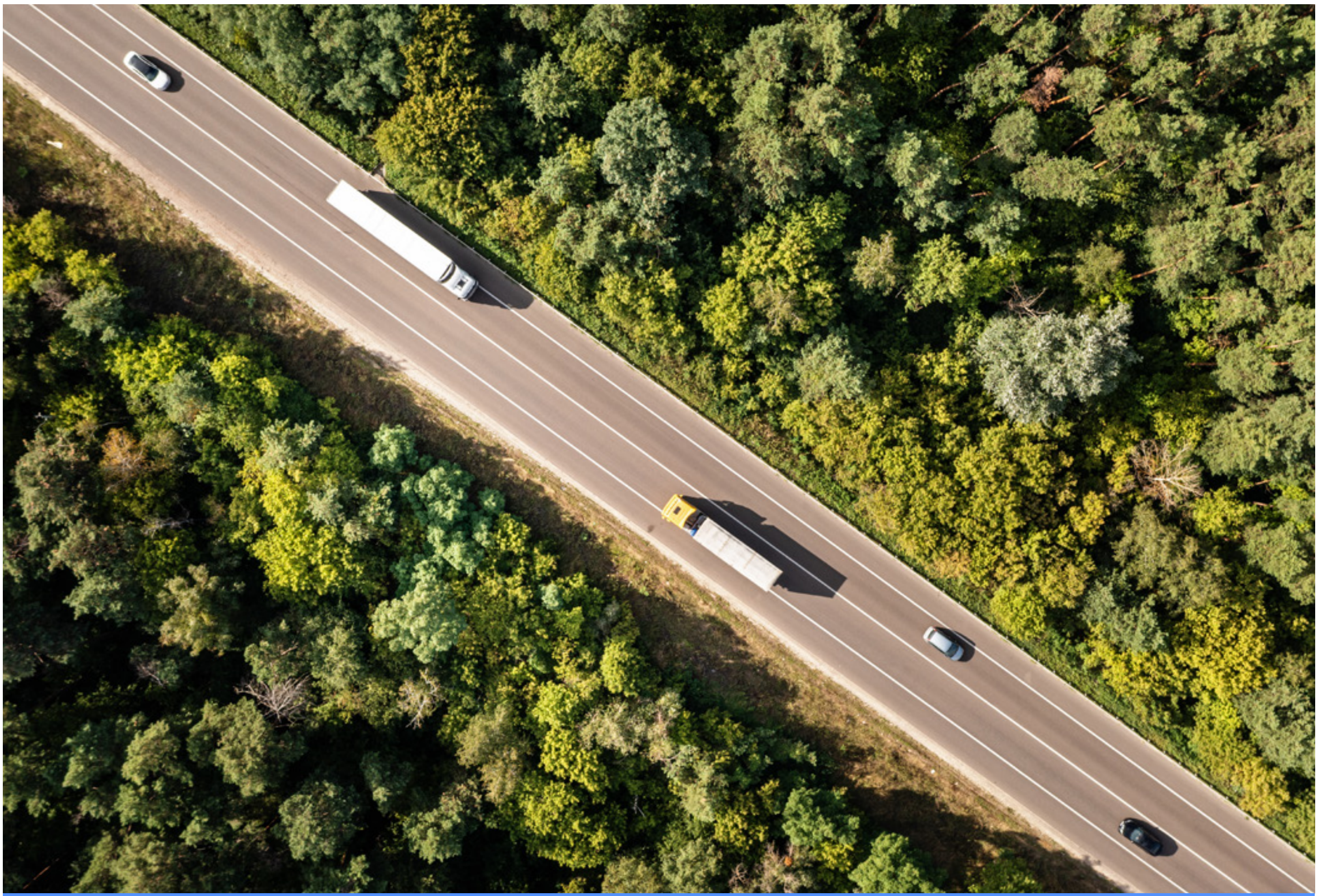
6 Trucking industry net-zero tracker

The industry must advance electric and hydrogen trucks for long-term emissions cuts, while prioritizing biofuels, synfuels and efficiency improvements for near-term impact.



- Global trucking demand is expected to double by 2050, making decarbonization of the trucking sector critical, as it remains a major source of CO_2e emissions due to continued fossil fuel reliance.
- Hydrogen- and battery-powered electric trucks are expected to be key pathways to net-zero emissions trucking by 2050.

