interim target of 30% by 2030. This thriving community of 42 countries and over 230 endorsers, including Australian capital Territory ACT and 12 other Australian endorsers .

All major sectors —industry, buildings, electricity— show progress in cutting carbon emissions, save one: transportation. The transportation sector is responsible for nearly a quarter of global CO_2 emissions, with medium- and heavy-duty vehicles (MHDVs) contributing a disproportionate share of climate heating and air pollution. While the transition to zero-emission (ZE) MHDVs is gaining momentum in leading regions like California, China, The European Union —supported by robust policies and regulation, rapid technology improvements, policy shifts, and early deployment support. However, in most countries, —the sector remains far from achieving mass adoption which risk deepening economic and health inequalities.

We welcome this Inquiry as a timely and vital opportunity for NSW to further solidify its leadership in the zero-emission freight transition and offer the following insights and recommendations.

2. Context: Freight and HDV Electrification in NSW and Australia

High Emissions & Aged Fleet: Australia’s heavy-duty vehicle (HDV) fleet, with an average age of 16 years, contributes 44% of national transport emissions. Without targeted action, this sector is projected to become the country’s highest-emitting transport category.

Freight Dependency: Trucks account for just 4% of vehicles globally, yet consume 36% of transport fuel. Australia's freight system is particularly vulnerable due to its reliance on imported fossil fuels and growing long-haul freight demand.

Regional Opportunity: NSW’s freight corridors—particularly the Sydney–Melbourne and Sydney–Brisbane routes—present ideal pilots for ZE-HDVs given the concentration of freight movement, opportunities for renewable energy integration, and the potential for co-located infrastructure investment.

3. Why Now? A Critical Window for Action

Australia is positioning itself to co-host COP31, offering a generational chance to demonstrate climate leadership. Scaling ZE-HDVs aligns with this ambition and sends a strong market signal to attract investment, drive down vehicle costs, and encourage local manufacturing.

By leveraging the Global MOU, providing a strategic infrastructure plan and starting with deployment for ze-HDVs along the main corridors —the state can create a blueprint for other nations and sub-national governments. NSW's progress is not only national leadership—it is global influence.

4. Recommendations to Support Freight and ZE-HDVs in NSW

To accelerate the decarbonization of freight and heavy-duty vehicle transport in New South Wales (NSW), the following strategic actions are recommended:

a. Develop a NSW Electric Freight Corridor Plan Aligned with the Global Green Road Corridors (GGRC) Initiative

The Global Green Road Corridors Initiative (GGRC) is an international partnership led by governments, nonprofits, and financiers to decarbonize freight corridors by deploying abundant, reliable charging infrastructure for zero-emission medium- and heavy-duty vehicles (ZE-MHDVs),unlocking electrification of hard-to-abate long-haul applications, through a proven, industry-vetted framework for global replication. NSW can position itself as a leader in this space by:

Identifying priority freight corridors for ZE-HDVs, such as Sydney–Melbourne and Sydney–Brisbane, based on freight volume, distance, and proximity to ports and urban hubs.

Investing in strategically located charging hubs near depots, logistics parks, ports, industrial zones, and regional rest areas to facilitate both return-to-base and long-haul freight operations.

Integrating on-site renewable generation and microgrids into charging sites to improve resilience, reduce peak demand charges, and accelerate grid readiness.

b. Endorse the Global Memorandum of Understanding (Global MOU) on ZE-MHDVs

Endorsing the Global MOU on ZE-MHDVs—which sets a collective ambition of 30% new ZE-MHDV sales by 2030 and 100% by 2040—would solidify NSW's leadership and align it with frontrunners such as the China, European Union countries, Canada, and California. As a subnational government NSW would "strive to convert their owned or leased MHDV fleets to zero-emission vehicles (ZEVs) in line with the Global MOU ambition, as well as put in place policies to enable, accelerate, or otherwise incentivize the transition to ZEVs as soon as possible, to the extent possible given our jurisdictional powers". A formal state-level endorsement would:

Reinforce NSW's international climate credibility ahead of COP31.

Send strong market signals to manufacturers, investors, and infrastructure providers.

Send a strong signal to the National government to Sign the Global MOU and put in place the needed supply side regulations to accelerate the market.

Unlock opportunities for knowledge exchange and cross-border project financing.

c. Other ideas to take into consideration include:

Introduce a Residual Value Guarantee for Electric Freight Vehicles Uncertainty around the resale value of ZE-HDVs limits access to financing, particularly for small and medium-sized fleet operators. A government-backed residual value guarantee (RVG) would: Reduce upfront capital expenditure by up to 20%, improving affordability. De-risk investment for financiers and stimulate private leasing options. Be cost-neutral over time and could be phased out as the second-hand market matures.

Establish Tailored Fleet Advisory Support for Small Operators Electrification presents operational, technical, and financial challenges for small and regional freight operators. NSW should: Create a Fleet Electrification Advisory Program, modeled on successful efforts in California, Chile, and Massachusetts. Offer direct advisory services or a voucher-based model to subsidize fleet assessments provided by qualified private-sector experts.

Target hard-to-reach regional operators and owner-operators who may otherwise be left behind in the transition.

Launch a Public Awareness Campaign and Set Clear ZE-HGV Targets Public understanding and industry confidence are critical to a successful transition. NSW should: Launch a targeted communications campaign highlighting the benefits of ZE-HDVs—such as reduced fuel and maintenance costs, improved public health outcomes, and local job creation.

Establish clear decarbonization targets and regulations for new heavy-goods vehicle sales to provide long-term certainty for industry and infrastructure providers.

5. Supporting a Just Transition for Regional Workers and Industries

Electrification will reshape industries, particularly in regional and freight-reliant areas. NSW should:

Provide upskilling programs for diesel mechanics, drivers, and logistics professionals

Prioritize regional infrastructure investment to ensure equitable access

Maintain employment standards and offer incentives for ZE-HDV manufacturing or retrofitting in regional communities

6. Conclusion

NSW is uniquely positioned to lead the next phase of zero-emission freight. Through smart planning, investment in infrastructure, and inclusive policy design, it can build on its pioneering role in the Global MOU and ZEV Mandate. We encourage the Committee to view freight decarbonization not as a future challenge, but as a current opportunity—for clean air, jobs, innovation, and global climate leadership.

Document to link to:

Annex 1: https://globaldrivetozero.org/publication/mcap-2024/

Annex 2: Global Green Road Corridors: Enabling Factors for Successful Launch, Development, and Scale https://www.globalgreenroadcorridors.org/pages/publications

WHITE PAPER

CALSTART | GLOBAL COMMERCIAL VEHICLE DRIVE TO ZERO | Ministry of Infrastructure and Water Management of the Netherlands | GLOBAL MEMORANDUM OF UNDERSTANDING

GLOBAL PROGRESS TOWARD DECARBONIZING TRANSPORTATION:

MULTI-COUNTRY ACTION PLAN 2024 UPDATE

Owen MacDonnell, CALSTART
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November 2024

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This document is based on information gathered as of October 2024. Any errors are the authors' own.

Cover images: Dennis Zaitsev (top right), Pamela Abreu (center), and electric bus and street sweeper on display at the Global MOU In-Person Summit held June 2024. Credit: Julian Gonzalez.

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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF ACRONYMS

ACF	Advanced Clean Fleets regulation
ACT	Advanced Clean Trucks regulation
AFIF	Alternative Fuels Infrastructure Facility
AFIR	E.U. Alternative Fuels Infrastructure Regulation
CaaS	Charging-as-a-Service
CO_2	Carbon dioxide
COP	United Nations Climate Change Conference
EaaS	Electrification-as-a-Service
EPA	U.S. Environmental Protection Agency
ETS	Emissions Trading System
EV	Electric vehicle
E.U.	European Union
GGRC	Global Green Road Corridors Initiative
GHG	Greenhouse gas
IaaS	Infrastructure-as-a-Service
ICCT	International Council on Clean Transportation
km	Kilometer
LDV	Light-duty vehicle
MOU	Memorandum of Understanding
NGO	Non-governmental organization
NOx	Nitrogen oxides
OEM	Original equipment manufacturer
PM	Particulate matter
PPP	Public-private partnerships
TCO	Total cost of ownership
TEN-T	Trans-European Transport Network

LIST OF ACRONYMS

U.S.	United States
ZETI	Zero-Emission Technology Inventory
ZEV	Zero-emission vehicle
ZEVIT	Zero Emission Vehicle Island Taskforce
ZE-MHDVs	Zero-emission medium- and heavy-duty vehicles
ZEV-RRF	Zero Emission Vehicle Rapid Response Facility
ZEV-TC	Zero-Emission Vehicle Transition Council

FIGURES

EXECUTIVE SUMMARY

2024 was a powerful year of progress and growth for the nations, industry, and stakeholders working to achieve the critical decarbonization goals of the Global Memorandum of Understanding (Global MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles (ZE-MHDVs). The number of Global MOU-committed nations grew by 40 percent and includes a meaningful addition of countries from emerging markets and developing economies. This growth brings impact: Roughly one in every five new commercial vehicles on the planet are covered by the Global MOU commitments, and market volumes for zero-emission trucks have grown by more than 50 percent. Led by successes in the first "beachhead" market segments, such as urban delivery, zero-emission trucks now represent almost 2 percent of new sales. Nearly one-third of Global MOU nations now have binding regulations cementing their goals in law. And the next stage of action to reach 2040 goals—the launching of the first long-haul green freight corridors—is underway on five continents.

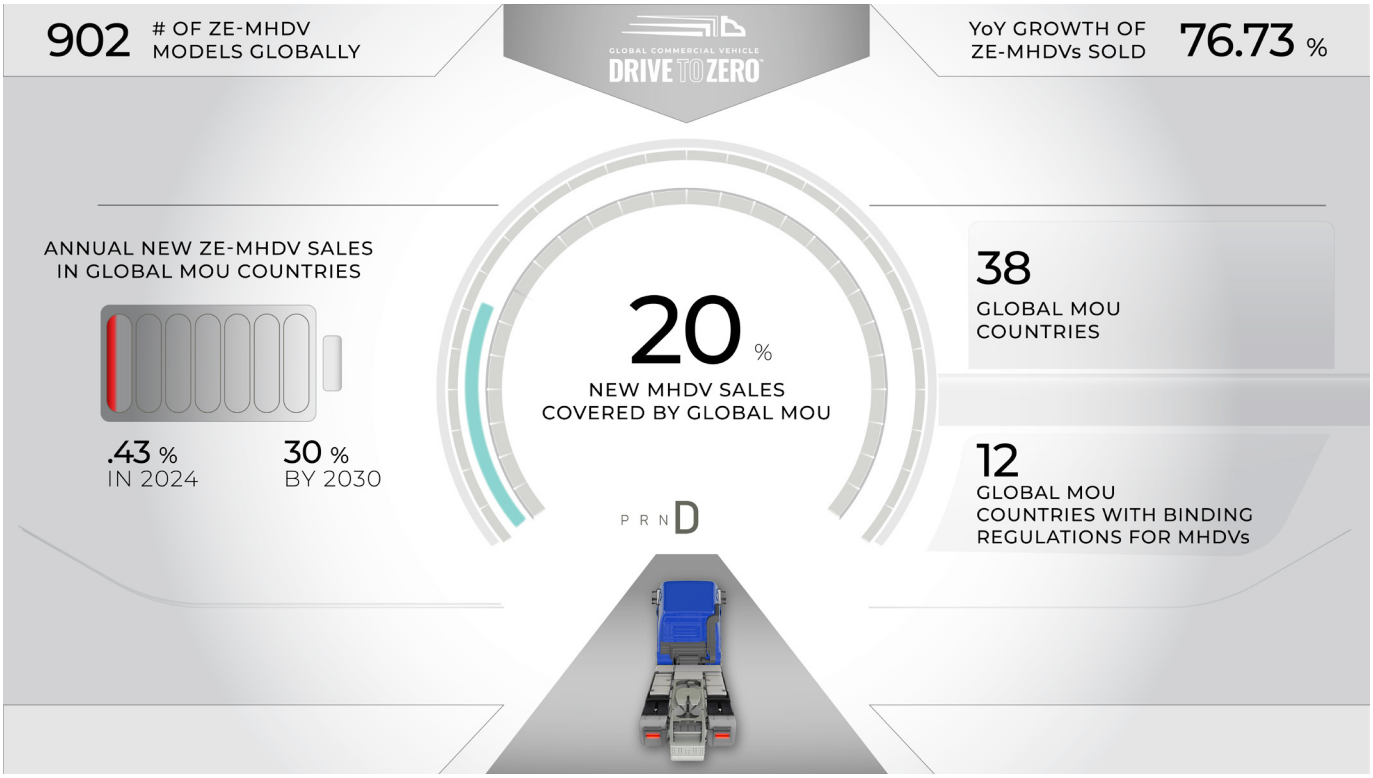
Progress and milestones achieved this past year include these meaningful actions:

- Eleven additional countries (Colombia, Cape Verde, Costa Rica, Ethiopia, Ghana, Iceland, Israel, Papua New Guinea, Mozambique, Seychelles, and Tonga) became Global MOU signatories, bringing the total number of national government signatories to 38.
- These nations now represent five major world regions (Africa; North America, including the Caribbean; South America; Europe; and Oceania) and, when sub-national government endorsers are included, six continents (Asia).
- These 38 nations contain approximately 20 percent, or one in every five, new MHDVs sold on the planet, and 39.5 percent of the world's GDP,[1] an incredibly powerful market share to influence global production and supply chains.
- As of this year, 12 out of the 38 countries are now covered by binding regulations for MHDV decarbonization that set Global MOU-aligned standards on greenhouse gas emissions.
- In the wake of the new rules adopted by the European Union (E.U.) on HDV carbon dioxide (CO_2) emissions, electric truck registrations grew by a robust 51.6 percent in the first half of 2024, increasing their market share to almost 1.9 percent, up from 1.3 percent last year.[2] New E.U. electric bus registrations rose by 45.4 percent in the first half of 2024, with the market share increasing from 13.7 percent to 15.5 percent.[3]
- In California, zero-emission truck sales hit the state's sales goal two years ahead of schedule, accounting for approximately one in six new MHDVs in the lead up to the Advanced Clean Trucks regulation enforcement.[4]

- A cumulative 7.8 gigatons of CO_2 from MHDVs will be avoided from 2024–2050[5] if ambitions of current signatories are achieved, subject to grow as additional nations join this effort.

This global action can be summarized and tracked via these key metric monitors, which highlight progress made against these critical-path outcomes (Figure ES-1).

Figure ES-1. Global MOU on ZE-MHDVs Progress Dashboard



Yet despite real progress, the illustration above shows a steep climb ahead and the need for accelerating and greatly multiplying actions in the coming years to meet 2040 vehicle goals and 2050 net-zero economy imperatives. Achieving the next level of outcomes will require targeting three foundational areas of action:

1. **Lock in regulation:** Secure supply-side regulations aligned with the targets adopted through the Global MOU.
2. **Roll out infrastructure planning:** Drive faster action in the most impactful and polluting applications, plus catalyze direct involvement of the transportation and energy sector, to develop zero-emission freight routes that consider the whole ecosystem, providing relief to the most pollution-damaged communities living near ports, logistics hubs, and highways.
3. **Unleash finance:** Accelerate the economic viability of ZE-MHDVs by establishing programs that use public and concessional funding to unleash private-sector investment in deployments and supportive infrastructure, mitigating the most pressing risks holding back financing, such as credit and residual value guarantees.

To succeed in this transformation, long-term planning implicating all stakeholders is not just a nice-

to-have but a need. Regulations that are in alignment with the Global MOU and grounded firmly in data and demonstrated feasibility are vital to achieve the global decarbonization goals established by the Paris Agreement. A systems-level approach is necessary to move the transport and energy sectors faster to achieve a resilient, carbon-free grid that supports the needs of businesses and communities. Recognizing the unique challenges that all fleets face, particularly small and medium fleets, there must also be a focus on new business models that better support the operational realities of ZE-MHDVs. Likewise, additional measures must be deployed to bring down the cost of financing to fleets and reduce the risk to financiers lending capital, especially for small-fleet borrowers.

Today, transportation stands as the world's second largest contributor to global emissions, second only to the power sector. According to this year's 2024 United Nations Environment Programme Gap Report, which takes stock of each country's nationally determined contributions, the world is not on track to limit warming to 1.5 degrees Celsius.[6] This crossroad marks a pivotal moment in which the world must choose progress or profits and pollution. With transportation relying on oil products for nearly 91 percent of its final energy consumption, a coordinated, global transformation must take place to decouple harmful externalities from transportation.[7]

SECTION I

GLOBAL PROGRESS SNAPSHOT

In 2021, the Global Memorandum of Understanding (Global MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles (ZE-MHDVs) was launched at the United Nations Climate Change Conference (COP26) in Glasgow, Scotland. The landmark agreement calls for signatories to achieve 30 percent new sales of ZE-MHDVs by 2030 and 100 percent new sales by 2040. With 15 governments forming the initial cohort in 2021, it marked a major step forward in elevating the ambitions for global MHDV decarbonization.

Today, the number of country signatories has grown to 38 strong, with more than 200 endorsers and knowledge partners encompassing the private sector, non-governmental organizations (NGOs), and sub-national governments. With action accelerating across the world, but not yet at the pace and scale required, it is more important than ever to focus collective efforts to realize the ambitions set forth in the Global MOU to enable healthy communities, clean air, and thriving business—and decouple the movement of goods and people from the emissions contributing to climate change and harming public health.

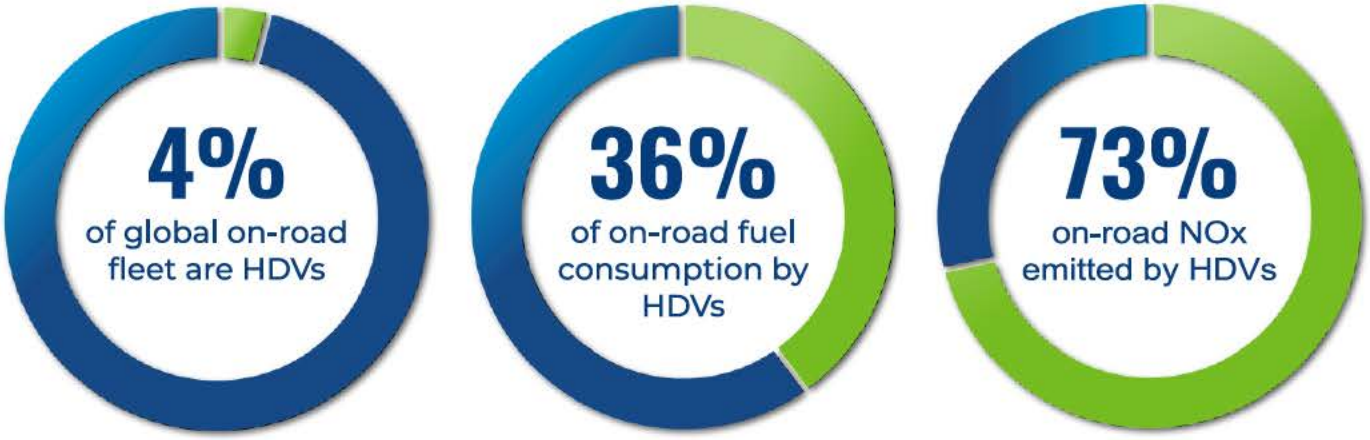
TRANSPORTATION, CLIMATE, AND HEALTH

Overall, transportation accounts for approximately 21 percent of global anthropogenic carbon dioxide (CO_2) emissions and more than one-third of CO_2 emissions from consumers.[8] In 2022, cars, trucks, and other road vehicles were responsible for approximately three-quarters of the total CO_2 emissions from transportation.[9] Diesel-burning trucks and buses are one of the most rapidly growing sources of deadly air pollution. From 2020 to 2050, greenhouse gas (GHG) emissions from freight are expected to double, and harmful particulate matter (PM2.5) associated with combusting diesel is predicted to increase by more than 40 percent in this time frame.[10] Contributing 73 percent of nitrogen oxide (NOx) and 60 percent of particulate matter from on-road vehicles, diesel contributes to more than 330,000 deaths annually and over $1 trillion in annual monetized health damages.[11] [12] This pollution impacts everyone, especially disadvantaged communities living near cities, highways, and ports where emissions are concentrated.

While just 4 percent of on-road vehicles globally, trucks and buses are responsible for 36 percent of on-road fuel consumption and GHGs—a critical barrier to global 2050 net-zero carbon goals (Figure

1). Working together to realize the goals of the Global MOU will result in an estimated cumulative 7.8 gigatons of CO_2 avoided from 2024–2050 if ambitions of current signatories are achieved.[13] This is the emissions equivalent of 877 billion gallons of gasoline consumed. Transportation, specifically MHDVs, must be the focus of rapid decarbonization and unprecedented action to ensure the measures of the Paris Agreement are met within the ever-shortening timeframe.[14] [15]

Figure 1. Impact of HDVs on Global Fuel Consumption and NOx Emissions

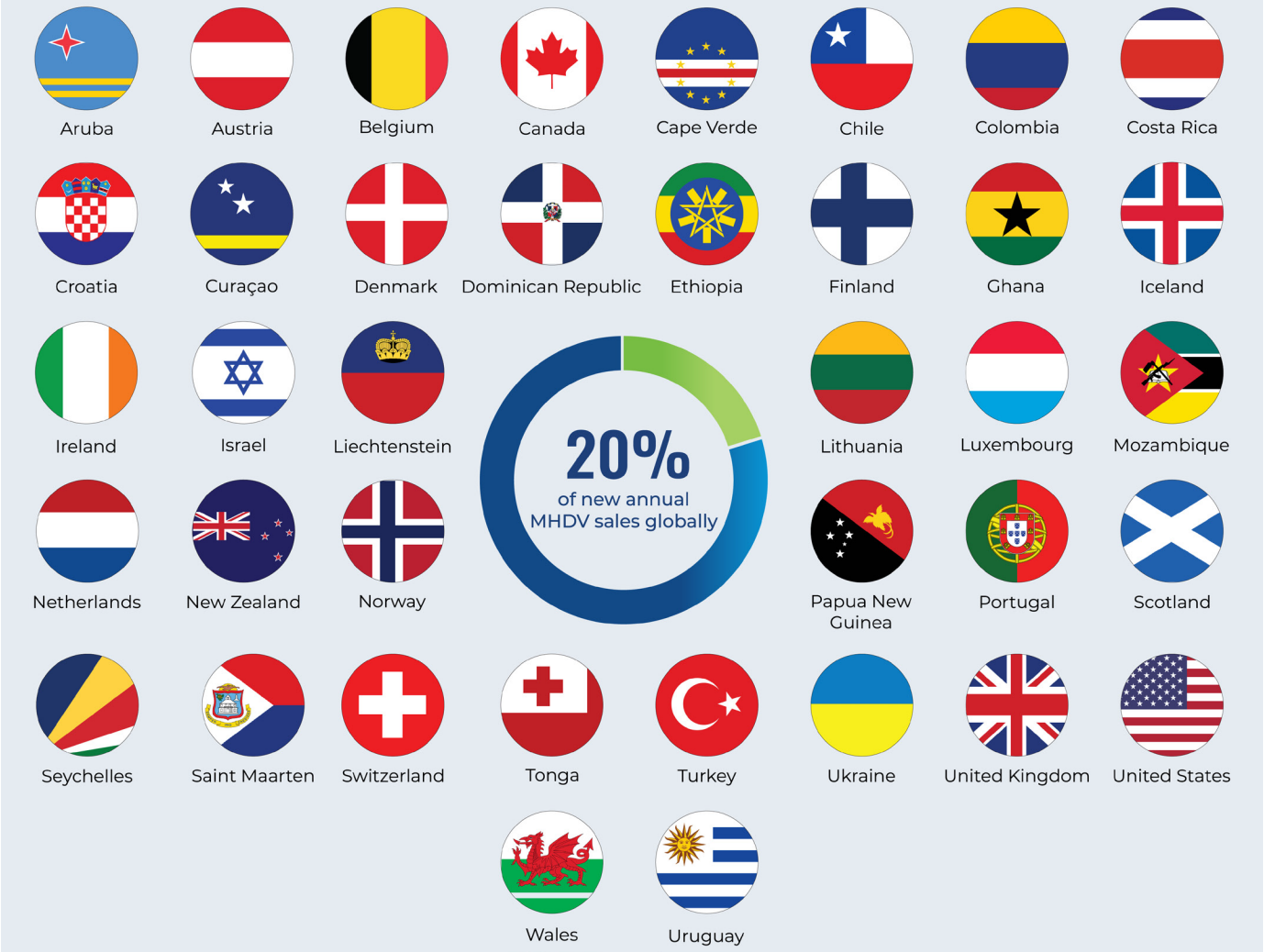


GLOBAL MOU COUNTRIES AND ENDORSERS

Since the last edition of this report in November 2023, Global MOU signatory nations, endorsers, and knowledge partners have made significant progress to accelerate the transition to ZE-MHDVs. Eleven additional nations have pledged their support to achieve the goal of 100 percent new sales of ZE-MHDVs, bringing the total to 38 nations. It is with tremendous accolades that Colombia, Cape Verde, Costa Rica, Ethiopia, Ghana, Iceland, Israel, Papua New Guinea, Mozambique, Seychelles, and Tonga are the newest signatories of the Global MOU. These signatories represent a remarkable growth in island nations and countries in emerging markets and developing economies, significantly broadening the knowledge base of the Global MOU network and making the absence of nations contributing the highest historic GHG emissions apparent and needed in joining this solemn commitment. The deepening of the community has yielded more robust perspectives and considerations of key challenges and opportunities faced by countries with different development statuses and governance structures and to help ensure the zero-emission transition is equitable and shared.

