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ELECTRIFYING THE FUTURE OF ON-ROAD HDVS

JUNE 2024

INDUSTRY BRIEF – CLEAN MOBILITY

Executive summary

Road transport accounts for about 75% of transport emissions worldwide and is responsible for around 21% of total emissions. More than a third is directly related to medium and heavy-duty vehicles (MHDV) i.e., buses and trucks, the bulk of which relates to freight.

With major economies gradually aligning themselves with the goals of the Paris Agreement, the transition to electric mobility is now inevitable. Consequently, the industry has begun its pivot, starting with passenger mobility, for which the transition to pure-electric reached the 5% tipping point in 31 countries in 2023; this is only the beginning. Not only are most major MHDV manufacturers gradually committing to increase their zero-emission vehicle (ZEV) sales share (>50% by 2030, and 100% between 2035-2040), but customers, both public authorities and private companies, are driving the adoption, complying with tightening regulations and satisfying end-user requirements. Indeed, major fleet operators are now pledging to electrify their MHDV fleets, with ZE targets ranging from 50% to 100% by 2030.

Still, as usual, the entire investment decision process remains driven by total cost of ownership, heavily dependent on operation costs, i.e., adopting cheap energy and/or energy efficient mobility alternatives. As electrification continues, not only are sourcing and manufacturing costs set to decrease, but every kWh available from the grid should get cheaper, thereby allowing for cost-competitive solutions.

As a consequence, while we expect Europe and specific regions like California to remain the most dynamic in terms of electric MHDV registrations, North America and developed regions across the world should gradually follow in embracing the transition. By 2035, close to 290k transit buses in key European, NAM and APAC regions as well as 750k HDV trucks in NAM alone should be electrified, respectively representing addressable markets of >EUR130bn and >USD240bn, several technology options already being available to market and innovations gradually closing the gap with traditional ICE vehicles in terms of logistics. This change in paradigm is ultimately driving the need for ZE-mobility infrastructure, for which public signals and private resources are optimizing the pace of adoption, capitalizing on renewed grid expansion momentum while boosting investments to provide visibility on EV charging and refueling schemes where needed.

01

CURRENT STATE OF ON-ROAD HDVs

UNDERSTANDING THE MARKET DYNAMICS AND ENVIRONMENTAL IMPACT

As environmental concerns increase, the need for a transition to electric heavy-duty vehicles (HDVs) becomes increasingly pressing. Despite the current dominance of diesel HDVs on the roads, the momentum driving the electrification of HDVs continues growing.

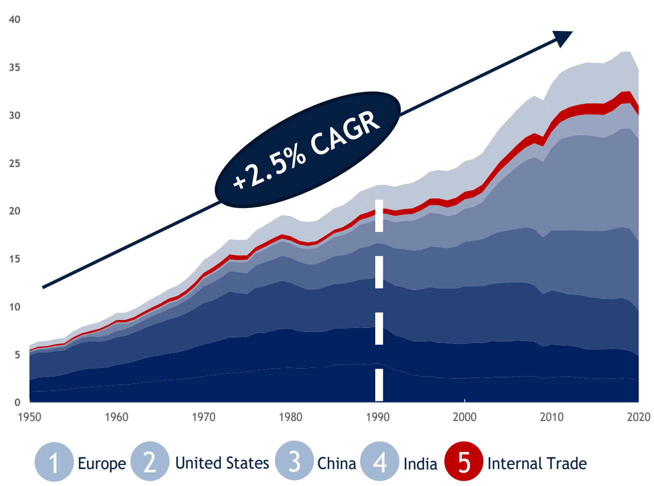
Zero Emission mobility ecosystem, visible opportunity ahead

Yesterday's legacy, a worldwide issue for today's generation

Carbon awareness clears the path towards a greener future

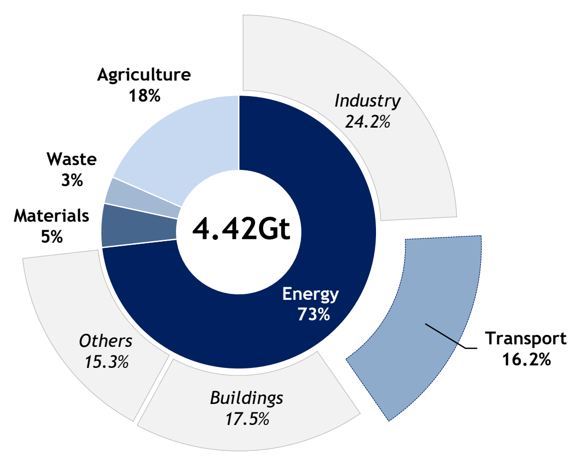
Carbon dioxide (CO2) is the biggest contributor to global warming, estimated to be responsible for around two-thirds of the increase in temperature since the pre-industrial era. Close to 40 gigatons of CO2 equivalent have been emitted into the atmosphere worldwide. The European Union is the world's third-largest emitter of GHGs and has a crucial part to play in achieving the 1.5°C target of the Paris Agreement. Between 2017 and 2021, domestic and international transport was responsible for more than 27% of total economy-wide GHGs in the EU, with France standing at more than 31% (because of its greener energy mix related to nuclear). This represents close to 100k premature deaths due to exposure to fine particles in France, which is more or less equivalent to a Covid crisis each year. As such, even with a sharp take-off in EVs, transport remains a key obstacle to decrease urban air pollution and meet the EU's climate targets.

Figure 1 - Global CO2-CH4 emission trends between 1950 and 2020 (in Gt/year)



*Source: Climate Watch, Stifel**

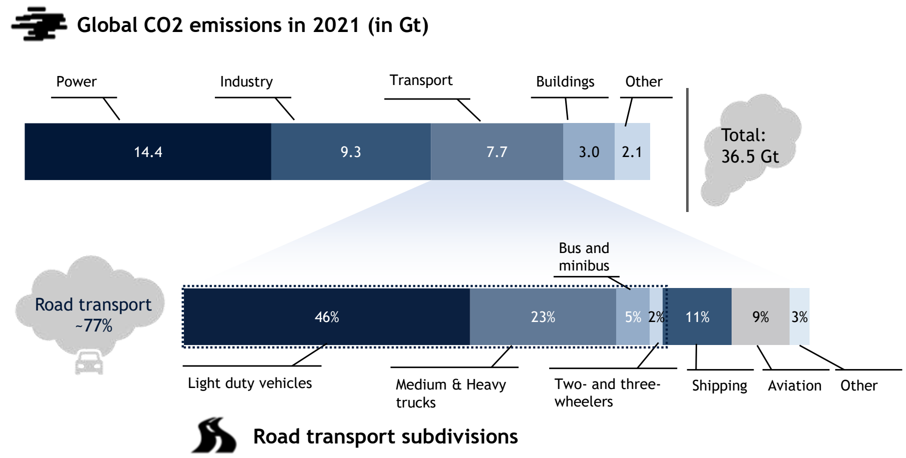
Figure 2 - European GHG emissions breakdown by sector in 2016



Source: Climate Watch, the World Resources Institute

Europe expects to reach net-zero by 2050. Aggressive commitments have been made by European regulators and European countries are applying the scheme locally with implied carbon budgets tightly set. Since 1990, transport emissions in the EU have grown by 33% even as other sectors have reduced emissions by 32%. According to the ICCT, even under the most ambitious transition scenarios, the EU transport sector as a whole could emit more than the entire EU economy's share of the global carbon budget to limit global warming to 1.5°C. The window for achieving net-zero emissions in the road transport sector by 2050 is closing quickly. An immediate increase in policy action has taken place to bend the curve towards net zero. Investments in public/goods transit and electric mobility have been prioritized as they are an important part of the solution mix for net zero. This has been reducing demand for ICE vehicles while also delivering public-health benefits, with a sharp take-off in demand for LEV (NGV, HEV and PHEV) and ZEV (BEV, FCEV and H2V) over the last couple of years. Likewise, at the municipal level, tighter regulations for vehicles entering urban areas are helping to make the economics of ZEV more attractive, especially for public and commercial fleet operators.

Figure 3 - Transport related CO2 emissions breakdown in Europe as of 2022



*Source: IEA, Stifel**

In this respect lorries, buses and coaches are responsible for more than a quarter of GHG emissions from road transport in the EU, and over 6% of total EU GHG emissions. Whereas buses represent only a small portion of heavy mobility (9x more for trucks than for buses/coaches combined as of 2021 according to the ACEA), they have a major role to play in paving the way and advertising government and municipality efforts to bend the curve. Led by public tenders, local regulations/municipal incentives and investment flows are tending towards a broad electrification of utility fleets, and e-buses should continue their progression.

HDV markets, underestimated e-mobility play

Who's who: a guide to determining available bus pools

The bus market encompasses various categories of bus, each catering to specific transport needs and usage scenarios. Below is an overview of the three major categories of buses: city buses, intercity buses, and school buses.

1. City or transit bus carrying utility services

Also known as urban buses, these buses are primarily used for public transport within cities, transporting passengers along predefined routes within urban areas. Typically designed to host high passenger capacity, featuring both seating and standing areas, these are robust enough to allow fast on-boarding as well as an intense stand-and-go routine to accommodate as many commuters as possible. While the design of transit buses varies across regions depending on cultural factors and specific needs, close to 80% of the market is composed of (i) standard single-deckers (12m buses, ~65-70% of the market), and (ii) articulated buses (18m buses, 10-15% of the market), the remaining being either minibuses, double-deckers or airport shuttles.

2. Intercity buses and coaches, for peripheral and longer-distance connections

Intercity buses, alternatively referred to as coaches, are specifically designed for travel between cities or regions. This medium to long-haul aspect comes with more challenging constraints in terms of autonomy/power capacity, storage and security. Indeed, while a typical bus speed is lower than 50km/h on average, a coach requires much higher capabilities allowing for a ~90-100km/h typical run-rate. A perfect alternative to air, rail and individual transport, these vehicles have been widely deployed, still with diesel engines, and should either be retrofitted or replaced with greener solutions going forward (RNG, electric whether battery or fuel cell).

3. School buses, where safety is the primary focus

These are exclusively designed to transport pupils/students to and from schools/establishments. Safety is of primary focus, with reinforced vehicles equipped with additional lights, high-visibility coverings while providing enough seats to accommodate with stringent safety standards. As such, school buses can be considered as hybrids between buses and coaches, predominantly existing as a dedicated vehicle category in NAM, otherwise served with mini/transit buses as in Europe.

Figure 4 - Ebusco' 3.0 12-18m, the rolls of transit BEB

Source: Ebusco

Figure 5 - DAI's Travego, EU's bestselling coach

Source: Daimler Trucks

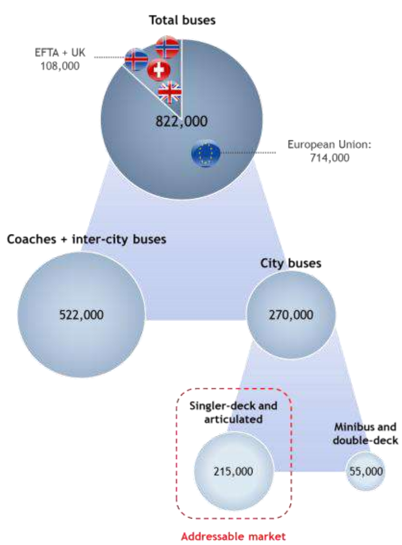
Figure 6 - Thomas Built's flagship Saf-T-Liner school bus

Source: Thomas Built

Deep dive into European and NAM bus markets

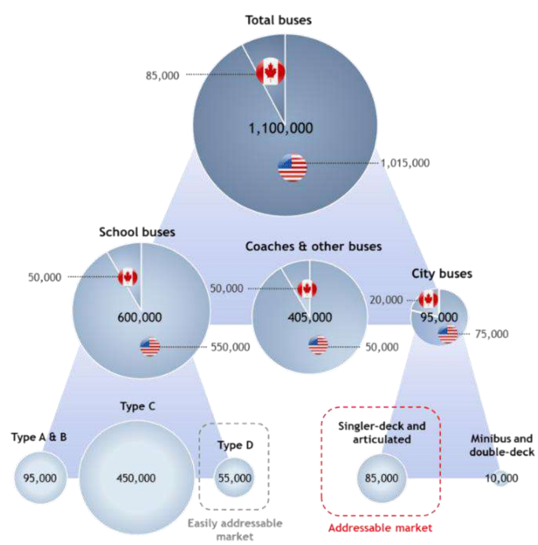
According to the ACEA, the total European bus market comprises approximately 0.8m buses. While school buses exist in most European countries, there is no specific legislation or design standard for these buses. Analyzing the bus fleet in various European countries (France, Germany, Italy and Spain), indicates the entire European fleet consists of approximately 270k city buses. However, this figure includes double-decker buses (predominantly specific to the UK) and minibuses, which are not addressed by Ebusco. Roland Berger's estimates indicate that these categories collectively account for around 20% of the total fleet, i.e. approximately 55k vehicles.

