

# CORPORATE CLIMATE STOCKTAKE: ROAD TRANSPORT

October 2023





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# Road transport emissions, mainly from vehicle use, need to drop ~30% by 2030 to stay on a Net Zero trajectory

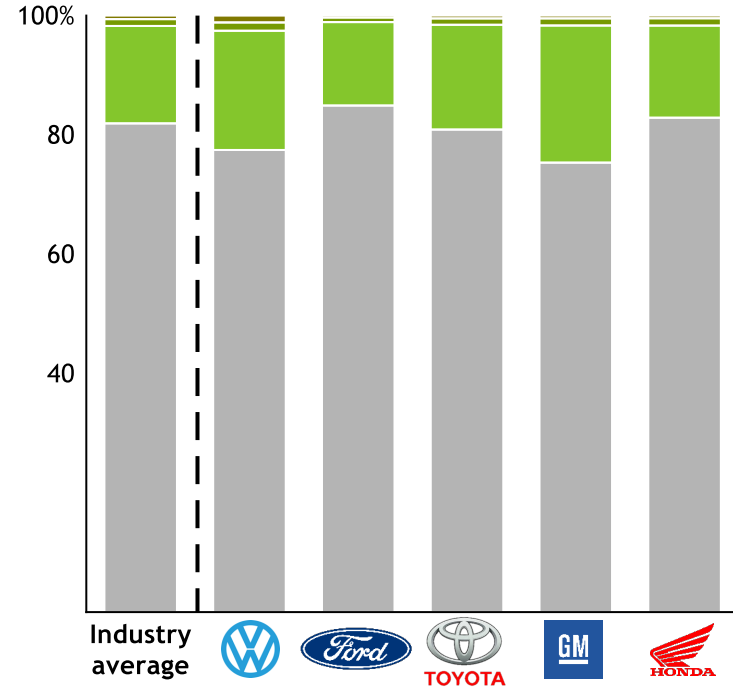
## 01 SECTOR OVERVIEW

02 03 04

### Most Road Transport emissions come from use of sold vehicles

Share of annual CO2 emissions for select road transport OEMs (%)

- Scope 1
- Scope 2
- Scope 3 Upstream
- Scope 3 Downstream



#### Scope 1 key sources

- Manufacturing of components
- Owned vehicle fleet

#### Scope 2 key sources

- Purchased electricity
- Steam, heating and cooling for own use

#### Scope 3 key upstream sources

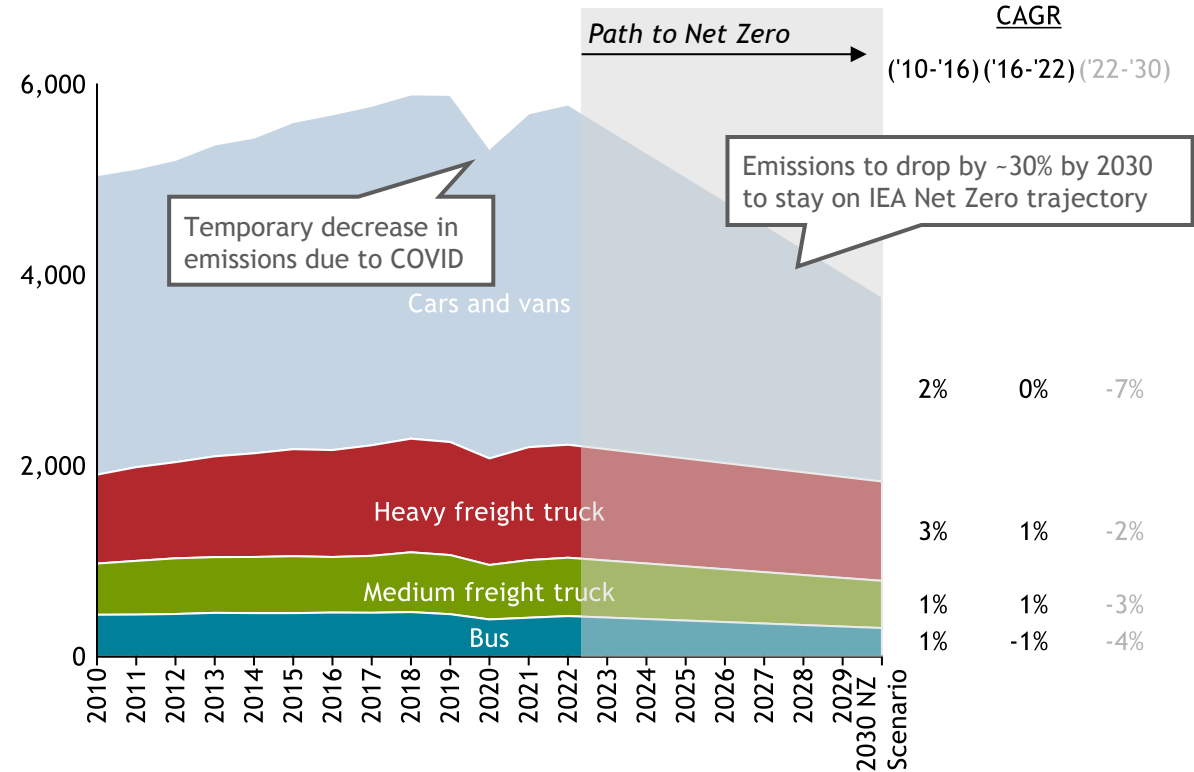
- Purchase of raw materials and parts
- Purchase of furnishings and equipment

#### Scope 3 key downstream sources

- Use of sold vehicles: Tailpipe emissions
- End of life treatment of vehicles
- Leased assets

### Progress on emissions reduction from use of sold road transport vehicles needs to accelerate

Annual CO2 emissions (Mt CO2)



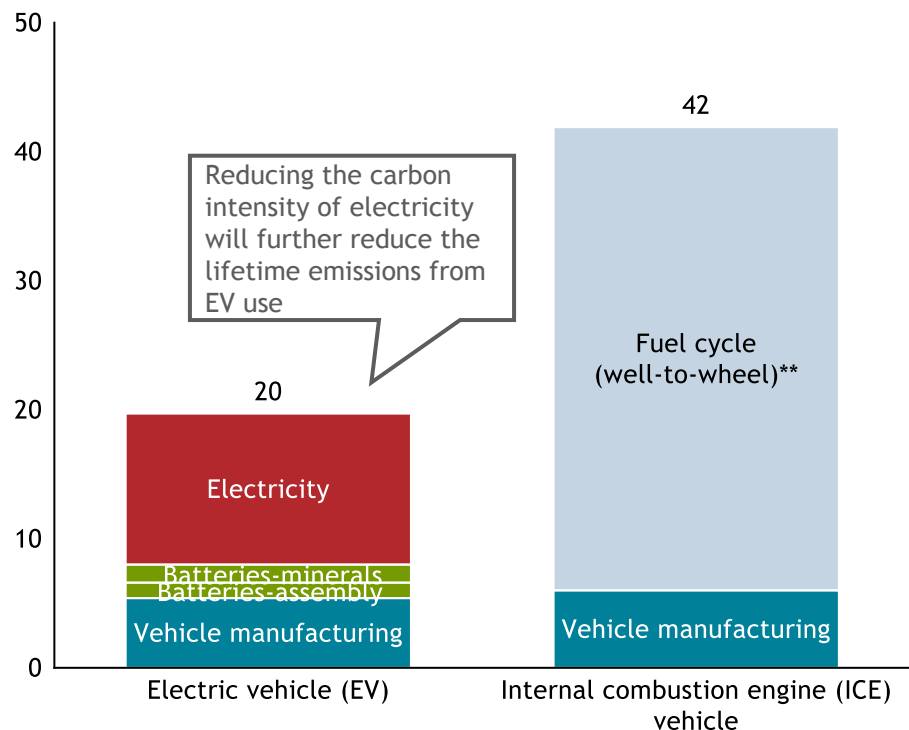
Source: IEA Fuels & Technologies Progress Reports (Cars and Vans, Trucks and Buses); 2021 General Motors Sustainability Report; 2021 Mitsubishi Motors Sustainability Report; 2021 Toyota Motor Company North America Sustainability Report; 2021 Renault Motors Sustainability Report; 2021 Volkswagen Group Sustainability Report; 2021 CDP data



# Electric vehicles (EVs) are a leap forward in decarbonization and associated emissions will further decline as the power sector decarbonizes

## EV emissions are less than half that of ICE vehicles

tCO2 emissions per vehicle lifetime\*



Note: PHEV - plug-in hybrid electric vehicle, (\*) Total emissions for a vehicle's lifetime includes emissions related to vehicle manufacturing, emissions related to battery production, emissions related to electricity use, and emissions related to traditional fuel use; (\*\*) Well-to-wheel fuel cycle refers to the full set of emissions from fuel production, processing, distribution, and use  
 Source: IEA ("Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle"),

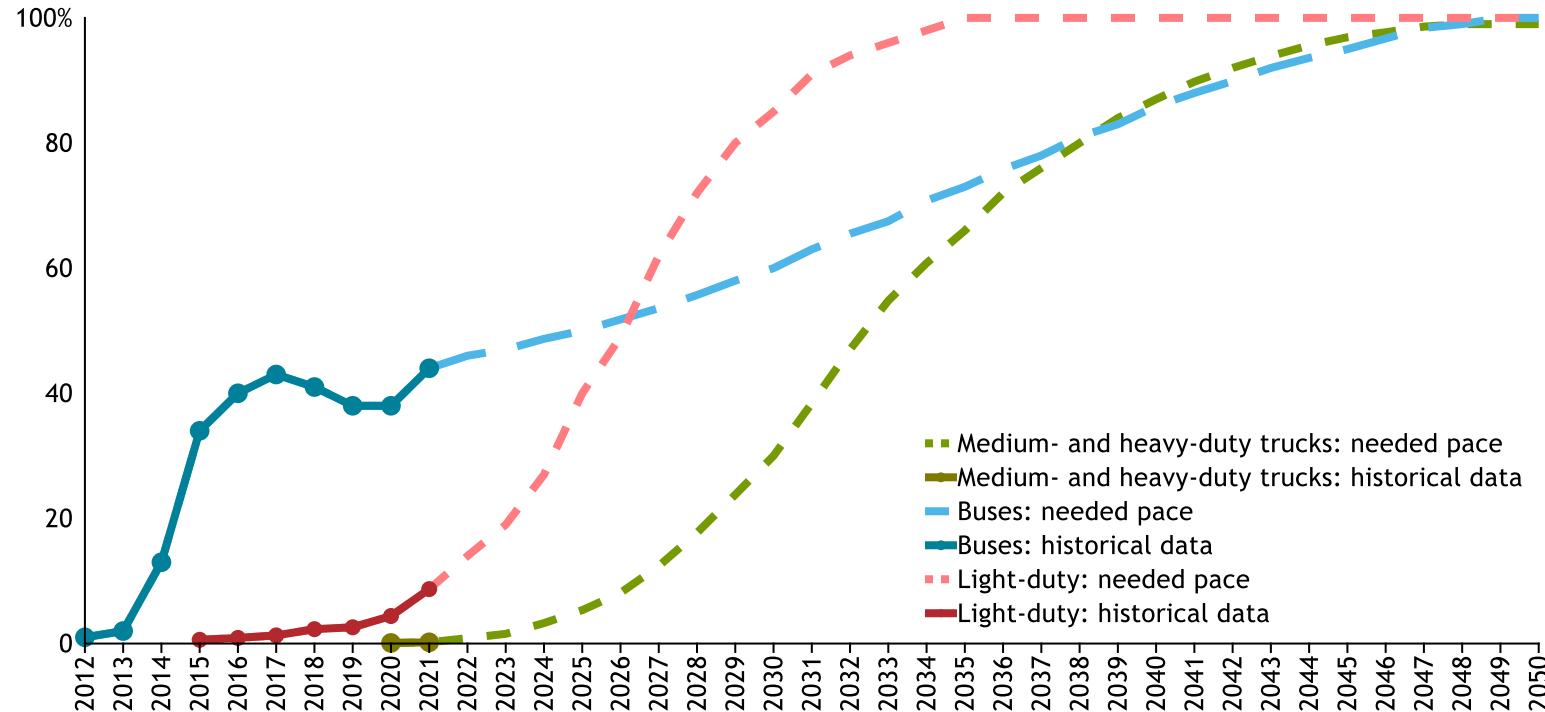
## Differences in the powertrain system enable EVs to generate reduced emissions over the lifetime of the vehicle vs. ICE vehicles

Emissions category	Internal combustion engine (ICE) vehicles	Electric vehicles (EVs)
Vehicle manufacturing	<ul style="list-style-type: none"> <li>The emissions footprint from manufacturing of ICE vehicles and EVs is similar, with as all non-powertrain components are the same including interior, chassis, and body</li> <li>ICE powertrain components not used in EVs, include:                             <ul style="list-style-type: none"> <li>- Combustion engines</li> <li>- Ignition / starters</li> <li>- Alternators</li> <li>- Engine cooling systems</li> <li>- Low voltage electrical components</li> <li>- Fuel and exhaust systems</li> <li>- Axles</li> <li>- Driveshafts</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>The integrated EV powertrain also has novel components vs. traditional ICE powertrains, including:                             <ul style="list-style-type: none"> <li>- eMotors</li> <li>- Inverters</li> <li>- High voltage electrical systems with chargers, invertors, DC converters, cables, connectors</li> <li>- Complex thermal management systems for batteries and electronics</li> </ul> </li> </ul>
Batteries (incl. minerals and assembly)	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>The mining and production of minerals for EV batteries and subsequent production of batteries releases incremental emissions vs. ICE vehicles</li> </ul>
Electricity	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>EVs consume electricity to fuel to e-powertrain that ICE vehicles do not</li> </ul>
Fuel cycle (well-to-wheel)	<ul style="list-style-type: none"> <li>ICE vehicles typically convert around ~30% of energy from liquid fuels which are typically fossil derived</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>

# Over the last few years there has been early adoption of EVs across light-duty, buses, and freight, but now adoption is accelerating across many vehicle types

Light-duty, bus, and freight EVs are beginning to penetrate the market, but they have yet to overtake ICE vehicles

Share of global vehicle sales (%)



EV adoption differs among vehicle type given distinct buyer groups

- Buses have seen the greatest EV penetration due to prevalence of government commitments to carbon-zero government fleets
- Passenger vehicles have begun to see an uptick in EV adoption, driven by adoption in developed markets with the resources to finance the transition
- The medium- and heavy-duty segment has not yet seen meaningful EV adoption driven by both demand- and supply-side barriers

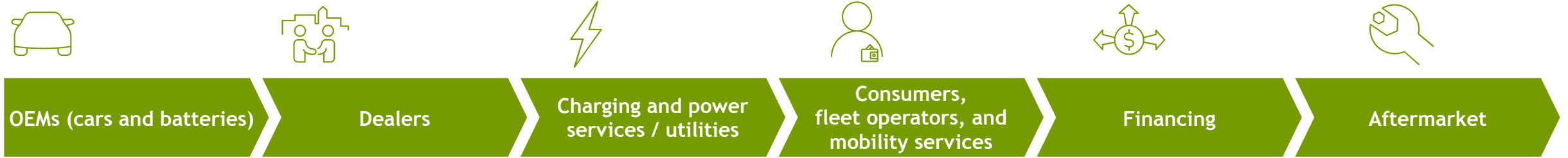
Source: Systems Change Lab, Corporate interviews

# WE MEAN BUSINESS COALITION

## Players across the value chain have a role to play in decarbonization...

### 01 SECTOR OVERVIEW

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### Key activities in the Road Transport value chain

Manufactures original vehicle components

Sells new and used vehicles  
Offers spare parts and maintenance services

Manufacture EV charging stations and charging points  
Provide power for charging stations

Purchase vehicles  
Manage fleet portfolios

Offers financing, leasing, and interest payment plans  
Manages payment collection

Performs maintenance and service requirements  
Provides opportunities to sell vehicles and parts at EOL

### Key activities in the Road Transport value chain

Source sustainable raw materials  
Recycle vehicle parts  
Develop diverse EV options  
Reduce emissions in manufacturing process

Continue to add EVs to vehicle portfolio and promote purchasing

Build out and manufacture diverse charging applications  
Improve power infrastructure to sustain energy demands with renewables

Drive demand towards EVs through intentional purchasing (and promotion for mobility services)

Offer attractive financing options for EVs compared to ICE vehicles

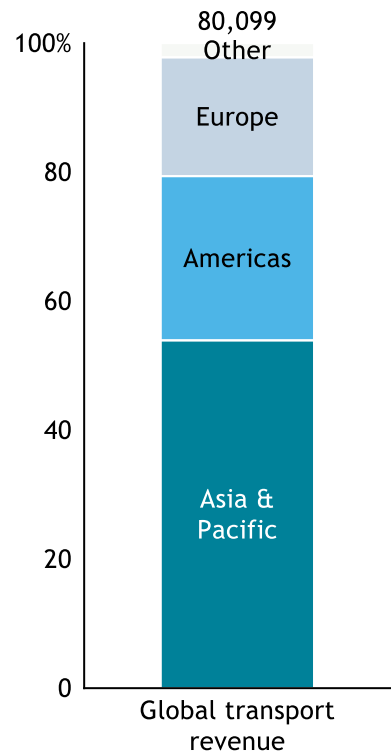
Provide specialized EV use, maintenance, resale, and recycling support

# ...and ~70% of road transport orgs are already on track to exceed Breakthrough emissions reduction guidance

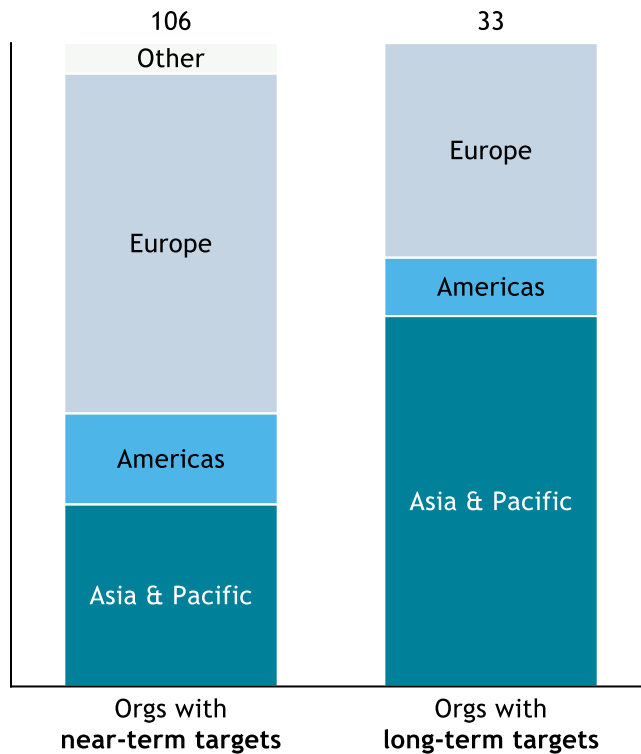
Legend: Company performance vs. Breakthrough ■ Missed target (<80%) ■ Near miss (80-100%) ■ Hit target (+100%)

## Companies reporting CDP goals are skewed to Europe

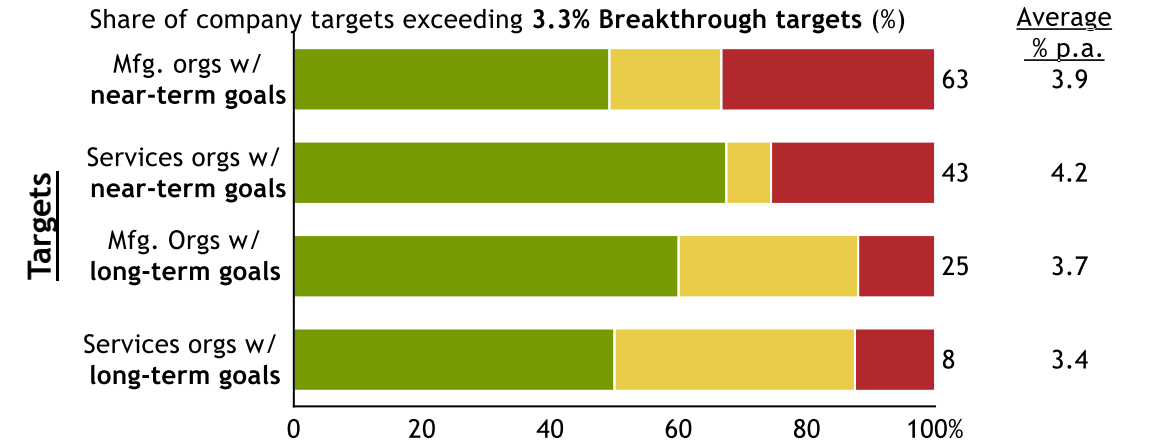
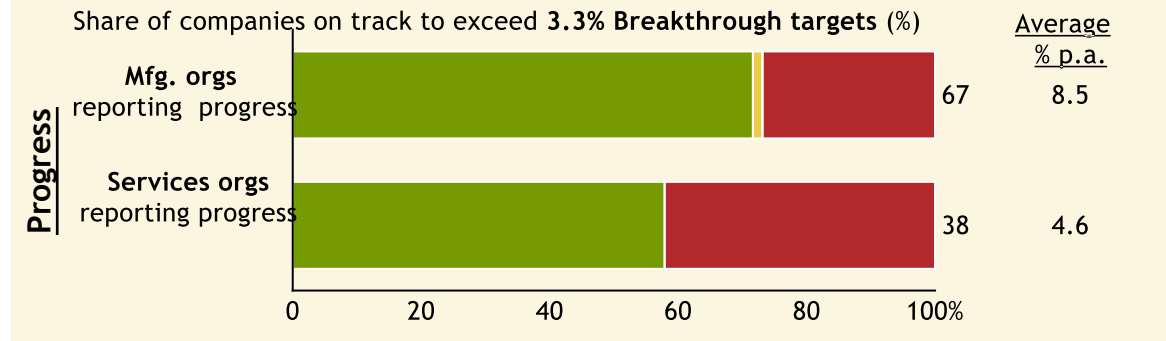
Global mix of new pass. and comm. vehicles in 2022 (K of vehicles)



Mix of companies reporting ambitions to CDP



## ~67% of road transport companies are on track w/ Breakthrough



Note: Annual reduction ambition shows the % reduction a company will need per year in order to reach their target from the base year (includes underway, new, or revised targets); near-term defined as target year before 2030; Priority countries selected based upon highest emission countries from 2022 Global Carbon Project Data; % reduction refers to an annual percentage and does not take into account compounding; Breakthrough Agenda goals account for Scopes 1+2 only  
 Source: 2022 CDP Climate Questionnaire Data; 2022 Global Carbon Project; The Global Economy

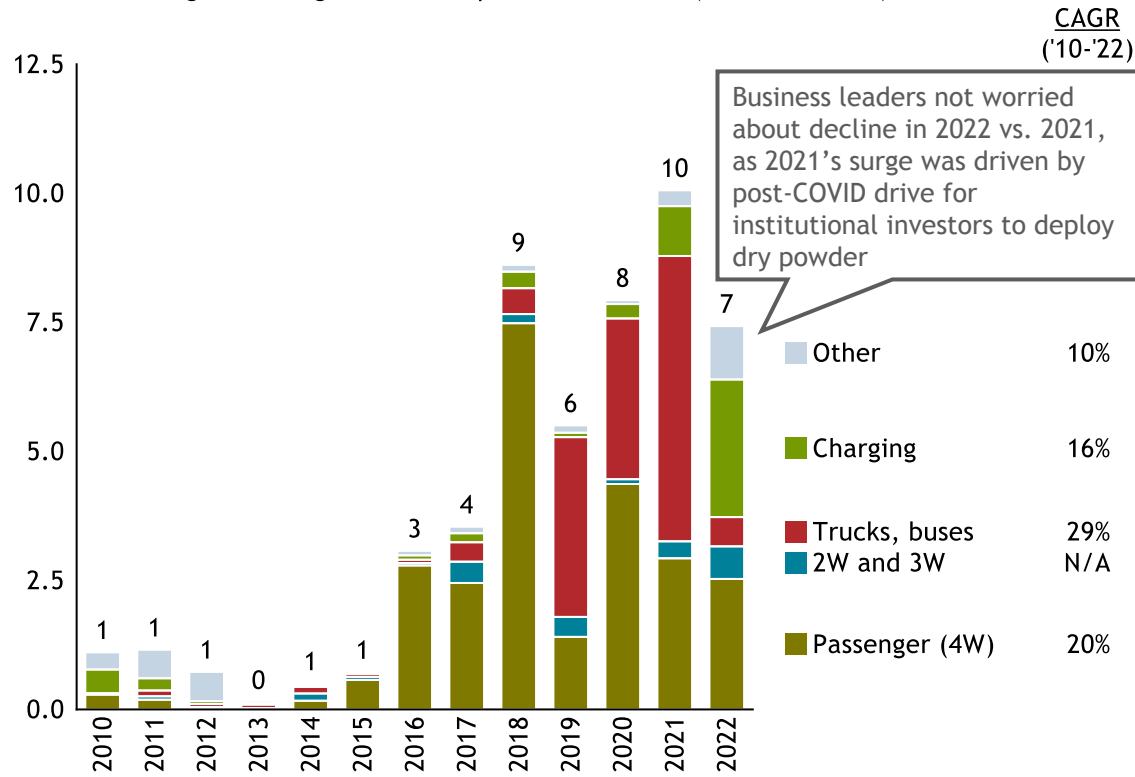
# Venture capital investments have grown their focus on EVs, with growing variety of investments across the EV value chain

## 01 SECTOR OVERVIEW

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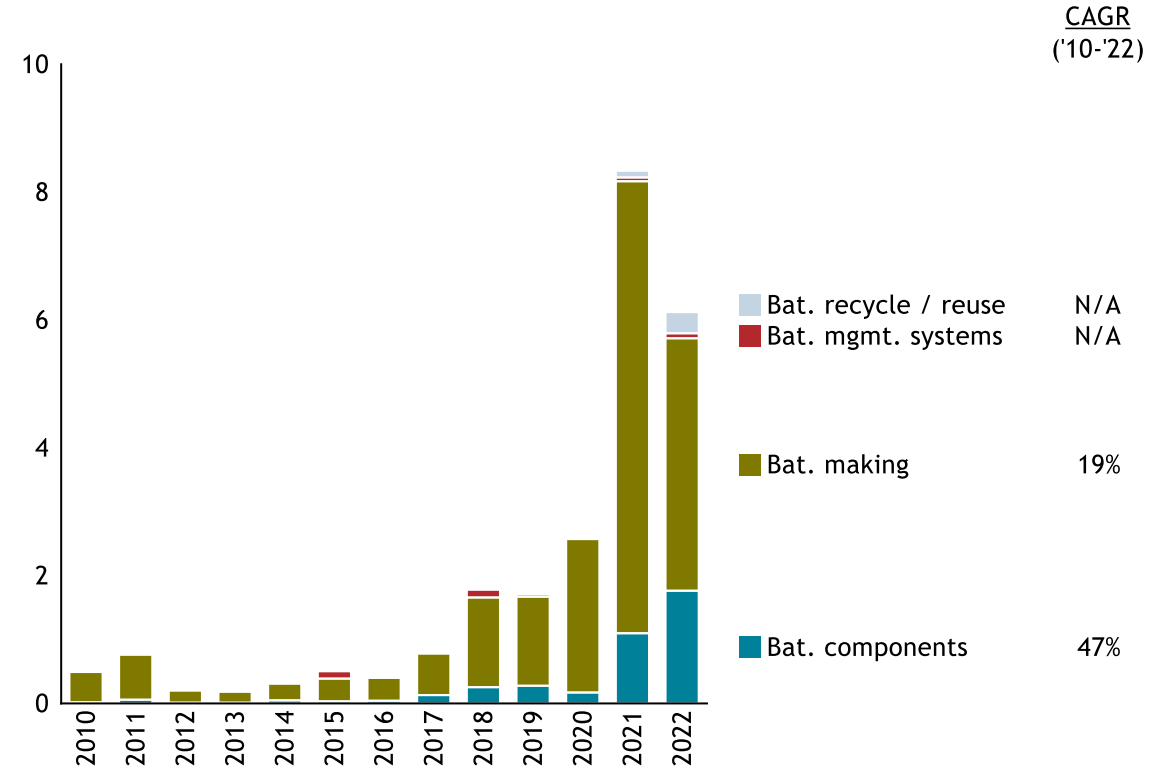
### Recent investments in Road Transport ventures indicate a shift in focus from passenger to trucks, buses, and charging

Global annual growth-stage venture capital investments (in 2023 \$B USD)



### Recent investments in battery ventures indicate increasing interest in battery components and recycling / reuse

Global annual growth-stage venture capital investments (in 2023 \$B USD)



Source: IEA



# Executive Summary: The State of the Transition in Road Transport



## Passenger vehicles in developed markets

Dimension of sector

Future decarbonization scenario

Indicators of progress towards accelerating decarbonization

Passenger EV adoption accelerates with improved charging infrastructure and secured supply chains

EV price is **progressing toward parity**, driving ranges are improving, but concerns remain over reliability, charging infrastructure, and resale value

Permitting timelines and **supply constraints on critical minerals** could prevent automakers from scaling EV production quickly enough to meet demand

Market-wide EV adoption will require expanded charging and underlying power infrastructure, which is expected to be **financed and installed by a combination of state and non-state actors**



## Freight in developed markets

Freight operators validate EV applications and deploy EV fleets as the infrastructure develops

EV TCO is **gaining ground on ICE trucks** with some large fleet operators now starting to invest

OEMs are focusing on the production for zero emission trucks - primarily battery electric technology, but some continue to **evaluate efficiency, cost, and range considerations of hydrogen fuel cell**

**While concerns remain about underlying power infrastructure, fleet operators are investing in their own charging depots for short- and long-haul trucks; some hope to co-invest with other fleet operators or pursue “as-a-service” models**



## EVs in emerging markets

Governments catalyze EV markets, targeting electrification of popular two- and three-wheelers

EV policies and funding in more developed markets like China serve as a **model for other countries at earlier stage of the EV adoption curve**; the provision of large-scale, early direct support kickstarts a self-sustaining transition once parity with ICE is reached

Many emerging economies face additional barriers in the transition to EVs - around **access to sufficient financing and underlying power infrastructure**; promising solutions to these barriers are emerging from development finance institutions and “as-a-service” providers





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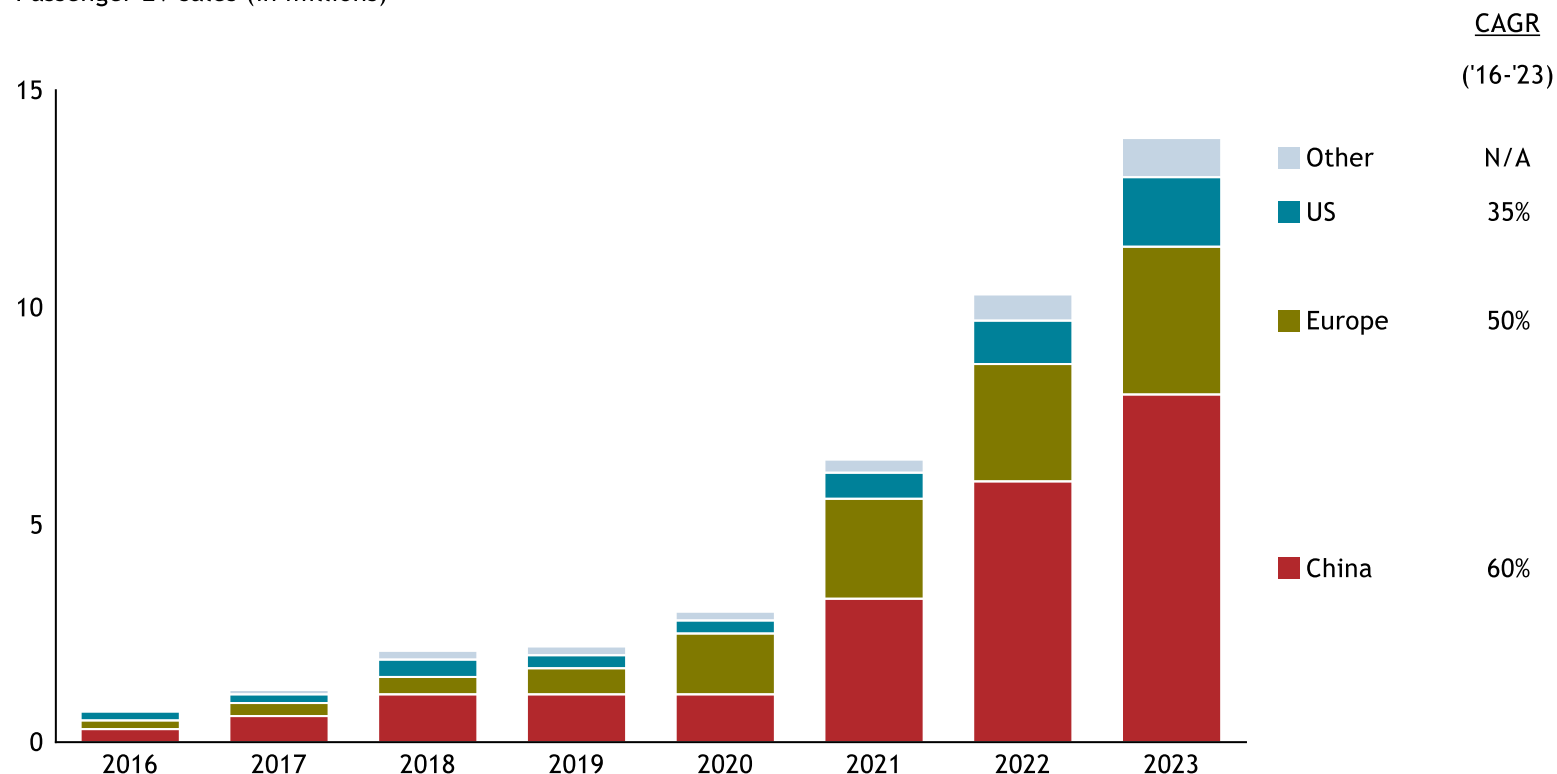
# “We are in the middle of a battery electrification revolution”

