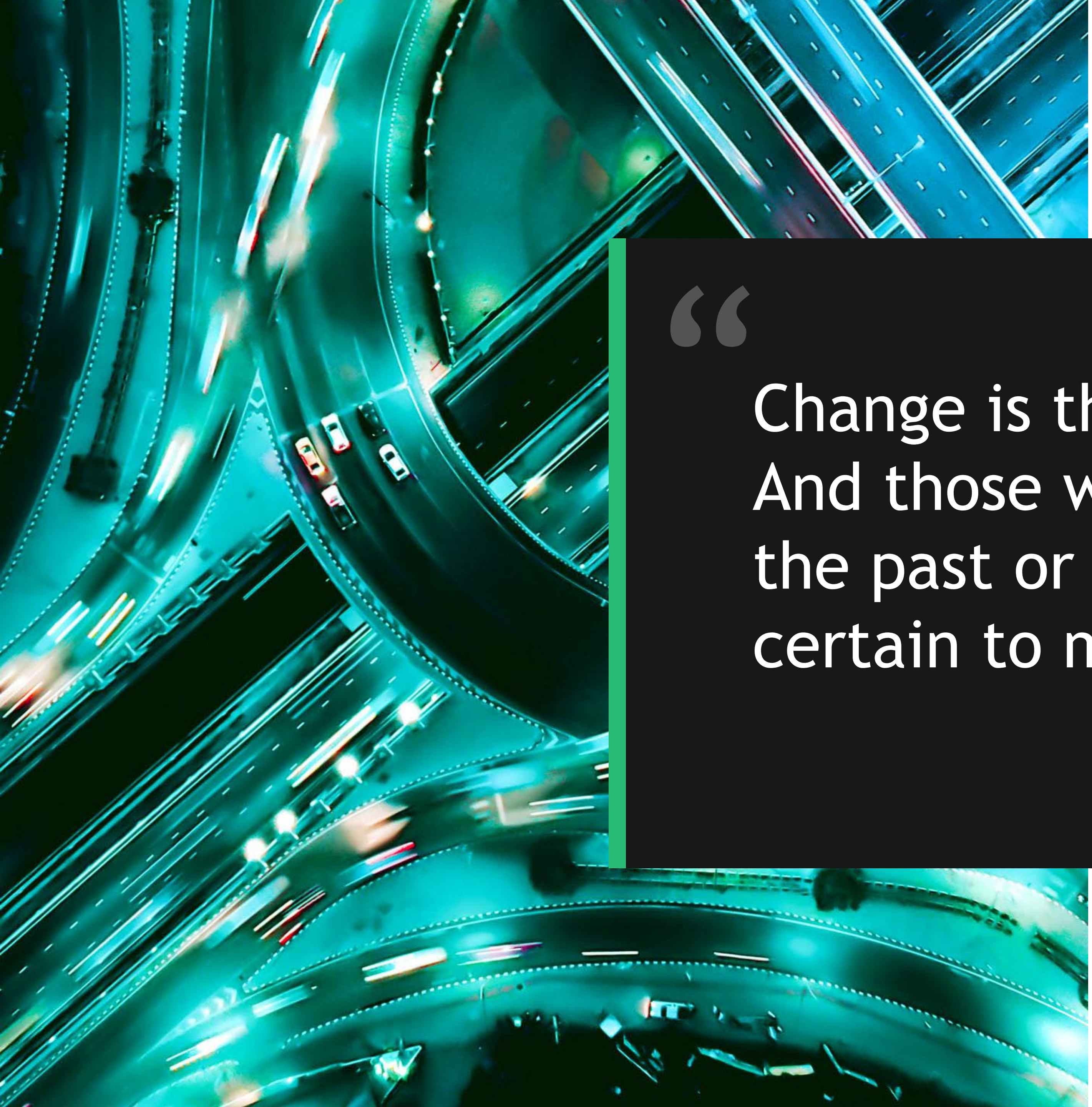
BOSTON CONSULTING GROUP

Moving the World Forward

THE FUTURE OF THE AUTO & MOBILITY INDUSTRY

Brian Collie
Managing Director and Senior Partner
Global Automotive and Mobility Leader

DECEMBER 2021



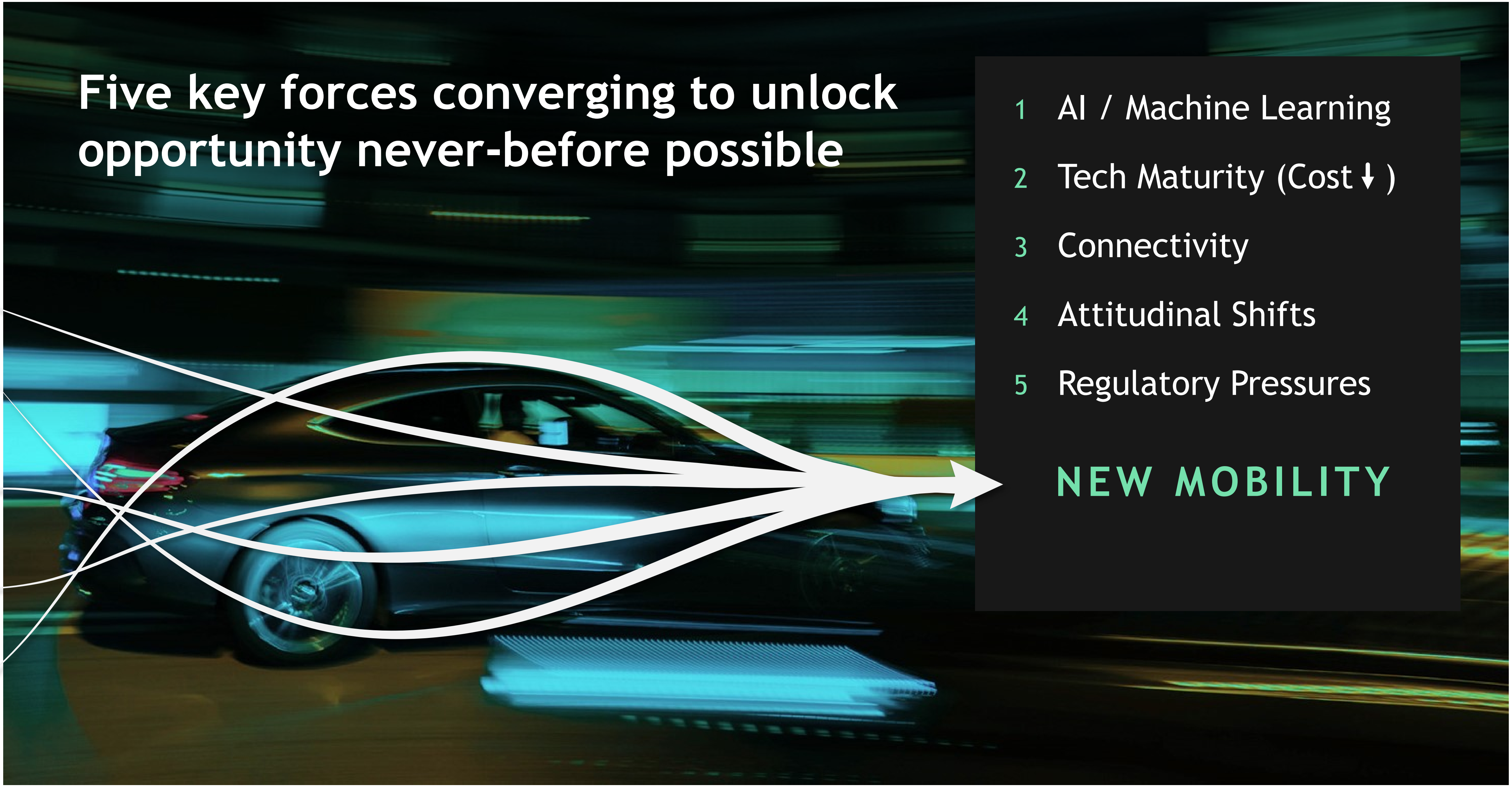
> Change is the law of life. And those who look only to the past or present are certain to miss the future