Figure 7 - Sizing the European bus markets, where growth lies in the short-medium term



Source: ACEA, Chatrou CME Solutions, Stifel*

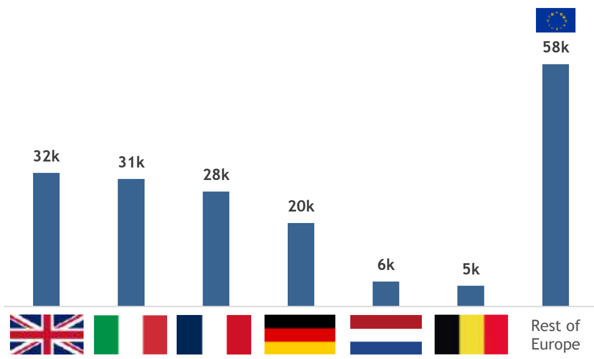
Figure 8 - NAM, adding to the European pool and tilting addressable markets further



Source: FTA, FHWA, APTA, Schoolbusfleet, Stifel*

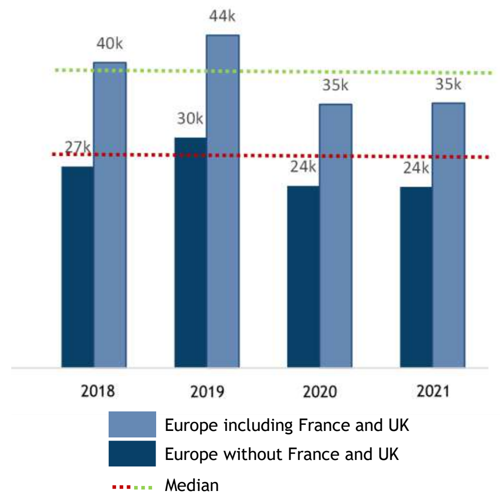
In North America, there are approximately 1.1m buses, the bulk of which identified as school buses (55%) and the remaining as 405k coaches and inter-city buses (37%), and 95k city buses (8-9%). However, the US accounts for approximately 90% of the North American bus market, with Canada only adding the remaining 10%. This highlights the fact that the proportion of city buses in NAM (9% of total buses and coaches) is relatively lower than in Europe. This disparity can be attributed to factors such as urban sprawl, lower population densities in certain areas, and a cultural preference to rely on private/personal vehicles.

Figure 9 - Number of buses in major European countries in 2020



Source: ING, ACEA, Stifel*

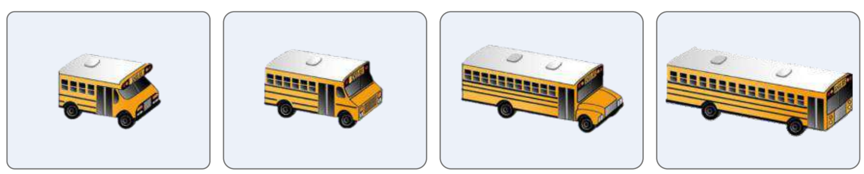
Figure 10 - Total new bus and coach registrations in Europe between 2018 and 2021



Source: ING, ACEA, Stifel*

The direct addressable markets for Ebusco in Europe and North America combined could therefore be estimated at approximately ~300k buses, i.e. 20-21k/year (10-15 year lifetime on average, 12 years according to the FTA). Looking specifically at Europe, out of 36k buses and coaches registered per year, about 50% correspond to buses (80% related to transit).

Figure 11 - Overview of school bus pools in North America



Type	Type A	Type B	Type C	Type D
Description	A **small** conversion bus with a left side vehicle driver's door. Constructed utilizing **cutaway chassis.**	A **small** school bus with the entrance door located behind the front wheel. Constructed utilizing **stripped chassis.**	A **large** school bus with the entrance door located behind the front wheel. Constructed utilizing **cutaway or hooded chassis.**	A **large** bus with the entrance door located ahead of the front wheels. Constructed utilizing **stripped chassis.**
Style	Van-style	Integrated-conventional	Conventional	Transit-style
Length	4-8m		7-12m	10-13.5m
Capacity *(# pax)*	10-30		54-78	72-90
% registrations *(last 10y average)*	19%		72%	9%

Source: Stifel*

Considering the similarities between Type D school buses in North America (even referred to as "transit school buses") and public transit buses, synergies exist in adapting the latter to the specifics of school transit buses. However, it is important to recognize that the school bus industry has its own set of regulations and safety standards that may differ from those applicable to transit buses. Consequently, a transit bus manufacturer looking to enter the school bus market would need to ensure that their Type D school bus complies with all specific requirements regarding design, safety, and equipment for school buses. Nevertheless, as of 2022, the type D school bus segment would have accounted for approximately 55k buses, i.e. less than the number of transit buses in Mexico.

02

PATHWAYS TO ELECTRIFICATION

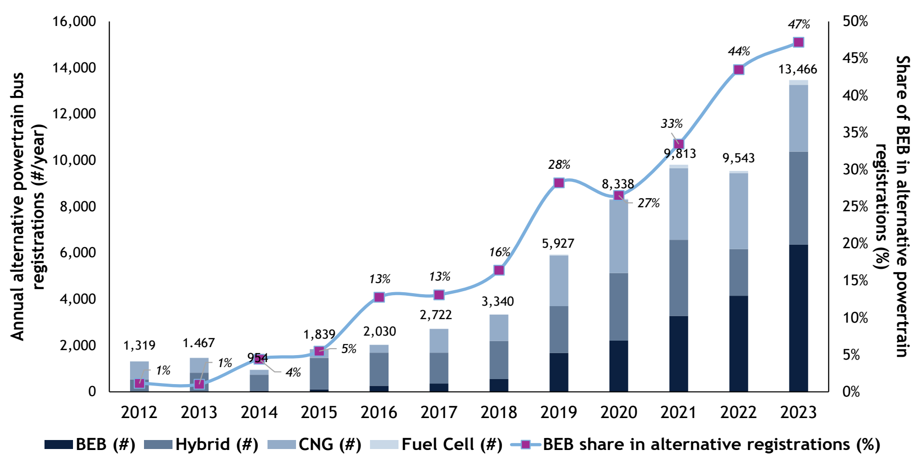
TECHNOLOGICAL ADVANCES AND MARKET READINESS

The roadmap to electrification is paved with technological advancements designed for electric HDVs, including battery innovations and the development of recharging infrastructure.

Wide-scale electrification ongoing

Whereas the global automotive industry experienced a slowdown due to supply chain disruption and weaker market visibility between 2020 and 2022, the European bus market showed resilience with steady sales volumes, experiencing only a marginal decline of 0.2% in FY21 (vs. -25% for the industry). According to Chatrou CME Solutions, ZEB registrations, which accounted for less than 3% in 2018, surpassed diesel bus sales in Europe for the first time in Q1 2023, capturing a 29% market share compared to 25% for diesel buses, with 97% of newly-registered ZEBs being battery electric buses (BEBs) resulting in a 66% CAGR for BEB registrations between 2018 and 2022.

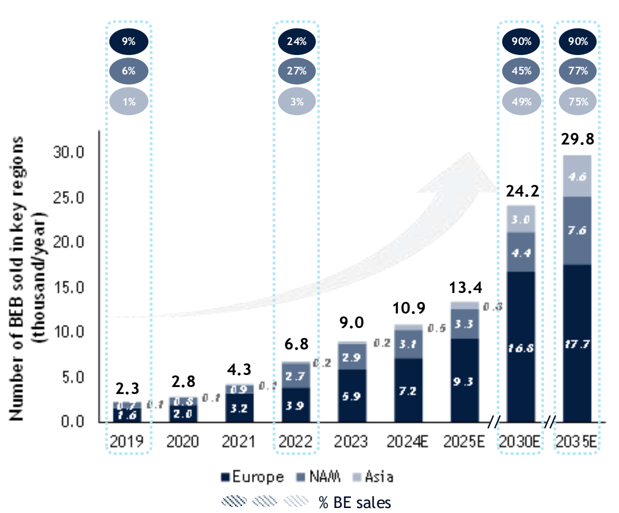
Figure 12 - Alternative bus powertrains sales in Europe from 2015 to 2022



*Source: Chatrou CME Solutions, Stifel**

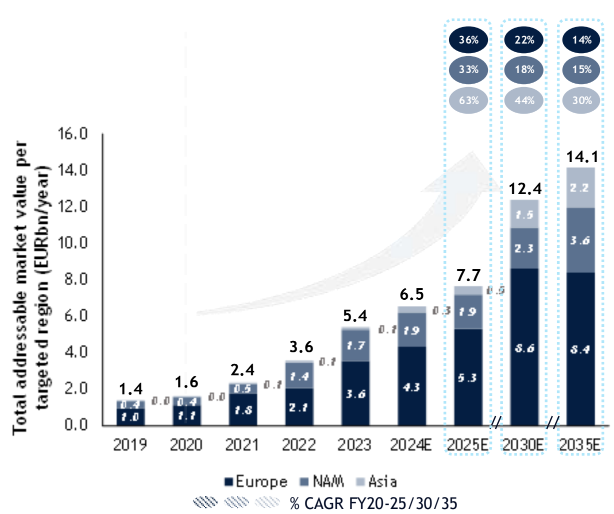
Similar adoption trends have started in the NAM and APAC markets. Although NAM figures (see Fig. 31-32) correspond to a combination between deliveries and awards/orders, they provide leading indicators for current/future adoption trends, anticipating upcoming BEB registrations over the next two years, supported by government stimulus. The same goes for Asian markets where, apart from China, the transition is only starting in the most developed countries (less than 500 hundred BEB in key countries such as Japan or Australia as of 2022).

Figure 13 - BEB sales volume up until 2035 in targeted regions ('000 unit/year)



*Source: Stifel**

Figure 14 - Targeted regions BEB dynamic up until 2035 (EURbn/year)



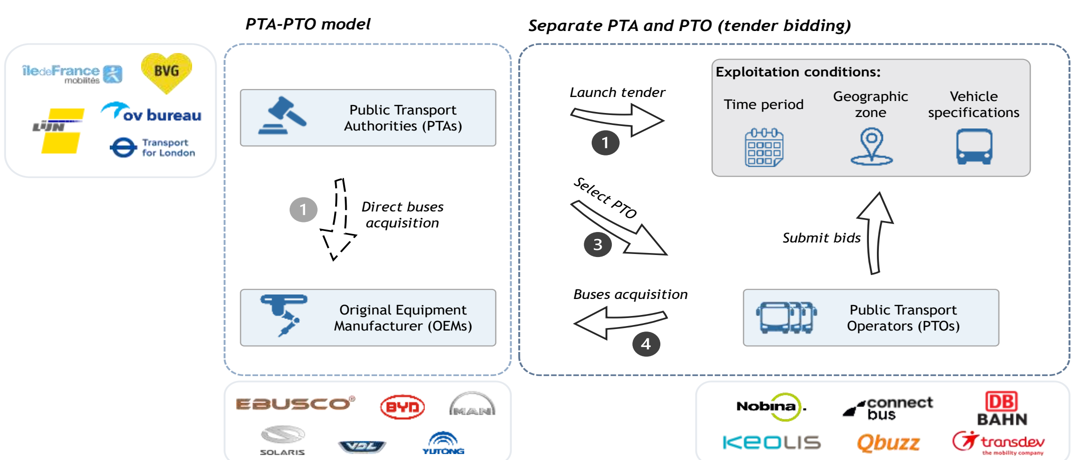
*Source: Stifel**

As such, according to relevant data providers such as the ACEA and government agencies, Roland Berger's analysis and our own assessment of bus market dynamics, the addressable market per year for transit-BEB in leading regions around the world (apart from China) could reach >13k units per year by 2025, and up to ~30k by 2035. This would correspond to a global BEB share of ~35-40% by 2025, ~65-70% by 2030 and ~80-85% by 2035 (from ~20-25% as of 2022 and ~10% in 2020) and imply a global share in the total fleet of ~12% by 2025 (~50-55k BEB) and ~60-65% by 2035 (~285-290k BEB). Consequently, the annual addressable market in these regions could represent <EUR8bn by 2025 and EUR14-15bn by 2035, implying a 15-16% CAGR over the 2020-2035 period.

