
Digital Auto Report 2021

Accelerating towards
the “new normal”

VOLUME 1



Digital Auto Report 2021 – Volume 1



- ✓ Tenth annual Digital Auto Report, developed by Strategy& and PwC
- ✓ Global consumer survey with a focus on the US, EU and China (n = 3,000) plus new view on Japan (n = 1,000)
- ✓ Quantitative market outlook up to 2035, based on regional structural analysis
- ✓ Interviews with industry executives at OEMs and suppliers, and with leading academics and industry analysts

Volume 1

Assessing global mobility market dynamics



- Market outlook – penetration of technologies and mobility types
- Technology – shifting gears in connected, electric, automated
- Customers – changing mobility preferences: everything-as-a-service?
- Regulation – slowdown or acceleration of key policies?

Volume 2

Capturing value with new mobility business models



What to offer and how much to gain?

Volume 3

Building software-defined vehicles and services



How to build up required capabilities?

The mobility ecosystem is entering a fragmented future, with different adoption patterns and use cases by region

Executive summary – Volume 1

In the “**new normal**” world, two themes are having a major impact on auto executives’ strategy with regard to connected, electric, automated and smart mobility – 1) rising market attention on decarbonization / **sustainability** and 2) competitive pressure from maturing **digital disruptors** / “new kids on the block”.

97% of Chinese consumers want to **change their mobility behavior** to improve their CO2 footprint – vs. **70% in Germany** and **52% in the U.S.**

Switching to an electric vehicle is the preferred measure for achieving this goal in China and in the US, while Germans would like to do more walking / cycling.

In light of the ongoing pandemic, **demand for public transport and shared mobility remains low** – about half of the survey respondents (n = 4,000) say they use those modes less often than pre-COVID; ~30% of Germans / Americans now want to use their own vehicle more (59% in China).

Total vehicle parc projections up to 2035 see a **stagnation in Europe** (-0,6% p.a.) and Japan (-0,9% p.a.) – vs. **marginal growth in the US** (+1.3% p.a.) and **stronger growth in China** (+3.9% p.a.); driven by 1) growing mobility demand, 2) customer preferences for own car and 3) vehicle disposal rate.

Vehicle **connectivity** is advancing, with **50% of total parc connected in Europe** by 2025 (US by 2023, China by 2029). While OEMs are reaching a critical size with their connected service customer base, they still **struggle with reliable service delivery at scale** (over-the-air update functionality).

E-mobility is at an **inflection point in Europe**, driven by a strong government drive (incentives and regulations), with **27% BEV share** of new car sales in 2025 – **ahead of China** (19%), **US** (6%) and **Japan** (5%). **Slow charging infrastructure build-up** will soon become the biggest growth hurdle.

Automated driving outlook is similar to previous year: in passenger transport, the **technology** will penetrate the market with a **range of specific use cases** that are difficult to scale – **L4 share of new cars at 14-15%** by 2035 in Europe / China / Japan; industrial / logistics applications likely to grow faster.

Despite consumer reluctance to share vehicles or rides during the pandemic, **smart mobility** modes beyond vehicle ownership are expected to grow in the long term. With rising number of car-subscription offerings, **shared-active** (e.g. rental, subscription) is expected to grow strongest **in Europe** (10% of total person kilometers by 2025), while **shared-passive** (e.g. ride-hailing) is expected to grow **significantly more in China** (10% vs. 1-3% in US and Europe).

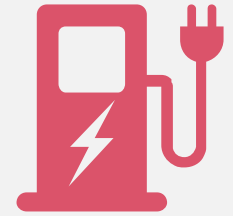
Conclusion: **differentiated view on CASE strategy** and investment priorities is crucial for maintaining “**license to operate**” and creating value in automotive. (→ covered in upcoming report volumes 2 and 3)

“

CASE themes continue to drive the automotive transformation – *Electric* currently has greatest impact”



Connected



Electric



Automated



Smart Mobility*

*Smart Mobility describes a transportation ecosystem where stakeholders use data and connectivity to move people and goods sustainably and efficiently. Shared mobility remains as a sub-segment and an important value pool in this ecosystem focusing on people transport with passenger vehicles.

As the mobility ecosystem adjusts to the new normal, many auto players will need to reboot their CASE strategies

Consumer

Consumer spend reaching pre-COVID levels; preference for own (EV) car vs. public transport remains high

Technology

Flex-work is here to stay, pushing demand for remote tech; chip shortage unlikely to be resolved before Q4-21

Regulation

EU/US decarbonization measures accelerate; rising attention on (open) data, privacy and cybersecurity

Economics

As auto topline recover, CEO attention is shifting from liquidity towards sustainable growth investments



Connected

With increasing digital service portfolio and functions-on-demand now available, car OS top priority for new models



Automated

Consolidation of ADAS players; OEMs review their partners; L4 people movers and robotaxis in trial mode everywhere



Smart mobility

Preference for private modes has paused smart mobility growth, but cities encouraged to run new transport trials



Electric

Public incentives and growing model choice has boosted EV demand – tipping point is near; infrastructure next bottleneck

Sustainability has become a major driver for change in auto



2021 Highlight I: Sustainability

Sustainability transformation drivers

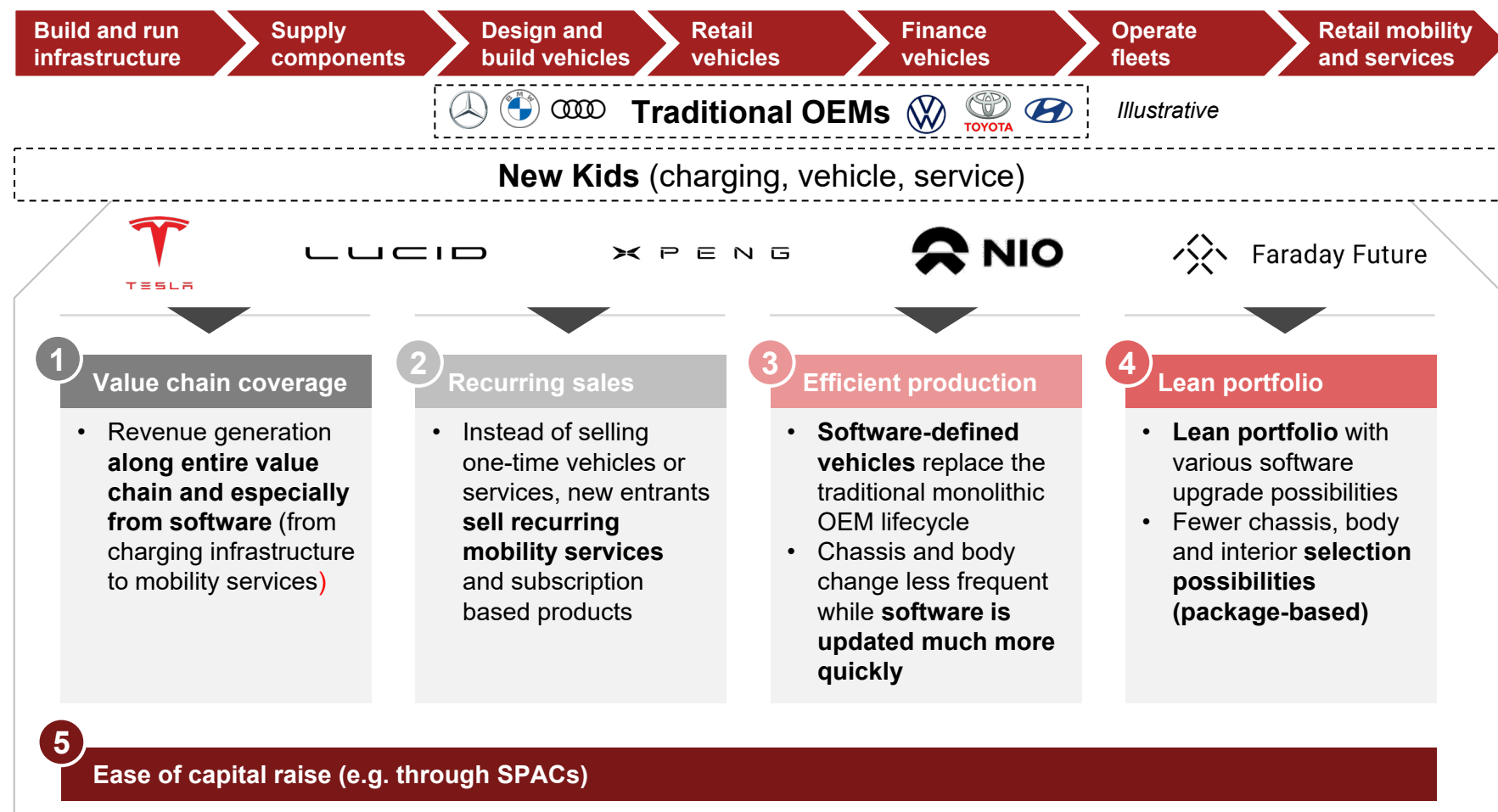
Public perception	Regulation	Net zero CO ₂ pathway	Capital markets
<ul style="list-style-type: none"> • Customers demand genuine ESG¹⁾ actions • Employer brand to meet ESG talent expectations • Higher transparency on social responsibility along supply chain, e.g. for battery materials 	<ul style="list-style-type: none"> • EU taxonomy and ESG reporting standards • Compliance system to fulfill new regulation, e.g. on cybersecurity • Recalibration of KPI systems to ESG topics, e.g. for executive pay 	<ul style="list-style-type: none"> • Portfolio shift towards sustainable vehicles • Invest balance of “old” (e.g. EURO7) vs. “new” tech (e.g. cell production) • Decarbonization of full product lifecycle including supply chain 	<ul style="list-style-type: none"> • Booming demand for ESG investment classes • Growing relevance of top ESG rating positions • Maturing ESG investor reporting and changing OEM equity story
<p>73% ... of customers want to change their mobility behavior to lower CO₂ emissions</p> <p>86% ... of employees prefer to work for firms that care about the same issues they do</p>	<p>41% ... Ø Zero Emission Vehicle sales required for CO₂ compliance in 2030</p> <p>...barrier to ESG effectiveness is the lack of reporting standards Nr.1</p>	<p>€1T ...EU Green Deal funding, of which sustainable mobility is a central pillar</p> <p>55% ...reduction in passenger car emissions by 2030 (EU Green Deal)</p>	<p>€120bn All-time high inflows in Q1/21 for EU sustainable funds²⁾ (plus 18% vs. Q1/20)</p> <p>6/10 ... of best-performing funds in EU were related to ESG in Q1 2021</p>

CASE implications

- More holistic view on ESG forces players to re-evaluate measures – from drivetrain to cyber/data
- **Connected:** Emission reductions via predictive driving/analytics, **but** pressure on sustainable high-tech production
- **Autonomous:** Emission efficiency via optimized driving, **but** growing energy consumption for data compute
- **Smart:** Environmental benefits from multi-mode mobility, **but** overall higher mobility demand as urban populations gain wealth
- **Electric:** Zero emission vehicles, **but** need for sustainable battery production and recycling

New entrants redefine the rules of the automotive value game

2021 Highlight II: New kids on the block











Selected key facts

- ~45%** Overall profit expected to be generated from software in 2025¹⁾
- \$199** Tesla's monthly subscription price for full self-driving capability²⁾
- 2024** Year in which BEV will achieve production cost parity with ICE³⁾
- ~4 vs. ~20** Average model variants in EU by new entrants vs. traditional OEMs⁴⁾
- \$99bn** Raised via automotive SPAC in 2020⁵⁾

Acceleration of technology penetration will occur at varying times and speeds globally, as local mobility is transformed

Key considerations for anticipating tipping point of exponential technology adoption