## 01 02 PASSENGER VEHICLES IN DEVELOPED MARKETS

03 04

Passenger EV adoption is on an exponential growth trajectory, with China leading the way among developed EV markets

Passenger EV sales (in millions)



Note: Title quote is from Stina Klingvall, Manager of Climate Action, Volvo Cars  
Source: IEA , Corporate interviews

## Commentary

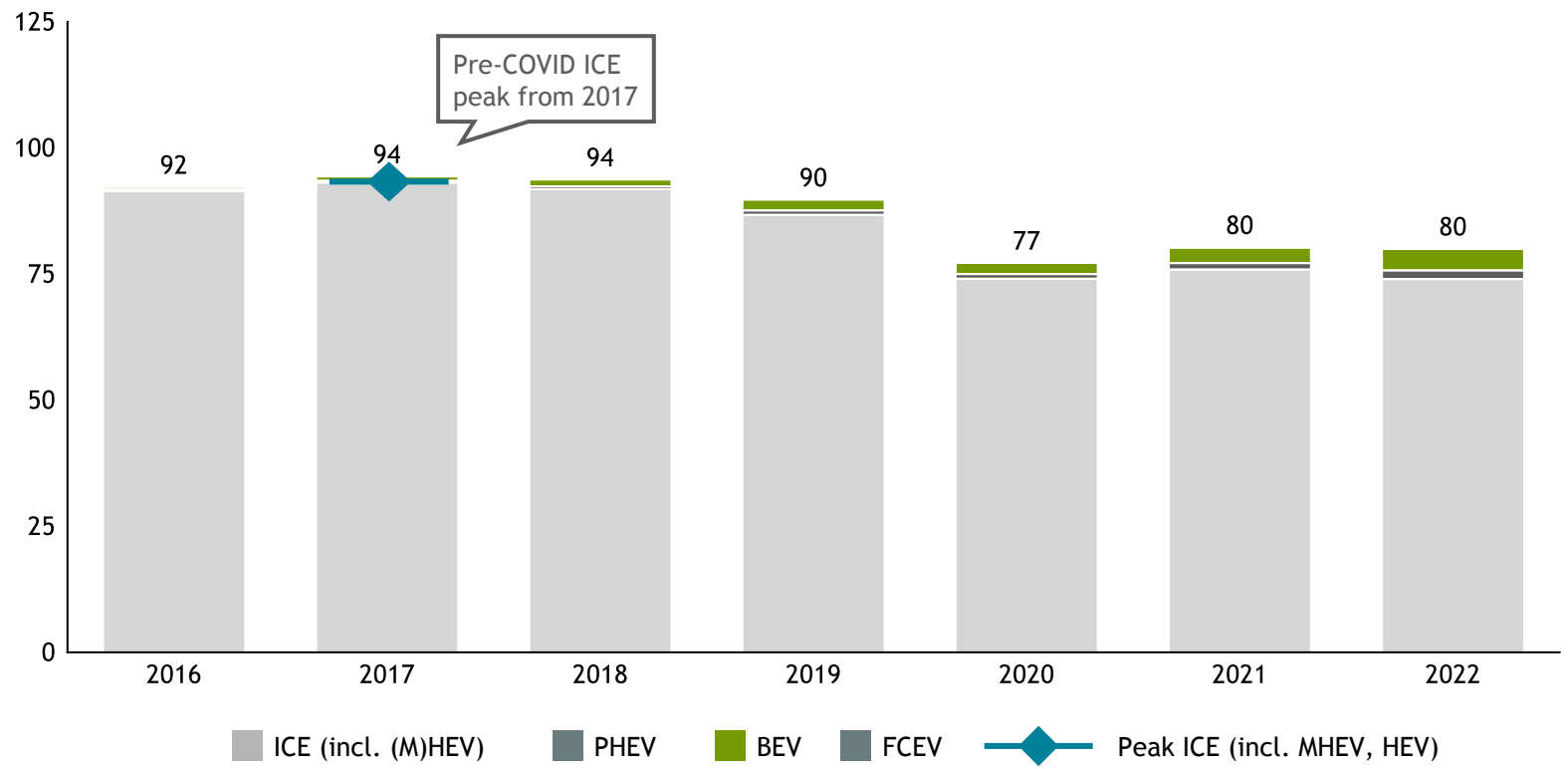
- **Global passenger EV sales have grown exponentially since 2016**
  - Global passenger EV sales grew 4x from 2020-2023
  - Passenger EV sales passed ~10% penetration of the global market in 2021
- **China and Europe have dominated total passenger EV sales thus far**
  - China EV sales have grown 4x+ from 2020-2023
  - Within Europe, Norway leads in EV sales, with 88% of new passenger vehicle sales in the country being EVs in 2020



# Combustion engine sales for light-duty, passenger vehicles globally already peaked back in 2017

## ICE sales already peaked in in 2017 with ~93M units of ICE, MHEV, HEV

Global vehicle sales (in M units)



## Commentary

- **Passenger vehicle market expected to grow through 2030**, with largest contribution expected from emerging economies
  - Post 2022-growth expected to be driven by BEV and PHEV as the technology develops and becomes more commercially viable
- While both BEV and PHEV are expected to grow over the next decade, **BEV are expected to be the preferred car technology** for the future as net zero carbon efforts progress
  - FCEV sales expected to grow post-2028, but FCEV growth will be limited in passenger vehicles given expected prevalence of battery electric technology

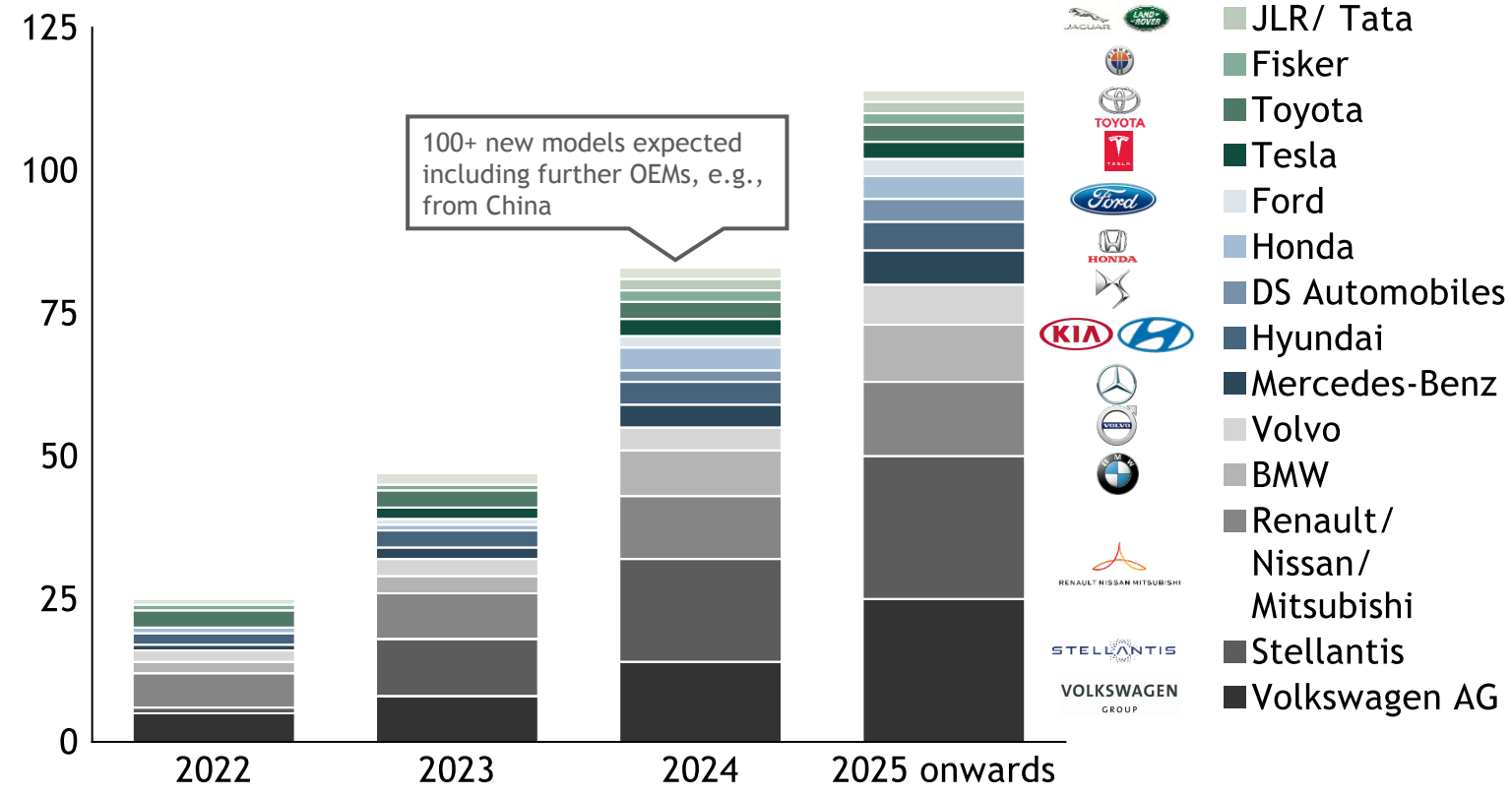
Note: ICE = Internal combustion engine; MHEV= Mild hybrid electric vehicle; HEV= Hybrid electric vehicle; BEV+ Battery electric vehicle; PHEV= Plug-in hybrid electric vehicle ;FCEV = Fuel cell electric vehicle  
 Source: IHS Markit (July 2022)

# “We are moving as fast as we can to shift completely to an electrified portfolio; capacity of the industry is the limiting factor to a permanent shift”

## OEMs ramping up BEV portfolio offering

## Comments

# of BEV model launches<sup>1</sup> planned globally, accumulated



- **Extensive plans to introduce BEV models and new architecture, in premium/ large segments**
  - BMW plans to launch 3 BEVs by 2023
  - Daimler to launch 3 new BEV architecture MB.EA, AMG.EA and VAN.EA
  - Fisker to launch 1 BEV in 2023; Rivian to launch R2 architecture by 2026
  - Jaguar to go all-electric by 2025
- **Ambitious OEM electrification plans**
  - Stellantis to offer 75 BEVs in the market by 2030 and reach BEV sales of 5M vehicles
  - Volvo intends to reach 50% BEV and PHEV market share by 2025; 100% BEV market share by 2030

Note: Title quote is from Head of Sustainability, Auto manufacturer #4; 1) As of Jan 2023; 2) North America  
 Source: JP Morgan analyst report, CALSTART, Corporate interviews

# Business leaders think commercial viability, standards, and willingness to adopt are holding back the transition, but infrastructure is the biggest challenge

01

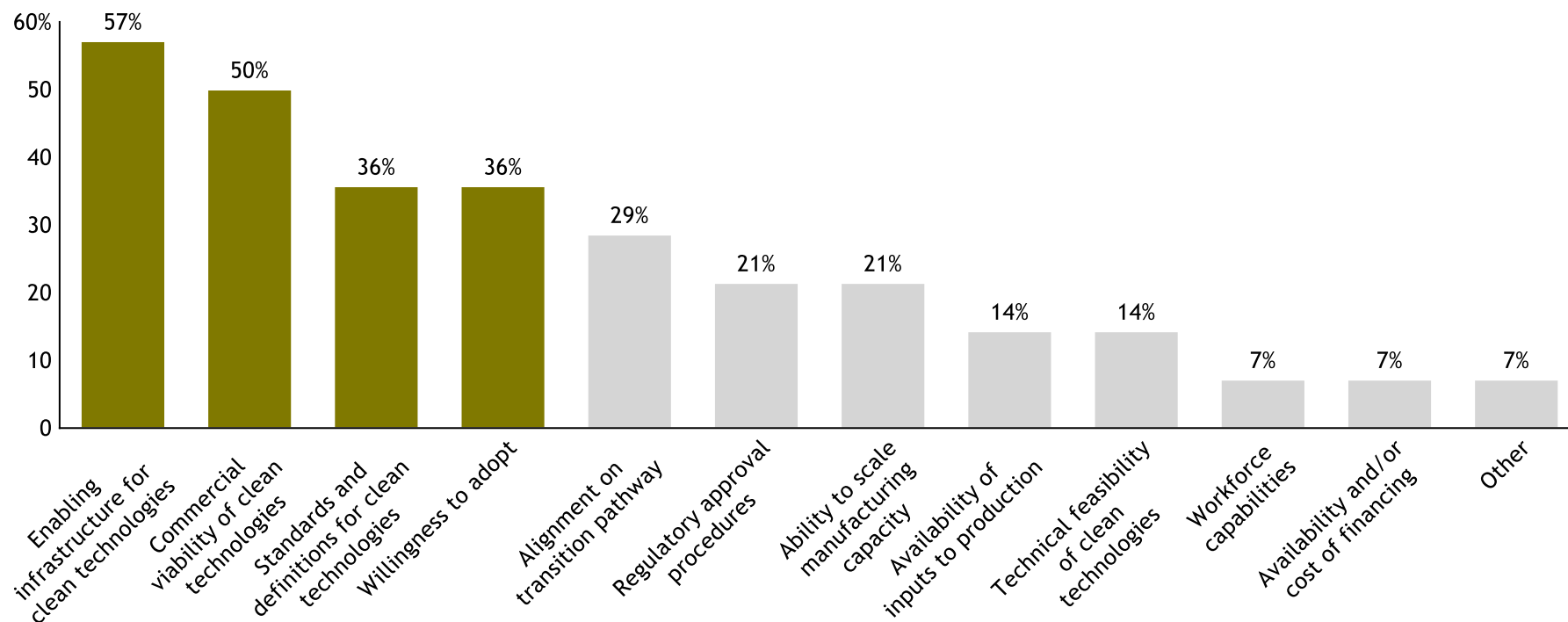
02 PASSENGER VEHICLES IN DEVELOPED MARKETS

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Which of the following do you view as the passenger road transport's largest barriers towards accelerating decarbonization?  
Please select the top 3 most impactful barriers.

Share of survey respondents selecting barrier in the top 3 (%)



Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 14)  
Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

## Commentary

- Business leaders are caught between a few concerns in considering the path to zero-emission-vehicles :
  - Enabling charging buildout to support market-wide EV charging consumption
  - Commercial viability of EVs, most notably their purchase price and driving range parity with ICE vehicles

*“Without indications of commitments to build out the infrastructure from governments and corporations, we worry about the potential for adoption in the near-term. That said, we are aiming to be fully electric by 2030.”*

Head of Climate Action,  
Automobile manufacturer #1

# “Higher purchase prices have historically deterred consumers from purchasing EVs, but EVs are quickly reaching price parity with ICE vehicles”

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02 PASSENGER VEHICLES IN DEVELOPED MARKETS

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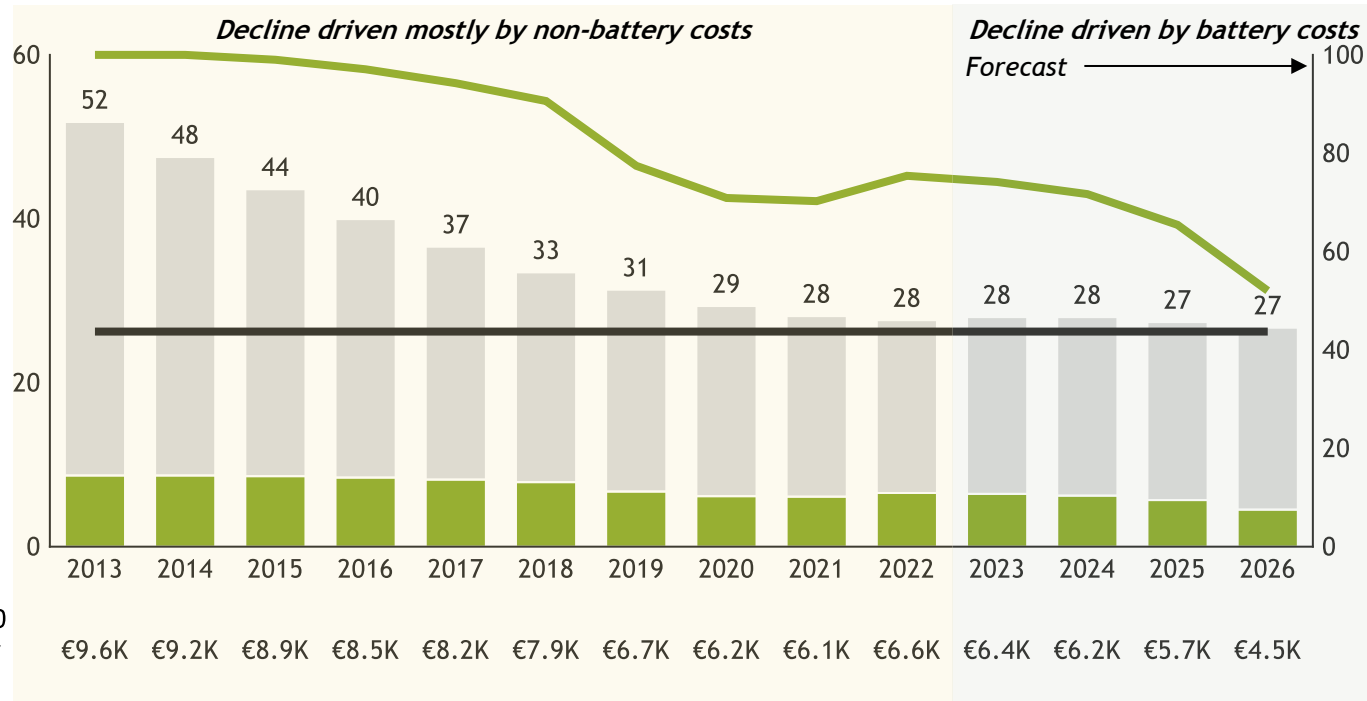
04

## Expected ~31% decrease in battery cost will drive BEV to price parity with ICE vehicles

■ All other non-battery costs ■ Cost for a 50 kWh battery — Cost for a 50 kWh battery (indexed) — ICE purchase price

Purchase price of a vehicle (bars, in 2022 €K)

Cost for a 50 kWh battery (lines, indexed to 2013 = 100)



Cost for a 50 kWh battery (in €K EUR)

Note: Title quote is from Head of Sustainability, Auto manufacturer #4; Cell module costs based upon industry reports of projected prices for cobalt, lithium, nickel, and other materials for cell module; Cell module scaled to assumed battery size to determine battery costs; All other non-battery costs include electric motor and inverter, materials costs, and production & development costs based upon costs for the Volkswagen ID.3 Pro in Germany; ICE price based on VW Golf 2.0 in Germany  
Source: P3/Bain battery cost model, Corporate interviews

## Commentary

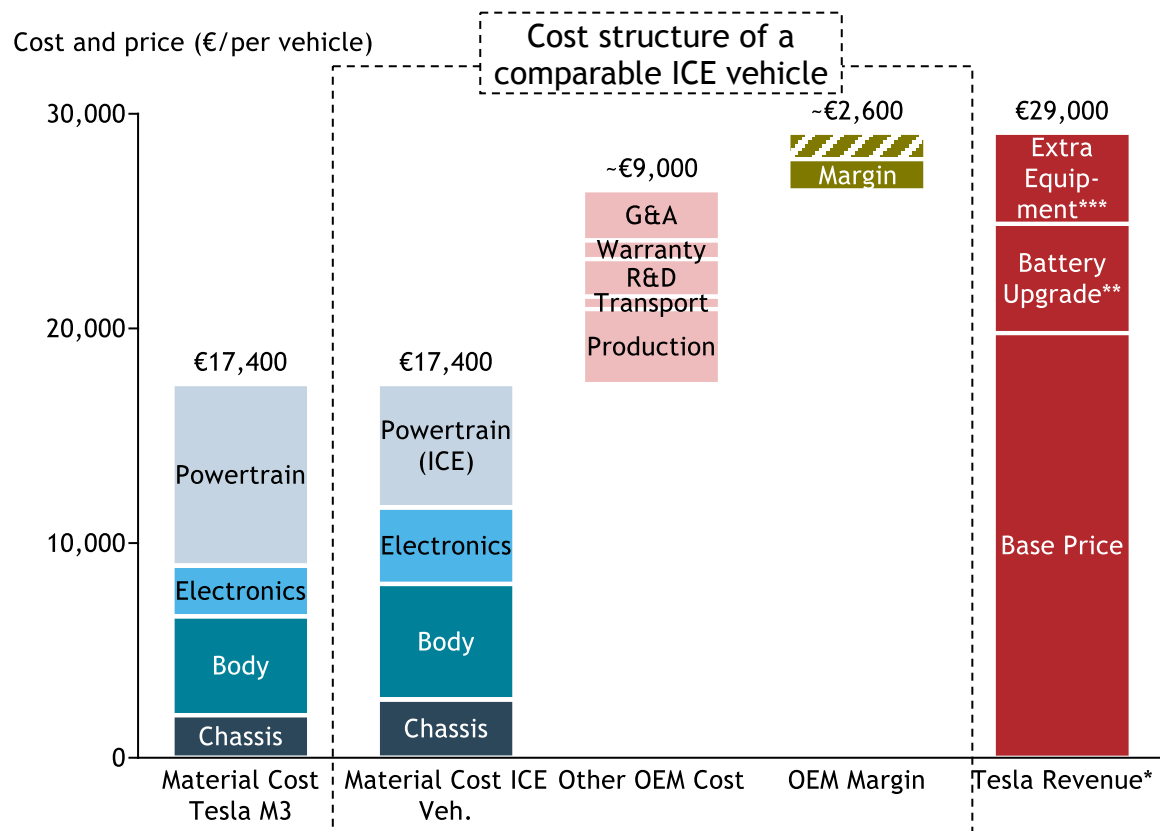
- BEVs prices have historically been higher than ICE vehicles due to expensive inputs and lower economies of scale
- Historical drivers of BEV cost reductions have primarily been non-battery costs, which are not expected to continue driving reductions
  - Lower costs for body, electronics, electrical
  - Technical optimization
  - Scale effects and optimized processes
  - Less R&D for newer generations of BEVs
- Moving forward, continued reductions in battery cost will drive BEVs to purchase price parity, driven by:
  - Better managed input costs incl. improved supplier management, optimized supply chain of inputs
  - Greater economies of scale from production
  - Cost optimized battery chemistries incl. managing share of battery from higher vs. lower cost minerals

# “We need to work together there so that we can all profitably sell EVs across the board once regulations kick in”



## Spotlight: Tesla

### Tesla with material costs in line with ICE vehicles



### Tesla advantage due to

#### ePowertrain

- 10+ years experience curve with standard cell/round cell type
- Usual 7% cobalt share reduced to 2.5% through substitutes
- Higher energy density in cells and thinner walls
- High efficient and compact gearbox and motor unit (one housing)
- Small and light-weight pulse inverters

#### Electronics

- Simplified EE-architecture (centralization of control units)
- Reduced control & display concept - only 1 central display
- Use of non-automotive electronic parts

#### Body

- Reduced crash requirements, battery security
- Reduced longevity/durability of materials
- Reduced acoustic measures
- Reduced number of parts

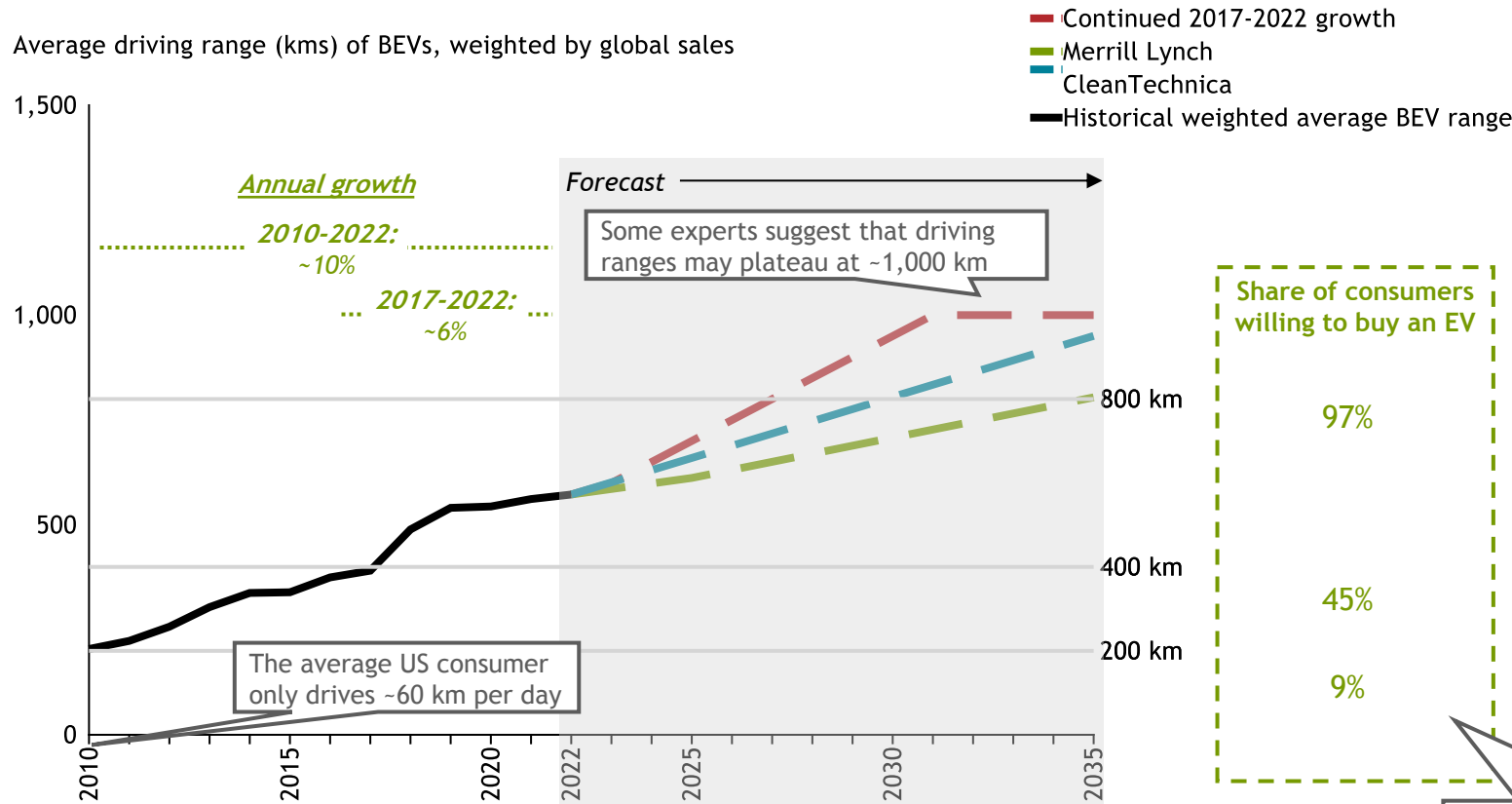
#### Chassis

- Use of standard products of suppliers
- Reduced corrosion requirement

Notes: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3; Tesla competitive under operational and organizational practices comparable to traditional OEMs e.g. excluding re-working, quality, once-off investments, etc.; Based on original price of \$51,500 (€44,300) excluding 19% VAT, 15% dealer gross margin and 8% wholesale margin; \*\*upgrade to 75 kWh battery; \*\*\*includes sport rims (-€850), premium package (-€4,300) and painting (-€1,300)  
Source: Polaris, Corporate interviews

# “People underestimate both the range of batteries and the availability of charging”

Driving ranges are expected to meet almost all consumers’ perceived needs by 2030-35, though current battery technology likely meets more consumers’ needs than perceived

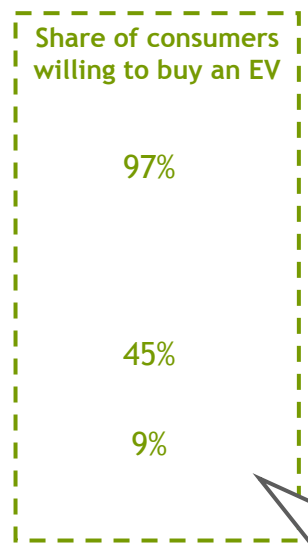


## Commentary

- For almost half of consumers today, EV driving range is sufficient to justify a switch from an ICE vehicle
- The remaining consumers have concerns regarding:
  - Long-distance, non-urban driving where they cannot always get to their destination on a single charge
  - Access to sufficient charging, especially in non-urban areas where charging options are often inconvenient
  - Variability in range due to inclement weather, especially in extreme hot or cold weather, that could cut range by up to 50%

*“We will need to fundamentally change the way consumers think about their refueling experiences if they are ever going to overcome the range anxiety that currently accompanies EVs.”*

Chief Sustainability Officer, Fleet operator #1



While exact consumer preferences vary by region, global sentiment is similar in major developed markets like the US, EU, and China

Note: Title quote from Director, Global Sustainability Strategies, Auto manufacturer #3; Survey responses are specific to non-EV owners  
 Source: IEA Electric Vehicles Analysis; EVAdoption Report; Clean Technica Report; Bain Car Customer Survey (20.08.20, N= 424); Corporate interviews

# “To get <\$100/kWh of battery capacity, we need to get to the next generation of batteries to combine, size, weight, core, and performance - it will go very fast”

01

02 PASSENGER VEHICLES IN DEVELOPED MARKETS

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/ NON-EXHAUSTIVE

Bat. types	Year when commercial viability is expected						Commentary
	2015	2020	2025	2030	2035	2040	
Lithium Ion	111	111-622	622-811	811			Adoption of high nickel blends (e.g. NMC 811) will continue to be driven by range and cost advantages
Sodium Ion			Na+				Na+ is much more abundant than Li and charges faster but less dense, and currently has significantly lower cycle life
Lithium-Sulphur			Li-S				Li-S has cost advantages, but with poor cycle life and weak volumetric density, it is more likely to be used in airplanes and large vehicles
Solid State electrolyte			SS				Solid state seems promising due to high performance and low costs, however it still needs to be proven on a large scale
Hydrogen fuel cell			FC				Allows for longer range and lower weight, but low efficiency, high cost and lack of infrastructure are expected to limit Fuel Cell adoption
Silicon/carbon mix anode				Si/C			Anodes with higher silicon content increase capacity, but change volume during charge / discharge, lowering cycle performance
Metal-Air				Li-Air			Li-air has good capacity, but lacks stability, which impacts recharging and cycle life

Numbers indicate different generations of Li-Ion technology

## Key takeaways

- Until 2025, Li-Ion will remain the preferred technology
  - NMC will be the global Li-Ion composition standard
  - LFP will remain relevant Li-Ion composition, especially in China for low-range BEVs
- Sodium-Ion and solid state are promising alternatives, as they keep charge in extreme weather better than Li-Ion
  - Commercial readiness not expected before 2025
- As battery technology matures and critical mineral supply for Li-Ion batteries tightens, batteries with resilient supply chains will win
  - Sodium-based batteries are most viable here in terms of efficiency, technical feasibility, and existing R&D

Note: Title quote from Pascal Chalvon, Chief Sustainability Officer, Solvay | Source: Credit Suisse Autocatalyst 2019; GEP; Lit. search; Corporate interviews



# “The battery market needs to multiply by five times just for the automotive market in 2030”

01

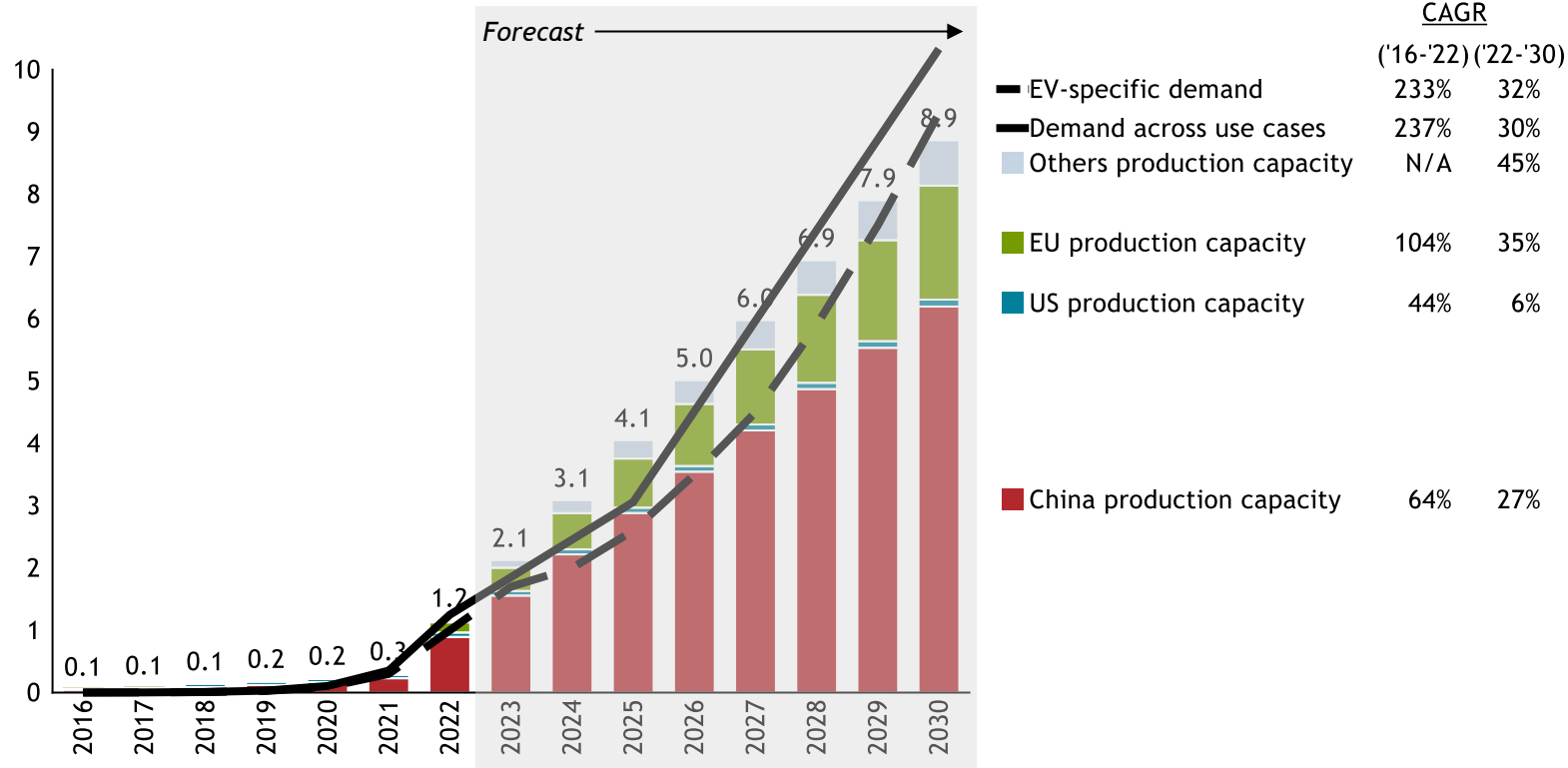
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Growth in demand for li-ion batteries will outpace growth in supply, suggesting need for alt. battery composition uptake, manufacturing improvements to avoid shortages

