

MAKING ZERO-EMISSIONS TRUCKING POSSIBLE

An industry-backed, 1.5°C-aligned transition strategy



EXECUTIVE SUMMARY / JULY 2022



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THE MISSION POSSIBLE PARTNERSHIP

At current emissions levels, staying within a global carbon budget aligned to 1.5°C might slip out of reach in this decade. Yet efforts to slow climate change by reducing greenhouse gas (GHG) emissions run into a central challenge: the biggest emitters of carbon dioxide equivalent (CO₂e) into the atmosphere – transportation sectors including aviation; shipping; and trucking; and heavy industries including steel, aluminium, cement, and chemicals manufacturing – are the hardest areas in which to lower emissions. Moreover, transitioning these industries to carbon-neutral energy sources is complex, requiring a comprehensive approach across entire value chains, with collaboration among companies, suppliers, customers, banks, institutional investors, and governments.

Catalysing these changes is the goal of the Mission Possible Partnership (MPP), an alliance of climate leaders focused on supercharging efforts to decarbonise these industries. Led by the Energy Transitions Commission, RMI, the We Mean Business Coalition, and the World Economic Forum, MPP has as its objective to propel a committed community of CEOs from carbon-intensive industries – together with their financiers, customers, and suppliers – to agree on the essential decisions required for decarbonising industry and transport. More importantly, the coalition must act on those decisions. MPP will orchestrate high-ambition disruption through net-zero industry platforms for seven of the world's most carbon-intensive sectors: aviation, shipping, trucking, concrete, steel, aluminium, and chemicals.

Transitioning these seven hard-to-abate sectors to net-zero emissions by 2050 will require significant changes in how they operate. MPP facilitates this process by developing sector transition strategies for all seven hard-to-abate sectors.¹

A Sector Transition Strategy informs decision makers from the public and private sectors about the nature, timing, cost, and scale of actions necessary to achieve net zero within the sector by 2050.

¹ Zero-emissions truck technology is or will be viable for almost all use cases. The sector remains a challenge to decarbonise because of the scale of change, the costs for some users, and new infrastructure required.



All sector transition strategies are based on similar assumptions about the costs and availability of technologies and resources such as renewable electricity, green hydrogen (H₂), and sustainable biomass. By providing a harmonised, cross-sectoral perspective, we hope to inform decision makers with a fair assessment of transition strategies for all seven sectors and to expedite innovation, investments, and policies to support the transition.

Within MPP, the Road Freight Zero (RFZ) initiative is working towards the goal of zero-emissions truck (ZET) deployment. A broad set of global stakeholders are engaged in this initiative, including major buyers of transportation, leading transporters and logistics companies, significant players in energy and infrastructure, financial institutions, and public-sector organisations. They all have the same ambition: to accelerate decarbonisation of heavy-duty urban, regional, and long-haul trucking.

This report sets out a zero-emissions transition strategy for the heavy-duty trucking (HDT) sectors in the United States, Europe, China, and India. It identifies what needs to happen to enable this future between now and 2050. The Trucking Transition Strategy model (“the model”) underpins this transition strategy, which has three main aims:

- Provide a detailed reference point for the changes needed over the next 30 years to underpin corporate target setting, science-based targets, and financial sector alignment methodologies.
- Inform the 2020s’ priority actions, trade-offs, and decisions of stakeholders that will shape the road freight markets, including transport buyers, logistics players, fleet owners, truck manufacturers, energy and infrastructure providers, policymakers, and financial institutions.
- Catalyse actions from stakeholders across the value chain that together will unlock investments in zero-carbon solutions.

The model used and the analytics behind it will be made open access to promote transparency and collaboration, such that the inputs and assumptions are available for inquiry, and future iterations may build on this effort. This open-access approach lends itself to regular refinement as data and insights evolve. Critically, it also ensures that the industry can align behind a strategy it considers technically and economically feasible, subject to appropriate value-chain collaboration, finance, and policy support.

Through this work, we hope to inspire and inform an accelerated transition to net zero for the HDT sector, including actions – innovations, investments, policies, and procurement decisions – taken by the broader industry value chain essential to support the transition.

Industry support for MPP’s Trucking Transition Strategy

This effort benefitted from the input of the MPP RFZ community, consisting of over 50 companies and 20 organisations representing the entire trucking value chain. Members of the initiative have validated the model and architecture and endorse the general thrust of the arguments made in this report, but should not be assumed to agree with every finding, input, or recommendation. These companies agree on the importance of reaching zero emissions from the HDT sector by mid-century and share a broad vision of how to achieve the transition.

This agreement among industry leaders should give decision makers around the world confidence that it is possible to meet global HDT demand and simultaneously reduce emissions from the sector to net zero by 2050. It should also inspire belief that the critical actions required in the 2020s to set the sector on the right path not only are clear but can be pursued without delay and that the industry is ready to collaborate with its value chain to achieve those goals.

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We would like to thank the RFZ initiative as well as other industry participants and experts for their input and review over the past months.





Mission Possible Partnership (MPP)

Led by the ETC, RMI, the We Mean Business Coalition, and the World Economic Forum, the Mission Possible Partnership (MPP) is an alliance of climate leaders focused on supercharging the decarbonisation of seven global industries representing 30% of emissions: aviation, shipping, trucking, steel, aluminium, cement/concrete, and chemicals. Without immediate action, these sectors alone are projected to exceed the world's remaining 1.5°C carbon budget by 2030 in a Business-As-Usual scenario. MPP brings together the world's most influential leaders across finance, policy, industry, and business. MPP is focused on activating the entire ecosystem of stakeholders across the entire value chain required to move global industries to net-zero. www.missionpossiblepartnership.org



RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing. rmi.org

McKinsey & Company

McKinsey & Company is a global management consulting firm committed to helping organizations create change that matters. In more than 130 cities and 65 countries, their teams help clients across the private, public, and social sectors shape bold strategies and transform the way we work, embed technology where it unlocks value, and build capabilities to sustain the change. Not just any change, but change that matters – for their organizations, their people, and in turn society at large. McKinsey & Company is a knowledge partner for the Mission Possible Partnership and provided fact-based analysis for this report. Learn more at www.mckinsey.com.