	Technology	Consumer	Regulation	Economics	Expected tipping points
 Connected	<ul style="list-style-type: none"> Connected service content and UX Vehicle system/EE architecture Network infrastructure 	<ul style="list-style-type: none"> “Digitally savvy” share of population “Freemium” segment services 	<ul style="list-style-type: none"> Scope and timing of enforced connectivity requirements Scope of data sharing and privacy restrictions 	<ul style="list-style-type: none"> Indirect value capture by OEM Effective end consumer pricing 	 earlier 2030 later
 Electric	<ul style="list-style-type: none"> Battery and powertrain performance EV manufacturability and production capacity Charging infrastructure 	<ul style="list-style-type: none"> Premium/early adopter segment size “Rational green” segment size 	<ul style="list-style-type: none"> Emission target levels BEV/PHEV incentives Diesel/ICE bans/restrictions in cities 	<ul style="list-style-type: none"> Superior total cost of ownership (TCO) of BEV vs. ICE in relevant number of segments Additional revenues/savings from V2G/V2X charging 	 earlier 2030 later
 Automated	<ul style="list-style-type: none"> ADAS capability by use case Data processing Driver UI Network and traffic infrastructure 	<ul style="list-style-type: none"> Premium/early adopter segment size Technology openness 	<ul style="list-style-type: none"> Scope and timing of enforced ADAS safety features Geographic range and quantity of AV test drive/vehicle approvals 	<ul style="list-style-type: none"> Superior TCO vs. non-AV in first commercial cases Additional value capture from riders 	 earlier 2030 later
 Smart Mobility	<ul style="list-style-type: none"> Smartphone penetration Access and fleet availability 	<ul style="list-style-type: none"> Intermodal openness People/traffic density “Frequent user” segment size 	<ul style="list-style-type: none"> Private car restrictions/taxes Passenger transport regulation 	<ul style="list-style-type: none"> Superior TCO vs. own vehicle Dynamic pricing for opt. use and availability 	 earlier 2030 later

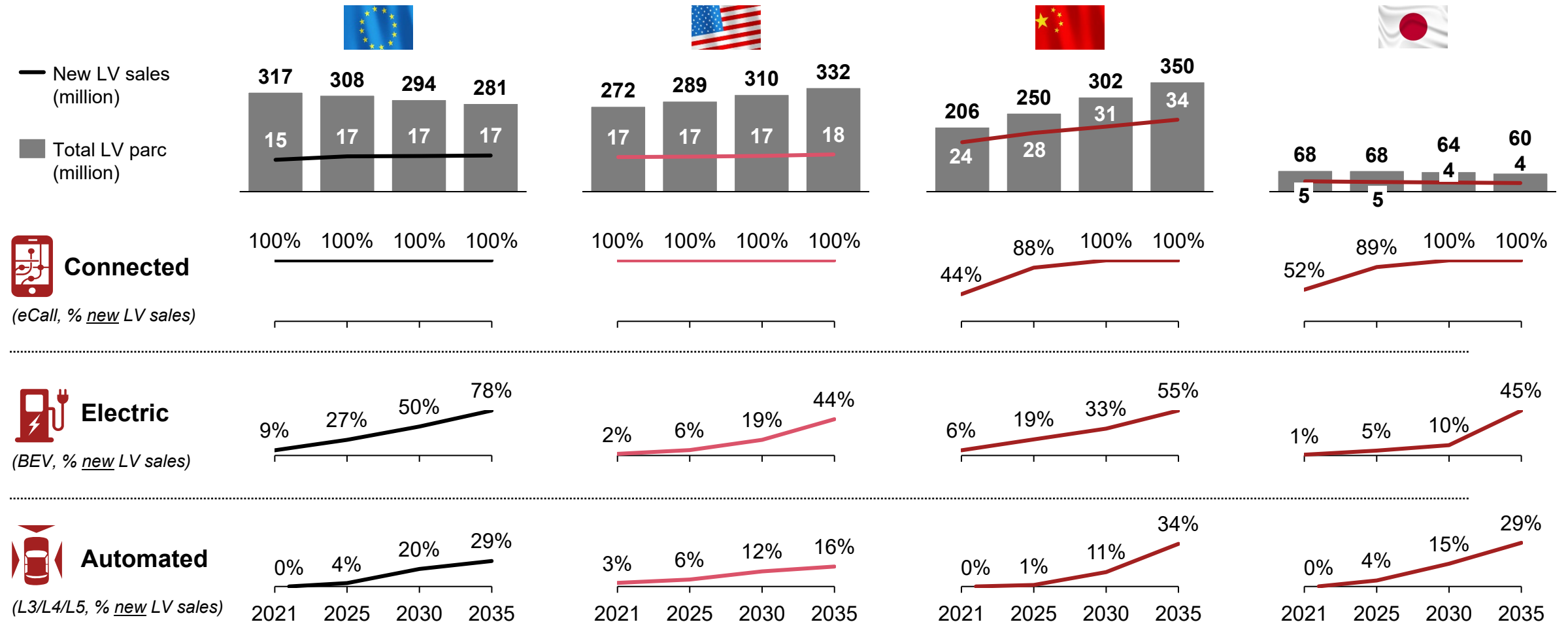
ADAS = Advanced Driver Assistance Systems; EE = Electric/electronics, V2G = Vehicle to grid, TCO = Total cost of ownership
 Note: A tipping point is defined as the start of exponential growth within a segment of the mobility transformation
 Source: Expert interviews, PwC AutoFacts®, Strategy&

Slow down
vs. 2020

Acceleration
vs. 2020

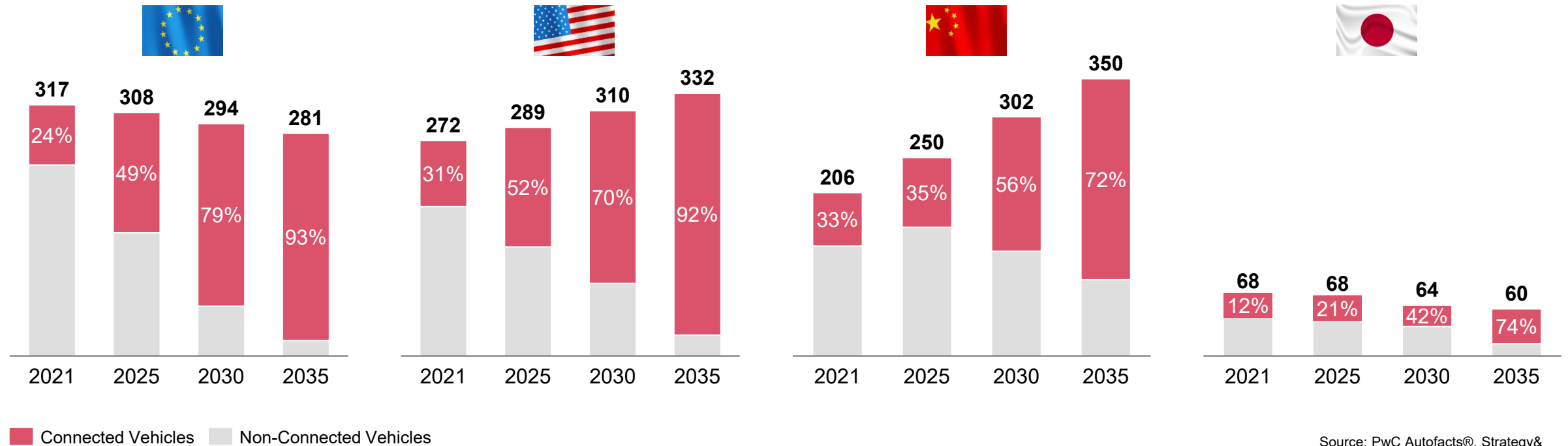
Total car parc growth strongest in China; electric forecast up from last year's prediction; automation notable only after 2025

Total vehicle parc and technology penetration of new car sales (in million, %)



Every second vehicle on EU/US roads will be connected by 2025 – China/Japan follow five years later due to less regulatory pressure

Total vehicle parc and connected car share (in million, %)

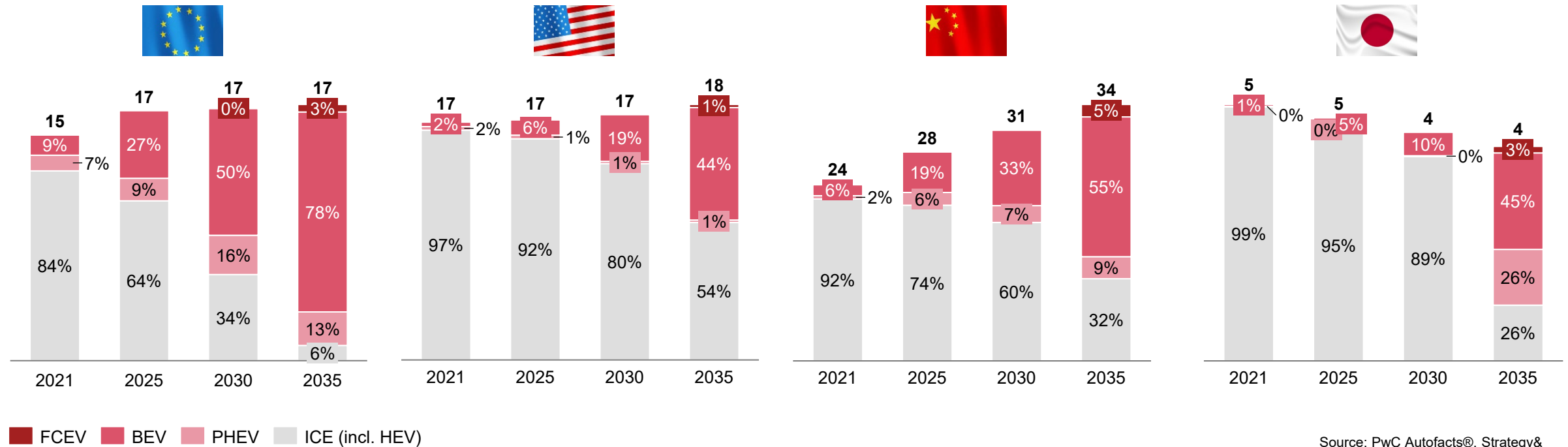


Source: PwC Autofacts®, Strategy&

“As the number of connected cars increases, more OEMs will be able to offer over-the-air updates (OTA) and other features for greater consumer convenience, however security and data protection remain important concerns.”

While BEV penetration in EU has accelerated vs. previous year expectations, China leads in total volume; Japan/US much slower

New vehicle sales by powertrain (in million, %)

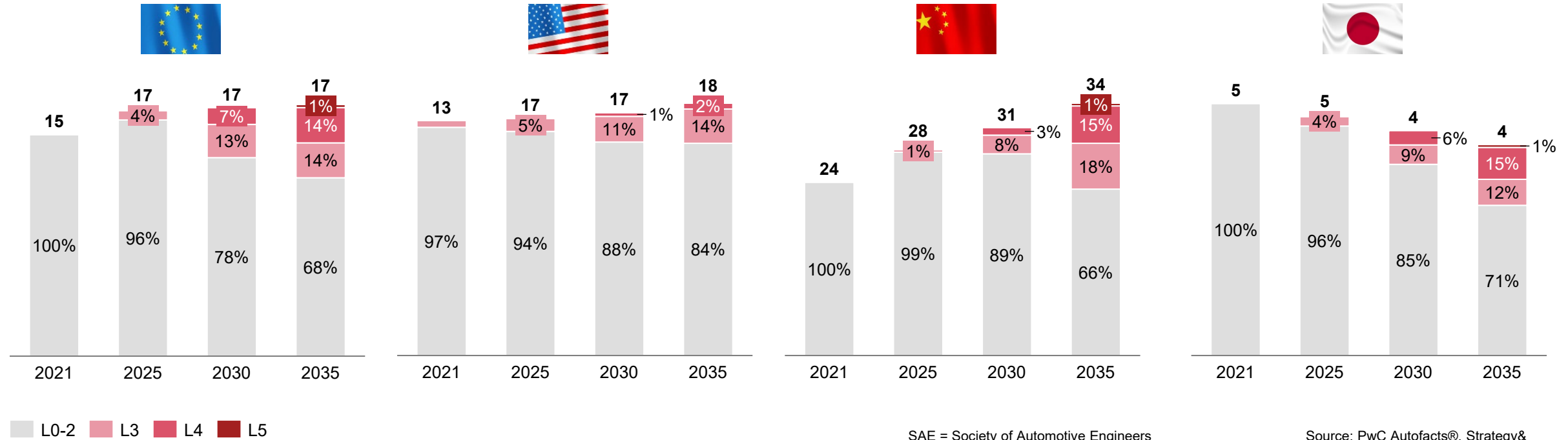


Source: PwC Autofacts®, Strategy&

“ The recently announced EU Green Deal seeks a 100% reduction in CO₂ from 2035. Similar announcements from other countries are expected in the next few years. ”

2021 has seen first deployments of L3 and L4 around the world, but relevant share of >20% expected only after 2030

New vehicle sales by SAE level (in million, %)