Importantly, these countries now represent 20 percent of the annual new MHDVs on the planet (Figure 2), making their signals, decisions, and regulations a powerful market force and driver of global supply-chain change.

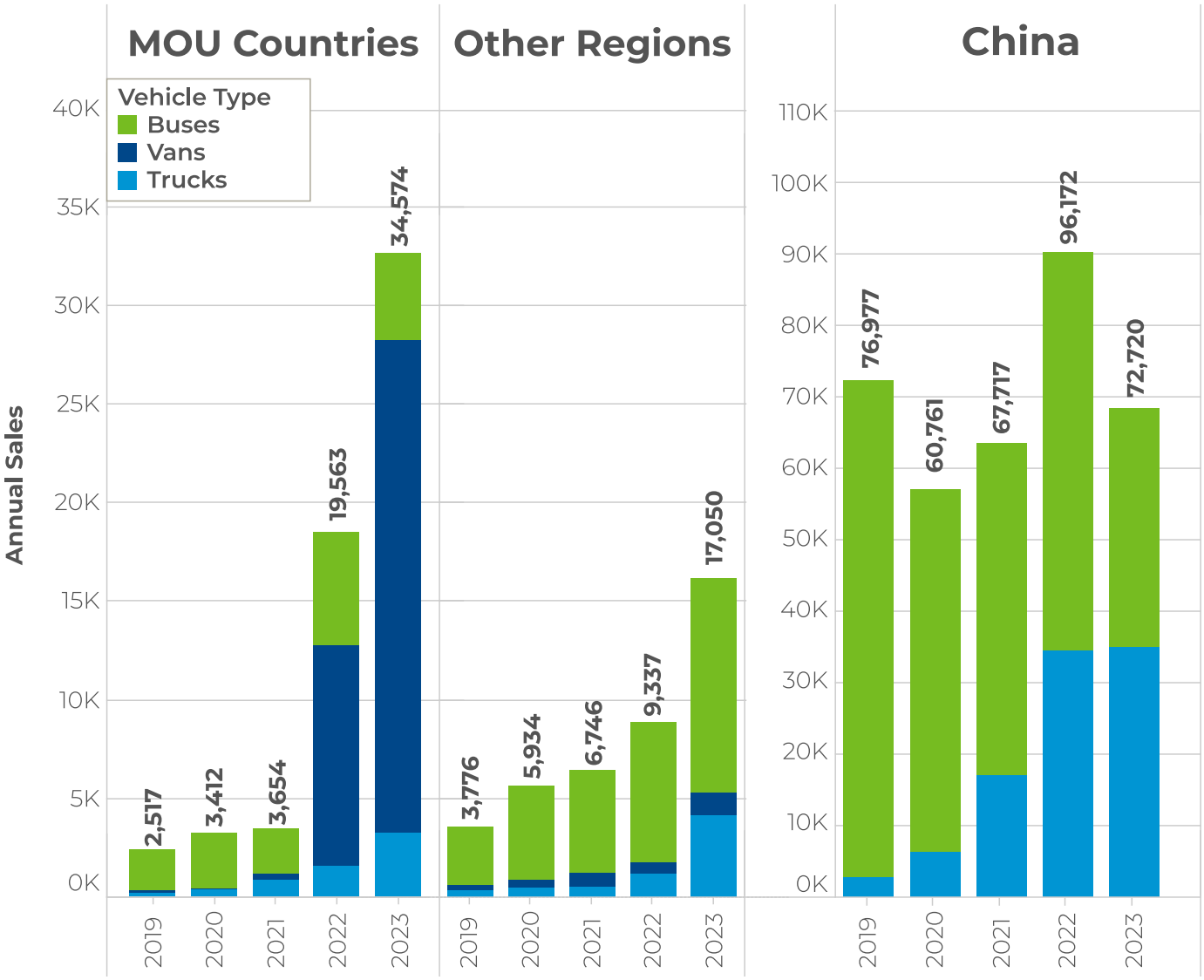
Figure 2. National Government Signatories of the Global MOU



ZE-MHDV SALES UPDATE

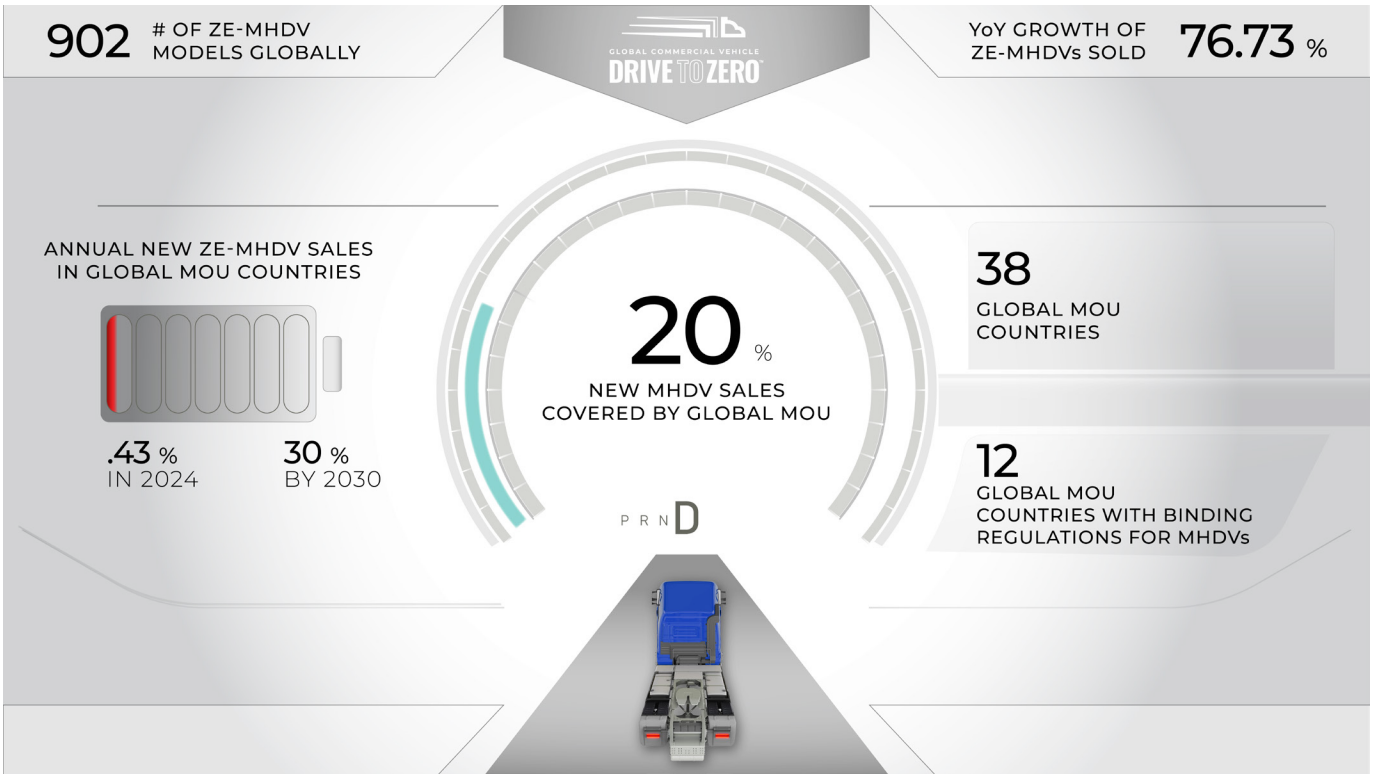
While the world has seen growing momentum behind MHDV electrification, current actions still fall short to hit key milestones that will fulfill the Paris Agreement. With a recognition that truck fleets can take anywhere from 10–15 years to turn over, there must be expedited action to ensure the last diesel vehicles are sold before 2040. In 2023, the Global MOU countries collectively achieved sales of approximately 34,574 ZE-MHDVs (Figure 3), marking 76.73 percent growth from last year—an encouraging indicator of progress.

Figure 3. ZE-MHDV Sales in Global MOU Countries, Other Regions, and China



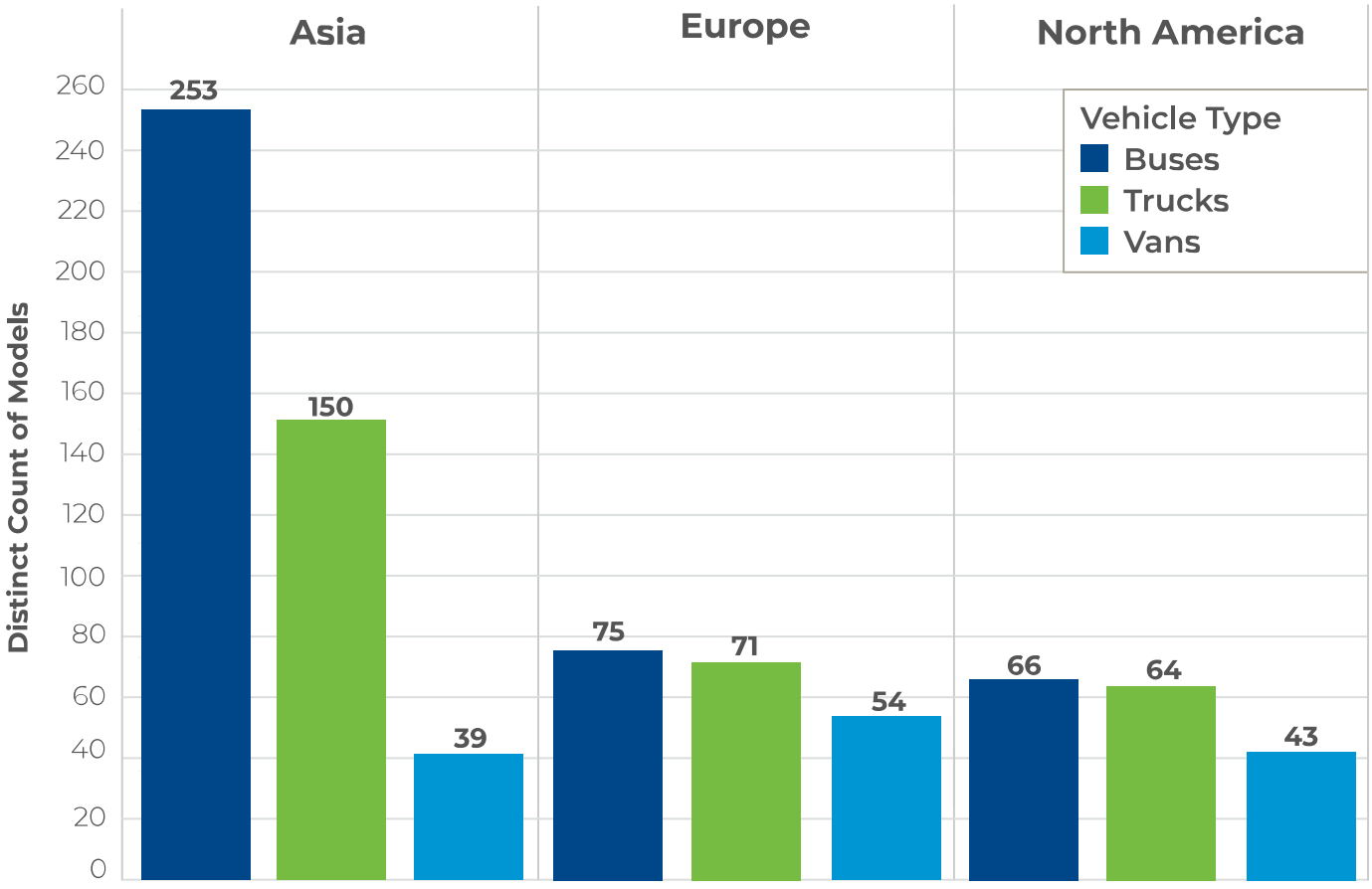
Even so, progress must accelerate. There must be an annual growth of ZE-MHDV sales of 44.59 percent each year to achieve 30 percent by 2030. By today's projections, this equates to approximately 456,798 ZE-MHDVs sold in 2030. Figure 4 below will be updated periodically to reflect progress made and will serve as the accountability tracker to reach the 2030 and 2040 goals.

Figure 4. Global MOU on ZE-MHDVs Progress Dashboard



According to the Zero-Emission Technology Inventory (ZETI), model availability of ZE-MHDVs shows encouraging growth year-over-year at 7.13 percent, bringing the total number of unique models of zero-emission trucks, buses, and vans (U.S. Class 2b–8) to an impressive 902 count as of July 2024 (Figure 5).[16] While nearly half of these vehicles are available primarily in China—many are available for order in other parts of the world—there has been robust growth in specific regions, with the European market adding 20 new ZE-MHDVs, bringing their total to 178. Due to some overarching market consolidation, the number of U.S. models decreased from 212 in 2022 to 164 in 2023. However, as of October 2024, that number has already increased to 189.

Figure 5. Available Models by Vehicle Type in Major Regions (2024)

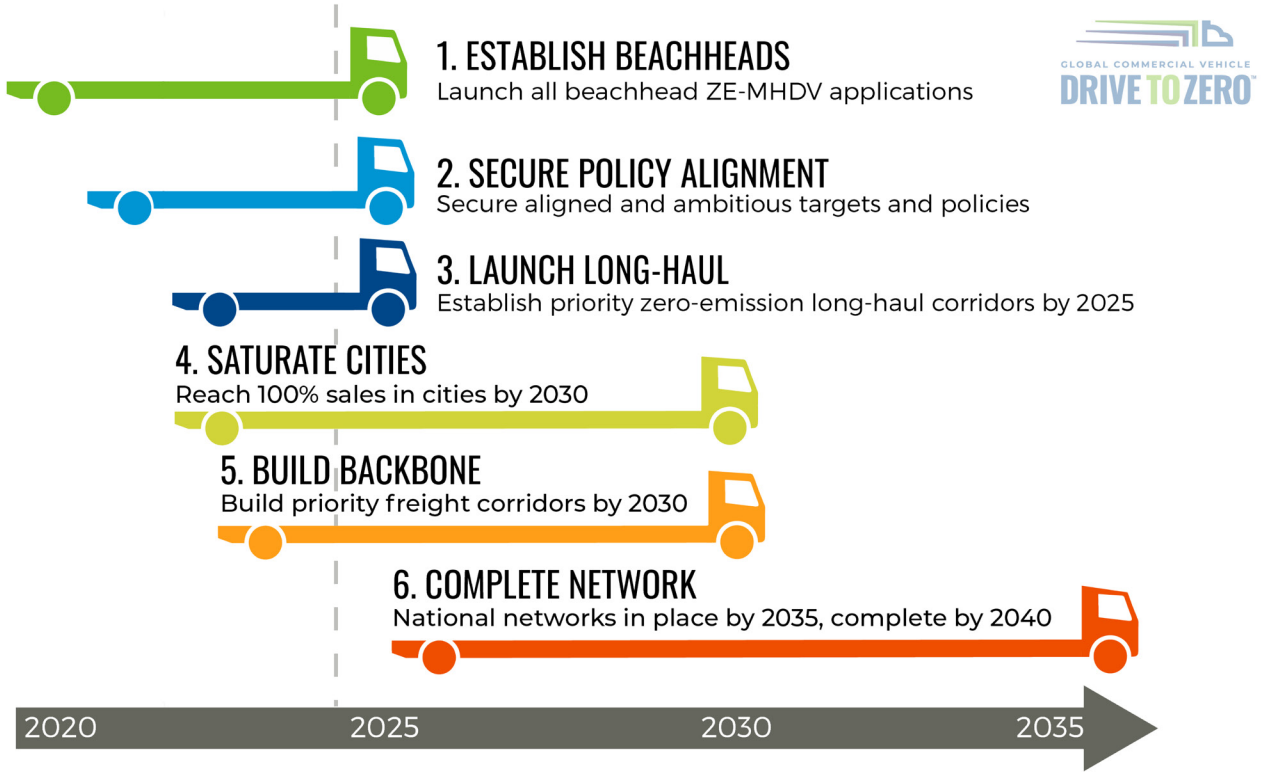


SECTION II

ARCHITECTURE FOR TRANSFORMING TRANSPORT

To outline the action and timeline necessary to achieve Global MOU goals, in 2022, the Global Commercial Vehicle Drive to Zero (Drive to Zero) program published a six-stage strategy (Figure 6) in the report *Global Roadmap for Reaching 100% Zero-Emission Medium- and Heavy-Duty Vehicles by 2040*.[17]

Figure 6. 6-Stage Strategy to Enable 100% ZE-MHDVs by 2040 (and 30% by 2030)



Note: Design modifications were made to reflect present day (dashed line).

To date, most actions have focused on the first two stages of this roadmap: 1) establishing the first "beachheads" (i.e., first success applications for ZE-MHDVs), and 2) securing policy alignment globally around the Global MOU goals and enacting the regulations and policies that drive them. Building on this strategy and the direction for action, this section is divided into three focus areas—Policy, Infrastructure, and Finance—that provide the basis to meet the goals of the Global MOU and eliminate harmful emissions from transportation.

Clear policy and firm regulatory measures provide certainty, signaling to industry that this transition is well underway. Regulations solidify the technology pathway, reduce risks for stakeholders, and spark market innovation. With greater confidence facilitated through regulatory measures, stakeholder actions accelerate and rise with ambition. In tandem, anchoring, ecosystem-level approaches are taking shape in the development of green corridors—a depiction of comprehensive planning across transport and energy sectors for inclusive and resilient infrastructure. This forward movement demands a tremendous amount of capital investment that goes far beyond the role that government subsidies can play. With the pace of the transition accelerating, there is a growing unmet need for private-sector involvement, new business models, and innovative financing measures that can meet the needs of small and large fleets alike. Already, novel public-private partnerships have been able to take advantage of the beneficial operating conditions that ZE-MHDVs bring. The convergence of these three critical topics begets the need for stakeholders across the value chain to champion their respective roles in establishing the rules for commercial vehicle transformation, designing and developing plans for the vehicles to obtain reliable, clean power with investments that match the market opportunity. The pace and scale of the needed transition requires leadership, decisive action, and truly unprecedented collaboration to succeed.

MOVING COMMITMENTS INTO REGULATION

Policy and regulation that are aligned to achieve Global MOU goals is foundational for a successful transformation to a carbon-free commercial vehicle sector. To provide market certainty and ensure progress toward these goals, aligned regulations are needed to delineate stakeholder action on a specific timeline. The Global MOU takes the first step and sets the bar for global ambition around ZE-MHDVs.

Regulations that limit harmful emissions such as GHGs and NOx, establish fuel economy standards, or create sales mandates for manufacturers are the most effective tools to accelerate the transition to ZE-MHDVs. While there are several ways that regulation on vehicle supply can ensure reduced pollution from the tailpipe, the most straightforward policy approach is to set a requirement that the technology be zero-emitting.

Policy Insights: Tracking Tools

Drive to Zero hosts and maintains a regularly updated Global MOU Policy Tracker that assesses the progress of Global MOU signatories (and limited selection of other nations) to build a complementary and comprehensive suite of policy elements.

Sub-national governments also have a large role to play. A new tool used in the United States tracks the actions of sub-national state governments to spur ZE-MHDVs in their borders. The ZET Ahead Dashboard tracks progress across six market dimensions similar to the Global MOU Policy Tracker and can serve as a model for sub-national government action worldwide.

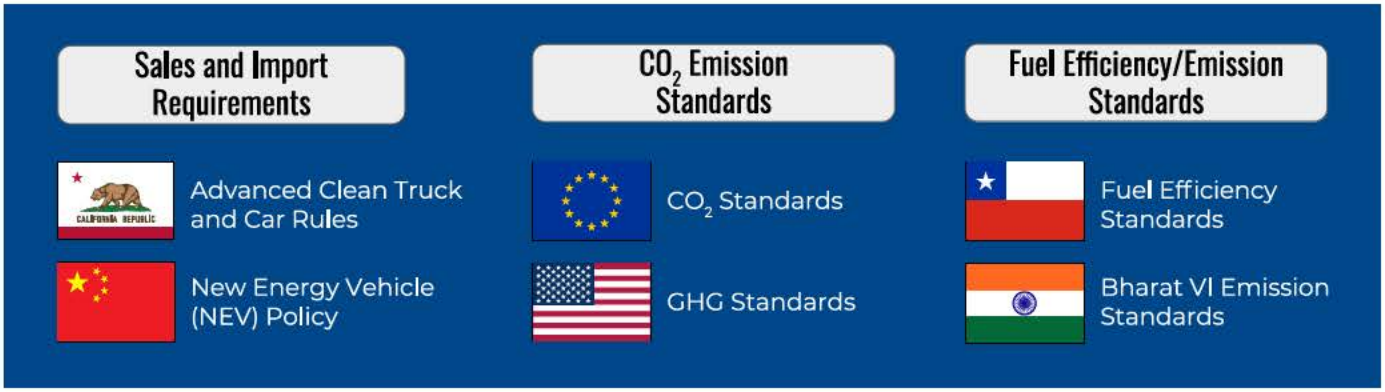
Such regulations create industry certainty, as they lay out clear expectations for future operations and compliance requirements, which allow manufacturers, fleets, and utilities to plan for the long term. While regulatory obligations will not succeed in a vacuum and must be joined by investment, planning, collaboration, and enforcement, they are a vital precursor to consistent action and a fair playing field. They also come with timelines and allocate responsibility for action or inaction.

These policies must include both "sticks" (e.g., supply-side regulations) and "carrots" (e.g., incentive and funding programs) to be effective given the rapid timescale of change required. The more simple and aggressive elements a nation can enact, the more successful its transition can be.

SUPPLY-SIDE REGULATIONS

Most regions around the world have some combination of requirements for MHDVs to limit what can be emitted, and these standards will vary depending on the country and kind of policy. Supply-side regulations, with three leading examples listed below, increase the stringency of emissions or outright require gradually increasing sales of ZE-MHDVs (Figure 7).

Figure 7. Global Examples of Supply-Side Regulations



These kinds of requirements place the responsibility on the manufacturers (i.e., the supplier) to make improvements or allocate additional investments toward zero-emission technologies. In turn, these policies create greater certainty in the direction of the industry, which help facilitate infrastructure deployment and the development of innovative financing measures to ensure affordability for all fleets. Further, as supply increases through economies of scale, the costs of ZE-MHDVs will fall while demand for carbon-free grid upgrades will grow, facilitating the transformation of the full ecosystem. The following are leading examples of supply-side regulations:

- **Fuel economy and GHG standards** aim to increase the fuel efficiency of vehicles (i.e., how many miles a vehicle can travel with one gallon of fuel) and reduce the amount of GHGs a vehicle emits during operation. Improving the fuel economy of MHDVs may take several forms, but the requirements are typically technology-neutral, thus allowing automakers (i.e., the subject of the

regulation) some flexibility on how to meet the minimum standards. Automakers are penalized if they are unable to meet the standards.

- **Emission standards** refer to regulations that establish limits on the harmful criteria pollutants that MHDVs emit as a result of the combustion of fossil fuels. Such pollutants like NOx, PM2.5, and hydrocarbons are common byproducts of combustion and contribute to smog, air pollution, and harmful health impacts.
- **Sales requirements for manufacturers** require vehicle manufacturers to sell zero-emission vehicles (ZEVs) as an increasing percentage of their annual sales. ZEV mandates—aimed at MHDVs—create a minimum market for ZEV manufacturers to grow their businesses, develop their supply chains, and innovate to meet new operational needs.