Energy Transitions Commission

Energy Transitions Commission (ETC)

ETC is a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century, in line with the Paris climate objective of limiting global warming to well below 2°C and ideally to 1.5°C. Our commissioners come from a range of organizations – energy producers, energy-intensive industries, technology providers, finance players, and environmental NGOs – which operate across developed and developing countries and play different roles in the energy transition. This diversity of viewpoints informs our work: our analyses are developed with a systems perspective through extensive exchanges with experts and practitioners. www.energy-transitions.org



World Economic Forum

The World Economic Forum is an International Organization for Public-Private Cooperation. The Forum engages the foremost political, business, cultural, and other leaders of society to shape global, regional, and industry agendas. The Forum brings together stakeholders to help address the greatest ecological crises of our time, focusing on topics like climate, mobility, energy, and the circular economy. The World Economic Forum's platforms aim to facilitate action-oriented communities of stakeholders from all parts of the international system, and the organisation is one of the core partners for the Mission Possible Partnership. <https://www.weforum.org>





Road Freight Zero

Road Freight Zero is a multi-stakeholder, cross-value chain coalition of first-mover champions, working together to fast-track zero-emission, heavy-duty trucking toward a 1.5° trajectory by 2030. It focuses on accelerating the viability and deployment of HD ZE fleets and infrastructure by aligning stakeholders on a common vision and roadmap; performing scalable corridor pilots that create learnings and replicable blueprints for ZET fleet and infrastructure; scaling up innovative financing to overcome first-mover disadvantages; and connecting companies with leading-edge solutions to start reducing emissions today. Road Freight Zero is led by the World Economic Forum, with support from knowledge partners including McKinsey, ETC, and RMI on specific projects such as this Transition Strategy. <https://www.weforum.org/projects/decarbonizing-road-freight-initiative>



North American Council on Freight Efficiency (NACFE)

NACFE works to drive the development and adoption of efficiency-enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including confidence reports on available technologies and guidance reports on emerging ones, which highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with RMI on a variety of projects, including the Run on Less demonstration series, electric trucks, emissions reductions, and low-carbon supply chains. Visit [NACFE.org](https://www.nacfe.org) or follow NACFE on Twitter @NACFE_Freight.



TEN CRITICAL INSIGHTS ON THE PATH TO A ZERO-EMISSIONS HEAVY-DUTY TRUCKING SECTOR



1. Trucking demand is surging globally, making it an important sector to decarbonise. A swift, decisive move to zero-emissions trucks and a rapid rollout of infrastructure are needed to achieve net zero by 2050.

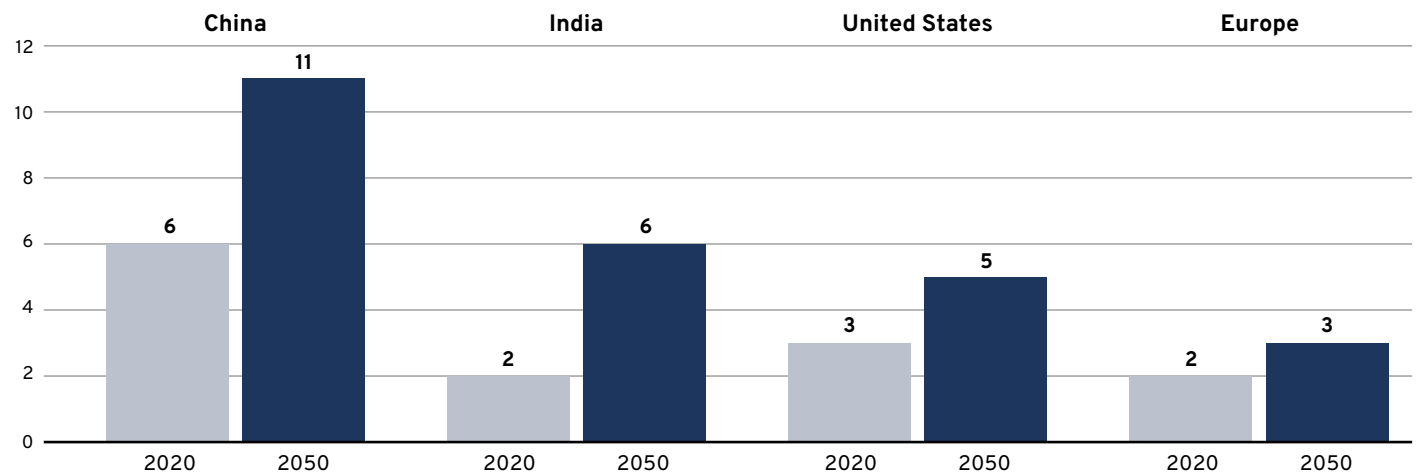
Heavy-duty trucking in China, Europe, India, and the United States emits approximately 1.5 gigatonnes (Gt) of CO₂ equivalent (CO₂e) today. Trucking demand is projected to more than double and increase from 12 trillion tonne-kilometres (tkm) to 26 trillion tkm. India's approximate 5% demand growth

will be the fastest, and China will continue to have the highest demand (Exhibit A).² Today, 95% of heavy-duty trucks use diesel. If most trucks continue to use diesel, by 2050 heavy-duty trucking in the modelled regions will emit nearly 3 Gt of CO₂e, double current levels.

Heavy-duty trucking demand expected to grow through 2050

EXHIBIT A

Annual trillion tonne-kilometres



Source: MPP analysis

Surging trucking demand and expected technology availability have largely dictated this report's recommended decarbonisation strategies.³ Renewable diesel, renewable natural gas (RNG), and other transitional fuels can play a role in the near term with legacy vehicles but have drawbacks, and other new fuels are likely to be prioritised for use in other sectors such as aviation and marine.

The main pathway to decarbonising trucking will be developing and using new vehicles and drivetrains: battery electric trucks (BETs) and hydrogen electric trucks (HETs), powered with fuel cells. This analysis concludes that achieving net zero by 2050 requires all trucks sold by 2040 to be either BETs or HETs.

Zero-emissions trucks (ZETs) are in early-stage production by manufacturers, are just starting to have an equivalent total cost of ownership (TCO) with diesel vehicles for many uses, and are already experiencing an encouraging level of adoption. Further actions can help ensure that trucking achieves two goals: reaching zero emissions by 2050 and reducing the cumulative amount of GHG emissions between now and then. Those actions include stakeholders putting in place the market incentives, policy frameworks, continued vehicle development, and timely charging infrastructure necessary for this major transition. It also depends on the rapid deployment of renewable generation for both electric vehicle charging and hydrogen production.⁴

² Autonomous vehicles, though not modelled in this report, would likely further increase total freight miles travelled and increase each vehicle's miles per year.

³ Efficiency improvements, such as shortening supply chains, ensuring that truck trailers are carrying fuller loads, and shifting to trains and ships, do play a role and can reduce trucking's emissions intensity by 20%.

⁴ In the MPP model, 100% of the H₂ is assumed to come from renewable sources. Electricity for BETs in the four regions is expected to be sourced from a grid that is 90% renewables and storage, with the remainder using carbon capture and sequestration. Reports from the International Energy Association and the Energy Transitions Commission consider a 90% renewable grid feasible. See the *Appendix* for more information on grid assumptions.



2. Most ZETs are expected to reach TCO superiority with diesel trucks between 2025 and 2034.

A zero-emissions industry is fundamentally possible because battery and hydrogen trucks are increasingly cost competitive. ZETs typically have higher upfront costs but lower operating costs than internal combustion engine (ICE) trucks. As technological development and economies of scale in production lower the upfront costs of ZETs, the ability of those lower operating costs to recoup increased upfront investment is growing. Zero-emissions vehicles may achieve TCO superiority in most use cases between 2025 and 2034, depending on usage and region.⁵

This report divides the trucking market into three usage categories: urban, regional, and long haul. For urban deliveries, BETs reach TCO superiority most quickly. They will have capital expenditure costs competitive with those of diesel, and greater operating cost advantages because of efficiencies during idling and stop-and-go traffic. Long-haul trucking requires larger batteries and more costly high-powered charging or extensive hydrogen infrastructure; these trucks should achieve TCO parity between 2032 and 2037 in every region except India, which will take longer.