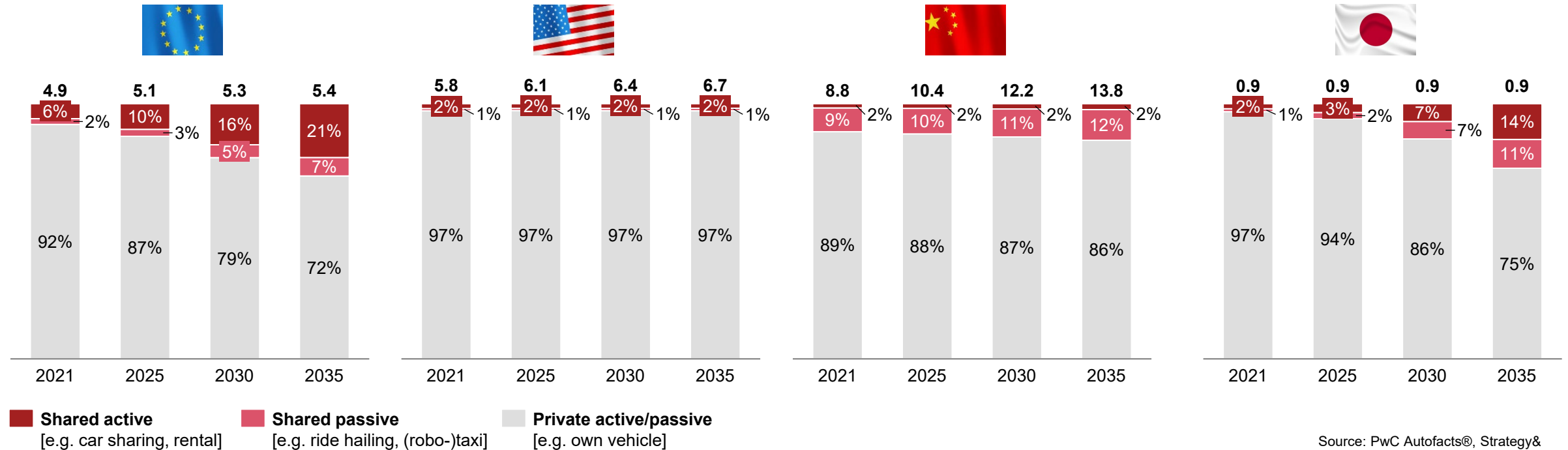
SAE = Society of Automotive Engineers

Source: PwC Autofacts®, Strategy&

“ ADAS players will strive in the coming years for selected, feasible automated driving applications in transport/fleets and logistics/industrial areas to recover investments – Germany first to pass national law for automated vehicle use. ”

Preference towards shared mobility still varies across the major markets; EU/Japan expected to lead by 2035

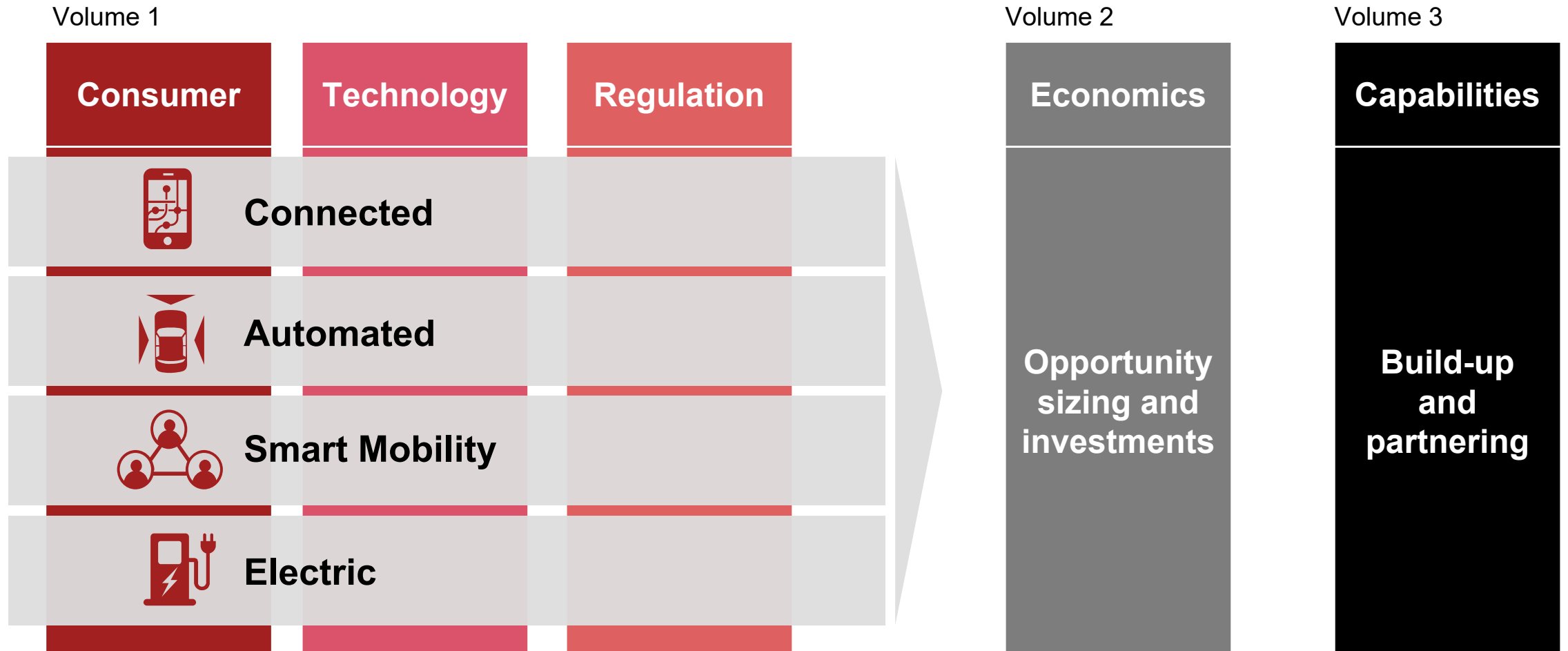
Market penetration by mobility mode (in '000 trillion person-kilometer, %)



Source: PwC Autofacts®, Strategy&

“ Despite demand shock for shared mobility due to COVID-19 in 2020/21, long-term outlook remains positive – driven by a growing number of sharing options on multi-mode transport platforms and increasing regulatory pressure for private car ownership, in particular in European and Japanese cities. ”

This report series is laid out in three volumes 1) CASE drivers, 2) economic opportunities, and 3) capability implications



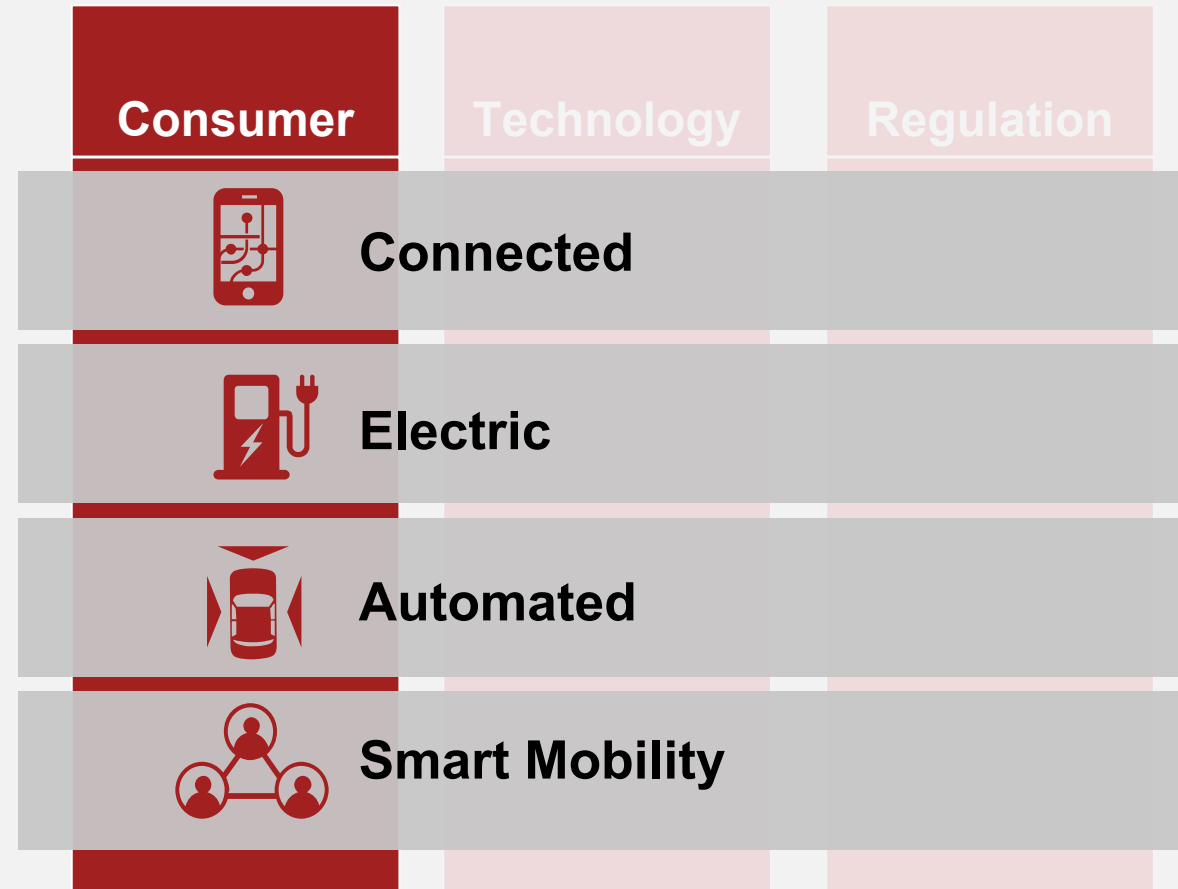


Volume **1** Assessing global mobility
market dynamics

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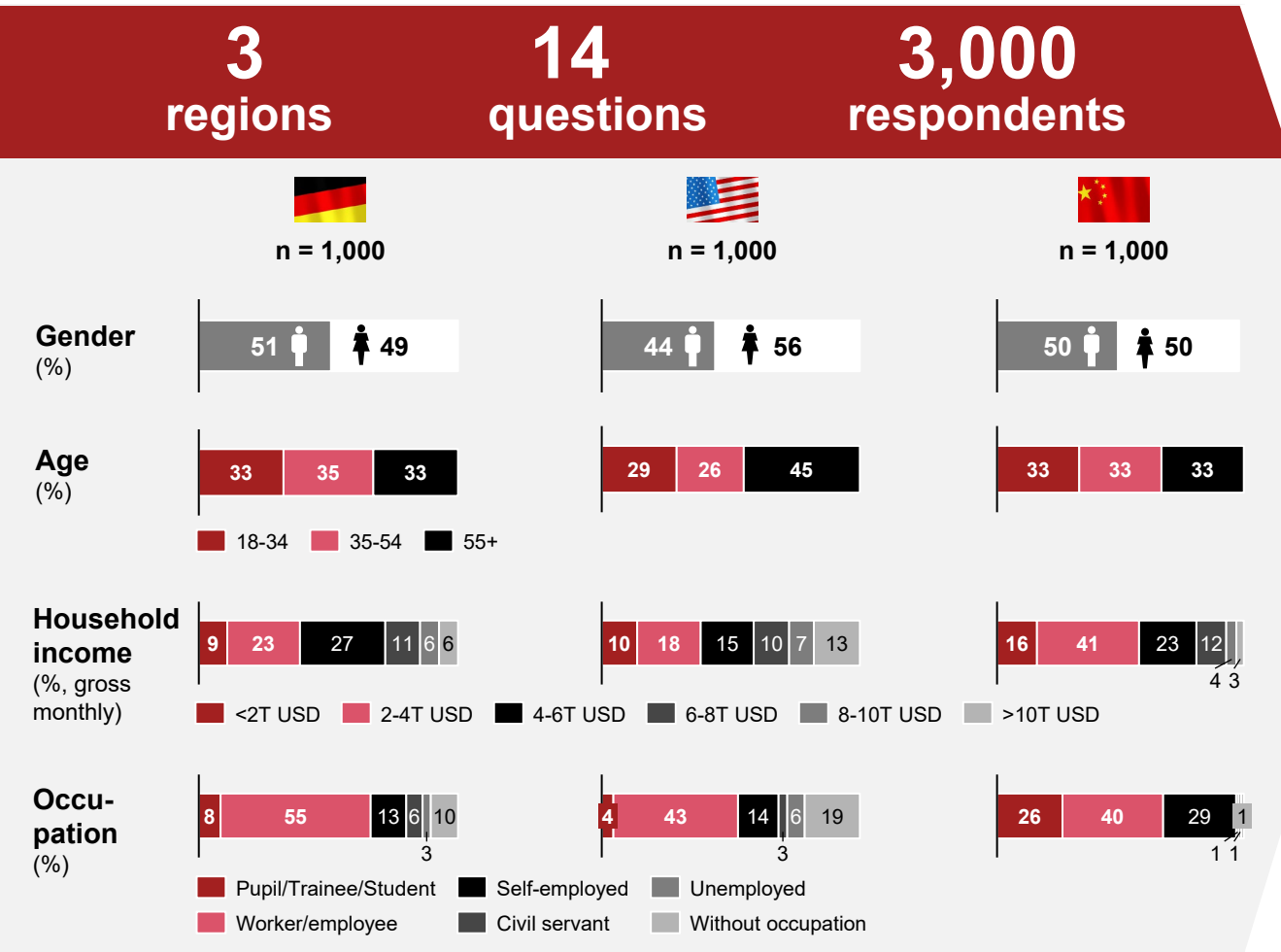
Consumers are seeking convenient and safe mobility – private transport modes remain important in 2021”