1.3%
Increase in absolute CO_2 emissions (2022-2023)

1.1%
Decrease in emission intensity (2022-2023)

2.4%
Increase in demand (2022-2023)

TRUCKING

Key performance data 2023[223,224,225,226]

5%
Contribution to global CO_2e emissions

1.9 Gt CO_2e
Scope 1 and 2 emissions

6%
Emissions increase (2019-2023)

58 gCO_2/tkm
Emissions intensity

14%
Decrease in emission intensity (2019-2023)

2 times
Demand increase in NZE scenario by 2050, compared to 2023

<1%
Current low-emission infrastructure

~$9 trillion
Additional investment required for net zero by 2050

Performance summary

- The direct emissions[227] were 1.89 Gt CO_2e[228] in 2023, a 6% reduction from 1.78 Gt CO_2e[229] in 2019.
- The industry has decreased emission intensity by 14%[230] in the last five years, driven by improvements in fuel efficiency.
- Activity is at all-time high, at 32.8 trillion ton-km[231] in 2023 as sector recovers from the COVID-19 pandemic, compared to 26.6 trillion ton-km in 2019.
- Low-emission fuel consumption contributed 4%[232] to the total fuel share of the heavy-duty trucking sector.
- Energy intensity was reduced by 15% from 1.24 MJ/ton-km in 2019 to 1.05 MJ/ton-km in 2022.[233]

Future emissions trajectory

- The industry is forecast to reduce emissions intensity by 28% by 2030 and 94% by 2050, compared to 2023 levels, according to the IEA.[234] The direct CO_2e emissions are expected to be 1.4 Gt in 2030 and 0.22 Gt in 2050.[235]
- According to MPP, 7 million[236] zero-emission trucks will be required by 2030 to align with net-zero emissions by 2050.

Readiness key takeaways

Technology — 3

- Compressed and liquified biogas and synfuels technologies (being the most mature) are in the early adoption stage (TRL 9).[237]
- Hydrogen fuel cell technology is in the demonstration stage (TRL 8), and battery electric trucks are in commercial operation in the relevant environment stage (TRL 9). However, hydrogen internal combustion (hydrogen IC) trucks are in the prototype stage.[238]

Infrastructure — 1

- Current infrastructure capacities are insufficient, as less than 1% of the necessary infrastructure is in place. This falls short of what is needed to enable the adoption of battery-electric trucks (BETs) and hydrogen-electric trucks (HETs).[239]
- Approximately 700 GW of clean power and 50 MTPA of hydrogen infrastructure is required for net-zero emissions by 2050.[240]

Demand — 2

- Approximately 4% of current trucking fuel consumption comes from low-emissions sources.[241]
- The green premium is estimated at 80% for manufacturers and original equipment manufacturers (OEMs), which translates to 1-3% for end consumers.[242]

Capital — 1

- Up to $9 trillion[243] additional cumulative investments are required by 2050 to achieve net-zero emissions by 2050, translating to an additional $320 billion annually until 2050.
- Currently, the trucking sector has an annual CapEx of $286 billion.[244]

Policy — 3

- Stricter GHG standards and ambitious ZET targets are being announced by governments. There is an increasing set of policies for infrastructure deployment strategy, incentives, subsidies, weight and dimension allowance, and carbon tax.

Sector priorities

Company-led solutions

Mid-term (by 2030)

- Accelerate the adoption of drop-in biofuels and synfuels in the interim.
- Invest in the development of BETs and HETs.
- Make use of efficiency and design improvement opportunities at an accelerated pace.

Long-term (by 2050)

- Accelerate the development of hydrogen- and battery-electric technologies for long-haul applications.

Ecosystem-enabled solutions

Mid-term

- Invest in clean power infrastructure to increase access to renewable energy sources.

Long-term

- Invest in R&D to accelerate the deployment of ultra-fast charging infrastructure.
- Coordinate with other sectors to achieve economies of scale for biofuels, hydrogen and grid requirements.

Performance

The sector currently accounts for 5%[245] of global direct CO_2e emissions. Fossil fuels account for approximately 96%[246] of fuel consumption in the industry, making them a critical driver for emission intensity.