Similar systems on both sides of the Atlantic

Mature public/utility transport markets for buses as in Europe and North America exhibit similarities in their functional structures and the involvement of various stakeholders. City transportation services are managed by public entities, predominantly municipalities or metropolises. Consequently, and as previously mentioned, transit bus markets are closely tied to public stimulus/demands and binding requirements of these entities. Therefore, to keep sight of evolving trends and operational implementation, the number of contact points/players that OEMs need to address has gradually concentrated significantly, with Public Transport Authorities (PTAs) on one hand and Public Transport Operators (PTOs) on the other.

Figure 15 - Typical bus concessions sourcing attribution process



*Source: Stifel**

Each tender is then complemented with rigid/flexible service level agreement (SLA) for which OEM must provide a way for customer to maintain their fleet

PTAs are responsible for allocating concession areas for public transport services, with two options available to manage their transport offer: either (i) directly operating transport services themselves, known as PTA-PTO (Metropole of Rouen, Ile de France Mobilités) and allocating public funding accordingly, or (ii) outsourcing operations to a PTO (Keolis, Transdev, DB, RATP, TfL), therefore dividing its territory into one or more concessions and initiating a tender process to assign concessions to PTOs. These contracts typically span over 10-15 years and include the procurement of a fleet of buses. Once a PTO wins a tender, decision-making autonomy increases as long as operators meet requirements specified by the PTA. PTOs often establish partnerships with OEMs, predefining terms/purchase and LCS conditions during the tender processes.

As such, whether price-centric whereby PTAs establish SLA parameters, or customer-centric where PTOs can negotiate service levels, pricing, warranties etc, lower technology maturity due to electrification tends to increase bargaining power for PTOs and OEMs.

Consequently, solely but closely managing a portfolio of serious relationships with global players such as Deutsche Bahn (>26k buses), Transdev (~25k buses), Keolis (~23k buses/ coaches) or regional experts such as Nobina (~4k buses) provides a strong edge in terms of market requirements, price/threshold trends and tender activity. Indeed, while many small PTOs exist, outsourcers present the larger opportunity in the short- to medium-terms for fleet renewal rates and requirements in doing so.

Figure 16 - Set of significant European PTA/PTOs as of June 2023

Source: Stifel*

Figure 17 - Set of significant American PTA/PTOs as of June 2023

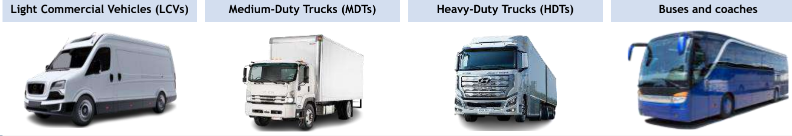
Source: Calstart, Stifel*

Trucks, the next in line

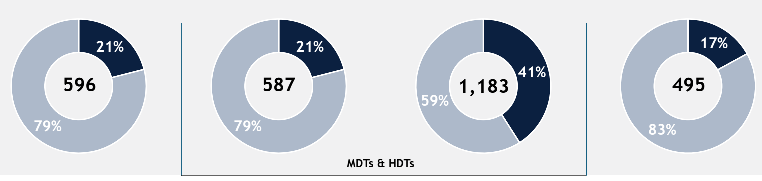
Trucks play a pivotal role in transporting a wide array of goods essential for daily life, ranging from supermarket products like milk to construction materials like cement. This sector is vital for global supply chains due to the unparalleled flexibility of trucks, which can access urban areas and leverage existing fueling and road infrastructure shared with personal vehicles. Indeed, globally, approximately three million companies operate in road freight which results in a highly fragmented and competitive sector characterized by narrow profit margins. According to the OECD, all combined, these vehicles collectively transport nearly 22 trillion tonne-kilometres of cargo annually.

Whereas buses do matter for urban CO2 and fine particle emissions, freight and logistics pollution occurring far from city centers is a clear issue. Together with buses, trucks account for close to 9% of total emissions, more than three times those of marine emissions. While shipping emissions originate from approximately 50,000 vessels, the global fleet includes about 217m vans, trucks, and buses. Among these, around 63m are medium-duty trucks (MDTs) and heavy-

Figure 18 - Breaking down the world's MHDV fleet (in million vehicles)



	Light Commercial Vehicles (LCVs)	Medium-Duty Trucks (MDTs)	Heavy-Duty Trucks (HDTs)	Buses and coaches
Max. tonnage	<3.5 tonnes	3.5-15 tonnes	>15 tonnes	Variable
Europe	28	2	4	1
US	20	5	3	1
China	21	4	7	3
India	5	3	2	1
Rest of World	70	22	11	4
Total	144	36	27	10
Road freight emission (Mt CO_2, % of road freight emission)	596 (21% / 79%)	587 (21% / 79%)	1,183 (41% / 59%)	495 (17% / 83%)

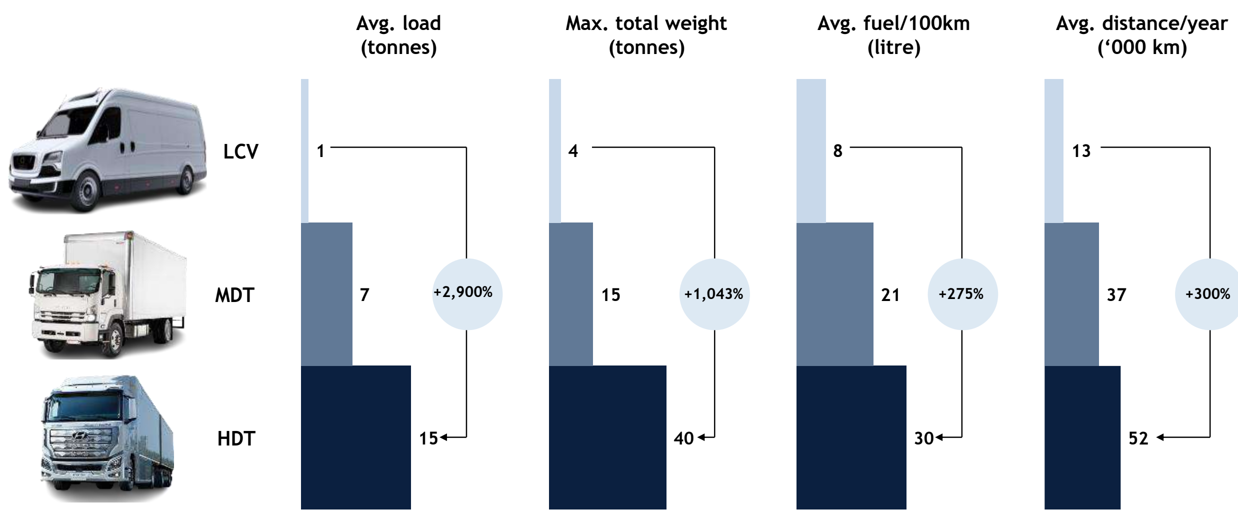


63 million trucks account for 62% of global road freight emissions

Source: IEA Future of Trucks, OECD, IEA Energy Technology Perspectives, IEA Tracking Transport 2020, Deloitte, Stifel*

North America is the western world's largest truck and trailer market. As such, while distances travelled, vehicle structures and classifications are different between the two regions, the technology consensus could primarily be driven by North American fleet operators with the US as a pioneer/trigger. However, decarbonizing HDT is challenging because of the industry fragmentation, characterized by efficiencies watch and cost competitiveness to survive. While operators are used to vehicle replacements, they require clear visibility for their fleet management and potential route optimization, i.e. a cost-effective and efficient operating environment.

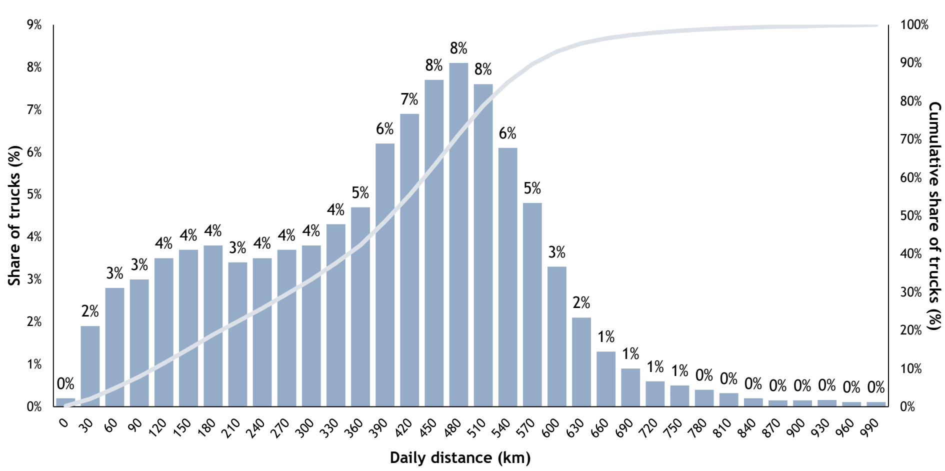
Figure 19 - Understanding different truck types key KPIs



*Source: Deloitte, Stifel**

Consequently, two kinds of industry players are pioneering electric truck uptake, The first are organizations, both public and private, whose vehicles follow fixed, unchanging duty cycles, driving relatively short daily routes, with enough time overnight to recharge. The second are organizations with strong commitments to decarbonize, regardless of likely higher costs in the short term. Indeed, public/utility fleets can create a ZE-path, with enough infrastructure momentum and data gathered from operations to derisk remaining efforts for the vast majority of the fleet (most trucks deal with a daily range of less than 450km). However, depending on their weight class, ZE-technologies either add technical weight or competition and infrastructure challenges.

Figure 3 - Transport related CO2 emissions breakdown in Europe as of 2022



*Source: ICCT, Wentzel (2020) Stifel**

Whereas weight allowance is less of an issue for LCVs and MDTs, it becomes a key consideration for HDT operators, arbitraging between more and bigger vehicles. Indeed, ZE-trucks tend to weigh more than their ICE counterparts, thereby hitting payload capacity under current regulations both in North America (maximum payload capacity of 80K lbs for ICE trucks vs 82K lbs for ZE trucks) and in Europe.

Weight allowance is therefore a critical factor for long-haul lorries and trucks. This is mirrored in Europe where the European Commission and Parliament have authorized road access for megatrucks (25m long/60tons weight limit). Nonetheless, industry players and governments are reticent. While the adopted text revised specs for all kinds of trucks, some would prefer only to allow ZE-megatrucks, while others are simply pushing for rail and other alternatives.

Strong dynamics have been observed on both sides of the Atlantic regarding the decarbonization of medium and heavy-duty trucks (M/HDT), with fleet electrification being gradually implemented. Numerous fleet owners have embraced the adoption of smaller alternative technology trucks. Specifically, battery electric vehicles (BEVs) are proving to be both technically and economically feasible in urban last-mile duty cycles characterized by short driving ranges, overnight vehicle idle times, and convenient access to charging infrastructure. Recent developments include Amazon's procurement of 100,000 electric trucks from US start-up Rivian and IKEA's pledge to use electric vehicles for all home deliveries worldwide by 2025, having already achieved this objective in cities like Shanghai. While these are the first-movers, mass adoption should follow as technologies and infrastructure mature.

Figure 21 - Linking potential technologies to duty-cycles in ZE-M/HDVs

Duty cycles		Idle time per day	Avg. Dist. (km/day)	LCV	MDT	HDT	Summary
	0. Last-mile e.g. door-to-door city delivery	2-3 x ~0.5h 1 x ~10h	<100	BEV	BEV		• Short distances make BEV more applicable • Possible use of personal vehicle charging infrastructure • Low-emission zones in cities require faster transition • Charging can be scheduled during off-peak hours to minimize disruption
1. Medium distance ~50%[1]	1a. Milk-run e.g. urban less-than-truckload delivery to supermarkets	3-5 x ~0.5h 1 x ~15h	<250		BEV	BEV and/or FCEV	• Medium distances and enough breaks for MDTs to use BEV • In HDTs, battery size and charging time may be impractical • Urban BEV charging stations may be overwhelmed by demand as more fleets go electric • In cases where delivery routes change frequently or unexpectedly extend in distance, FCEVs provide more flexibility to handle range anxiety
	1b. 24/7 regional operations e.g. clothes from regional hubs to local depots	8-12 x ~1h	250-500		BEV and/or FCEV	BEV and/or FCEV	• BEV can be flexible enough in the long term if opportunity charging infrastructure is widely available, with high power charging and relevant battery chemistries/architecture • FCEV may be viable sooner, with less need for a dense fueling infrastructure, **if price of hydrogen declines**
2. Long distance ~50%[1]	2a. Multi-day trips e.g. full truckload production material delivery	1-2 x ~0.5h 1 x ~1h 1 x ~12h	500-1,200			BEV and/or FCEV	• FCEV likely more viable given long distances and few breaks, **if price of hydrogen declines** • BEV only if batteries significantly improve density or if fast charging becomes available • Advances in lightweight materials for construction of the vehicle chassis and body could improve overall efficiency for both BEVs and FCEVs
	2b. 24/7 long-haul e.g. long-haul fixed-route trucking corridor	1-2 x ~0.5h 2 x ~1h	1,200-2,000			FCEV	• FCEV likely the only option in foreseeable future • BEV battery weight significantly impacts cargo capacity, and charging infrastructure for heavy-duty transport is not yet adequate • FCEV align well with the need for quick refueling and minimal downtime on fixed routes

Likelihood of alternative technology

- **BEV** more likely
- **FCEV** more likely

1) Estimated share of total MDT and HDT truck volume (tonne-kilometres)

*Source: Deloitte, Stifel**

03

FUTURE OUTLOOK AND STRATEGIC IMPLICATIONS

POLICY, INVESTMENT, AND ADOPTION STRATEGIES

Looking ahead, policy frameworks, investments, and strategic actions will shape the future of electric HDVs.