Global GWh of lithium-ion batteries (in K)



Note: Title quote is from Pascal Chalvon, Chief Sustainability Officer, Solvay  
Source: Bloomberg NEF, IEA, US Department of Energy, Corporate interviews

There are alternatives to Li-Ion in the long-term

• Today, Lithium-Ion batteries are the most widely available batteries for EV use due to their energy density and cost effectiveness

- ~80-90% of Li-Ion batteries go to EVs, with the remaining ~10-20% used for stationary power storage like solar panels as well as consumer electronics



• However, there are other alternatives that may become viable in the longer-term that can be pursued instead of filling the Li-Ion supply gap:

- Sodium ion
- Solid state
- Lithium-sulfur
- Fuel cell
- Metal-air
- Silicon / carbon mix anode

Chinese automaker JAC Group and tech company HiNa Battery just released a prototype for a sodium ion EV that they propose will be more cost effective and sustainable than lithium ion EVs



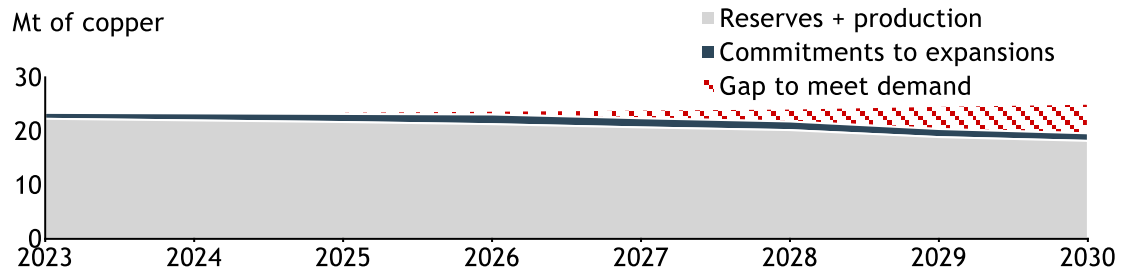
# “In its Gen 4 batteries, Solvay is doubling energy capacity, meaning better performance, charge speed, and safety”

Overview	Technology overview	Activities
<ul style="list-style-type: none"> <li><b>Description:</b> Solvay is a materials, chemicals, and scientific solutions company that provides components for products in the transport, healthcare, and industrial sectors</li> <li><b>Founded:</b> 1863</li> <li><b>Headquarters:</b> Brussels, Belgium</li> <li><b>Ownership:</b> Public (SOLB.BR)</li> <li><b>Revenue (2022):</b> €13.4B</li> </ul>	<div style="display: flex; justify-content: space-between;"> <div data-bbox="428 378 573 449"> <p><b>Li-ion batteries</b></p> </div> <div data-bbox="794 378 1031 885"> <ul style="list-style-type: none"> <li>Solvay’s original generation of batteries for EVs consists of many battery types, including the industry leading Lithium-ion technology with cutting edge NMC 811 cathode composition and up to 320 Wh/kg energy density</li> </ul> </div> </div> <hr style="border: 1px solid green;"/> <div style="display: flex; justify-content: space-between;"> <div data-bbox="428 928 598 1035"> <p><b>Next generation batteries</b></p> </div> <div data-bbox="794 928 1031 1213"> <ul style="list-style-type: none"> <li>For Solvay’s next generation batteries, they are investing in solid state, Li-S, metal air, li-metal, and anode free battery types</li> </ul> </div> </div>	<div style="display: flex; justify-content: space-between;"> <div data-bbox="1151 378 1324 564"> <p><b>Building a flexible battery production pipeline</b></p> </div> <div data-bbox="1516 378 2458 635"> <ul style="list-style-type: none"> <li>While for now the industry has coalesced around lithium-ion batteries as the solution for EVs, <b>Solvay recognizes that in the future, resources will be scarce and require multiple battery solutions to continue to meet EV demand</b></li> <li>As a result, <b>Solvay has developed its Solgain platform to evolve its current generation of batteries</b> to accommodate several potential future state battery features, including:                             <ul style="list-style-type: none"> <li>Higher energy anodes, hybrid electrolytes, high voltage composite cathodes, and advanced polymers</li> </ul> </li> </ul> </div> </div> <div style="text-align: center; margin: 10px 0;">  </div> <div style="display: flex; justify-content: space-between;"> <div data-bbox="1151 849 1312 963"> <p><b>Battery optimizing portfolio</b></p> </div> <div data-bbox="1516 728 2458 1206"> <ul style="list-style-type: none"> <li><b>The “end goal” for solvay is to be able to develop its “Solid State Gen4” battery, which will include:</b> <ul style="list-style-type: none"> <li>Li-Metal anode, solid inorganics, composite electrolytes, and high energy composite cathodes</li> </ul> </li> <li><b>Solvay recognizes many levers to optimize battery performance and cost with its diverse portfolio:</b> <ul style="list-style-type: none"> <li>Solef PVDF binders and separator coatings</li> <li>LiFSI lithium salts</li> <li>Energain fluorinated solvents for High Voltage Electrolytes</li> <li>TAB electrolyte additives</li> <li>Hyflon perfluoropolymers</li> <li>Ryton PPS for cell gaskets and battery modules</li> <li>Evolite for battery enclosures</li> </ul> </li> </ul> </div> </div> <div style="text-align: center; margin: 10px 0;">  </div>

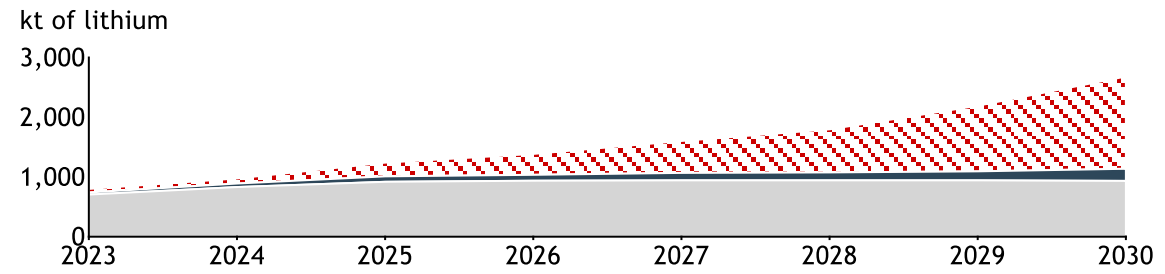
Note: Title quote is from Pascal Chalvon, Chief Sustainability Officer, Solvay  
 Source: Solvay; Bloomberg; Lit. search; Corporate interviews

# “Policy is going to be important to managing critical mineral supply and avoid splitting supply across too many parallel technologies”

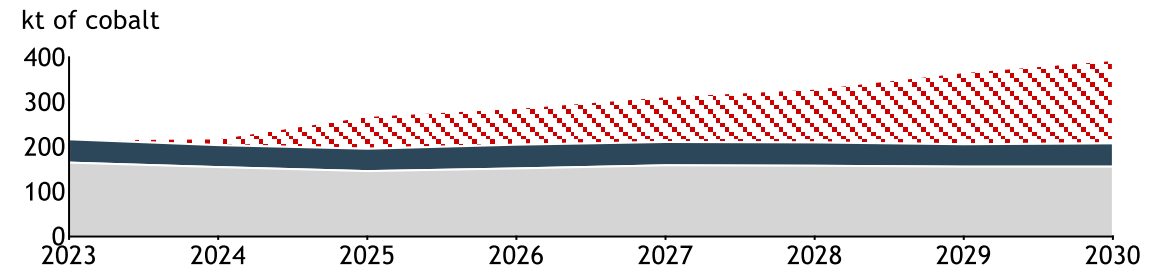
**Copper**  
 Key sources of demand include EV batteries, building construction, consumer, industrial machinery, and medical equipment



**Lithium**  
 Key sources of demand include EV batteries, industrial applications like glass, and pharmaceuticals



**Cobalt**  
 Key sources of demand include EV batteries, steel, construction tools, industrial chemicals, and magnetic materials



## Commentary

- For EV and EV battery producers, current battery technologies rely on critical minerals that will soon face supply constraints due to:
  - Insufficient planned supply
  - Competing demand for their use
- In order to address this shortage, there are two options:
  - Further investing in building out supply of these minerals, which require years to both identify new reserves and build production capacity
  - Pivoting EV and EV batteries away from reliance on these critical minerals towards alternatives such as sodium ion batteries

Note: Title quote is from Stina Klingvall, Manager of Climate Action, Volvo Cars  
 Source: IEA; US Geological Survey; Corporate interviews

# “It is particularly tricky from a permitting perspective - you often have many different jurisdictions of government involved”

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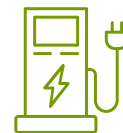
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## EV manufacturing regulation is in its nascency, posing challenges to permitting approvals especially for batteries

- **Guidance for EV manufacturing is under development, slowing the approval of production permits**
  - Bureaucratic checkpoints limit the speed of finalizing regulatory processes for EVs
  - E.g., the US delayed guidance on key EV component and battery manufacturing until March 2023
- **Established regulations strictly govern hazardous and battery waste for environmental compliance**
  - **Manufacturers face incremental challenges to expanding EV production** compared to equivalent ICE production facilities
  - Especially for EV battery production facilities (e.g., Tesla Gigafactories), risks of water and air pollution yield complex permitting approval processes
- For those EV manufacturing facilities leveraging federal funding, they are **subject to both federal- and state-level regulations**



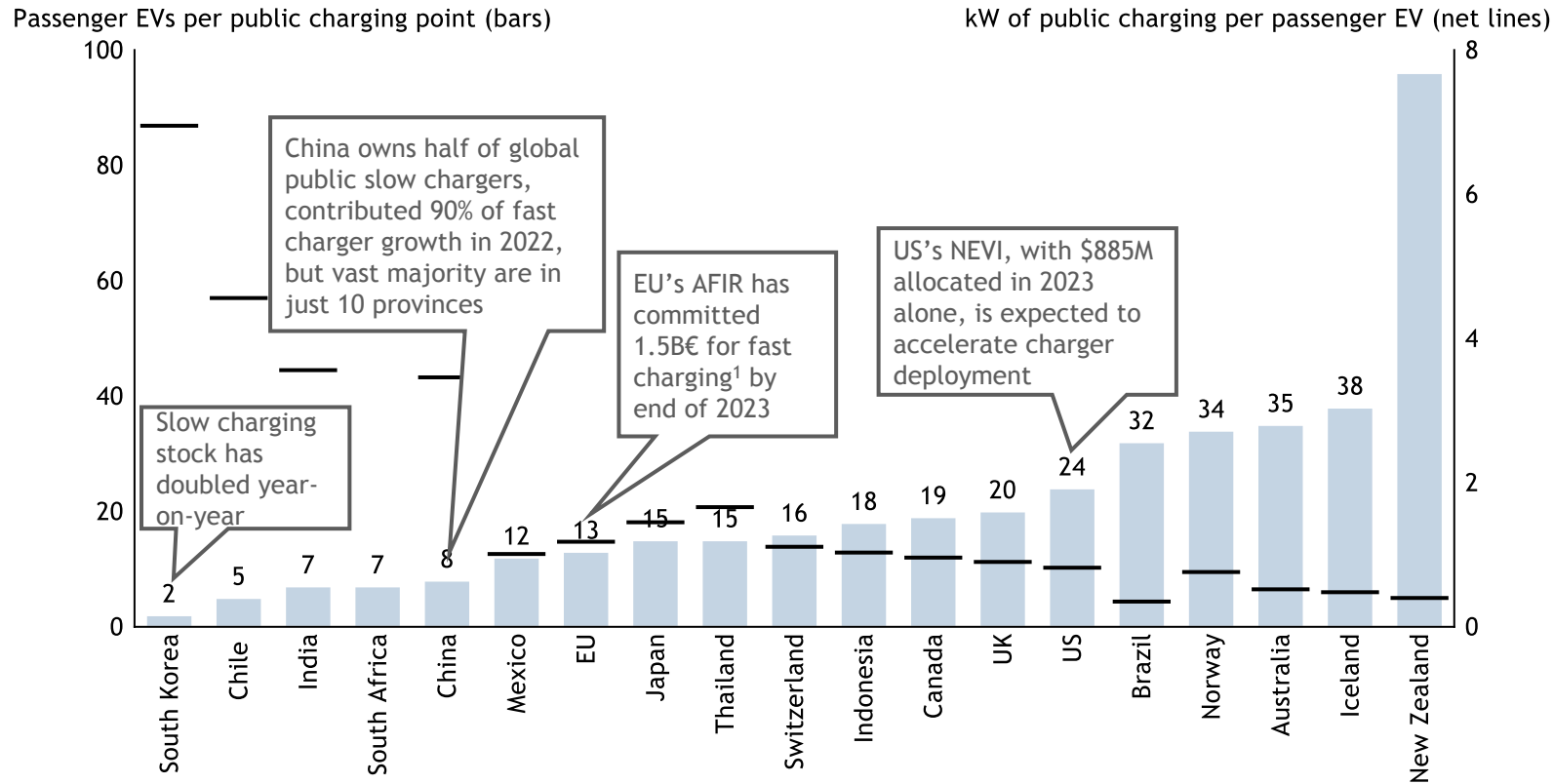
## Permitting approvals for charging and underlying power installations are also underdeveloped

- **Guidance is underdeveloped for EV charging regulations**
  - Bureaucratic checkpoints limit the speed of finalizing regulatory processes for charging buildouts
  - Regional permitting variations hinder uniform, efficient rollouts of EV charging infrastructure by auto OEMs and others
  - Smaller, more rural governments maintain outdated ordinances that need to be updated to accommodate stipulations for charging infrastructure
- **Beyond EV-specific rules, heavy regulations on utilities slow the infrastructure buildout for EV charging**
  - E.g., in CA, for a property owner to plan a charging depot, they must apply 5-7 years in advance of when they expect to make the installation
- **Projects that receive federal funding also must comply with both federal- and state-level regulations and requirements**
  - E.g., U.S. charging stations must be ADA & NEVI compliant

Note: Title quote from Head of Climate, Sustainability, and Environmental Policy, Fleet operator #4; NEVI - National Electric Vehicle Infrastructure Formula Program  
Source: US Dep of Transportation; Bipartisan Policy Center; IRS; Electrek; Corporate interviews

# Progress on charging buildout varies according to levels of existing EV adoption, access to grid infrastructure, physical space, upfront costs

## South Korea leads the world in density of chargers per electric vehicle



## Charger buildouts faces barriers

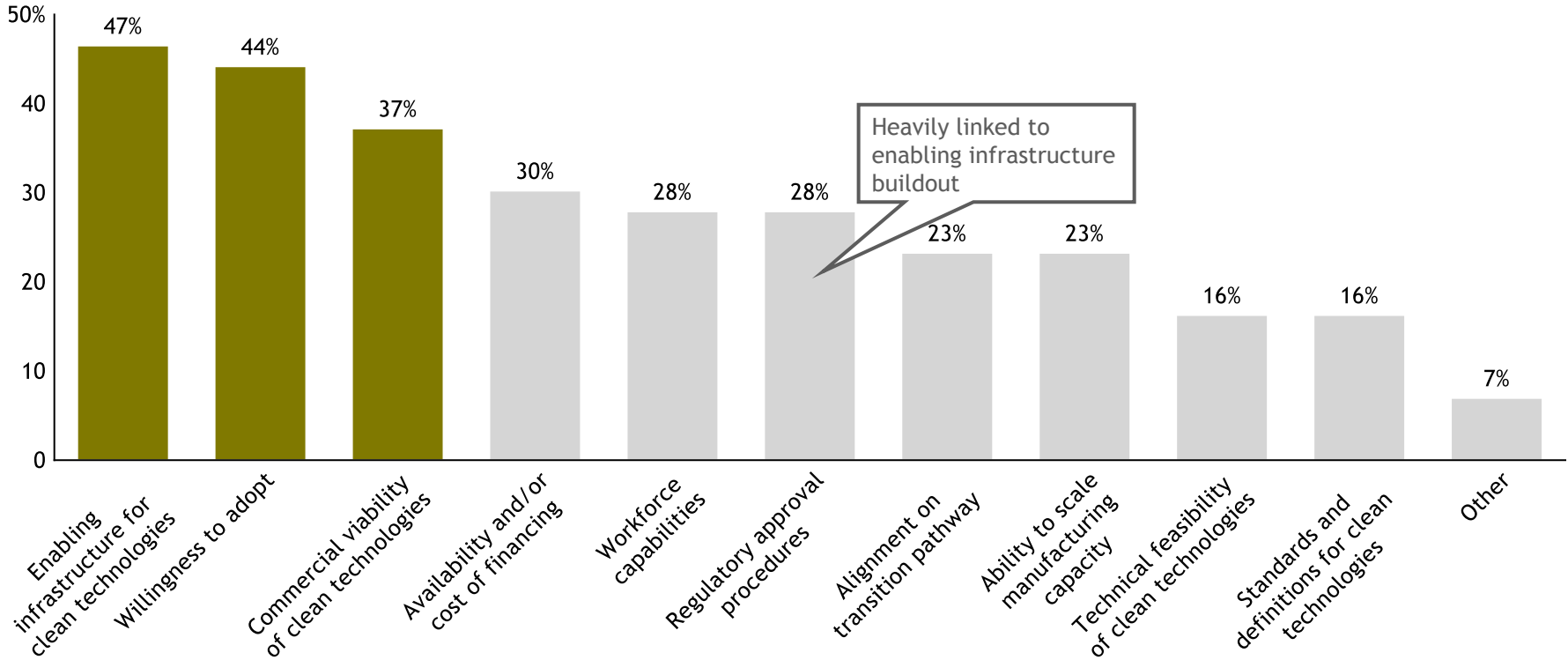
- Initial EV adoption came from single-family homes (85% of EV owners) ; next wave is expected from multi-family dwellings with limited charging space
- Many places lack the power infrastructure for rising electricity demands
  - Grid capabilities will need to be expanded to support Level 2 slow charging and Level 3 DC fast charging
  - Rural areas will require more infrastructure investment to support EV's charging needs compared to urban
- Crowded urban centers lack sufficient space for EV charging buildout absent specific land allocations for this infrastructure
- Many countries lack the policy incentives and regulations to galvanize public charger buildout in the private sector

Note: Public charging points include both slow and fast chargers (types 2-4), 1 - funding is allocated for alternative fuels infrastructure, including fast-charging, AFIR - Alternative Fuels Infrastructure Regulation, TENT - trans-European network-transport, NEVI - National Electric Vehicle Infrastructure Formula Program  
 Source: IEA Global EV Outlook 2023

# Business leaders cite underlying power grids, willingness to adopt EVs, and commercial viability as top barriers to passenger EV charging buildout

Which of the following do you view as the *largest barriers towards scaling passenger electric vehicles charging infrastructure*?  
Please select the top 3 most impactful barriers.

Share of survey respondents selecting barrier in the top 3 (%)



Heavily linked to enabling infrastructure buildout

## Commentary

- Business leaders are caught between a few concerns trying to justify investments in EV charging infrastructure:
  - Willingness for consumers to use the chargers they may invest in, in lieu of home charging or ICE vehicles
  - Enabling power infrastructure and the regulatory frameworks to support buildout
  - Profitability of installing and operating charging points (i.e., the commercial viability)

*“From a buildout perspective, the best way to propel action is through legal requirements. Without any demand signals, there is no incentive to invest in the charging buildout.”*

Quality and Climate Change Manager, Road infrastructure provider #1

Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 43)  
Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

# EVs will require a diverse set of charging applications depending on consumers' location and time requirements



	Level 1	Level 2	Level 3 (DC Fast Charger)	Level 4 (DC Supercharger)
<b>Voltage potential</b>	120V	240V	480V	900V
<b>Power capacity</b>	~1 kW	~4-19 kW	~50-350 kW	~1 MW
<b>Range added per hour</b>	~3-5 miles	~12-80 miles	~75-400 miles	~800-1,200 miles
<b>Locations where this charger is used</b>	<ul style="list-style-type: none"> <li>Private only (e.g., single- and multi-family dwellings)</li> </ul>	<ul style="list-style-type: none"> <li>Private</li> <li>Public (e.g., offices, retail locations, highways)</li> </ul>	<ul style="list-style-type: none"> <li>Public</li> </ul>	<ul style="list-style-type: none"> <li>Public</li> </ul>
<b>Vehicle types to use this charger type</b>	<ul style="list-style-type: none"> <li>Passenger vehicles only</li> </ul>	<ul style="list-style-type: none"> <li>Passenger vehicles</li> <li>Class 3-6 trucks (e.g., at a depot)</li> </ul>	<ul style="list-style-type: none"> <li>Passenger vehicles</li> <li>Class 3-6 trucks (e.g., at a depot)</li> <li>Class 4-6 trucks (e.g., on-road)</li> <li>Class 7-8 trucks (e.g., at a depot or on-road)</li> <li>Long-haul trucks</li> <li>Motorhomes</li> </ul>	<ul style="list-style-type: none"> <li>Passenger vehicles (limited)</li> <li>Class 3-6 trucks (e.g., at a depot)</li> <li>Class 4-6 trucks (e.g., on-road)</li> <li>Class 7-8 trucks (e.g., at a depot or on-road)</li> <li>Long-haul trucks</li> <li>Motorhomes</li> </ul>
<b>Purchase and installation costs</b>	<ul style="list-style-type: none"> <li><b>Purchase:</b> ~\$200-300, typically included with vehicle purchase</li> <li><b>Installation:</b> none</li> </ul>	<ul style="list-style-type: none"> <li><b>Purchase:</b> ~\$250-1K</li> <li><b>Installation:</b> ~\$1-13K</li> </ul>	<ul style="list-style-type: none"> <li><b>Purchase:</b> ~\$10-40K</li> <li><b>Installation:</b> ~\$5-50K</li> </ul>	<ul style="list-style-type: none"> <li><b>Purchase:</b> ~\$50-150K</li> <li><b>Installation:</b> ~\$20-70K</li> </ul>
<b>Additional notes</b>		<ul style="list-style-type: none"> <li>Prevalent charger in public spaces and office locations</li> </ul>	<ul style="list-style-type: none"> <li>Adds substantial charge relative to charging time</li> </ul>	<ul style="list-style-type: none"> <li>Technology still in development - not yet commercially available</li> </ul>

Source: Lit. search

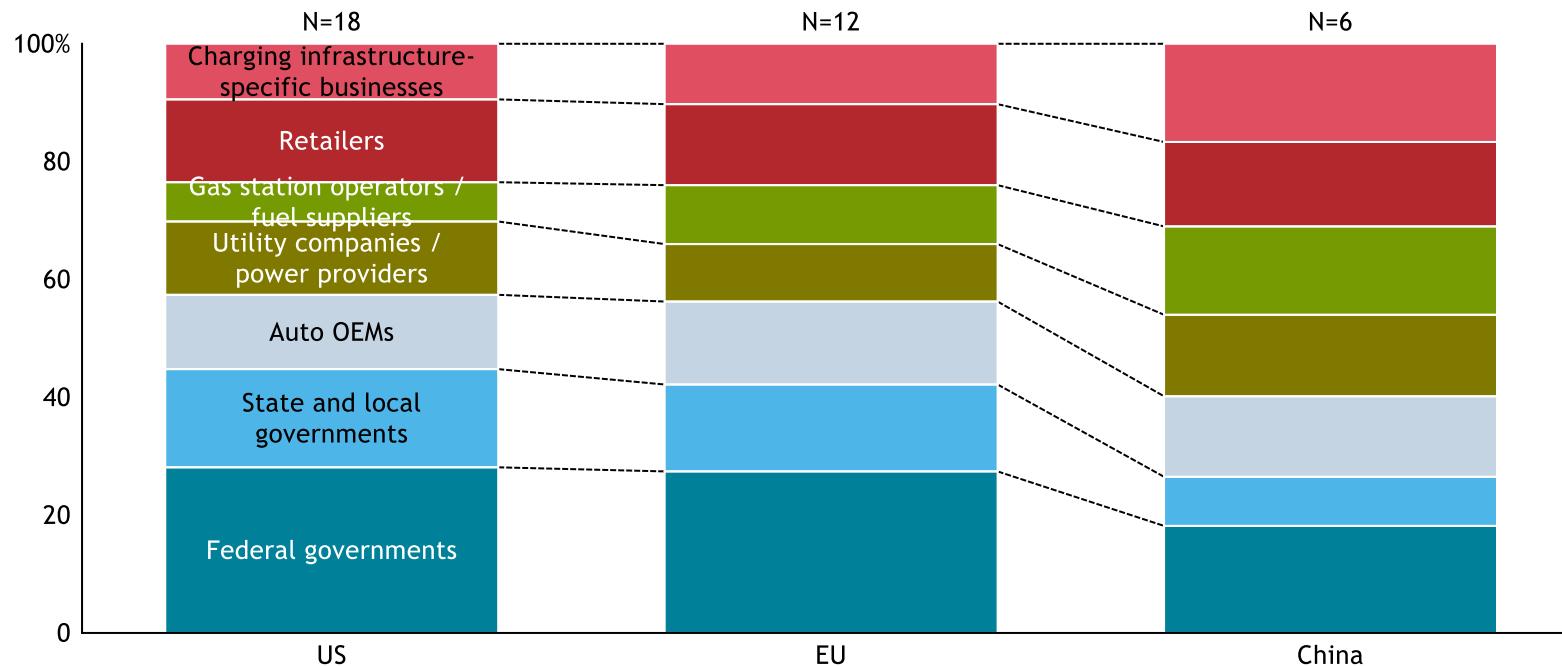


# Business leaders expect financing for passenger EV charging infrastructure to come from a mix of public and private funding sources

## US business leaders expect more public financing than those in the EU and China

Considering all the costs associated with the charging infrastructure of passenger electric vehicles, *what share of financing will each of the following groups provide for these infrastructure investments in <region>? Please allocate 100 points across the following stakeholders, considering your own organization's anticipated contributions.*

Expected share of total investment to be put towards passenger EV charging infrastructure by region (%)



Note: Chart includes respondents from the U.S. (N = 18), EU (N = 12), and China (N = 6)  
 Source: Bain / WMBCC Global Stocktake Survey (N = 215), Corporate interviews

## Commentary

Business leaders seek government funding for charging infrastructure, with government funding expected to contribute to 50% of funding in the US and ~25% in China

A relatively even mix of investment is expected between charging infrastructure businesses, retailers, fuel suppliers, utilities, and OEMs

In China, ~20% of investment expected to come from charging infrastructure-specific businesses, encouraged by government initiatives

*“Automakers cannot be energy distributors alone. We can share the investment, but it will cost billions.”*

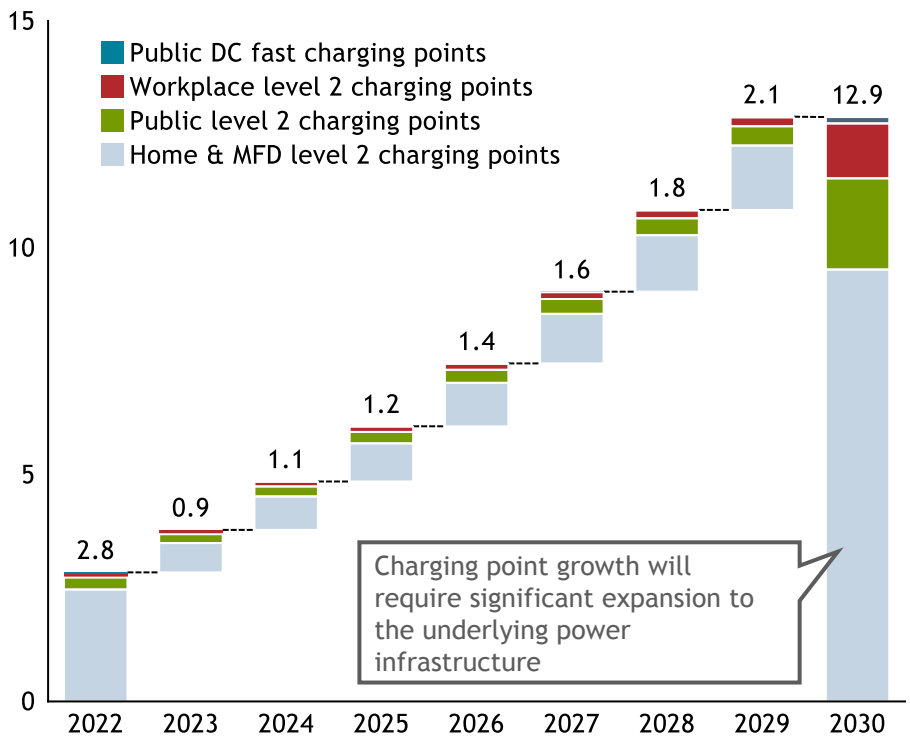
Head of Sustainability, Auto manufacturer #4

# "The struggle will be for those in apartment buildings and urban centers; their access to charging will be important"



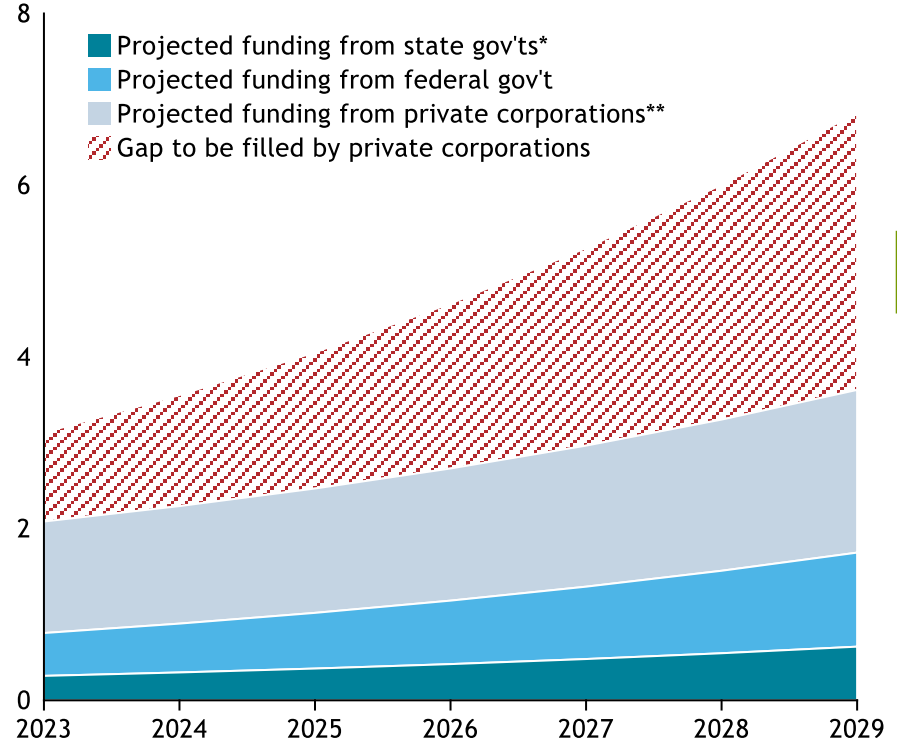
## By 2030, ~13M chargers will be needed

EV charging infrastructure needs by charger type in the US (in millions of chargers)



## Private investment must bridge the investment gap

Total investment for passenger EV charging infrastructure (in 2022 \$B USD)



- Private firms are investing in charging infrastructure, indicating **future profitability prospects**
- Unprofitable companies like **EVgo** and **ChargePoint** expect profitability by 2025
- Diversified revenue firms like **Tesla** and **Shell** are also investing in charging infrastructure
- In July 2023, seven auto makers pledged ~\$1B to build ~30K charging points in the US and Canada (BMW, GM, Honda, Hyundai, Kia, Mercedes-Benz, and Stellantis)

Note: Title quote from Director, Global Sustainability Strategies, Auto manufacturer #3; (\*) States include CA, NY, NJ, MA, and MD; (\*\*) Includes Tesla; Projected funding from federal gov't includes payments via the Inflation Reduction Act (IRA)  
 Source: IEA; Electric Edison Institute; US Department of Energy; Corporate interviews