TABLE 8

Trucking industry performance

Performance metric	Change (2019-2023)
Industry activity (trillion ton-km)	+23%[247]
Emission intensity (gCO_2/ton-km)	-14%[248]
Total CO_2e emissions	-6%[249]

In 2023, the trucking sector produced 1.89 Gt CO_2e in direct emissions, marking a 6% increase from 1.78 Gt CO_2e in 2019.[250] Despite the growth in emissions, the industry has made significant strides in reducing emission intensity, achieving a 14%[251] reduction over the past five years due to improvements in fuel efficiency. Trucking activity reached an all-time high of 32.8 trillion ton-km in 2023, compared to 26.6 trillion ton-km in 2019, as the sector recovered from COVID-19 pandemic-related disruptions.[252]

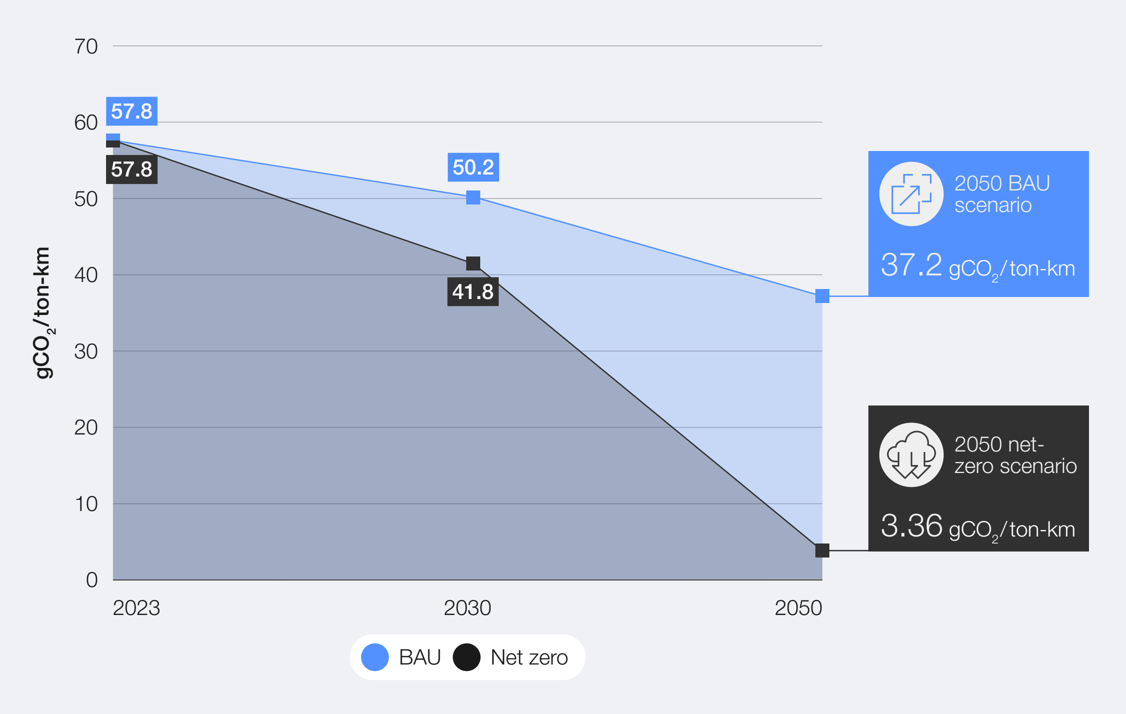
The sector's energy intensity dropped by 15%, from 1.24 MJ/ton-km in 2019 to 1.05 MJ/ton-km in 2022.[253] Low-emission fuels, while representing a small share of the total fuel used in the sector, highlight the growing (albeit slow) shift away from diesel. For example, Tesla delivered its highly anticipated Tesla Semi,[254] marking a major step towards the electrification of long-haul trucking. The electric trucks, delivered to PepsiCo, demonstrated a range of up to 500 miles on a single charge, pushing the boundaries of what electric trucks can achieve in long-haul operations.

However, with global trucking demand expected to double by 2050,[255] further innovation and policy actions are essential to accelerate the sector's transition to net zero.