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Latest consumer attitudes within CASE are reflected in a survey of 3,000 respondents in Germany, US and China

Overview consumer survey



Key results



- Order of preferences of **connected** services remains **stable** – safety and navigation still most important
- **Willingness to pay** for **on-demand** car functions much **higher** than for **connected services**



- **PHEVs** and **BEVs** are most preferred type of powertrain **only in China** while **Hydrogen** gains popularity in Germany
- **Insufficient driving range** and **concerns** about **charging options** put respondents **off** driving **electric cars**



- Respondents **have not gained more trust** in the use of **automated cars** – negative development compared to last year
- **High willingness to pay** for **automated driving** among those respondents who trust the technology

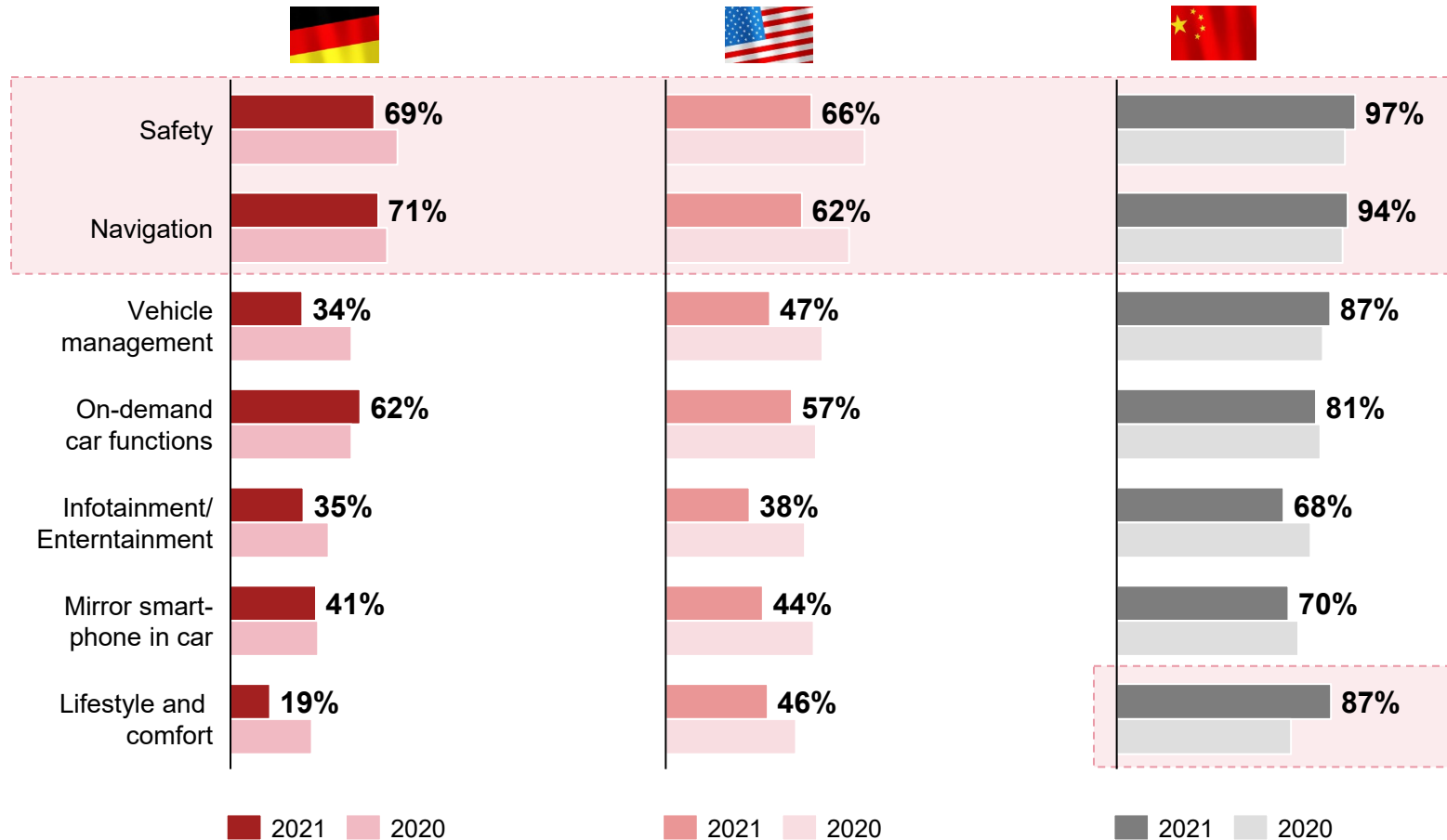


- **Moderate intention to purchase a new or used car**, **subscription models gaining traction**
- Even as immediate COVID-19 risk declines, using one's **own car remains most popular** while costumers are **reluctant** to use **shared** and **public transport**

Order of preferences for connected services remains stable – safety and navigation still most important



Connected services – By importance for consumers



Question: “Which connected service categories are particularly important to you?”

”

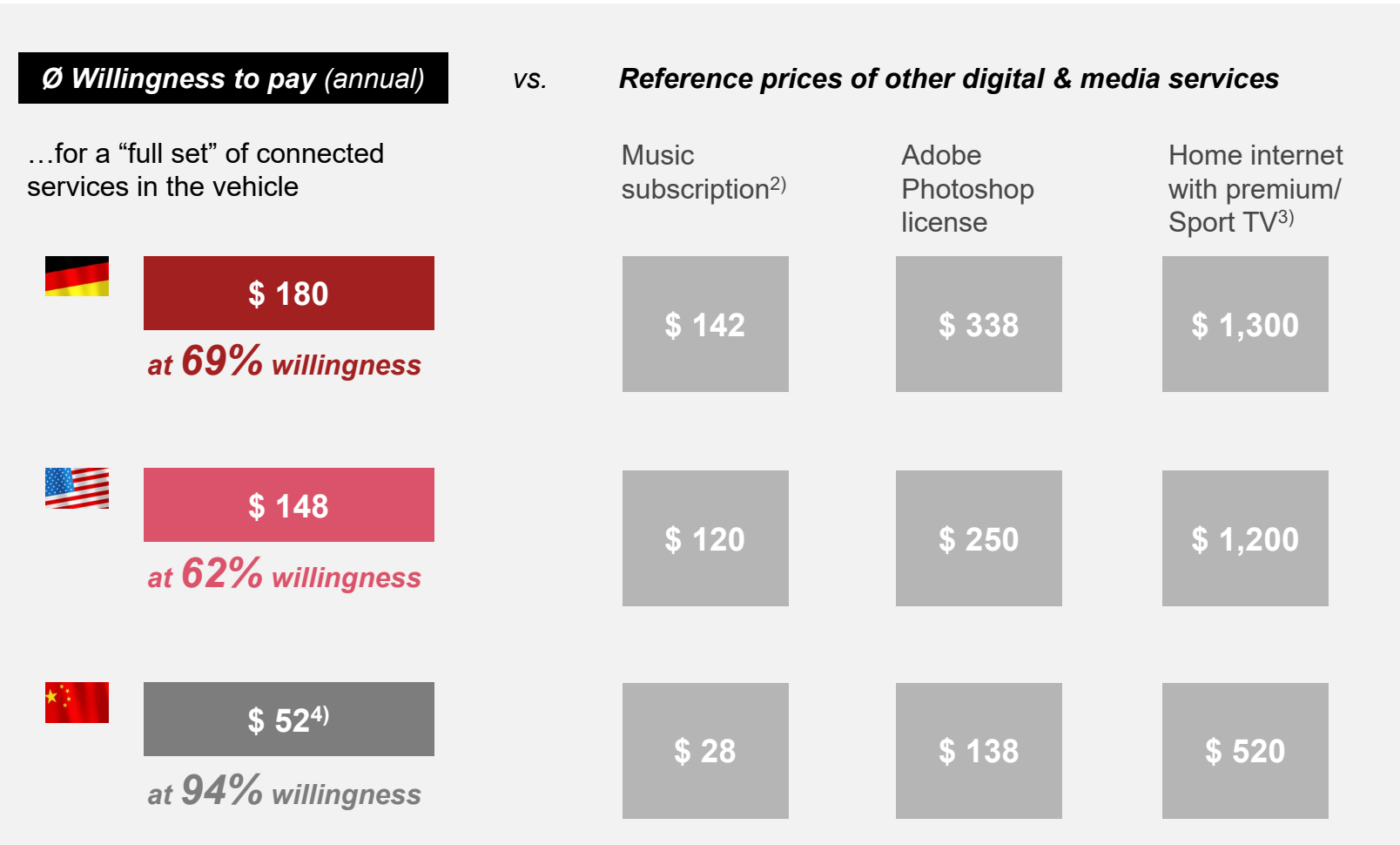
Safety and navigation still most important feature for respondents across all regions.

With **lifestyle and comfort** features, OEMs mainly attract **Chinese consumers.**”



More than 2 in 3 respondents are willing to pay for connected services; but respective amount varies greatly between regions

Connected services – Average willingness to pay¹⁾



”

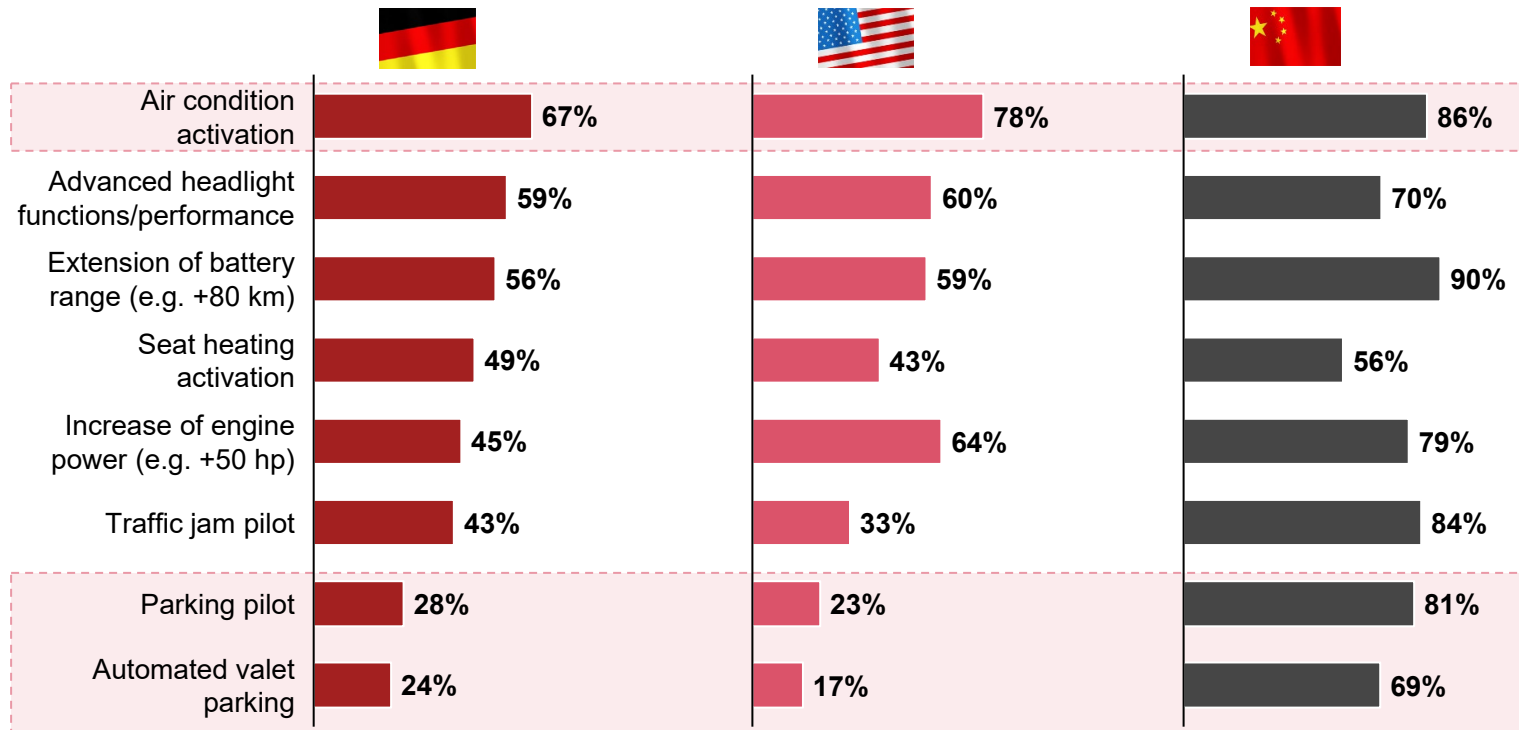
Acceptance of paying at all for connected car services **has increased across regions**

However, there are strong **differences in perceived value** among consumers – Chinese are willing to pay least for it, while consumers in US/Germany are prepared to pay a sum comparable to a music subscription.”