U.S./E.U. Supply-Side Regulations in Place

In last year's Multi-Country Action Plan, the proposed regulations in the United States (U.S.) and the European Union (E.U.) were yet to be finalized. In May 2024, the European Commission adopted new standards for MHDVs, requiring a 45 percent reduction in CO_2 emissions by 2030, 65 percent reduction by 2035, and 90 percent reduction by 2040. The regulation also includes more accelerated timelines for buses, requiring 100 percent new sales to be zero-emission by 2035. These actions significantly advance the previous standards that required 15 percent CO_2 emissions reduction from MHDVs by 2030 and 30 percent reduction by 2030.[18] The European Commission has also adopted the next phase of the Euro pollutant standards for MHDVs, with Euro 7 to enter into effect in 2028. Euro 7 will further restrict the amount of other kinds of pollutants that are harmful for air quality and public health, such as NOx.[19] The Global MOU nations covered by this newly passed legislation include: Austria, Belgium, Croatia, Denmark, Finland, Ireland, Lithuania, Luxembourg, Netherlands, Portugal, and Norway, and policies referring to the E.U. are inclusive of these nations. However, implementation plans and processes may differ, as well as country-specific programs and priorities. In this context, Türkiye also continues its harmonization efforts with the Euro 7 regulation for MHDVs, which is planned to enter into force gradually between 2026 and 2029.

In the U.S., the Environmental Protection Agency (EPA) finalized the Phase 3 Standards for MHDVs beginning in 2027 that establishes trajectories for CO_2 reductions based on vehicle type and vocation. The rule covers U.S. Class 2b–8, and while technology neutral, it is expected to significantly boost sales of ZE-MHDVs especially in U.S. states that have already adopted the more ambitious Advanced Clean Trucks (ACT) regulation spearheaded by California.[20] Based on initial projections and modeling, the Phase 3 standards are expected to yield $13 billion in net benefits by 2055, including $10 billion in climate benefits, $300 million in health benefits, and $2.4 billion in net savings for the HDV industry due to lower fuel and maintenance costs. In terms of emissions reductions, the standards are expected to cut roughly 1 billion tons of GHG emissions by 2055.[21] Alongside the Phase 3 regulation, the EPA also finalized their Multi-Pollutant Emission Standard beginning with model year 2027 that will limit air pollutants for MHDVs similar to Euro 7.[22]

Sales Requirements in California: ZEV Mandates

A specific highlight must be made for California and the ACT regulation, a first-of-its-kind sales requirement for manufacturers beginning in model year 2024.[23] Each following year, manufacturers will be required to sell an increasing number of ZE-MHDVs depending on the vehicles class and type. In California, ACT is complemented by a demand-side regulation, Advanced Clean Fleets (ACF), that requires fleets to purchase zero-emission trucks, with the stringency of the purchasing requirements varying by fleet type and size starting with model year 2036.[24] Eleven other U.S. states have adopted these two measures, constituting approximately 27 percent of the U.S. MHDV market. Analysis indicates that by 2030, ACT and ACF compliance will lead to the deployment of at least 461,000 ZE-MHDVs in the 11 ACT/F states.[25] Preliminary results from California show that they have met their ZE-MHDV sales target two years ahead of schedule and that every one out of six trucks sold in the state is zero-emission, representing a doubling from 2022 to 2023.[26]

Proposed Chilean MHDV Standard

Chile's National Electromobility Strategy aims to transition fully to electric vehicles (EVs) by 2035, focusing on achieving carbon neutrality by 2050.[27] The strategy proposes mandates that would require 100 percent of light and medium vehicles, public transport (i.e., buses, taxis, shared taxis), and large machinery sold must be zero-emission by 2035. By 2040, all small mobile machinery (i.e., construction, agriculture, forestry) will also be zero-emission, and by 2045, freight transport and intercity buses will follow.[28]

This transition is supported by regulations such as the Energy Efficiency Law and new incentive programs. Key initiatives include the reduction of circulation permit costs for EVs, enabling vehicle-to-grid charging, where EVs can supply energy to the grid, and accelerated depreciation of EV or plug-in hybrid EV for a 10-year period.[29]

Chile's regulation on EV charging infrastructure sets clear requirements to ensure efficient and interoperable public and private charging networks. Technical requirements mandate compliance with safety standards like Supreme Decree N° 8 (2019) and Pliego 15, which cover the design, construction, and maintenance of charging stations.

BEYOND SUPPLY-SIDE REGULATIONS

Supply-side regulations have the unique capacity to significantly expedite the transition to ZE-MHDVs. At the same time, these measures must be paired with and complimented by a mix of other interventions for a more robust ecosystem that will support the uptake of ZE-MHDVs. Different policy levers will be more applicable to certain countries based on the market conditions and overall differences in governance structure and capacity for enforcement and implementation.

Road Pricing in Europe

As more ZE-MHDVs are deployed, countries are exploring how to best implement mechanisms that will incentivize fleets and operators to utilize ZEVs in their operations. Consistent with polluter-pays principles, the European Commission has introduced a framework to encourage member states to leverage taxation and user fees as an instrument to accelerate the adoption of ZE-MHDVs. These measures will expand funding for the Trans-European Transport Network (TEN-T) and facilitate more widespread availability of charging and hydrogen refueling stations.[30] This framework considers distance-based charges (tolls), as well as time-based charges (vignettes) and requires that these fees be reduced for vehicles that are zero-emission—unless the distance-based toll consists only of a flat infrastructure charge. Thus far, several countries have adopted the framework such as Denmark, Netherlands, Lithuania, Lichtenstein, and Switzerland, but more are expected soon.[31] [32] [33] [34] Notably, the revenues from road pricing can be incorporated into countries' upcoming budgets, such as the Netherlands has done to finance subsidy programs for ZE-MHDVs and supporting infrastructure in the near term.[35]

Import Restrictions

For the many countries that do not domestically manufacture MHDVs, effective regulatory and management options can serve to limit emissions of the vehicles entering their borders. Older vehicles predominantly have worse emissions control systems and are less fuel efficient, leading to a commonly observed dilemma of secondary markets where vehicles from developed economies are sold in countries with weaker or nonexistent criteria for efficiency or roadworthiness.[36] Earlier in 2024, Global MOU signatory the Dominican Republic announced prohibitions on automobiles older than five years and goods movement vehicles, like trucks, that are more than 15 years old.[37] While not specific to MHDVs, Global MOU signatory Ethiopia recently announced a ban on diesel light-duty vehicles (LDVs) in alignment with their goal of 152,800 EVs in the country by 2030.[38] However, the timeline and enforcement mechanisms remain unclear. While these measures are being explored for MHDVs, they will have an important role to play in what kinds of vehicles may enter a country.

E.U. Emissions Trading System 2.0 (ETS 2)

A key fixture of the E.U. Green Deal is the Emissions Trading System (ETS) that leverages a "system of allowances" or permits for industry to emit CO_2.[39] These allowances can be traded, and certain industries receive free allowances. However, the number of allowances across industry is capped each year and progressively reduced annually. The revenue generated from the ETS is then reinvested to fund climate investments within the E.U. Up until 2024, the ETS covered only large industry, aviation, and fossil fuel-based energy generation, resulting in a CO_2 emissions reduction of 47 percent from 2005 levels. Moving forward, ETS is being enlarged and strengthened. Most notably, from 2027 onwards, road transport will be covered under the ETS2, requiring fossil-fuel providers to buy allowances and comply with the limits and caps. Member states will then decide how to prioritize the funds in various areas of climate action and mitigation. Notably, this will strengthen the cost-competitiveness of ZE-MHDVs by assigning costs to pollution. This will advance country-level programs through additional funding and revenue and accelerate the transition by instituting limits on polluters that will result in fees if surpassed.

ACTIONABLE INSIGHTS: REGULATION

Regulations that are in alignment with the Global MOU and grounded firmly in data and demonstrated feasibility are vital to achieve the global decarbonization goals established by the Paris Agreement. Supply-side regulations like California's ACT and the E.U. HDV CO_2 standard have exhibited early successes in boosting the supply and sales of ZE-MHDVs in the regions where they have been adopted. The impact goes beyond these short-term victories, however, to establish firm timelines and benchmarks for the whole industry. In other words, strong supply-side regulations ensure an even playing field for competition and innovation. Even so, other interventions must also be considered as a part of the whole ecosystem approach to drive action forward on all fronts. Different ways to levy fees or impose restrictions on polluting technologies with avenues for reinvestment in clean technologies have been effective levers to catalyze change. Ensuring the availability of chargers and hydrogen refueling stations and the right mix of financial support will be discussed in the following sections to make sure that regulatory action is backed up by a robust set of supportive policy.

BUILDING THE CHARGING AND CLEAN POWER NETWORK

A tremendous effort is required to grow and scale an entirely new energy system to recharge and refuel ZE-MHDVs. Global MOU nations are actively working to implement the necessary enabling conditions to ensure that this vital aspect of the transition does not become a hinderance to the uptake of ZE-MHDVs now and in the future. Recognizing that this topic now intersects two massive sectors, inclusive of transportation/road infrastructure and power generation/distribution, there must be a fundamental transformation in approaching this challenge, driven by unprecedented proactive planning and collaboration between governments, NGOs, and private-sector actors. The opportunity to comprehensively plan across energy and transportation presents an opportunity for robust infrastructure planning across a country unlike any other. By accounting for additional energy demand stemming from the deployment of ZE-MHDVs, larger scale investments can be made that go beyond additional energy generation. Domestic energy security, investments in grid resilience against disasters, and accelerated timelines for renewable energy projects all lay the groundwork for a just and equitable transition that seeks to empower local communities and provide access to a clean, accessible grid that does not necessitate harmful externalities like air pollution.

Volumes of electric trucks are growing rapidly, not just in the U.S. and Europe but in every region of the world. To support and enable these vehicles to integrate seamlessly into the logistics system, there must be accelerated action to advance the deployment and maintenance of charging stations and refueling infrastructure for ZE-MHDVs.

INFRASTRUCTURE REGULATIONS

Regulations for infrastructure are an important part of a complete ecosystem for ZE-MHDVs. By establishing requirements and timelines for the planning and buildout of charging and refueling stations, fleets and shippers gain confidence in the reliability of the public network. With greater confidence and expanded operational range, more routes can be covered with ZE-MHDVs, as the nominal range of those vehicles continues to grow.

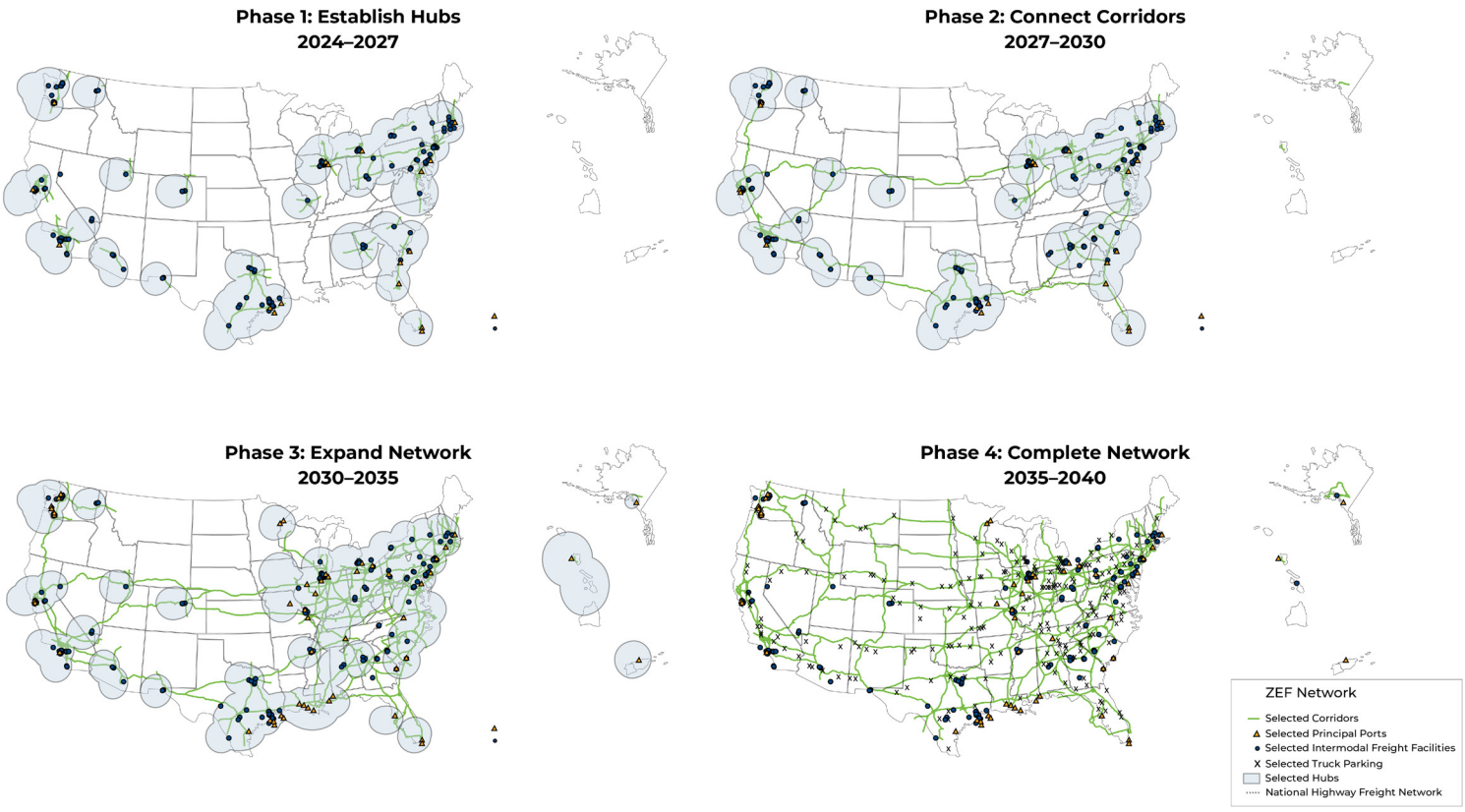
The E.U. Alternative Fuels Infrastructure Regulation (AFIR), which came into force in 2024, sets minimum binding requirements for distance between recharging pools that can accommodate ZE-MHDVs along the E.U.'s primary road system (TEN-T core and comprehensive road network), and that these recharging or refueling stations must meet specific capacity targets (e.g., power output).[40] AFIR's intent is for publicly accessible ZE-MHDV infrastructure to be deployed progressively from 2025, with a vision of covering the entire TEN-T network by 2030. The regulation specifies that charging stations for ZE-MHDVs must be located along the TEN-T core network with a maximum distance of 60 kilometers (km) for HDVs and 100 km on the comprehensive network, and sets requirements for a minimum individual power output of 350 kilowatts. It also sets provisions for supporting urban and regional ZE-MHDV fast-charging and reliability metrics. To accelerate and enable reaching the alternative fuels targets in AFIR, the E.U. announced the second wave of funding for the Alternative Fuels Infrastructure Facility (AFIF) to compliment AFIR. A total of €1 billion will be disbursed to member states between 2024 and 2026 to support implementation of AFIR and network buildout.[41] The AFIR regulation is a key fixture of the E.U. policy ecosystem and provides an advanced level of certainty for shippers, fleet users, financiers, and other stakeholders that the supporting infrastructure will be ready as ZE-MHDV volumes increase.

LONG-TERM STRATEGIES ON CHARGING INFRASTRUCTURE FOR ZE-MHDVS

Long-term planning for ZE-MDHV infrastructure provides a clear scheme for transition and coordinating structure, enabling all stakeholders across the transportation and energy ecosystem to know and assume their role. Establishing a comprehensive blueprint or strategy allows stakeholders to navigate the complexities of transitioning to ZEVs with greater confidence and send clear signals of needs, timing, and location to investors and operators, ideally enabling more efficient, cost-effective, and rapid infrastructure rollout.

In March 2024, the U.S. launched its comprehensive National Zero-Emission Freight Corridor Strategy, a collaborative effort by the recently formed Joint Office of Energy and Transportation. The strategy outlines a national vision for country-wide deployment of supportive public infrastructure for ZE-MHDVs in alignment with the goals of the Global MOU (Figure 8).[42] The strategy describes in detail the phased approach needed to move from priority hub locations to the buildout of the complete network by 2040. The strategy is one of the most robust examples of proactive network planning from a government and specifically ties the outcomes to the objectives of the Global MOU.

Figure 8. U.S. National Zero-Emission Freight Corridor Strategy



Source: Joint Office of Energy and Transportation (2024). National Zero-Emission Freight Corridor Strategy. https://driveelectric.gov/files/zef-corridor-strategy.pdf. Design modifications made by CALSTART.

By prioritizing logistics and freight hubs, and gradually expanding the network through corridor development to connect hubs and nodes, the strategy effectively scales as greater volumes of vehicles are deployed. The strategy is an effective piece of high-level planning and coordination that in turn provides private-sector actors with an anticipated trajectory to further plan for and invest in. The Joint Office of Energy and Transportation that published the strategy is also one of the first-of-its-kind collaborative efforts between agencies to accelerate transportation electrification.

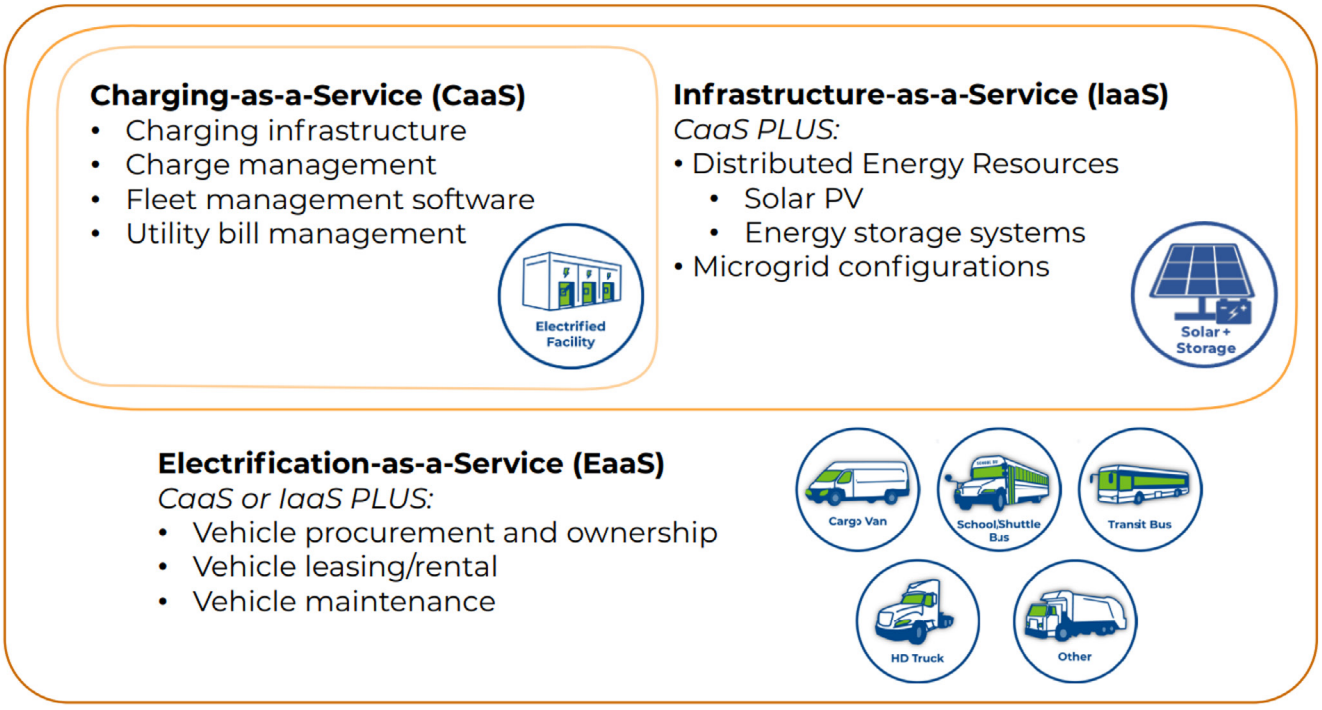
In a similar way, other countries have also been pushing forward efforts to plan for infrastructure deployments. In Türkiye, the Heavy Commercial Vehicles Charging Infrastructure Working Group was established under the coordination of the Ministry of Industry and Technology to conduct a detailed study and assess infrastructure needs. The group is currently conducting a needs analysis along the part of the road network connecting the E.U. and Türkiye, and work has also begun on designing a support program based on these needs.

"AS-A-SERVICE" MODELS

There are significant efforts underway to rethink business models that will lead to cost-effective deployments of ZE-MHDVs.[43] Among those emerging are the "As-a-Service" models that may take shape in a few different ways (Figure 9):

- **Charging-as-a-Service (CaaS)** is a turnkey EV charging offering in which a developer installs, owns, and maintains all charging equipment and infrastructure and provides the charging service to the fleet operator for a specified term and for a fixed fee. This eliminates the cost of charging infrastructure as a capital expense for a fleet, instead transferring it to a fleet's operating budget, which should have extra flexibility owing to reduced vehicle operating and maintenance costs.
- **Infrastructure-as-a-Service (IaaS)** encompasses the elements of CaaS with the addition of distributed energy resources, such as solar photovoltaic systems and/or stationary energy storage systems, and possibly configured as a microgrid to enhance energy resiliency.
- **Electrification-as-a-Service (EaaS)** refers to a full-service arrangement that bundles EV procurement and operation into the same fixed-fee arrangement with charging infrastructure and potential additional energy infrastructure. This model resembles traditional vehicle leasing in many respects but with the addition of enabling infrastructure specific to an EV project.

Figure 9. Types of "As-a-Service" Models



Looking ahead, there is anticipation for a shared commercial vehicle charging infrastructure model, where several fleets work together to develop and share a common infrastructure charging hub. In practice, this could apply to specific locations such as airports, marine ports, or terminals, each of

which would feature several disparate EV fleets sharing a more cost-effective, centralized charging infrastructure installation.[44]

INTEROPERABILITY STANDARDS

For the growth and expansion of ZE-MDHVs, charging processes must be seamless and user-friendly. This requires that charging stations are not only safe, available, and reliable but also interoperable at both software and hardware levels for the growing number of available vehicles. Achieving interoperability offers significant advantages, benefiting not just users but also companies. By adopting standards, manufacturers can avoid the complexities of producing varied equipment, leading to cost savings that can be passed on to customers. The two standards from Chile and Portugal highlighted below pertain to LDVs, but the lessons and insight they provide can inform the design of similar standards for ZE-MHDV interoperability.

In 2023, Chile enacted regulations aimed at establishing the guidelines for the interoperability of EV charging systems. These regulations outline the information and operational requirements needed for the implementation and functionality of such systems, as well as the criteria for delivering EV charging service.[45] They apply to charging infrastructure owners, charging point operators, electromobility service providers, and other stakeholders within the EV charging ecosystem. The regulations mandate that key information about charging stations—including their location, nominal power, types and number of connectors, simultaneous charging capacity, and communication protocols—must be declared. For publicly accessible chargers, owners are required to register on the designated interoperability platform, and non-compliance with these regulations can result in sanctions.[46]

In Portugal, Mobi.E, the public organization responsible for managing the Electric Mobility Network, provides a robust and extensive charging infrastructure network throughout the mainland and islands. The network provides interoperability between the various charging point operators and charging point owners, allowing any user with a valid contract from an electric mobility service provider to charge their vehicle at any station in the system.[47] This interoperability ensures a unified and easy charging experience for EV users, regardless of which operator manages the specific charging point.

ACTIONABLE INSIGHTS: INFRASTRUCTURE

A systems-level approach is vital to transform transport and energy to achieve a resilient, carbon-free grid that supports the needs of businesses and communities. To succeed in this transformation, long-term planning implicating all stakeholders is not just a nice-to-have but a need. Regulatory models like AFIR show how nations can take steps to firmly set rules in place that give rise to market certainty. Actionable and cross-collaborative strategies that represent a shared vision of the future and integrate measures such as interoperability, firm regulatory standards, innovative business models, and pathways for financing support the network building that will serve as the future backbone of road freight networks.