Readiness

FIGURE 35

Emissions intensity trajectory for the trucking sector



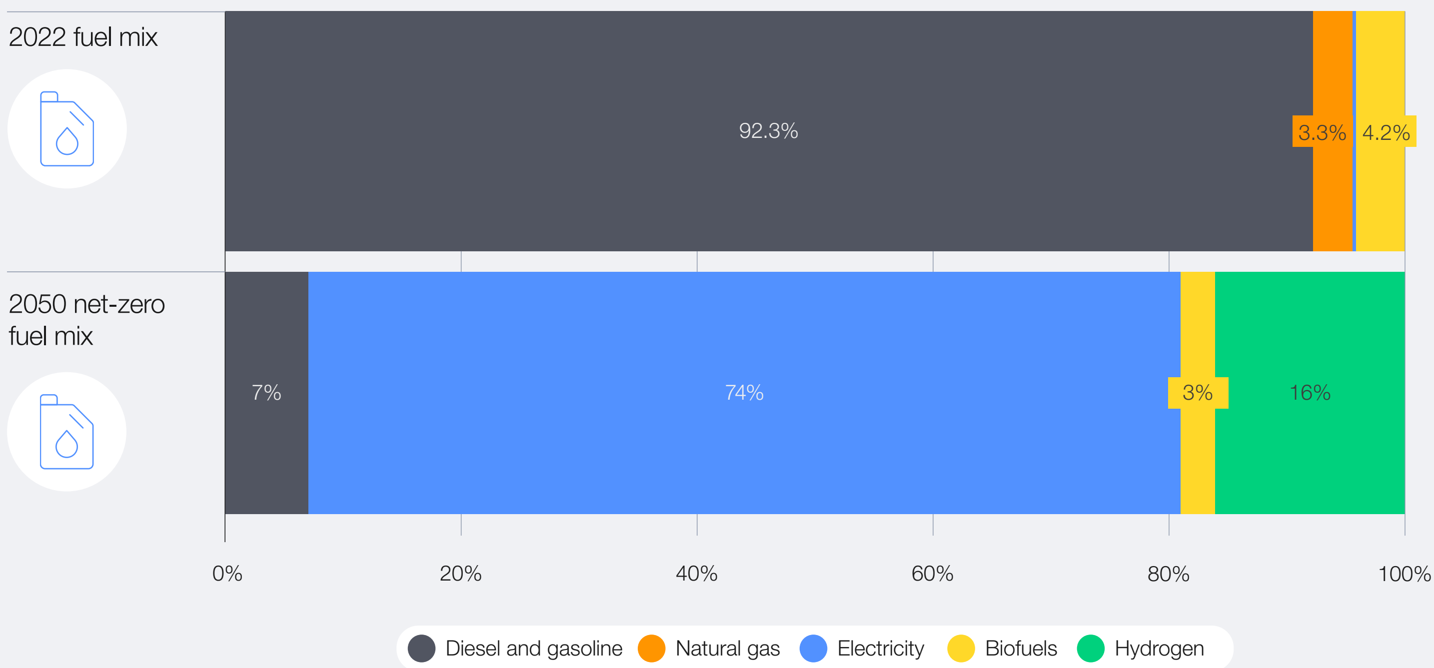
Source: IEA Net Zero Scenario.

The trucking industry is on a path to significantly reduce its carbon emissions, with the goal of cutting emissions intensity by 28% by 2030 and 94% by 2050, according to the IEA's Net-Zero Scenario.[256] By 2050, direct CO_2e emissions are expected to drop to just 0.22 Gt, down from 1.89 Gt in 2023.[257] Achieving this goal will require the deployment of 7 million zero-emission trucks by 2030, as outlined by the Mission Possible Partnership (MPP).[258] Currently, the adoption of alternative fuel technologies remains in the early stages: compressed and liquified biogas and synfuels are in their mature phase but still early in market penetration, while BETs and HETs are in the demonstration phase.

Infrastructure readiness is a critical challenge, with less than 1%[259] of the necessary infrastructure for BETs and HETs in place. Massive clean energy investments are needed, including 700 GW of renewable power and 50 million tons per annum of hydrogen capacity by 2050.[260]

The shift to zero-emission trucks comes with high costs; the green premium for manufacturers stands at 80%, which translates to a 1-3% price increase for consumers.[261] Up to $9 trillion[262] in additional investments are required by 2050, amounting to an extra $320 billion annually. Despite these challenges, governments are announcing stricter emissions standards and more ambitious zero-emission truck targets, with global collaboration on infrastructure expected to accelerate innovation and adoption.