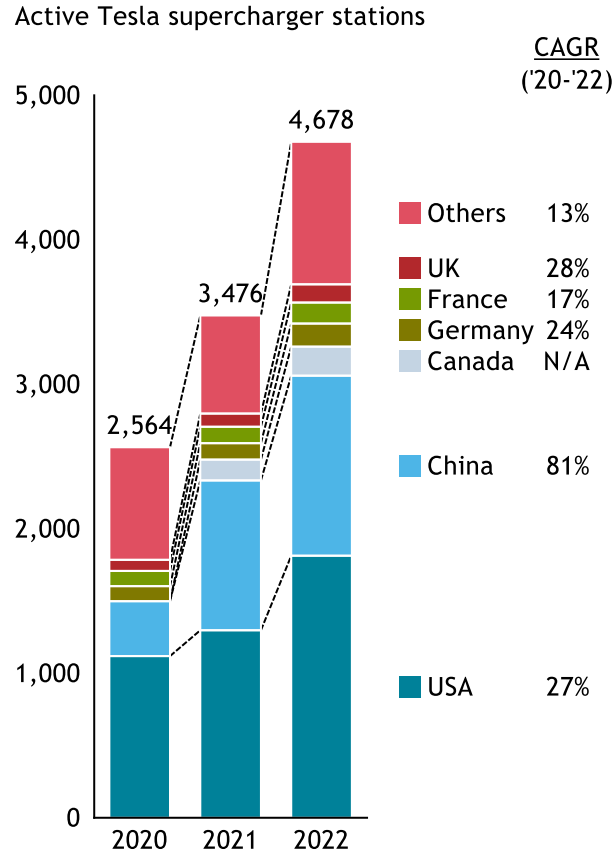


# "The first wave of charging was Tesla; now, we need other automakers to step in, but we're not coordinated"

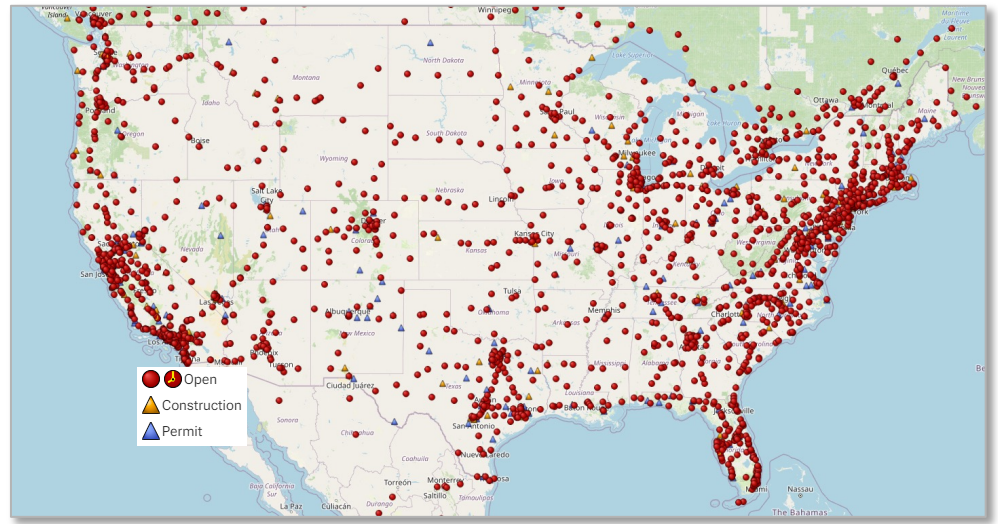
## Company overview

- **Description:** Tesla designs and manufactures electric vehicles, stationary battery energy storage devices from home to grid-scale, and related products and services
- **Founded:** 2003
- **Headquarters:** Austin, Texas, United States
- **Ownership:** Public (NASDAQ: TSLA)
- **Revenue (2022):** \$81.46B USD

## Tesla Supercharger network has rapidly expanded recently in the US, EU, and China



### US Example: Tesla Supercharger Network



Note: Title quote is from Head of Sustainability, Auto manufacturer #4; Superchargers referring to supercharger stations, not charging points  
 Source: Supercharge.info, Tesla, Corporate interviews

# “[OEMs] will continue to work to support charger buildout and apps and services to help customers find chargers”

## Ionity overview

- **Description:** Founded with the primary goal to set up charging infrastructure along main traffic routes
- **Founded:** 2017
- **Ownership:** JV between BMW, Daimler, Ford, and Volkswagen (includes Audi and Porsche)
  - Hyundai and Kia joined in 2020
  - Cooperation with Shell, OMV, Tank&Rast, MRH, etc. to build the charging stations on their property
  - Combined Charging System (CSS) with up to 350kW, delivered by Tritium, ABB, Porsche Engineering

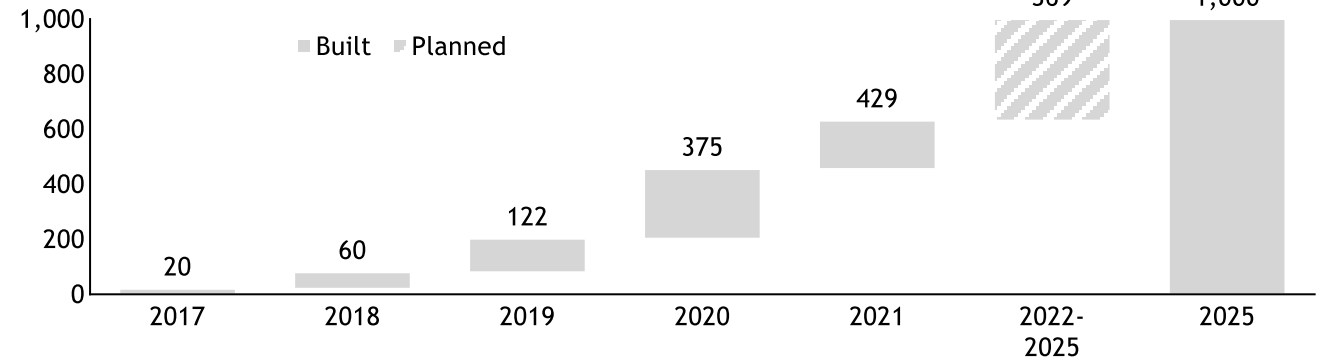
A similar alliance to Ionity in North America was announced in July 2023 involving BMW, GM, Honda, Hyundai, Kia, Mercedes-Benz Group, and Stellantis

## Decarbonization activities

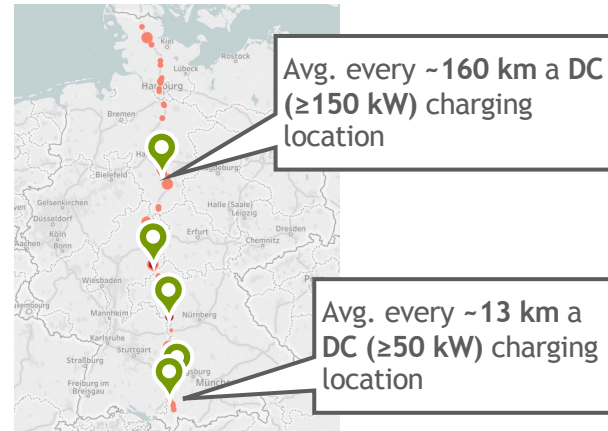
Ionity is planning its own charging network across the EU

Ionity is also partnering with Fastned to build a fast-charging corridor along highway A7

Number of Ionity charging stations



Chargers on A7 highway



**Ionity:** To build fast-charging stations every 120 km along major traffic routes:

100 DC charging locations with ~6x350 kW charging points in Germany

**Fastned:** To build 25 DC charging locations with 175 kW

**Strong improvement in charging convenience by DC charging locations with ≥150 kW:**

Stand times reduced to ~10 to 30 min

Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3  
Source: Ionity; Handelsregister; Corporate interviews

# “GM is working on educating its customers and ensuring the charging infrastructure is there”

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general motors



Case Study: General Motors (GM)

Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• <b>Description:</b> An American multinational automotive manufacturing know for its four core automobile brands of Chevrolet, GMC, Cadillac, and Buick. By sales, it was the largest automaker in the United States in 2022 and largest in the world for 77 years until 2008</li> <li>• <b>Founded:</b> 1908</li> <li>• <b>Headquarters:</b> Detroit, Michigan, United States</li> <li>• <b>Ownership:</b> Public (NYSE: GM)</li> <li>• <b>Revenue (2022):</b> \$156.74 USD</li> </ul>	<p><b>2025</b></p> <ul style="list-style-type: none"> <li>• 100% renewable electricity in operations</li> <li>• Divert &gt;90% of waste from landfills, incinerators, and energy recovery facilities</li> </ul> <p><b>2035</b></p> <ul style="list-style-type: none"> <li>• Reduce Scope 1+2 emissions by 72%</li> <li>• Reduce energy intensity of GM ops. by 35%</li> <li>• Reduce Scope 3 emissions by 51% per vehicle km</li> <li>• Eliminate tailpipe emissions in US light duty models</li> </ul>	<p><b>Educating prospective EV consumers</b></p>  <p><b>Making EVs accessible to consumers</b></p> 
		<ul style="list-style-type: none"> <li>• <b>GM launched a platform called EV Live in July 2022</b> with the goal of educating car shoppers on EVs, targeting first time EV buyers</li> <li>• The platform connects shoppers with EV specialists through 1-on-1 live video tours, lessons on EV technology and sustainability, and a mobile app with group tours and pre-recorded sessions, with the <b>goal of speeding EV adoption and creating a larger market for BEVs</b></li> <li>• The program is aimed at <b>addressing common misconceptions about EVs such as battery safety and durability and range anxiety concerns</b></li> <li>• GM recognizes that EVs have a reputation for being more expensive than their ICE counterparts, so they have made a <b>concerted effort to make EVs as financially accessible as ICE vehicles</b></li> <li>• Specifically, the just-launched <b>Chevrolet Blazer SS has retail pricing comparable to ICE vehicles</b> in the GM portfolio</li> <li>• Simultaneously, <b>GM has put \$750M to investments in charging infrastructure</b> to further make EV adoption more accessible to prospective customers</li> </ul>

Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3  
 Source: GM; Lit. search; Corporate interviews

# “We need to include charging in road concession contracts - highways have space to produce renewable electricity”



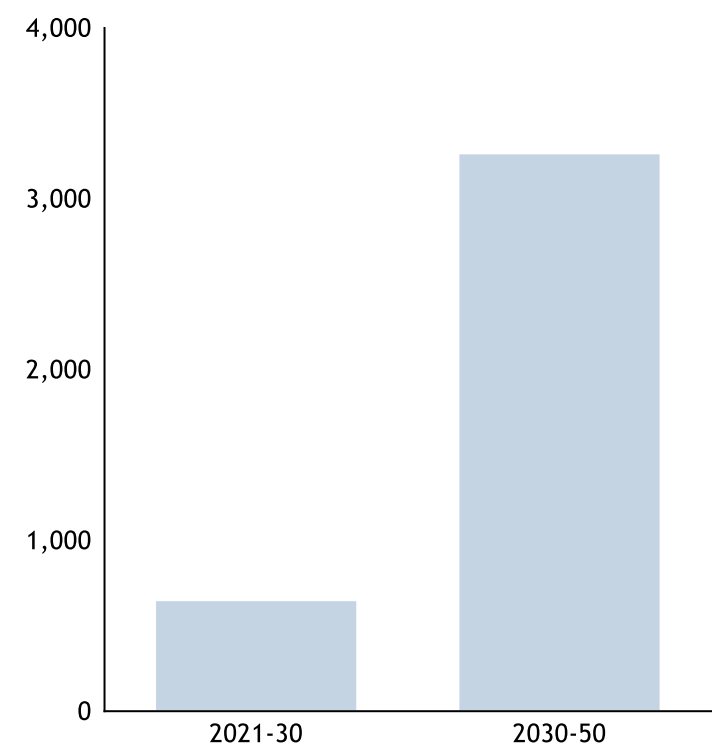
Overview	Targets	Activities
<ul style="list-style-type: none"> <li>In April 2023, the state of California passed Senate Bill 49 (SB 49), authored by State Senator Josh Becker and sponsored by Environment California</li> <li>The bill is intended to encourage solar over parking lots and along highways</li> </ul>	<p><b>2035</b></p> <ul style="list-style-type: none"> <li>All new cars, SUVs and pickup trucks sold in the state to generate zero tailpipe emissions</li> </ul> <p><b>2045</b></p> <ul style="list-style-type: none"> <li>100% of state of California’s power from clean energy</li> </ul>	<p><b>Solar installations in parking lots</b></p>  <p><b>Highway renewable energy installations</b></p> 
		<ul style="list-style-type: none"> <li>SB 49 spurs more solar installations over parking lots via a sales tax exemption for the materials to build solar canopies</li> <li>Installing this capacity on-site at parking lots will enable EV charging installations at these sites without concern about expanding transmission infrastructure from another site</li> <li>SB 49 has the state developing a plan to make its highway rights-of-way available for renewable energy generation, energy storage, and transmission lines</li> <li>By leasing state-controlled land along highways for solar power, California can earn revenue from lease payments and save money through avoided maintenance costs of leased areas, all while producing much-needed renewable energy throughout the state</li> <li>By extension, installing this capacity alongside highways will enable EV charging installations without concern for expanding transmission infrastructure from other generation sites</li> </ul>

Note: Title quote is from Global Sustainability Lead, Utility company #5  
 Source: Lit. search; Corporate interviews

# “Power infrastructure is the biggest barrier to building out charging; you need enough electricity to charge EVs and the grid is not there yet”

## Electricity demand from passenger EVs will increase significantly through 2050

Global electricity demand for passenger EVs\* (TWh)



Note: Title quote from Head of Climate, Sustainability, and Environmental Policy, Fleet operator #4; (\*) Based on Announced Pledges Scenario (APS)  
Source: IEA World Energy Outlook 2022; Corporate interviews

## Increasing EV adoption will test the power sector’s ability to meet future demand

Capacity planning

Transmission flexibility

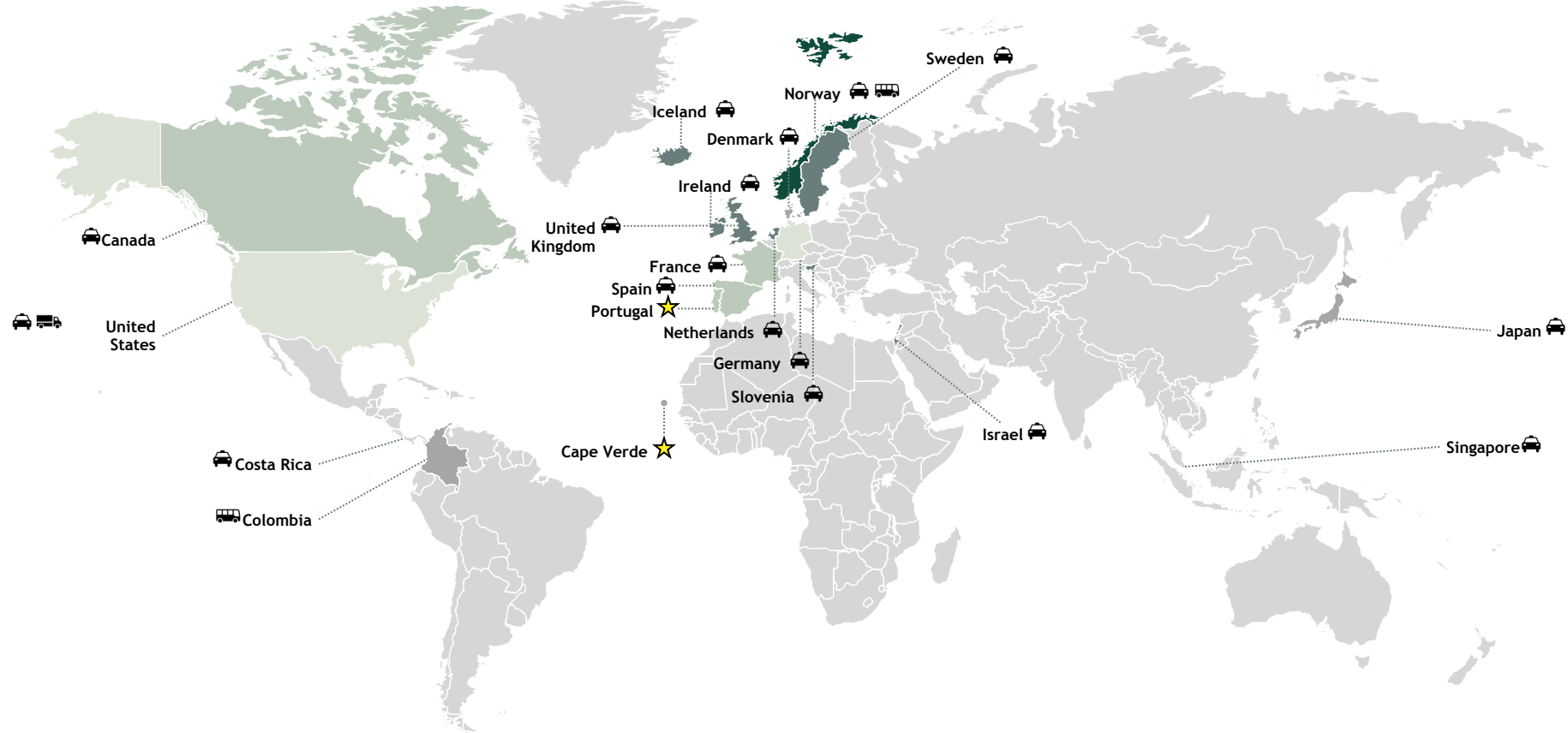
Potential innovations

- Growth in electricity consumption from EV charging will require power providers to **plan for enhanced operational capabilities and stronger grid infrastructure**
- The power grid needs to match **instant energy demand**, which is uncertain due to factors like consumer habits and regulations
- EV charging could **alter daily electricity demand curves** based on charging time and location
- Evolving grid needs emphasize the importance of innovation
  - **“Smart” charging**: Charger connects to EV but only provides electricity selectively based upon current grid capacity and transmission needs
  - **Vehicle-to-grid applications (V2G)**: Bi-directional power flow that allows EVs to provide grid support as power sources themselves

# “The best way to forge ahead is for EV adoption to be a legal requirement; if there is no demand, then there is no reason to build infrastructure”

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Year by which ICE ban is applicable



Type of vehicles covered



Notes: Title quote from Quality and Climate Change Manager, Road infrastructure provider #1; 1) Personal Cars and Light Commercial Vehicles; 2) These countries cover only PCs and not LCVs: Norway, Netherlands, Denmark, Iceland, Ireland, Sweden, Germany, and Israel; 3) US has state-wide bans: PCs and LCVs by 2035: California, PCs by 2050: Connecticut, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, Washington, Medium and Heavy Duty Vehicles by 2050: Connecticut, Colorado, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, District of Columbia

Sources: 1) Auto World Credit, Societe Generale (March 2023); Corporate interviews



# “The direction must be pointed out by government - there is not room for too many efforts for the sector to execute on its emissions reduction goals”

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*The United States is focused on setting mandates charging buildout and supporting organizations with funding to meet those mandates*

- The federal government provides 30% of cost of charging infrastructure installation as tax credits up to \$100K per public charging site and \$1K per residential charging point
- The federal government has provided \$12.5B to build out a network of public EV chargers, with focus on highways
- The state of California has allocated \$15M in grants to build out battery swapping infrastructure
- States like NY, MA, and OR have mandated that a certain share of parking spaces have EV charging available
- The federal government has established standards for installation, operation, and maintenance of charging infrastructure



*The European Union is adopting a similar approach, implementing standards and mandates for charging paired with funding to support buildout*

- 15 EU member states have subsidies for public charging installations in the form of tax deductions, installation subsidies and grants, and post-installation refunds, and 3 member states have subsidies for private charging in the form of tax credits
- The EU has ~€50B set aside for clean transport, with significant parts of the budget earmarked specifically for EV charging and hydrogen refueling buildouts
- Some countries like Germany have ~€5B specifically set aside to fund EV charging buildout
- The EU has set minimum standards for power capacity of chargers, minimum distance between chargers, and combined charging standards to ensure interoperability between EVs and interconnection with the grid



*China is also adopting a similar approach, setting standards to guide the buildout and providing funding to encourage businesses to invest*

- The central government allocated ~ €2.2B from 2017-20 to subsidize public EV charging buildouts
- The central government dedicated ~€1.15T to “new infrastructure” with ZEV charging and battery swapping stations as top priorities
- Provinces and state-run utilities funding buildout
  - E.g., Hainan funding 75K chargers in the province, State Grid Co. funding 78K chargers along highways
- The central government has set safety, plug configuration, and grid integration standards for charging and battery swapping as well as space requirements for a share of new parking being reserved for EV charging and maximum number of EVs per public charger

Note: Title quote is from Stina Klingvall, Manager of Climate Action, Volvo Cars  
Source: Lit. search; Corporate interviews

# “Recycling is the key to reduce the pressure on the supply side, and so the business case here is evolving as we become our own customer”

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US

Federal government committed **\$335M** for lithium-ion recycling programs and **\$60M** for 2<sup>nd</sup> life applications for EV batteries, with states (CA, NY, MN, WA) requiring manufacturers recycle used batteries



EU

EU has set **collection requirements for portable batteries** and **recovery requirements for battery makers of nickel, cobalt, and lithium**, with member states (Finland, Belgium, France) implementing their own recycling programs for batteries



China

Gov't mandates **manufacturers to build 10K+ battery recycling outlets nationwide**, requires **full life-cycle traceability of batteries in 20 provinces**, **recovery requirements for manufacturers of several critical minerals**, and specifications for batteries to facilitate further recycling



Canada

Each Canadian province is required to implement its own battery collection, recycling, and management practices in-line with federal Recycling and Environment Management Regulations



South Korea

Korean gov't has pledged **~£25B** to a lithium-ion battery technology development project focused on ensuring batteries are either recycled or used in 2<sup>nd</sup> life applications



Switzerland

Consumers are **obliged to return batteries** to retailers or collection sites, and suppliers are **obliged to take back used batteries for free**, with **prepaid disposal fees included in purchase price of products with batteries** to cover cost of collection, transport, and recycling of batteries




India

Manufacturers are subject to battery-specific mandates including **prohibition of disposing of batteries**, obligations to **recycle, refurbish, or re-purpose used batteries**, and ensure they are reaching minimum recovery targets that will reach up to **90% by 2027**

Note: Title quote is from Pascal Chalvon, Chief Sustainability Officer, Solvay  
Source: Lit. search; Corporate interviews



# “Daimler is convinced of its decarbonization path; by 2025, Daimler will sell an all-EV platform”

Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• <b>Description:</b> German multinational automotive manufacturer whose flagship auto brand is Mercedes-Benz</li> <li>• <b>Founded:</b> 1926</li> <li>• <b>Headquarters:</b> Stuttgart, Germany</li> <li>• <b>Ownership:</b> Public (FWB: MBG)</li> <li>• <b>Revenue (2021):</b> €133.9B EUR</li> </ul>	<p><b>2025</b></p> <ul style="list-style-type: none"> <li>• Increase EV sales share to 50%</li> <li>• All new models are electric, and every existing model has an electric alternative</li> </ul> <p><b>2030</b></p> <ul style="list-style-type: none"> <li>• Reduce CO<sub>2</sub> emissions in manufacturing plants and new vehicles' emissions intensity by 50%</li> <li>• Daimler sells only electric vehicles</li> </ul> <p><b>2039</b></p> <ul style="list-style-type: none"> <li>• Entire new vehicle fleet is CO<sub>2</sub>-neutral on balance sheet across all stages of value chain</li> </ul>	<p><b>Setting the industry standard for rapidly shifting fleet mix to electric vehicles</b></p> <p><b>Maintaining future-proofed plans to expand portfolio and bolster supply chain</b></p> 
		<ul style="list-style-type: none"> <li>• <b>Adopted a multi-drivetrain strategy</b> due to higher flexibility but with strong focus on BEV</li> <li>• Daimler is partially <b>internalizing its battery value chain</b>, operating a <b>worldwide battery pack production network*</b> (7 locations, 3 continents)             <ul style="list-style-type: none"> <li>- Partners with Farasis Energy (Ganzhou) Co., Ltd to produce carbon neutral battery cells and buys battery cells from LG Chem</li> <li>- Investing &gt;€1B in a <b>global battery production network</b> and ~€20B in supplier contracts to ensure battery cell supply</li> </ul> </li> <li>• Daimler is investing <b>€10B into electric fleet</b> <ul style="list-style-type: none"> <li>- <b>10 existing passenger EV models</b> with plans to launch of <b>10+ additional models</b> by 2025</li> <li>- <b>'Electric first' ambition &gt;50% EV sales share by 2030</b></li> <li>&gt; 15% EV in 2021</li> </ul> </li> <li>• <b>Daimler has a strategic partnership with Volvo</b> to manufacture fuel cells and fuel-cell based heavy-duty and long-range trucks</li> <li>• Daimler is planning to offer electric semi-trucks, box trucks, buses, and walk-in vans</li> <li>• Daimler is investing in a <b>mix of battery and fuel cell technology</b> <ul style="list-style-type: none"> <li>- Adding hydrogen fuel cell extenders to electric buses to increase range (e.g., eCitaro fuel cell bus)</li> </ul> </li> </ul>

Note: : Title quote is from Ulf Zillig, VP Group Research, Sustainability & RD Functions, Mercedes-Benz Group; (\*) Not their own cell production  
 Source: Daimler, Freight Carbon Zero, Clean Technica, LandLine, Corporate interviews

# BYD is an industry leader in the transition from ICE to EV manufacturing, from batteries to full electric vehicles



## Overview

- **Description:** German multinational automotive manufacturer whose flagship auto brand is Mercedes-Benz
- **Founded:** 1926
- **Headquarters:** Stuttgart, Germany
- **Ownership:** Public (FWB: MBG)
- **Revenue (2021):** €133.9B EUR

## Technology overview

### Blade battery

- Has ranges up to 605 km per charge
- Can reach full charge in 1 hour

### Two-way charger

- Connected system where EVs can be part of grid and provide electricity instead of just consuming it

### ePlatform 3.0

- Powertrain is an integrated platform with all components produced together

## Activities

### Pushing the industry to electrify applications across the sector



### Expanding electrifying efforts to emerging markets



### Showing industry expertise throughout EV supply chains



- **BYD has manufacturing capabilities across Road Transport applications**
  - BYD began as a rechargeable battery manufacturer
  - BYD Auto was founded as a subsidiary of BYD in 2003, dedicated to producing hybrid and electric vehicles
  - BYD has expanded capabilities to produce products such as SkyRail (an autonomous monorail transportation system), electric buses, electric taxis, electric bicycles, and electric passenger vehicles
- **BYD is expanding the reach of its electrified product portfolio beyond China**
  - BYD is partnering with Brazil's gov't to provide eTaxis and eBuses
  - BYD's subsidiary SkyRail is expanding to locations outside of China, including Brazil and other parts of Latin America
  - BYD is also launching passenger EV sales in North and Latin America (e.g., Chile, Mexico, US), Europe, and the Middle East
- **BYD distinguishes itself through proprietary technology across the EV supply chain**
  - BYD launched the world's first plug-in hybrid sedan in 2008 and has continued to make advancements in EVs since then, from batteries, to drivetrains, to EV-specific safety features
  - BYD was the first automaker to have expertise across batteries, electric motors, electronic controls, and auto-grade semiconductors

Source: BYD, Bloomberg

# Changes in demand, supply, and charging access will drive the next wave of passenger EV adoption in developed markets



## Demand trends

- EV adoption is on an **exponential growth path**
- **High initial purchase prices** relative to ICE vehicles have historically deterred consumers from purchasing EVs, but EVs are quickly reaching price parity with ICE vehicles
- Consumers are reluctant to transition to EVs due to **shorter driving ranges, charging access, and extreme weather durability** compared to ICE vehicles, but battery advancements are alleviating some concerns

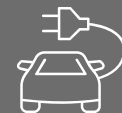
*~50% of business leaders consider commercial viability of EVs a top barrier to EV adoption*



## Supply trends

- Current EV battery technologies rely heavily on many **supply-constrained minerals** such as copper, lithium, and cobalt, which may soon see demand outpace supply if recycling practices are not implemented or if new battery technologies take time to come on stream
- Some OEMs are **struggling to scale production capacity quickly** due to **permitting laws**, despite local government interests in boosting local job opportunities and tax revenue

*“Raw materials will be a bottleneck for the industry - with minerals like copper and lithium where costs are rising.”*  
Head of Sustainability,  
Auto manufacturer #4



## Infrastructure buildout

- The first frontier of EV adoption has been driven by single-family homeowners, while the second wave of adoption is constrained by **insufficient investment in charging infrastructure**, especially on highways, in urban centers, and in multi-family homes
- Investment in public transport would be complementary in urban areas to enable more sustainable passenger transport
- **Power grids currently lack sufficient capacity and flexibility to manage future large scale distributed demand from EV charging at scale**, especially during peak charging times

*~55% of business leaders consider charging infrastructure a top barrier to EV adoption*

*~45% consider underlying power infrastructure a top barrier to charging buildout*

As governments think about what is required to sustain growth in EV adoption, focus should shift from demand-side policy to supply-side policy



Ensure long-term demand for passenger EVs

- As passenger EVs come to purchase price and driving range parity with ICE vehicles, **demand-side purchase subsidies become less critical**
- **Consistent policy around the phase out of ICE vehicles** - well in advance of implementation dates - is important for **aligning the industry around the transition pace**, but this phase out can only be sustained against a backdrop of broad societal support, with effective communications campaigns to enable drivers' understanding and acceptance of necessary behavior changes



Shift government policy and funding to charging buildout

- Charging infrastructure should be the most important policy priority - the market may not fix itself as EV adoption accelerates; **direct funding and subsidy programs can improve the economics of EV charging particularly at low penetration**, and especially in multi-family homes, urban centers, and along major highways
- **New business models for charging may also be needed** - such as **contracts for maintaining public charging infrastructure** and new infrastructure standards required for new large-scale or public building construction, parking areas, and road construction
- **Effective coordination of cross-border infrastructure will be important**, including international standardization of charging connections and ensuring open access to on-the-go infrastructure; accelerated permitting processes for power utilities can help ensure grid capabilities keep pace with an expanding charging network



Support manufacturers to sustain EV supply

- **Prioritized permitting processes will enable battery manufacturers to move quickly to expand production capacity**
- **R&D support to bring new battery technologies to scale** will play an important role in avoiding critical mineral supply shortages
- **Circular economy practices are also critical**, with mandated mineral recovery levels creating strong market incentives for recycling



# Road Transport: Table of Contents

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The **Sector Overview** section provides context on the state of emissions, the transition pathway, and corporate disclosures

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The **Passenger Vehicles in Developed Markets** narrative explores the state of transition in the light duty, passenger vehicles in developed electric vehicle markets

03

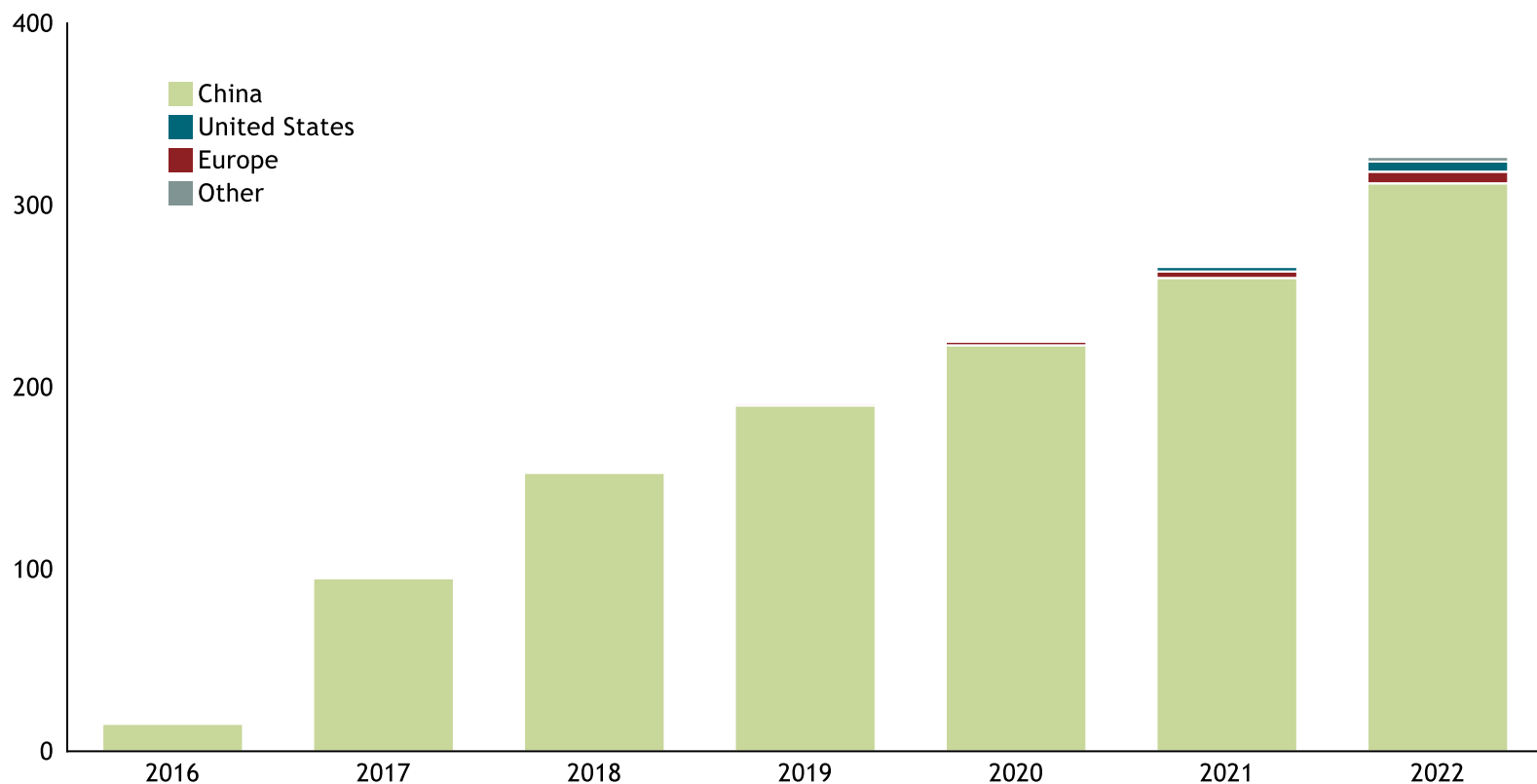
The **Freight in Developed Markets** narrative explores the state of transition in medium- and heavy-duty freight vehicles in developed electric vehicle markets