With first on-demand functions becoming available, GER/US users rate air conditioning/headlights/engine power highest



On-demand car functions – Importance for consumers



Question: “How important would be on-demand car function [...] to you?”

“Particularly **basic functions** like **air conditioner activation** ranked most **important**, whereas **sophisticated functions** like parking pilot or automated valet parking **do not yet seem very important** – at least in Germany and the US.”



Ø **annual willingness to pay¹⁾** for car that offers a full set of multiple on-demand car functions

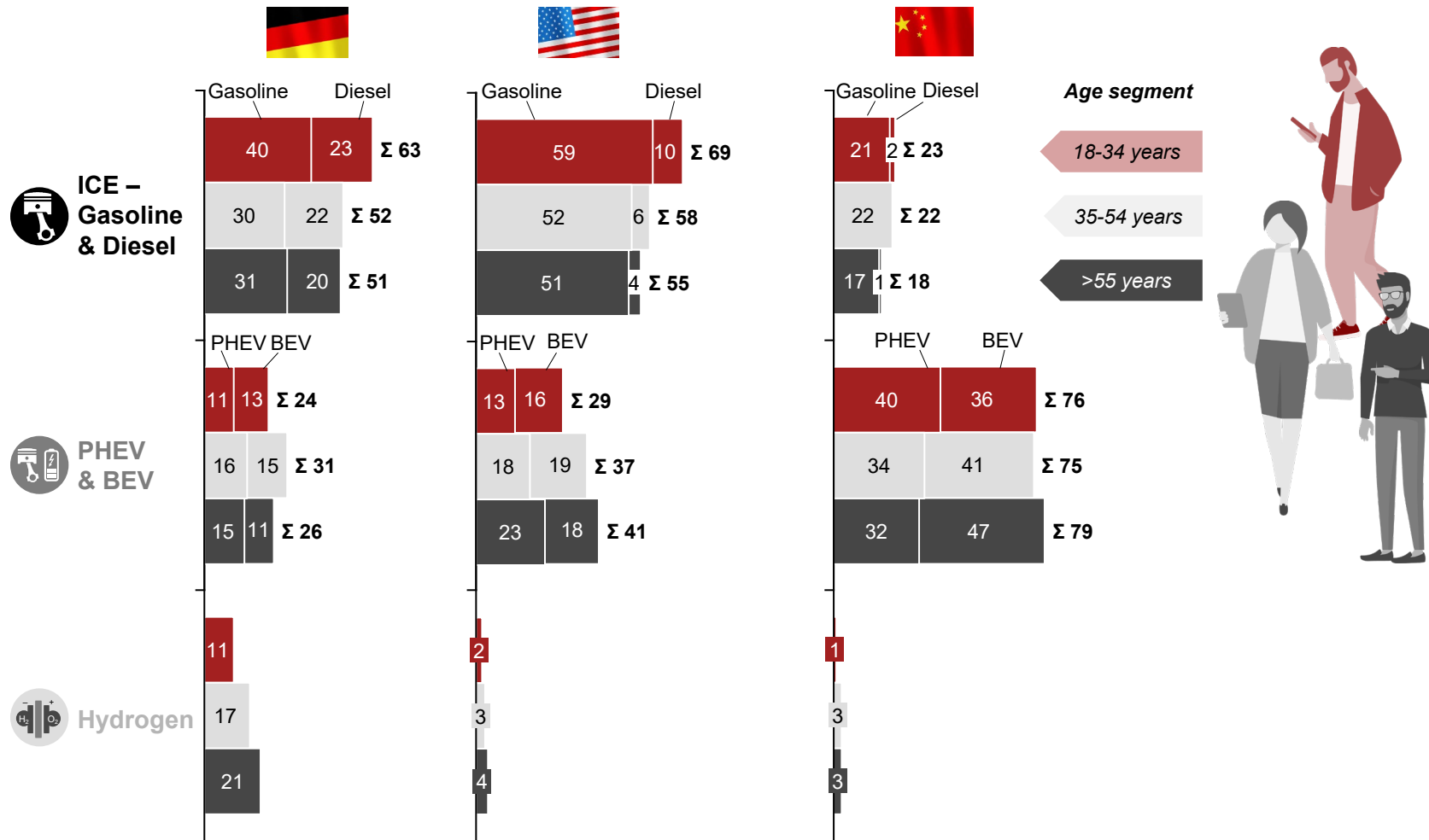
\$ 675
at **60%** willingness

\$ 760
at **45%** willingness

n/a

>50% of US and Germany consumers retain strong preference for ICE – even young segments. Chinese clearly prefer PHEV/BEV

Preferred type of powertrain/engine by age (%)



Question: “Assuming you would buy, lease or subscribe to a passenger car, what type of engine would you like?”

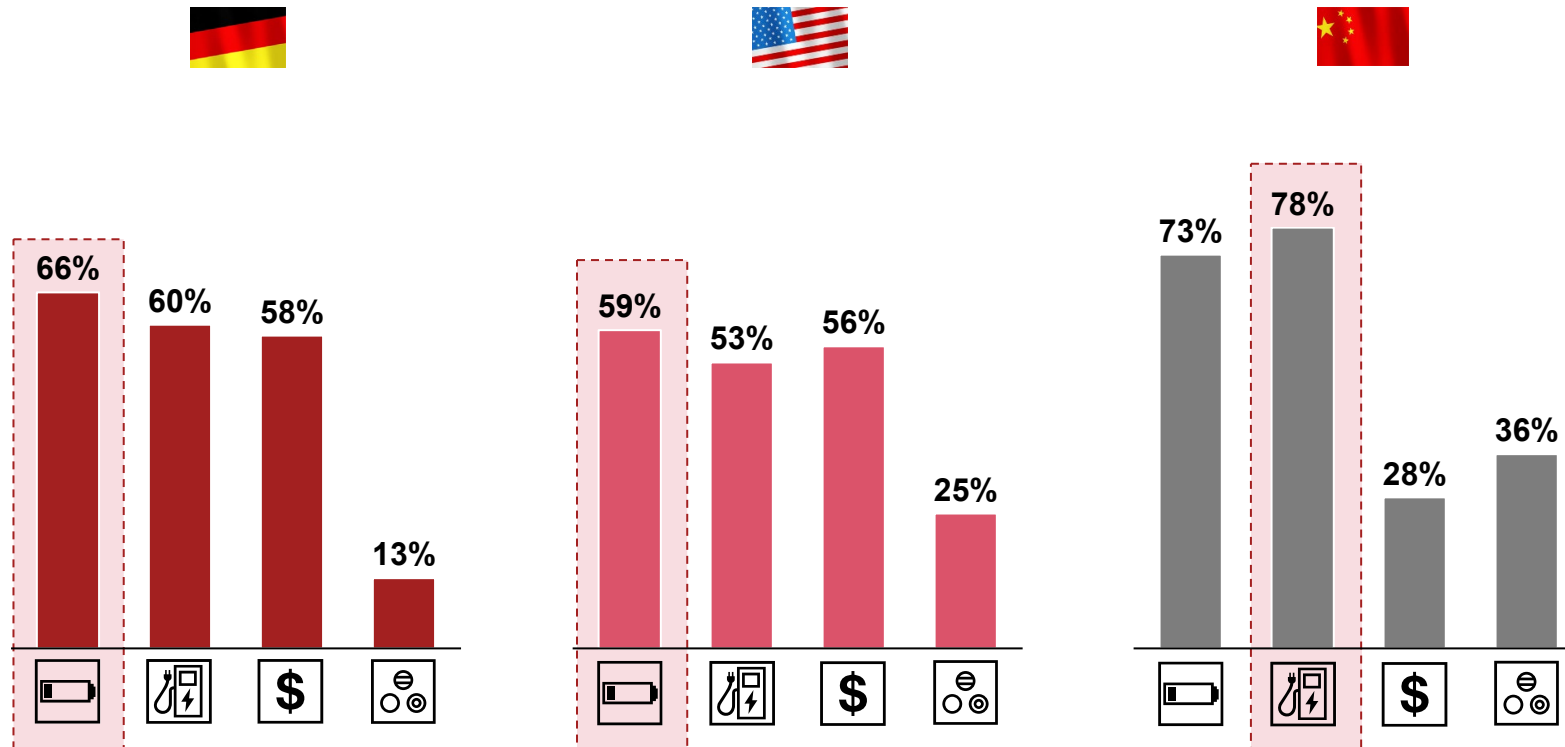
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US consumers retain a strong preference for ICE (55-69%) followed by Germany (51-63%), while Chinese clearly prefer BEV/PHEV (75-79%).

Despite the common image of being a climate-aware generation, **younger segments** in Germany and US have clear **preference for ICE.**

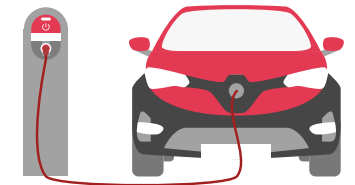
Hydrogen gains popularity in Germany – likely due to increasing press coverage and public debate.”

Range anxiety and charging options are major obstacles to choosing an electric car – price is less of an issue, particularly in China

Deterring factors using an electric car



Question: “What is holding you back from choosing a car with an electric powertrain?”