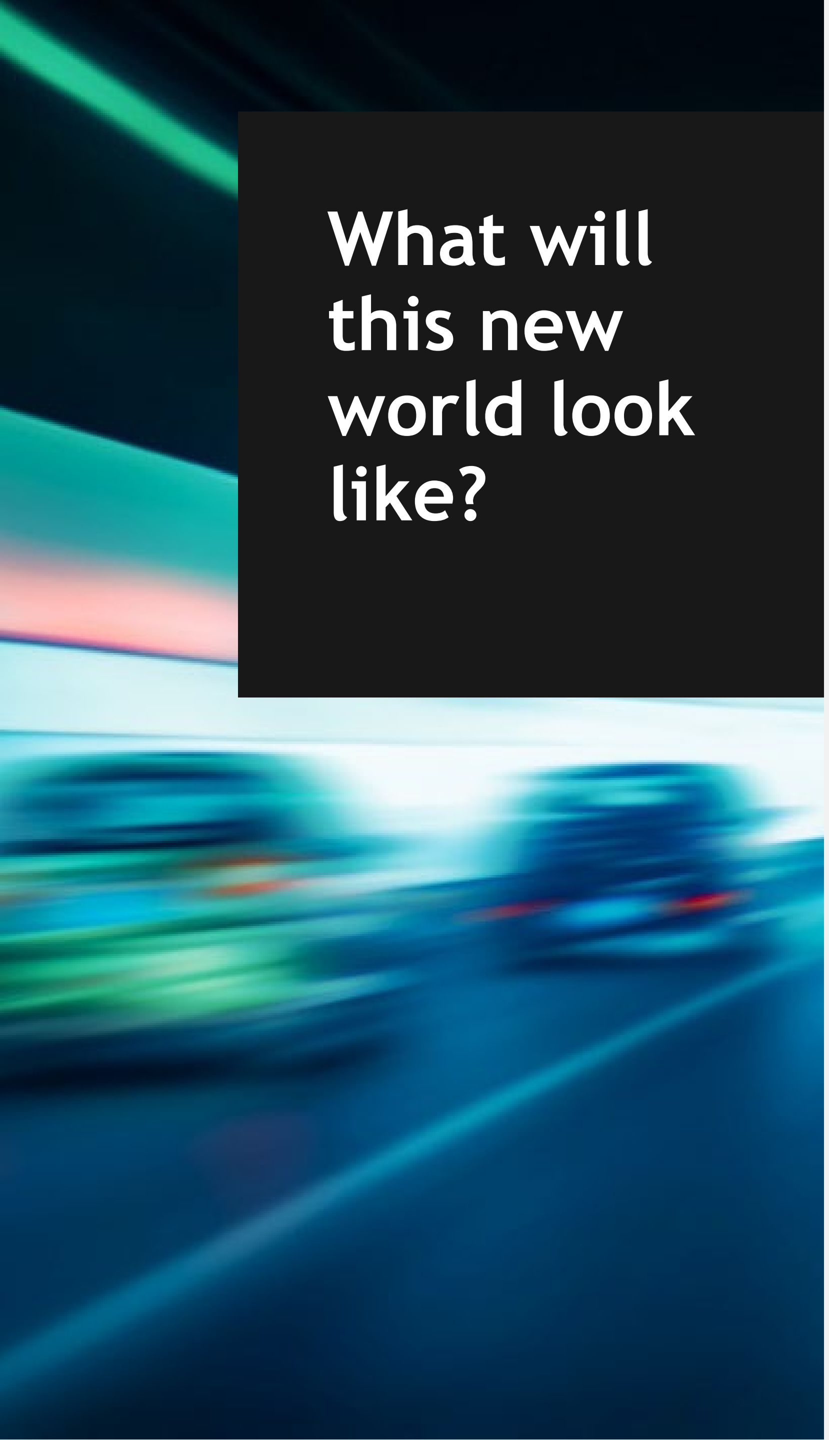
John F. Kennedy

We have no choice but to get this right

+1H	$88B	70%	1.3M deaths	6 Gt
Daily commute time in Chicago's low- vs. high-income areas … limiting access to jobs & contributing to economic inequality	2019 congestion cost in the U.S. +42% extra daily travel time in Chongqing, China	Population that will live in urban areas by 2050, with more than 40 mega-cities globally	Road traffic deaths every year, 7th leading cause of death in lower-income countries	CO2 emitted from light duty vehicles on road per year, representing 12% of total global emissions

Source: INRIX 2019 & 2020 Global Traffic Scorecard; TomTom Traffic Index 2020; European Environment Agency (EEA); IEA; WHO; World Bank; BCG Inclusivity Quotient Project


Five key forces converging to unlock opportunity never-before possible
1 AI / Machine Learning
2 Tech Maturity (Cost ↓)
3 Connectivity
4 Attitudinal Shifts
5 Regulatory Pressures
NEW MOBILITY



What will this new world look like?

Gas guzzlers to electrified vehicles →	More than 70% of new vehicles full hybrid or cleaner by 2035, 95%+ if including mild hybrid
Hardware to software →	100% connected by 2030; OTA updates the norm; new biz models emerge
Product to service →	Lifetime revenues from subscriptions, upselling, and ecosystem services up to $10k per car
Single-use to circular →	Net-zero production, recycled content quotas, modular & upgradeable components
Active safety from luxury to common good →	~50% of new vehicles in 2030 to be L2 /L2+
Privately owned to sharing →	Sharing to account for ~30% VMT in major MSAs (due in large part to L4); seamless intermodal mobility providing greater mobility access and reliability

Deeper dive on following pages

By 2025, EV will be advantaged on total cost of ownership (TCO) relative to traditional ICE in most key markets