At the crossroads between regulation push and investment flows

Acceleration in European green-mobility incubation

Europe is at the forefront of the transition from diesel buses to alternative fuel buses and zero-emission buses, driven by public policies and funding at both the local and European levels. Indeed, European countries have quickly realized the need to decarbonize the heavy mobility sector, representing over 6% of total EU greenhouse gas (GHG) emissions and more than 35% of GHG emissions from road transport in Europe.

The European mobility transition is therefore triggering binding and nationwide targets for the conversion of diesel fleets. Consequently, at least a quarter of new buses bought by local authorities and public companies will need to be clean vehicles by 2025. This has opened a corridor to e-mobility solutions, already aggressively biting into market share of traditional passenger vehicle manufacturers, where OEMs cannot position themselves for short-term cycles with billions of investments in brand-new product line designs.

Therefore, based on what we have observed with passenger vehicles, we estimate that ZEB should de facto benefit from a sharp ramp-up. Ongoing progress related to mobility technologies could replicate what took place between BEVs and PHEVs for small passenger vehicles: first, LEVs took the lead due to apprehension by traditional players regarding technology maturity, then growing customer/political awareness and a gradual phase-out of less efficient (either energy- or carbon-related) solutions grabbed the market.

For BEB, this should be further reinforced by road congestion with private cars (45% of all trips globally) and the implementation of fine particles regulations (NOx, brakes, tyres) in the future (Euro 7 norm or not) unrelated to exhaust pipe emissions. To combat this, over 150 cities have implemented measures to limit emissions from private cars and promote greener transport.

Finally, the EU provides funding through various programs to support the adoption of zero-emission buses, including the Connecting Europe Facility (EUR34bn up until 2027), the European Regional Development Fund, and the Horizon 2020 program (EUR80bn over seven years). These programs provide financial support for the purchase of ZEBs, as well as the development of charging infrastructure and other necessary infrastructure to support their operation. Complementing the initial European Green deal (2019), Fit for 55 and the AFIR (2022), an additional package of regulatory actions was put in place in February 2023 with stronger (and finer) CO2 emissions standards for almost all new HDVs compared to 2019 levels, mainly 45-65% in reductions by 2030/2035 and 90% by 2040. Interestingly for all new city buses, regulations are even tighter at the EU level with a 100% ZE target by 2030, leaving significant space for BEB players to grow in the future.

Figure 22 - European purchase and tax incentive schemes for electric buses

	France	Germany	Italy	Poland	Netherlands	United Kingdom	Spain	Sweden
Bus fleet	27,900	35,000	30,500	11,500	5,300	36,500	20,000	4,750
Battery Electric Bus (BEB) fleet*	1,562	1,809	506	757	1,414	1,835	453	886
Implied BEB share	5.6%	5.2%	1.7%	6.6%	26.7%	5.0%	2.3%	18.7%
New BEBs registrations last year (2022)*	549	581	121	149	95	685	136	256
Key regulations or supporting schemes	• Up to €100k subsidy for ZEBs • Parisian public transport operator RATP planning to add 800 electric buses by 2024 (€400m budget) • Ile-de-France region planning to have a fleet of 70% biogas and 30% electric buses by 2030 • Clean buses platform: €200m (€100m from the EIB and €100m from the Territories Bank) invested to facilitate the energetic transition of bus fleets	• €1.25 billion available until 2024 for the procurement of around 3,000 buses and the associated infrastructure. Fundings cover 80% of additional purchase cost of electric buses versus ICE buses • Berlin to have 100% of its fleet electrfiied by 2030 • Electricity tax reduction for e-buses in public transportation networks	• The National Recovery and Resilience Plan establishes an allocation of 1.9 billion for the purchase of ZEB in large citie. • Genoa's public transport system to become full electric by 2025. €470m allocated from the Italian government.	• Subsidy for purchase of electric buses and trolley buses • Estimated 25% electric bus share of all transit buses in Warsaw by end of 2030, with half of the fleet (800 buses) to be converted by 2027 • Green Public Transport Programme: €242m in subsidies and €44m in loans for towns and cities that will buy the eco-friendly buses.	• Subsidy of up to €50k per electric bus • Higher subsidies for smaller companies, allocation is related to fleet size • All EVs are exempted from registration tax and VAT, with additional local governmental support • From 2025, all new buses in public transport will be zero emission and the whole parc in 2030.	• ZEBRA scheme: £200m in government funding towards the target of 4,000 zero emission (ZE) buses in service by 2025. • Subsidies of up to 75% of the cost increase from a diesel to a ZE vehicle and infrastructure • 30% of new medium and heavy duty vehicles zero emission by 2030, 100% by 2040	• Spain's recovery and resilience plan: €13.2 billion to be invested in sustainable mobility in urban and long-distance. Includes financing green public buses among other measures.	• Electric bus premium set at up to 20% of purchase price compared to ICEVs

*Source: European Commission, Chatrou CME Solutions, Stifel**

**According to Chatrou CME Solutions (2022)*

Most European countries have taken initiatives to electrify public and private vehicle fleets, adapting the Commission's decision (mainly vehicle procurement %) in local laws and generally (i) providing subsidies for the purchase of ZEBs, whether fixed or based on the price premium paid over traditional ICEBs at the state level, or (ii) implementing low and zero emission zones in major cities (setting binding constraints on vehicles emissions in certain areas) from a local standpoint.

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Figure 23 - Minimum procurement targets for light duty vehicles, heavy duty vehicles and buses by 2025 and 2030 in European member States

Member State	Buses (vehicle category M3) - half of the target to be fulfilled by procuring ZEVs*	
	From 2nd August 2021 to 31st December 2025	From 1st January 2026 to 31st December 2030
Luxembourg	45%	65%
Sweden	45%	65%
Denmark	45%	65%
Finland	41%	59%
Germany	45%	65%
France	43%	61%
United Kingdom	43%	65%
Netherlands	45%	65%
Austria	45%	65%
Belgium	45%	65%
Italy	45%	65%
Ireland	45%	65%
Spain	45%	65%
Cyprus	45%	65%
Malta	45%	65%
Portugal	35%	51%
Greece	33%	47%
Slovenia	28%	40%
Czech Republic	41%	60%
Estonia	31%	43%
Slovakia	34%	48%
Lithuania	42%	60%
Poland	32%	46%
Croatia	27%	38%
Hungary	37%	53%
Latvia	35%	50%
Romania	24%	33%
Bulgaria	34%	48%

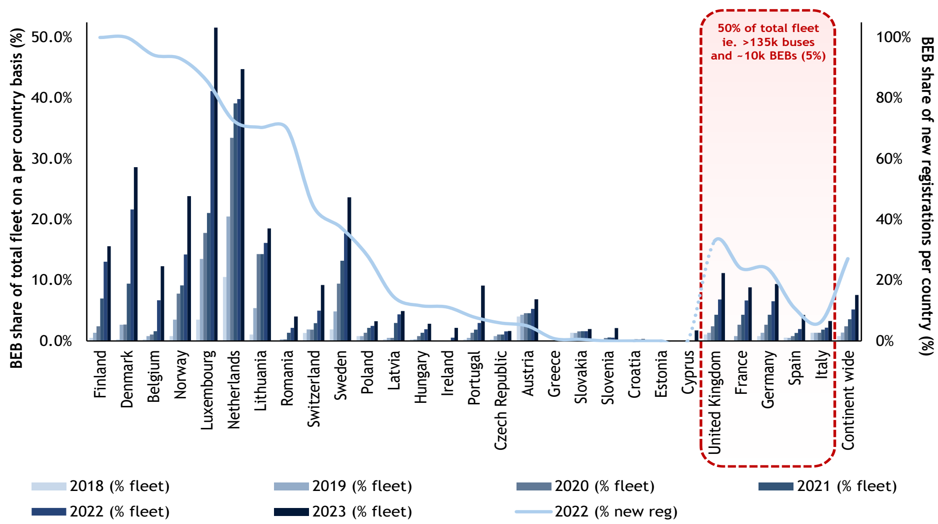
Source: Europa

** This requirement is lowered to one quarter of the minimum target for the first reference period if more than 80% of the buses covered by the aggregate of all contracts awarded during that peirod in a Member State are double-decker buses*

Source: European Regulator

As was the case with passenger cars, Northern European countries led the pack. This leaves an average BEB procurement rate in European countries of <30% of total new bus registrations in 2023 as most of the bigger countries could be latecomers in meeting EU 2025 and 2030 targets. Nevertheless, less than 7% of the European bus fleet is likely to have been electrified by end-2023, meaning that most of the transition still lies ahead of us with a significant gap to bridge before 2030 in terms of BEV share in new registrations.

Figure 24 - BEB electrification pace in European countries from 2018 and as of 2023 (fleet and new registration %)



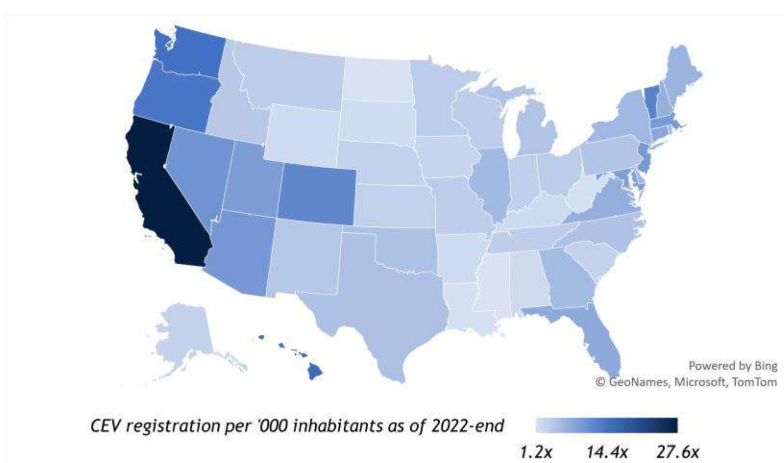
*Source: ACEA, Stifel**

North America following closely with big money coming in

Bus electrification can also be attributed to the upsurge in investments in public transport. Escalating population and urbanization trends serve as primary drivers, directing public investments towards enhancing the transportation network. Led by politics and public authorities, investments in transit infrastructure have therefore been on the rise globally, enabling countries both to curtail their carbon emissions and propel economic progress.

Consequently, despite lagging behind Europe in terms of public transport network and electrification, the US has recently accelerated its deployment of ZEVs, largely driven by the distribution of grants resulting from the implementation of the Bipartisan Infrastructure law. As a result, the pace of electrification in the US has been rising sharply, led by California as always, still with a strong disparity in terms of BEV adoption between the US coasts and rural areas, a pattern identified in Europe with richer Northern countries vs Southern ones.