FUNDING THE ZE-MHDV TRANSITION

A key challenge for many fleets is accessing affordable capital to make a purchase. This is particularly prevalent for small fleets, defined by the ownership of one to six trucks, which account for approximately 84 percent of fleets in operation.[48] These numbers may shift slightly by geography, but this trend is prevalent across the globe and manifests significant barriers to invest in ZE-MHDVs even to those that are highly motivated. Compounding fiscal challenges, beyond access to capital, small fleets often encounter knowledge gaps when it comes to understanding how to operate, recharge, and fuel ZE-MHDVs, and how to ensure the supporting infrastructure is right-sized for their needs, as well as what models are available for purchase and the various subsidies or tax benefits available to them.

While the upfront cost of ZE-MHDVs remains relatively higher today, the total cost of ownership (TCO) in some markets has achieved price parity with diesel or other combustion engine equivalents.[49] TCO parity for the resounding majority of ZE-MHDVs is expected before or by 2030, including heavy-duty long-haul, cross-border tractor trucks.[50] Ultimately, regulations and technology innovation will spur the supply of ZEVs and reduce costs in the medium term through economies of scale and nature of competitive markets. In the near term, however, there is a need for interventions inclusive of incentives, tax exemptions, and de-risking interventions that can accelerate TCO parity between zero-emission and combustion engine technologies. Programs that drive down costs, enable access to capital, and reduce risks for investors should all be considered in finding the right combination of policies that suit specific market needs. Approaches will vary from country to country, recognizing differences in economic status and that there is not a one-size-fits-all solution.

VEHICLE SUBSIDIES

Many countries, regions, and cities have already rolled out incentives in different formats and scales, the most common of which are direct vehicle purchase subsidies, providing cost reductions to the upfront price of a new ZE-MHDV. While vehicle incentives and subsidies are an important part of a robust ecosystem to support the acceleration to ZE-MHDVs, they are most effectively used to spur the market forward and to help achieve TCO cost parity in the near term. There are other effective uses of government dollars to reduce costs that are less capital intense and explored in later sections.

Examples of programs that are in effect and have seen success are Canada's iMHZEV program, offering point-of-sale cost reduction up to $200,000 for zero-emission trucks and buses.[51] The AanZET program in the Netherlands is offering a maximum subsidy of €115,200 for ZE-MHDVs over the next year.[52] Finland's program is offering subsidies from €6,000 to €50,000 for zero-emission vans and truck, and in Austria, the ENIN program funds up to 80 percent of the difference in cost between diesel and zero-emission.[53] [54] Similarly, in Ireland the ZEHDV grant funds a portion of the cost differential between diesel and zero-emission.[55] While these are just a sampling of the kinds of subsidy programs that have been deployed by Global MOU countries, thoughtful design and revision of programs based on market realities must be prioritized in their implementation. Set-asides for small fleets or specific vehicle types can be effective in stimulating a specific sector as has been seen through the HVIP program, unique to California.[56]

TAX BENEFITS AND EXEMPTIONS

Preferential taxation schemes are another pathway that many Global MOU countries have implemented to advance TCO of ZE-MHDVs in the near term. In countries like Lithuania, New Zealand, Austria, and Aruba, ZE-MHDVs are exempt from select road taxes, boosting operational savings. In Ireland, under the Vehicle Registration Tax for commercial electric vehicles, a lower rate will be introduced for vehicles with lower emissions thresholds. Denmark will introduce a kilometer-based and CO_2-differentiated road toll for trucks above 12 tons used for transportation of goods from January 1, 2025.[57] In Austria, ZE-MHDVs benefit from a 75 percent discount on the mileage-based motorway toll. Countries like Uruguay and Ukraine have reduced or eliminated value-added taxes on ZE-MHDVs, and Switzerland and Lichtenstein have eliminated the performance-based heavy-vehicle charge (kilometer-based road fee). Similarly, other countries have chosen to exempt ZE-MHDVs from purchase taxes or offer tax credits (for example, the U.S. offers 30 percent of a vehicle's cost as a tax credit, up to $40,000). In Switzerland, certain cantons offer tax rebates, and Uruguay offers a zero percent internal tax for EVs. In Türkiye, motor vehicle taxes and excise duties have been reduced for ZE-MHDVs as well. Incorporating novel taxation mechanisms that reward innovation are an important element to craft a robust policy ecosystem within a country. This is especially true for countries that may not have dedicated resources for large-scale subsidy programs. Ireland, for example, introduced a carbon tax in 2010, now at €56 per tonne, that will fund green initiatives through the revenue generated.[58] As technology costs decline, tax incentives can be rolled back, allowing governments to recover their tax revenues.

REDUCING FINANCING RISKS THROUGH GUARANTEES

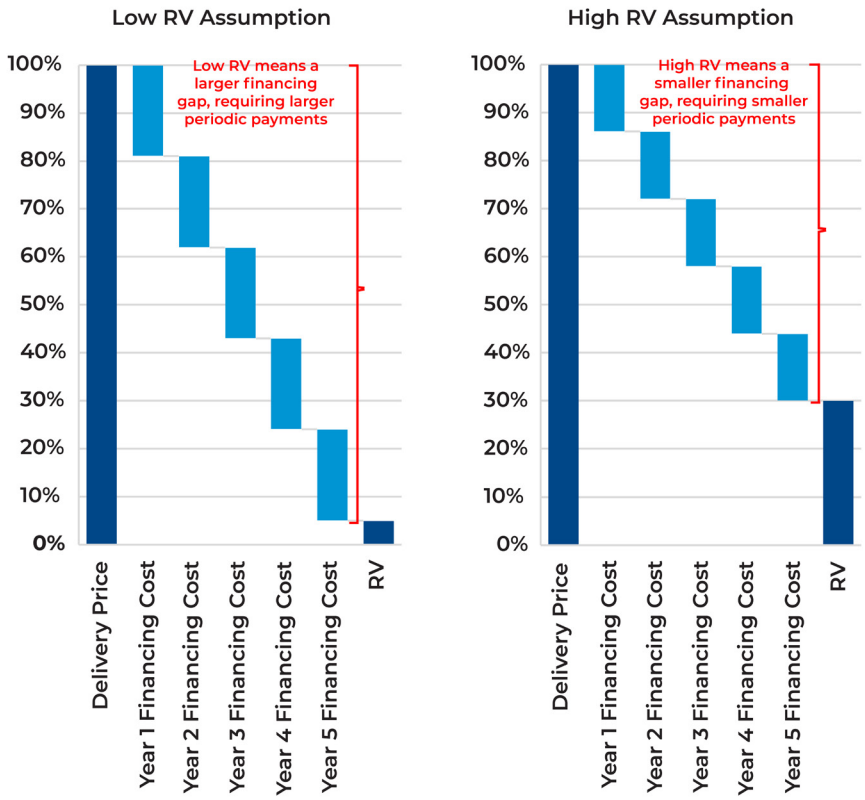
In finance, guarantees seek to improve financing conditions for projects to attract investment by protecting private investors against risks that they are usually not well suited to assess or manage.[59] Small fleets are often viewed as a greater financial liability than large fleets due to their lack of collateral, good credit, and liquidity, which results in financial institutions either rejecting their loan applications or offering poor loan terms with high interest rates, which impact TCO. Through the implementation of programs that effectively manage risks, such as credit and residual value guarantees, governments can broaden access to capital with significantly more favorable terms. Guarantees are highly effective in bringing in private investment with limited public spending, as funding is disbursed only when the guarantee conditions are triggered (e.g., a fleet is unable to make a loan repayment or the resale value of a truck falls below a certain threshold).[60]

In California, the Zero-Emission Truck Loan Pilot Project establishes a loan-loss reserve system to improve the credit profile of small businesses wishing to access loans for ZE-MHDV procurement. The loans are provided by third-party lenders, who are protected by the program against potential losses that could occur if the business is unable to make a payment.[61] For each qualified ZE-MHDV loan made, the California Air Resources Board contributes 25 percent of the loan amount into a participating lender's loan-loss account.[62] In the event of a qualifying loan default (i.e., the borrower is unable to repay), the lender can request reimbursement for the principal loss from the loan-loss account.[63] The previous iteration of this program, which was in place since 2009 and not exclusive to zero-emission technologies,

mobilized $11 in private investment for every $1 spent, financing more than 45,000 low-emission vehicles and demonstrating the efficacy of such measures to leverage private capital.[64]

In asset-backed financing, commonly used for trucks and other commercial vehicles, the value of the vehicle at the end of its first use is an important factor to define the amount of capital that will be provided, as well as the collateral that the lender or lessor can rely on in case of a default. Combustion engine vehicles have well-known residual values, given by decades of historical data on the price of used vehicles on the secondary market. This is not the case yet with ZE-MHDVs. As adoption is still in early stages, very few vehicles have entered the used market and technologies are rapidly improving. This uncertainty drives financiers to assign very low to zero residual values, which makes financing more expensive and harder to access. Thus, guarantees for the residual value of the vehicle can be effective and impactful measures to enable access to capital for fleets (Figure 10).[65]

Figure 10. Impact of Residual Value on Affordability of Financing Terms in 5-Year Vehicle Financing Case



Source: Nadkarni, K. (2024). Financing Fleet Electrification: Battery-Electric Truck Component Resale Highlights Residual Value Update. CALSTART. https://calstart.org/bet-component-residual-values.

SOFT LOANS

ZE-MHDVs cost more upfront but make up for this investment through the savings they generate when used. As such, fleets require financing solutions that allow them to borrow larger amounts, and to extend the repayment periods in a way that more accurately accounts for the multiple years that

the vehicle will be in operation to maximize savings. Soft loans (i.e., loans that offer lower interest rates, longer repayment periods, low upfront fees, and/or complementary incentives) can allow fleets to adopt these technologies and pay for them as they save. For emerging markets and developing economies, where public funding may be limited, development finance institutions can play a big role in facilitating access to finance by blending concessional resources with public- and private-sector funds.[66]

AGGREGATED PROCUREMENT

Aggregated procurement for ZE-MHDVs is an approach to vehicle acquisition that leverages the combined buying power of a group of companies or buyers that can effectively reduce the upfront purchase cost due to increased order size and economies of scale. By aggregating demand, strong signals are sent to original equipment manufacturers (OEMs) that there is demand for ZE-MHDVs in large volumes, providing those suppliers with greater certainty. Not only does this signal reach the private sector, it also sends the message to policymakers that fleets are ready to move beyond pilot deployments and acquire vehicles in significantly greater volumes.

In India, NITI Aayog and Convergence Energy Services Limited carried out an electric bus tender aggregating demand across cities, homogenizing procurement specifications, and requesting a procurement on a fully bundled (Gross Cost Contract) basis. The prices per km received were 23–27 percent lower than the equivalent cost of diesel or compressed natural gas buses without subsidies, and 31–25 percent lower when considering the subsidies. The first tender aggregated 5,450 electric buses across five cities.[67] The successful model has been replicated two additional times, facilitating procurement of 6,465 and 4,675 buses.[68]

In the U.S., a demand aggregation study carried out by the Fleet Electrification Coalition in partnership with Amazon identified a demand of more than 60,000 heavy-duty trucks over the next several years from the world's largest fleets across Europe and the U.S.[69] Similar efforts are unfolding in other parts of the world in countries such as India through the E-FAST program where a demand of approximately 7,750 zero-emission trucks has been identified.[70]

PUBLIC-PRIVATE PARTNERSHIPS

Electric buses, often seen as the precursor to electric trucks, are one of the most tested segments of the ZE-MHDV market. With consistent and fixed routes, stop-and-go urban duty cycles, and predominant return-to-base operations, electric buses lead the charge for MHDV electrification in many regions around the world. Like trucks, electric buses' higher upfront capital expenditure is offset by their significantly lower operating costs, making them financially viable over their useful life.

City transit buses can also take advantage of public-sector funding to facilitate effective public-private partnerships (PPP) to further advance viability. Through PPP, private energy companies supply buses and charging infrastructure while operators lease these buses, avoiding high upfront costs. This unique structure separates asset ownership and management from the day-to-day operation and maintenance of the bus fleet. The model effectively addresses the high initial costs associated with deploying electric buses by leveraging the financial capabilities of private investors and fleet providers. These private entities

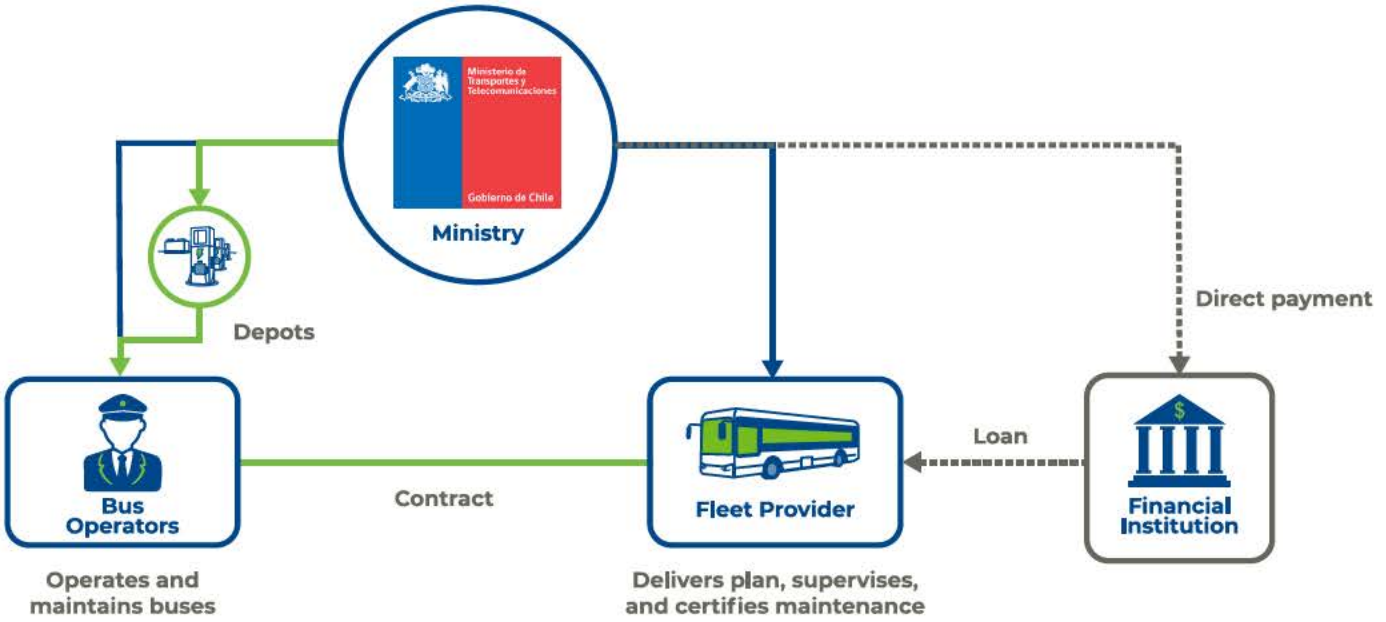
are responsible for acquiring, financing, owning, and maintaining the electric buses and charging infrastructure.

Chilean Bus Fleets

Chile's transition to electric buses, as part of its broader National Electromobility Strategy, focuses on achieving carbon neutrality by 2050. In Santiago, the PPP system for electric buses involves collaboration between the Ministry of Transport and Telecommunications and private electricity companies.[71] These private companies provide buses, charging infrastructure, and energy, while public transport operators lease the buses rather than purchasing them outright. The operators pay monthly leasing fees that cover fleet provision, charging infrastructure, and energy supply through this system.[72]

The leasing model separates ownership from operation and maintenance, with contracts lasting 10 to 15 years. More extended contracts for electric buses reduce monthly payments and increase competitiveness based on TCO. Moreover, government incentives such as tax exemptions, subsidies, and regulatory support further bolster and accelerate the financial feasibility of e-bus adoption.

Figure 11. Government of Chile Public-Private Partnerships Model



Source: Saka, F. (2020). How we made e-bus a reality in Santiago, Chile. C40 Knowledge Hub. https://www.c40knowledgehub.org/s/article/How-we-made-e-bus-a-reality-in-Santiago-Chile?language=en_US. Design modifications made by CALSTART.

The government plays a critical role in managing revenues from public transportation fares, ensuring that a portion is allocated toward the leasing payments, making the system financially sustainable for private investors and public operators. A third-party financial entity is typically involved in handling fare

revenue, deducting leasing fees from the operators' income to guarantee steady payments to the private investors. This minimizes financial risks for private companies, as the state guarantees that the buses will remain in operation until the debt is repaid.

By leveraging this PPP structure, the state ensures the availability of the latest electric bus technology and mitigates financial and operational risks for public transport operators and private-sector partners. Leasing contracts are central to this model, providing a stable and predictable revenue flow for the private companies that invest in the fleet and infrastructure.

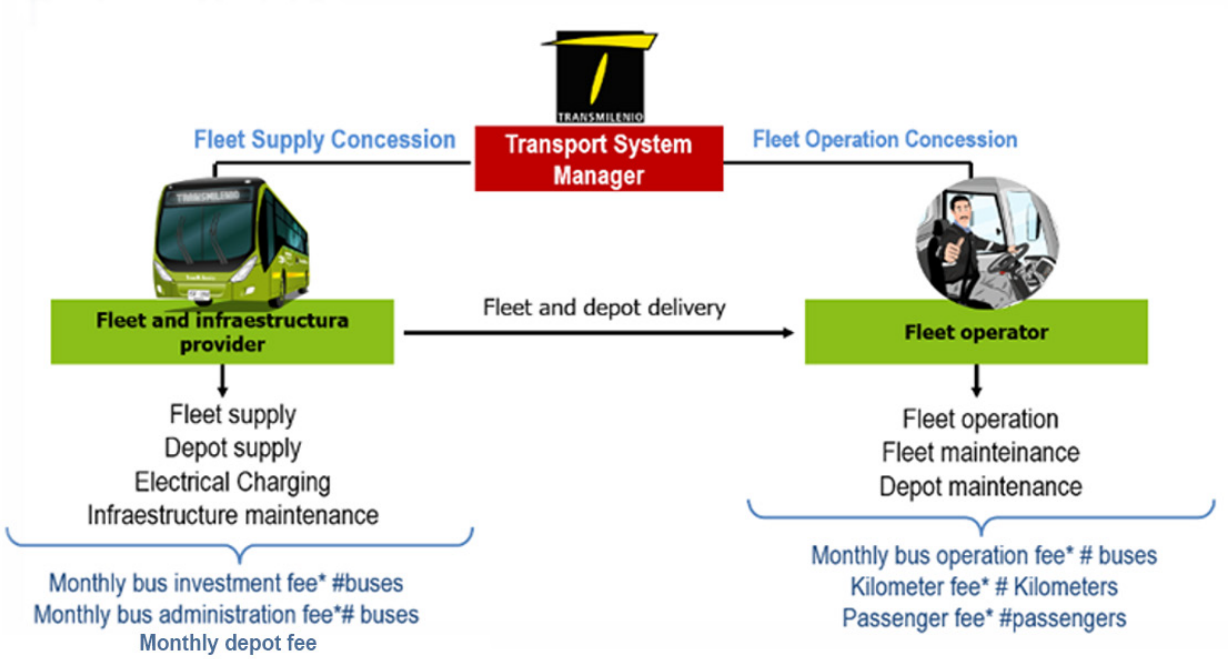
Colombian Bus Fleets

Colombia has implemented leasing and financing models to address the high upfront costs of ZE-MHDVs and the necessary infrastructure, specifically through PPP.[73] In this system, like in Santiago, Chile, private fleet providers own the buses and charging stations, while public transport operators contracted through TransMilenio oversee the buses' everyday operations.

TransMilenio implemented a new business model due to two main reasons. First, many areas in Bogotá were still not covered due to concessionaries' financial problems under the traditional model. Concessionaries were then unable to provide service to passengers. Second, concessionaires did not pay credits, so commercial funding was not willing to enter the transport business. With the traditional model, the asset ownership and operation was under the same concessionaire, many of whom did not pay their debts. A pivotal aspect of the new model is the concession contracts with operators, which extend to 15 years for electric buses (compared to 10 years for diesel buses).[74] This new model demanded many discussions with the financial and insurance sector about risk allocation, guarantees, and bankability. This longer concession period provides stability for investors and allows for a longer duration to recoup the higher initial investment costs of electric buses.

For the first business model, TransMilenio structured the concessions under three specific agents, each responsible for a different aspect of operations. Notably, this model was designed through contracts with a time frame of 15 years. Through proactive assessment and improvement, TransMilenio has simplified and restructured the business model to better address efficiency, bankability, flexibility, and the overall experience to the end user. For the second business model some changes were included, namely simplifying the structure and operations to two agents instead of three (Figure 12).

Figure 12. TransMilenio Updated Business Model



Source: TransMilenio S.A. (2023). Energy Transition in Transport Sector: Successful Case Study Bogota. Internal presentation.

This model has facilitated the rapid scaling of Bogotá's electric bus fleet, with 1,485 electric buses deployed as of 2024, and contributed to Colombia's GHG reduction goals and improvement in urban air quality.[75] Other Colombian cities are following this lead, as Medellín and Cali have deployed 69 and 36 buses respectively, bringing Colombia's total to approximately 1,590 electric buses in operation.

ACTIONABLE INSIGHTS: FINANCE

Investment in the ZE-MHDV transition must significantly increase to meet the goals of the Global MOU and the Paris Agreement. Recognizing the unique challenges that all fleets face, particularly small and medium fleets, there must also be a focus on new business models that better support the operational realities of ZE-MHDVs. Likewise, additional measures must be implemented to bring down the cost of financing to fleets and reduce the risk to financiers lending capital, especially for small-fleet borrowers. While there is no one-size-fits-all solution, guarantee mechanisms (i.e., credit and residual value) as well as soft loans have demonstrated significant potential for improving financing conditions. Direct subsidies for vehicles such as California's HVIP, the Dutch AanZET, and Canada's iMHZEV have been impactful early on, but at this stage, these programs must be deployed in conjunction with regulations or other policy measures and be compatible with leasing and "As-a-Service" models to ensure the greatest impact given their high cost of implementation.

SECTION III

IMPLEMENTATION ACTIVITIES

As the ambition for an accelerated transition to ZE-MHDVs increases, so must efforts around implementation. No single country, state, or city has the answer to the multitude of complexities surrounding such a massive systemic change to the fundamental way goods and people are moved. As such, this circumstance demands collaboration between stakeholders to maximize success, minimize risk, and ensure lessons learned are carried forward to avoid progress stalling due to challenges that others may have already successfully navigated. The momentum and support for the goals of the Global MOU by national governments and endorsers has enabled the formation of specific efforts aimed at tackling key roadblocks to unleashing greater, systemic change. In this section, these efforts are highlighted as examples of ways to get engaged and to showcase actions necessary to achieve a clean transportation future. With 38 countries aligned in Global MOU goals, a dozen countries advancing aligned regulations, and more contemplating a shift toward ZE-MHDVs, there is no time left to delay action—getting zero-emission trucks, buses, and infrastructure successfully on the map in every region is imperative. Whether it is the development of green road corridors, fleet transition planning, or regional stakeholder project collaboration, implementation time is now. The successes and failures learned will contribute to the transformation of a transportation system that is clean, equitable, and defining of a carbon-free era.

GREEN ROAD CORRIDORS

Road corridors are the backbone of the interconnected world. Building capacity around and ultimately launching corridor ecosystems inclusive of the ports, cities, and hubs they connect will support the needs of ZE-MHDVs enabling seamless long-haul freight operations and providing a pillar of action to achieve Global MOU 2040 goals. Establishing foundational conditions and understanding key enabling success factors that drive effectiveness, as well as identifying, organizing, and coordinating multiple stakeholders, is required to make an entity as complex as a zero-emission corridor succeed. By engaging, coordinating, and acting toward this concrete outcome, stakeholder action will become highly visible and produce vital lessons, giving rise to scaled transition.

This year, CALSTART's Global Drive to Zero program, alongside partners and allies in the ZEVWISE coalition, launched an ambitious Global Green Road Corridors (GGRC) initiative to advance a diverse set of the world's road corridors to transition to a ZE-MHDV ecosystem. As of this writing, eleven GGRCs have been announced with the support of broad networks, including government, industry, and financiers.

These corridors, each led by an array of different partners worldwide, will establish the basis for replicable, adaptable models that will accelerate global ZE-MHDV deployment (Figure 13) shared through a set of public briefings, internal clinics, and online resources rolling out in 2025.[76] GGRCs will serve as a real-time resource and framework for growth and success. Beyond the scope of the initiative, Drive to Zero has identified nearly 30 green road corridors in development worldwide and will continue building out and on the momentum, scale, and benefit of this effort.