Regulations tightening further in many markets

Concrete steps toward net-zero; ICE bans starting as early as 2025

+

Battery costs declining faster than anticipated

Purchase cost parity vs ICE; Less than $75 / kWh pack price by 2030

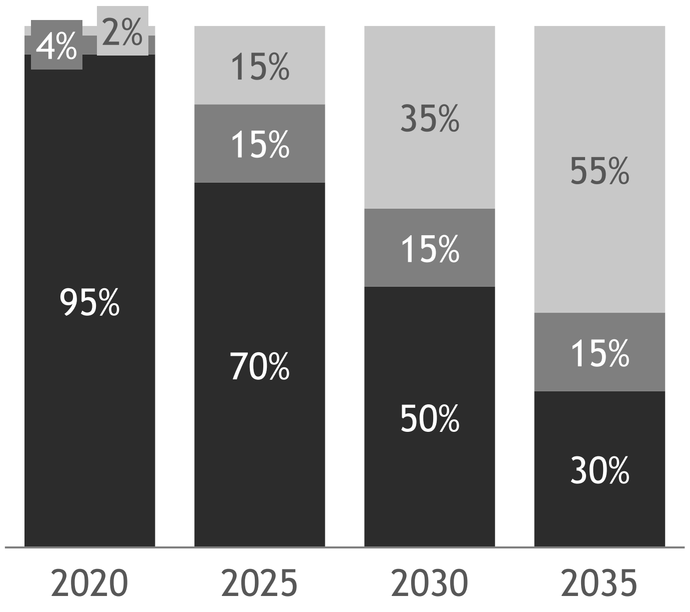
+

OEM competition intensifying though broader offerings

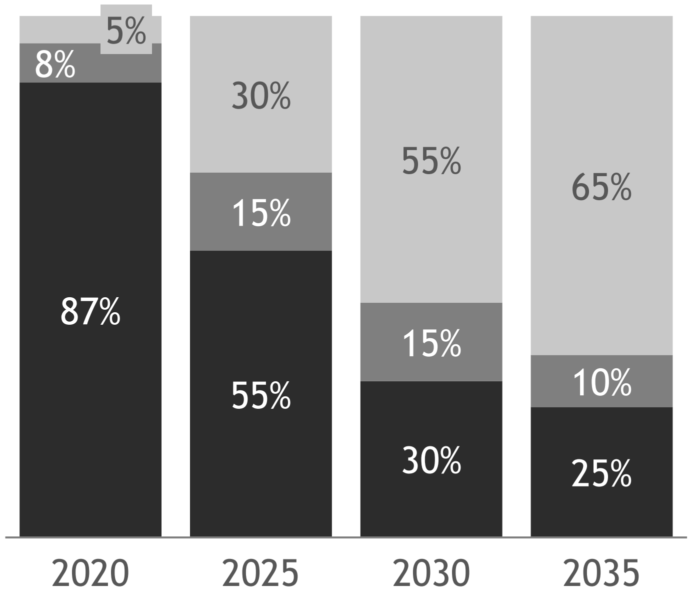
400 models by 2025; Availability across all vehicle segments

Nearly 70% of new vehicles sold will be full hybrid or cleaner by 2035

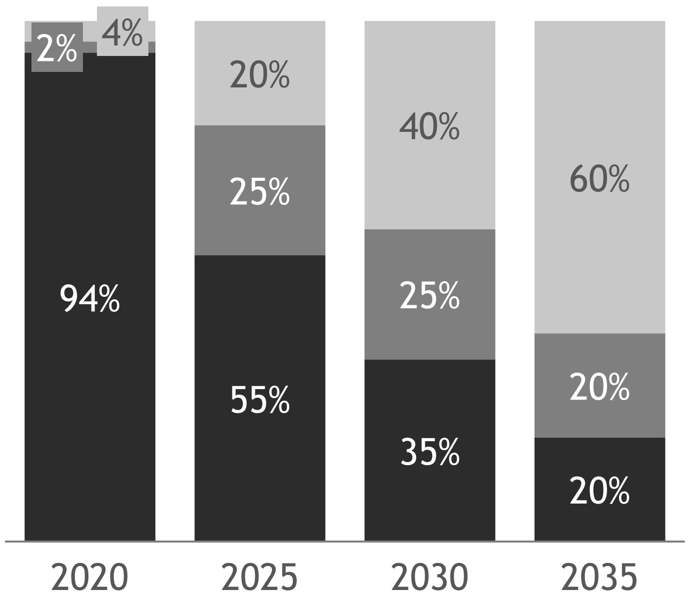
US volume projections



EU volume projections



China volume projections



Zero emission Full hybrid Gas/Diesel

Note: Forecast includes all light vehicles, except HVAN. 'Zero-emission' is BEV + FCEV, 'Full hybrid' is PHEV + HEV, 'Gas/Diesel' includes MHEV
Source: BCG analysis

Dozens of new players will emerge, but most new EV players will face significant hurdles carving out meaningful positions

EXAMPLE: U.S. PICKUP TRUCKS

Slow growth, mature market w/ 90% sales concentrated among 5 brands, each of which is taking steps to electrify and evolve business models

Ford Motor Co.	RAM Trucks	Toyota Motor Corp.	Chevrolet	GMC

Hercules Electric Mobility

Bollinger Motors

Canoo

Atlis Motor Vehicles

Lordstown Motors

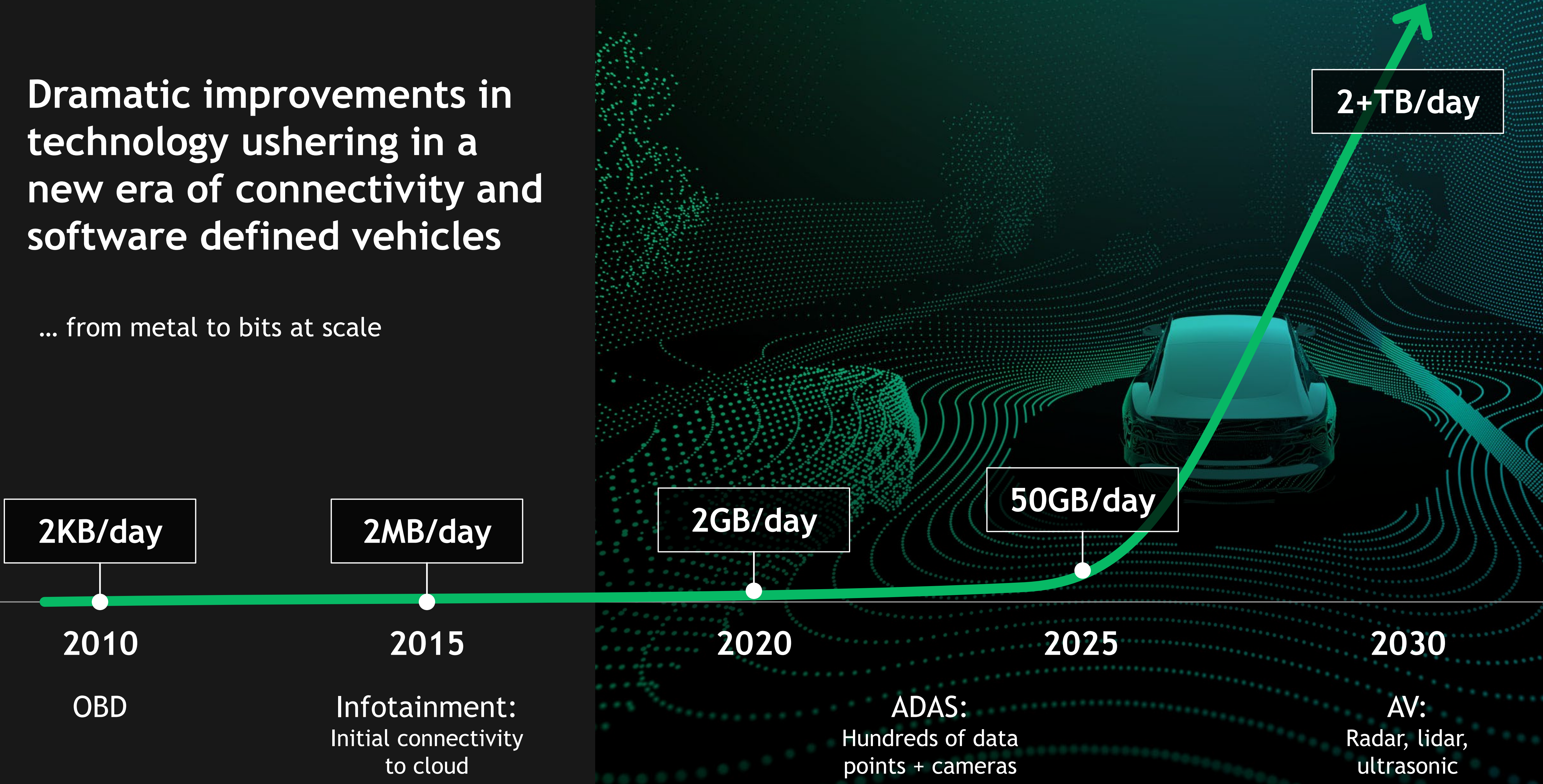
Rivian

Tesla, Inc.