”

In **Germany and the US**, insufficient **driving** range with one battery charge is the biggest deterrent, whereas **Chinese** respondents raise concerns about whether there is sufficient **charging network coverage.**”

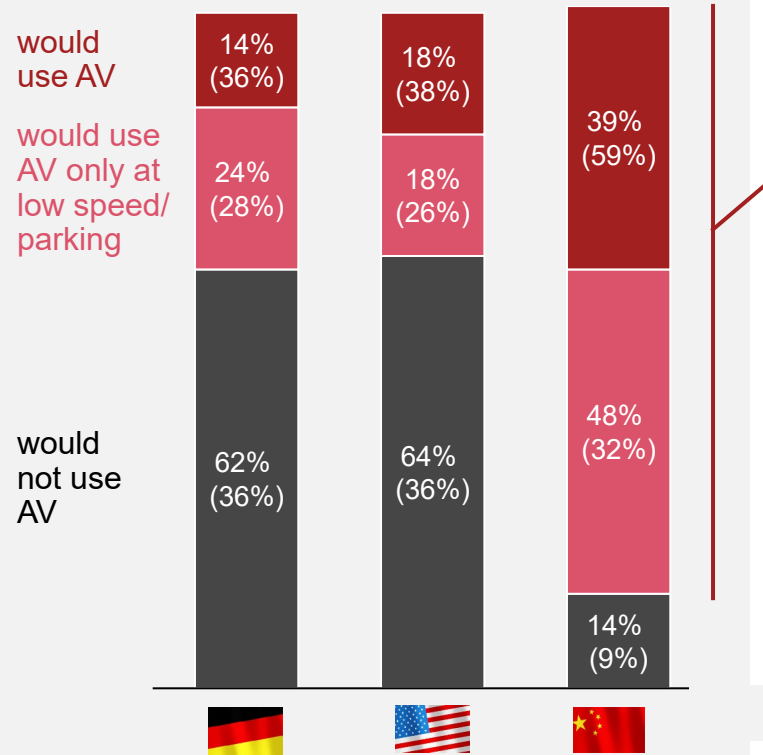
- Relatively high purchase price
- Insufficient driving range with one battery charge
- Limited choice and availability of cars
- Concerned about sufficient charging options/stations

Trust in automated cars is not growing – and has even declined in US and Germany from last year



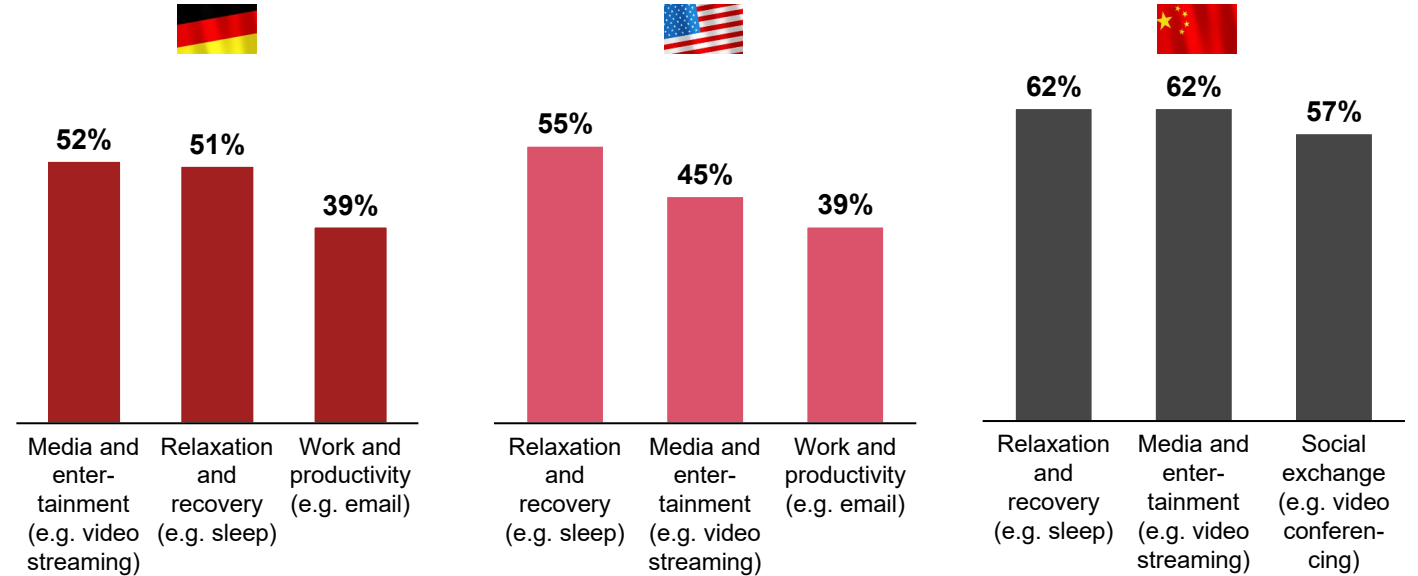
Automated driving – Consumer attitudes and usage of time gained

Question: Would you personally use a fully autonomous car?



(xx %) = Previous year's values

Top 3 activities to use within time gained
(% of respondents)



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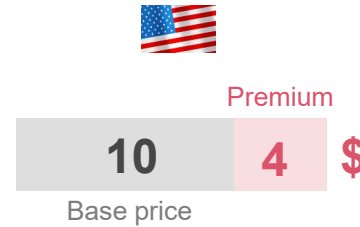
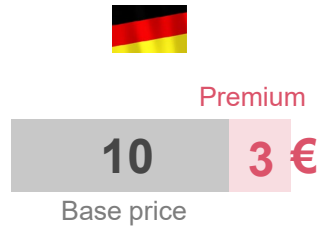
In general, **willingness to use fully automated cars has declined**, especially in **Germany** and the **US**. **Trust in autonomous driving is seen as susceptible to change**, and **consumer attitudes might fluctuate rapidly as critical headlines emerge**, e.g. following **accidents** and **cybersecurity threats**.”

High willingness to pay for automated driving experience among respondents who would use a fully automated vehicle



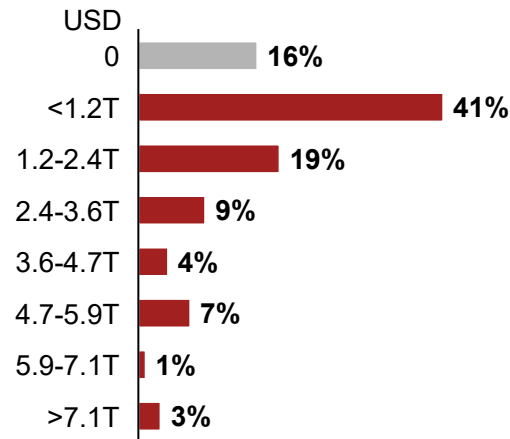
Automated driving – Willingness to pay

Question: “When using car sharing or ride hailing, what would be the extra price you would be ready to pay to get an autonomous car driving you around?”¹⁾

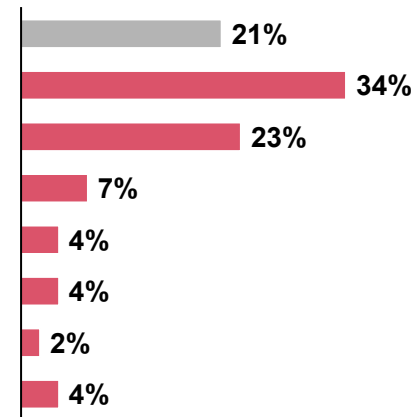


Question: “How much would you be ready to pay on top of the regular car price to have full autonomous car functionality?”

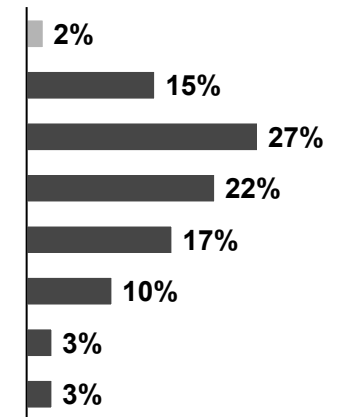
84% willingness



79% willingness



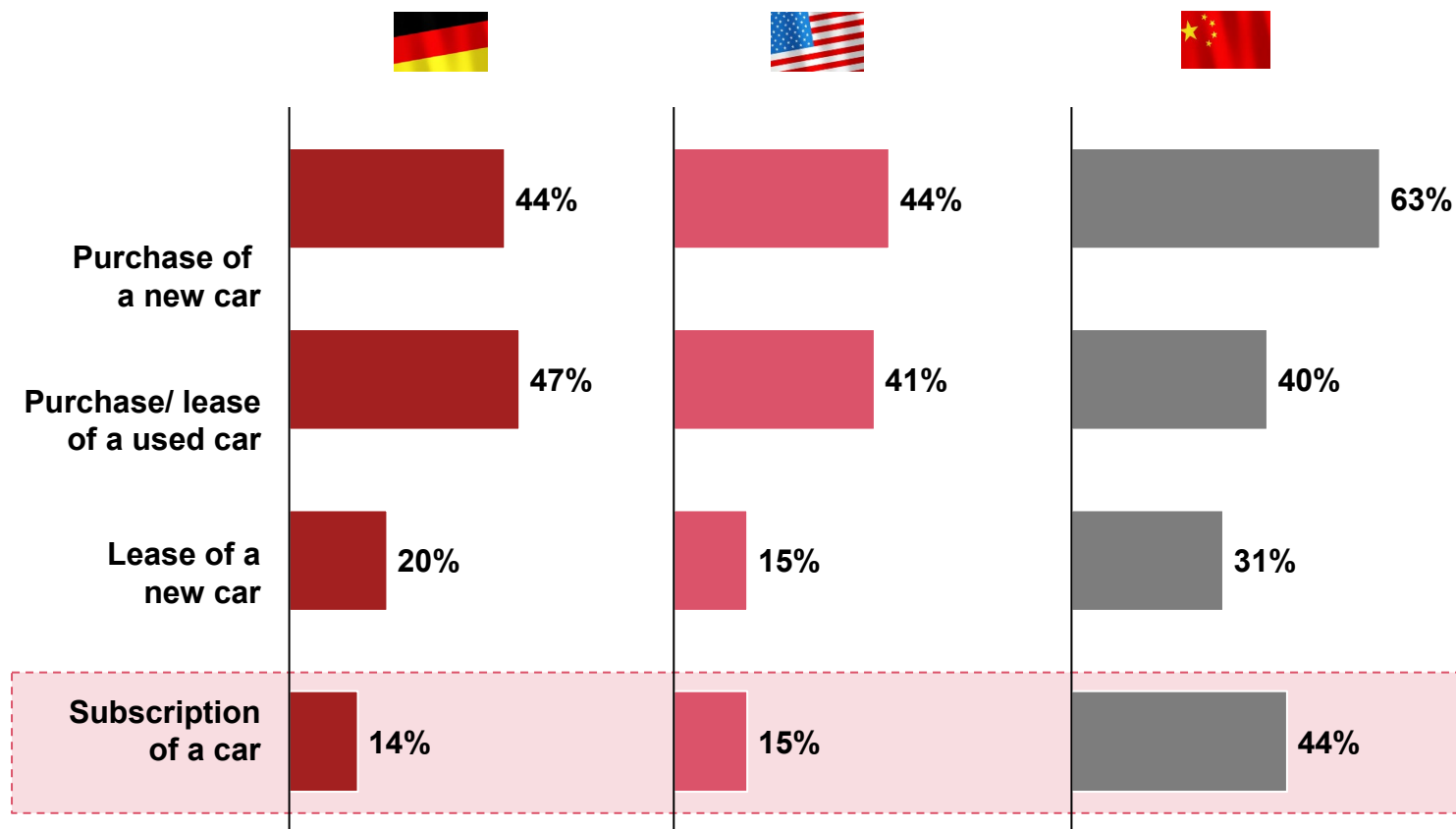
98% willingness



Source: PwC Strategy& consumer research 2021; 1st question n=198 (57 DE, 141 US) , 2nd question n=1604 (383 DE; 356 US; 865 CN) respondents who would use an AV
 1) Extra-price you to pay for a 5 km/ 3 miles ride (knowing the amount for a traditional car is 10 EUR/ 10 USD/ 40 CNY)

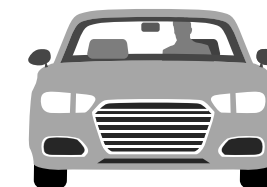
More than 40% of respondents want to purchase a new or used car in next 1-2 years; subscription models attracting more attention

Likelihood to buy/lease/subscribe to a car



█ Likely/very likely

Question: “How likely might you or your household purchase, lease, or subscribe to a passenger car in the next one to two years?”