Figure 13. Global Green Road Corridors

1	**FIFA 2026 Corridor:** Canada – USA – Mexico *(U.S.)*
2	**USA-Mexico Border Corridors:** California – Baja California, Texas – Nuevo Leon, Arizona – Sonora *(WBSCD)*
3	**Southern Africa Container Corridor:** Port of Durban, including South Africa, Lesotho, Eswatini, Zimbabwe, Botswana, and Zambia *(UNEP (ZEVWISE Focal Point))*
4	**India Corridor:** Mumbai – Delhi and Delhi – Jaipur *(WBSCD)*
5	**India Corridor II:** NH48: Delhi – Mumbai – Chennai *(ICCT)*
6	**European Corridor to Zero:** Netherlands, Germany, Poland, and Ukraine *(AVERE Ukraine / EVConsult)*
7	**Trans-Caspian International Transport Route (TITR) Corridor:** China, through Kazakhstan, Azerbaijan, Georgia, and Turkey to Europe *(UNEP (ZEVWISE Focal Point))*
8	**USA I-95 Corridor:** Georgia – New Jersey *(CALSTART)*
9	**Northern Corridor:** Kenya, Uganda, South Sudan, Rwanda, Burundi, and DRC *(NCTTCA)*
10	**I-10 Corridor:** California – Los Angeles, Palm Springs, Blythe, Arizona – Tuscon, New Mexico – Lordsburg, Vado *(Smart Freight Centre)*
11	**Poland Corridor:** Poznan, Warsaw, Wroclaw, Krakow *(Smart Freight Centre)*

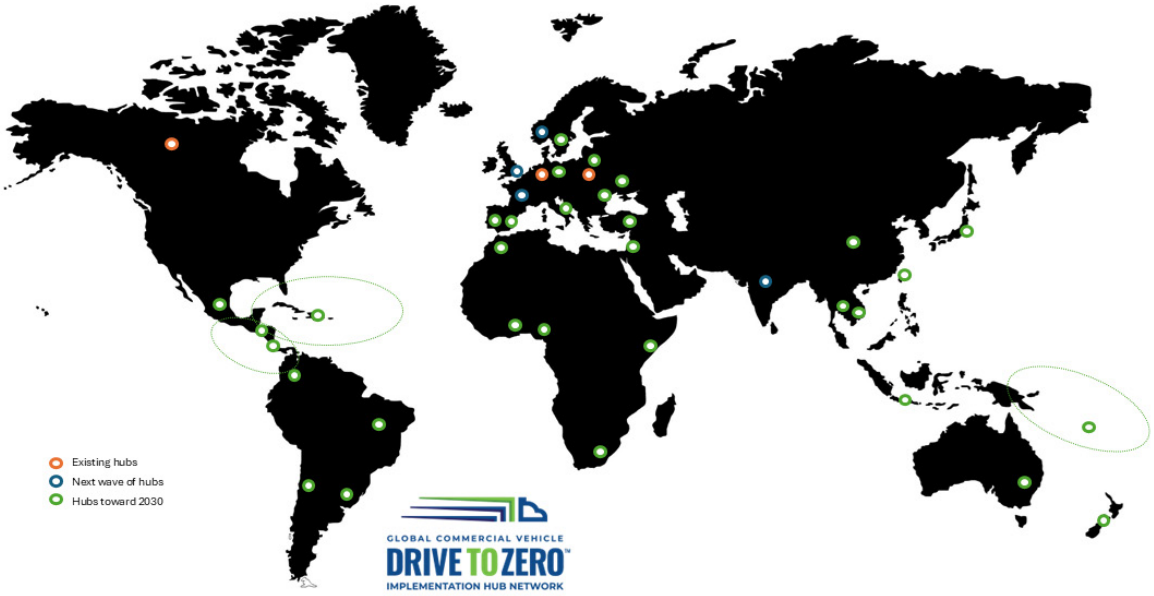
Learn more about the GGRC corridors, key stakeholders, and success factors in the recently published Global Green Road Corridors: Enabling Factors for Successful Launch, Development, and Scale.

GLOBAL IMPLEMENTATION HUB NETWORK

Recognizing the specific need to accelerate the deployment of ZE-MHDVs and unique barriers around costs and financing, implementation hubs seek to facilitate connections between the different entities involved in advancing solutions. Ensuring project bankability, access to affordable capital, and engaging partners that are looking to invest in this rapidly growing industry are all ways that implementation hubs will get more ZE-MHDVs on the road. Residing in the middle between fleets, financiers, governments, and other private-sector actors, there is significant capacity for matchmaking between those that need support in specific areas, and those with business models, financing mechanisms, and innovative approaches that can address those needs.

Drive to Zero is working collaboratively with fleet electrification experts around the world to build out a Global Implementation Hub Network that supports countries and fleets who set ambitious zero-emission transport goals (Figure 14).[77] As ZE-MHDVs are deployed with fleet support from the implementation hubs, the Global Implementation Hub Network gains insight into how policies and regulations are impacting adoption and the kind of technical support needed. These learnings are channeled toward government agencies, creating a feedback loop for policy improvement and accelerated adoption.

Figure 14. Global Implementation Hub Network



Each implementation hub is powered by a local organization that utilizes tools and tailored resources, co-developed with Drive to Zero, to provide information to fleets about replacement schedules, deployment costs, charging infrastructure requirements, model availability, financing solutions, and potential partners. The first hub was launched in the Netherlands in collaboration with Fier Sustainable Mobility in 2023, and another hub was launched earlier this year in Poland in collaboration with PSNM. New hubs will soon be launched in the United Kingdom and India.

Learn more about the Global Implementation Hub Network and the project's goal to encompass at least 30 local hubs by 2030 to enable the targets set by the Global MOU.

REGIONAL TASKFORCES

Local governance structure, socio-economic conditions, and physical geography are crucial to consider in designing solutions for creating a successful ZE-MHDV ecosystem. By embedding locale context in policy, regulation, and implementing programs, decision-makers will be positioned to effectively engage their constituencies, increasing the likelihood of success in entrenching new or improved rules and their implementation.

The Zero-Emission Vehicle Island Taskforce (ZEVIT) is one such example of this bespoke approach. ZEVIT convenes leaders from island nations who have signed the Global MOU, committing to work together to ensure all new sales of trucks and buses are zero-emission by 2040.[78] While the island nations' contributions to climate change are marginal, the impact that many of these countries will face due to sea level rise and more extreme weather patterns is disproportionate. As such, the imperative for action is even more pronounced and must begin now. For island nations specifically, there are numerous benefits to advancing zero-emission truck and bus deployments in these geographies, including reduced dependence on fossil fuels, improved air quality, cost-savings, and resilience against natural disasters. Members of ZEVIT come together to share their experiences, challenges, and opportunities related to truck and bus decarbonization, and they collaboratively work together to advance the transition. These exchanges will help to propel global, inclusive achievement of the goals set forth by the Global MOU.

This year, the taskforce has expanded participants' familiarity with the technological capabilities and deployment of electric buses in island contexts, learning from first-mover countries, importers, and research institutions to inform their ongoing deployment plans. Many island states are not eligible for Official Development Assistance despite being at the forefront of the climate crisis and sharing the many challenges of emerging markets. A first step in this direction was the expansion of the Zero Emission Vehicle Rapid Response Facility (see the Short-Term Technical Assistance subsection) to include countries located in developing regions as defined by the United Nations Statistical Division, in addition to those eligible for Official Development Assistance.[79]

Learn more about ZEVIT members and their areas of focus, including electric bus deployments, long-term infrastructure planning, supply-side mandates, and more.

SHORT-TERM TECHNICAL ASSISTANCE

Recognizing the imbalance in resources available to emerging markets, short-term technical assistance plays an important role in jumpstarting action to decarbonize MHDVs. Launched at COP27, the Zero Emission Vehicle Rapid Response Facility (ZEV-RRF) is an initiative of the Zero-Emission Vehicle Transition Council (ZEV-TC) aimed at providing targeted and simplified short-term technical assistance to emerging markets and developing economy (EMDEs) countries that are decarbonizing their road transportation sectors and transitioning to zero-emission vehicles.[80]

ZEV-RRF aims to execute short-term (18 months or less) tangible projects that develop and implement strategies, policies, and regulations to advance the global ZE-MHDV transition. ZEV-RRF operates in a "Hub and Spoke" model to create a single point of entry. The International Council on Clean Transportation (ICCT), secretariat of ZEV-TC, serves as the Hub; the Spokes are partner organizations with technical expertise in topics related to the transition and various geographies served. Drive to Zero/CALSTART, for example, is a spoke. The Hub collects requests from eligible countries and connects these countries' governments to the appropriate Spoke(s) able and willing to assist. The ZEV-RRF supports technical projects like research and scenario development, development of policies and regulations, project formulation, and technical trainings.

Emerging markets signatory to the Global MOU are eligible for support through the ZEV-RRF and are strongly encouraged to submit a request by filling out this form.

SECTION IV

PRIORITY ACTIONS

Global MOU nations are making important progress toward their 2040 goals, but the work ahead must accelerate with increasing momentum and scale. Based on analysis of underlying barriers and roadblocks for faster action, the Drive to Zero program, through detailed input and feedback from Global MOU countries and endorsers, has identified and refined the three primary pillars of action required over the next several years to keep the countries on track to transport decarbonization goals:

1. **Lock in regulation**: Secure supply-side regulations aligned with the targets adopted through the Global MOU.
2. **Roll out infrastructure planning**: Drive faster action in the most impactful and polluting applications, catalyzing direct involvement of the transportation and energy sector to develop zero-emission freight routes that consider the whole ecosystem, providing relief to the most pollution-damaged communities living near ports, logistics hubs, and highways.
3. **Unleash finance**: Accelerate the economic viability of ZE-MHDVs by establishing programs that use public and concessional funding to unleash private-sector investment in deployments and supportive infrastructure, mitigating the most pressing risks holding back financing, such as credit and residual value guarantees.

SECURE SUPPLY-SIDE REGULATIONS ALIGNED WITH GLOBAL MOU GOALS

The Global MOU establishes the international standard for achieving 100 percent zero-emitting trucks and buses by 2040. To move these policies into enforceable requirements, countries must promulgate regulations as done this past year in the U.S. and E.U. Regulatory options and lessons in the rulemaking process shared between nations within the Global MOU community have demonstrated that knowledge transfer is powerful for countries that may be just starting the process. Navigating opposition, working to build strong public-private coalitions, and making the benefits of the transition known to policymakers, businesses, and the public are all strategies employed by the Global MOU community to add value and insight to achieve Global MOU goals. Actions to progress Global MOU goals into aligned regulations include:

1. Pursue ZEV mandates as the simplest and cheapest regulation to set up, monitor, and enforce, locking in the pace of the transition and accelerating cost reductions through increased investments in innovation and production at scale. Other options include fuel efficiency standards and CO_2 regulations.
2. Identify and share the benefits of transportation decarbonization driven by regulatory measures with decision-makers by uplifting or commissioning robust studies that highlight job creation, TCO parity with diesel, and public health savings associated with cleaner air alongside meeting country climate targets.
3. Engage with Global MOU signatory countries and/or regions to learn about their policy choices and experiences with obstacles to understand how they tackled challenges.
4. Elevate information and case studies to decision-makers that demonstrate the availability of ZE-MHDVs and presence of innovative business models like the "As-a-Service" model to meet all use cases and showcase how leading businesses are adopting the zero-emitting trucks, buses, and infrastructure in the region.
5. Integrate diesel phase-out requirements (or restrictions on imports) implicating secondary markets to support a just and inclusive transition away from carbon-polluting vehicles.

DRIVE FASTER ACTION VIA TARGETED INFRASTRUCTURE AND GLOBAL GREEN ROAD CORRIDORS

ZE-MHDVs are finding great success operating in and around cities and between hubs, showcasing the proficiency of the technology in action. At this stage, the refueling network needs to expand at the pace of vehicle deployments. Corridors are the key to enabling longer trips without the need for additional battery capacity, effectively modulating costs associated with larger batteries while increasing the operational range that ZE-MHDVs can travel. When it comes to charging and hydrogen refueling stations, given they intersect both the transportation and energy sectors and often cross local or national borders, significantly more effort must be placed on collaboration and coordination between governments and other stakeholders—national and sub-national, the private sector, grid operators and utilities, and local communities. With this understanding, these large projects with multi-year time horizons must begin in earnest now if they are to support the 2030 goals of the Global MOU and enable the full transition by 2040. The following recommendations have been synthesized to ensure forward progress is made:

1. Identify national and local stakeholders. The first step is to firmly identify and understand the role of government agencies, the private sector, NGOs, grid operators, and others involved in the development of infrastructure for ZE-MHDVs.
2. Create roadmaps to forecast infrastructure demand and identify priority deployment locations. Infrastructure roadmaps are needed to align national progress through the identification of high-capacity freight corridors and urban hubs that result in highest impacts.
3. Create regulatory structures that direct utility investment toward ZE-MHDV infrastructure. Organize

a governance structure and accountable agency to oversee the timely buildout of infrastructure and coordinate efforts for near- and long-term grid modernization.

4. Identify future electricity needs inclusive of ZE-MHDVs to develop comprehensive plans for clean and resilient grid modernization.
5. Collect and standardize data that will feed infrastructure development strategies and plan the network buildout.
6. Direct utility action toward beneficial rate structures for fleet charging. Electric utilities must adjust electricity rate structures to ensure that fleets will not incur demand fees or higher costs from ZE-MHDV charging, particularly when charging off-peak. Utilities define different rates for different industries and must adjust similarly for MHDV charging.

ACCELERATE THE ECONOMIC VIABILITY OF ZE-MHDVS

With regulations establishing firm, actionable timelines for commercial vehicle decarbonization, the economic viability of ZE-MHDVs increases and invites actions to rapidly achieve TCO parity with diesel. Regulation helps plan across a long-time horizon and increases comfort to more risk-averse financiers; in tandem, financial products and approaches toward financing and residual value need to be baked into policy and practice to expedite TCO parity. Small and medium fleets must be a key consideration in the interventions deployed to reduce upfront costs, recognizing the unique roadblocks these fleets face as small enterprises. New business models have emerged that provide robust solutions to many of these challenges, but governments can do more to facilitate these efforts. While there is no single one-size-fits-all solution, governments are in a unique position to leverage private-sector actors enabling market mechanisms to facilitate the transition to zero-emission technologies as smoothly as possible.

1. Reduce investment uncertainties through regulation, standardized data collection, and long-term planning to shape the market in the mid to long term.
2. Focus public funds in areas with high potential to mobilize private investment, such as mitigating credit and residual value risks, and facilitate aggregated procurement.
3. Where economically feasible, implement a direct cash-purchase subsidy program alongside supply-side regulations for ZE-MHDVs that reduces the point-of-sale price of the vehicle, ensuring it is compatible with leasing and as-a-service business models that split ownership and use. Stand-alone subsidies are not sufficient.
4. Introduce tax-based mechanisms that exempt ZE-MHDVs from certain taxes or levy additional taxes or fees on polluting vehicles; revenues can be used to further finance zero-emission vehicles and supportive, clean infrastructure. Phase out fossil-fuel subsidies (for fully assembled vehicles and vehicle parts) that artificially keep prices of fossil fuels low at the expense of the environment and technology innovation—redirect funds to ZEVs.
5. For emerging economies, prioritize ZE-MHDVs in country strategy negotiations with multi-lateral development banks that have the capacity to leverage concessional funds and reduce costs of deployment through investment de-risking.

CONCLUSION

Today, transportation stands as the world's second largest contributor to global emissions, second only to the power sector. According to this year's 2024 UNEP Gap Report, which takes stock of each country's nationally determined contributions (NDCs), the world is not on track to limit warming to 1.5 degrees Celsius.[81] This crossroad marks a pivotal moment in which the world must choose progress or profits and pollution. With transportation relying on oil products for nearly 91 percent of its final energy consumption, a coordinated, global transformation must take place to decouple harmful externalities from transportation.[82]

The actions of decarbonizing the transport sector are grounded in a pollution-burdened reality that billions of individuals around the world face. Recognizing that demand for transportation, particularly freight, is expected to grow, there is a once-in-a-generation opportunity to double down on efforts to decarbonize this sector and deploy every tool available to reduce harmful emissions to both communities and the planet. It is not just a volume of preventable harms to avoid but an unprecedented opportunity to shape the future new generations deserve.

While it may be challenging, the path ahead must be done to achieve a clean and healthy future for all. Already, countries from across the world are making clear the need for the rapid decarbonization of MHDV transportation through regulations, deployment of infrastructure networks, and supporting fleets in their transitions. Recognizing that none of this can be achieved overnight, collaboration between governments and industry must prevail to co-create solutions that address the impact of this sector. In a way that has not been needed in the past, the energy sector and transportation sector must work in greater harmony to ensure growth in power production is in alignment with the growing energy demand of the transportation sector.

The priority actions outlined in this report provide a clear yet demanding path forward. Through the leadership of the 38 national governments united in their commitment to the Global MOU, and the more than 200 endorsers that have dedicated their actions to achieving Global MOU goals, the systemic decarbonization of the transport sector that is unfolding must grow in action and scale across all actors in the value chain—through innovation, collaboration, and persistence of will.

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WHITE PAPER

GLOBAL GREEN ROAD CORRIDORS:
ENABLING FACTORS FOR SUCCESSFUL LAUNCH, DEVELOPMENT, AND SCALE

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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF ACRONYMS

ACF	Advanced Clean Fleets regulation
ACT	Advanced Clean Trucks regulation
CPO	Charging point operator
DFIs	Development financial institutions
EMDE	Emerging markets and developing economies
ESG	Environmental, Social, and Governance
EVI	Electric Vehicles Initiative
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
ESG	Environmental, Social, and Governance
GGRC	Global Green Road Corridors Initiative
GHG	Greenhouse gas
ICCT	International Council on Clean Transportation
ITF	International Transport Forum
KF	Kühne Foundation
LCFS	Low Carbon Fuel Standard
MCS	Megawatt Charging Systems
NCTTA	Northern Corridor Transit and Transport Agreement
NCTTCA	Northern Corridor Transit and Transport Coordination Authority
NGO	Non-governmental organization
OEM	Original equipment manufacturer
PPA	Power purchase agreements
SFC	Smart Freight Centre
SME	Small and medium-sized enterprises
TCO	Total cost of ownership
UNEP	United Nations Environment Programme

LIST OF ACRONYMS

WBCSD	World Business Council for Sustainable Development
ZE-MHDV	Zero-emission medium- and heavy-duty vehicle
ZET	Zero-emission truck

FIGURES AND TABLES

FIGURES

TABLES

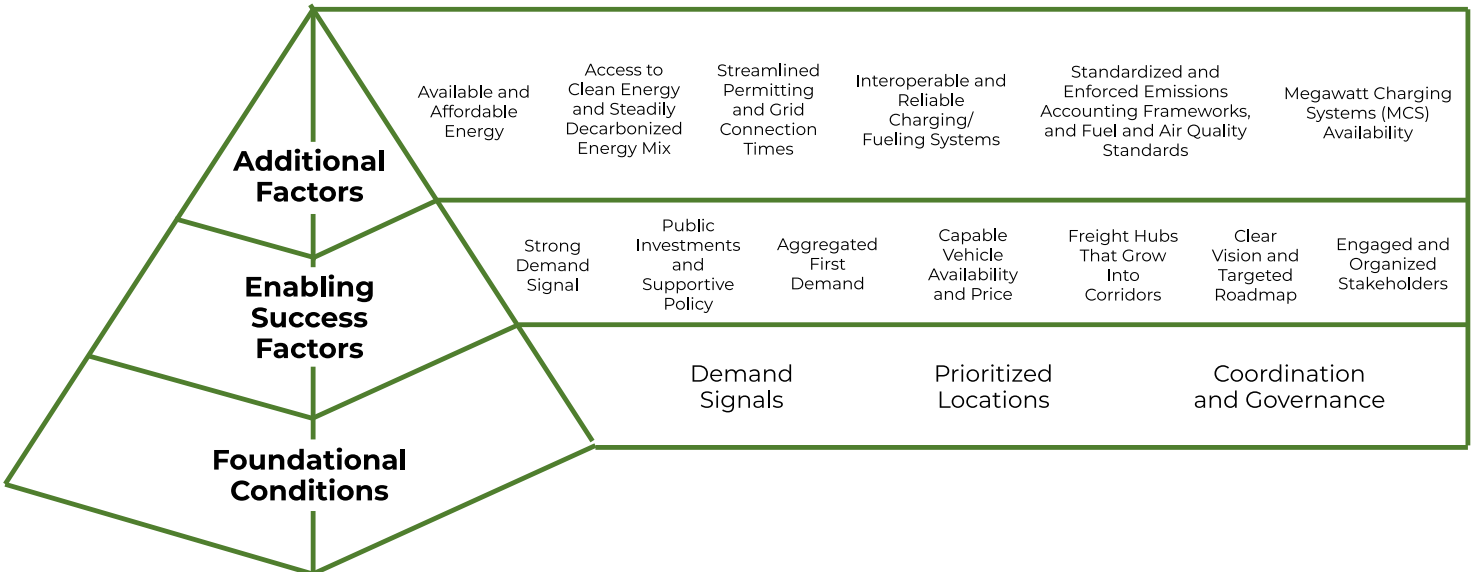
EXECUTIVE SUMMARY

Green road corridors utilizing zero-emission medium- and heavy-duty vehicles (ZE-MHDVs) play a crucial role in achieving net-zero emissions by 2050. The transportation sector, particularly MHDVs, remains a significant contributor to greenhouse gas (GHG) emissions and public health risks.

This report, based on insights from multiple stakeholder interviews, outlines the key parties who must be involved in the development of green road corridors and establishes the essential base conditions: demand signals, prioritized locations, and coordination and governance. These foundational conditions are critical for scaling up the implementation of ZE-MHDVs, especially in the long-haul and regional freight segments, which face cost and operational challenges at this stage of the market.

In addition to these base conditions, the report provides a comprehensive list of factors that contribute to their success, offering a roadmap for the practical implementation of green road corridors. These factors, which include regulatory requirements and support, funding, accessible infrastructure, and technology readiness, serve as key drivers for a successful transition to ZE transport (Figure ES-1). The report also highlights best practices and showcases real examples of corridors under development globally. These examples demonstrate ongoing efforts to support green corridors but underscore that their success depends on establishing a robust foundation of collaboration, policy, finance, technology, and stakeholder alignment.

Figure ES-1. Key Elements of a Successful Global Green Road Corridor Ecosystem



The findings of this report establish a model for action on green road corridors and call for a comprehensive, proactive, and collaborative approach to firmly establish these foundational conditions, setting the groundwork for a sustainable and widespread adoption of ZE-MHDVs and fostering a resilient and climate-aligned transportation sector.

SECTION 1

WHY GREEN ROAD CORRIDORS?

A transportation corridor refers to a strategically planned network of infrastructure designed to optimize the traffic flow between key sites, such as hubs, ports, industrial centers, or cities, along vital routes. Corridors are fundamental to economies, providing the essential infrastructure that enables trade and supports the movement of goods, services, and people. By integrating supply chains and creating financial and logistical links between regions, corridors stimulate economic growth, promote regional development, and deliver a range of benefits to the communities they connect.

While corridors can incorporate various and more efficient modes of transport, road corridors have the flexibility and ability to provide both inter-hub connections and last-mile transportation where other modes are not feasible. Road corridors act as critical connectors that make the entire transportation system function efficiently, ensuring goods and people can flow effectively across industries and regions.

However, road corridors also present siginficant challenges, particularly as transport remains the only major sector where emissions continue to rise [1]. Within this sector, the fastest growth in emissions comes from medium- and heavy-duty commercial vehicles (MHDVs), representing a disproportionate impact on climate and public health [1]. For example, regional and long-haul segments, which utilize the largest trucks driving longer distances, make up less than 15 percent of the U.S. fleet but are responsible for approximately 60 percent of greenhouse gas (GHG) emissions, urban nitrogen oxides, and particulate matter due to their higher mileage and more intensive use [2]. As the demand for freight transport continues to grow globally, these numbers are expected to increase.

To reverse this trend and improve air quality in communities heavily burdened by diesel pollution, a rapid transition to zero-emission (ZE) MHDVs is crucial. While the first big growth of ZE-MHDVs is taking place in return-to-base applications, such as urban transit and local goods movement giving rise to hubs, technology is now able to serve the regional and long-haul segments and turn the world's road corridors green.