Success requires more than just the product; landscape littered with failed entrants

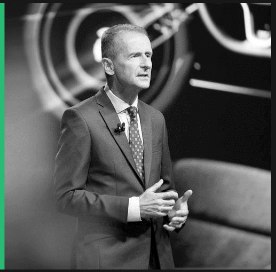
Dramatic improvements in technology ushering in a new era of connectivity and software defined vehicles

… from metal to bits at scale



Note: Only small share of (post-processed) data leaves the vehicle
Source: BCG analysis

A software-defined car completely reshapes where value is realized



“ If we want to remain independent, we have to develop car software ourselves

Herbert Diess, VW

“ The critical role of software […] cannot be overstated

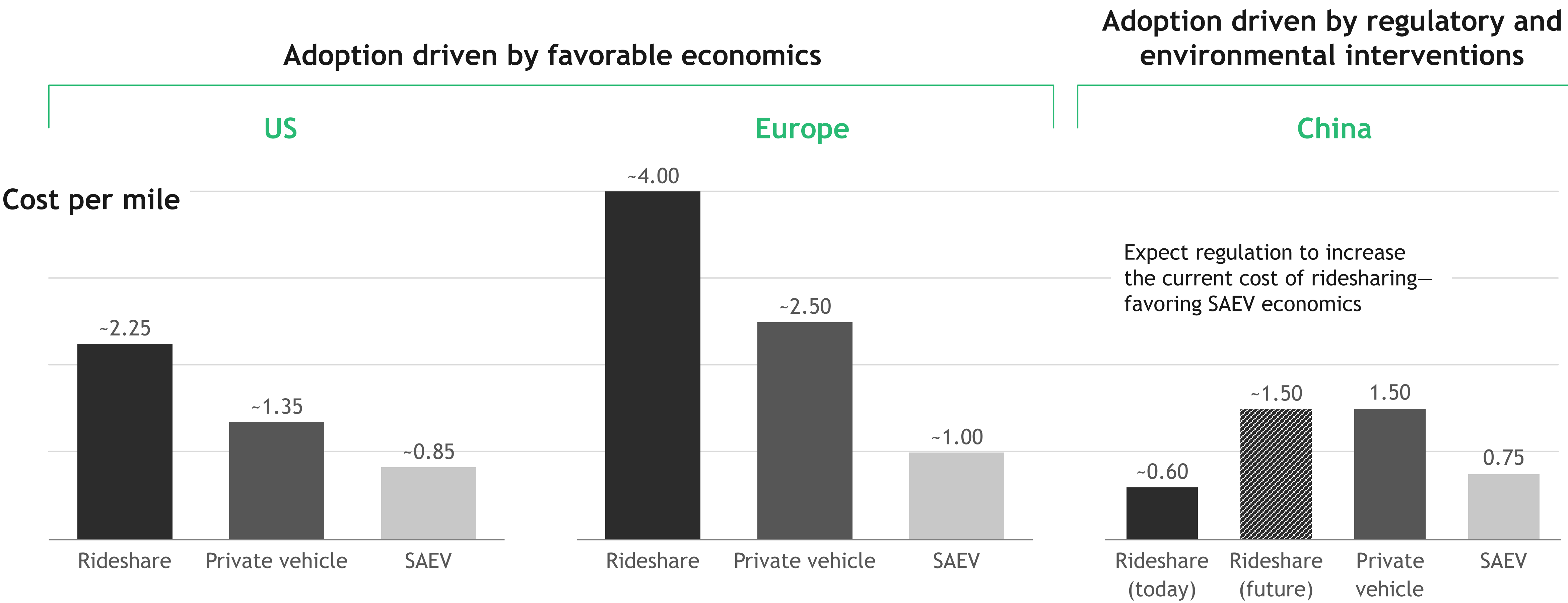
Mark Reuss, GM

… by 2030

90%	of future differentiating car features to be software-based
$26B	annual software R&D spend by suppliers and vehicle manufacturers
$500-1,000	per car BoM reduction opportunity from standards/ commoditization/ re-use
$150B	annual car software market size with competition between OEMs & suppliers
$1B+	potential annual revenue for major OEMs through software-based services

Source: BCG analysis, Expert interviews, Bank of America, CapitalIQ

While euphoria has somewhat waned, compelling SAEV unit economics will spur longer-term adoption



Source: BCG analysis

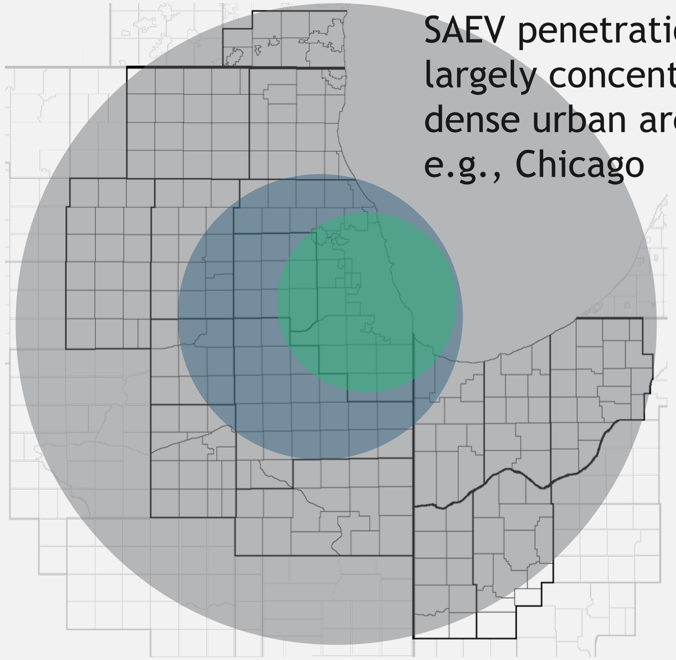
SAEVs to account for over 30% of passenger miles by 2035 in large metro areas

3 elements needed:

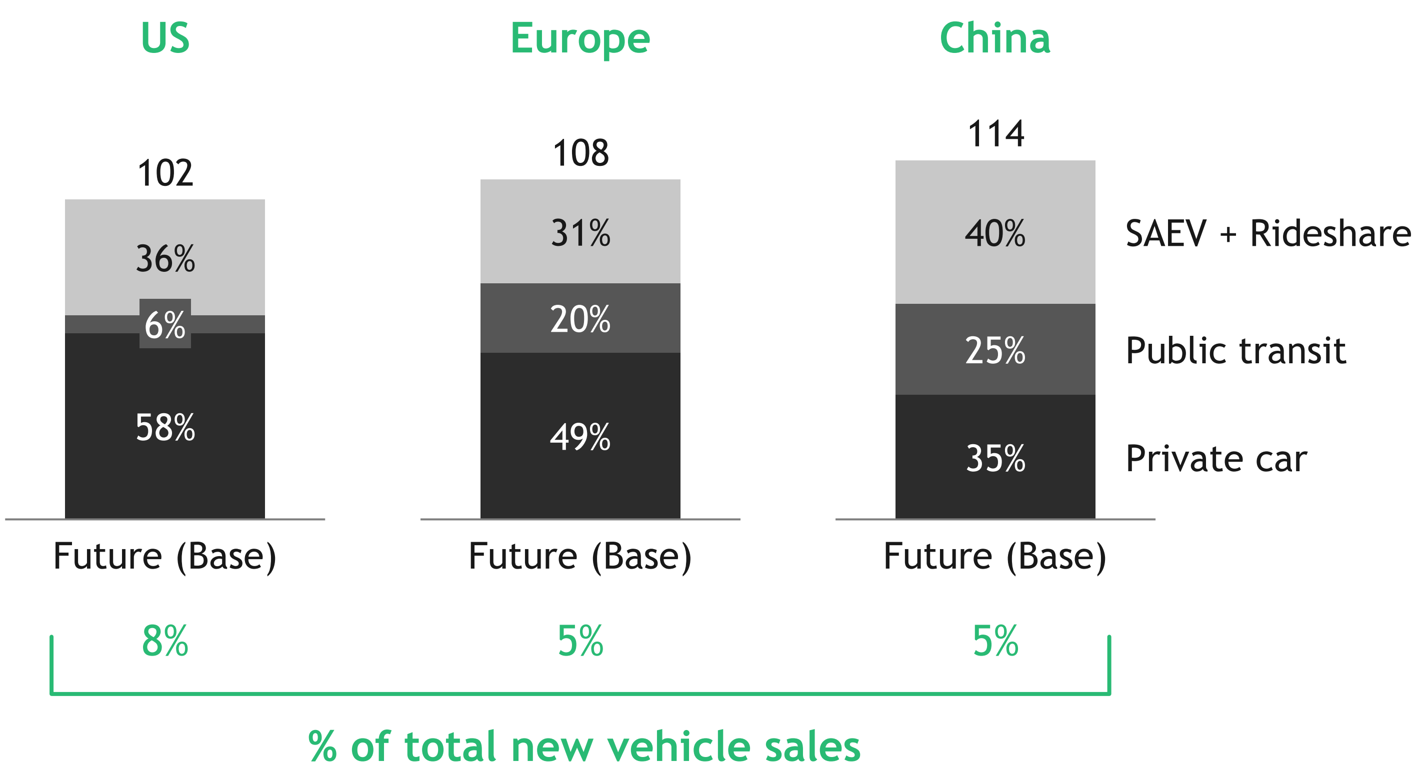
Demand density

Low complexity environments (ODD)

Major mobility pain points

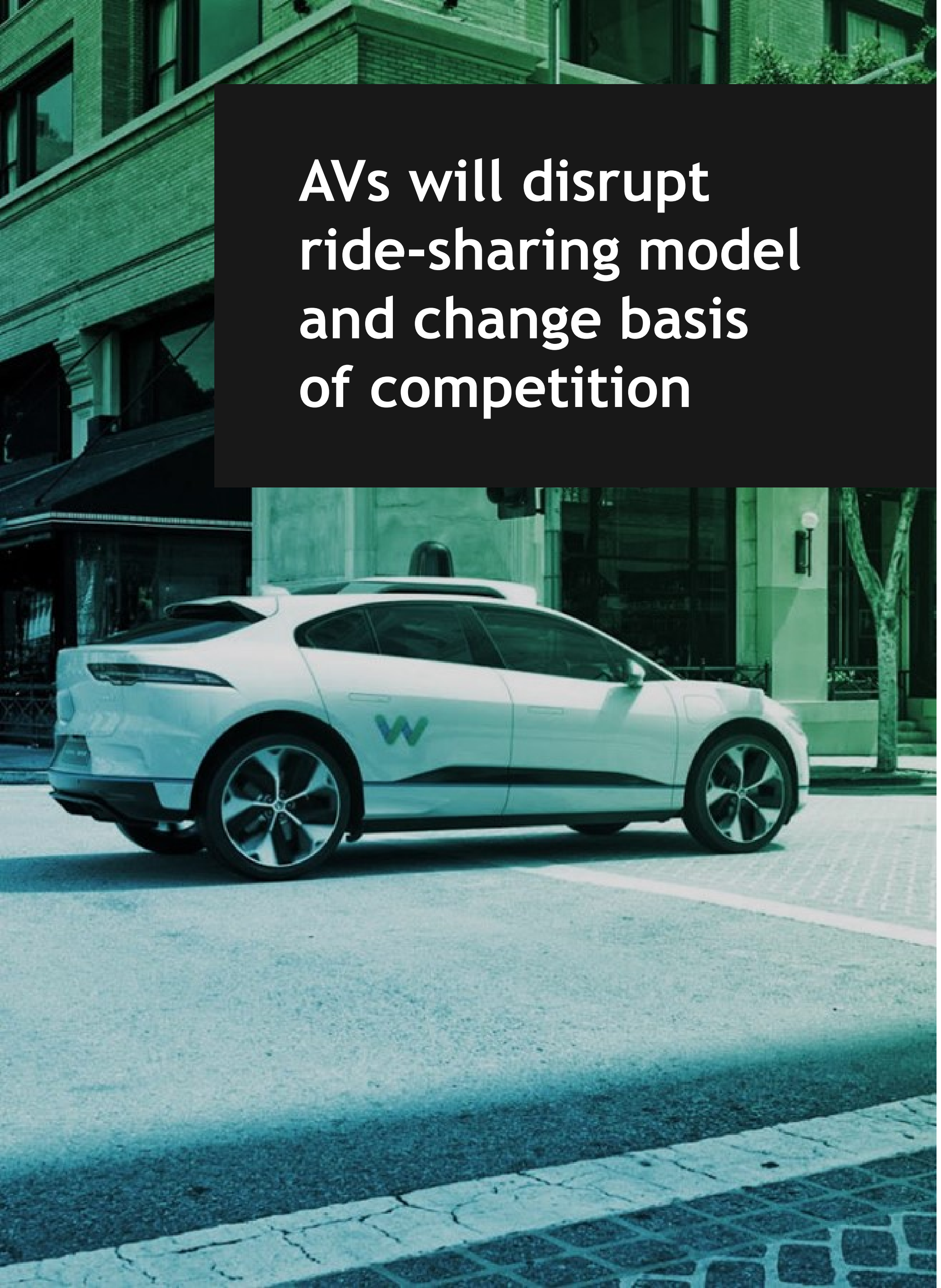


Passenger mile index' in largest metro areas



1. Indexed to current annual passenger miles in each region
Note: Passenger miles calculated on the basis of modal breakdowns, average trip distances, and number of trips (weighted by metro area population)
Source: BCG analysis

AVs will disrupt ride-sharing model and change basis of competition



Today, ride-sharing players capture value by controlling a key choke point

Ride-sharing firms operate a two-sided marketplace connecting drivers & riders and take advantage of arbitrage between buyer and seller "willingness to pay".

In the future, AVs will change the nature of the competitive game

In urban areas, shared AV fleets will emerge as a major form of transportation. Traditional ride-sharing capabilities will become less relevant as drivers are no longer needed and fleets are owned.

Future basis of competition is uncertain, winners depend on how industry evolves

Advantaged players will be determined by where chokepoint emerges – AV mobility marketplace, AV tech stack or AV fleet operations – and who controls it. Jockeying for positions already well underway.

Source: BCG analysis, 2021.