04

The **Electric Vehicles in Emerging Markets** narrative explores the state of transition in emerging electric vehicle markets and prospects for sustaining the transition to electric vehicles

# “We are executing the shift to sustainable transport at full speed; by 2030, half of our sales will be electric”

Electric truck registrations (bars, thousands)



## Commentary

- Electric trucks are **gradually approaching TCO parity** with ICE trucks globally, but fall short in heavier duty and longer haul use cases
- **In China, government procurement policy is driving most electric truck registrations**
  - These policies have been supplemented by subsidies and direct funding, bolstering demand for OEMs to scale production and manage pricing for electric trucks
- **In the US and EU, there are select mandates in place that are driving adoption in certain geographies**
  - For example, in the US, the state of California has introduced trucking-specific mandates that will render ICE trucks obsolete in the coming years
  - California has supplemented these mandates with several funding and subsidy sources to ease the transition

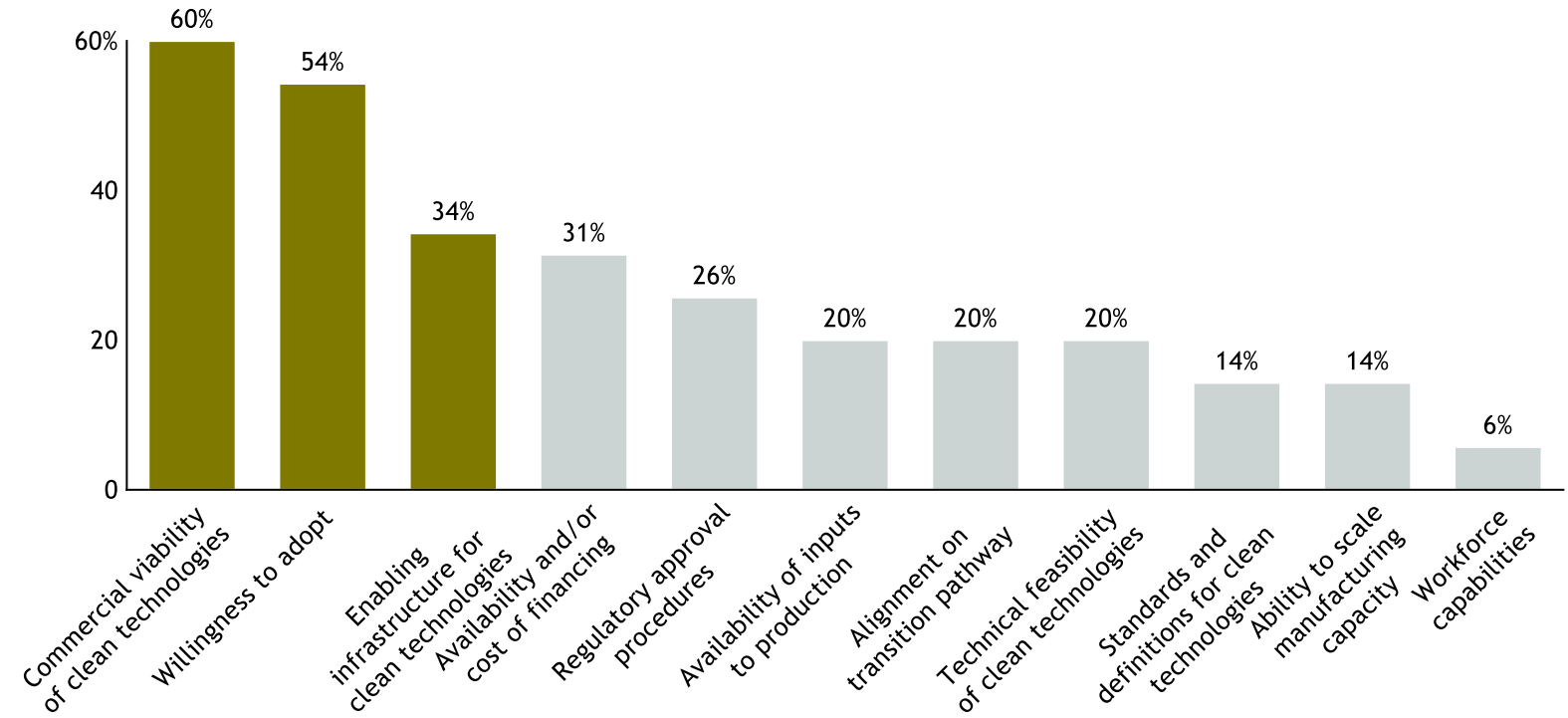
Note: Title quote is from Jennie Cato, Head of Public Affairs and Partnerships, Scania; IEA analysis based on country submissions and data from EV100 and vehicle insurance registration data  
Source: IEA, Corporate interviews



# Business leaders view commercial viability of ETs, operators' willingness to adopt ETs, and charging infrastructure as top barriers to decarbonizing freight

*Which of the following do you view as road freight's largest barriers towards accelerating decarbonization? Please select the top 3 most impactful barriers.*

Share of survey respondents selecting barrier in the top 3 (%)



## Commentary

- Freight leaders see the TCO of ETs versus ICE trucks as a barrier to adoption by fleet operators and commercial viability for OEMs, notably for larger trucks (e.g., Class 8), while medium-duty trucks may reach TCO parity sooner

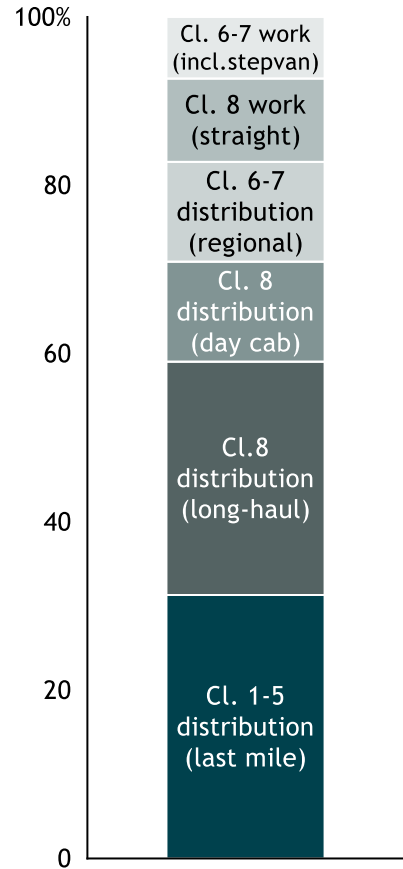
*“The top barrier is affordability and buying power - people can’t afford electric trucks at their current price. As a result, the average age of existing fleets has increased by 3 years.”*  
 Head of Sustainability, Auto manufacturer #4

Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 35)  
 Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews



# There are a variety of freight types, each of which has different needs as the sector thinks about a transition to ETs

Total vehicles sold (US, 2021)



Source: IHS vehicle sales (2021)

## LH Freight

### Sleeper LH

Cl. 8 vehicles that travel cross-country and don't return to terminal



Focus for TCO analysis

## Distribution

### Regional

\*May have municipal use

Cl. 8 vehicles that travel regionally and return to terminal



### Mid-mile

\*May have municipal use

Cl. 5-7 vehicles that do intercity/intracity pick-up/delivery



### Last mile

Cl. 1-4 vehicles that serve intracity needs



### Drayage

Cl. 8 vehicles used to transport goods to/from ports and rail



## Vocational

### Refuse

Cl. 8 vehicles used to haul garbage and waste



### Utility

Cl. 5-7 vehicles used for energy-related work



### Construction

Cl. 8 vehicles used for variety of job-site functions (e.g., dump truck)



### Bulk / special haul

Cl. 5-8 vehicles that include bulk and large haul use-cases



## Municipal

### School bus

Cl. 6 vehicles that transport passengers for education



### City bus

Cl. 8 vehicles used for mass transit



### Specialty

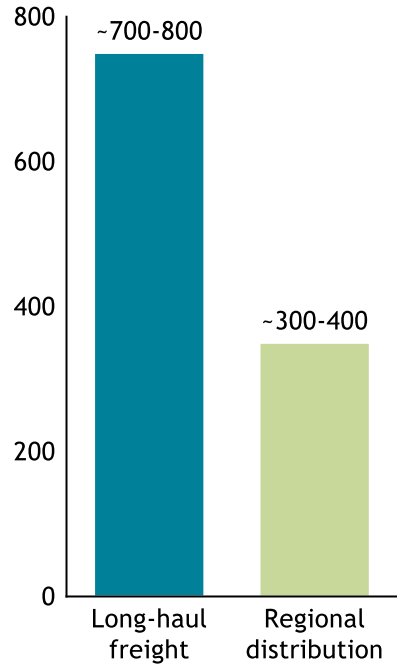
Special use vehicles (e.g. fire trucks)



# Longer distance freight vehicles require larger batteries and have higher associated battery costs

## Driving range<sup>1</sup>

Driving range without recharging (in km)



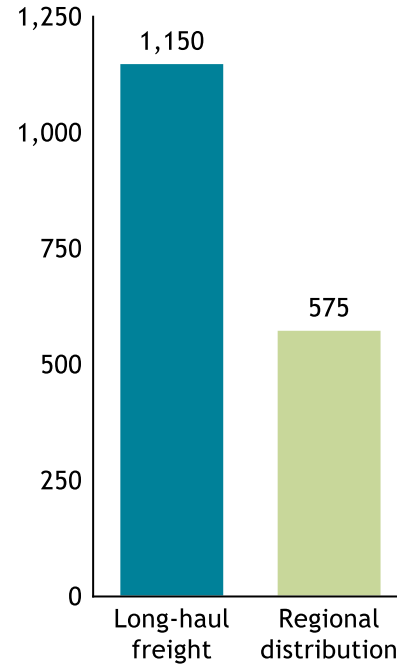
## Energy consumed per km<sup>2</sup>

Energy consumed per km (in kWh)



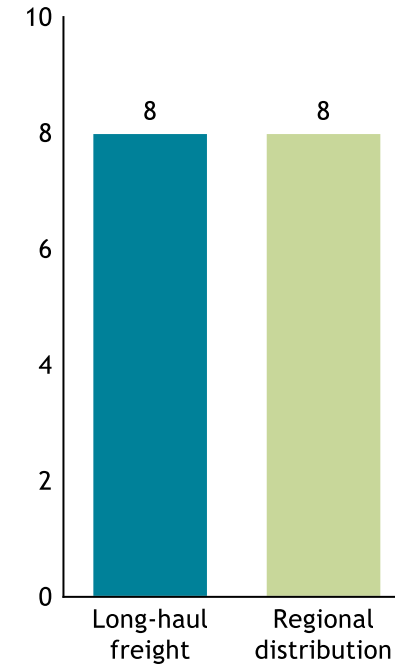
## Battery capacity<sup>3</sup>

Battery capacity (in kWh)



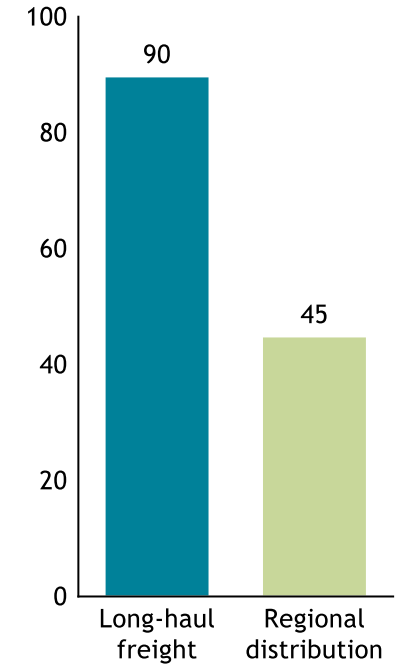
## Refueling time

Time required to return to full charge (in hours)



## Cost per battery<sup>4</sup>

Battery cost (in 2023 €K)



Note: 1 - without recharging, 2 - onboard energy storage capacity which is required to reach the max range without refueling / recharging, 3- usable capacity capped at 80%, 4 - 2030 estimate based on Bloomberg NEF w battery density of 318 Wh/kg  
 Source: 2022 Transport & Environment "Electric Trucks Take Charge" Report

# Batteries are the largest driver of disparity between ICE and electric trucks, both in terms of range and cost



*“We will close the cost gap with ICE vehicles by scaling battery production efforts, but the top barrier today is affordability and buying power. People can’t afford electric trucks at current battery prices and costs associated with a shorter range. Newer solutions are getting more efficient. The question is about the weight. If we have lighter trucks, then we can reduce battery size without reducing the range.”*

Head of Sustainability, Auto manufacturer #4

Source: Corporate interviews

# That said, there is some evidence of auto manufacturers starting to bring models to market that may meet fleet operators' needs, like the Tesla Semi



*“The Tesla Semi drove over 1,600 miles in 48 hours, 1,076 miles in one 24-hour period, and all near the maximum 82,000 pound gross vehicle mass. Few diesel trucks operate with this intensity, ever. No hydrogen (or diesel) truck will be able to keep up with these low costs. The point is, the range of use cases that this truck cannot perform is limited, essentially restricted only by truck charging infrastructure.”*

James Carter, Principal Consultant, Vision Mobility

Source: Lit. search



# “When managing fleets, we weigh payloads, fueling and charging, maintenance needs along our routes - you need to manage many levers at once”

Cost category	Considerations comparing electric trucks to internal combustion engine (ICE) trucks
Purchase price	<ul style="list-style-type: none"> <li>ETs generally have a <b>higher initial purchase price</b> than ICE trucks</li> </ul>
Residual value	<ul style="list-style-type: none"> <li><b>Residual value of ETs remains uncertain and is usually less than ICE</b>, and sometimes is even \$0 for an ET, given uncertain resale demand</li> </ul>
Maintenance	<ul style="list-style-type: none"> <li><b>ETs have fewer drivetrain parts compared to ICE trucks, requiring less maintenance on parts and oil changes</b></li> </ul>
Payload opportunity costs	<ul style="list-style-type: none"> <li><b>Weight of the payload carried on trucks impact’s an electric truck battery’s range</b>, thus limiting the amount of profitable cargo that be can transported while maintaining necessary driving ranges compared to ICE trucks</li> </ul>
Charging opportunity costs	<ul style="list-style-type: none"> <li>Electric trucks would need to <b>spend additional time charging vs. refueling times for ICE trucks not using depot charging, increasing trucker hours and delaying delivery times</b></li> <li><b>Cold weather temperatures can also reduce a full battery charge</b>, requiring consideration when planning</li> </ul>
Battery replacements	<ul style="list-style-type: none"> <li>ET owners must factor in the <b>additional cost of replacing batteries every 3-5 years</b></li> </ul>
Insurance	<ul style="list-style-type: none"> <li><b>Higher-priced vehicles cost more to insure</b>, and ETs are more expensive and have more specialized parts                             <ul style="list-style-type: none"> <li>- These specialized parts require specially trained technicians, leading to higher insurance rates for BETs compared to ICE trucks</li> </ul> </li> </ul>
Charging infrastructure costs	<ul style="list-style-type: none"> <li><b>ET owners must factor in the additional cost of investing in charging infrastructure, including:</b> <ul style="list-style-type: none"> <li>- The base charger cost</li> <li>- How many vehicles each charger can handle</li> <li>- Groundwork and installation costs</li> </ul> </li> </ul>
Fueling	<ul style="list-style-type: none"> <li><b>ETs typically have better fuel economy and lower fueling costs vs. ICE trucks</b></li> </ul>
Regulation-driven costs	<ul style="list-style-type: none"> <li><b>ETs can receive low carbon fuel standards (LCFS) or zero-emissions (ZE) incentive revenue in some markets (e.g., CA)</b></li> </ul>

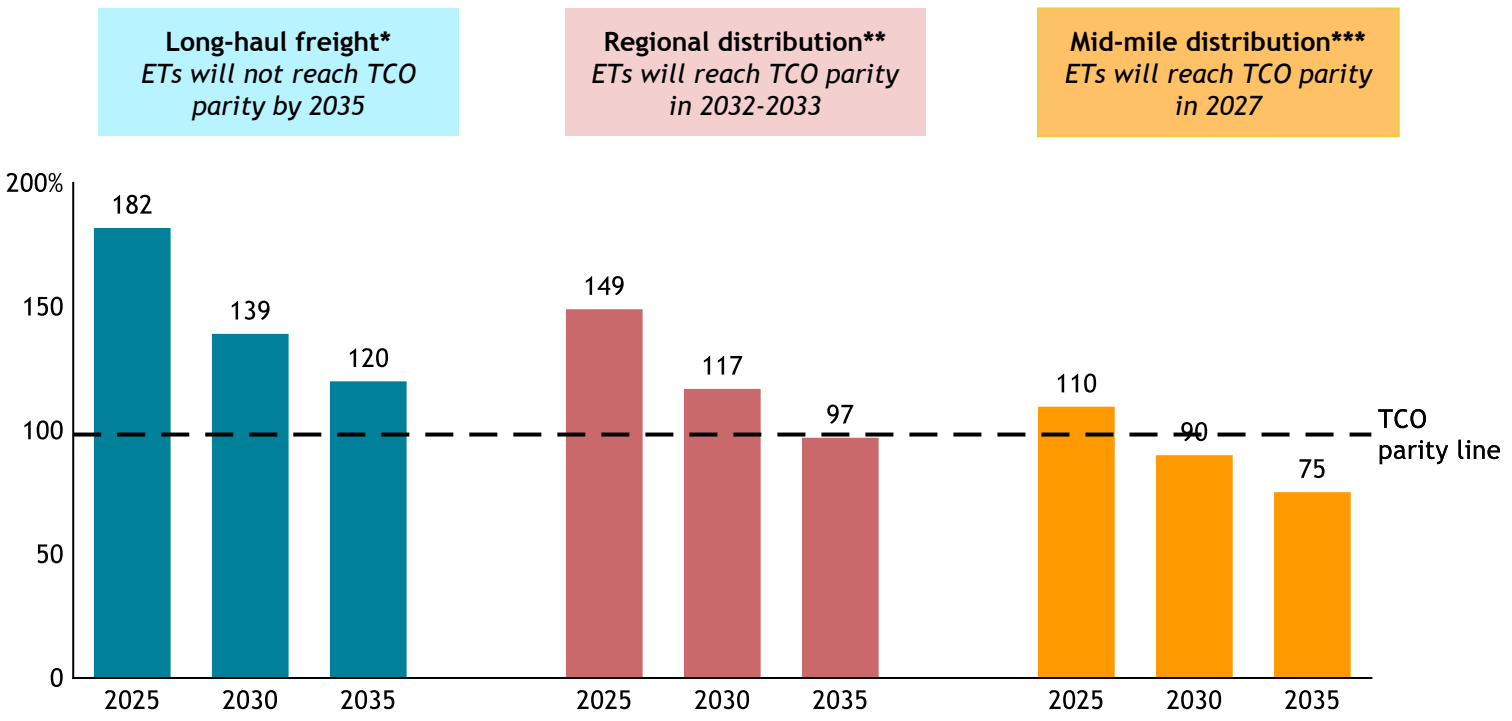
Note: Title quote is from Shane Menefee, Director, EHS, Legrand North & Central America  
 Source: Progressive, Lectron EV, Corporate interviews

# Many already see a clear path to parity for inter-city and regional trucks, though more extreme applications need to accelerate to reach parity



Regional and mid-mile distribution trucks will reach TCO parity within the next 10 years, while long-haul distribution has a longer path to parity

TCO of an electric truck as a % of TCO for an ICE truck in that year (%)



## Commentary

- **Improvements in battery technology and economics will drive TCO reduction, including:**
  - Better managed input costs incl. improved supplier management, optimized supply chain of inputs
  - Greater economies of scale from production
  - Cost optimized battery chemistries incl. managing share of battery from higher vs. lower cost minerals
  - ICE TCO also increases over time as diesel non-inflation based prices increase and biofuel blending mandates are enforced
- **Despite these trends, opportunity costs in terms of both payload and charging are still too significant to bring BETs to parity with ICE trucks**
  - For those trucks that measure capacity by weight (“weigh out”) instead of volume (“cube out”), truckers must limit capacity to maintain battery range, limiting revenue potential, and by extension, potential adoption of EV trucks
  - For long-haul trucks not charged overnight at operator-owned depots, hours waiting for ETs to charge may exceed driver break times, adding charging opportunity cost
- **Long-haul trucks will also have to use public charging depots, which have 3x the costs of private charging points**

Note: (\*) Long-haul freight trucks include Class 8 vehicles that travel cross-country and don't return to terminal; (\*\*) Regional distribution trucks include Class 8 vehicles that travel regionally and return to terminal; (\*\*\*) Mid-mile distribution trucks include Class 5-7 vehicles that do intercity and intracity pick-up and delivery  
 Source: Lit. search, Industry reports

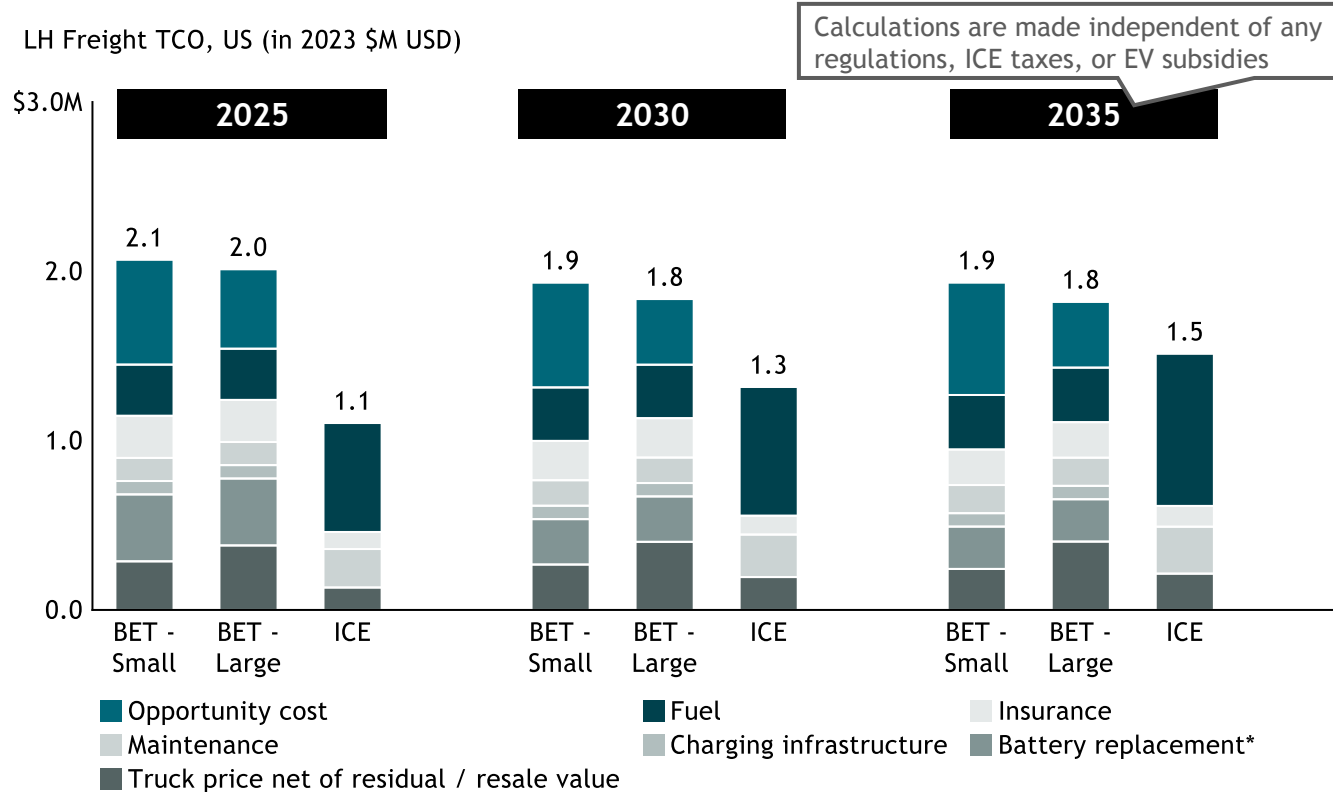
# Long-haul freight trucks will not achieve parity by 2035, though large battery TCO differentially declines as battery density improves

## LH freight



Long-haul freight trucks include Class 8 vehicles that travel cross-country and don't return to terminal

## Neither small nor large battery reach TCO parity by 2035



## Commentary

- Improvements in battery technology and economics will drive TCO reduction, including:
  - Better managed input costs incl. improved supplier management, optimized supply chain of inputs
  - Greater economies of scale from production
  - Cost optimized battery chemistries incl. managing share of battery from higher vs. lower cost minerals
  - ICE TCO also increases over time as diesel non-inflation based prices increase and biofuel blending mandates are enforced
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- Long-haul trucks will also have to use public charging depots, which have 3x the costs of private charging points

Note: (\*) Assumes battery replacements every ~4 years with a cost of up to ~\$50K per replacement; Assumes truck useful life of 12 years; BET - Small = 250-mile range battery, BET - Large = 500-mile range battery; Daily DCFC charging is necessary during the trip for "BET - Small" to complete the required daily range; Opportunity cost = payload opportunity costs and charging opportunity costs from trucker hours spent charging; Payload opportunity costs calculated via data on battery weight, freight rates, expected truck mileages and speeds, and share of trucks at capacity; Charging opportunity cost calculated via data on charging time requirements compared to expected trucker hours, charging needs vs. overnight charging capacity, and freight rates; Residual value assumed to be 50-60% of original purchase price

Source: ATRI, JP Morgan analyst reports, US Department of Transportation, Kelley Blue Book, US Office of Energy Efficiency and Renewable Energy, US Department of Energy, National Renewable Energy Laboratory, Lit. search



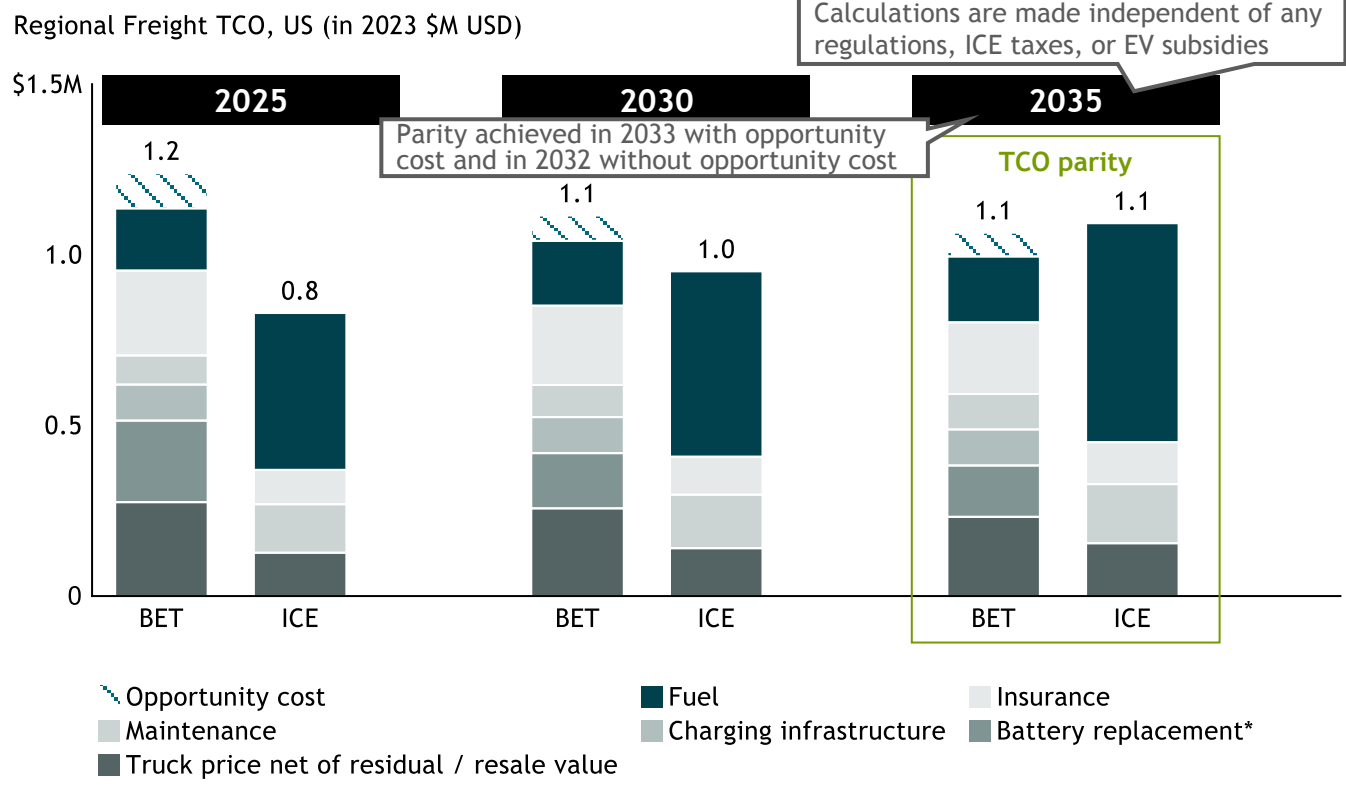
# Regional distribution will achieve TCO parity between 2030 and 2035, even with payload restrictions

## Regional dis.



Regional distribution trucks include Class 8 vehicles that travel regionally and return to terminal

## Parity reached between 2030-2035, driven by battery improvements



## Commentary

- **Improvements in battery technology and economics will drive TCO reduction, including:**
  - Better managed input costs incl. improved supplier management, optimized supply chain of inputs
  - Greater economies of scale from production
  - Cost optimized battery chemistries incl. managing share of battery from higher vs. lower cost minerals
  - ICE TCO also increases over time as diesel non-inflation based prices increase and biofuel blending mandates are enforced
- **Fleet operators who can manage payload opportunity cost will achieve TCO faster**
  - For those trucks that measure capacity by weight (“weigh out”) instead of volume (“cube out”), truckers must limit capacity to maintain battery range, limiting revenue potential, and by extension, potential adoption of EV trucks

Note: (\*) Assumes battery replacements every ~4 years with a cost of up to ~\$50K per replacement; Assumes truck useful life of 12 years; Assumes battery capable of supporting 250-mile range; Charging done at end of day; incentives include \$1.5k for charging infrastructure and installation for entire site, Opportunity cost = payload opportunity costs and charging opportunity costs from trucker hours spent charging; Payload opportunity costs calculated via data on battery weight, freight rates, expected truck mileages and speeds, and share of trucks at capacity; Charging opportunity cost calculated via data on charging time requirements compared to expected trucker hours, charging needs vs. overnight charging capacity, and freight rates; Residual value assumed to be 50-60% of original purchase price  
 Source: ATRI, JP Morgan analyst reports, US Department of Transportation, Kelley Blue Book, US Office of Energy Efficiency and Renewable Energy, US Department of Energy, National Renewable Energy Laboratory, Lit. search

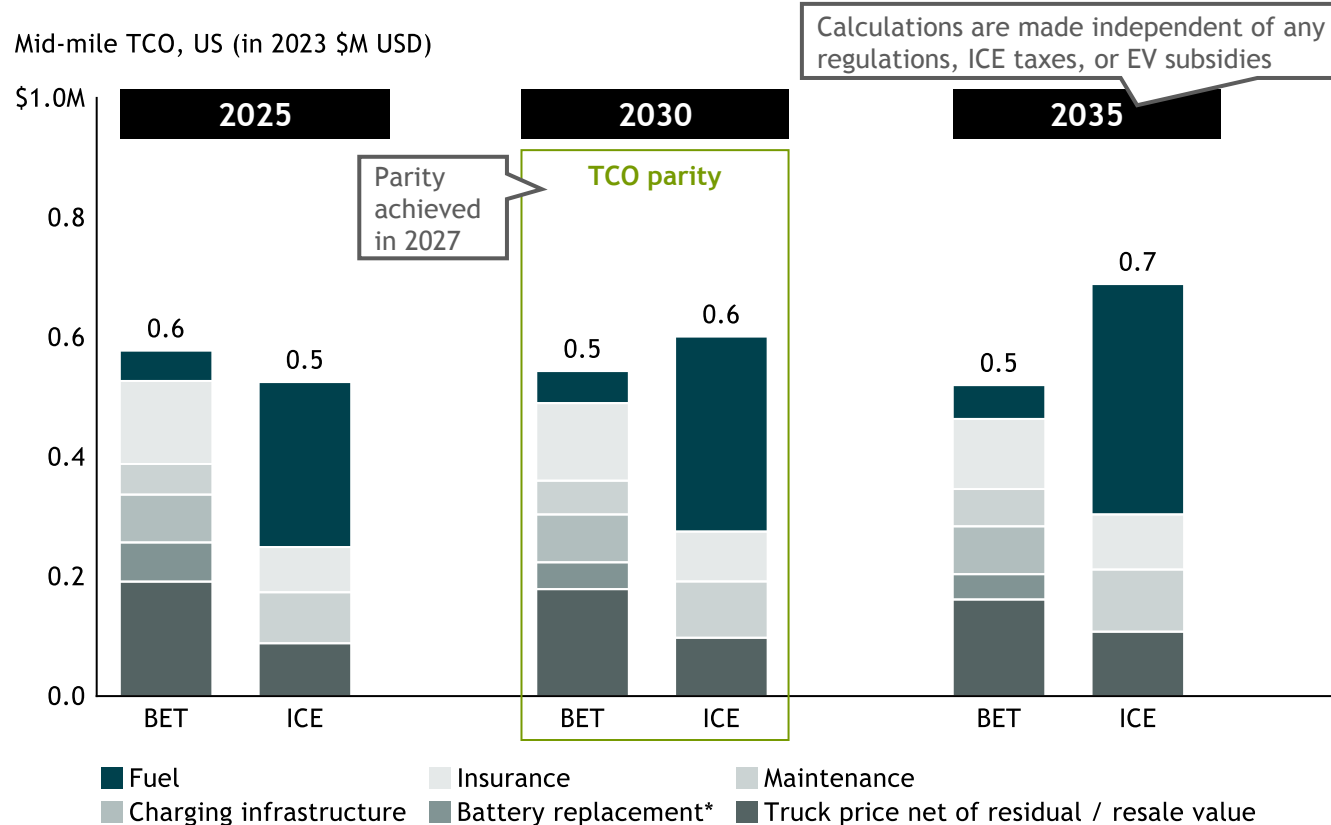
# Mid-mile distribution will achieve TCO parity by 2027