Green road corridors build upon the existing framework of traditional road corridors but place a specific emphasis on sustainability and resilience. By prioritizing the reduction of environmental and health impacts—specifically through the use of ZE-MHDVs—while maintaining operational efficiency, green road corridors will transform how transport infrastructure is approached. Environmentally, they cut air pollutants and GHG emissions, contributing to better public health and helping meet global climate targets. Economically, they reduce fuel costs and stimulate future-proof job creation in ZE transport,

infrastructure, and renewable energy sectors. Moreover, developing green road corridors to establish public and semi-public infrastructure promotes a just transition by ensuring that small and medium enterprises (SMEs) without their own facilities have access to charging and refueling facilities.

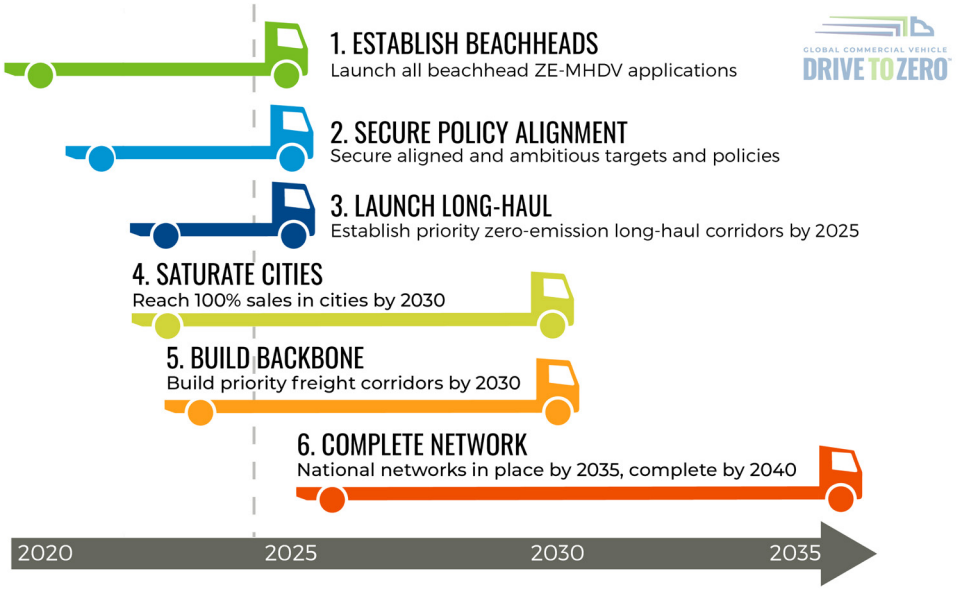
SECTION 2

WHY ACT NOW?

To avoid the worst impacts of climate change, the world must achieve a net-zero economy by 2050. For trucks and buses, this means 30 percent of new sales must be ZE by 2030 and 100 percent by 2040, as is being carried forward by 38 nations through the Global Memorandum of Understanding (Global MOU) on ZE-MHDVs [3]. To achieve these targets, efforts to organize and develop green road corridors must advance.

It is imperative to begin the buildout of these first corridors by 2025 to stay on track to 2040 outcomes (Figure 1) [4]. Acting now provides valuable lead time to address the unique requirements of ZE regional and long-haul vehicles, including capital costs, operational demands on longer routes, and high-power infrastructure. Building the first key corridors proactively positions the world to stay on pace to reach climate neutrality and sends a powerful message of certainty to the entire market.

Figure 1. 6-Stage Strategy to Enable 100% ZE-MHDVs by 2040 (and 30% by 2030)



Note: Original first published in Drive to Zero's "Global Roadmap for Reaching 100% ZE-MHDVs by 2040" [4]. Modifications made to show present day (dashed line).

GLOBAL GREEN ROAD CORRIDORS INITIATIVE

CALSTART's Global Commercial Vehicle Drive to Zero program, alongside partners and allies in the ZEVWISE coalition, have launched an ambitious effort to advance a diverse set of the world's road corridors to transition to a ZE-MHDV ecosystem (Figure 2). These autonomous Global Green Road Corridors (GGRC), each led and/or supported by an array of partners worldwide, will establish the basis for replicable, adaptable models that will serve as a real-time resource and framework for growth and success. The initiative intends to catalyze the development of additional corridors worldwide to support the widespread adoption of ZE-MHDVs. Beyond the scope of the initiative, Drive to Zero has identified nearly 30 green road corridors in development worldwide, showing the momentum, scale, and benefit of this effort.

Figure 2. Set of Corridors Supported by Global Green Road Corridors Initiative

1	**FIFA 2026 Corridor:** Canada – USA – Mexico *(U.S.)*
2	**USA-Mexico Border Corridors:** California – Baja California, Texas – Nuevo Leon, Arizona – Sonora *(WBSCD)*
3	**Southern Africa Container Corridor:** Port of Durban, including South Africa, Lesotho, Eswatini, Zimbabwe, Botswana, and Zambia *(UNEP (ZEVWISE Focal Point))*
4	**India Corridor:** Mumbai – Delhi and Delhi – Jaipur *(WBSCD)*
5	**India Corridor II:** NH48: Delhi – Mumbai – Chennai *(ICCT)*
6	**European Corridor to Zero:** Netherlands, Germany, Poland, and Ukraine *(AVERE Ukraine / EVConsult)*
7	**Trans-Caspian International Transport Route (TITR) Corridor:** China, through Kazakhstan, Azerbaijan, Georgia, and Turkey to Europe *(UNEP (ZEVWISE Focal Point))*
8	**USA I-95 Corridor:** Georgia – New Jersey *(CALSTART)*
9	**Northern Corridor:** Kenya, Uganda, South Sudan, Rwanda, Burundi, and DRC *(NCTTCA)*
10	**I-10 Corridor:** California – Los Angeles, Palm Springs, Blythe, Arizona – Tuscon, New Mexico – Lordsburg, Vado *(Smart Freight Centre)*
11	**Poland Corridor:** Poznan, Warsaw, Wroclaw, Krakow *(Smart Freight Centre)*

The GGRC coordinated effort includes the collaboration of 11 leading organizations, including governments, nonprofits, financing institutions, and international development organizations. These partners bring a diverse array of expertise and experience to support the development of ZE-MHDVs and infrastructure: Drive to Zero, Electric Vehicles Initiative (EVI), International Council on Clean Transportation (ICCT), International Transport Forum (ITF), the Government of the Netherlands, Smart Freight Centre (SFC), United Nations Environment Programme (UNEP), United Kingdom, United States, The World Bank, and The World Business Council for Sustainable Development (WBCSD).

SECTION 3

WHO NEEDS TO BE INVOLVED?

Corridors are complex, dynamic transportation systems that require involvement and coordination of multiple stakeholders to be successful, including government, independent authorities, industry, nonprofit organizations, and communities.

Due to this complexity, developing global green road corridors requires collaboration and governance that balances top-down approaches (i.e., decisions made and managed centrally, either from a national government or a corridor authority) with bottom-up approaches (i.e., initiatives from local governments and other actors), along with a clear vision. Stakeholders involved in the development and operation of corridors can be categorized into two main groups.

STAKEHOLDER ROLES AND INTERCONNECTIONS

Implementing stakeholders are directly engaged in the construction, deployment, use, management, and maintenance of the corridor network and associated publicly available infrastructure. They include charge/refuel point operators (CPOs, also known as infrastructure service providers), shippers/freight owners, transport companies, and site developers. These entities can be partners, especially in the early stages, but at minimum are bound together by providing demand for and utilization of corridor facilities. They ensure that the logistical and physical components of the corridors function effectively and their business case depends on this success.

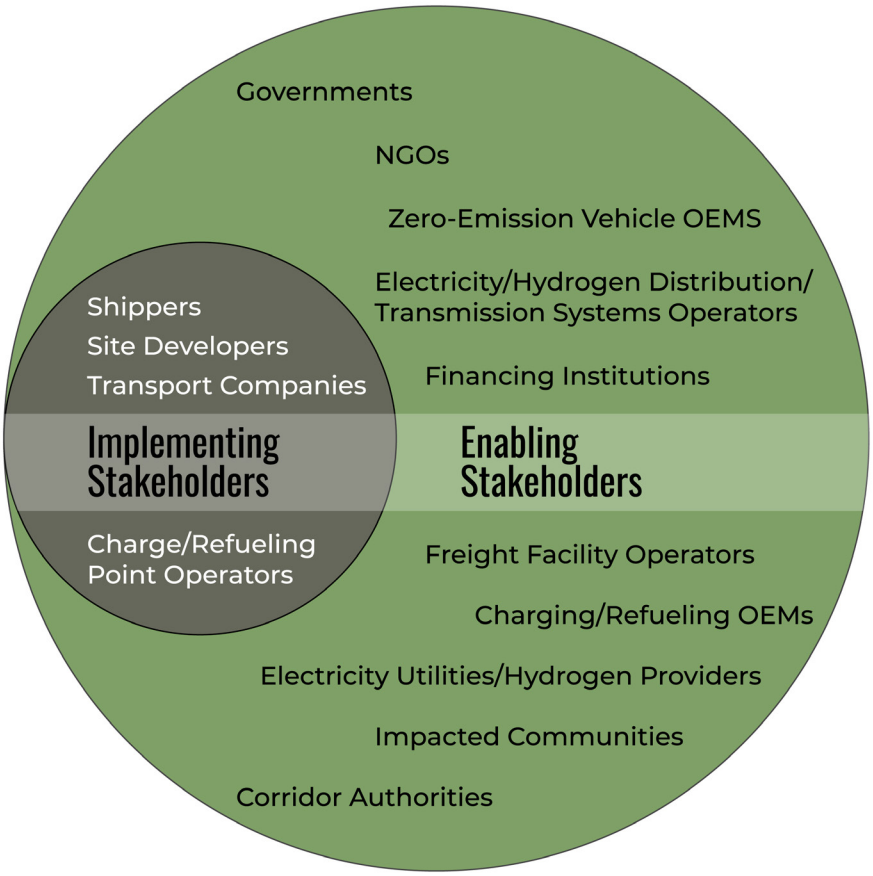
Enabling stakeholders focus on creating the conditions necessary for the successful development and operation of corridors. They can support a corridor system by providing the regulations that can drive demand, supplying funding for assets that will operate in the corridor, coordinating efforts among different organizations, supplying the necessary equipment, and providing access to fuels, electricity, or hydrogen.

Governments are perhaps the most important enabling stakeholder with significant abilities to set conditions for success. Local governments also control critical functions such as permitting and zoning, which can hinder or help site deployment. Financing institutions also play a key role. Other enabling stakeholders include electricity and hydrogen providers (e.g., utility distribution and transmission companies), original equipment manufacturers (OEMs) for vehicles and charging/fueling equipment,

freight facility operators (e.g., ports, multi-modal freight locations, distribution centers), corridor authorities, and/or NGOs that can provide demand aggregation, stakeholder coordination, and best practices and knowledge sharing. Impacted communities also form an important stakeholder set for emphasizing location, need, and urgency of timing.

Figure 3 illustrates the interconnected nature of the corridor stakeholder ecosystem, and the following sections describe each of these stakeholders, their primary roles, and how they interconnect in detail.

Figure 3. Stakeholders Involved in Road Corridors Development



IMPLEMENTING STAKEHOLDERS

Shippers and Cargo Owners

Shippers and cargo owners represent an important and core stakeholder set that can drive the success of early corridors. Their demand for ZE shipping modes is driven by a combination of voluntary commitments to carbon reduction, ESG (Environmental, Social, and Governance) goals, and compliance with regulations.

Transport Companies

Transport companies are the cargo carriers for the corridor, ranging from multi-national logistics providers to regional, local, and small fleet operators. Their primary customers are the shippers and cargo owners. While many transport companies are making investments in ZE-MHDVs either in response to regulations or proactively, they move fastest when motivated by their shipper customers. Their business is highly dependent on vehicle and fuel prices and availability.

Charge/Refueling Point Operators (CPOs)

CPOs provide the ZE fueling services—electricity or hydrogen—at strategically placed locations in regional hubs and along corridors. To succeed, they must integrate their sites with the freight movement needs of the corridors and address the specific needs of the early adopters, who are critical during the initial years of the transition. Their business is highly dependent on utilization of their infrastructure—customers must regularly and consistently use their sites at minimum threshold levels to justify the investment.

Site Developers

Site developers can take on the role of building and sometimes operating a charging/refueling site, either as a stand-alone facility or integrated within freight facility locations. Site developers would need to bring a deep understanding of freight flows and customer demand on their own or serve at the behest of specific customers.

ENABLING STAKEHOLDERS

Governments

Governments at all levels (i.e., national, sub-national, and local) are critical enabling stakeholders.

National and sub-national:

- First and foremost, governments can set regulations with requirements for vehicle emissions that can drive the need and demand for ZE-MHDVs. They can also set requirements for infrastructure installation and standards.
- Equally important, governments can be co- and seed funders for the transition in the form of purchase incentives for vehicles, project co-funding for infrastructure, policies to support the use of ZE-MHDVs, and encouragement to use carbon-free fuels and install infrastructure.
- Governments can prioritize corridor locations and coordinate stakeholders around corridor projects.
- Government agencies often oversee electric utilities and energy providers and can set requirements for investment, service, price, and connection timing. This is sometimes done at the local level.

Local:

Local governments generally have the primary oversite of permitting and zoning, which can slow deployment of infrastructure if local laws are not streamlined and modernized.

Corridor Authorities

Corridor authorities are especially essential in the development of multi-country corridors. They coordinate efforts among national governments, as well as with private entities and local communities. Additionally, they can homogenize regulations and standards, including those for emissions, technology, and safety.

Electricity/Hydrogen Distribution/Transmission Systems and Utilities

While generally not considered implementing stakeholders, there are cases where utilities, distribution, or even transmission operators may play that role. However, they are usually the critical providers of access to the fuel and "interconnection" to the electrical grid. It is imperative that these stakeholders are brought in early to charging infrastructure projects, since they, along with utilities, are responsible for providing connections to the grid and any necessary additional capacity, which often involves lengthy processes. Potential time delays from these processes and localized capacity gaps are critical issues for infrastructure site developers.

Financial Institutions

As with all large system changes, the transition at scale to ZE-MHDVs will require significant investment. Some initial funding from the public sector will help the launch, but private capital will be the real driver of large deployments for the longer term. Financial institutions, including banks, development institutions, and an array of private investors are poised for this transition and already have experience in renewable energy. But they are highly sensitive to risks, project bankability, asset owner/operator profiles, and return on investment, requiring tangible evidence of deployment volumes and infrastructure site utilization underway before committing to large-scale investments. First corridors offer the chance to organize demand, build shared understanding on bankability through market analysis and project financial modeling, and test revenue or risk mitigation models that investors need to see.

Non-Governmental Organizations (NGOs)

NGOs can play a variety of highly valuable roles, particularly in the early market stages of ZE-MHDVs and the first corridors that support them. NGOs can serve as third-party trusted conveners and coordinators of stakeholders around first corridors. They can help identify and solve initial partner challenges as well as recruit and aggregate additional demand for identified corridors to reach minimum thresholds for success. They can also help to capture, share, and elevate best practices and success factors for use in other regions.

Freight Facility Operators

Freight movement is defined by a variety of key facilities where freight assembles, ships, and is transported on. These include air and sea ports, rail yards, multi-modal freight facilities, transshipment, and distribution centers. Each of these sites can play host to thousands of cargo visits per day, and as such, are prime locations for locating and operating regional hub and corridor infrastructure. These operators must be encouraged to add infrastructure capabilities at or near their sites to support the growing customer set that will make the transition to ZE.

ZE Vehicle and Equipment OEMs

Vehicle OEMs are vital stakeholders as they provide the core capability to perform the corridor role with their vehicles, significantly influencing the business case of the transport companies and the cargo carriers using their trucks. While vehicle range has reached a stage to perform corridor operations, it does

not yet support the high-speed charging desired, and vehicle pricing remains one of the key barriers to the success of these corridors. Incentives and supportive policies are the current strategies to mitigate this cost while the vehicles' cost drops due to economies of scale. Charging equipment OEMs are vital for providing reliable charging/fueling equipment that can work with all truck types at low to zero failure rates. They also need to provide the next generation of high-power Megawatt Charging Systems (MCS) needed for effective corridor operations.

Impacted Communities

While most regulations focus on the carbon-reducing benefits of ZE-MHDVs, these vehicles also provide substantial and immediate elimination of combustion emissions that are harmful to human health. These criteria emissions from diesel trucks are of prime impact to communities closest to freight routes and facilities—often the least advantaged communities in urban and other regions. Engaged communities can identify and help solve primary concerns, provide insights into optimal locations for charging and fueling facilities, and support local job markets. With their insight, corridor development can include the appropriate type of training initiatives and skill building required for maintaining and installing new equipment, benefitting communities historically marginalized.

SECTION 4

FOUNDATIONAL CONDITIONS FOR GREEN CORRIDORS AND STAKEHOLDER INVOLVEMENT

The core stakeholders listed above, and their interactions, form the framework of a successful green road corridor. Yet just as a corridor is much more than a line on a map, developing one requires more than simply assembling key entities. In evaluating the initial global corridors emerging worldwide, some foundational base conditions and steps are becoming clear. Demand signals, prioritized locations, and coordination and governance all outline the initial needs to spur green corridors and define the first stages of a green corridor's launch.

DEMAND SIGNALS

Demand is the overriding prime condition. For a green corridor to be developed, there must be conditions, requirements, or other factors that create near-term demand for ZE transport. There must be a willingness to procure, charge/refuel, and operate ZE-MHDVs for a customer. While ZE-MHDV technology is now in production and available worldwide, it is still in relatively low volumes and more expensive than its diesel counterpart in most parts of the world. Even with much lower operating costs—including considerably lower fuel and maintenance costs—the business case for ZE-MHDVs is still emerging in most regions.

"We need confidence to keep investing. We need strong signals and data that our corridors and site locations make sense for fleet customers. At this early stage in the market, we also need incentives and regulations that help ease the path to EV adoption."

– Emilia Sibley, Head of Solutions, Terawatt

This means that market forces alone will not drive ZE-MHDV adoption fast enough to meet climate reductions needed nor drive most corridors. Regulation still drives this early market. While it is true that many large shippers have strong carbon reduction and ESG goals that cause them to explore electrification, these drivers alone do not create sufficient ZE-MHDV demand today to support a corridor. Therefore, there is a need for strong policy and regulatory signals of the requirement for transitioning to ZE transportation, combined with supportive policy and public investments and incentives to assist the early market.

Importantly, this demand signal is most powerful when it can combine several critical elements:

- Strong regulatory requirements, such as supply-side requirements for sales of ZE-MHDVs and/or stringent carbon and air pollution emissions regulations.
- Effective supporting public investments, such as infrastructure grant funding, vehicle purchase incentives, and loan guarantees.
- Effective supporting policies, such as utility grid interconnection requirements and truck weight wavers to accommodate batteries or fuel tanks.
- Strong shipper and industry carbon-reduction commitments and ESG goals.

PRIORITIZED LOCATIONS

To succeed, green road corridors must first be located where there is sufficient high-volume freight flow, early demand for ZE-MDHVs, supportive policy and funding, availability of power/fuels, and willing early adopters. In other words, the focus should be on connecting hubs or corridors that are transitioning to or showing interest in adopting ZE-MDHVs and/or where there is a robust set of enabling factors supporting this development (see the following section). Having power providers who are engaged and electricity rate structures that are competitive (e.g., volume vs. peak-load based) is highly valuable. So too are locations, such as communities surrounding major freight hubs, that would see air quality benefits from ZE-MHDVs. While many locations can provide one or two, corridors need a strong combination of these elements to justify launch.

"We believe electrification is not if but when, but [we] need the right industry data to identify which corridors are the best places to start. Our partners have provided access to data on routes and freight lanes to make thoughtful decisions."
– Patrick Macdonald-King, CEO, Greenlane

Therefore, in addition to creating a strong demand signal, it is imperative that either in parallel or as a second stage of action the key freight routes that can support ZE-MHDVs be identified and prioritized by these elements and other key factors. Such prioritization creates a staged or phased roadmap for growth and provides clear guidance to investors and stakeholders on where to begin. Coupled with this approach, a commitment to focus government funding on these priority locations will further reduce risk to stakeholders and can speed implementation.

COORDINATION AND GOVERNANCE

These two conditions ideally work together for the success of implementing a green road corridor. Most stakeholders agree that coordination is a critical element. The needs and integration of the core implementing and enabling stakeholders must be brought together and aligned with the timing and requirements of the corridor. A valuable role to play includes shining a spotlight on a priority corridor

location, convening the key stakeholders who should be involved, and encouraging cooperation and joint action. Governments and corridor authorities are well suited to play this role as are NGOs, but industry stakeholders can also step in, including shippers or partnerships of infrastructure providers, investors, and other stakeholders.

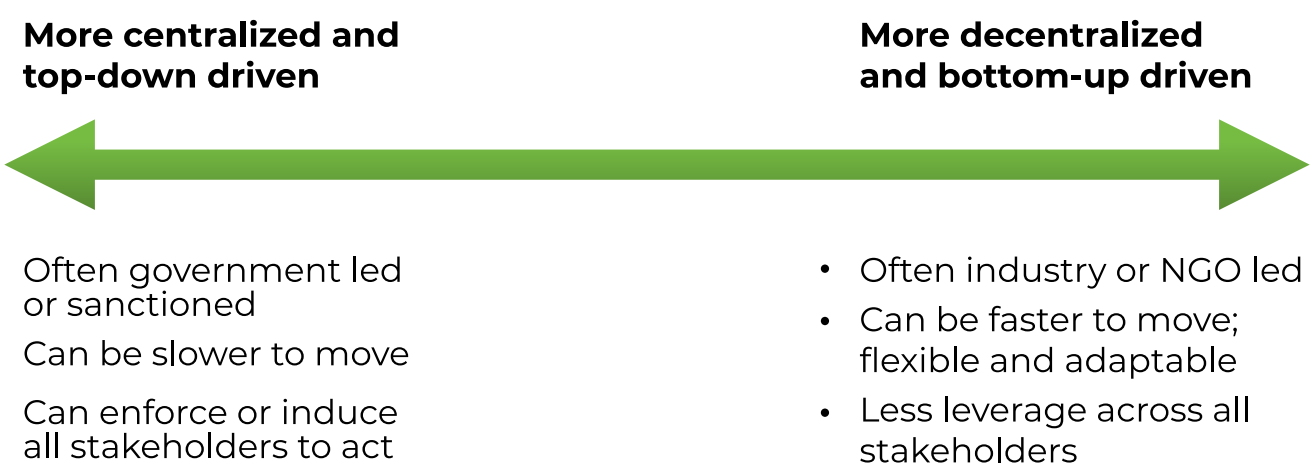
Effective coordination cannot exist without governance, and governance must go beyond merely coordination. In this case, governance means a set of rules, responsibilities, and objectives agreed to by a core set of stakeholders for how they will work together to fund, operate, and use a green road corridor. In essence, this governance defines the basic "rules of the road" for launching the corridor. Several early corridor efforts report that developing an effective way to coordinate stakeholders through some form of governance was a key to progress.

"By extending a hand and working together as partners, we can cultivate ideas and solutions to advance clean and sustainable freight. It is important that we are on this mission together - industry, government, labor, environmental groups, and communities."

– Alycia Gilde, Senior Transportation Advisor, White House Office of Climate Policy

Governance approaches and structures can take many forms and be driven by different stakeholders. Generally, they fall along a spectrum of structure, from centralized top-down designs on one end of the spectrum to decentralized, bottom-up structures managed by self-organized stakeholders on the other (Figure 4). As described earlier, a top-down form could be driven by a government or governments and/or corridor authorities setting the rules and even designating an oversight or guidance entity to manage corridor stakeholders and sites. At the other end of the spectrum, a group of stakeholders, such as shippers, can identify a corridor of mutual benefit and priority and agree to work with a minimum set of other stakeholders to implement this route. Most corridors will likely fall somewhere between these points.