A few key trends in ZET adoption will determine the pathway to zero emissions:

- Sales uptake for BETs will accelerate fastest in urban and regional segments compared with long-haul segments, due not just to TCO but also to operational feasibility such as shorter trips and greater charging availability. BETs, rather than HETs, will dominate this market.
- Long-haul HDT should see a higher uptake of HETs than urban and regional duty cycles, mainly due to hydrogen's higher energy density and shorter refuelling times. Up to 50% of long-haul truck sales will be HETs; BETs will likely be adopted for predictable routes that have on-the-go charging.
- Of the regions we studied, Europe will adopt zero-emissions vehicles fastest due to ambitious net-zero policies.⁶ Europe will be followed by the United States, which has ambitious state policy frameworks and some supportive federal policies. China, which lacks significant policy for ZETs but has ambitious policies for other transportation segments, will follow later. Because of vehicle costs and lower policy support, India will be last among our studied regions to adopt ZETs.
- ZET policy works with existing fleet costs and behaviour to influence market outcomes. Because existing diesel vehicles are more expensive in the United States and Europe, ZETs have a greater cost advantage than ICE vehicles – positioning them for faster adoption. In Europe, this advantage is compounded by high diesel fuel prices. India and China have cheaper ICE trucks and relatively low fuel prices, leading to a later transition.
- Transitional fuels and drivetrains are expected to coexist during the next 5–10 years before BETs and HETs reach TCO parity at scale. These technologies will likely include liquefied/compressed renewable natural gas (renewable LNG/CNG) and biodiesel trucks (Exhibit B).



⁵ Total cost of ownership is the cost of the truck, the fuelling infrastructure (diesel, electric, or hydrogen), and the ongoing fuel and maintenance operating costs over the vehicle's lifetime. The *Appendix* further describes the analysis.

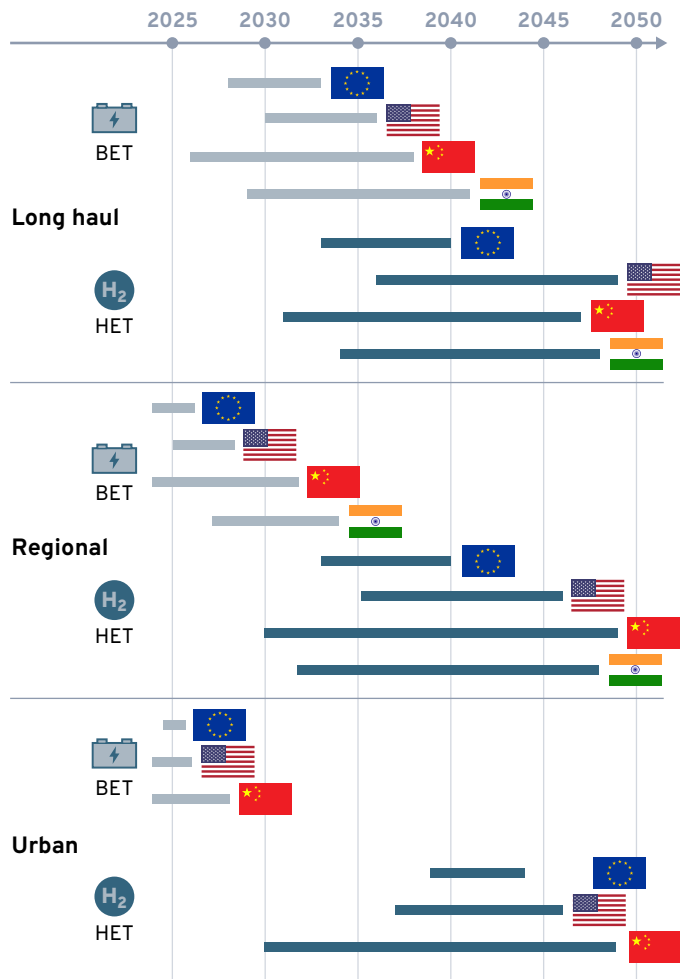
⁶ The EU has introduced targets for heavy-duty vehicles to reduce emissions by 15% as of 2025 and by 30% as of 2030.



3. Adoption of ZETs based on cost optimisation can substantially advance progress towards net zero.

EXHIBIT B

ZET TCO parity varies depending on usage, technology development, and policy choices



Note: Flags reflect TCO dates of Expected Adoption scenario. Bars reflect range of TCO breakeven dates for the other modelled scenarios. HDT is legally restricted from urban deliveries in India; the country is therefore excluded from the segment analysis.

Source: MPP analysis

This report models four scenarios for increasing ZET adoption, and the “Do Nothing” Baseline of fossil fuel usage at current levels.

First is the *Expected Adoption scenario* as the TCO of BETs and HETs improves. This is a market-based scenario. Many fleets will buy ZETs because they make financial and operational sense, and by 2050, 80% of trucks on the road will produce zero emissions. Yet without additional action to support ZETs, trucking will not achieve zero emissions by 2050. Trucking will also create 41 Gt CO₂e between now and then, consuming nearly 6% of the world’s remaining “carbon budget”. TCO improvements, infrastructure development, and new policy are needed to enable a zero-emissions industry by 2050.

The second scenario, the *Rapid Technology Improvement scenario*, is also solely market based. However, the significant economic superiority of ZETs leads to a nearly zero-emissions trucking sector by 2050, even without policy intervention.⁷ This scenario is modelled in two different ways: accelerated BET deployment and accelerated HET deployment. They include achievable improvements in vehicle supply, fuel costs, and fuelling station usage. In these scenario models, we also relax non-cost constraints on BET adoption (e.g., battery weight makes hauling heavy loads impossible), reflecting non-cost technology gains, such as greatly increased battery energy density.

It is possible that technological improvements will happen more quickly than is currently anticipated. (Consider that zero-emissions vehicle prices have decreased far more than was projected a decade ago.) This scenario assumes rapid development of renewable electricity generation and transmission, as well as hydrogen production and transportation.⁸ Complementary clean energy investments in adjacent sectors can also help, including:

- Charging infrastructure for medium-duty vehicles
- Hydrogen production infrastructure for heavy industry
- Lessons and economies of scale from light-duty electric powertrains and battery production that reduce BET costs
- Guaranteed demand through investor and institutional climate commitments

There are many plausible developments that can further reduce the projected costs of zero-emissions technologies.

7 Modelling assumptions leave a minimal amount of continued ICE usage.

8 The EU has introduced targets for heavy-duty vehicles to reduce emissions by 15% as of 2025 and by 30% as of 2030.



4. Policy is another means of helping trucking achieve zero emissions by mid-century. Strategies that prioritise ZET uptake before 2050 prevent 6–13 Gt of cumulative CO₂e emissions.