FIGURE 36 **Fuel mix in 2022 and 2050 (NZE Scenario)**



Source: IEA Net Zero Scenario.

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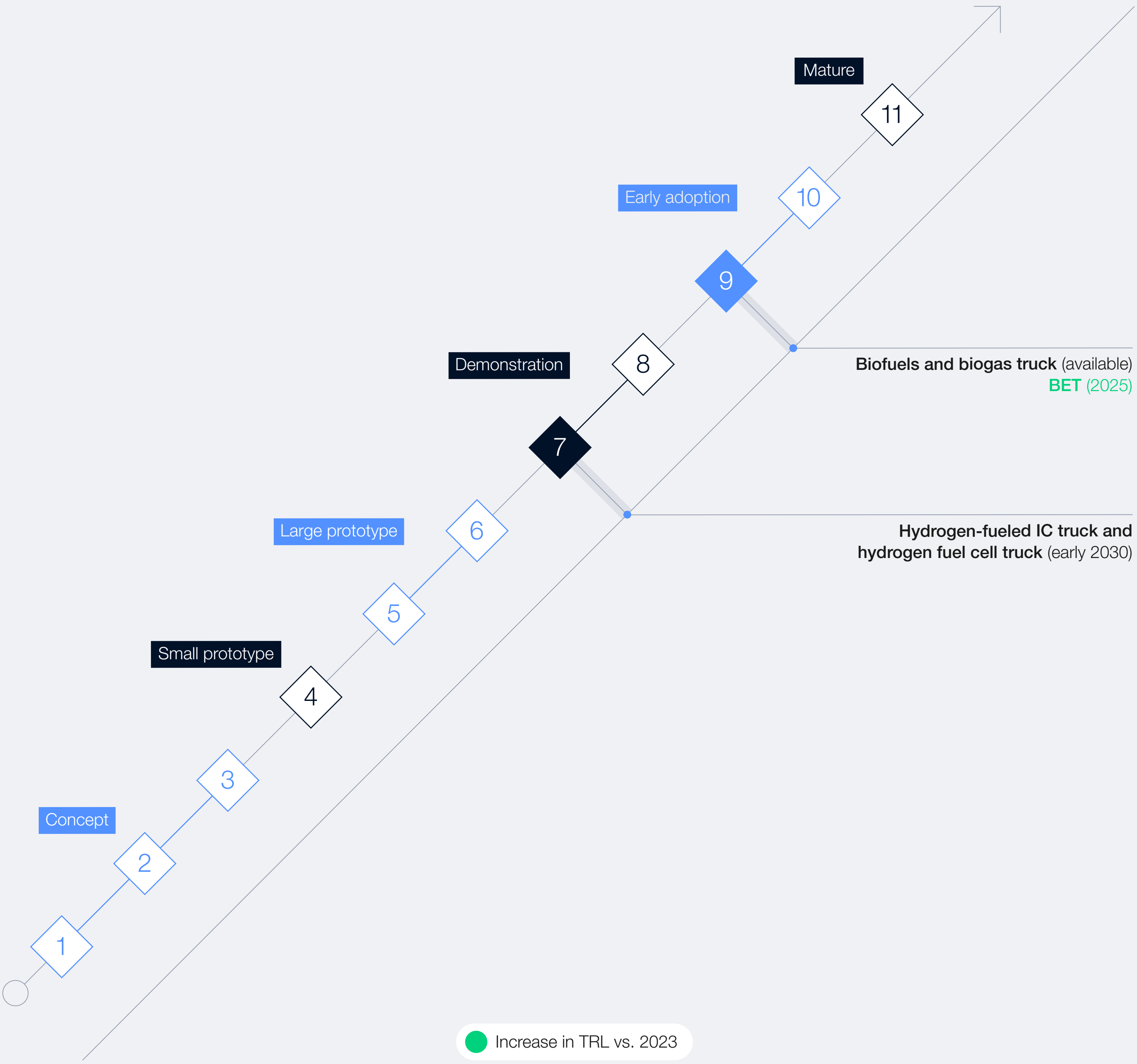
3 Technology

Technologies to achieve net-zero emissions are at different readiness levels. Two leading levers have emerged: BETs and HETs.

FIGURE 37 **Decarbonization TRLs and year of commercial availability**



Source: Accenture analysis based on data from IEA ETP Clean Energy Technology Guide and MPP.