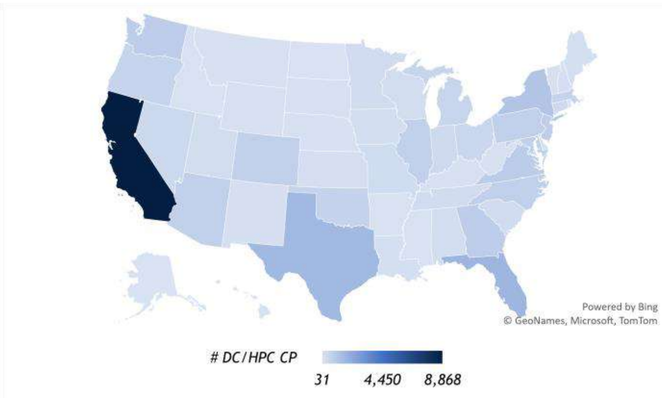
Figure 25 - CEV registrations per thousand people in the US as of 2022



*Source: US DOE, Stifel**

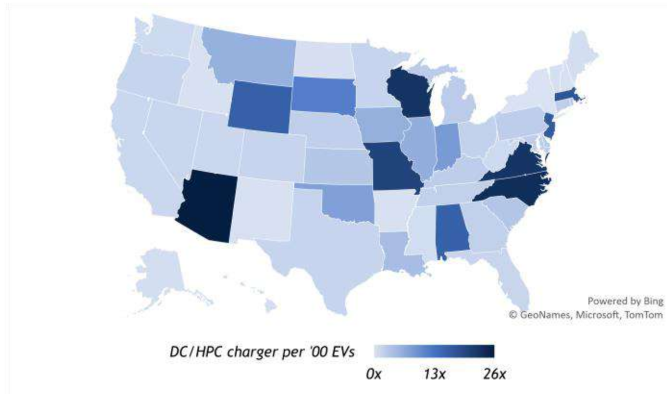
However, with most of the US population on the East coast, the country is clearly underpenetrated by BEVs which is also reflected in DC/HPC charging infrastructure (saturated in states advanced in the e-transition, such as California and Oregon, but ahead of the BEV adoption pace in Virginia or in the diagonal void).

Figure 26 - Number of DC/HPC chargers in the US, breakdown per State as of 2022-end



*Source: AFDC, Stifel**

Figure 27 - DC/HPC charger per '00 EV in the US, breakdown per State as of end-2022



*Source: AFDC, Stifel**

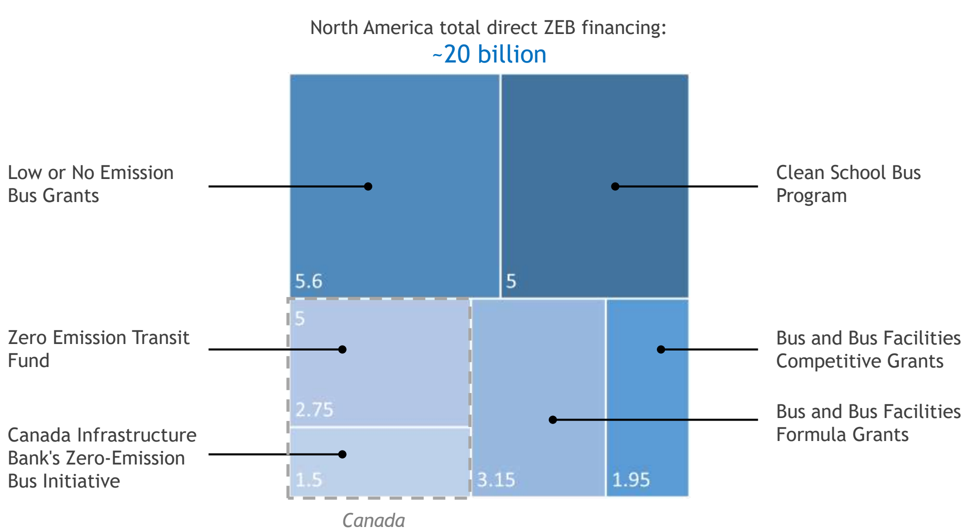
Signed in November 2021 the Bipartisan Infrastructure Law, represents a 10-year investment plan of roughly USD1.2tn dedicated to upgrades and developments of US transport networks, broadband, and public works projects (o/w USD550bn in additional spending according to McKinsey). Mechanically, any type of BEV would benefit from this government stimulus, with an impact on public authorities' decisions on BEB investments that should be even greater given the grants directly related to bus financing:

1. **Clean School Bus Program:** representing a USD5bn investment over five years to replace existing schoolbuses with ZE/LE versions.

2. **Low or No Emission (Bus) Grants:** with a USD5.6bn plan over five years (~6x more than previous five years plan) for State and local governments to purchase or lease ZE/LE transit buses as well as the dedicated infrastructure.

3. **Bus and Bus Facilities Grants:** about USD5.2bn to replace, rehabilitate and purchase buses/vans and construct bus-related facilities. Within this additional scheme, USD2bn will be distributed through a discretionary process (competitive grants) and USD3.2bn will be automatically awarded to recipients (formula grants).

Figure 28 - Summary of ZEB financing support in NAM as of 2023

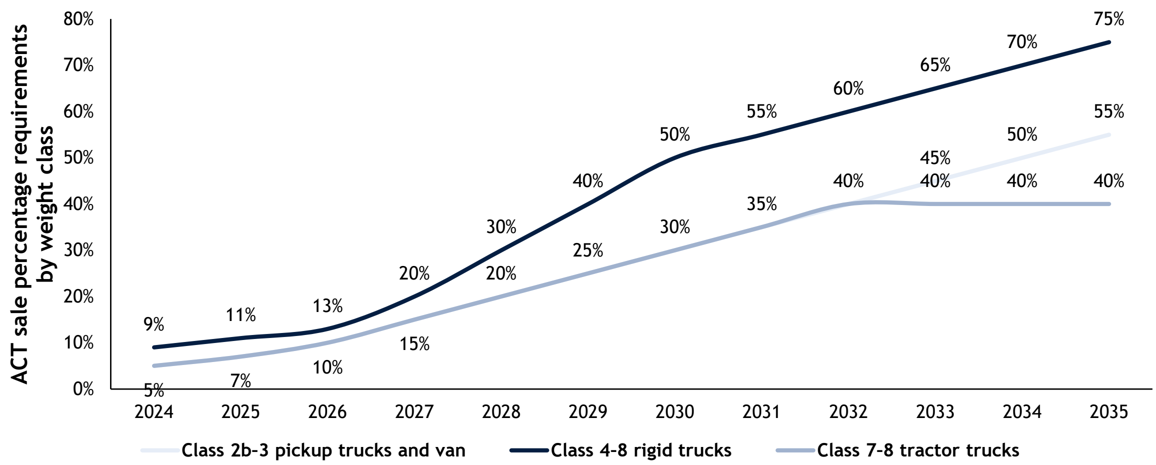


*Source: FTA, APTA, US DOE, CIB, Stifel**

In 2022 alone, more than USD1.6bn was allocated through the Low/No Emission Grants and the Bus and Bus Facilities Grant (representing investments in more than 1,100 transit ZEBs) and USD1bn through the Clean Bus School Program (supporting 400 school districts in the purchase of more than 2,400 school ZEBs). This resulted in a strong acceleration in BEB orders, as shown in the charts below, further highlighting efforts to respect the COP27 agreement in November 2022 on Zero-Emission Medium- and Heavy-Duty Vehicles, an agreement supporting a path towards 100% new ZE medium/heavy-duty vehicle (MHDV) sales by 2040, at least with a 30% target by 2030.

Similarly, on the truck side, the Advanced Clean Trucks (ACT) regulation mandates that M/HDV OEMs incorporate a growing share of ZEVs and hybrids into their yearly sales mix from 2024 to 2035. This regulation operates on a cap-and-trade framework, limiting the quantity of conventional ICEVs sold by 60% from 2030 onwards. However, the Advanced Clean Fleets (ACF) regulation in California and other states joining will be phased-in over the next two decades, mandating 100% ZEV sales for OEM by 2036 disregarding vehicle classification, thereby pushing harder for the transition.

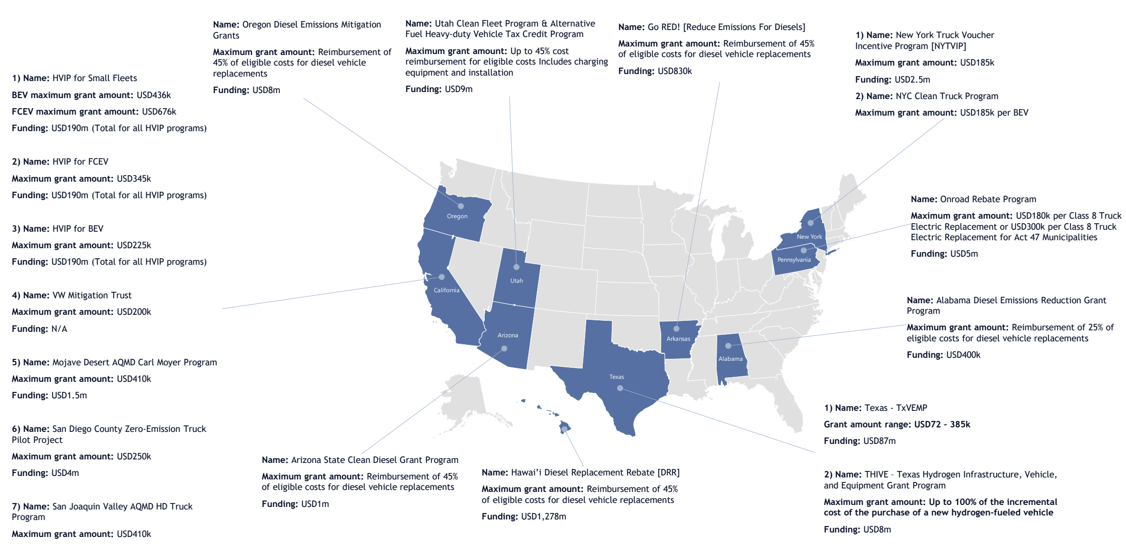
Figure 29 - Advanced Clean Trucks Regulation, one step further for US trucks



*Source: CARB, Stifel**

In the end, the ACF regulation's objective is to achieve complete ZEV fleets by 2045, with specific targets including 100% ZE-drayage trucks, last mile delivery vehicles, and government fleets by 2035, 100% ZE-refuse trucks and local buses by 2040, and 100% ZE-capable utility fleets by 2040. While this a huge challenge from both an industrial and infrastructure standpoint, California would show the way forward for NAM and serve as a reference point for the scale-up.

Figure 30 - Incentives for the acquisition of ZE-HDV trucks in the US

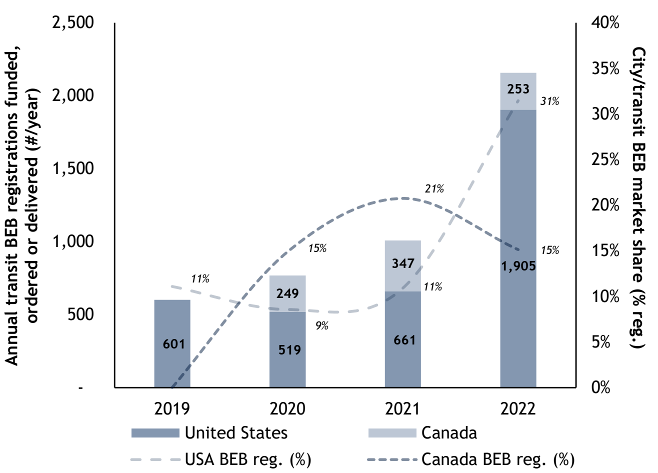


*Source: Nikola, state subsidies platform, Stifel**

Unsurprisingly, several funding programs administered by state agencies/offices facilitate the adoption of ZE-trucks and related infrastructure. The most relevant one is the Californian Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) providing point-of-sale rebates to offset the purchase price of BEV and FCEV trucks and buses, initially with USD190m envelopes available to operators. Moreover, California's Public Utilities Commission has allocated >USD1bn to support M/HDV charging installations, with investor-owned utilities eligible for state support when investing in infrastructure upgrades to back the electrification of transport.

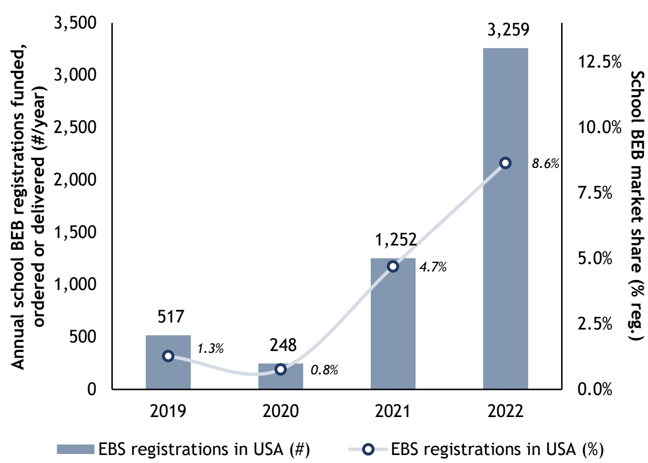
On the Canadian side, electrification of the transport network, whether transit/scholar or freight, is also underway with the Canadian government presenting decarbonization of public transit as an important part of its climate change and economic development strategy. As such, since the release of the Action Plan for Clean On-Road Transportation in December 2022, Canada has at last a 35% ZE target for MHDV sales by 2030 and 100% by 2040

Figure 31 - City/transit buses electrification pace in NAM over 2019-2022



*Source: Calstart, Stifel**

Figure 32 - School bus electrification dynamic in the US over 2019-2022



*Source: Schoolbusfleet factbook 2023, Stifel**

As in the US, this ramp-up has come with different financing solutions, the most important ones being:

1. The Zero-Emission Public Transit Fund: with USD2.75bn, live since 2021 to support PTO electrification plans regarding transit/school buses and their corresponding infrastructure, with the aim of commissioning 5,000 new buses over five years (i.e. USD550k/bus), together with

2. The Canadian Infrastructure Bank's Zero-Emission Bus Initiative: representing a commitment of at least USD1.5bn in flexible financing for ZEBs as part of a three-year growth plan.