Unlike the Expected Adoption scenario and the Rapid Technology Improvement scenario described earlier, the remaining two scenarios below rely on both vehicle policy and market forces for completely decarbonising HDT by 2050. The *Zero-Emissions – ZET Mandate scenario* (“Zero-Emissions scenario”) represents the implementation of a diesel ban by 2040, the latest date to ensure that trucks on the road in 2050 will produce zero emissions. Between now and 2050, it would avoid 6 Gt CO₂e compared with the Expected Adoption scenario (Exhibit C).

The *Accelerated Zero-Emissions – Carbon Cost scenario* (“Accelerated Zero-Emissions scenario”) represents policy

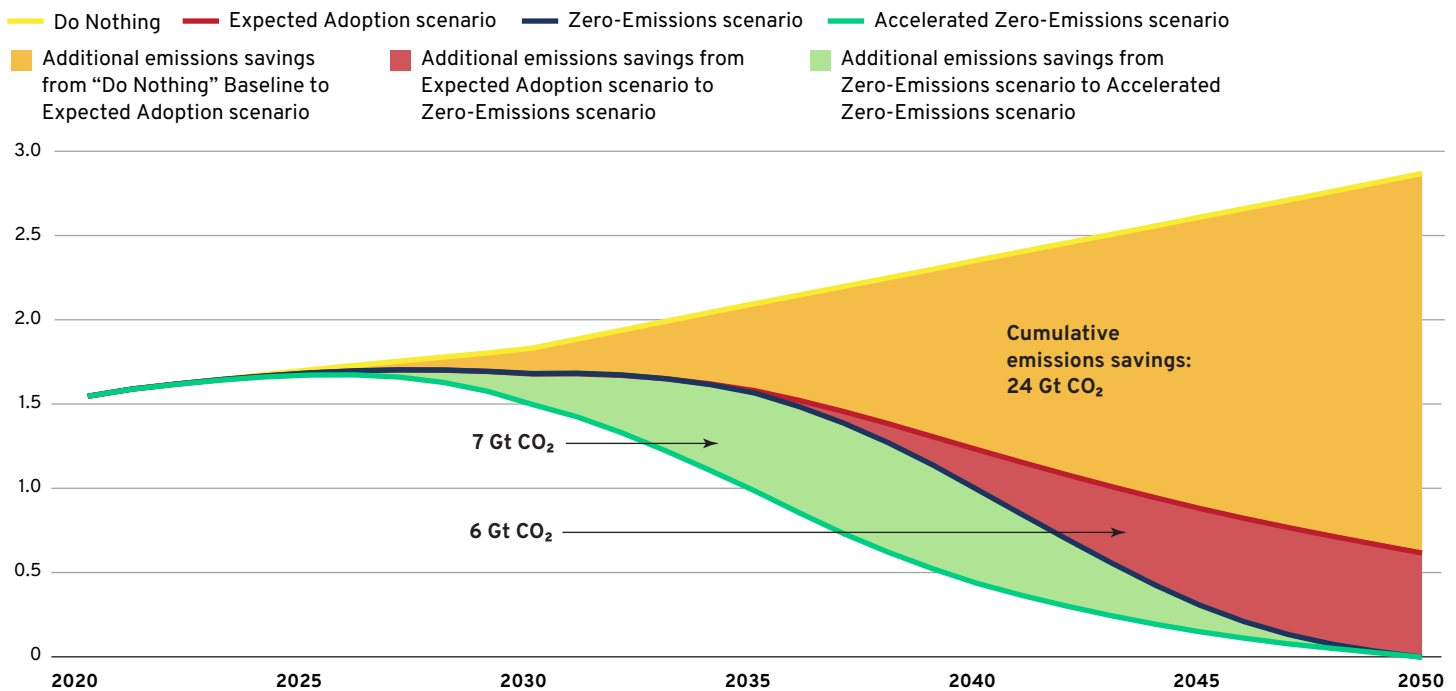
measures in which the cost of carbon affects the TCO of trucks powered by fossil fuel and other CO₂e-emitting technologies.⁹ This scenario achieves net zero by 2050 and avoids 13 Gt CO₂e compared with the Expected Adoption scenario.

MPP’s Rapid Technology Improvement scenario nearly achieves zero emissions, while the Zero-Emissions scenario and Accelerated Zero-Emissions scenario reach the no-GHG goal. Each MPP scenario assumes different, discrete policies and technology developments to reach zero emissions. However, a real-life path to net zero is likely to include elements of all three.¹⁰

EXHIBIT C

Fully decarbonising trucking requires market forces and other action

Annual GHG emissions by scenario, Gt CO₂e



⁹ Well-to-wheel emissions, including tailpipe emissions, are included in this report’s greenhouse gas analysis.

¹⁰ See *Appendix* for a detailed review of TCO and main TCO assumptions.



5. Achieving zero-emissions trucking is cheaper than continuing to burn fossil fuels. Higher vehicle costs will be more than recouped through lower operating costs.

A trucking sector that is zero emissions is not only more sustainable than the status quo but also more economical. When compared with the cumulative investment that would have been required in a “Do Nothing” diesel-dominated future, investments in ZETs are cheaper in all markets. Though BETs and HETs will usually have higher upfront costs, they more than recover the difference from reduced fuel and operating expenses (Exhibit D).

As the market continues to scale, ZETs will represent a growing share of vehicle sales. A zero-emissions industry by 2050 is cheaper than a diesel-dominated one and is only slightly more expensive than a cost-only optimised mix of ICE trucks and ZETs. However, there are important regional differences: Europe and the United States have lower transition costs than do China and India.