Technology lever 1: BETs

BETs are in the early adoption stage with a TRL at 8-9.[263] Electric trucks use batteries (today almost exclusively lithium-ion batteries) arranged in a battery pack. The battery pack is combined with inverters and an electric motor to convert electrical energy into mechanical energy. Heavy-duty trucks in particular require either devoted infrastructure (e.g. battery swapping) or high-energy density battery chemistries (e.g. solid-state batteries, as of 2023, are at the prototype level) to be competitive. Medium-duty trucks have similar (but less demanding) requirements.

Technology lever 2: HETs

HETs are based on two types of technology: hydrogen fuel cell trucks (TRL 8-9[264]) and direct hydrogen internal combustion trucks (TRL 7). Hydrogen fuel cell trucks have significant advantages for long-haul trucking. Compared to BETs, they offer longer driving ranges and faster refuelling times – typically within 10 to 15 minutes,[265] which is similar to conventional diesel trucks. In addition, fuel cells can consistently provide power without the need for large, heavy battery packs, making them a viable option for heavier freight transport.

Hydrogen internal combustion trucks involve combusting hydrogen directly in an engine that does not rely on fuel cells. Although less energy efficient than fuel cells today (40-50% efficiency for hydrogen engines vs. 50-60% for fuel cells[266]), the hydrogen engine does not require rare materials like platinum and could represent a cost-effective solution. Hydrogen internal combustion engines may also offer transient behaviour that performs more effectively and is easier to regulate than fuel cells. Over the longer term, it could also reach up to 55%[267] energy efficiency for trucks; as such, it could be particularly suitable for heavy-duty applications. R&D (at TRL 5-6[268]) is currently underway to improve fuel efficiency, which is another key area of future development for this technology.

TRUCKING

1 Infrastructure

The commercial deployment of BETs and HETs depends heavily on the availability of essential infrastructure. Currently, less than 1%[269] of the required infrastructure is in place, which is inadequate to support the widespread adoption of BETs and HETs. To meet the projected goal of having 53% BETs and 47% HETs on the road by 2050, the trucking industry will need a substantial increase in clean power and hydrogen production capacity to meet expected 700 GW of clean power and 50 MTPA of hydrogen infrastructure capacity by 2050.[270]

For BETs to become feasible for medium- and long-haul transport, they need access to charging infrastructure, both on-site and on the road. By 2050, an estimated 31 million EV public charging points will be required to meet the rising demand for BETs.[271] HETs require access to on-site hydrogen refuelling infrastructure. An estimated 46,000 hydrogen refuelling stations are required to meet the demand for HETs by 2050.[272]

FIGURE 38 **Infrastructure for decarbonization capacity**

	Current capacity used	Capacity required (2050)
Clean power generation	Approximately 0 GW	Approximately 700 GW
Clean hydrogen production	Approximately 0 MTPA	50 MTPA
Charging and refueling infrastructure	Less than 1%	31 million public charging points 46,000 refuelling stations

Source: Accenture analysis based on data from IEA and MPP.