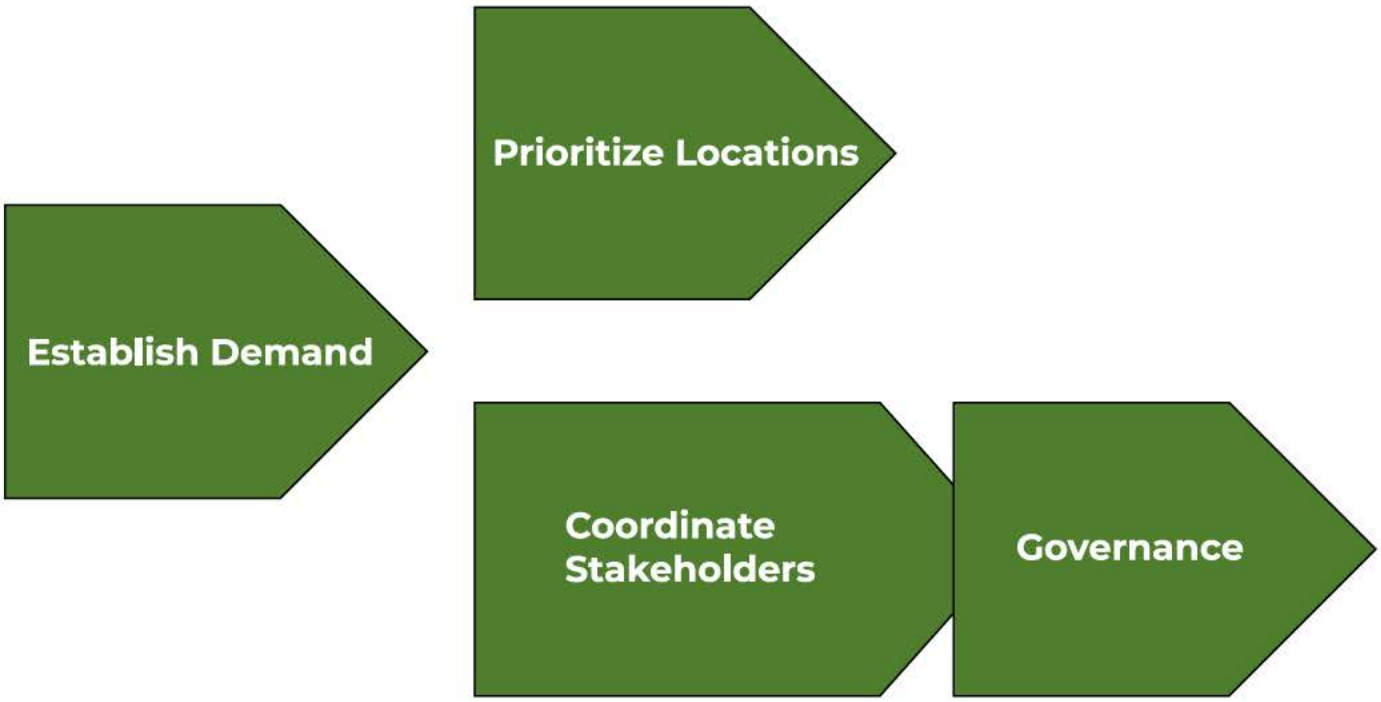
Figure 4. Corridor Governance Spectrum



These foundational conditions do not have a strict, linear relationship. They will likely proceed almost concurrently, but looking at how these conditions roughly sequence in time highlights the need for

establishing strong demand signals as the primary step (Figure 5). Identifying and prioritizing corridor locations is valuable but has less impact without established demand. Similarly, while coordination and governance working in advance of demand can help identify issues, there is little urgency to address them without demand.

Figure 5. Corridor Foundational Conditions



SECTION 5

ENABLING SUCCESS FACTORS

The foundational conditions described above frame the necessary starting point for green road corridors but are insufficient alone. The more complete framework for developing green road corridors requires understanding the core factors that drive their establishment and effectiveness, and which build from the foundational conditions (Figure 6). Governments and corridor governance leaders have a significant role to play. By engaging and coordinating stakeholders on all of these factors early on, leaders can speed up action and increase the likelihood of launch and longer-term success. Importantly, these factors form an interconnected ecosystem of support, all of which should be implemented in tandem with one another.

Figure 6. Key Enabling Success Factors for Developing Green Road Corridors

Building ZE corridors is a work in progress and actively taking place in real time around the world. Therefore, the following preliminary success factors are the beginning of an active learning process. They distill the current and best learnings from leading site developers, CPOs, shipper and transport companies, and governments interviewed by Drive to Zero (see the appendix for full list of interviewees) actively engaged in several corridors, together with the experience and knowledge of CALSTART and partners.

STRONG DEMAND SIGNAL

Driving and supporting vehicle and infrastructure demand is both the main foundational condition and the primary enabling success factor to establish green road corridors on the timeline needed. The reason is clear: While poised for breakout, the market for ZE-MHDVs is still early and emerging. There has been remarkable progress in deploying ZE-MHDVs, and they are showing advantageous total cost of ownership (TCO) in several truck applications today. However, relying only on market forces alone is insufficient to meet climate timelines.

To compensate for the early-stage market conditions, early demand can and must be driven by several elements. Based on extensive stakeholder discussions, the most effective form comes from strong and clear government regulations that require an increasing number of ZE-MHDVs to be bought and sold each year. Examples of these requirements include supply-side regulations (SSR) such as Advanced Clean Trucks (ACT) [5] in California and other U.S. states and the heavy-duty CO_2 emission standards in Europe [6]. Demand-side regulations, such as California's Advanced Clean Fleets (ACF) [7], which requires fleet purchase of ZE-MHDVs, can complement SSR.

Setting a clear goal and vision, such as nations do in signing on to the Global MOU, is a good step that should be strengthened by making these goals mandatory requirements. These regulations establish a clear transition timeline, encourage production at scale and associated price reductions, and bring certainty to companies—and investors—to plan for the future.

PUBLIC INVESTMENTS AND SUPPORTIVE POLICY

Coupled with a strong signal based on requirements, demand must also be backed by strong initial funding and supportive policy. While private capital is anticipated to provide the backbone for the long-term buildout of green road corridor infrastructure, initial public co-funding of infrastructure deployments, for purchasing ZE-MHDVs and even underwriting the charging business case, is a critical enabling condition. This can take the form of grants, incentives, loan funding utilization guarantees, or other innovative

"In this stage of the market, public funding is the single most important factor to securing private investment. Public funding helps to offset early utilization risk while driving the confidence required for private sector investment by building out the necessary infrastructure today to catalyze future fleet electrification."

– Zeina El-Aziz, Co-Founder and CEO, Gage Zero

financial mechanisms that reduce the risk of investing in and using ZE-MHDVs and infrastructure. Development financial institutions (DFIs) play a critical role in enabling this supportive environment in emerging markets and developing economies (EMDEs) that lack access to public funding. The public has an immense stake in ensuring corridor success to reap the economic and health benefits from these vehicles.

In addition to a commitment to co-fund, there are other supportive policies that play an important role in corridor success. Generally, these policies fall into three categories:

- Requiring the energy sector—and the electric power industry—to invest in and support rapid infrastructure deployments.
- Providing greater flexibility in vehicle operations to encourage ZE-MHDV use.
- Streamlining and aligning local regulations to speed permitting and siting of infrastructure.

Energy Sector Integration

The energy and electric power industries are not adequately aligned with the transportation sector on such basics as the timing for electrified vehicles and the urgency for infrastructure planning, capacity development, and fast interconnection to the grid. Oversight of the electric power industry is often performed at the sub-national level and by agencies or regulators not directly connected with transportation or transportation emissions regulations. There are a variety of examples of utilities and energy agencies actions that are useful. Several sub-national governments were lauded for their leadership (see the Emerging Best Practices section for additional detail).

Greater Vehicle Flexibility

This can take many forms but most generally involves rules governing vehicle use and operation. Among those is allowing weight waivers for ZE-MHDVs because of the greater weight from batteries or hydrogen storage tanks. Many governments allow up to 2,000 pounds/900 kilograms of excess weight, but it does not apply to all highways; interviewees from the industry believe that a higher weight allowance is needed. Another example is involving driver hours of service limitations and allowing more flexibility on measuring these to accommodate vehicle charging time at stops.

Streamlined Local Regulations

For infrastructure service providers, this issue was one of the most common causes of delays separate from utility capacity and interconnection delays. Local governments generally oversee and manage zoning of land use and permitting of business sites. However, most local governments have not updated their zoning and permitting rules to accommodate large charging sites for vehicles and often do not know how to categorize them. Stakeholders call for better alignment across all levels of government to support the deployment speed and scale needed. In response, national infrastructure strategies have included educational initiatives to help local governments understand the unique complexities of charging sites.

CLEAR VISION AND TARGETED ROADMAP

Alongside regulatory certainty and financing, identifying and prioritizing the locations where corridors can succeed first is vital. It is one of the foundational conditions for corridors and a success factor. Infrastructure site operators, investors, and fleets cannot afford to launch their efforts everywhere all at once. They all require targeted locations chosen for success metrics. These success metrics can include:

- Routes with the highest-volume freight traffic
- Regions with supportive policy and financing mechanisms
- Available energy, supportive utilities, and conducive energy rates
- Proximity to high-volume freight hubs, such as ports, railyards, warehousing centers, and multi-modal shipping sites
- Locations where emissions reduction of local and non-local air pollutants would produce the greatest benefits to air quality and GHG reduction

Such prioritization can also help the energy industry by focusing capacity optimization, expansion, and interconnection resources in key areas to start.

Several stakeholders can realistically establish a prioritized vision, and many initial corridors have grown from motivated industry stakeholders in areas of strong demand signals identifying opportunistic first locations. However, this prioritization is ideally a role for national and sub-national governments to take, building off the inputs from industry and other stakeholders. Governments can look beyond regional boundaries and assess national freight and goods movement trends. They have the ability to engage all stakeholder sets and the power to focus their funding assets and incentives on the prioritized regions to drive alignment and co-investment.

By developing a national prioritized and phased infrastructure plan, a country can set the timing of each phase of infrastructure growth and align them with national carbon goals. At the subnational level, more detailed local strategies can then build off the national vision and provide a finer level of detail for investments (see the Emerging Best Practices section for additional detail).

ENGAGED AND ORGANIZED STAKEHOLDERS

Effective stakeholder coordination and governance are foundational conditions and essential success factors for developing green road corridors. Achieving a successful corridor requires early and ongoing collaboration and some level of organization. Trusted and well-resourced governments, independent authorities, and/or NGOs can serve this role.

As noted, governance can take many forms but generally falls on a continuum between top-down centralized approaches on one hand to bottom-up decentralized approaches on the other. Most governance structures will be somewhere between these points, and many will use approaches from both.

Top-down engagement from central authorities, like national governments or corridor management bodies, provides policies, resources, and guidance. Bottom-up involvement from industry (e.g., shippers and carriers), infrastructure services providers, and other stakeholders can move quickly. Including local governments and community groups, for instance, also ensures sensitivity to local contexts and support for development efforts.

AGGREGATED FIRST DEMAND

While regulations will provide broad demand certainty, aggregating initial specific demand from shippers and transport companies in targeted regions can greatly help accelerate early corridor deployment, mitigate risks, reduce costs, and unlock finance.

Shippers and the carriers they contract with are key stakeholders when aggregating demand. Many global shippers have strong carbon reduction and ESG goals while also directly influencing the vehicle purchasing decisions of multiple carriers. These carriers will generally—depending on conditions—adopt technology requested or required by their shipper customers. By identifying the shared freight routes of a handful of key shippers, it is possible to influence multiple carriers to adopt ZE-MHDVs and thereby aggregate initial vehicles into a threshold level of demand. Fleets in the same location can also coordinate timing on truck orders and infrastructure installation to promote asset sharing and help utilities coordinate.

This activity is critically important because CPOs require a minimum level of utilization (i.e., vehicles charging each day at their sites) to justify investment and make their business case work. Realistically, most early users will not represent sufficient utilization of first sites on their own for third-party site developers to attract capital—unless the demand from additional users can be combined. Several NGOs are providing such valuable coordinative services to bring fleets and developers in business parks or hubs together, and more of this creative coordination around shared asset-use is needed.

CAPABLE VEHICLE AVAILABILITY AND PRICE

ZE-MHDVs are currently available in nearly 1,000 models and most applications from the world's major manufacturers [8]. They are also rapidly increasing in volume each year. As of 2023, ZE trucks capable of pulling the heaviest loads have become available with ranges between charging or refueling (more than 240 miles or 400 kilometers) that make the operation of corridors practical [8]. This has enabled the first green corridors to develop and the first longer segments to operate.

"We are treating this as a rapid learning exercise. We plan to get started - iterate as we go - learn - then rebuild. What we are really investing in is next-generation thinking."

– Nico De Golia, Director of Cloud Logistics Sustainability, Microsoft

Three key factors currently limit even faster expansion: vehicle price, availability, and charging rate. During interviews for this

report, corridor implementing stakeholders consistently cited the need for greater availability of vehicles, noting that infrastructure was not always their limiting factor. They also said they wanted access to vehicles that could charge at megawatt levels to limit dwell times (i.e., the time a truck spends waiting while charging). Truck manufacturers have been testing MCS, but most do not expect to field such trucks before 2026 or 2027, likely to happen first in Europe. Finally, truck prices remain prohibitively high (i.e., up to almost three times the cost of a diesel truck [9]), even as volumes increase and battery prices drop.

To support the needs of freight hubs and early corridors, faster-charging, long-range vehicles are needed sooner than some manufacturers are currently planning. Their price must also be low enough to ensure affordability (especially for SMEs with limited access to financing), support a viable life-cycle business case, and provide a competitive choice versus a diesel vehicle. In the near term, strong regulations combined with public incentives can help bridge the gap as vehicle volumes rise and supply chains grow.

However, an additional forcing mechanism may be required. This could take the form of a partnership with manufacturers, or a competitive challenge to them, to offer reduced pricing in exchange for high-volume commitments. Manufacturers seeking to differentiate themselves could also offer more competitive "forward pricing" (i.e., pricing vehicles to match expected future costs) to stimulate early market growth. Such strategies are often used with other technologies and would provide significant support to corridor and hub growth.

FREIGHT HUBS THAT GROW INTO CORRIDORS

At their core, corridors are high-volume freight routes that connect important freight hubs, such as ports and major centers of distribution. Most stakeholders believe the first focus of any corridor must be to build out an effective regional charging capability at hubs and consequently grow the planned corridor from these success points.

This expansion from hubs to corridors is not strictly linear and will vary based on market maturity in different regions of the world. However, generally the first wave of market penetration for ZE-MHDVs will be in regional applications and then expand as capabilities grow. This sequencing concept is based on two proven models of change for the ZE-MHDV transition: the beachhead strategy [10], the foundational paradigm for Drive to Zero, and the infrastructure phasing-in [11] strategy, which was developed to inform national infrastructure prioritization efforts in the United States. Taken together, these models emphasize building out ZE-MHDVs from a base of steady market success.

Nonetheless, in many regions the growth of ZE freight hubs and the expansion to corridors can and is happening concurrently, and their strategies are cross supporting. As hub charging expands outward from a region to support full regional freight operations, it also forms the basis of the next charging points for the corridors that radiate out from these hubs. Thus, hub charging must be an integral part of planning corridors.

ADDITIONAL ENABLING FACTORS

Available and Affordable Energy

Most infrastructure service providers noted that in the early years demand was their first concern, and that they could work around issues such as limited distribution grid capacity via careful site selection, phasing in infrastructure over time, and implementing smart, managed charging strategies. However, going forward, the energy sector and electric power providers specifically need to plan for providing adequate and affordable power that meets the locations and load demands of ZE transportation.

Coupled with this, electric energy pricing structures must be adapted to meet the unique needs of the transportation segment. Most power providers are adept at—and designed for—servicing the stationary market (i.e., homes, buildings, and industries) but not for mobile customers represented by transportation. As ZE-MHDVs start at low volumes and grow, with relatively low initial utilization of charging or refueling sites, they can face high rates caused by factors such as "demand charges" that can far exceed the base energy cost. Regions expanding their ZE-MHDV utilization should ensure that the regulatory oversight of electric power providers includes deep integration and accommodation of vehicle electrification.

Access to Clean Energy and Steadily Decarbonized Energy Mix

While not a direct limiter of ZE-MHDV introductions and growth, it is vital that the electric power generation mix and hydrogen feedstock sourcing decarbonize on the same or greater pace as vehicles are growing in the market to achieve greater environmental benefits. Additionally, a renewable energy mix is generally and in principle more cost-effective than fossil-fuel alternatives, which positively impacts the operational costs of ZE-MHDVs.

Although the electric generation mix has been decarbonizing on a much faster pace than the transportation segment, particularly in regions where ZE-MHDVs are being introduced, there can be a premium associated with purchasing renewable electricity at wholesale markets [12]. More competitive pricing can be achieved through power purchase agreements (PPAs), which are typically long-term contracts between renewable electricity generators and off-takers, such as fleets or CPOs. These contracts secure stable electricity prices over the long term, but there can be a mismatch between the typical electricity volumes covered by PPAs and the actual needs of fleets. This often necessitates the pooling of multiple customers to achieve the scale generators require.

Alternatively, while implementing onsite renewable generation adds complexity, longer implementation times, and increased initial investment costs for charging infrastructure projects, renewable energy can deliver long-term economic benefits, even when combined with battery storage. Additionally, decentralized or off-grid systems can help reduce the required grid connection capacity and associated lead times, especially beneficial in areas with congested grids. These systems can create extra revenue streams by enabling participation in ancillary services, balancing markets, demand response programs, and capacity procurement markets.

Even in energy mixes dominated by fossil fuels, ZE-MHDVs can provide benefits because of their significantly higher efficiency in using energy [13]. But ideally, as ZE-MHDV volumes grow, they will be

powered by steadily decarbonized energy sources. As global nations commit to and implement the transition to ZE transportation, it is imperative they have strong goals, regulations, and inducements for decarbonizing their energy sectors as well.

Streamlined Permitting and Grid Connection Times

Carbon reduction strategies and regulations are usually set at the national or sub-national level. However, actually implementing these strategies on the ground is a localized action. Since building permits and land-use zoning that allow charging or refueling sites is usually determined at the local and municipal level, it is critical that all levels of government know and serve their role in supporting this transition.

Providing local governments with recommended practices and templates for accommodating charging and refueling sites can be a useful step to address this issue. Providing guidance to local agencies on the urgency of the transition, its benefits, and information on the critical nature of timing to hold back projects can assist.

Similarly, oversight bodies for electric power providers need to set clear guidance and rules governing grid connection times that prioritize transportation charging projects. Several jurisdictions have developed useful processes to manage this (see the Emerging Best Practices section for additional detail).

Interoperable and Reliable Charging/Fueling Systems

Even more so than for passenger cars, commercial vehicles require highly reliable charging and refueling sites. Commercial vehicles are performing work tasks, from carrying freight to providing services. Delays or an inability to charge or fuel means lost revenue and disappointed customers. While still in the early stages, infrastructure equipment is proving to be less reliable than required and does not always provide error-free connections to all vehicles.

Infrastructure service providers emphasize that standards for connectors, testing to ensure reliability, and even setting reliability metrics to receive government co-funding could all be useful to guarantee the level of service commercial vehicles need. In the interim, some site operators are using work-around strategies to address these issues, such as installing more equipment than needed to ensure a back-up capability is available. However, this adds costs to installations that do not help the business case.

Standardized and Enforced Emissions Accounting Frameworks, and Fuel and Air Quality Standards

To build a successful business case, it is important to develop and make use of as many revenue streams as possible. This can include providing services for passenger car charging at a HD charging site to increase utilization of the asset, as both segments have complementary usage patterns—MDHVs typically operate more during the weekdays, while passenger cars are used more during the weekends.

Another intriguing source is via environmental and emissions reduction credits. Where operating ZE-MHDVs can be shown to provide net-emissions reductions beyond requirements, there can be an opportunity to generate and sell credits. Similarly, some existing regulatory programs such as California's Low Carbon Fuel Program (LCFS) support generating sellable credits for using low carbon fuels, including electricity.

To enable this capability, however, standardized and common accounting frameworks for such emissions must be in place and enforced to ensure real reductions are made, tracked, and not double counted.

Global protocols have been established that could serve as a standardized framework for emissions credits, but they would need to be adopted and enforced by the appropriate jurisdictions. Attention to both enabling and enforcing such structures would provide real additional value to grow the ZE-MHDV market.

Megawatt Charging Systems (MCS) Availability

As has been previously noted, having MCS-capable ZE-MHDVs is an important success factor for corridors. The corollary is equally true: MCS equipment must be available, reliable, and installed to support this capability. As of this writing, MCS charging equipment remains in the pilot phase. The capability is being proven in real-world use, but the equipment is not yet in serial production. Most observers have indicated the first production equipment will likely emerge in Europe by late 2025 and later in other regions of the world.

SECTION 6

INTERCONNECTING SUCCESS FACTORS: AN INTERACTIVE ECOSYSTEM

When considering both the foundational conditions and the enabling success factors, it is vital to realize that they represent interconnected elements of a complete system. Each factor influences and is influenced by the others, and if one is missing, it can reduce overall effectiveness. That said, these factors do not always move forward at the same pace; sometimes progress or setbacks in one area will ripple out to others, but the impact varies. While not all factors must be implemented absolutely, it is helpful to visualize what outcomes the factors help drive.

"At the site level, success is all based on utilization/ throughput. That is the key factor. If vehicles are not charging, the operator is losing money."

– Jason Gies, Vice President, Global OEMs and North American Fleet Solutions, ABB

Figure 7. Key Elements of a Successful Global Green Road Corridor Ecosystem

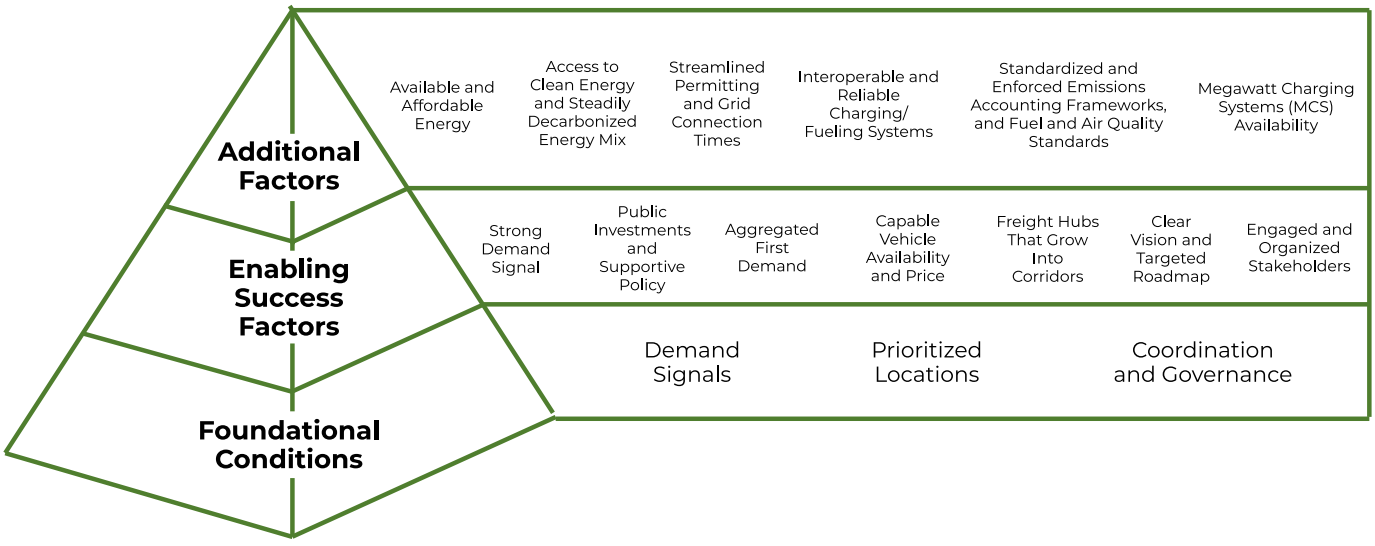
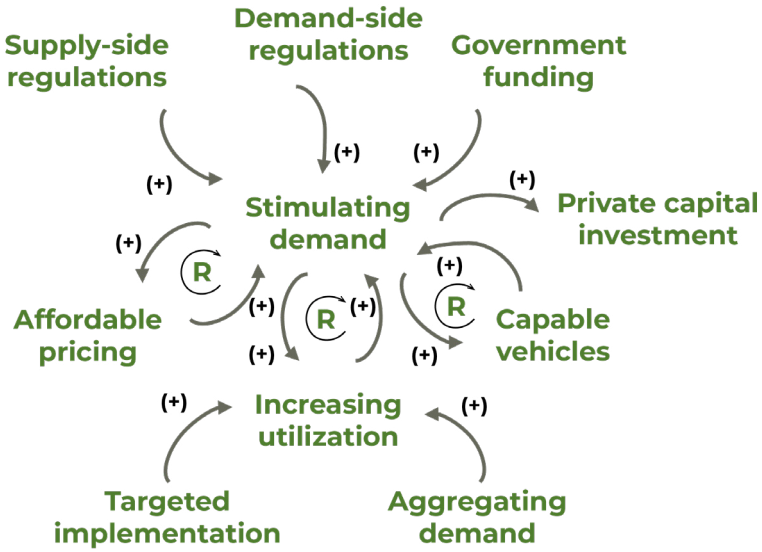


Figure 8 provides a simplified model that illustrates the interactions among the enabling factors and the intermediate actions they initiate. These actions create reinforcing loops that propel the system toward achieving larger outcomes. Ultimately, the key measure of success for the corridor at large and

the individual business cases within it (i.e., CPOs, carriers, shippers, fuel providers) is utilization—that the charging/refueling assets are being sufficiently used, carriers are moving goods within time and cost constraints, and shippers are using and demanding ZE service because it meets their economic and carbon commitment needs.