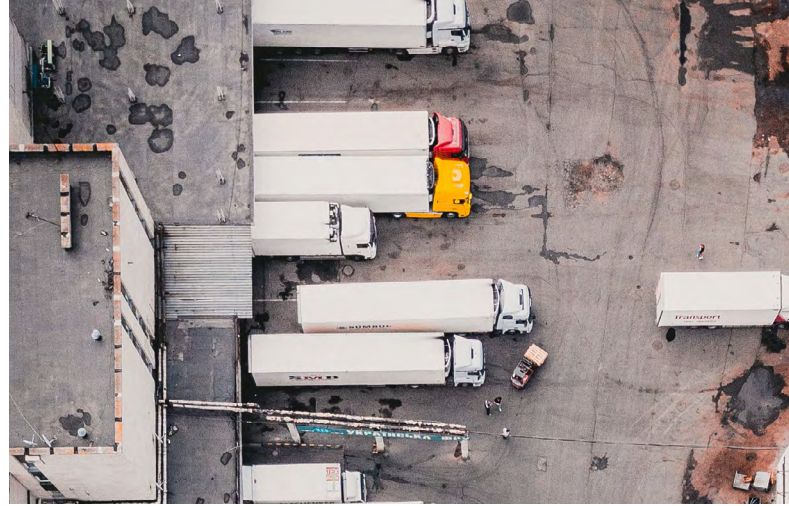
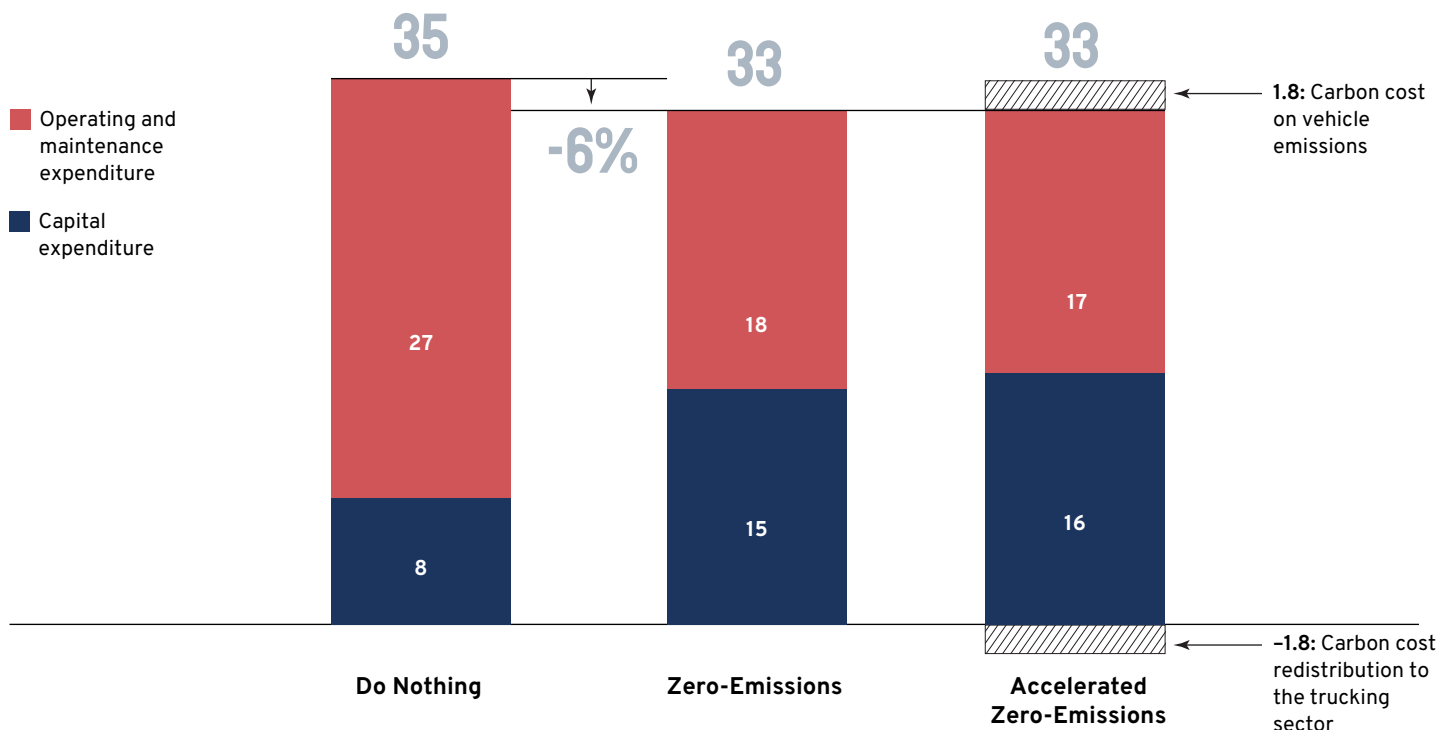


EXHIBIT D

ZETs are expected to reduce overall trucking costs

Cumulative capital investments and operating expenditures by scenario, Trillion US\$, 2020-50



Source: MPP analysis



6. Financing the transition in developing economies will require more capital, creating an opportunity for global climate finance to enable a worldwide transition to zero emissions.

In the United States and Europe, where ICE trucks are substantially more expensive than in India and China, the upfront net capital investment required to achieve net zero is 25% to 30% more than continuing to use mostly diesel. However, in India and China, where ICE trucks are cheaper, the incremental costs of ZETs and their infrastructure are more significant (Exhibit E).

However, even in India and China, where the overall capital burden from the transition is highest, making the

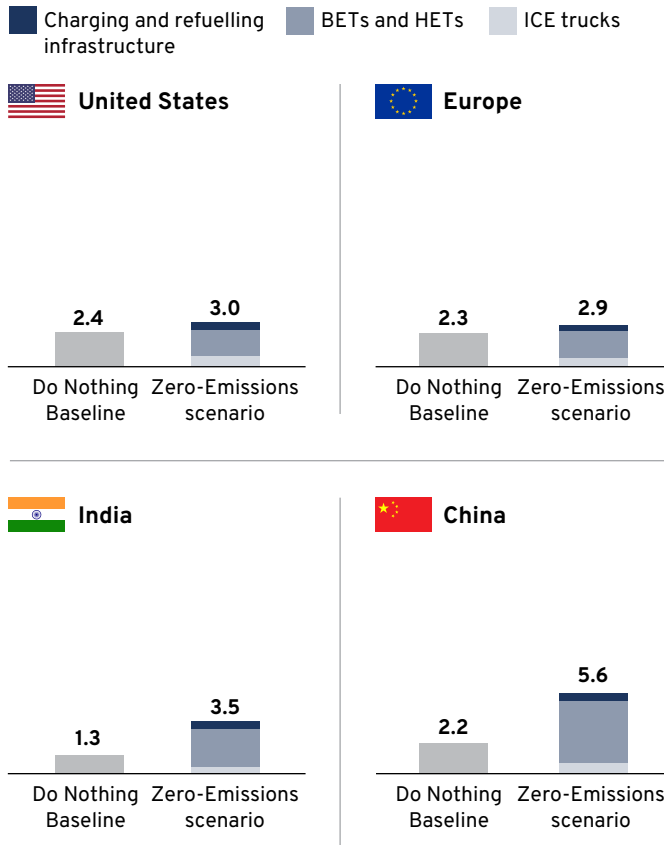
transition is better than continuing on the current pathway. The value of operational savings from ZETs justifies the transition (Exhibit F).

Mobilising the financing to secure this transition in developing countries will be an important enabler for a zero-emissions trucking industry. Global multilateral financing bodies should align their financing portfolios with the needs of the trucking industry.