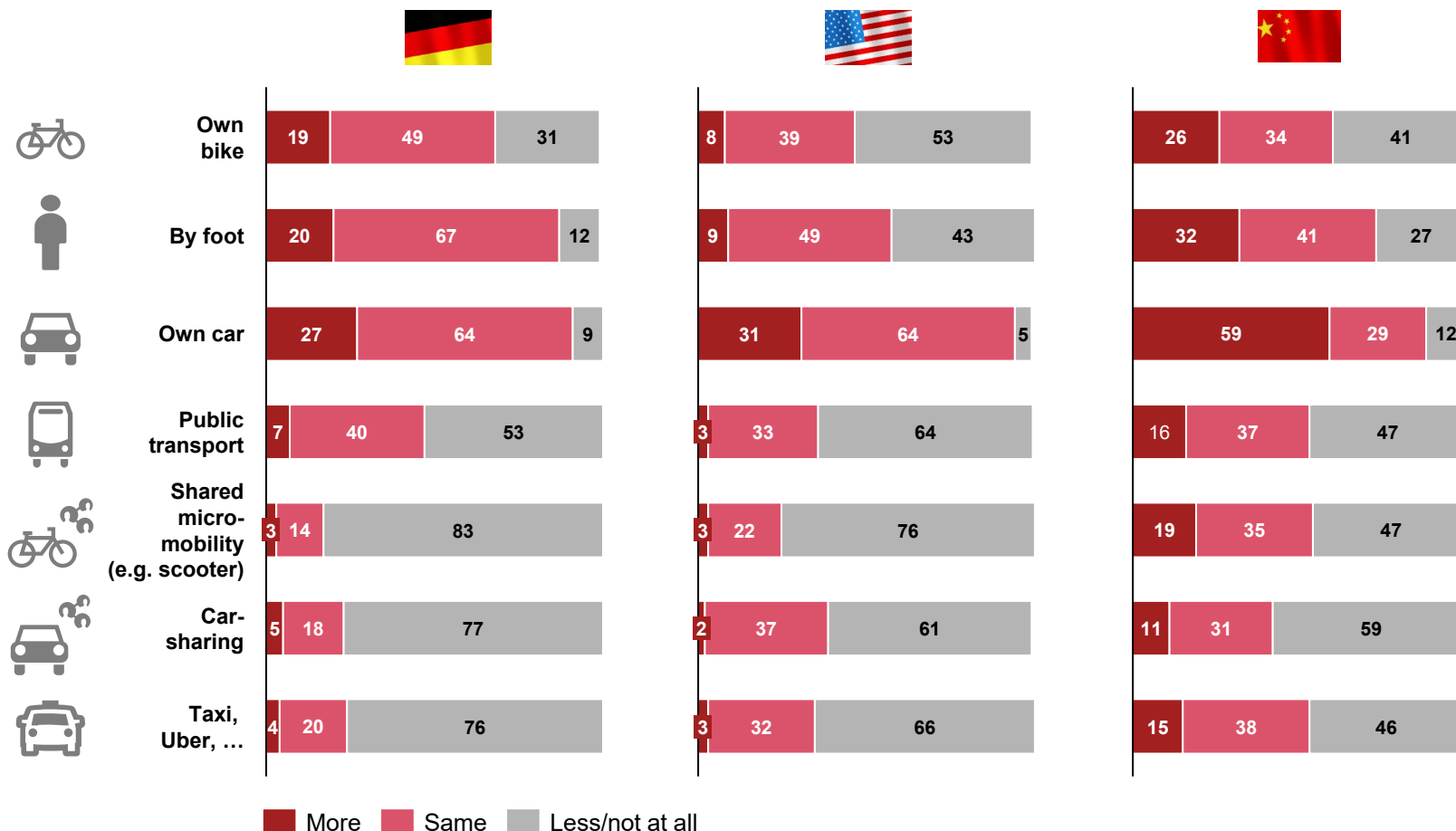
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As the economic impact of COVID-19 appears to be more predictable in Germany, the **intention to get a car grew in that country** compared to last year’s survey.

Subscription is gaining in popularity – in China, it is seen as more attractive than leasing; in US it is on a par with leasing, and in Germany its popularity is clearly growing (14% vs. 8% last year).”

Even as immediate COVID-19 risks decline, own car remain most popular as people shy away from shared and public transport

Mobility pattern after COVID-19 restrictions (%)



Question: “COVID-19 has temporarily changed our mobility behavior in many aspects. How do you plan to use modes [...] of transport once we have left the pandemic behind us?”

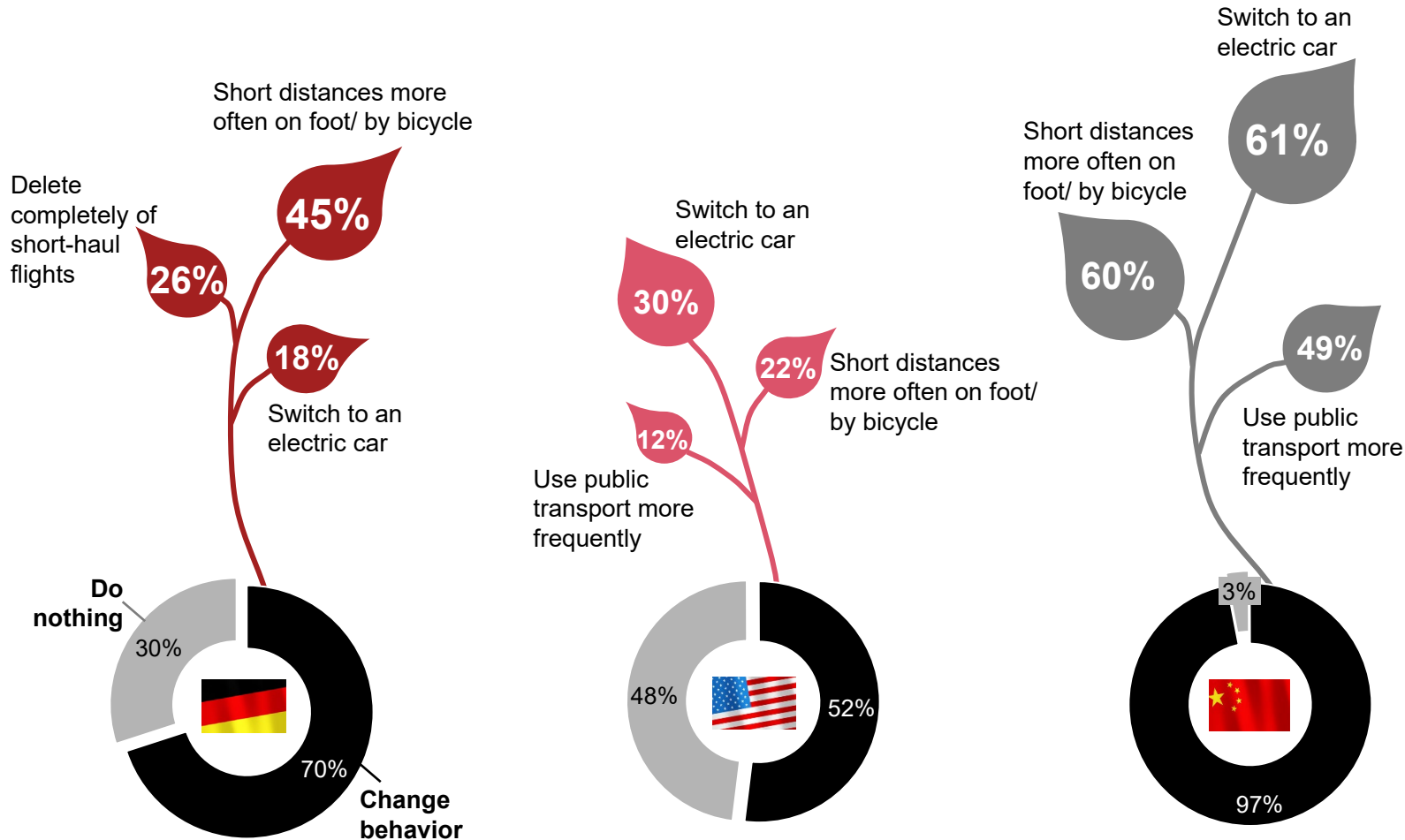


Own car is still seen as the safest and most convenient means of transportation – and therefore has the highest increase in demand, in particular in China.

Across all regions, consumers plan reduced use of **shared modes** as well as **taxi and ride-hailing** – even after the pandemic.”

Respondents want to contribute to CO₂ reduction – mainly by switching to an electric car or more walking/cycling (in Germany)

Top-3 contributions to CO₂ reduction



Question: “What major personal changes would you like to do to contribute to a reduction in CO₂ emissions?”

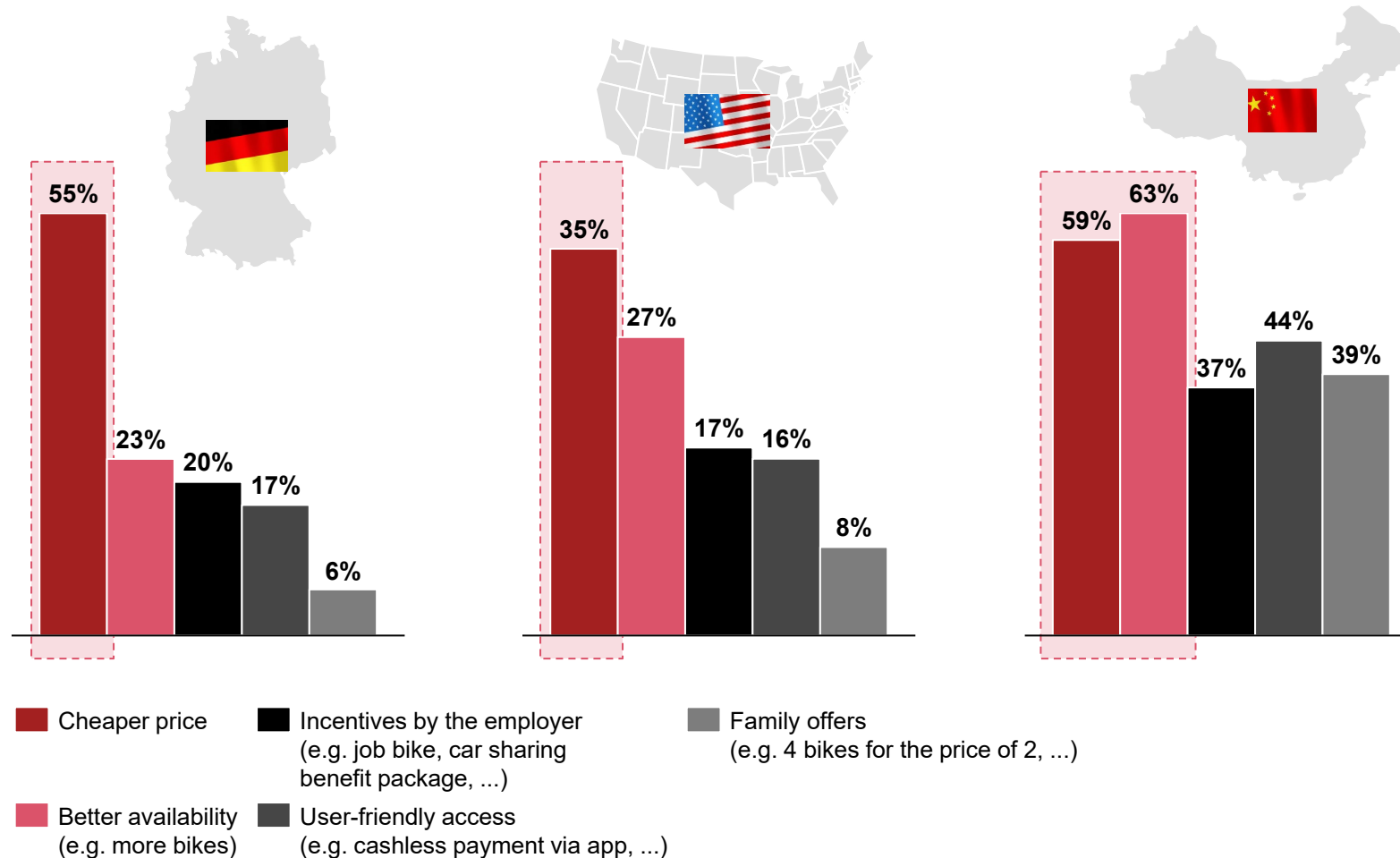
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High willingness to contribute to CO₂ reduction, esp. in China (97%) and in Germany (70%) whereas US respondents are less willing (52%).

Main contributions will be short distances more often on foot/by bicycle, or switching to an electric car.”

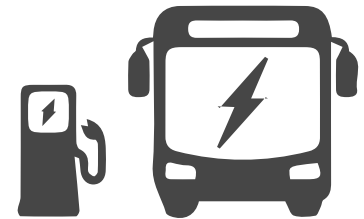
Price and availability are by far the top drivers for increasing the use of sustainable transport

Factors encouraging sustainable transportation modes



Question: “What would encourage you to use sustainable transportation (e.g. bike sharing, car sharing, public transportation) more frequently?”