TRUCKING

2

Demand

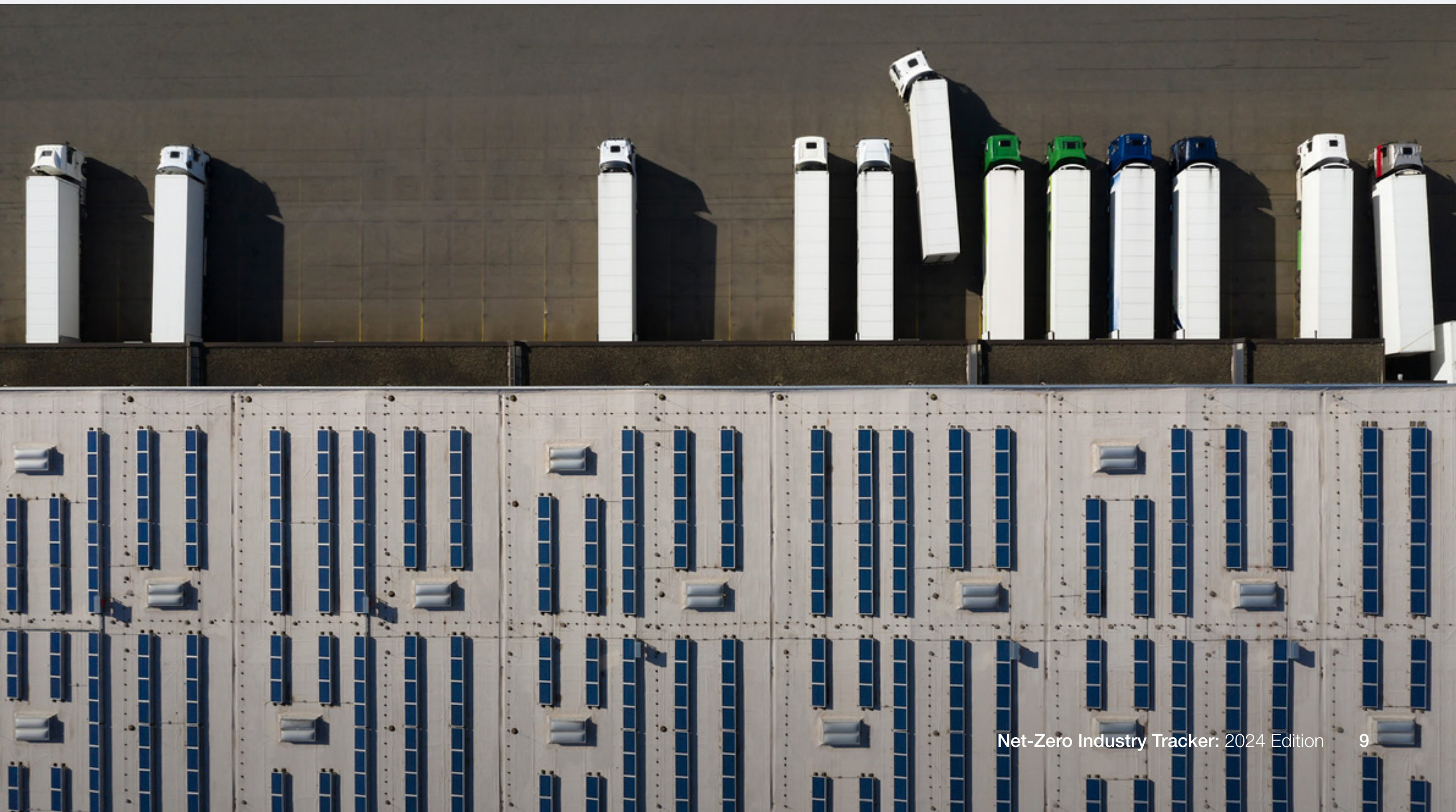
Sales share of plug-in hybrid, battery and fuel cell electric heavy trucks was less than 1% in 2022 and is expected to increase to 37% of total global sales by 2030.[273] This growth is driven by a combination of stricter emissions regulations, advancements in EV technology and increased demand. Leading truck manufacturers, such as Volvo, Daimler and Tesla, are launching new electric truck models, contributing to the anticipated surge in sales. China continues to lead on deployment of electric trucks, with over 70% of global electric truck sales in 2023.[274]

For manufacturers and OEMs, the green premium is estimated at 80%,[275] reflecting the higher costs of producing electric or hydrogen-powered trucks compared to conventional diesel models. However, for end consumers, this translates to a more manageable 1-3%[276] increase in the total cost of ownership, showing that while upfront manufacturing expenses are high, the impact on consumer prices is relatively modest. This green premium highlights the financial challenge the industry faces in scaling low-emission technologies.

FIGURE 39 **Global sales share of electric trucks[277] (2022) and hydrogen commercial vehicles[278] (2023)**

Electric truck registrations and sales share by region, 2022	
1 China	86%
2 US	5%
3 Europe	5%
4 Others	4%

Global sales of fuel cell commercial vehicles, 2023	
1 China	95%
2 US	3%
3 Europe	1%
4 Others	1%



1

TRUCKING

Capital

Achieving net-zero emissions in the trucking industry by 2050 will require substantial financial investment. An estimated $9 trillion[279] in additional cumulative investments is needed by 2050, which translates to an annual investment of $320 billion until 2050. This is a significant increase from the current annual capital expenditure (CapEx) of $286 billion in the trucking sector. These investments will be crucial for scaling up clean energy infrastructure, developing zero-emission vehicle technologies, and transitioning to alternative fuels like hydrogen and electricity. This funding will support the expansion of BETs and hydrogen fuel cell trucks, and the development of refuelling and charging networks. Without this financial commitment, the industry will struggle to meet its emissions-reduction targets and the growing demand for sustainable transportation.