EXHIBIT E

Diesel truck costs vary by region, impacting ZET's upfront cost competitiveness

Net present value of 2020–50 capital costs by scenario, Trillion \$

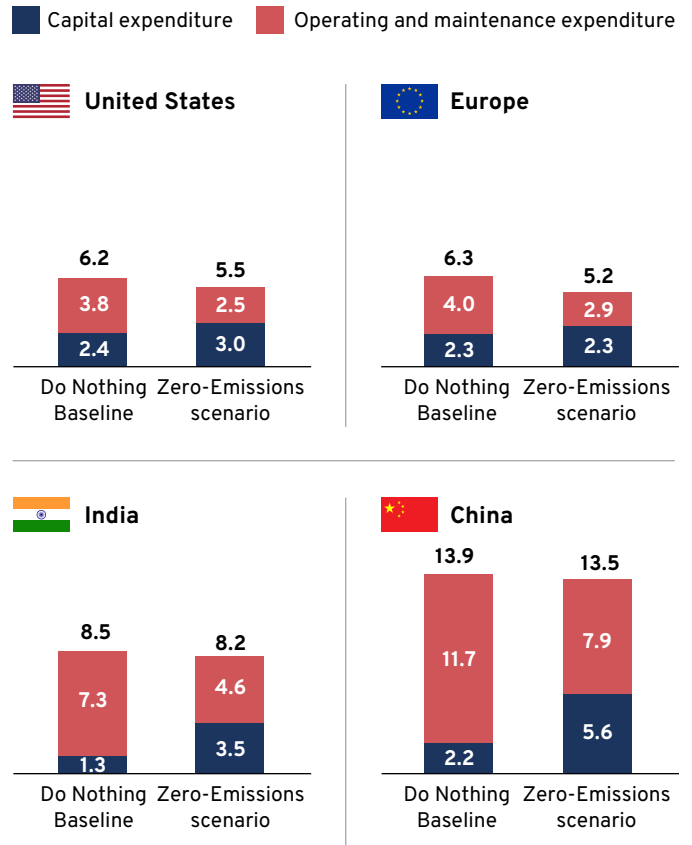


Source: MPP analysis

EXHIBIT F

ZET operating savings are projected to create positive TCO in all regions

Net present value of all 2020–50 costs by scenario, Trillion \$



Source: MPP analysis





7. Innovative business models and financing instruments can leverage ZETs' lower operating costs in order to mobilise capital to pay for their purchase.

A fleet's access to financing depends on national financial infrastructure and the fleet's size. Typically, larger fleets have better access to capital than small ones, meaning they will be in a better position to finance the purchase of expensive ZETs and ultimately recoup those extra costs through operational savings. However, globally, most fleets are owned by small businesses, which sometimes have just a single vehicle.

These small businesses typically have much less access to capital than their larger competitors and often have less ability to maintain and repair new technologies such as ZETs. The market needs models that reduce this burden on small businesses and enable them to gain access to ZETs without having to make large upfront payments or develop specialised maintenance capabilities. Business models such as truck-as-a-service (TaaS) and battery-as-a-service (BaaS) are short-term leasing arrangements that can help small fleets gain access to

these new and expensive technologies. The transition should include innovative financing and business models that can minimise economic harm to individual firms.

Furthermore, many truck operators understand the promise of ZETs but see substantial near-term risk in the transition. ZETs are a new technology with a relatively short track record. If they fail prematurely, they will be very expensive to replace or repair. Offering extended warranties for critical components such as batteries and including original equipment manufacturer (OEM) service agreements can bolster fleets' confidence in ZET ownership and accelerate the transition. Another way to increase fleets' confidence is to strengthen the residual value of their end of life trucks. Though this analysis does not measure second hand market value for either diesel trucks or ZETs, cultivating the downstream battery recycling industry helps the environment and improves the ZET business case.



8. Enabling policy and coordination in the timing of supply and demand for both vehicles and refuelling infrastructure can reduce fleets' risk during this transition.

Although trucking decarbonisation is ultimately enabled and accomplished by ZETs that are technically and economically superior to ICE vehicles, local policy designed to promote ZETs can help secure the transition – especially in the early stages. Those enacting policy should focus on simultaneously bringing to market the supply of ZETs, creating demand for them, and ensuring the upstream infrastructure that enables them. If any of those three elements is lacking, the transition will be slowed and net zero may not be achieved by 2050.

Of the three, demand has historically been where most policy action has been focused. A very common policy approach increases demand for ZET technologies with vehicle purchase incentives that support early market development. A similar approach is to alter the economics of operating trucks in favour of ZETs by increasing the prices of fossil fuels and subsidising the purchase of green electricity and hydrogen. Finally, more forceful demand-side tools such as diesel bans and diesel truck purchase requirements have been announced in several jurisdictions.

Although demand is crucial, if policymakers stimulate demand for ZETs that is then unmet by supply, they will only have

created increased costs to fleets. Especially in the early stages of market development, increased demand alone is not sufficient to draw supply into the market in a way that is compatible with ambitions for zero emissions. Policies designed specifically to induce supply must also exist. Such policies could include tax incentives or other subsidies to produce ZETs, such as in the Netherlands, as well as specific regulatory regimes that require the ZETs to make up an increasing share of vehicles sold, as in California.

Finally, both supply and demand for ZETs are contingent on upstream value chains that enable the production and use of those vehicles. Policymakers should look upstream at issues such as the ability of OEMs to ethically source raw materials for critical ZET components and should invest in the infrastructure to distribute electricity and hydrogen to places where trucks will need it.

As they formulate these portfolios, policymakers should ensure both that they are catalysing the action needed from all parties (supply, demand, and infrastructure) and that any costs created by their policy portfolios to a particular party do not exceed the ability of that party to pay.

9. Operators need more public charging and hydrogen stations, a more mature ZET production value chain, and enough grid power for both charging and hydrogen production.

Depending on the scenario, there will be between 6 million and 9 million ZETs by 2030. These trucks will require dense charging and refuelling networks (Exhibit G).



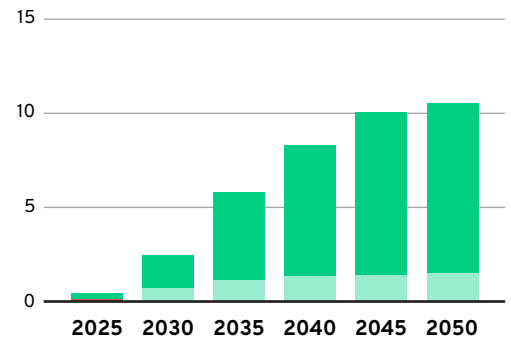
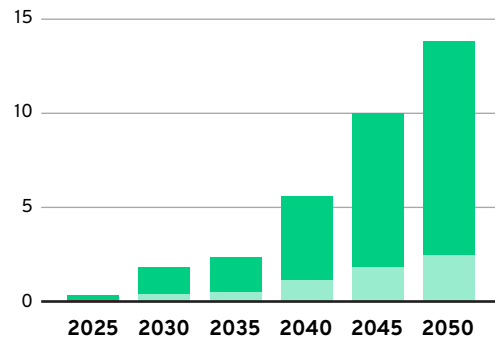
ZET adoption requires a major infrastructure ramp-up

■ BET overnight chargers ■ BET fast chargers ■ Hydrogen refuelling stations

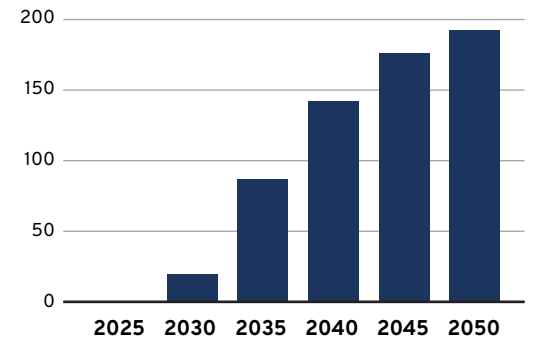
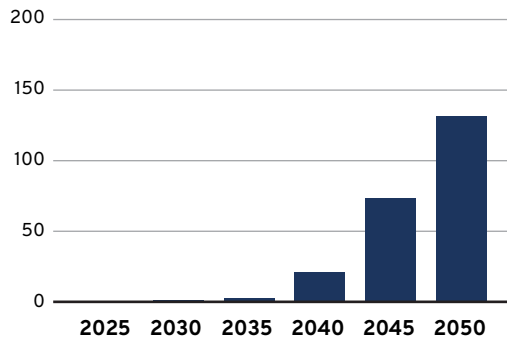
Zero-Emissions scenario

Accelerated Zero-Emissions scenario

Number of chargers, millions



Number of hydrogen refuelling stations, thousands



Note: Overnight chargers are assumed to have a capacity of 100 kW and fast chargers are assumed to have one of 500 kW.