## Mid-mile dis.



Mid-mile distribution trucks include Class 5-7 vehicles that do intercity and intracity pick-up and delivery

## Mid-mile reaches parity with ICE driven by gains in fuel efficiency



## Commentary

- **Improvements in battery technology and economics will drive TCO reduction, including:**
  - Better managed input costs incl. improved supplier management, optimized supply chain of inputs
  - Greater economies of scale from production
  - Cost optimized battery chemistries incl. managing share of battery from higher vs. lower cost minerals
- **ICE TCO increases over time as diesel non-inflation based prices increase and biofuel blending mandates are enforced**

Note: (\*) Assumes battery replacements every ~4 years with a cost of up to ~\$50k per replacement; Assumes truck useful life of 12 years; Assumes battery capable of supporting 250-mile range; Charging done at end of day; incentives include \$1.5k for charging infrastructure and installation for entire site; Residual value assumed to be 50-60% of original purchase price

Source: ATRI, JP Morgan analyst reports, US Department of Transportation, Kelley Blue Book, US Office of Energy Efficiency and Renewable Energy, US Department of Energy, National Renewable Energy Laboratory, Lit. search

# “Without indications of financial commitments from governments and corporations, we worry about the potential for adoption in the near-term”



*The United States is bringing up the price of ICE trucks as well as providing funding to help alleviate investment costs to shift to electric trucks*

- The Federal government has implemented an **excise tax that is heavier on diesel**, increasing costs for ICE trucks relative to electric trucks
- The Federal government, through the Inflation Reduction Act, is now granting a collection of potential **tax credits that could be as high as \$40K per purchased ZET**
- The state of California is pledging **~\$2.6B in subsidies** for BETs (up to \$120K per truck) and FCETs (up to \$240K per truck)



*The European Union is also bringing up the cost of ICE trucks in conjunction with subsidy programs that improve the purchase price of electric trucks*

- The EU has implemented an **energy tax directive that taxes conventional fossil fuel consumption** at ~70x the rate of electricity consumption (€10.75/GJ vs. €0.15/GJ)
- 21 EU member states have **subsidy programs for ZETs**, with subsidies ranging from 20-80% of the difference in price between a ZET and its ICE equivalent as well as 50%+ discounts on road tolls



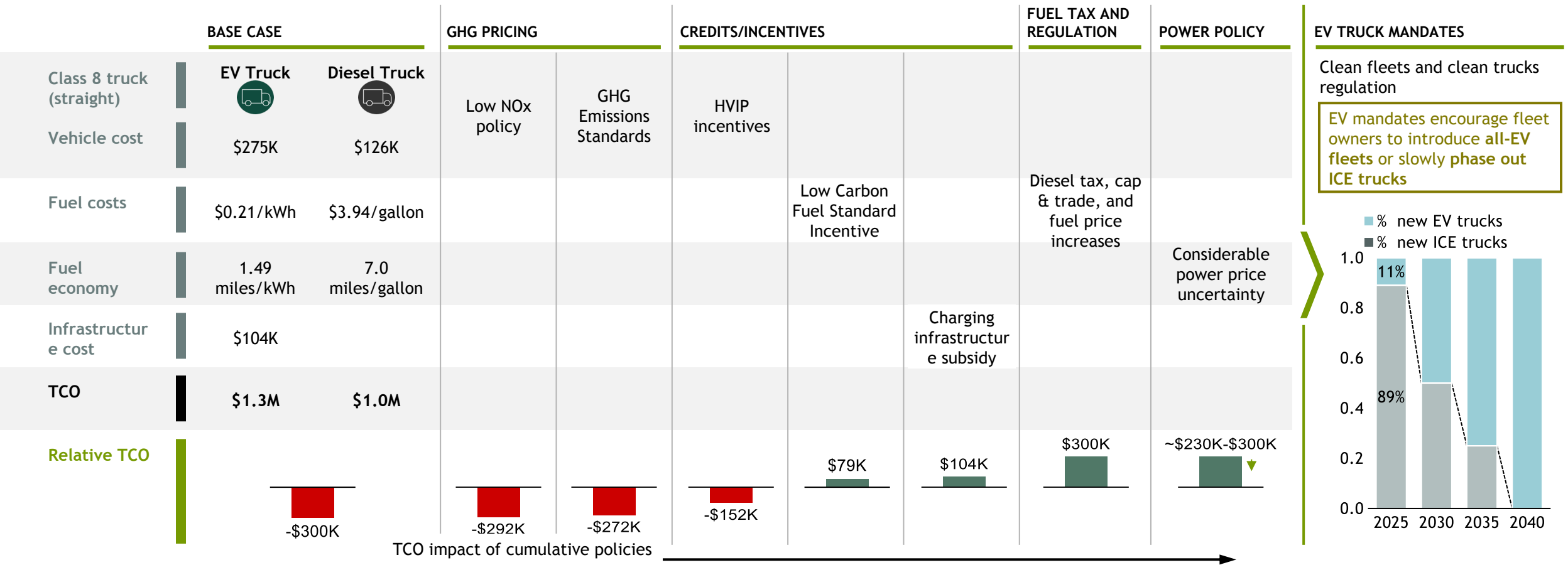
*China is focused on improving electric truck supply by financing OEMs while supporting the demand-side with subsidies to improve electric trucks' investment profiles*

- OEMs have been able to secure **tax credits since 2018 based on the amount of their ZET vehicle production**
- ET buyers have been able to access **~\$72B in tax breaks** that amount to as much as ~\$4K per truck
- The central government has set aside **~\$1.5B for grants and loans for municipalities to purchase electric trucks**

Note: Title quote is from Stina Klingvall, Manager of Climate Action, Volvo Cars  
Source: Corporate interviews

# "We don't have a choice but to shift to ZETs - the industry is going to need to shift as regulations remove diesel options"

## California 2025 EV truck policies



Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3; TCO: Total Cost of Ownership; HVIP: Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project  
 Source: California Air Resources Board; ICF; NCST; RMI; California HVIP; Corporate interviews

# “We are working across fuel types to identify and pilot the right mix across our operations, from EVs for last mile to hydrogen forklifts at distribution centers”

Hydrogen allows longer driving range with less weight and fast refuelling compared to battery electric trucks



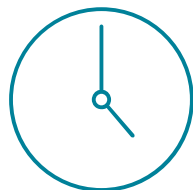
## Longer driving range

FC with higher energy density vs. battery (5x in trucks, 3x in cars) allowing long driving ranges, similar to ICE  
>1.000 km range possible with hydrogen currently not feasible for battery vehicles



## Low weight

Weight of fuel cells significantly lower than batteries, enabling same payload as ICE HDT already today  
~FCET powertrain weighs 20% vs. that of BET, for a 800km range



## Fast refuelling

Fuel cell vehicles with charging times similar to ICE vs. BET with longer time particularly for full recharge  
3-5 min. for FCEV  
15-20 min. for FCET (faster with liquid hydrogen)

However, fuel cell trucks face challenges due to higher TCO, scarcity of green energy, and costly refuelling infrastructure



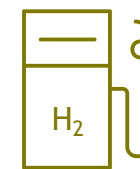
## Insufficient green electricity

Low efficiency of FCET leads to significantly higher primary energy demand vs. BET  
FC vehicles require ~2x electricity per km vs. battery powered



## High TCO

Higher total cost of ownership (TCO) driven by expensive hydrogen used as fuel  
Hydrogen ~3x more expensive than electricity per km



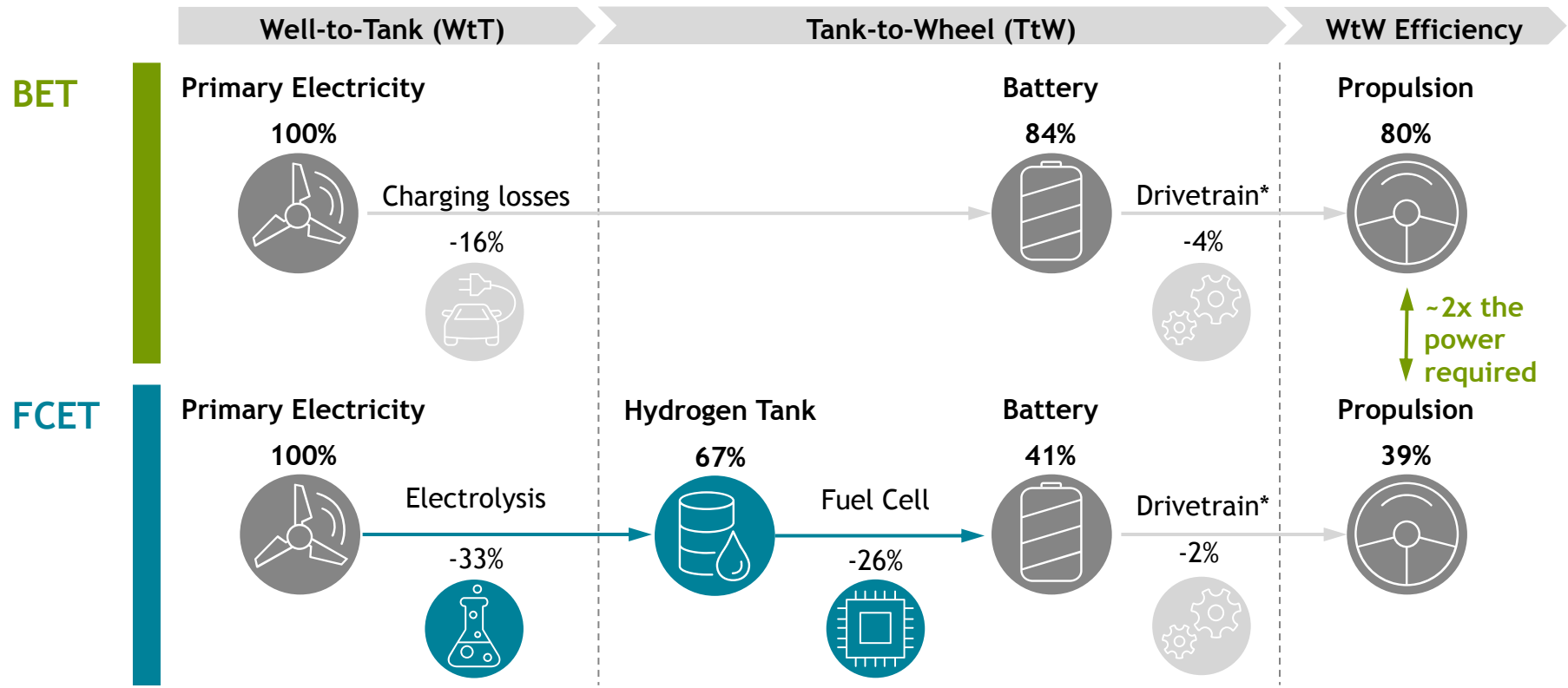
## Lack of refuel infrastructure

Currently no noteworthy hydrogen infrastructure in place (on-site/ along high-traffic corridors)  
Long-haul infra. cost ~50% higher than BET

Note: Title quote from Walmart; 2020 data used when comparing vehicles  
Source: ICCT; Lit search; Corporate interviews

# "Hydrogen fuel cell is not new - we have been investing for years; it's all about scale and securing hydrogen supply given lower WtW efficiency vs. BETs"

## 2020: Well-to-Wheel efficiency of Battery and Hydrogen powered vehicles



## Commentary

- There are structural barriers to improving the energy efficiency of hydrogen
  - While investments continue to be made in electrolysis, the process is inefficient today
  - There many energy transfer points from primary electricity to hydrogen tank and tank to battery that risk energy loss
- Even if OEMs and fleet operators tolerated lower efficiency, the power grid also could not support the energy consumption associated with a major shift to FCETs

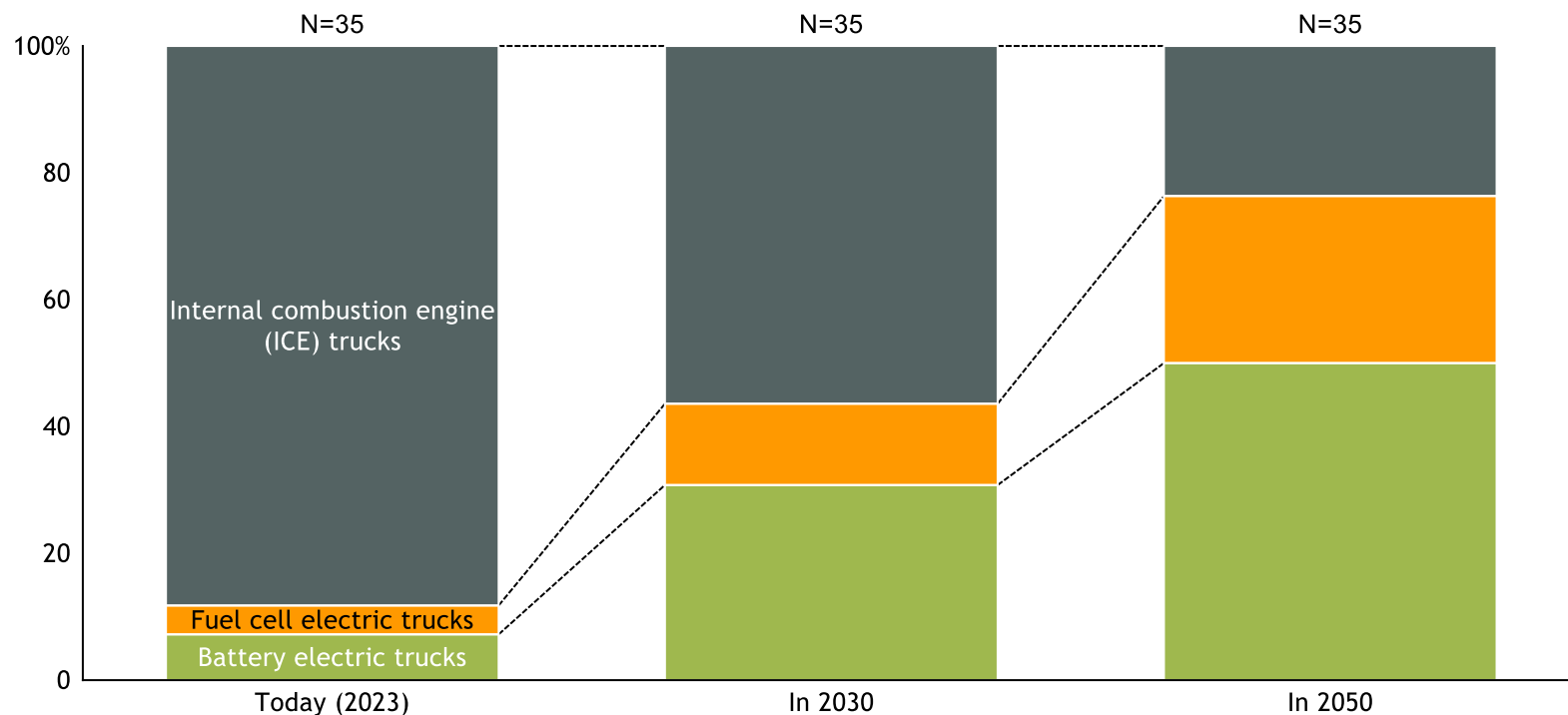
Legend:  Use/storage of energy  
 Conversion process  
 Fuel cell specific

Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3; Percentage losses are referenced to entire energy chain; \*Drivetrain losses assumed with 16%, subsequent recuperation regains 84% of remaining efficiency;  
 WtW = Well-to-Wheel - Energy chain, representing the primary electricity production required per km;  
 TtW = Tank-to-Wheel - Energy chain from the vehicle's storage to the wheels, representing the energy to be refilled at a fuel/ charging station.  
 Source: US DOE, Corporate interviews

# Business leaders see mixed future in trucking - with ~50% battery electric, ~30% hydrogen fuel cell trucks in 2050, and ~20% yet to transition

What share of your *company's vehicle mix* is represented by each of the following technologies today? What do you expect this share to be in 2030? What do you expect this share to be in 2050?

Current and expected share of global trucking fleets by powertrain type (%)



Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 35)  
 Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

## Commentary

- For short-haul trucks and many freight applications, **business leaders expect battery electric to be the preferred technology**
- However, many business leaders expect a mixed-use future with **hydrogen fuel cell technology** for applications in construction, heavy equipment, or for the longest-haul freight routes

*“We see that in the future, most vehicles are going to be electric for short-haul solutions. For long-haul solutions, however, we are thinking it will be hydrogen-based.”*

Sonnie Førrisdahl, Sustainability Manager, ColliCare Logistics



# Fleet operators are reluctant to transition to ETs due to high TCO, resulting in an uncoordinated demand for ETs and, subsequently, limited supply from OEMs



*"We are battling with whether and how much to invest in electrification all the time. It's because the new technology is still under development... we believe that when the technology gets a little bit more mature, the prices will go down."*

Sonnie Førrisdahl, Sustainability Manager, ColliCare Logistics

*"As a commercial fleet operator, we are facing a number of unknowns, which makes it very **unstable and difficult to make decisions and investment commitments**. Moving to electrification right now may be more expensive, and it could be more cost-effective to wait."*

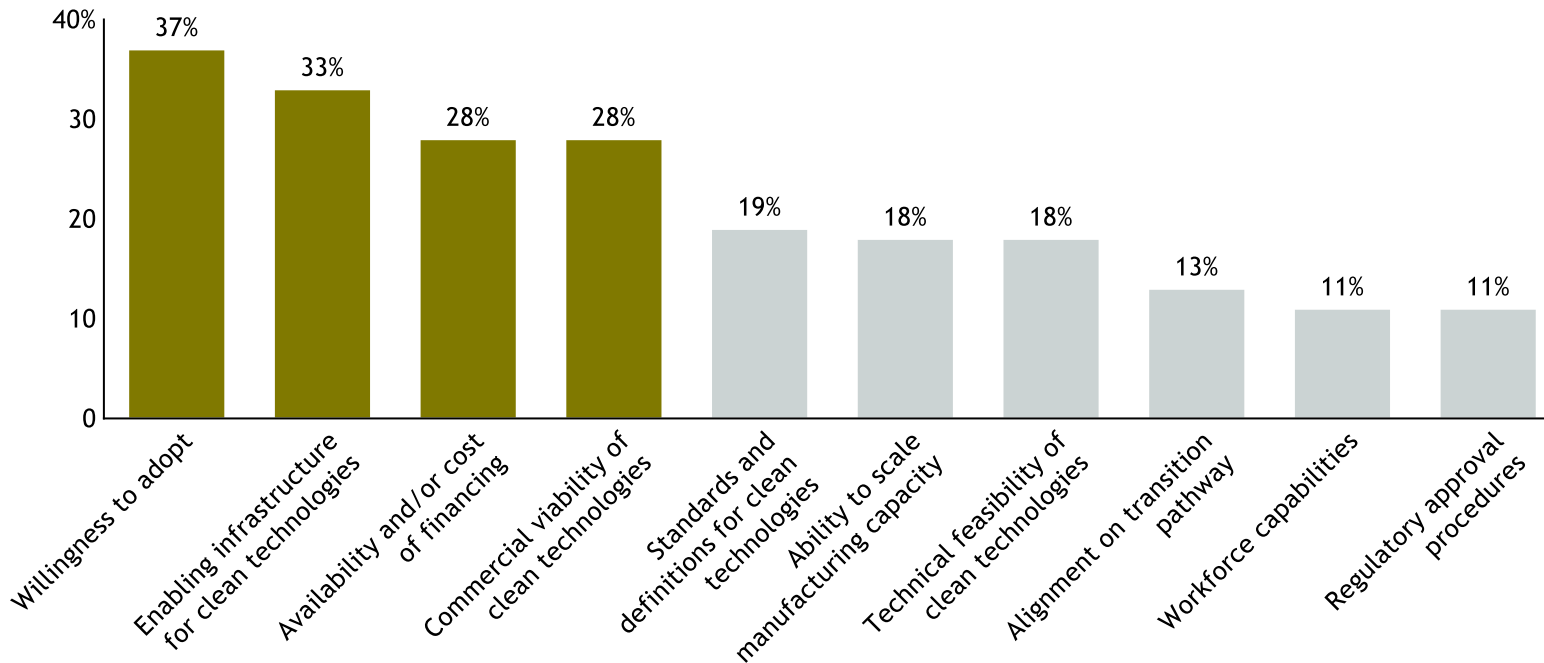
Abby Chicken, Head of Sustainability, Openreach

Source: Corporate interviews

# Business leaders view willingness to adopt ETs, underlying power capability, financing availability, commercial viability as top barriers to charging buildout

Which of the following do you view as the *largest barriers towards scaling freight electric vehicles charging infrastructure*? Please select the top 3 most impactful barriers.

Share of survey respondents selecting barrier in the top 3 (%)



Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 72)  
 Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

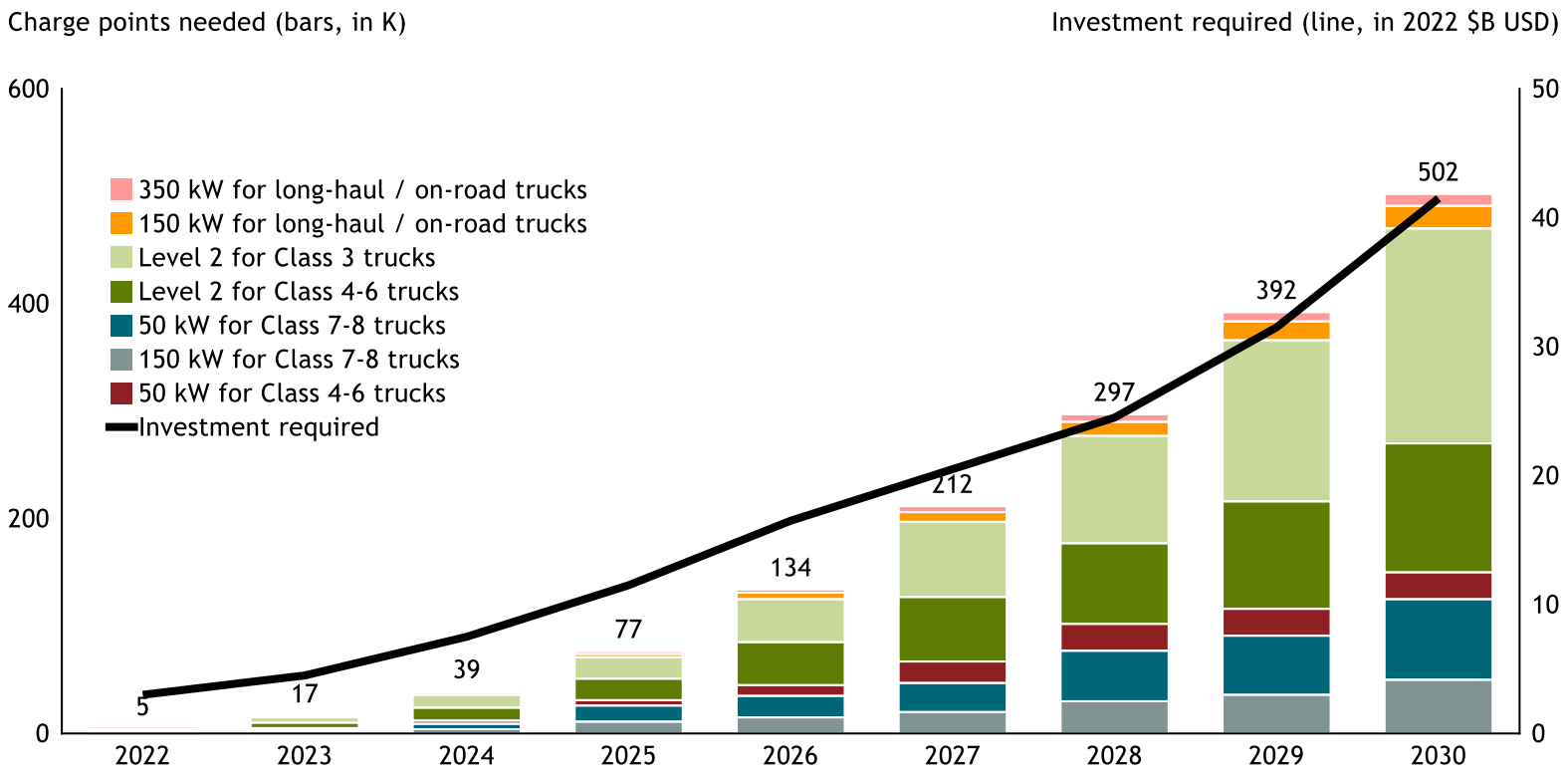
## Commentary

- Business leaders know that building charging infrastructure for freight EVs will be challenging due to a few drivers:
  - Many of those likely to be the ones to lead the buildout may be unwilling to do so
  - The underlying power infrastructure cannot support the transmission needs of freight EV charging stations today
  - Charging is a bigger challenge for long-haul trucks, while short-haul trucks can return to private charging depots owned by their operators
- Many organizations have stake in the buildout:
  - Fleet operators will need to build their own charging, but only larger operators will have capital and property to support a buildout
    - > Smaller operators will need to aggregate demand and invest in shared charging or seek consolidation with other operators
  - Gas stations have interest as demand shifts to gas but are concerned about trucks taking space for long periods to charge
  - Power utilities and auto manufacturers will have a strong business case to participate in the buildout
  - Passenger-focused charging infrastructure companies will likely play a smaller role in freight

*“Charging infrastructure is insufficient to meet our driving range needs, and the path to closing the gap is going to be difficult.”*  
 Sonnie Førrisdahl, Sustainability Manager,  
 ColliCare Logistics

# "We can't rely on governments to propel charging transition; we need private action if we want to see movement on EV charging"

## By 2030, >\$40B investment and >500K chargers needed to meet charging demand



## Commentary

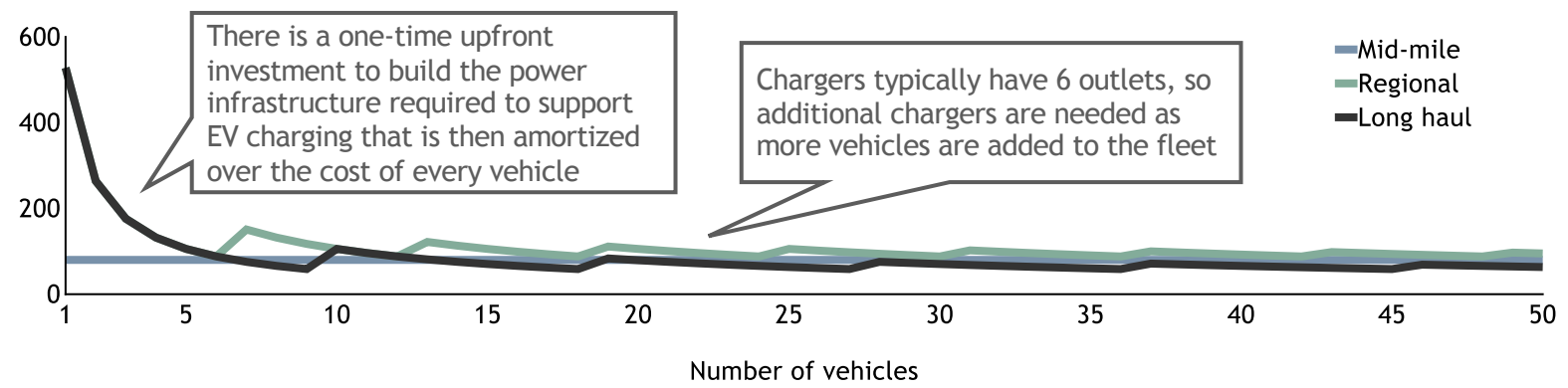
- Most charging investments will be expected to come from fleet operators
  - Larger fleet operators are already investing in short-haul EV charging infrastructure
  - Smaller fleet operators are considering shared charging infrastructure investments to manage their costs, including government-orchestrated charging corridors to aggregate demand for charging
  - Challenges remain for long-haul trucking needs
- Due to the lengthy charging times for EV trucks, charging point needs are greater than many believe, especially at peak demand times
  - E.g., Depots will need to ensure that each truck has sufficient charger access time overnight, and many fleets are already doing so
- Given the wide variety of trucking types, charging infrastructure buildout will need to be customized to meet fleet needs
  - Lower class trucks do not need chargers with the same capacity or speed as higher class trucks
  - While long-haul trucks have outsized capacity and speed requirements, they only represent a small share of total charger use

Note: Title quote from Gabrielle Ginér, Head of Environmental Sustainability, BT Group  
 Source: Atlas Public Policy, US Department of Transportation; Corporate interviews

# "You can tailor infrastructure for HDVs to their specific routes, but it's going to be on the fleet operator to plan and invest"

## Larger fleets face lower per vehicle costs from charging infrastructure by amortizing upfront investment across many vehicles

Per vehicle cost of charging infrastructure (in \$K USD)



### Assumptions

Use case	Required charger voltage	Charger cost as of 2023	Installation cost per charger**	Number of charging outlets	Vehicle: Charger outlet ratio***
Long-haul	DCFC - 500 kW	\$278,000	\$250,000	6	1.5 : 1
Regional					1 : 1
Mid-mile	DCFC - 50 kW	\$30,000	\$50,000	1	1 : 1

Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3; (\*) Overall cost represent cost to outfit fleet of 20 vehicles; \*\*Installation cost scaled as proportion of kW compared to DCFC - 50 kW charger; \*\*\*Vehicle : charger outlet ratio assumes Regional and Mid-mile charge overnight every night, long haul charges in depot intermittently  
Source: PG&E EV infrastructure calculator; Corporate interviews

## Commentary

- Despite high upfront costs to purchase and install charging infrastructure and higher operational costs due to more expensive grid connection costs, **per-vehicle costs decline when fleets spread costs over many trucks**
  - Trucks do not need to be charging all day, which means with **fewer trucks, charging points may have significant downtime**
  - With more trucks, **charging points can be utilized all day by different trucks to make the most of the investment until you reach the capacity for that charging point**
- Implications for the investment case vary by fleet operator type
  - **Large fleet operators can justify investments in the near-term, making sure to optimize schedules around charging times**
  - **Smaller owner-operators can work with other smaller operators to co-invest in charging infrastructure to bring down costs**



# Insufficient investment, policy guidance, and underlying power infrastructure present barriers to charging infrastructure buildout for electric trucks



***“We have been advocating for more government guidance and policies to help accelerate the transition to EV fleets and charging infrastructure buildout... As fleet operators, we want to buy these vehicles, so we are trying send demand signals by saying ‘yes we are committed to converting our fleets.’”***

Gabrielle Ginér, Head of Environmental Sustainability, BT Group

***“I just don’t see where all the renewable electricity is going to come from. We need policymakers from across the world to work with investors and businesses to accelerate the transition to renewables.”***