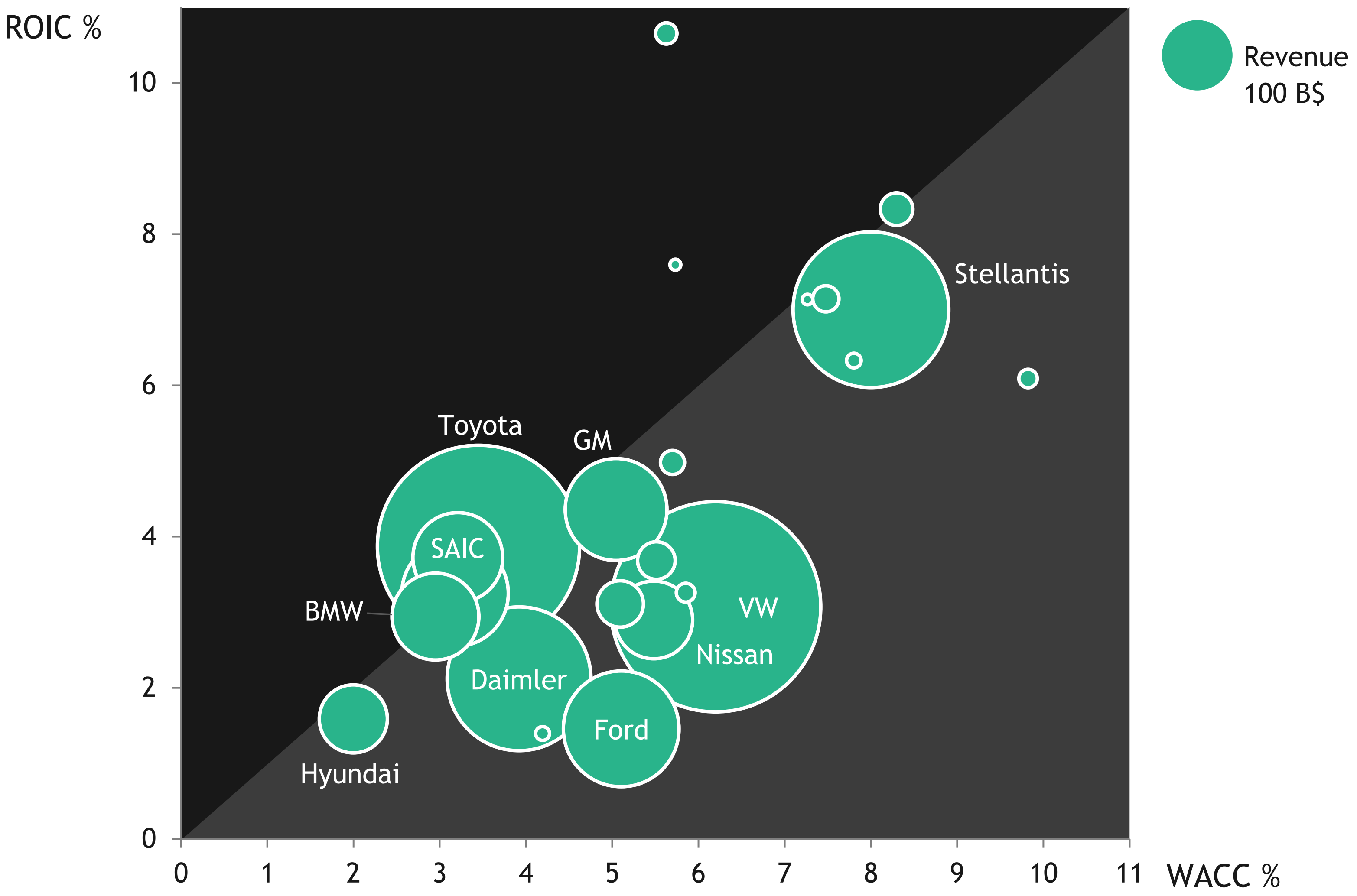
But radical industry disruption is never easy - five key challenges our industry most navigate in years ahead

Capital intensive Business models	Increasingly complex supply chains	Insufficient infrastructure	Ill-Equipped regulatory frameworks	Mis-aligned public / private incentives

Source: BCG analysis

Traditional auto players have long-relied on capital intensive business models which have historically destroyed capital

2016-2019 Average Return on Invested Capital (ROIC) and Weighted Average Cost of Capital (WACC)



Source: OEM Financials from publicly available information, Capital IQ, BCG Analysis

As we move forward, OEMs must break free from these constraints and industry dogmas, fundamentally changing how cars are…

…Designed

Reducing need for scale, unbundling HW from SW, shifting from metal to bits at scale, reducing time-to-market, leveraging recycled content

…Built

Decoupling product from production, unlocking operational efficiencies, reducing need for scale, achieving net-zero emissions

…Sold

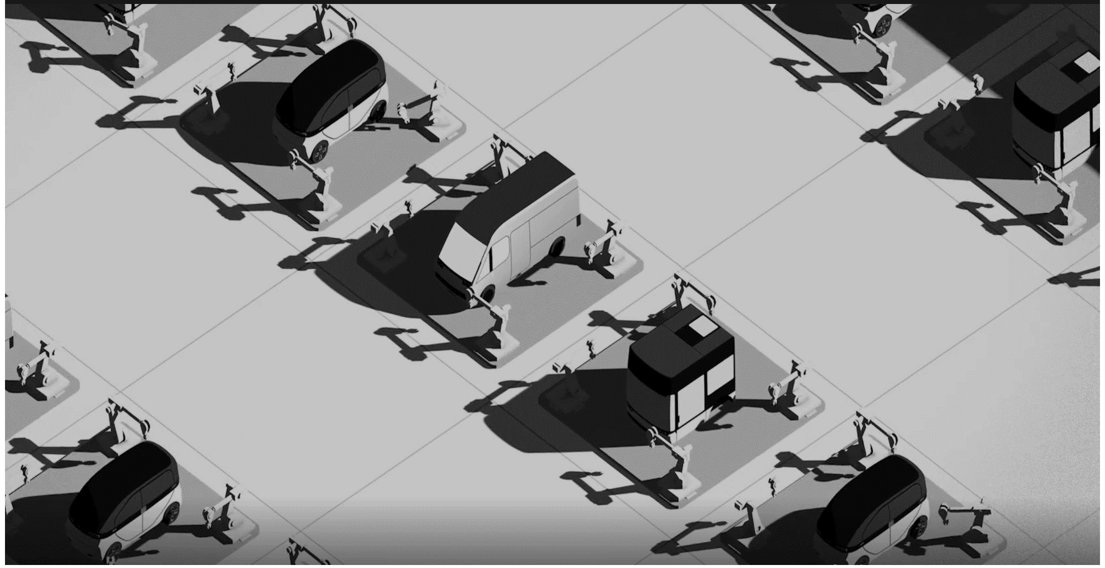
Introducing innovative sales models, abandoning traditional dealerships in favor of fully-online / city-center owned stores

…Used

Introducing vehicles designed for a specific purpose, integrated in multiple ecosystems

New flexible cell layout:

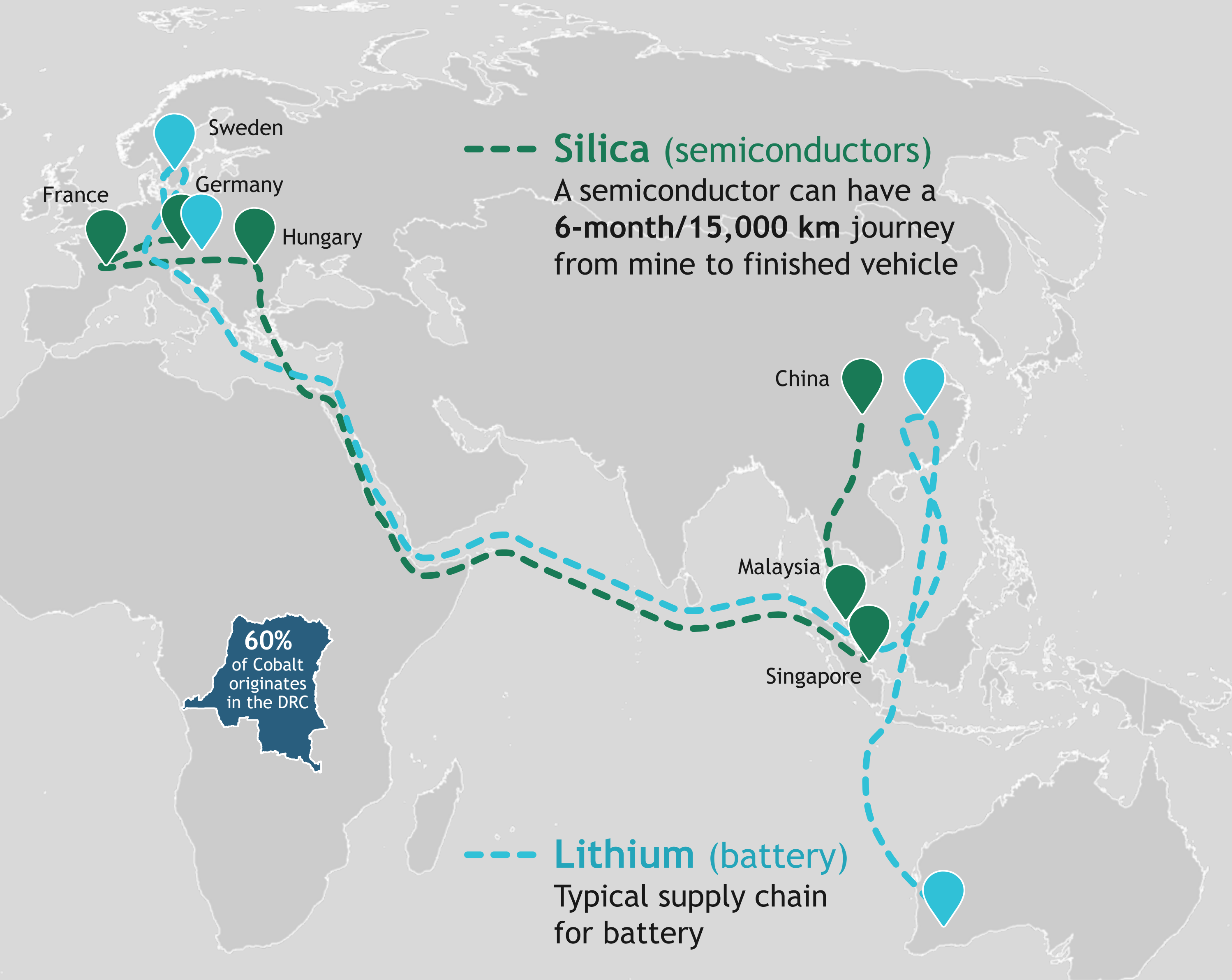
Fully automated assembly of different vehicles



KEY BENEFITS

- Eliminated stamping and painting shops
- Operational in 6 months, w. lower CapEx / smaller footprint
- Decentralized production, w. limited floorspace required
- Reduced break-even point, enabling low volume production

Supply chains are increasingly long and complex, necessitating that the industry finally place value on resiliency



More (trade) roads leading through China

$75B	in vehicle and part exports (from $16B in '05)
70%	of world's battery manufacturing capacity
>50%	of world's supply of rare earth metals

Source: OEC, BCG analysis

Regulators have yet to establish clarity on a critical dimensions required for full potential of new mobility to be realized – e.g., Autonomous Vehicles

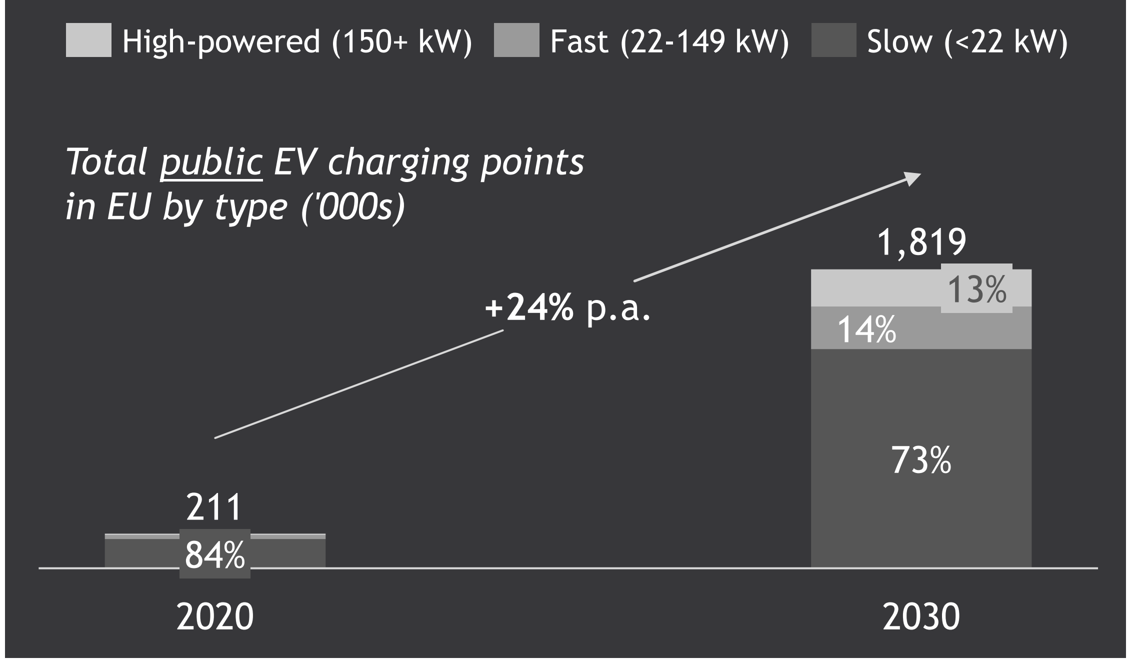
Open topics for regulators

- **Data**: Who ultimately owns data collected by AVs, and who is allowed to analyze and commercialize it?
- **Operation**: How does the law need to be adjusted to allow Level 4 AV operation? (e.g., steering wheel requirement, driver responsibilities)
- **Safety**: How are the large array of AV players kept in line with safety standards? What's the "driver's license" equivalent?
- **Ethics**: Can a system consider ethical implications of potential actions—especially in an emergency? What is "good enough"?
- **Liability**: Who bears responsibility in an accident with a Level 4 vehicle?