Figure 33 - Main HDV policies in Europe/NAM as of 2023

State Level	Policies	When ?	Goal ?	Measures
	Green Deal	2019	Reduce net GHG emissions by 55% vs 1990 by 2030 Reach net zero by 2050	• over €1 trillion investments
	Clean Deal Vehicle (1161) & Directive 2019/1242	2019	Electrify heavy-duty fleets (including buses)	• 25% LEVs threshold on new bus registrations in 2022, 35-45% by 2025 and 50-65% by 2030 in leading countries, of which 50% have to be ZEVs, >30% ZEV registrations throughout Europe by 2026 • Significant penalties for OEM who don't match expectations (€4,250 per gCo2/tkilometer for heavy duty vehicles)
	Fit for 55 Plan	2021-	Revise EU legislation in order to reach the European Green Deal targets	• Ban on new sales of carbon-emitting petrol and diesel cars by 2035 • Requirement to have charging stations at least every 60km on European main roads (Ten-T) for passenger cars by end of 2025 and trucks by end of 2030 • For heavy-duty vehicles, at least 2 recharging points in each safe and secure parking area by end of 2027 and 4 four by end of 2030
	Proposal from the European Commission	2023	Electrify heavy-duty fleets	• Raise CO2 emissions standards for new HDVs compared to 2019 levels: (-45% from 2030; -65% from 2035; 90% from 2040) • Make all new city buses zero-emission as of 2030.
	LTECV	2017-2021	Define a roadmap for the development of renewables ecosystems	>250k inhabitants agglomerations and/or >20 buses fleet have to comply with EU directive
	Clean Buses Plaform	2021	Ease the tender process and allow for public access to data	Initiatives such as Cleans Buses Platform in France with €100m deployed aiming at facilitating EU tenders and market monitoring
	National Bus Strategy	2021	• 100% ZEVs bus fleet by 2034 • 68% GHG emissions reduction in the UK by 2030	100% ZEVs procurement in major cities
	Non-binding MoU on Zero-Emission Medium- and Heavy-Duty Vehicles	2022	Accelerating the adoption of ZEBs across the country	• 30% new medium- and heavy-duty vehicle (MHDV) sales to be zero emission by 2030 and 100% by 2040
	Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law)	2021	Invest in and improve the infrastructure of the United States	• $1.2 trillion investments on a wide range of infrastructure sectors • Around 20 billion directly targetting buses
	California: Innovative Clean Transit rule	2019	Shift Californian transit agency fleets to zero-emission buses	• 25% of new bus purchases to be zero-emission from 2023 and 100% from 2029 • Fleets 100% zero emission by 2040
	Action Plan for Clean On-Road Transportation	2022	Achieve net-zero emissions by 2050	• 35% new medium- and heavy-duty vehicle (MHDV) sales to be zero emission by 2030 and 100% by 2040
	Zero Emission Transit Fund	2021	Deploying 5,000 ZEBs (both transit and school buses)	• $2.75 billion fund supporting public transit and school bus operators
	Canadian Infrastructure Bank	2021	Deploying 4,000 ZEBs (both transit and school buses)	• $1.5 billion funding to assists transit agencies and school bus operators
	Zero Emission Buses Transition Plan (New South Wales)	2022	Decarbonising the public transport bus fleet	1,200 new electric buses for Greater Sydney customers by 2028 100% zero emissions fleet by 2030
	Zero Emissions Vehicle Roadmap (Victoria)	2022	Decarbonising the public transport bus fleet	target for all public transport bus purchases to be ZEVs from 2025.
	New Zealand government's commitment	2021	Decarbonising the public transport bus fleet	• Only zero-emission public transport buses to be purchased by 2025 • Decarbonisation of the public transport bus fleet by 2035 • Support through a $50 million fund over 4 years.

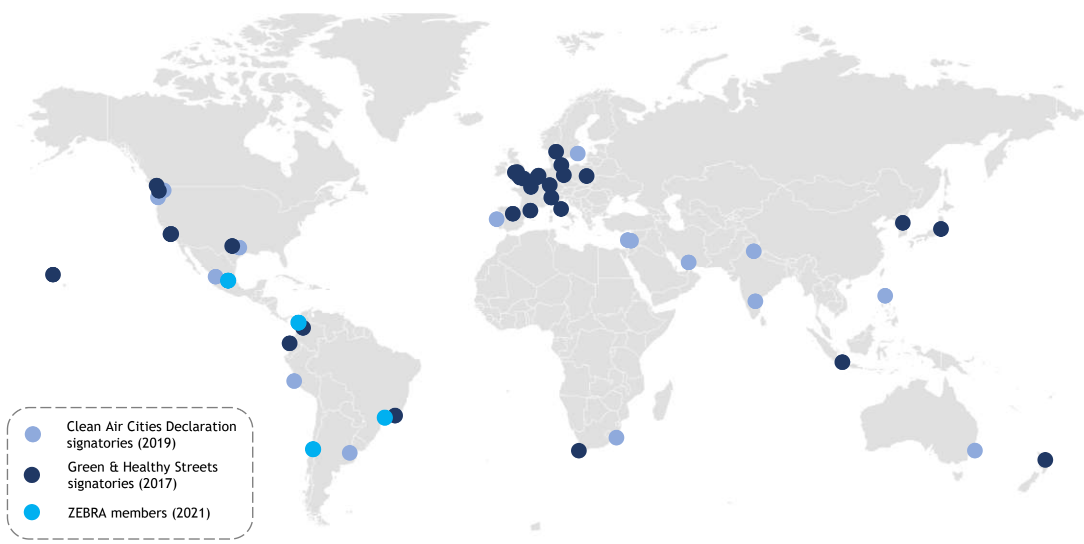
*Source: Climate Watch, APTA, US DOE, Stifel**

Finally with cities and environmental activism in motion

Although city buses are one of the most energy-efficient transport means, they remain one of the biggest polluters for urban areas. The same goes for last mile deliveries and suburb node logistics. As such, cities are increasingly opting for ZEVs in order to improve air quality and reduce noise pollution. Moreover, public initiatives are also heavily impacted by image concerns, which is a key factor for diesel fleet operators or cities they actually service.

This is why cities are actually playing a crucial role in leading the transition to electric buses. Major urban hubs are often seen as leading indicators because they showcase how national policies are implemented on a local scale before they are mature enough to be deployed across the rest of the country. As such, renewables need a complete refoundation of the power system, refocusing on regional advantages to accelerate and get the best out of each technology, meaning the decision-making process should become more decentralized which is reinforced when ambitious targets are set.

Figure 34 - Committed C40 cities network



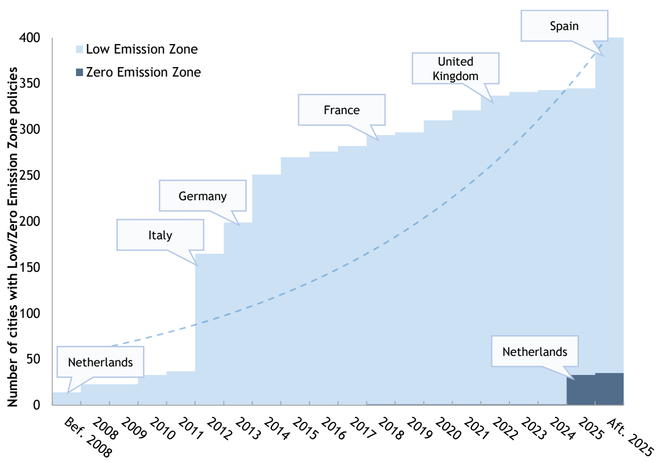
Source: C40 cities leadership group

A recent example of this type of initiative is the collaborative network C40 with its Green & Healthy Streets declaration whereby 36 cities have committed to transitioning their entire bus fleets to zero emissions at a faster pace than state-owned policies. This would imply 100% procurement of ZEBs by 2025 and that significant areas of these cities will become zero-emission areas by 2030, as proposed in the EU.

Indeed, EU regulations have adopted mandatory thresholds for cities with more than 150k inhabitants or annual average concentration in NO2 higher than 10µg/m^3 to implement Low Emission Zones by the end of 2024. The aim is to significantly reduce CO2 and other GHG concentration in cities, starting by removing older vehicles from city centers and incentivizing substitutes such as alternative mobilities, BEVs and hydrogen vehicles. However, in LEZs, new ICE, hybrid and LNG vehicles are still accepted.

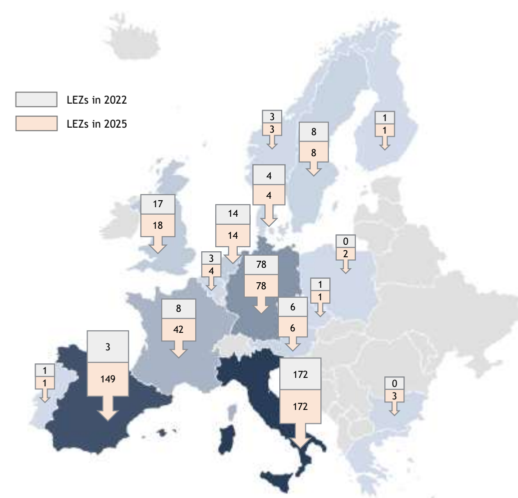
As a result, while LEZs and ZEZs initiatives exist since the middle of the 90s in Sweden and the Netherlands, a clear switch in favor of this model has taken place over the past 15 years. Already with 318 LEZs operational in 2023, more than 500 should come online by 2025 representing most major cities in Europe such as Amsterdam, Berlin, London, Madrid and Paris. This means that over 2025-2030, most European city centers should only see recent, low polluting vehicles on their streets, setting binding constraints for all taxpayers, from inhabitants to corporate individuals and larger activities.

Figure 35 - Cumulated Low and Zero Emission Zones initiatives in Europe since 1996



Source: Stifel*, Urban Access, Regulation, EU Commission

Figure 36 - European Low and Zero Emission Zones from 2022 to 2025



Source: Stifel*, Urban Access Regulation

Nevertheless, Zero Emission Zones go well beyond this. In a ZEZ, vehicles are subject to restrictions on exhaust emissions beyond those in an Ultra Low Emission Zone or Low Emission Zone. As a result, ZEZs can help improve local air quality while encouraging a switch to zero-emission vehicles, walking, cycling and public transport use. It is therefore accompanied by the corresponding subsidy schemes to finance vehicle acquisition/leases. As a direct consequence, for most capitals and other core European cities, any fleet operator whether public or private would need to completely switch to electric mobility, either with battery or electric vehicles. On the top of that, history has tended to show the oldest LEZs adopted stricter measures going into ZEZs, which would imply preparing for ZEZs is safer on longer duration investments.