Figure 8. Causal Loop Map for Utilization



To reach utilization targets according to this general model, the starting point involves actions to **stimulate demand**. Given the early stage of market maturity, government **regulations** are the primary tools for this, but more is required: **Public investments and incentives** to match with **private capital** along with supportive policies must be integrated with requirements. Regions that have set in place strong regulations, investments, and economic support are showing the fastest progress on ZE-MHDV implementation.

Targeting where first corridor implementations take place is another critical factor shown in the model. It helps to focus often limited public and private resources on locations most likely to succeed first. Amplifying this signal are efforts to **aggregate demand** to drive the highest utilization of assets on a given route. Coordinating stakeholders within this corridor and providing governance (i.e., defined responsibilities, timing, and role for the first implementers) further speeds implementation and can guarantee minimum utilization levels.

In the near term, incentives can defray some of the higher costs of ZE-MHDVs, but vehicle makers need to **reduce prices** and consider forward pricing to support initial utilization. Similarly, speeding the availability of vehicles **capable of faster charge** rates can also support carrier and shipper adoption.

Implementing the additional success factors help support the key areas outlined in the model, speed near-term success, and create the conditions for long-term sustainability. Together, these factors help green road corridors play their vital role in enabling the complete transformation of freight movement and commercial vehicles to ZE.

SECTION 7

WHICH EMERGING BEST PRACTICES CONTRIBUTE TO FOUNDATIONAL CONDITIONS AND SUCCESS FACTORS?

Corridor stakeholders are not sitting still. Despite the early stage of the market and the range of acknowledged challenges, they are turning lessons learned into next-step actions. Most stakeholders realize they cannot wait: They need to create the structures that work as part of an iterative learning, refining, and improvement process.

That template is starting to take shape. While not yet complete nor final, key implementing stakeholders have identified the main lessons developed from addressing challenges in the field combined with their emerging knowledge of what enabling factors truly drive successful implementation. Based on interviews with key stakeholders, an emerging set of best practices and examples can be framed to guide global partners evaluating their own corridor implementation (Table 1).

Table 1. Emerging Best Practices and Examples for Enabling Success Factors

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
Strong Demand Signal	1. Implement strong regulation, both at the supply and demand side. • *Most stakeholders acknowledge that demand is not yet market driven and needs to be accelerated by government requirements. There are multiple examples of such regulations from around the globe at both the national and sub-national levels. Most are supply-side regulations (SSR), but there are also examples of demand-side regulations (DSR).*	1a. Tailpipe carbon emissions limits – the more stringent the standards, the faster electrification is driven: • European Commission CO_2-Standards for HDVs – 45% carbon reduction by 2030, 90% by 2040. Already driving ZET penetration. • U.S. EPA Heavy-Duty CO_2-Regulations – From 25% to 60% CO_2 reduction, depending on the segment, by 2030. Will likely drive small to moderate ZET penetration. 1b. ZE sales requirements: • California Advanced Clean Trucks (ACT) regulation – requires steadily increasing ZET sales percentages (varied by weight and use profile) starting in 2024. It is already driving ZET penetration. Ten other U.S. states have adopted. 1c. ZE purchase requirements: • California Advanced Clean Fleets (ACF) regulation – requires steadily increasing purchase of and fleet percentages of ZETs. Implementation delayed. If implemented, likely will drive strong ZET penetration by 2030. • Zero-emission zones – although typically applied in urban centers, they could be explored for implementations along corridors.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
	2. Work with industry partners who have made real carbon reduction commitments. • *Corporate, science-based carbon target commitments are useful and often powerful tools for action. They are insufficient alone, but when combined with regions implementing requirements and investments, they can drive action.* 3. Aggregate demand. • *Aggregating the demand of multiple parties does not itself create demand, but it is a strong tool for focusing and multiplying its force at specific locations. Combined with stringent regulations and industry commitments, it can justify faster investment and deployments in specific locations or applications*	3a. Interstate 10 (I-10) corridor in the United States is a shipper-driven corridor where they have aggregated demand among several global shippers to launch (see Examples of Foundational Conditions and Enabling Factors in Action section below). 3b. India's e-FAST platform to facilitate collaboration between government stakeholders and private-sector partners to shape strategies and actions that support freight electrification at scale. They have signaled aggregated demand for more than 5,000 electric trucks by 2027 and around 7,700 by 2030.
Public Investments and Supportive Policy	1. Vehicle and infrastructure purchase and installation incentives: • Direct incentives/rebates • Public project co-funding • Support "shared charging" models • Tax credits	1a. Polish National Fund for Environmental Protection and Water Management support programs for the electric heavy-duty vehicle sector, including EUR 1.4 billion subsidies for the purchase of vehicles, charging stations and electricity infrastructure for high-power public charging stations. 1b. "Colombia's Fund for the Promotion of Technological Advancement", which will offer soft loans and co-funding for the purchase of clean vehicles. The program will be funded through multiple income streams, including federal funding, and more interestingly an increased tax on vehicle purchases.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
		1c. California HVIP: incentives for clean trucks and buses; New York Truck VIP: voucher incentive program for trucks; California EnergIIZE: funding of ZE-MDHV charging and refueling deployment for fleets. 1d. U.S. Bipartisan Infrastructure Law (BIL) 1e. Infrastructure service providers in North America urge funders to allow early charging stations to be shared use or subscription services instead or being purely public until utilization rates rise. 1f. U.S. Inflation Reduction Act (IRA) 1g. AFIR's AFIF €1 billion subsidies including the support to megawatt recharging stations for HDVs. 1h. Dutch subsidy for public charging stations (SPULA) for the costs to install or expand charging infrastructure for heavy electric vehicles.
	2. Innovative finance	2a. Wider suite of financing programs/projects from Multilateral Development Banks, governments, and private sector in Latin America. 2/b. BancoEstado, Chile's public bank, offers concessional loans for the purchase of ZEVs, including lower interest rates, longer repayment periods, and grace periods. 2c. A partnership between Lombard and Natwest in the U.K. offers a Residual Value Lease for commercial ZETs. 2d. California Pollution Control Financing Authority provides financing support for small fleets to purchase ZE-MHDVs via a loan-loss reserve system to cover lender risks.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
	3. Vehicle rule flexibility to accommodate ZE-MHDVs	3. E.U.'s proposal to revise the Weights and Dimensions Directive to allow higher weight limits for battery and fuel cell electric HDVs.
	4. Aligning energy sector/utility engagement: • Require utility investments in infrastructure capacity and installation support • Allow utilities and grid operators improved access to financing to invest in advance of demand • Set enforceable timelines for energization	4a. Utility and grid operators "Make-ready" investments such as those in New York and California, such as Southern California Edison's Charge Ready Transport Program. 4b. New York Public Service Commission pending Case 23-E-0070 would allow "no-regrets" investment in ZE-MHDV infrastructure in high priority locations. 4c. E.U.'s Action Plan for grids to promote among other, long-term planning and access to finance for grids. 4d. California Senate Bill (SB) 410 requires the California Public Utilities Commission to establish average and maximum energization times for EV infrastructure. 4e. California Public Utilities Commission Rulemaking 24-01-018 sets goals and maximum timelines for utilities to connect to and energize EV charging sites.
Clear Vision and Targeted Roadmap	1. Develop an infrastructure vision.	1. California Executive Order (EO) N-8-23 establishes an Infrastructure Strike Team to identify priority projects, coordinate government support, streamline approvals, and focus funding.
	2. Focus on prioritization/ roadmapping.	2a. E.U. Alternative Fuel Infrastructure Regulation (AFIR) – requires specific infrastructure installations for ZE-MHDVs along major E.U. freight routes by 2030.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
		2b. U.S. National ZE Freight Corridor Strategy – establishes a four-phase priority implementation framework and timeline for freight infrastructure at hubs and corridors. 2c. Colorado State Infrastructure Phasing Plan to inform the development of the state's forthcoming charging incentive program for MHDVs. 2d. German tendering process for the construction of a fast-charging network for trucks along federal motorways.
Engaged and Organized Stakeholders	1. Stakeholder ecosystem coordination: • Promote collaborative partnerships that align and leverage different stakeholders' interests and expertise. • Establish clear governance structures that outline responsibilities and decision-making processes, balancing top-down and bottom-up approaches.	1a. U.S. Interstate 10 partnership of shippers, carriers, and infrastructure provider (see Examples of Foundational Conditions and Enabling Factors in Action section below). 1b. The Northern Corridor Transport Network, led by the Northern Corridor Transit and Transport Coordination Authority (NCTTCA) (see Examples of Foundational Conditions and Enabling Factors in Action section below).
Capable Vehicle Availability and Price	See Regulations and Supportive Policy above.	
Freight Hubs That Grow into Corridors	See Prioritization/Roadmapping above under Clear Vision and Targeted Roadmap.	
Available and Affordable Energy	1. Collaborative and integral long-term planning with the energy sector.	1a. Austria's Integrated Network Infrastructure Plan, including renewables, different energy vectors, and economic sectors. 1b. Austria's STELE - exchange platform to integrate electromobility into power grids, focusing on match-making events to bring relevant stakeholders, including electricity DSOs and CPOs.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
	2. Implementation of tailored pricing structures that cater to the needs of ZE-MDHVs.	2. Introduction of alternative electricity contract types in the Netherlands that incentivize consumption during off-peak hours, thereby increasing available capacity for customers and reducing overall costs.
Access to Clean Energy and Steadily Decarbonized Energy Mix	1. Implementation of strong goals, regulations, and inducements for decarbonizing energy sector. 2. Promoting the use of decentralized or off-grid energy systems. 3. Use of PPAs to source renewable energy at charging sites.	1a. E.U.'s Renewable Energy Directive – E.U.'s legal framework for the development of clean energy across all sectors of the E.U. economy. 1b. Dutch Sustainable Energy Production and Climate Transition Incentive Scheme (SDE++) - subsidies to companies and nonprofit organisations that generate renewable energy or reduce CO_2 emissions on a large scale. 2. Charging Energy Hubs project funded by the Dutch Government. 3. CPO Fastned signs its first multi-year Power Purchase Agreement (PPA) in the Netherlands.
Streamlined Permitting and Grid Connection Times	1. Work with local authorities and utilities to provide guidance and establishing fast-track permitting for ZE-MDHV infrastructure projects, prioritizing projects according to their impact: • Involve local communities and environmental groups in the planning process from the project outset to gather input and address concerns.	1a. California Assembly Bill AB 1236 requires counties and cities to create an expended permitting process for EV charging stations. 1b. California Assembly Bill AB 970 establishes specific time frames for local agencies to approve EV charging permits (additional info on 1236 and 970). 1c. Clean Ports Plan, Ports of Los Angeles and Long Beach. 1d. Dutch National Charging Infrastructure Agenda – "Flying Brigade" Taskforce - training municipal officials on policy regarding charging infrastructure. 1e. E.U.'s best practices guide for permitting and grid connection procedures for recharging infrastructure.

FACTOR	BEST PRACTICES	EXAMPLES/REFERENCES
Standardized and Enforced Emissions Accounting Frameworks, and Fuel and Air Quality Standards	1. Promote and leverage emissions reduction credit and programs as additional revenue source. 2. Enforce and utilize internationally recognized emissions protocols to track and validate reductions.	1a. California's Low Carbon Fuel Standard (LCFS) credit generation opportunities. 1b. Smart Freight Centre's Book and Claim Community - connects, supports, and catalyzes efforts across stakeholders working to develop a coordinated book and claim approach for heavy transport decarbonization. 1c. European Union Emission Trading System 2, including the road transport sector from 2027.
Interoperable and Reliable Charging/Fueling Systems	1. Support and adopt standards based on national and global standards organizations. 2. Establish reliability and operational standards for charging systems.	1a. ISO 15118, UL, and IEC 61851 standards. 1b. CharIN (Charging Interface Initiative) helps create alignment for standardization and interoperability within the EV industry. 2a. Chile's regulation of interoperability of electric vehicle charging systems, including differentiation of publicly accessible systems. 2b. E.U.'s AFIR – mandates standardization and interoperability requirements of charging and payment interfaces. 2c. California Energy Commission reliability reporting and performance standards.
Megawatt Charging Systems (MCS) Availability	See Interoperable and Reliable Charging/Fueling Systems above.	

SECTION 8

EXAMPLES OF FOUNDATIONAL CONDITIONS AND ENABLING FACTORS IN ACTION

AFRICA'S NORTHERN CORRIDOR

Africa's Northern Corridor, led by the Northern Corridor Transit and Transport Coordination Authority (NCTTCA), stands as a model of a corridor built on a robust institutional foundation. This is especially important in multi-country corridors, where policies, regulations, and procedures are often heterogeneous and a wide range of organizations and economic spheres intersect and engage.

"In multi-country corridors, establishing a coordinating authority is essential to create an integrated framework that aligns diverse policies, standards, and regulations. Such coordination ensures a seamless and efficient transit, transport, and trade, stimulates economic development, and fosters mutual growth, making the corridor a true engine of regional integration and prosperity."

– Dr. Eng. John Deng Diar Diing, NCTTCA Executive Secretary

Established through a Treaty known as Northern Corridor Transit and Transport Agreement (NCTTA), initially signed in 1985 and revised in 2007, the Northern Corridor is a multi-modal surface transport system encompassing road, rail, pipeline, and inland waterways transport. The NCTTCA was established to oversee the implementation of the NCTTA, whose primary objective is to guarantee free passage of transit traffic through the respective territories of the member states while ensuring environmental sustainability across Burundi, the Democratic Republic of Congo, Kenya, Rwanda, Uganda, and South Sudan. The Northern Corridor also serves Northern Tanzania, Somalia, and Ethiopia.

Through a collaborative approach, the NCTTCA has facilitated numerous partnerships. A notable example is their Green Freight Strategy 2030, developed in collaboration with UNEP (CCAC), the Smart Freight Centre (SFC), and the Kühne Foundation (KF), which aims to promote sustainable, climate-resilient solutions along this key East African trade route, including plans to be electric vehicle-ready by 2030 for its road segments and achieve net ZE by 2050.

This strategy is rooted in stakeholders' consultations and considers regular exchange forums to provide a platform for knowledge exchange, collaborative problem solving, and joint approaches to develop

green freight initiatives among the private-sector stakeholders. This approach is further strengthened by the corridor's participation in and support from the Green Global Road Corridors (GGRC) initiative, which elevates corridors to a gobal platform, enabling collaboration opportunities and the transfer of knowledge.

The Northern Corridor exemplifies a balance of effective top-down coordination from central authorities and bottom-up engagement from local and private actors, ensuring robust high-level guidance while remaining sensitive to local needs and a broad range of capacities.

U.S. INTERSTATE 10 CORRIDOR

Driven by shippers and coordinated by an NGO, the emerging Interstate 10 (I-10) ZE corridor in the United States illustrates the interaction of several of the identified success factors as well as a potential organizing principle: building corridors around demand from motivated shippers.

The key players launching the corridor speak to this model. Coordinated by Smart Freight Centre (SFC), a global transportation NGO and GGRC partner, the corridor partnership includes global-scale shippers, their prime carriers, and an infrastructure service provider: AIT Worldwide Logistics, DB Schenker, Maersk, Microsoft, and PepsiCo, with infrastructure provider Terawatt. Driven by shipper commitment and initial demand, the partnership identified locations where they each had interest and initial volume and capability. This initial corridor segment will connect Los Angeles, California, and its ports with El Paso, Texas, and its cross-border manufacturing.

"[Stakeholders] realized none of them represented sufficient demand to make the corridor work alone. They needed to share risks and costs to overcome the early barriers."

– Cristiano Façanha, Director of Road Freight Electrification, Smart Freight Centre

"The solution MUST be developed in tandem with willing customers. This is a new ecosystem and operational solution - this is not just a "drop in" fuel. It requires a full supply chain transformation that must include the cargo owner - the carriers - the infrastructure provider - and government."

– Nico De Golia, Director of Cloud Logistics Sustainability, Microsoft

Stakeholders realized this first corridor could only succeed by joining together to provide enough demand to justify investments by the charging provider and carriers. Big as they were, they could not make it happen alone.

Working together under a partnership model SFC coordinates, the parties began digging into the details of the operational model they needed. In parallel, corridor charging partner Terawatt secured U.S. federal co-funding for two of the key corridor sites, as the I-10 corridor is one of the priority corridors recognized by the U.S. government's National Zero Emission Freight Corridor Strategy, which helped raise its profile for funding.

First ZE trucks should start rolling on the more than 800-mile corridor in 2027, with shippers each running a limited number of trips per week to start. An initial six charging plazas will be positioned roughly 150 miles apart on the corridor. The plazas will be designed to accommodate tens of chargers. Additional shipper and carrier partners are expected to join before launch and additional infrastructure providers may be added later. Yet

promising as this first step is, partners also acknowledge the business models for carriers, infrastructure providers, and shippers are in flux in this new endeavor. Their strength is that they have pledged to work together to learn, refine, and adapt as they proceed.

In addition to the shipper focus, this corridor illustrates the interaction of several of the identified success factors: aggregating user demand, focusing on shared high-volume routes, leveraging public funding for infrastructure and vehicles, and building a process to reduce risk and cost for all partners.

RECOMMENDATIONS

WHAT CAN MOTIVATED GOVERNMENTS DO?

- Establish clear goals, strong regulations, and supportive, equitable policies for ZE-MHDVs and their infrastructure.
- Develop a national/sub-national prioritized and phased ZE freight infrastructure plan to identify and target first hub and corridor locations.
- Provide government co-funding and incentives to launch hub and corridor infrastructure and reduce vehicle cost.
- Coordinate, assist, or actively take part in stakeholder collaboration around priority corridors to support faster development and launch.
- Enable and require utilities and energy providers to accelerate and prioritize investments in and support for ZE-MHDV interconnection, renewable energy, and competitive rates.
- Support innovative financial mechanisms—and inclusive access to them—that reduce the risk of investment and operation of ZE-MHDVs and infrastructure.
- Engage with the partners and allies in the GGRC initiative to advance ZE transportation together.

WHAT CAN MOTIVATED TRANSPORT INDUSTRIES DO?

- Prioritize decarbonized transportation, speed evaluation of integrating ZE-MHDVs into operations, and engage sooner to launch pilot projects to demonstrate the benefits and feasibility of ZE-MDHVs along corridors, collecting data to inform future decisions.
- Collaborate and create partnerships with shippers, carriers, infrastructure providers, government, utilities, and other stakeholders to develop comprehensive and timely solutions that benefit all parties (e.g., by aggregating demand, utilization agreements, alternative energy contracts, etc.).
- Adopt sustainable practices that provide both economic and operational benefits. Acting early allows organizations to capitalize ahead of regulatory requirements, positioning them as leaders in sustainability and gaining a competitive advantage in the market.

- Engage with policymakers to advocate for supportive regulations and policies that facilitate the development of public and semi-public infrastructure.
- Make use of public funding and utilize innovative financing models that lower the barriers and risks to deploy vehicles and infrastructure.

WHAT CAN MOTIVATED ENERGY SECTORS DO?

- Prioritize powering decarbonized transportation projects and consider their needs into all grid modernization and integration planning.
- Collaborate with government oversight agencies to prioritize electric and hydrogen transportation investments to enhance grid infrastructure in hub and corridor areas to accommodate increased electricity demand from charging stations.
- Develop long-term charging infrastructure programs in collaboration with governments and industry to invest in and/or incentivize the installation of charging stations at strategic locations.
- Offer competitive pricing to transportation customers, find creative new business models to mitigate high utility demand charges in the early ZE-MHDV market, and make investments in distribution grid capacity and faster connections for charging infrastructure.
- Invest in renewable energy sources, including decentralized and off-grid systems, to ensure that ZE-MDHVs operate with minimal environmental impact.
- Utilize PPAs to secure long-term contracts between energy producers and transport/charger operators, ensuring stable pricing and supply for charging operations.

CONCLUSION

Implementing green road corridors is a vital yet challenging stage in the rapid transition to a fully decarbonized transport sector by 2050 in line with net-zero outcomes. While traditionally corridors drive economic growth, they also disproportionately impact the climate and public health. Organizing the transition of the regional and long-haul road segments must begin moving with greater speed today to meet medium- and long-term climate goals. However, success depends on overcoming multiple political, technical, financial, and social barriers.

Based on discussions with numerous stakeholders and tapping industry experience from first corridors, there are solutions to overcome these barriers. ZE-MHDV capabilities have now reached the threshold levels—including minimum range and charging times—to satisfy the initial performance required in first corridors. Green road corridors represent a compelling opportunity to redefine transport, requiring not only ambition but effective coordination and execution at all levels. Therefore, implementation requires a clear understanding of the key stakeholders who must be involved, either to enable or directly implement these corridors. It requires establishing the foundational conditions to make first corridors possible and setting in motion a suite of enabling factors for success in the early years.

First, generating sufficient demand for ZE-MDHVs and infrastructure to support them—the primary foundational condition—requires regulatory certainty and substantial public investment. Policies must be enforceable with priority on supply but also demand levels to create a clear pathway for adoption. Yet, policies alone are not sufficient, especially in the early stages when utilization levels of infrastructure do not yet justify investments along corridors. To overcome this gap, the public and private sectors must organize and collaborate, a vision and prioritization framework must be developed to target those first segments best able to succeed, and those first corridors must be prioritized to link high-volume hubs where motivated organizations and demand can be established.

Significant coordination among a diverse range of stakeholders is needed to achieve corridor success, from international to local levels. It is particularly important to connect goals, timing, and requirements between the electricity/energy and transport sectors, which have not been strongly involved with each other until now. Each stakeholder brings unique interests, agendas, and perspectives to the table. To ensure the implementation of effective and affordable solutions, it is crucial to foster understanding and meaningful collaboration among all parties.

Fortunately, both the public and private sector have demonstrated ability and agility in forming partnerships, enhancing the potential for successful outcomes. Based on these first endeavors, a rich matrix of best practices is now available to inform and assist regions worldwide that are exploring green road corridors. The GGRC initiative will regularly monitor, distill, update, and share these best

practices that support the enabling success factors, providing valuable insights for future corridors. Beyond this, the GGRC initiative will serve as connective tissue between the autonomous initial corridors projects, ensuring that these early learnings reach the global community and progress made visible for policymakers, investors, and industry stakeholders to see, believe, and act to accelerate ecosystem transformation.

While nascent green road corridors may not have all the enabling factors in place initially, this will not deter progress. Instead, it highlights the need for increased support, organization, and coordination, not only among different stakeholders but across different countries on different stages of development to facilitate the exchange of experiences and solutions. Although there is no one-size-fits-all solution, the interconnected foundational conditions and enabling success factors outlined in this report offer a scalable model that can be adapted to diverse contexts.

FURTHER RESEARCH

While the templates illustrated stem mostly from examples in developed economies, they provide a highly valuable starting point for modifying and adapting them to a more localized approach. This can be particularly salient in EMDEs, where specific social, economic, and infrastructural needs must be addressed to ultimately ensure a more equitable distribution of resources, knowledge, and benefits across regions. Outlining a model more directly suited for EMDEs is a potential next-step project for the initiative.

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APPENDIX

LIST OF STAKEHOLDER INTERVIEWEES

Alycia Gilde, Senior Director for Transportation, Climate Policy Office, The White House, U.S. Government

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