FIGURE 40 **Investments required by the sector and enabled by the ecosystem**

Approximately **$9 trillion** required in investment by 2050

Investments by the sector (around 66% of investments)

- Scale manufacturing and battery technology (BETs)
- Invest in battery recycling for sustainable disposal (HETs)
- Improve battery energy density to increase hauling and/or range performance (HETs)
- Develop fuel cell technology to reduce costs (HETs)
- Increase production of hydrogen fuel cell trucks (HETs)
- Enhance hydrogen storage technologies for safety and efficiency (Biofuels and biogas)
- Modify engines to run on biofuels effectively (Biofuels and biogas)

Enabled by the ecosystem (around 34% of total investments)

- Build rapid charging infrastructure for heavy trucks (BETs)
- Expand grid capacity for increased electricity demand (BETs)
- Integrate renewable energy for powering charging stations (HETs)
- Expand hydrogen refuelling station networks (Biofuels and biogas)
- Produce green hydrogen from renewable sources (Biofuels and biogas)
- Develop sustainable feedstock for biofuels (Biofuels and biogas)

BETs · HETs · Biofuels and biogas

Source: Accenture analysis based on data from MPP.

3

TRUCKING

Policy

Global trucking activity is highly concentrated in US, Europe, China and India. This underscores the importance of implementing effective and tangible policies to improve the adoption of zero-emission trucks in these regions.

In 2022, more than 70% of heavy-duty vehicles (HDVs) sold were subject to fuel economy or vehicle efficiency regulations, an increase from 60% in 2017 – though this figure is down from a peak of 80% in 2020 due to rising sales in countries without such policies.[280] While many countries are setting ambitious emissions targets, advanced economies could take cues from the European Union, the US and China by implementing a mix of regulations and incentives to effectively address CO_2 emissions from HDVs.

TABLE 9 **Trucking industry policy summary**

Policy type	Policy instruments	Key examples	Impact
Market-based	**Carbon price**	UK Carbon Pricing Mechanism[281]	Establishes a financial cost for carbon emissions, incentivizing trucking companies to adopt cleaner technologies and reduce emissions.
	Border adjustment tariff	EU Carbon Border Adjustment Mechanism (CBAM)[282]	Imposes tariffs on imports based on carbon emissions, encouraging domestic trucking companies to lower their emissions and compete effectively against foreign firms.
	Product standard	California's Low-Emission Vehicle Program[283]	Sets strict emissions standards for HDVs, promoting the development and sale of cleaner trucks and driving manufacturers towards zero-emission vehicles.
Mandate-based	**Direct regulations**	EU Revised CO_2 emission standards for Heavy-Duty Vehicles[284]	The revised CO_2 emission standards for HDVs will be key to drive down emissions in the road transport sector and ensure the increasing supply of new zero-emission vehicles (ZEVs) to the market.
	Direct regulations	EU Alternative fuels infrastructure[285]	More recharging and refuelling stations for alternative fuels will be deployed in the coming years across Europe. This will enable the transport sector to significantly reduce its carbon footprint following the adoption of the alternative fuel infrastructure regulation (AFIR).
	Government targets	EU Emissions Trading Scheme for transport[286]	Revised CO_2 standards for HDVs and the Alternative Fuels Infrastructure Regulation will aid heavy-duty ZEV deployment.
Incentive-based	**Incentives**	EU Eurovignette Directive[287]	The directive is expected to incentivize the use of cleaner trucks, discourage the use of less-efficient trucks and reduce diesel consumption and emissions.
	Incentive-based subsidies	US Federal Electric Vehicle Tax Credit[288]	Provides financial incentives for purchasing electric trucks, lowering the upfront costs for fleet operators and accelerating the transition to zero-emission vehicles.
	Incentives	California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project[289]	Offers vouchers to fleet operators for purchasing clean trucks, incentivizing the shift to low-emission vehicles and helping offset initial costs.
	Direct R&D funds/grants	US Department of Energy's Vehicle Technologies Office[290]	Funds R&D projects focused on advanced vehicle technologies, including electric and hydrogen fuel cell trucks, encouraging innovation and reducing costs over time.

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