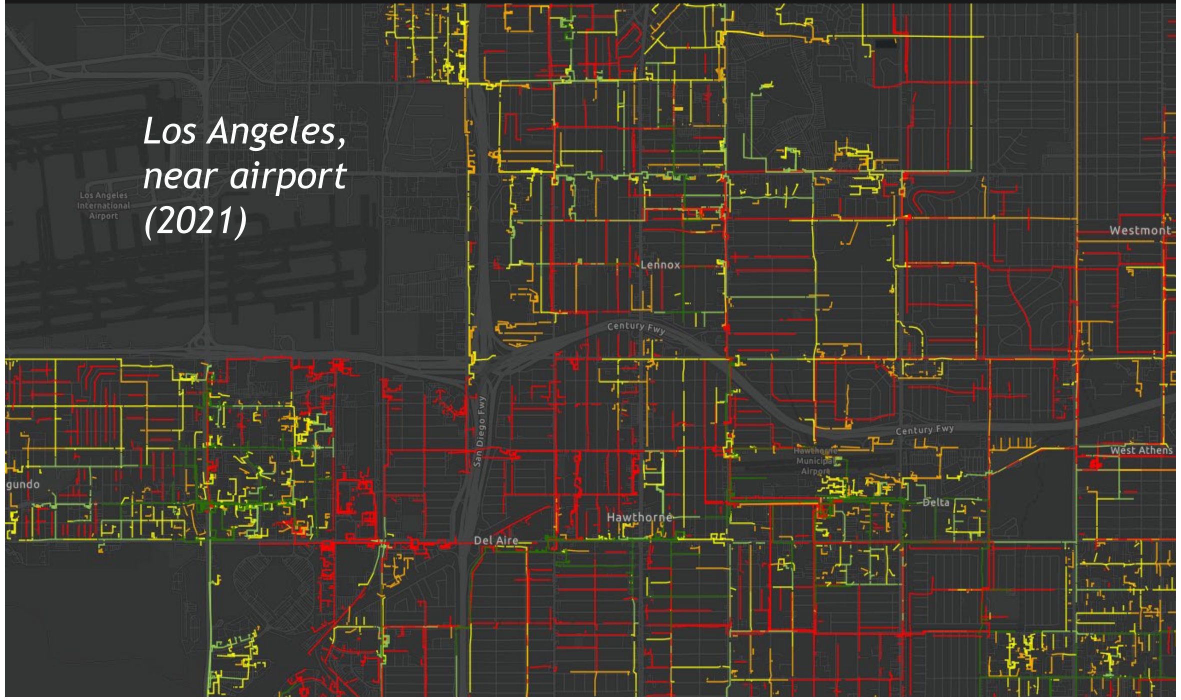
Source: BCG analysis, 2021.

Significant infrastructure investments required to support EV ambition; critical coordination with utilities, property owners, & permitting organizations needed

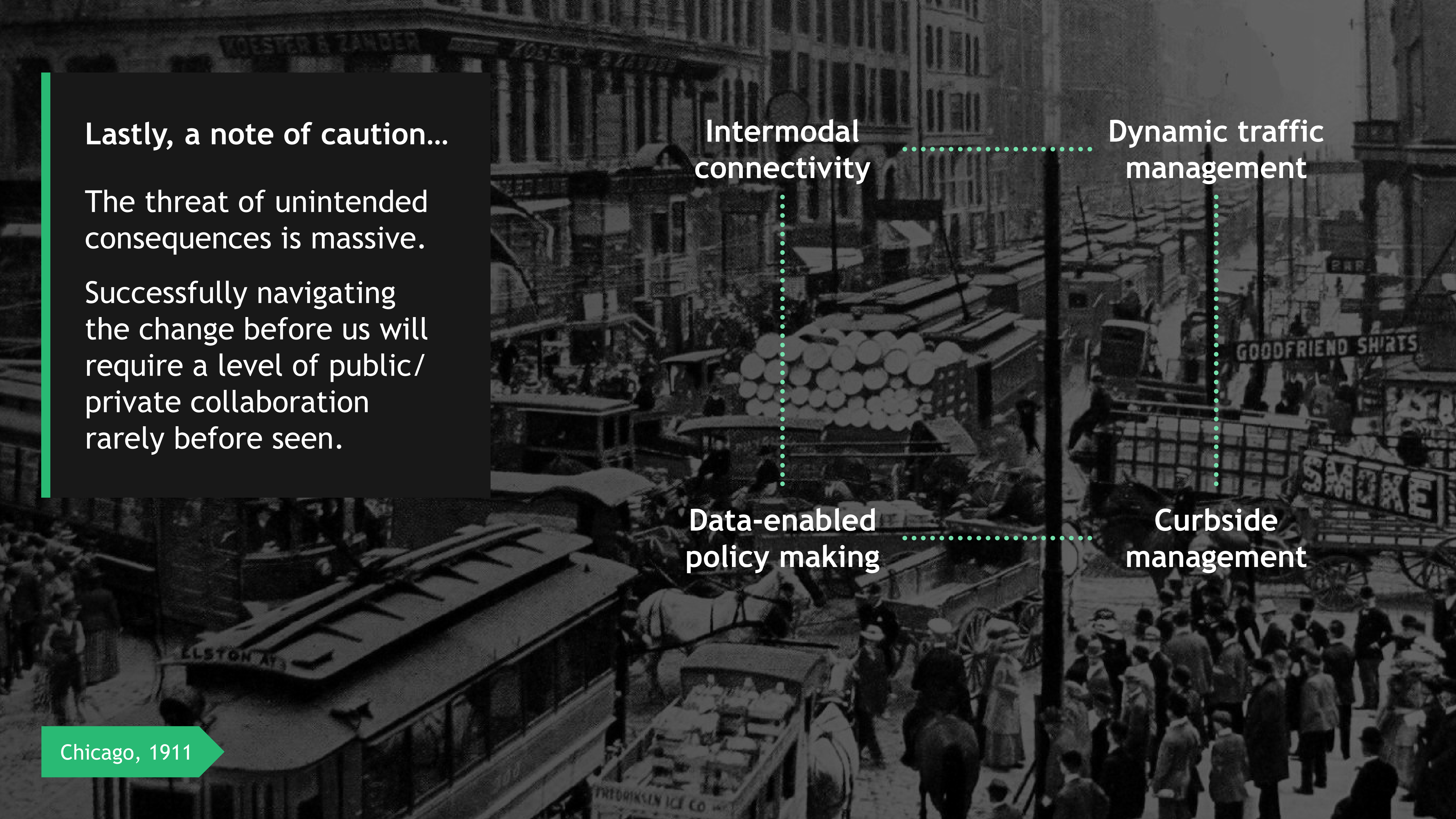
Large public charging network needed to support EV adoption



… but significant constraints to grid (transmission, distribution) could risk rapid build out



Source: BCG analysis



Lastly, a note of caution…

The threat of unintended consequences is massive.

Successfully navigating the change before us will require a level of public/ private collaboration rarely before seen.

Intermodal connectivity

Dynamic traffic management

Data-enabled policy making

Curbside management

Chicago, 1911

Way forward …

For companies to thrive in this increasingly complex world they must:

Focus

Ensure laser like clarity on what you stand for and how you will create sustained value

Challenge everything

Shake up the status quo and ruthlessly re-invent for advantage (e.g., business model, operating model, path to net zero, etc.)

Secure scale

Gain an advantaged scale position (cost, talent access, ability to reinvest)… either owned or thru broader partnership ecosystem

Master data

Ingrain throughout the org the ability to access, integrate, and manipulate data at scale (and quickly)

Win the war for talent

Break free from traditional talent models / cultural constraints and accelerate move to new skills and new ways of working

The task before us is immense, but when we get this right, we will change the world

→ A safer, far cleaner world

→ Equitable mobility access & reliability

→ Engine for economic growth

BOSTON
CONSULTING
GROUP