Gabrielle Ginér, Head of Environmental Sustainability, BT Group

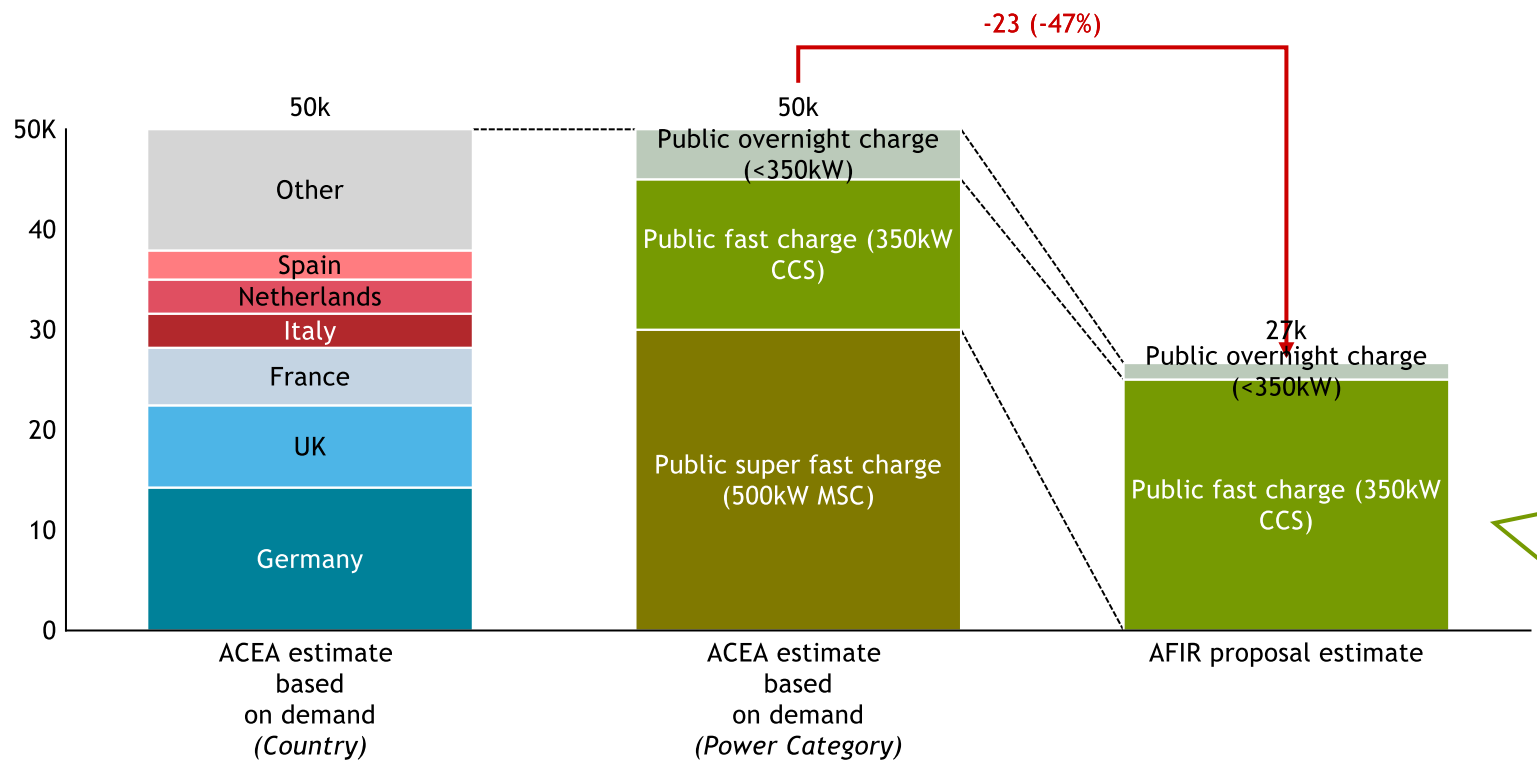
Source: Corporate interviews

# “Private companies cannot work alone; government needs to be more alert, to work more toward implementing new regulations around infrastructure”

## Future charging infrastructure need potentially significantly higher than AFIR proposal

## EU not progressing at required pace

Estimated number of charging points in EU27 + UK by power category by 2030 (ACEA vs. AFIR)



- According to AFIR, EU member states propose deployment of at least 27k charging points for e-HDT by 2030
- ACEA<sup>1</sup> estimates the need for charging stations to be even higher (50k) and at higher capacity
- High uncertainty if AFIR proposal will be implemented and if proposal will be enough to enable BEV adoption (likely not)

Charging infrastructure is especially important for the long-haul segment; seldom returning to base and dependent on by-the-road charging

Notes: Sonnie Førrisdahl, Sustainability Manager, ColliCare Logistics; ACEA estimates assumes 350kW/500kW charging points are equipped to delivery low-power overnight charge. If not, the estimate will increase to -40k, bringing the total to -85k; 1) The European Automobile Manufacturers' Association (ACEA) represents the 14 major Europe-based automobile manufacturers (e.g. Volvo, Renault, Mercedes, Daimler Truck, DAF, Volkswagen)  
 Source: ACEA1 position paper; AFIR; Corporate interviews

# Fleet operators are deterred by limited access to and slow speeds of charging points that drive up trucker hours and costs



***“One of the barriers that we find is that there aren’t enough charging points. We must work together with energy companies because many of us are going to need to invest in that service.”***

Quality and Climate Change Manager, Road infrastructure provider #1


***“The main problem is the lack of enabling factors. **The first question we get from potential BEV customers is ‘so, where do I charge?’ We need charging infrastructure, a massive build-out of the electricity grid, and we need green electricity in that grid.**”***

Jennie Cato, Head of Public Affairs and Partnerships, Scania

Source: Corporate interviews





# “Walmart is central to the buildout, providing public charging for its customers and private charging for its fleet”

Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• <b>Description:</b> Global multinational retail corporation that operates a chain of supercenters, discount department stores, and grocery stores</li> <li>• <b>Founded:</b> 1962</li> <li>• <b>Headquarters:</b> Bentonville, Arkansas, United States</li> <li>• <b>Ownership:</b> Public (NYSE: WMT)</li> <li>• <b>Revenue (FY2023):</b> \$611.3B USD</li> </ul>	<p><b>2040</b></p> <ul style="list-style-type: none"> <li>• 100% zero emissions fleet by 2040 on a science-based trajectory with annual reporting on progress</li> </ul>	<p><b>Becoming the first-mover to electrify trucking fleet</b></p> <p>→ · → · →</p> <p><b>Modelling how to manage charging buildout alongside fleet mix shift</b></p>  <ul style="list-style-type: none"> <li>• Walmart has a <b>wide array of trucks across its fleet</b>, from last-mile delivery trucks up to Class 8 vehicles, which all have <b>unique electrification needs</b> <ul style="list-style-type: none"> <li>- For its last-mile delivery trucks, <b>Walmart has already committed to electrifying its entire home delivery fleet</b> due to the comparable TCO, minimal concern with driving range, and easily installable charging</li> <li>- Heavier duty vehicles do not yet have a clear TCO or driving range justification compared to ICE vehicles, but <b>Walmart is piloting Tesla Class 8 vehicles in Canada</b> where distribution can leverage central Walmart-owned charging depots</li> <li>- Walmart is actively piloting multiple powertrain technologies and expects its zero emissions fleet of 2040 will require a mix of technologies including both hydrogen fuel cells and BEVs</li> </ul> </li> <li>• Walmart is <b>working to build out its own public fast charging EV charging infrastructure</b> <ul style="list-style-type: none"> <li>- Both for their own fleet and for their supply chain partners</li> <li>- Walmart plans to play an active role in procurement of green hydrogen and assumes that hydrogen fuel cell trucks and the associated hydrogen refueling infrastructure will be a part of their strategy</li> <li>- Concerns about supply chains for charging (e.g., transformer switch gears), but Walmart leadership feels that an operator as big as Walmart making upfront commitments could justify a manufacturing line on its own</li> </ul> </li> <li>• Walmart’s plans to <b>leverage charging investments to introduce consumer-facing charging as well</b>, intending to change how consumers think about retail and refueling experiences           <ul style="list-style-type: none"> <li>- Strong business case for them to drive foot traffic, frequency of visits, and increased data generation from consumers</li> </ul> </li> </ul>



Note: Title quote is from Chief Sustainability Officer, Fleet operator #1  
Source: Walmart, Corporate interviews

# “Amazon wanted to send a big demand signal to the market - that they want it to go EV across every mode”

Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• <b>Description:</b> Multinational technology company focusing on e-commerce, cloud computing, online advertising, digital streaming, and artificial intelligence</li> <li>• <b>Founded:</b> 1994</li> <li>• <b>Headquarters:</b> Bellevue, Washington, United States</li> <li>• <b>Ownership:</b> Public (NASDAQ: AMZN)</li> <li>• <b>Revenue (2022):</b> \$513.98B USD</li> </ul>	<ul style="list-style-type: none"> <li><b>2025</b> • Power trucking operations with 100% renewable energy</li> <li><b>2030</b> • Operate &gt;100K electric delivery vehicles</li> <li><b>2040</b> • Become an entirely carbon-zero operation worldwide</li> </ul>	<p><b>Making an ambitious commitment to an electrified delivery fleet</b></p> <ul style="list-style-type: none"> <li>• Amazon co-founded The Climate Pledge in 2019 and made a <b>commitment to achieve net-zero operations by 2040</b> <ul style="list-style-type: none"> <li>- As part of that Pledge, Amazon also announced a partnership with Rivian to bring 100,000 electric delivery vehicles on the road by 2030</li> <li>- Amazon began rolling out its electric delivery vans in the summer of 2022 and now has more than 5,000 across the U.S.</li> <li>- Amazon has also brought the custom vans to Europe and recently announced <b>more than 300 will hit the road in Germany</b>, joining a fleet of thousands of electric vans already in operation in Europe.</li> <li>- Amazon’s custom electric vans are on the road making deliveries in more than <b>800 cities and regions across the US</b></li> <li>- Amazon’s vans have delivered more than 150 million packages in the US</li> </ul> </li> <li>• <b>Alongside its fleet investments, Amazon will also invest in thousands of chargers across its European facilities</b> <ul style="list-style-type: none"> <li>- The investment will allow the company and its partners to improve fleet charging hardware</li> <li>- Some chargers will be specialized fast chargers that charge vehicles in ~2 hours</li> </ul> </li> </ul>  <p><b>Investing in adjacent technology to enable a fully carbon-zero trucking operation</b></p> <ul style="list-style-type: none"> <li>• Amazon has also put more than 15 models of electric vehicles on the road, including delivery vehicles, e-cargo bikes, and e-rickshaws, to test and learn across the US, EU, and India</li> <li>• Amazon is investing in solutions like green hydrogen and other alternative fuel methods for delivery and operations.</li> <li>• Amazon announced plans to invest &gt;€1B over the next five years to further electrify and decarbonize its transportation network across Europe, part of the company’s work to deliver packages to customers more sustainably             <ul style="list-style-type: none"> <li>- The investment is also intended to drive innovation across the industry and encourage more public charging infrastructure, which will help enable the broader transportation industry to more quickly reduce emissions</li> </ul> </li> </ul> 

Note: Title quote is from Chief Sustainability Officer, Fleet operator #1  
 Source: Amazon, Corporate interviews

# "When diesel vans come to end of life we are replacing with electric vehicles as part of reaching our net zero target"

Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• <b>Description:</b> Leading multinational communication services company and the UK's leading provider of fixed and mobile telecommunications and related secure digital products, solutions and services                             <ul style="list-style-type: none"> <li>- Also provides managed telecommunications, security and network and IT infrastructure services to customers across 180 countries</li> </ul> </li> <li>• <b>Founded:</b> 1846</li> <li>• <b>Headquarters:</b> London, UK</li> <li>• <b>Ownership:</b> Public (LSE:BT.A)</li> <li>• <b>Revenue (FY2023):</b> £20.7B</li> </ul>	<div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); border-left: 2px solid green; margin-right: 10px; height: 100%;"></div> <div> <p><b>2030</b></p> <ul style="list-style-type: none"> <li>• Help customers to avoid 60 MtCO<sub>2</sub>e</li> <li>• Building towards BT's products, network and operations becoming circular</li> </ul> <p><b>2031</b></p> <ul style="list-style-type: none"> <li>• BT Group's own operations will be net-zero</li> <li>• All engineers in Openreach team will be able to drive an EV</li> </ul> <p><b>2041</b></p> <ul style="list-style-type: none"> <li>• Net-zero supply chain and customer emissions (all Scope 3)</li> </ul> </div> </div>	<div style="display: flex; align-items: center;"> <div style="margin-right: 10px;"> <p><b>Creating opportunity to leverage existing investments for EV charging</b></p>  </div> <div> <ul style="list-style-type: none"> <li>• <b>BT Group is innovating EV charging units to provide pivotal EV charging infrastructure</b> <ul style="list-style-type: none"> <li>- BT Group is repurposing street cabinets, which are currently used to provide broadband and phone services and will be phased out in favor of fiber optics, as charging stations</li> <li>- 2 year technical and commercial pilot program based out of Northern Ireland beginning in Fall 2023                                     <ul style="list-style-type: none"> <li>&gt; Conducted by the BT Group start-up Etc.</li> <li>&gt; Estimated that over time 60K out of 90K cabinets could be converted to charging points</li> </ul> </li> </ul> </li> <li>• <b>BT Group is forming multi-corporate collaboration to accelerate EV transition in the UK</b> <ul style="list-style-type: none"> <li>- Formed the UK Electric Fleets Coalition with Openreach and the Climate Group</li> <li>- The coalition is comprised of the largest fleet operators in the UK and calls for policies to support the transition to ultra-low emissions vehicles</li> </ul> </li> </ul> </div> </div> <div style="margin-top: 20px;"> <p><b>Aggregating demand for EV trucks through partnerships with fleet operators</b></p>  </div>

Note: Title quote is from Gabrielle Ginér, Head of Environmental Sustainability, BT Group and Abby Chicken, Head of Sustainability, Openreach  
 Source: EVFA Report 2021; BT; Corporate interviews

# Changes in demand, supply, and charging access will drive the next wave of passenger EV adoption in developed markets



## Technology developments

- The industry is coalescing around BET technology for most use cases and both short-haul and long-haul trucks, but BEVs face technical challenges for the longest haul and heaviest-duty applications, prompting continued research into FCET and BET technologies
- Heavy-duty fleet operators are reluctant to commit to EV procurement - both due to limited production and the risk of a “first mover disadvantage;” trucking technology is expected to improve (e.g., longer range) and become cheaper as production scales and OEMs release new models

*By 2050, business leaders expect that ~50% of trucks will be BETs, and another ~30% will be FCETs*

*~55% of business leaders consider lack of fleet operator demand to be a top barrier to freight EV adoption*



## Total cost of ownership

- Higher total cost of ownership relative to ICE trucks remains a concern for fleet operators, driven by higher purchase prices, low or zero residual EV values, issues around trucker hours / turnover, opportunity costs with payloads, and less favorable financing terms
- In some markets, early demand signals are emerging - often driven by policy, but OEMs do not yet see large scale coordinated demand for EV trucks; as a result, investment levels in BET are constrained, which slows potential learning rates and cost declines

*~60% of business leaders consider commercial viability to be a top barrier to freight EV adoption*



## Infrastructure buildout

- There is insufficient investment and strategic policy roadmaps for charging infrastructure to support requirements of trucking networks
- Power grids do not have the transmission capacity, speed, or coordination with utilities to meet charging needs of EV trucks
- Fleet operators are deterred by limited access to and slow speeds of charging points that drive up trucker hours and costs during long-haul routes, though short-haul routes are expected to slow charge overnight at operator-owned “return-to-base” depots
- While hydrogen fuel cell refueling times are similar to those of diesel, higher costs and lower energy efficiency associated with hydrogen transport and storage remain concerns

*“We can’t rely on national governments to help propel the charging transition. We need localized and private action if we want to see switch action on EV charging.”*

*Abby Chicken, Head of Sustainability, Openreach*



Policy objectives for freight EVs are similar to passenger EVs, though demand-side policy must still be prioritized



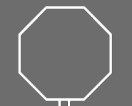
Tackle total cost of ownership via demand-side policy

- Commercial fleet operators still cannot justify the economic tradeoffs of an ICE truck vs. an electric truck in some applications - **purchase price subsidies, operating subsidies, guaranteed residual values, differentiated road taxes, and preferential interest rates on EV financing** will all help bring down TCO
- At the same time, **governments can introduce pricing policies to increase the costs of ICE technologies**, including through additional taxes on diesel fuel consumption, but ensuring the net effect of policy is clearly understood and visible even to smaller fleet operators is critical



Create incentives for EV charging and supply expansions

- TCO matters, but governments also need to get ahead of the charging buildout through ambitious commercial road transport charging strategies, which could include the **provision of direct funding and subsidies to infrastructure providers, establishing charging mandates in construction projects, and ensuring utilities have sufficient funding and accelerated permitting access** to keep pace with demand
- Alongside the charging buildout, governments should **support OEMs to build out their production capacity through continued support of R&D as well as government procurement commitments**



Signal the long-term trajectory with an eventual ICE ban

- As the TCO gap closes, charging infrastructure expands, and OEMs build out capacity, **governments can set the timeline for ICE phase out, ensuring fleet operators, OEMs, and fuel providers are investing with a shared understanding on the pace of transition and end state**



# Road Transport: Table of Contents

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The **Sector Overview** section provides context on the state of emissions, the transition pathway, and corporate disclosures

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The **Passenger Vehicles in Developed Markets** narrative explores the state of transition in the light duty, passenger vehicles in developed electric vehicle markets

03

The **Freight in Developed Markets** narrative explores the state of transition in medium- and heavy-duty freight vehicles in developed electric vehicle markets

04

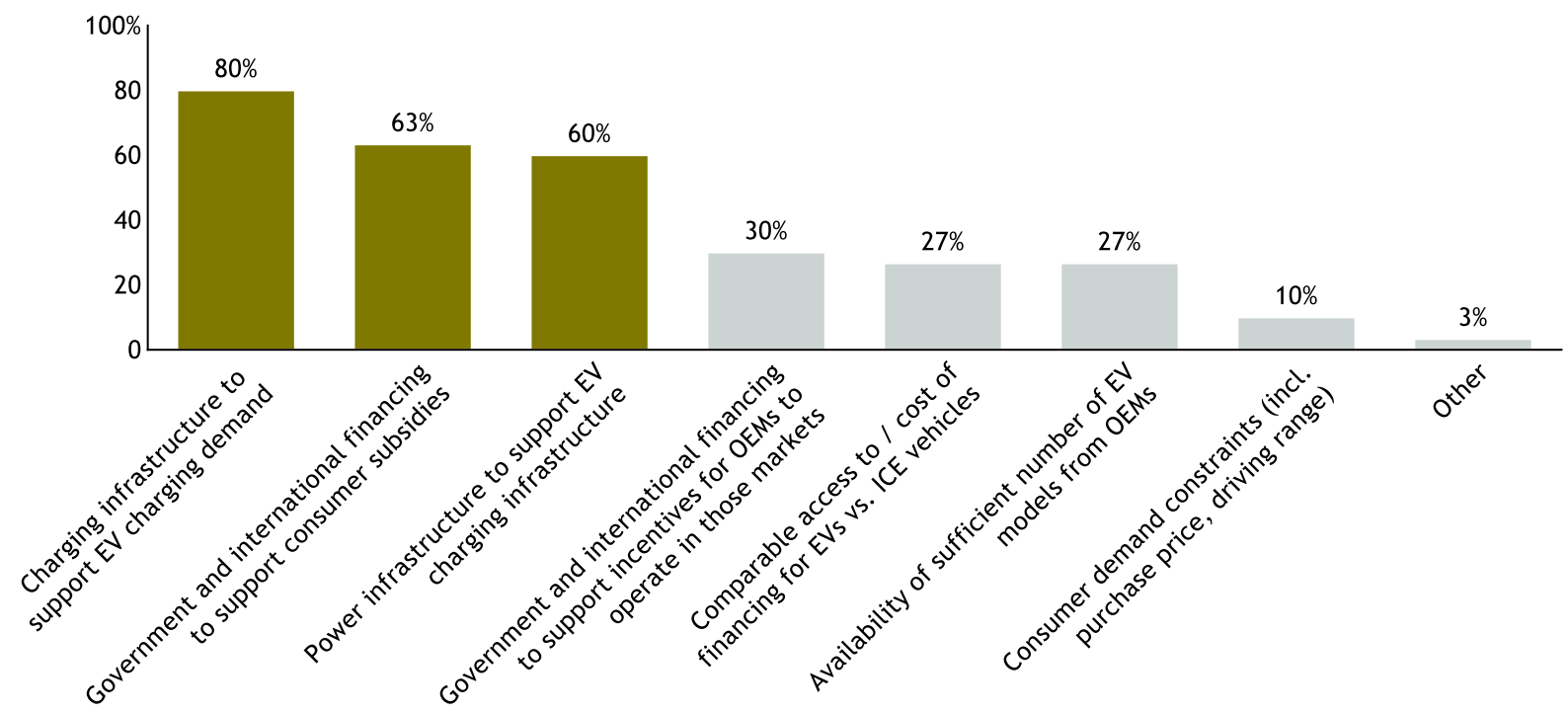
The **Electric Vehicles in Emerging Markets** narrative explores the state of transition in emerging electric vehicle markets and prospects for sustaining the transition to electric vehicles



# Business leaders view infrastructure development and government finance as key factors influencing attractiveness of investment environment for EVs

Global EV demand is growing in many markets, while in others the transition is just beginning. Which of the following are the most important indications that a country is an attractive market for EV investments?

Share of survey respondents selecting barrier as the top indicator (%)



## Commentary

- While there are several variables that could start the flywheel of EV adoption in emerging markets, **business leaders views financing and supporting infrastructure as most important**

*“The economics of the electric charging is still weak for developers in most of countries. Part of the problem is that governments aren’t always aligned with and contributing to this effort.”*  
 CEO Carbon Technologies, Utility company #5

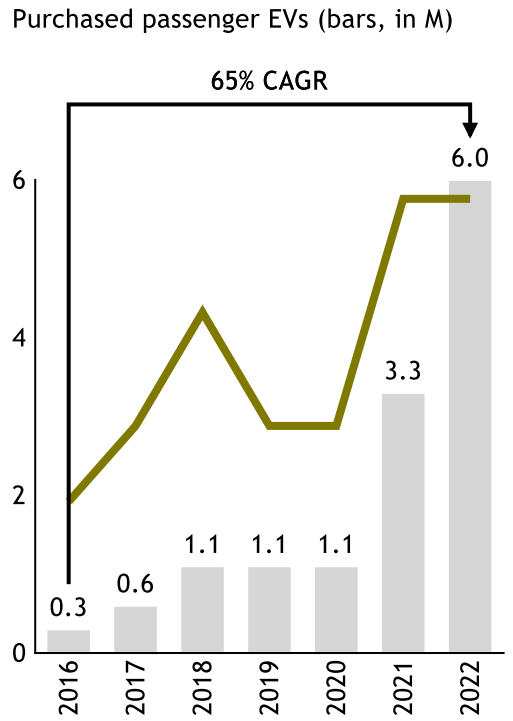
*“The extent to which EVs can reduce emissions is dependent on national governments, and the rate at which they promote fully decarbonizing power systems whilst rapidly scaling up renewable energy power generation.”*  
 Stina Klingvall, Manager of Climate Action, Volvo Cars

Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 30)  
 Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

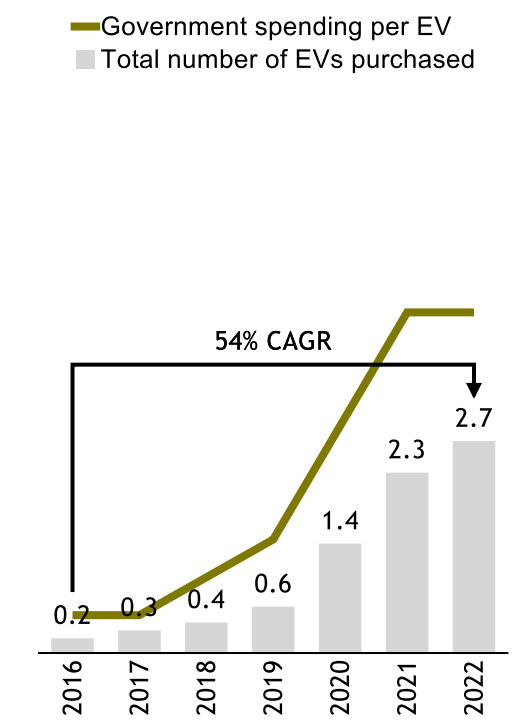
# Government spending is a helpful driver of EV adoption, looking at historical government spending in developed EV economies like China, EU, and US

EV adoption scaled with government spending in China, EU, while in the US EV adoption saw slower but notable recent growth in adoption despite minimal spending

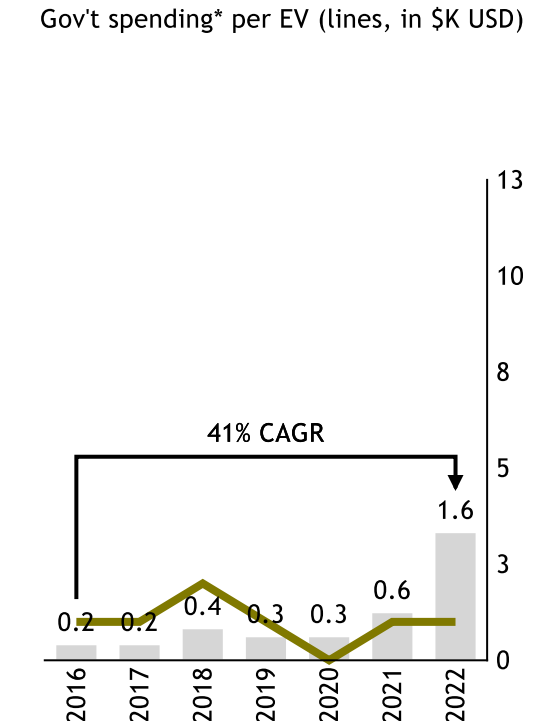
## China



## European Union



## United States



Note: (\*) Government spending includes spending on vehicle subsidies, charging infrastructure, and battery supply chains  
Source: IEA, Electric Vehicles Initiative, Energy Research Institute, Reuters

## Commentary

- China serves as a model for emerging EV economies, demonstrating the impact of government spending on adoption
  - China was estimated to spend more than ~\$15B from 2016-2022
- The US counterpoint shows EV adoption moving more slowly when the government does not support early adoption, though EV sales grew in 2022 showing the beginning of the shift in the US
- Where available financing is limited, governments can focus efforts on specific urban centers before expanding the scope of policies and associated funding

# “China is far along in terms of EV adoption and charging buildout because they have strong coordination between the public and private sectors”

## National policies focus on purchase subsidies

- The New Electric Vehicle (NEV) subsidy program was introduced in 2017 to drive EV sales and paid out over ~\$15B through 2022
- For consumers, ZEV subsidies ranged from 14-18% of a vehicle’s purchase price depending on the vehicle’s driving range, fuel economy, and battery density
- For OEMs, ZEV tax credits were granted based upon share of annual vehicle sales coming from ZEVs vs. ICE vehicles
- The state also set aside funding for its own ZEV procurement commitments

## Sub-national policies further encourage EV adoption through local restrictions and benefits

Initiative	Shanghai	Beijing	Chengdu	Guangzhou	Zhengzhou	Chongqing	Shenzhen	Suzhou	Hangzhou	Dongguan	Xi’an	Wuhan	Tianjin	Changsha	Foshan	Ningbo	Nanjing	Kunming	Jinan	Shijiazhuang
<b>Car plate restrictions and ZEV direct access</b> <i>Restricting ICE vehicles’ access to car registration services while providing expedited servicing for ZEV owners</i>	☑	☑		☑			☑		☑				☑							
<b>Traffic restrictions and ZEV waivers</b> <i>Restricting certain lanes and roads from ICE vehicle use while providing specific space for ZEV owners to drive</i>	☑	☑	☑			☑			☑		☑	☑	☑						☑	☑
<b>Lower cost or free parking</b> <i>Providing subsidized or free parking for a specified period to encourage ZEV vs. ICE use in dense urban spaces</i>				☑	☑	☑	☑	☑			☑	☑					☑	☑	☑	
<b>Subsidies for the use of charging infrastructure</b> <i>Discounts on charging for ZEV users vs. conventional fossil fuels</i>	☑					☑							☑							☑
<b>Direct ZEV purchase subsidies</b> <i>In addition to federal subsidies, cities provide additional subsidies on initial purchase price of ZEVs</i>	☑	☑	☑	☑				☑	☑	☑	☑		☑	☑	☑	☑	☑	☑	☑	☑

Note: Title quote is from Director, Global Sustainability Strategies, Auto manufacturer #3  
Source: IEA; Electric Vehicles Initiative; Energy Research Institute; Reuters; Corporate interviews

# Focusing investments on specific urban centers equipped to adopt EVs has been successful in demonstrating economic viability and expanding flow of financing

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*“Specific geographies, like countries and even **specific cities and urban metros, should be adopting taxonomy and disclosure rules. Banks need to show they are lending into these specific transition areas. The moment you ask them to disclose they do change behavior.**”*

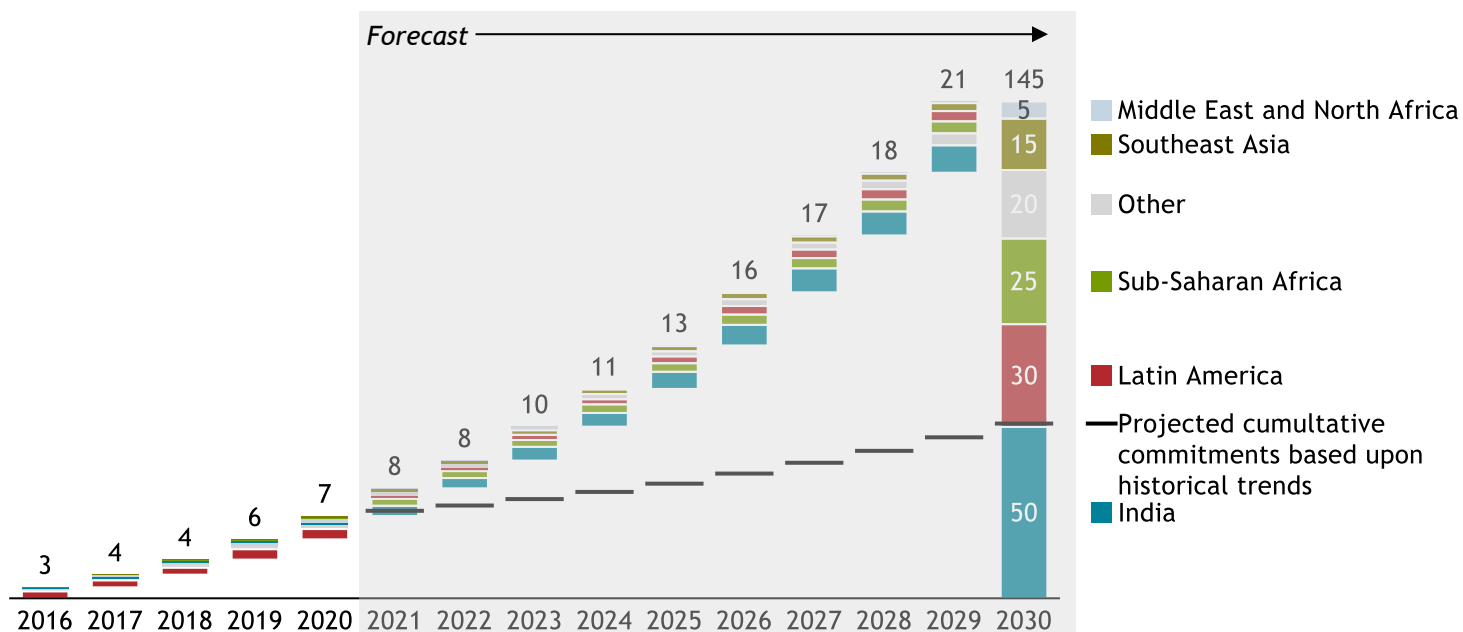
Managing Director, Sustainable Finance Group, Financial services provider #1

Source: Corporate interviews

# “We need financial institutions to play a larger role; if they’re shown a strategy driving money to greener infrastructure investments, it would make a difference”

## Infrastructure investment needs to scale across emerging markets to encourage early adopters to get comfortable with access to EV charging

Total investment required to support EV infrastructure (in 2020 \$B USD)



% private (vs. public)	11%	13%	14%	17%	19%	22%	25%	31%	38%	44%	50%	56%	63%	69%	75%
% equity (vs. debt)	8%	9%	10%	12%	13%	15%	17%	20%	24%	27%	31%	34%	38%	41%	45%
% leasing (vs. purchasing)	10%	11%	12%	13%	14%	15%	17%	18%	20%	22%	24%	26%	27%	29%	31%