Source: MPP analysis

By 2030 about 1.4 million to 1.8 million overnight depot chargers and 400,000 to 700,000 public high-speed chargers will be needed for BETs, and 1,000 to 19,000 hydrogen refuelling stations across key markets will be needed for HETs. Putting such an infrastructure in place requires cooperation with governments and utilities, which must enable and support it.

A gradual build-out of public charging is already happening in urban areas. Continued infrastructure development of major transportation routes and the electrification of HDT hubs (e.g., large harbours, large industrial areas) would trigger the transition to ZETs for longer and more heavy-duty cycles. For infrastructure build-out, it will be necessary to balance the needs of various stakeholders. For example, fleet operators need enough conveniently located charging stations to serve their routes, whereas charging station developers need to have sufficient station utilisation to justify their investments. While this report

models 500 kW public fast charging, charging of a MW or more can improve BET economics. With higher powered chargers, each station can serve more vehicles and potentially access lower cost electricity generation. Improved economies of scale and lower energy costs would improve TCO, particularly for long-haul trucking. Parties have to coordinate charging and vehicle investments to be successful.

Needs go beyond charging infrastructure availability. Increased electricity generation, grid upgrades, and the development of green H₂ production and distribution are also required to meet significant demand increases over the next decades. Electricity demand for HDT will likely increase more than 100-fold between 2020 and 2030, and in our Zero-Emissions scenario, green hydrogen demand takes off from zero in 2020 to as much as 1,000 terawatt-hours (TWh) in 2040 (Exhibit H).





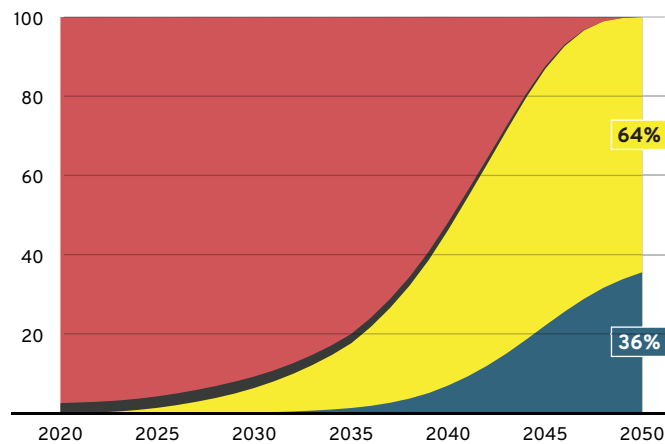
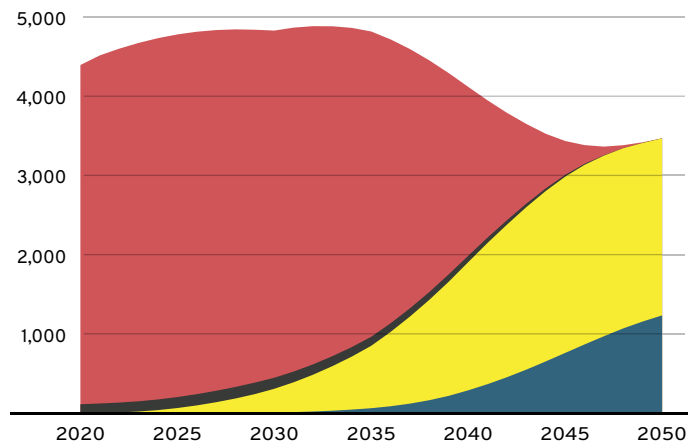
Energy consumption by scenario, 2020-50

■ Diesel
 ■ Biodiesel
 ■ Electricity
 ■ Hydrogen

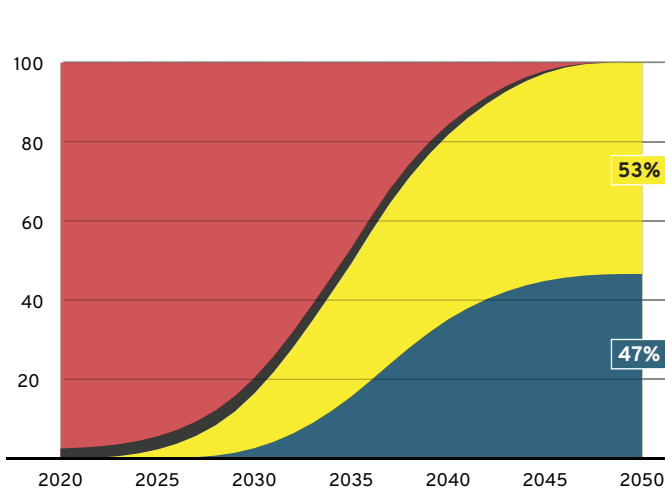
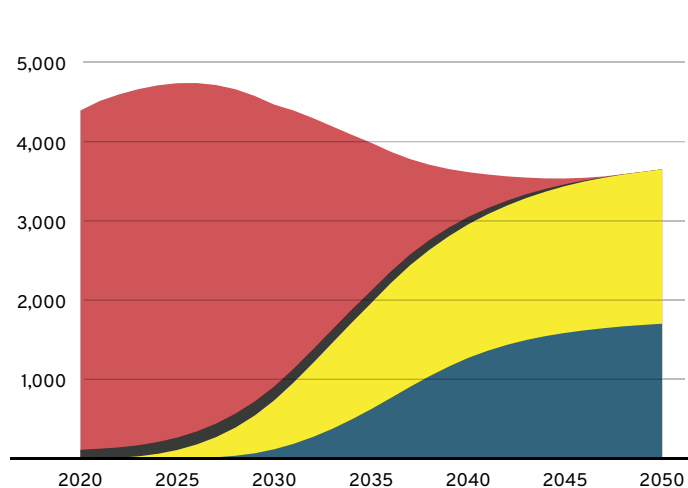
Total energy demand by fuel, TWh