Figure 37 - Timing is even tighter for some key European cities

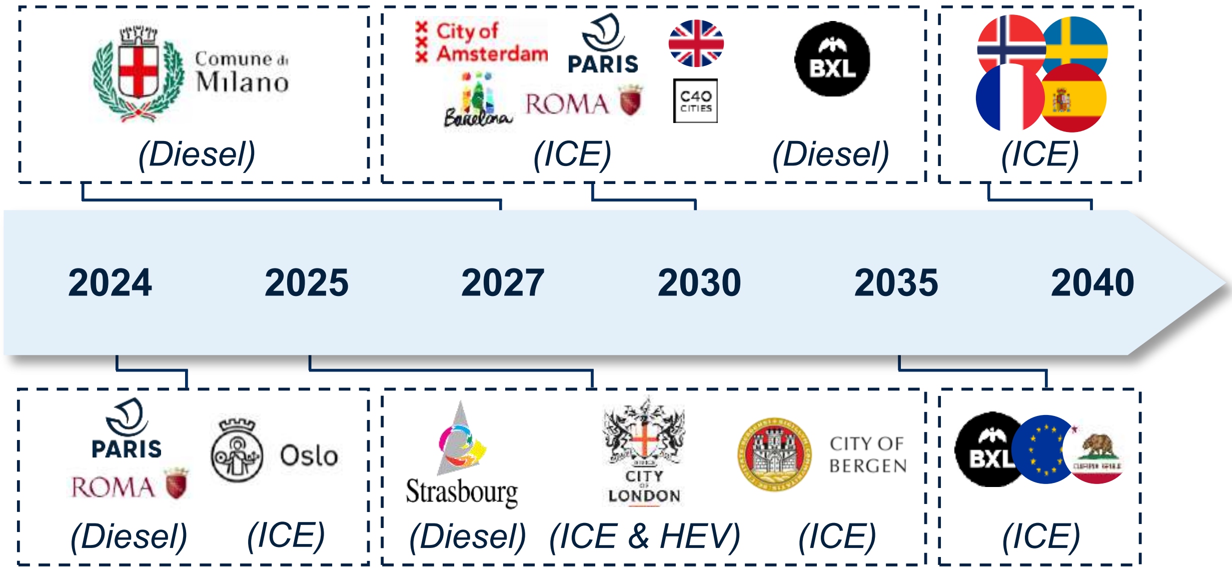
Schemes	Municipality	Type	Implementation date	Operation scheme	Vehicles affected	Areas affected	Upgraded from existing LEZs
Implemented schemes	London Boroughs of Hackney and Islington	Near-ZEZ	September 2018	Road access restriction	All	Five streets	No
	City of London	Near-ZEZ(18-month pilot)	March 2020	Road access restriction	All	One street	Yes
	Rotterdam	ZEZ-F	January 2015	Road access restriction	Heavy-duty trucks > 3.5 tons	One street	Yes
Planned Schemes	Oxford	ZEZ (pilot)	Late 2021	Charging scheme	All	Eight streets	No
		ZEZ	Spring 2022	Charging scheme	All	~ 1.6 km²	No
	Oslo	ZEZ	2022	Road access restriction	Light-duty vehicles	~ 1.3 km²	No
		ZEZ	2023	Road access restriction	All	~ 1.3 km²	No
		ZEZ	2026	Road access restriction	All	~ 13 km²	No
	Amsterdam	ZEZ	2022	Road access restriction	Buses andcoaches	~ 6.5 km²	Yes
		ZEZ	2025	Road access restriction	All except passenger cars	~ 70 km²	Yes
		ZEZ	2030	Road access restriction	All	City-wide	Yes
	Paris	ZEZ	2030	Road access restriction	All	Greater Paris metropolis	Yes
	London	ZEZ or Near-ZEZ	From 2020	Unspecified	Unspecified	Town centers	Yes
		ZEZ or Near-ZEZ	2025	Unspecified	Unspecified	Central London	Yes
		ZEZ or Near-ZEZ	2040	Unspecified	Unspecified	Inner London	Yes
		ZEZ or Near-ZEZ	2050	Unspecified	Unspecified	City-wide	Yes
	Bergen	ZEZ (pilot)	2020 (delayed)	Unspecified	Unspecified	Unspecified	Yes
		ZEZ	2030	Unspecified	Unspecified	City center	Yes
	Berlin	ZEZ	Unspecified	Unspecified	Unspecified	Urban area within S-Bahn	Yes
	Copenhagen	ZEZ (pilot)	2023	Unspecified	Passenger cars	Medieval City	Yes
		ZEZ (pilot)	2023	Unspecified	All	Unspecified	Yes
		ZEZ-F (pilot)	2023	Unspecified	Delivery vans	Unspecified	Yes
		ZEZ-F (pilot)	2025	Unspecified	Delivery vans and trucks	Unspecified	Yes
	Milan	ZEZ	2030	Road access restriction	All	Area C (8.2 km²)	No
	30-40 Dutch cities	ZEZ-F	2025	Road access restriction	Delivery vans and trucks	City centre and surrounding neighbourhoods	Not specifically
	35 C40 cities*	Unspecified	2030	Unspecified	Unspecified	Unspecified	Not specifically

Source: IEA, Stifel*

*C40 cities follows the Green and Healthy Streets Declaration, signed by 35 global cities to match the ambition of the Parisagreement. Among signatory cities in Europe, we can find: Amsterdam, Athens, Barcelona, Berlin, Copenhagen, Heidelberg, Lisbon, London, Madrid, Milan, Oslo, Paris, Rome, Rotterdam, Stockholm, Warsaw. But key cities such as Los Angeles, Seoul, Montreal and Auckland by 2030 are also part of the club.

As such, it becomes of major importance for any public fleet to switch to electric vehicles, getting the most adapted mix of technologies as soon as possible to deal with clean and renewable energies. In this context, hydrogen and battery legitimacy as key complementary solutions remains entire, with hydrogen complementing batteries in avoiding plug access and congestion/range anxiety as well as reducing grid pressurization..

Figure 38 - ICEV phase-out schemes in various European cities



Source: Stifel, municipalities, EU Commission*

… which technology should win the race?

BEV vs FCEV, energy efficiency's the name of the game

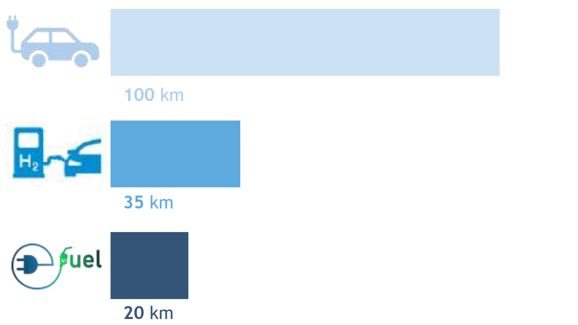
Figure 39 - Net-zero mobility technologies

	e-fuel ICE	BEV	Hydrogen FCEV	Hydrogen Combustion
No tailpipe emissions	✗	✓	✓	✓
Autonomy	High	High // Medium	High	High
Charging/ Refueling Time	Low	High // Medium	Low	Low
Network	High	Medium	Low	Low
Subventions	✗	✓	✓	✓
No use of noble metal	✓	✗	✗	✓

*Source: Stifel**

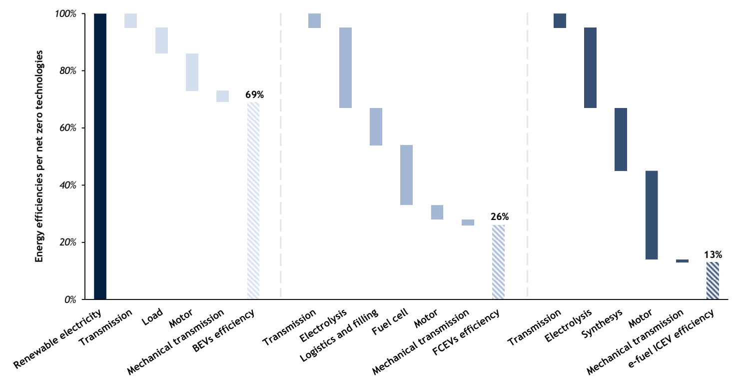
Well-to-wheel electricity consumption analysis shows hydrogen is less efficient than battery electric vehicles (>2 times less). This is why the trade-off between weight, energy efficiency, grid pressure and ease of charge could make more sense in heavy mobility than in light mobility. Otherwise, from a pure OPEX perspective, battery vehicles should always be cheaper and cleaner to operate. Therefore, the bulk of ZE light mobility would be adapted to renewables with batteries as cars are parked 80-90% of the time, allowing for residential and workplace/destination charging, which is not the case for more intensive use cases where supply/demand for renewable electricity might need to be thought from a broader angle.

Figure 40 - 15kWh range equivalent



Source: Climate Watch, Stifel*

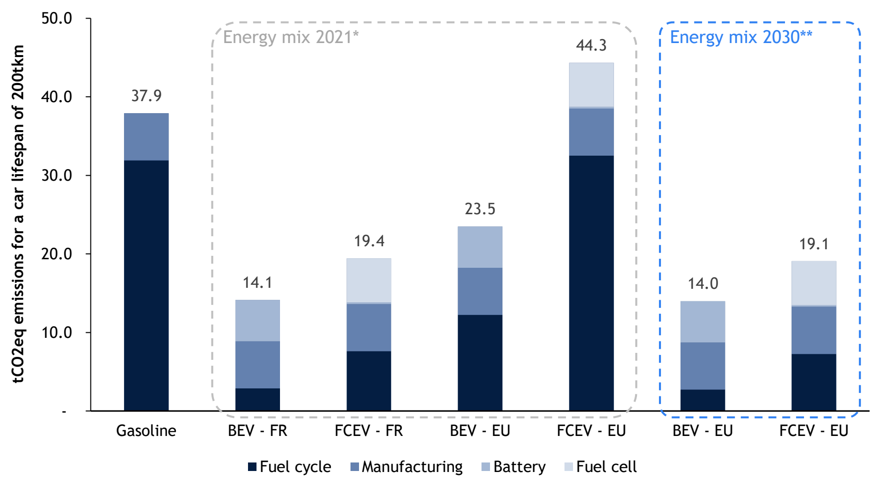
Figure 41 - Energy efficiencies of BEVs, FCEVs and ICEVs



Source: Climate Watch, the World Resources Institute

For now, hydrogen vehicles are more carbon-intensive than ICE vehicles with the current EU energy mix but should be far greener with the 2030 and 2050 renewable mix, therefore adding a solution to the ongoing transition. However, in any of these scenarios, BEVs generate fewer emissions than FCEVs on a LCA basis, mainly due to additional steps ahead of e-transmission, with energy losses ranging from hydrogen electrolysis to pressurization, distribution and fuel cell conversion rate. Low efficiency of hydrogen solutions and a lack of infrastructure explain the slow development of hydrogen mobility as an alternative to BEVs in mobility. However, as e-fuels can buffer ICE emissions during the transition, political and industrial factors support heavy-duty fleet adoption of hydrogen considering the technology offers a complementary option to batteries while keeping a straight focus on GHG emission reduction going forward.

Figure 42 - GHG emissions per technology for 200tkm



Source: Stifel*, RTE, ADEME, UNECE, ICCT, Ballard

Assuming 6tCO2eq for manufacturing, 5.2tCO2eq and 5.6tCO2eq for a 80-85kWh battery and a >100kW PEMFC

*considering 25% nuclear, 15% coal, 19% natgas, 3% oil, 14% wind, 6% solar, 12% hydro and 6% biomass

**considering 25% nuclear, 5% natgas, 24% wind, 20% solar, 12% hydro and 14% biomass

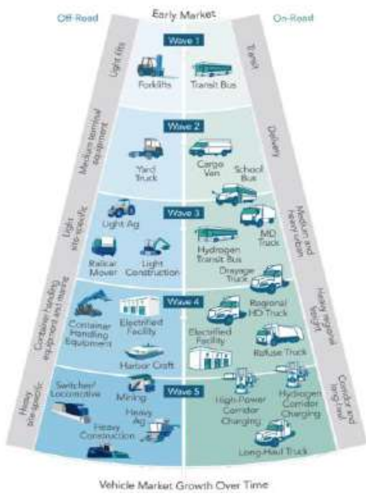
Nevertheless, this remains skewed to trucks and haulage in the longer-term. Indeed, while European regulations have set significant constraints for HDV OEMs on the manufacturing side (Euro 7 norm) and for operators with regards to the sourcing of their vehicles, FCEVs might remain an isolated option, at best with ~10% of buses sold by 2030 and potentially more for coaches and trucks, if available.

"Euro 7 standards put OEMs in a difficult situation: it's not possible to develop Euro 7 for the whole range, investments for the Class I segment would never been recouped. Looking at the evolution of the city bus market in Europe, we don't see gas drivetrains to have a market in the future. We see room for fuel cell buses but no more than 10 per cent of the bus market."