## Commentary

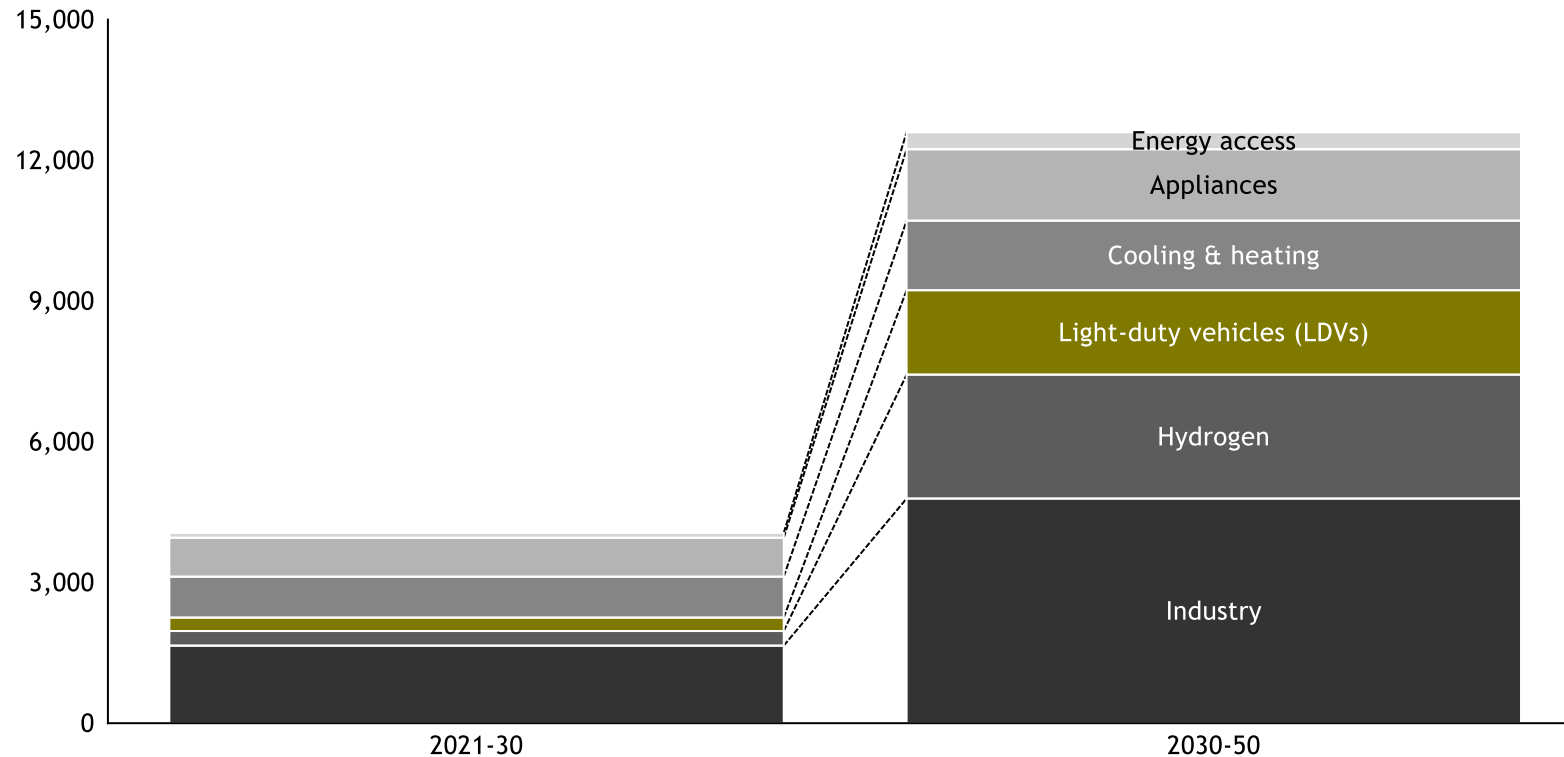
- To start the EV transition in emerging markets, a **critical mass of charging infrastructure** is needed to build confidence with early adopters
- Investment is needed to scale across several key emerging markets, with the **highest investment needs in India, Latin America (esp. Brazil), and Sub-Saharan Africa**
- Despite these notable investment needs, investments and commitments to-date imply a **large gap in the financing needed to begin the EV flywheel**
- To fill that gap, the **types of financing that have historically funded EV infrastructure investments may evolve**, including:
  - More private investments vs. public
  - More equity financing vs. debt
  - More lease agreements vs. purchasing
- **Development finance institutions and innovative “as-a-service” businesses** are expected to help fill and navigate around this financing gap, respectively

Note: Title quote is from Managing Director, Sustainable Finance Group, Financial services provider #1  
 Source: IEA Report on “Financing the Clean Energy Transition in Emerging Markets”, Corporate interviews

# "We need governments to push renewables investments towards road infrastructure; otherwise, we can't shift investments to include charging"

## Emerging markets will shift energy demands towards cooling & heating, hydrogen, and light-duty vehicles (LDVs) by 2050

Share of energy demand by application in emerging markets\*



## Competing power needs necessitate prioritization in EMDEs

- While passenger EVs' share of energy demand is expected to increase by 2050, other applications such as **cooling**, and **industry** will also be competing energy priorities for **EMDEs** and likely take precedence in energy allocation
  - Industry and appliances will demand a higher share of electricity demand in the future as EMDEs continue to develop
  - Cooling is also expected to continue contributing to electricity demand growth due to climate change
- **Charging corridors offer a short-term solution** to begin demonstrating viability of EV charging buildout on a small scale
  - Even if EMDEs are not yet prepared to scale infrastructure to meet market-wide EV adoption, **governments could choose to invest in specific urban centers or heavily traveled routes as proof points** for the viability of the broader buildout

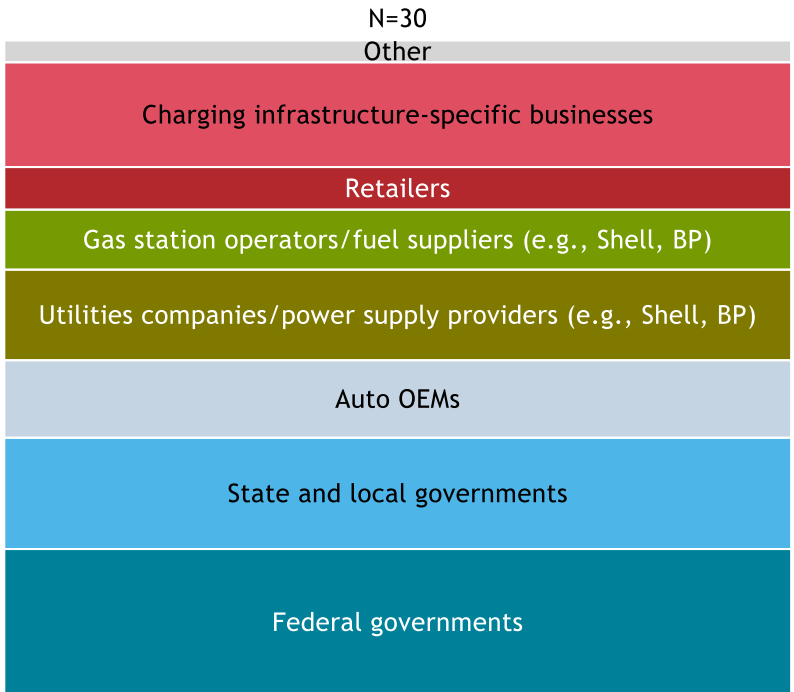
Note: Title quote is from Quality and Climate Change Manager, Road infrastructure provider #1; (\*) Based on Announced Pledges Scenario (APS)  
Source: IEA World Energy Outlook 2022; Corporate interviews



# Road Transport business leaders expect financing for EV charging infrastructure in emerging markets to come from a mix of public and private funding sources

Considering all the costs associated with the charging infrastructure of electric vehicles in emerging markets, what *share of financing will each of the following groups provide toward infrastructure investments?* Please allocate 100 points across the following stakeholders, considering your own organization's anticipated contributions.

Share of financing for EV charging infrastructure in emerging markets by stakeholder (%)



## Commentary

- A mix of public and private efforts will be needed to propel investment in EV charging in emerging markets, but there is evidence of business leaders collaborating to support the buildout
- For example, in markets like India, the **government is helping to facilitate “charging corridors”** where they agree to facilitate charging buildout if private businesses will commit to utilization of chargers along the corridor
  - Government can fast track permitting, prioritize land rights for charging, and provide direct funding or subsidies

Note: Chart includes data from energy consumers, energy providers, infrastructure providers, and financing providers with expertise in the road transport sector (N = 30)  
 Source: Bain / WMBC Global Stocktake Survey (N = 215); Corporate interviews

# In countries with strong renewables, there is evidence of a smoother transition to EVs, but in most emerging markets OEMs cannot yet justify investment

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***“We need policymakers from across the world to work with investors and businesses to accelerate the transition to renewables.”***

Gabrielle Ginér, Head of Environmental Sustainability, BT Group

***“We need investment from governments, support and grants especially, because otherwise we won't be able to assume alone taking on the big challenges we are facing in the next frontier of EV markets.”***

Environment Manager, Auto manufacturer #2

Source: Corporate interviews

# High initial purchase prices and shorter driving ranges relative to ICE vehicles will deter consumers from purchasing EVs

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*"In China, **EVs are very economical**, whereas in many other markets they are more luxury. That's why **they've been able to drive adoption more quickly than in some emerging markets.**"*

Director, Global Sustainability Strategies, Auto manufacturer #3

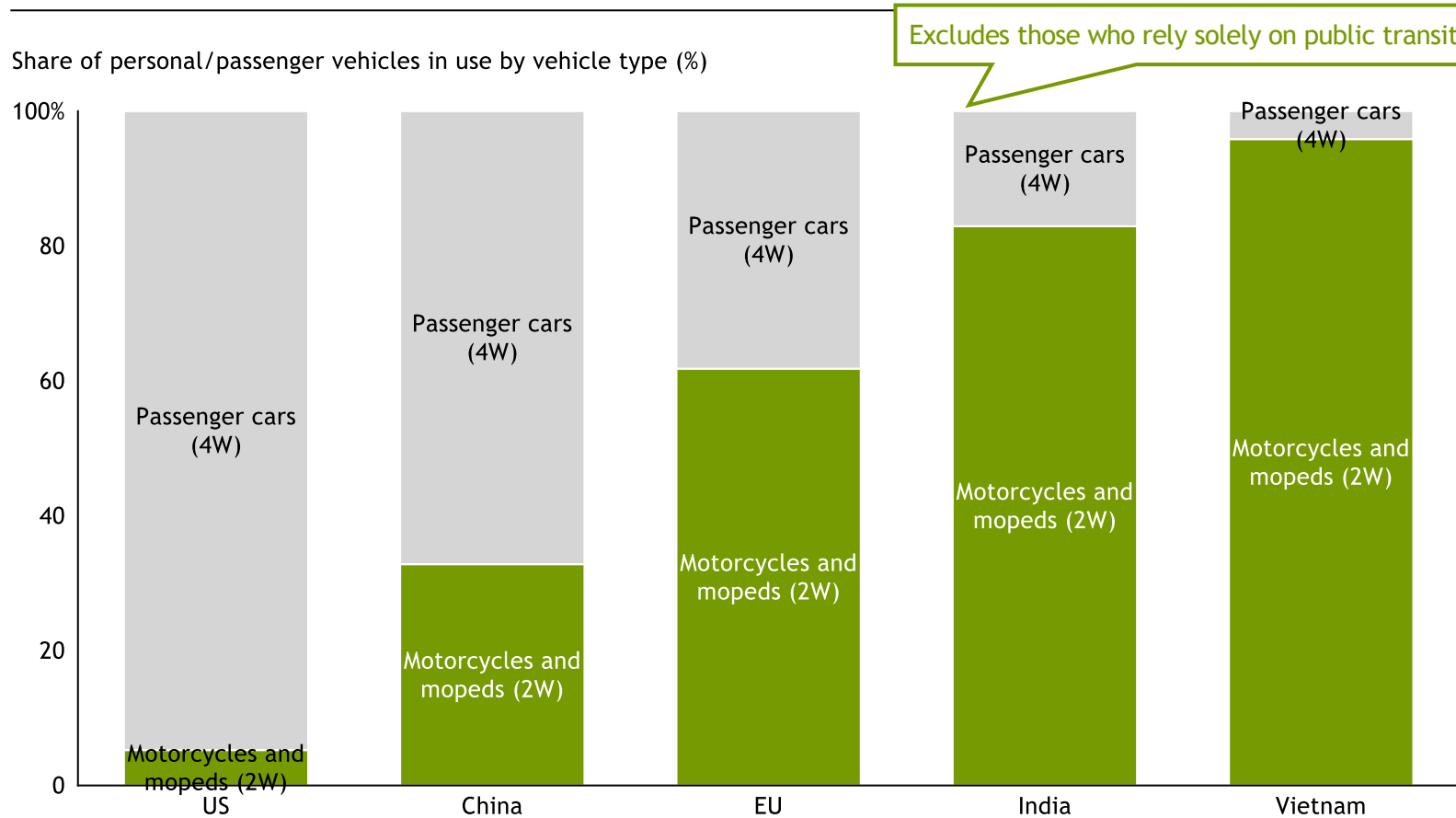
*"**Consumers need to overcome their range anxiety fears. We need to educate them** because the barrier is psychological. This is one role that governments can play to better promote electrification efforts."*

Head of Sustainability, Auto manufacturer #4

Source: Corporate interviews

# Some markets have higher proportions of 2- and 3-wheelers, opening opportunity for faster EV adoption, as they are already at cost parity with ICE

Emerging EV markets see many more 2- and 3-wheeler use compared to developed EV markets like the US and China



## Commentary

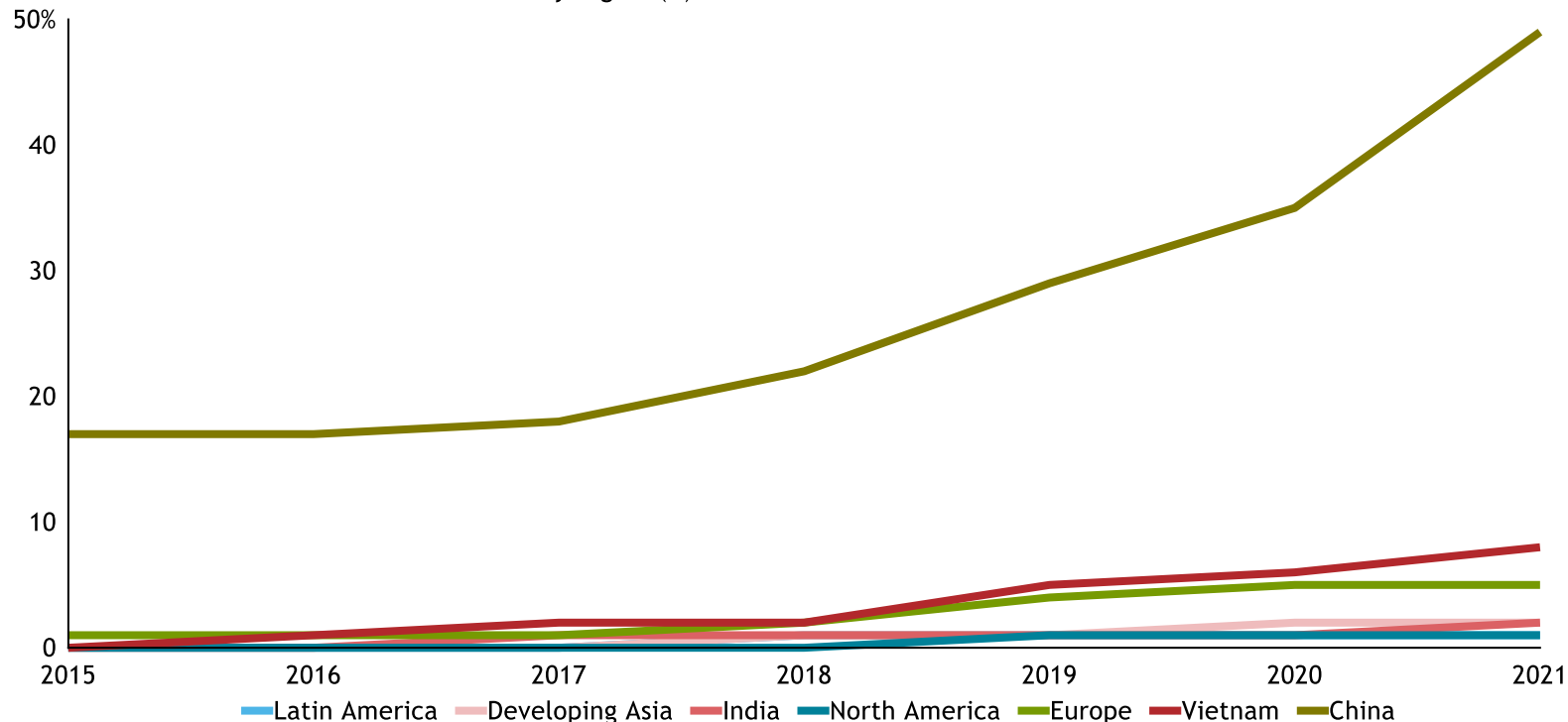
- Since electric 2- and 3-wheelers are already at purchase price parity with ICE vehicles and require much less involved charging (e.g., largely private), markets like India and Vietnam, with >80% 2- and 3-wheelers, can drive much faster adoption of EVs
- By comparison, developed EV markets like the US and China see majority 4-wheeler use, making the transition more challenging to accelerate given higher costs and more complex charging needs

Source: Euromonitor

# EV adoption for 2- and 3-wheelers has gained traction over the past 5 years

China leads the world in EV adoption for two- and three-wheelers at ~50% EVs as of 2021

Electric two- and three-wheeler sales share by region (%)



Source: IEA, Reuters

## Commentary

- In large urban centers in emerging markets, **2- and 3-wheelers are the most common form of personal transportation**
- In many markets, **two- and three-wheeler EVs do not suffer the same consumer demand constraints as 4-wheelers**
  - Many EVs are already at cost parity with ICE vehicles
  - Because they are used within urban centers, **driving range is not a concern**
  - It is **easy for individuals to charge two- and three-wheelers in their homes**
- As a result, **OEMs have invested in building out supply**
  - E.g., One of the world's largest two- or three-wheeler EV production facilities is in India



# “The future will be circular - with materials being reintegrated in new products; we are closing the loop instead of reselling cars into other markets”

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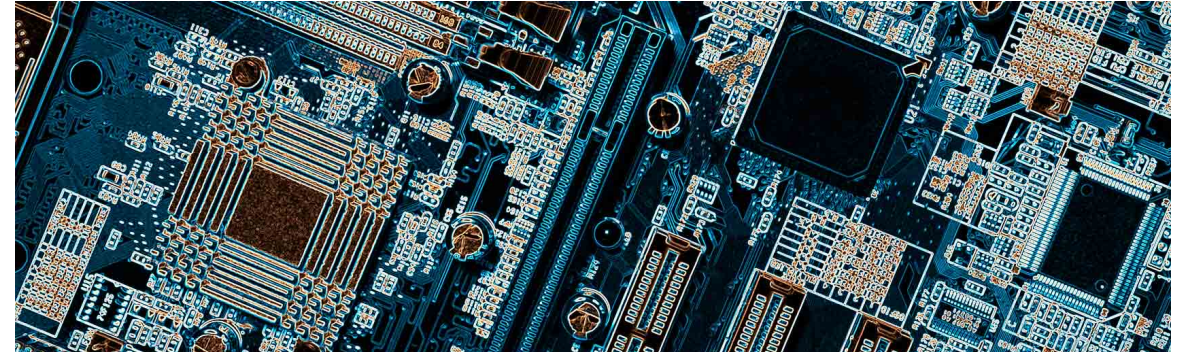
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**Circular economy regulations in EV-exporting economies will limit the ability to export EVs to other markets**

- Even if a company were to consider more exports of used vehicles, **upcoming regulations would disincentivize these exports:**
  - E.g., the EU is implementing battery recirculation requirements, asking battery makers to recover up to **95% of their nickel and cobalt used and 80% of their lithium used by 2031**
  - As a result, OEMs would have every incentive to want vehicles back after their useful life to recover the minerals



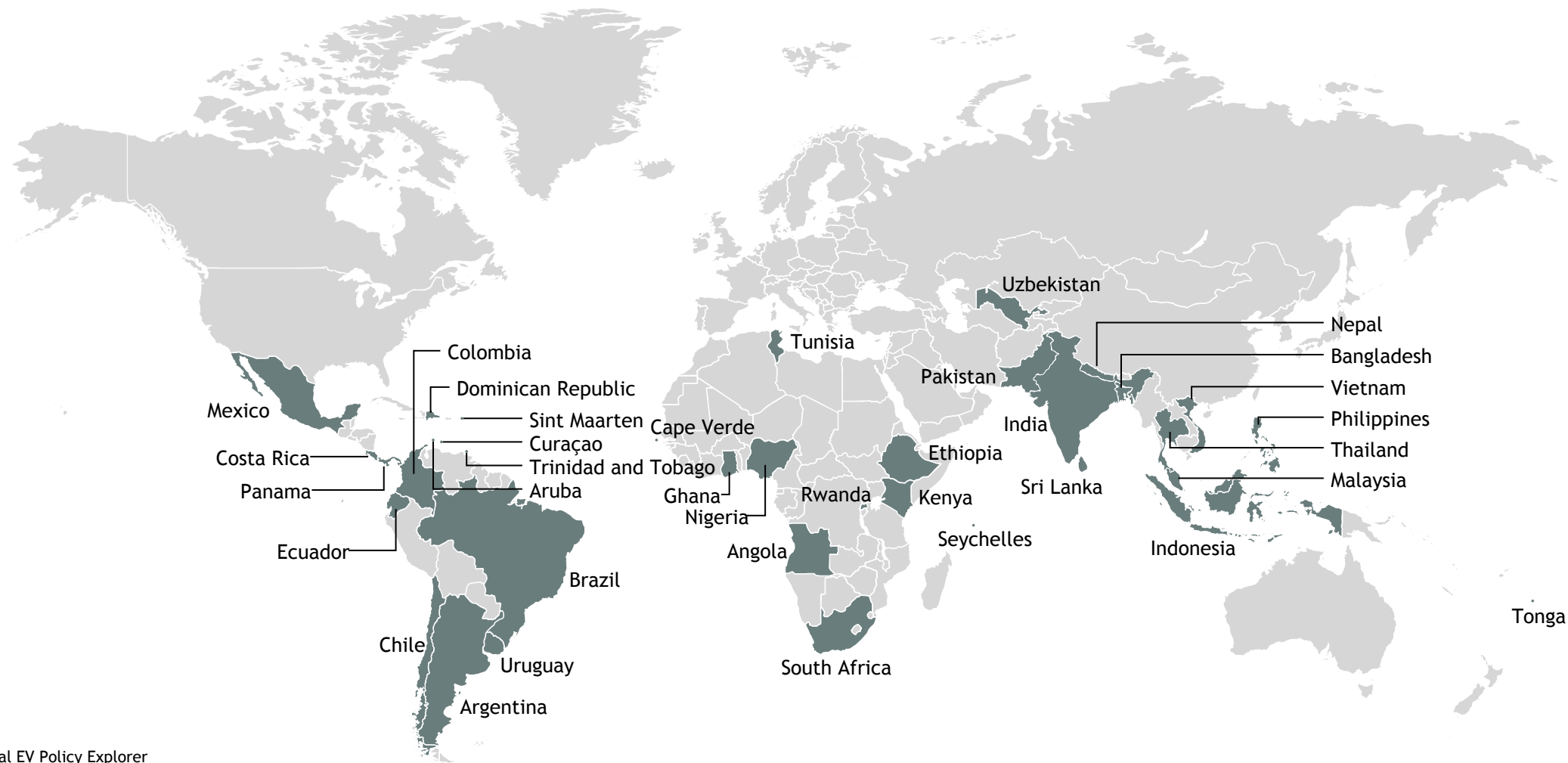
**Uncertain battery conditions will limit residual value of EVs and their viability for resale**

- As early generations EVs begin to reach end-of-life, **uncertain battery condition may limit their residual value for second-hand markets**

Note: Title quote is from Ulf Zillig, VP Group Research, Sustainability & RD Functions, Mercedes-Benz Group  
Source: Lit. search, Corporate interviews



# In many emerging markets across the Global South, governments are stepping in, introducing EV policy to begin the transition



Source: IEA Global EV Policy Explorer

# “Prioritizing charging is a no brainer; countries have space along highways, it is easy to install solar capacity - governments need to ease administrative burdens”

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*India is focusing its EV adoption efforts around improving EV price parity with ICE vehicles and EV charging mandates - both to bolster demand*

- The state government has **imposed taxes that increase ICE vehicle prices** like a 10-25% tax upon inspection or emissions-based taxes at purchase based upon expected GHG emissions
- The state government has **allocated ~\$1.4B to support charging infrastructure buildout**
- **Delhi is funding 18K chargers by 2024 and Maharashtra is funding ~2.4K chargers by 2025**
- The state government has **introduced battery swapping policy and unified battery specs for EVs and plans for ZEV-only zones** along major routes
- The city of Delhi's **2025 plan requires 25% ZEV sales and 100% ZEV gov't fleets** with bans on diesel vehicles >10 y.o. and petrol vehicles >15 y.o.
- The state government provides **purchase subsidies on EVs and subsidies to boost EV manufacturing**, including ~\$6.8B to expand India's battery and ZEV manufacturing footprint



*Thailand is focused on improving the economics of EVs vs. ICE vehicles for consumers and assuaging EV charging concerns with funding for the buildout*

- The state government has **imposed excise taxes and registration fees** based on engine size and emissions
- The state government has **provided R&D to build out swappable battery platforms for electric motorcycles**
- The state government has also provided **grants to develop EV charging** up to 2M baht per station
- The state government has pledged that **all public fleets will be ZEV by 2025**
- The state government has **pledged ~\$1.2B to:**
  - Reduce import and excise taxes for ZEVs and components
  - Provide up to ~\$4K subsidies per ZEV
  - Grant income tax exemptions to charging operators



*Mexico is looking heavily to mandates as a demand signal for consumers and suppliers alike to shift to EVs, supplemented by tax incentives to shift*

- The state government has **imposed excise taxes** on the production, sale, and import of ICE vehicles
- **Mexico City is committing to 50 electric buses** on Line 3 of its transit system
- The state government has said **50% of vehicles sales must be ZEV by 2030**
- Mexico City is **banning diesel vehicles in 2025** and targeting a **100% electrified bus fleet by 2035**
- The state government provides many **tax exemptions for ZEVs and EV charging**, with tax credits up to 30% for public utilities investing in capacity and transmission intended to support EV charging
- **Mexico City to grant ~\$5K to each taxi driver to shift to a ZEV** and provide ZEV discounts on road tolls

Note: Title quote is from Global Sustainability Lead, Utility company #5  
Source: Lit. search, Corporate interviews

# India is investing heavily in policies to lower costs associated with transition to EVs, from two- and three-wheelers to trucks



## Overview

- India is well-positioned to accelerate EV adoption
  - >80% of personal use vehicles in India are two-wheelers, where EVs are already at purchase price parity with ICE vehicles
- However, barriers remain to driving adoption
  - Access to **low-cost financing**
    - > Currently high interest and insurance rates, low loan-to-value ratios, and limited special financing options
  - **Consumer awareness** to adopt EVs
  - **Limited infrastructure** availability

## Targets

- 2030**
  - 30% of all road vehicles in India to be electrified
- 2050**
  - Avoid 3.8 up to GT of CO<sub>2</sub> emissions from Road Transport sector



## Activities

Government is prompting EV adoption at national, state, and city levels



Positioned to lead globe in electric truck adoption



- **National:** Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) India Scheme
  - FAME I (2015) supported ~280K EV/HEV with demand incentives totaling about \$130M
  - FAME II (April 2019) allocated \$1.4B USD to drive large-scale adoption of EVs and charging infrastructure and support a domestic EV ecosystem, which is cumulatively estimated to save 7.4Mt CO<sub>2</sub> over a vehicle's lifetime
  - Goods and Services Tax (GST) on EVs sold with batteries reduced from 12% to 5%
  - Ministry of Road Transport and Highways exempted EVs from permit requirements and recommended states reduce or waive road taxes for EVs
  - Ministry of Housing and Urban Affairs legislated charging stations in private and commercial buildings
  - National Mission on Transformative Mobility and Battery Storage aims to increased domestic battery manufacturing
- **State:** 33 of 36 states have EV policies - 26 states have EV policies that are being implemented, and 7 have policies drafted
- **City:** The Delhi City government is electrifying its fleet of final-mile delivery vehicles
- India has an opportunity to become a market leader in electric truck market
  - The number of trucks on Indian roads is expected to quadruple by 2050
  - ZET adoption can avoid 838 billion liters of diesel consumption cumulatively by 2050, resulting in upward of \$1.5 trillion of reduced oil expenditures
  - Estimated TCO in India for medium-duty ZETs under a mature production scenario is lower than diesel, with TCO parity in the heavy-duty truck segment feasible by 2027



Source: DDC Delhi, RMI, RMI India

# Vietnamese auto makers are leading the charge to expand EV supply in the country, with government support driving demand



Case Study: Vietnam

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Overview	Targets	Activities
<ul style="list-style-type: none"> <li>• Vietnam is well on its way to market-wide EV adoption                             <ul style="list-style-type: none"> <li>- &gt;90% of personal use vehicles in Vietnam are two-wheelers, where EVs are already at purchase price parity with ICE vehicles</li> <li>- Among two-wheelers, Vietnam has seen EV market share grow from 0% in 2015 to 8% in 2021</li> </ul> </li> <li>• However, many barriers to adoption remain                             <ul style="list-style-type: none"> <li>- Government EV policy frameworks are limited                                     <ul style="list-style-type: none"> <li>&gt; Lack of specific incentives for EV uptake (e.g., subsidies, ICE bans)</li> </ul> </li> <li>- Limited charging and supporting power infrastructure                                     <ul style="list-style-type: none"> <li>&gt; Public charging stations could contribute up to a 32% electric overload for some transmission lines</li> </ul> </li> </ul> </li> </ul>	<div style="display: flex; align-items: center;"> <div style="margin-right: 10px;"> <span style="font-size: 2em; color: green;">↓</span> </div> <div> <ul style="list-style-type: none"> <li>• <b>2030</b> <ul style="list-style-type: none"> <li>• 5% electric two-wheelers in Hanoi</li> <li>• All new taxis nationally must be electric</li> </ul> </li> <li>• <b>2040</b> <ul style="list-style-type: none"> <li>• Annual domestic EV manufacturing capacity to reach 3.5M units</li> </ul> </li> <li>• <b>2050</b> <ul style="list-style-type: none"> <li>• Net zero GHG emissions in Road transport sector</li> <li>• All taxis, new and existing, must be electric</li> </ul> </li> </ul> </div> </div>	<ul style="list-style-type: none"> <li>• <b>VinFast is modelling industry leadership with complete EV, charging, and battery transition strategy</b>  </li> <li>• <b>Government policies beginning to provide economic incentives to propel EV adoption</b>  </li> <li>• VinFast Group, the largest EV manufacturer in Vietnam, is leading Vietnam to focus vehicle production around EVs                             <ul style="list-style-type: none"> <li>- Launched two new EV car models in 2021</li> <li>- Built ~20K electric cars and ~1.5K buses in 2022</li> <li>- Installed ~500 EV charging stations and plans to have ~2K charging stations nationwide with over ~40K charging ports by end of 2023</li> <li>- Established Battery Manufacturing Factory with ~\$174M investment                                     <ul style="list-style-type: none"> <li>&gt; Provides lithium batteries for VinFast's electric cars and buses</li> </ul> </li> <li>- Stopped producing vehicles with internal combustion engines (ICE) in 2022</li> </ul> </li> <li>• <b>Government has set several targets to achieve net-zero GHG emissions in the Road Transport sector by 2050</b> <ul style="list-style-type: none"> <li>- New taxis must be electric from 2030, with target for all taxis to be EVs by 2050</li> <li>- Target of 200 electric buses in circulation by 2025 in Nha Tran</li> </ul> </li> <li>• The government also introduced its <b>National Automobile Development Strategy (2021-2050)</b> <ul style="list-style-type: none"> <li>- The strategy aims to increase domestic EV production capacity to 3.5 million vehicles by 2040</li> </ul> </li> <li>• <b>The government also introduced a reduced excise tax for EV cars, buses, and bikes to 2-3% (from current 15% rate) and an exemption on registration fees for EVs</b></li> </ul>

Source: IEA, International Trade Administration, Nikkei, ICCT

Financing, power grid capacity, and consumer interest will drive the speed at which emerging markets reach at-scale EV adoption



### Transition financing

- At the early stage of the EV transition, governments can play a major role in driving adoption; where financing is constrained, focusing **investments on specific urban centers** equipped to adopt EVs has proven to be the most successful approach
- Aside from public actors, there is **mixed support from private financing sources as well, from OEMs to intuitional financing actors**, given a lack of clarity on investment returns in emerging markets

*“The clean energy transformation requires every organization to play a role: from utilities to governments and businesses.”*

Walmart



### Power and charging infrastructure

- Many power grids currently **lack both the generation capacity and transmission capabilities** to support the adoption of EVs, and governments will likely prioritize investments that service buildings and public transit over EVs
- Charging infrastructure is also nascent, with few actors willing to focus on advancing infrastructure installation in many regions

*“Infrastructure is the biggest barrier to adoption in nascent markets. The technology is further ahead, but we are years away from anyone being able to reliably use it.”*

Sonnie Førreisdahl,  
Sustainability  
Manager, ColliCare  
Logistics



### Modifying consumer behavior

- **High initial purchase prices relative to ICE vehicles** will deter consumers from purchasing EVs, especially given availability of low-cost ICE vehicles, though many two- and three-wheelers are already priced similarly to ICE
- Range anxiety is an even greater issue in less developed markets, particularly given limited expectations of a rapid build out of charging infrastructure; variable weather conditions can also be a factor in some regions

*“There is not enough information out there for consumers considering purchasing EVs. They feel there are a lot of unknowns that prevent them from committing to an EV purchase.”*

Quality and Climate  
Change Manager, Road  
infrastructure provider

#1



In emerging EV markets, there is opportunity to leapfrog countries like the US, EU, and China with targeted policies focused on specific vehicles and geographies



Identify urban centers with public transit and short-range driving needs

- Governments can focus on a limited number of urban centers to create successful test cases that can help significantly strengthen the investment case in emerging markets, attracting more private sector investment and opening the flow of financing

- City governments can kickstart the transition through public procurement commitments in urban centers - converting buses, taxis, trains, trucks, and vans (where possible) to electric vehicles and creating clear signals for OEMs to shift their attention to the market and demonstrate viability to consumers in that market

- Alongside government and public transit commitments, cities can implement long-term, gradual bans on 2- and 3-wheeler ICE vehicles; government funding is best prioritized on supporting 2- and 3-wheeler charging purchases and installations to focus the shift on the vehicles that the city's residents drive most



Facilitate charging corridors between urban centers

- Even if sustainable within a city, government procurement commitments, ICE bans, and financial support for personal charging will not enable inter-city travel with EVs, so governments need to help facilitate EV travel between populated areas

- Governments can stimulate or de-risk investments in charging infrastructure buildout along specific identified routes between major cities to create a “charging corridor” and begin to demonstrate viability of inter-city travel with EVs by ensuring individuals will have access to the charging they need



Encourage cross-border financing and policy support

- In the second wave of global EV adoption, where emerging markets will come more into focus, much greater attention to international energy policy and how to best enable renewable capacity to underpin the power and charging infrastructure for EVs is critical, namely international financing support from development banks and similar institutions

- Alongside financing for energy investments, facilitating access to low cost EVs is critical, namely through support of FDI programs to enable countries with stake in growing electric vehicle and EV battery value chains



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