Total energy demand by fuel, %

ZERO-EMISSIONS SCENARIO



ACCELERATED ZERO-EMISSIONS SCENARIO



Source: MPP analysis

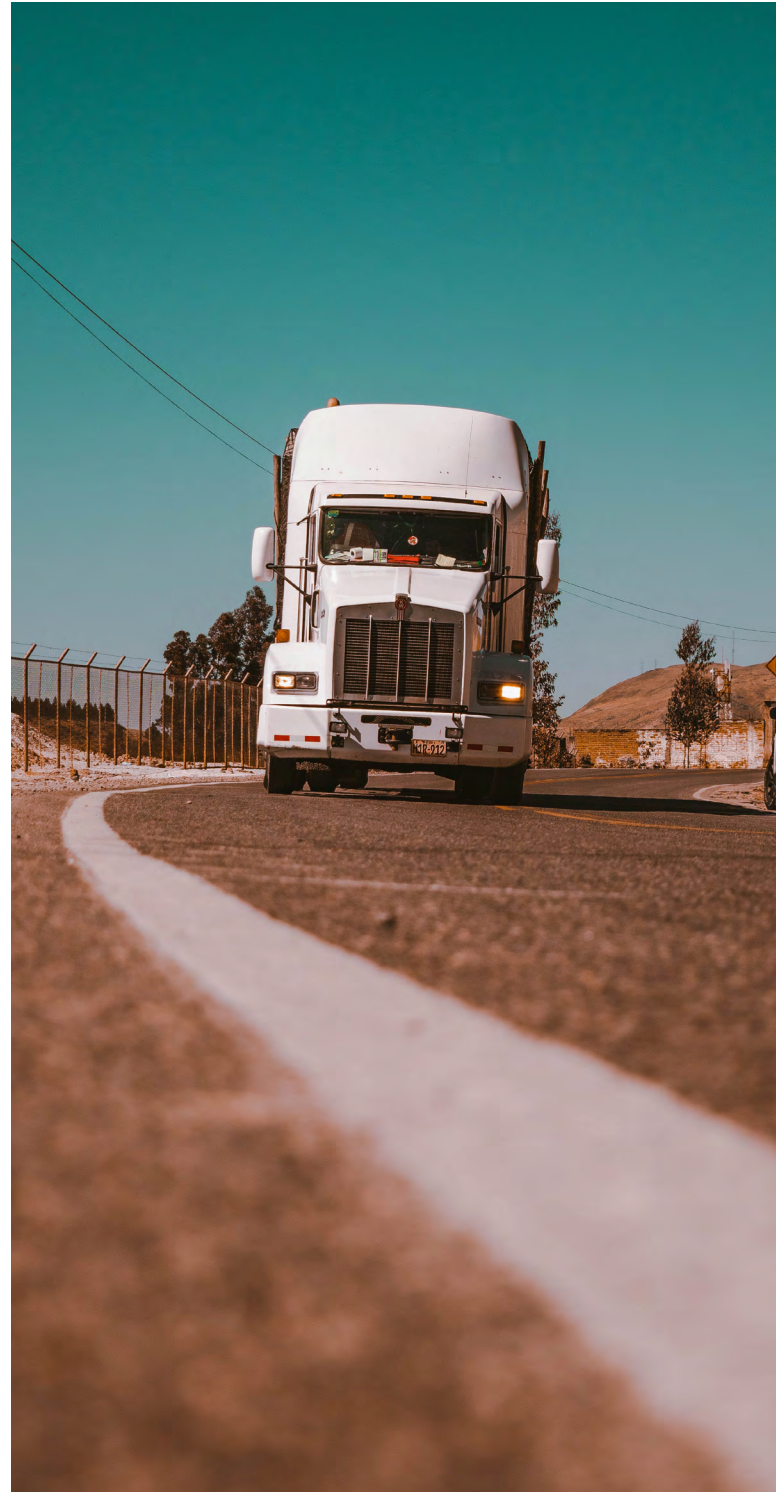


10. Fleets today are already successful with ZETs. Their experiences help identify the bottlenecks that must be addressed in the larger market in order to kick-start the transition to ZETs.

Some of the world's largest fleet owners have committed to taking action to reduce their carbon emissions in this decade. These forward-looking fleet owners are transitioning to ZETs. Fleets that are successful with ZETs share some characteristics: they match vehicles to predictable routes, have enough electrical and physical space for depot charging, receive incentives based on purchase price or distance travelled to improve vehicle TCO, have OEM support, and utilise "green corridors" that provide charging for many vehicles.

These fleet owners' success helps identify the steps necessary to enable wider adoption of BETs. They include:

- **Removing electric distribution cost and technical constraints.** Depots often have limited capacity for charging, and electrifying the full fleet can require upgrading the power grid connections at depots. EV charging loads are a new challenge for grid operators, requiring more power for more customers in less time than traditional building or industrial loads. These electric service updates require alignment between utilities, regulators, and the industry, which can, in a worst-case scenario, take years.
- **Creating truck-centric infrastructure.** Public charging is also currently focused on passenger vehicles, with pricing, locations, and layouts that may not suit trucks. For example, some trucks will require ultra-fast charging at power levels of up to 1 MW, nearly three times the level of the fastest public charging stations.
- **Achieving expected TCO.** Although BETs are at or near cost parity in the urban segment, the current TCO of a BET is higher in regional and long-haul use than a comparable diesel truck (including infrastructure). ZETs achieve TCO superiority as vehicle, electricity, and hydrogen price declines add to existing maintenance savings. HETs require greater price declines than BETs to reach TCO parity. In addition, hydrogen vehicle and fuelling technology is less available and less market proven.
- **Increasing product variety and availability.** Limitations in the quantity and variety of vehicles available inhibit fleet adoption. Vehicle manufacturers currently offer only a limited number of models to accommodate the variety of use cases among fleet operator services. Also, fleet owners experience uncertainty about product availability when placing orders.





CONCLUSION

Trucking is correlated with a country's economic health, and thankfully ZETs enable the trucking industry to grow and result in zero emissions. Trucking demand is growing just as ZETs are becoming increasingly viable. This makes reaching zero emissions very possible under several scenarios that involve government policy, technological improvements, or likely a mix of the two.

The economics vary, both by region and usage (urban, regional, and long haul). For those reasons, private financing, transport buyers, and government policy must be attuned to fleets that are less able to make the technology shift. New needs include building fuelling infrastructure and managing high initial costs. In general, sooner action is better action. An early signal allows stakeholders to plan, and encouraging fleets that have positive TCO today to adopt ZETs creates a virtuous circle of increased product development, experience, and core fuelling infrastructure. Though building the needed infrastructure is comparable to past efforts to electrify or create fuelling

networks, it is still a massive and challenging endeavour. We can learn from fleets that are already successful and follow in their footsteps.

To summarise, there is no single policy or measure that alone can decarbonise the trucking industry. Decarbonising trucking is a shared responsibility that will require action from all market participants – including manufacturers, vehicle owners, government, utilities, and energy suppliers. Collaboration between industry players across the value chain is needed, as is a portfolio of policies that address the cost of ZETs, the ability of small fleets to procure ZETs, supply bottlenecks involving ZETs, and the availability of ZET refuelling infrastructure. Resolving the sector's barriers is a shared responsibility that can be overcome with ambitious and smart policy, financing, and corporate leadership. The rest of this report seeks to elaborate on actions to take and opens the door to increased dialogue and deeper alignment on the path forward to zero-emissions trucking.





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The Mission Possible Partnership is an alliance of climate leaders focused on supercharging efforts to decarbonise some of the world's highest-emitting industries in the next 10 years.

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