Heinz Kiess, Head of Product Marketing Bus, MAN Truck & Bus, UITP Summit June 2023

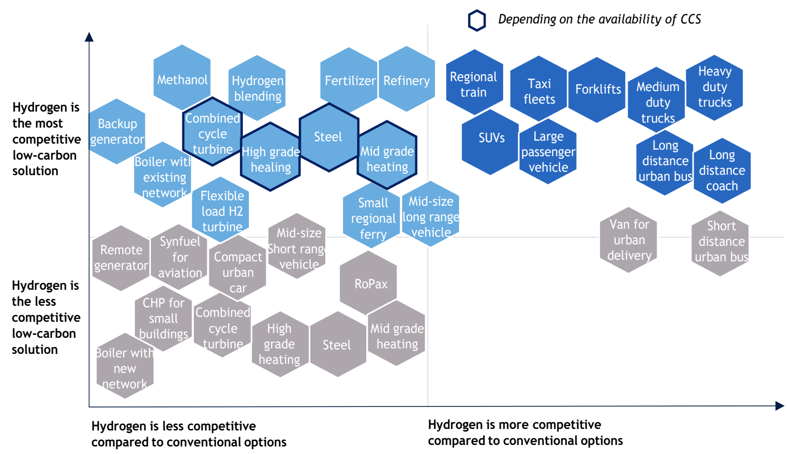
Therefore, as the transition towards decarbonized transport is seriously kicking off, BEV would take the lead over FCEVs. The relevance of FCEBs versus BEBs is therefore being examined at a local level and developed alongside regional public/private initiatives (taking into account geographical specifics: slopes/variety of landscapes, temperature, average shift distance and availability of renewable electricity, i.e. centralized solar/wind, etc...).

Figure 43 - The ZE beachhead



Source: Calstart "Zeroing in on ZEBs" study

Figure 44 - Competitiveness of H2 vs other alternatives



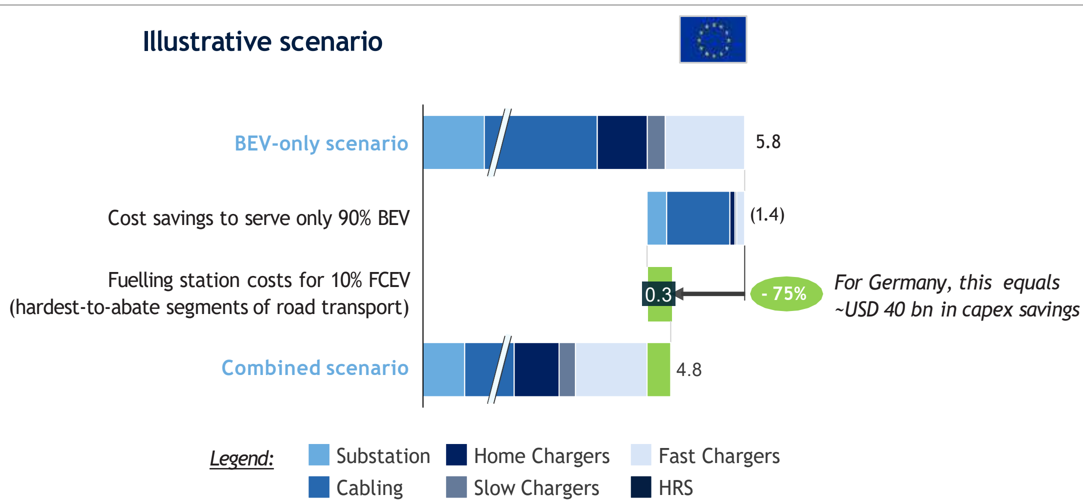
Source: Climate Watch, the World Resources Institute

Leading the TCO dynamic: the bulk of the answer

Nothing like hybrids' replacement by pure BEVs should happen with FCEVs. Technology leadership should be well defined by (i) TCOs, (ii) switching cost for operators and (iii) OEM investment return probabilities. As such, regulatory pressures could not leave enough time for NGV-bus lines given the phase-out of carbon/particles emission from city centers/peripheral agglomerations and the urgency for OEMs to transition towards ZEV. Consequently, OEMs have been rushing to release their own BEB/FCEB, usually plugging electric systems on legacy lines.

Therefore, still in the early phases of the e-mobility roll-out, TCOs would be one of the most important factors during decision-making processes to differentiate between the efficient/available products. However, TCO calculation are not consensual given building a hydrogen refuelling network alongside battery charging infrastructure could be cheaper than building a powerful charging infrastructure covering the entire AC and DC charging markets. According to McKinsey, 10% of EVs powered with fuel cells would easily reduce total refuelling/charging infrastructure capex by 17%. This complementarity between powertrains and charging infrastructure backs our approach concerning hydrogen and EV charging deployment schemes, only factoring a small share of the pie for FCEBs relative to BEBs.

Figure 3 - Transport related CO2 emissions breakdown in Europe as of 2022



*Source: Hydrogen Council, McKinsey, Stifel**

Long time denied due to their expensiveness compared with traditional ICEB, a significant reduction in TCOs relative to diesel and hydrogen buses triggered flourishing initiatives in Europe and NAM to equip cities with BEBs (which further highlights the impact of this indicator). As such, BEB depots popped all around the world with operators going beyond the chicken-and-egg dilemma and scalability fears. Indeed, even if grid updates are costly (EUR80k on average per substation transformer) and mandatory to obtain a certain amount of power, at the end of the day, a bus fleet operator relies heavily on its depot. As such, switching to ZE and BEB/FCEB does not only require investing in fleet conversion but also in depot transformation/expansion either being able to host enough power for multiple 150KWh chargers plugging simultaneously or a privately owned 1ton/day HRS (equivalent to 20-25 daily bus consumption).

Figure 46 - Leipzig EV charging / 21 BEBs investment project in 2020

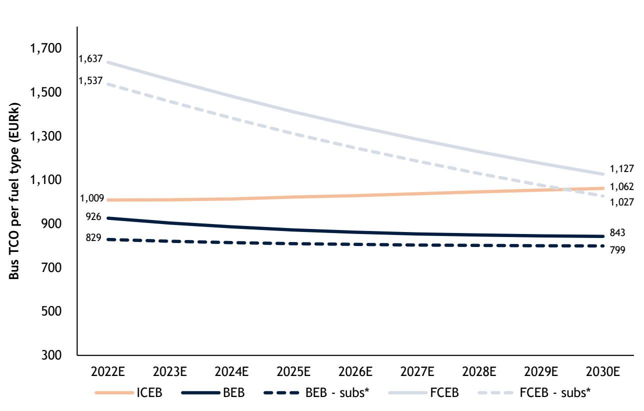
Source: Smart Cities World, Leipzig

Figure 47 - Cologne's operator KVB depot charging infrastructure for 51 BEBs since July 2021

Source: Urban Transport, VDL

As such, although BEB and FCEB have a higher purchase cost upfront than ICEB, they benefit from various government grants and incentives that help partially offset the initial investment. These financial aids can significantly reduce net purchase costs of e-buses, but the economically viable solution in the short-to medium-term might only be with batteries, catching FCEBs threshold later in the decade.

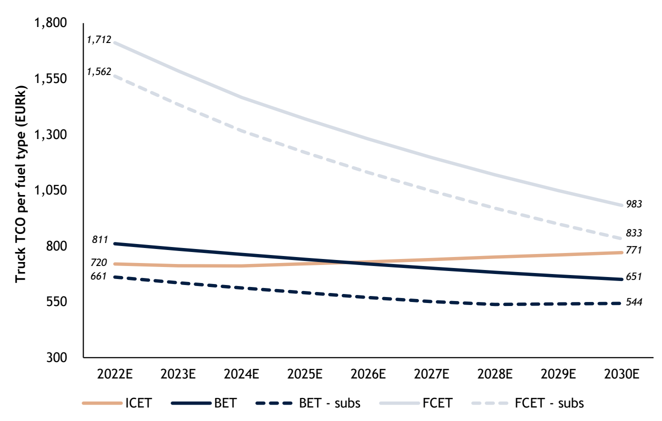
Figure 48 - TCO for buses up until 2030



Source: Stifel, ICCT, European subsidy plans*

**study from the Foothill Transit Authority in California show 1:1.3 BEBs should be needed to replace an old ICEB and ensure a stable passenger volume, compared to 1:1 with FCEVs because of range limitation and recharging vs refueling times. However, this is not factored in our TCO calculations.*

Figure 49 - TCO for trucks up until 2030



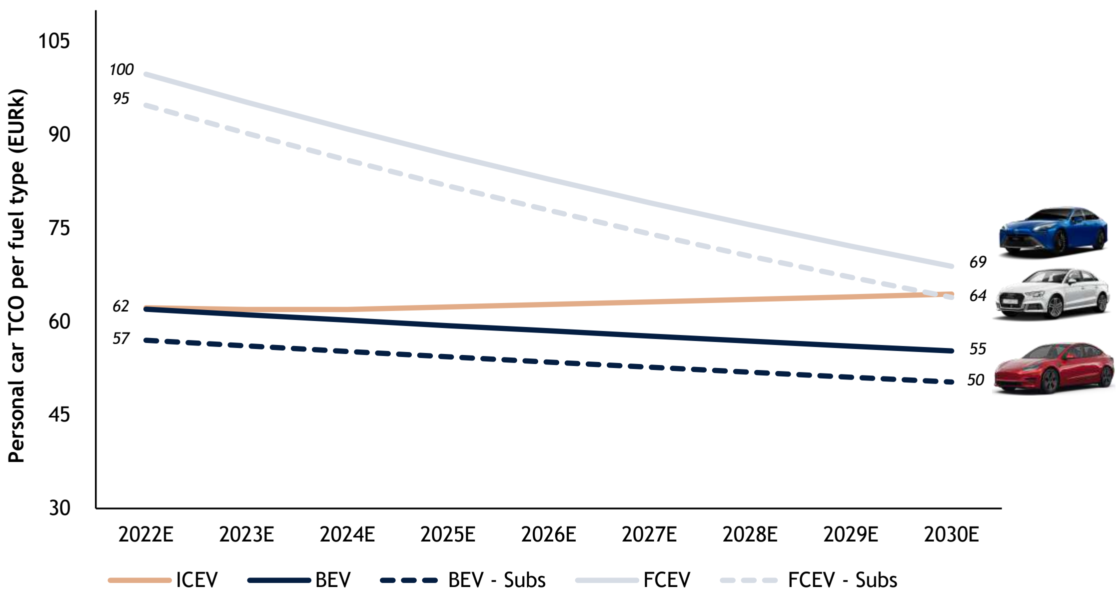
Source: Stifel, ICCT, European subsidy plans*

**to allow for similar freight volumes delivered by a truck fleet, a 1:2 ratio between battery-electric trucks and FCEV trucks could be observed because of battery weights and reduced load capacities. This has not been factored in the above calculations.*

While BEBs already offer compelling solutions according to our estimates, the hydrogen case would only be supported with subsidies before 2030. In France for example, grants can go up to EUR30k for a ZEB, but as high as USD180k for the same electric transit bus in California.

Nevertheless, the cost of fuel plays a crucial role in TCOs. Getting hydrogen prices at the pump from EUR12/kg to EUR4-5/kg more quickly could support further the entry of hydrogen vehicles on our roads. Coupled with infrastructure/grid and load transfer synergies unlocked with hydrogen mobility as well as binding constraints on haulage, this should pave the way for trucks going forward. Indeed, the ability to store renewable electricity whether for fast or seasonal reserves would become increasingly strategic going forward. Nevertheless, in the case of batteries, a significant cost advantage should remain, powered by similar green/ low carbon electricity, and less transformation intermediaries.

Figure 50 - TCO for personal cars up until 2030



Source: Stifel, ICCT, European subsidy plans*

While BEVs are vital for fast decarbonization and are set to be a mainstream solution in many use cases, FCEV singularities can be more appropriate for some. In this context, while our TCO calculations are more conservative and share similar but three/four-year later trends than those of Ballard, McKinsey and Deloitte market research for buses and trucks, FCEVs could be more competitive than ICE vehicles, but still more costly than BEVs by 2030, heavily relying on green or at least low-carbon hydrogen prices.

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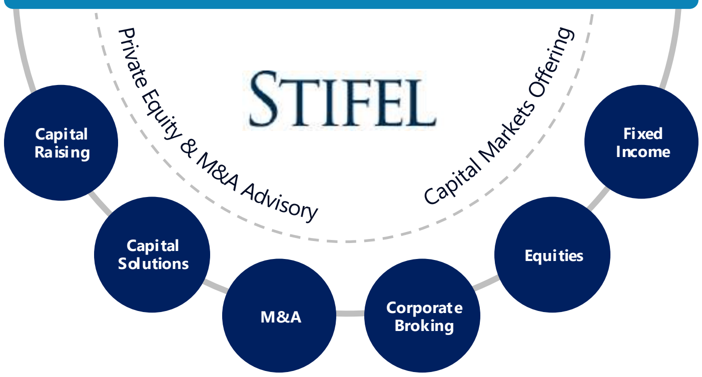

CORE SECTOR EXPERTISE


Diversified Industries


Healthcare


Natural Resources

FIG


Infrastructures


Real Estate


Technology

Note: (1) As at 02 February 2025; (2) as of 31 December 2024

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