”

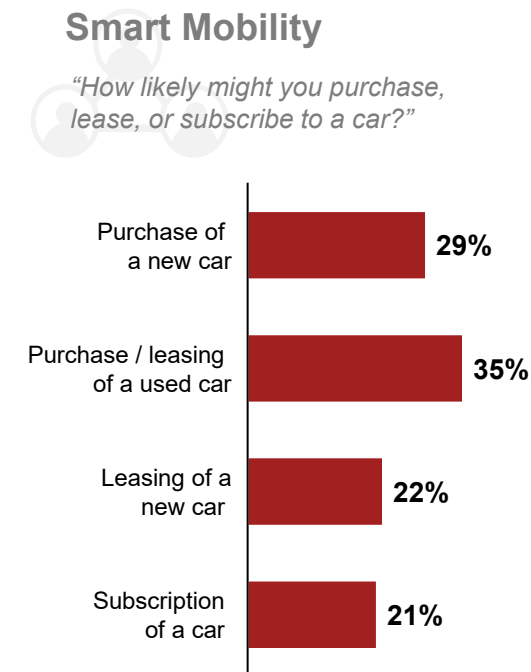
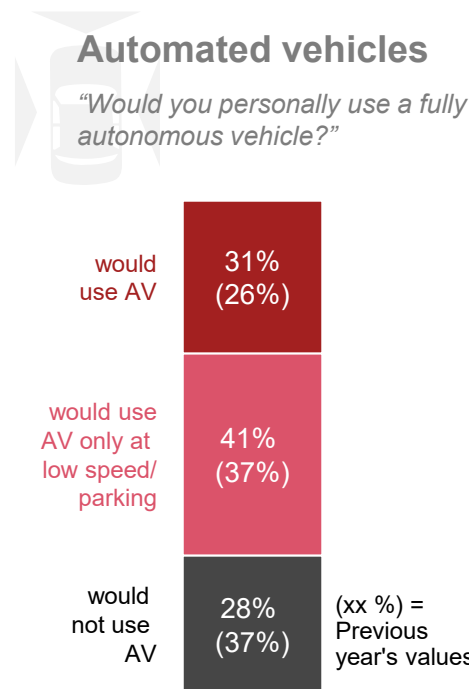
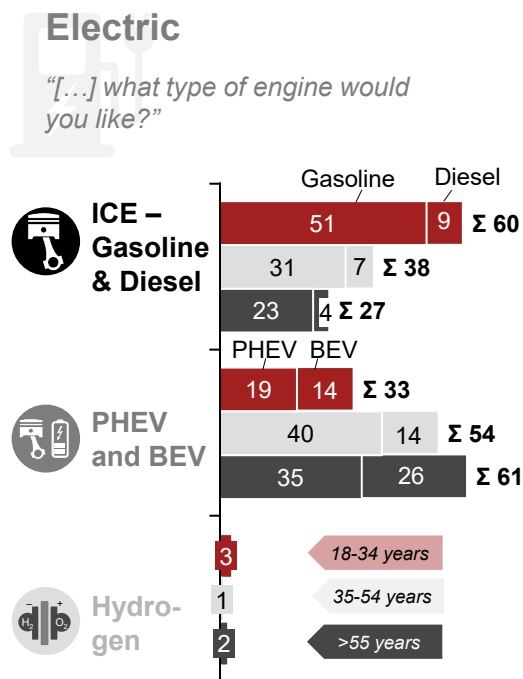
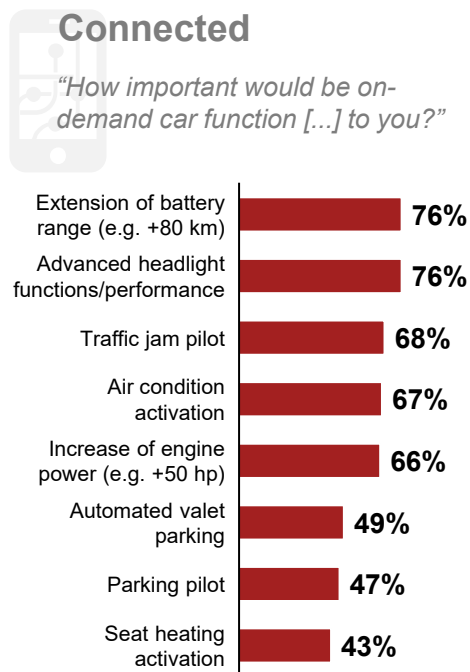


In **Germany** and the **US**, **cheaper prices** are most likely to encourage respondents to use sustainable transportation.

Chinese respondents, meanwhile, focus on **better availability.**”

Contrast: Japanese consumers display varied preferences – skeptical towards BEV, but open to AV and car subscriptions

Key highlights from Japanese consumer survey



” **Different order of preferences** of on-demand car functions in **Japan from other countries** – extension of battery range is rated most highly, along with advanced headlight functions/performance

Gasoline still most preferred type of engine among **youngest respondents**. However, esp. **PHEV most popular among 35-54 and 55+ year old respondents**

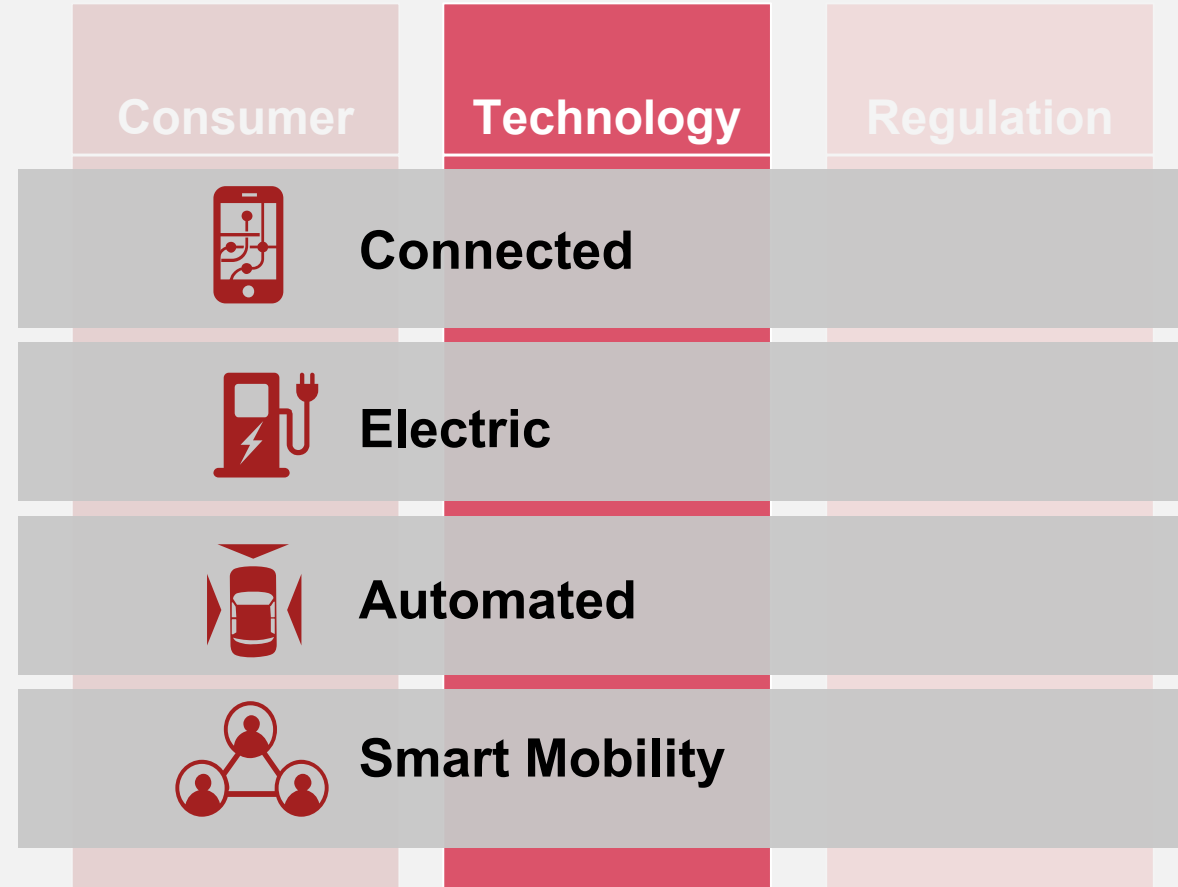
In contrast to other countries, positive development compared with previous year – **Japanese respondents gaining trust** in AVs

Lower intention to purchase/lease new/used car than in other countries. However, **subscription is gaining interest** when compared to **last year's survey (15%)**

“

Technology progresses fast – software-defined vehicle architecture and chip shortage most pressing topic in 2021”

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Enabling connected services will become the make-or-break factor for OEMs in the coming years

Connected services


Data/Insights Services

Vehicle optimization


 Cloud-supported vehicle analytics and optimization of configurations

Vehicle-Centric Connected Services


Automated driving

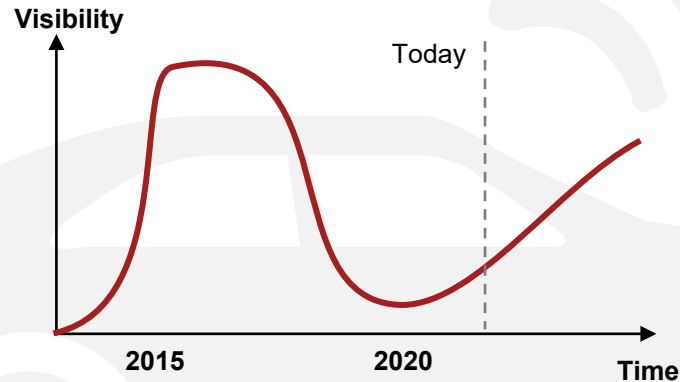
 Cloud-supported situation analytics and driving assistance

Secure software update

 Over-the-air update to elevate functionality and fix issues


Alarming and assistance

 Automatic notification in case of severe accidents or vehicle issues




Vehicle Features as a Service

Feature activation

 Dynamic activation/ deactivation of paid add-on services

5th Screen Services

Value added services

 Access to value-added services and revenues

Beyond Vehicle Services


Fleet management

 Support of fleet management and tracking services

Navigation and traffic information

 Access to up-to-date navigation and traffic information

Drive efficiency and safety

 Information exchange between road users and infrastructure

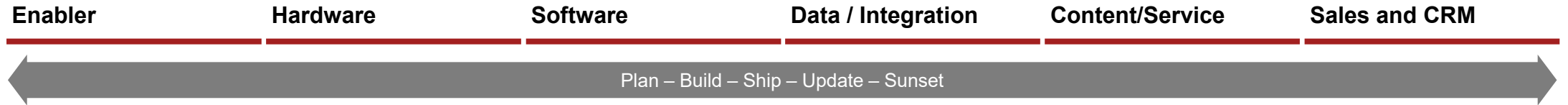
Still in its infancy

- Connected car services have the potential to transform the driving experience and to unlock new revenues streams for OEMs
- After initial hype, however, OEMs have lessened their focus on connected services. Available vehicle functionality is largely in its infancy
- New entrants are likely to enter the automotive market and differentiate themselves with new cloud-based services and an ability to adapt vehicle software on demand
- First movers will set the standard for future connected car technology and revenue models
- Traditional OEMs need to reconsider strengthening their commitment so that they can transform their vehicle and cloud platforms swiftly, and provide the foundation and scale for future growth



For connected services, OEMs are currently rethinking their build vs. buy strategy on key technology components

Connected service components of a software-defined vehicle



Key value blocks

Enabler	Hardware	Software	Data / Integration	Content/Service	Sales and CRM
Cloud infrastructure	Hardware and electronics architecture	Vehicle OS and Automotive cloud platform	Automotive Security and Compliance	Vehicle services and apps	Offering bundling and pricing
Communication technology (5G, V2x)	Integrated Circuits and Semiconductors	Vehicle OS and Automotive cloud platform	Data Analytics, Privacy and Ethics	Cloud/hybrid services incl. vehicle health services	User identification and personalization
Terrestrial and satellite communication networks	I/O devices (e.g., sensors, displays)	Secure Over-the-Air Update management	User interface and controls	3 rd party content and services	Customer support

Current limitations

<ul style="list-style-type: none"> Regional regulations Cybersecurity concerns MNO costs 	<ul style="list-style-type: none"> Transformation of E/E architecture Semiconductor availability 	<ul style="list-style-type: none"> Software capabilities Development processes Cybersecurity regulations 	<ul style="list-style-type: none"> System test capabilities Decision on closed vs. open systems Certifications 	<ul style="list-style-type: none"> Data ownership Revenue models 	<ul style="list-style-type: none"> Customer access/identification Data privacy
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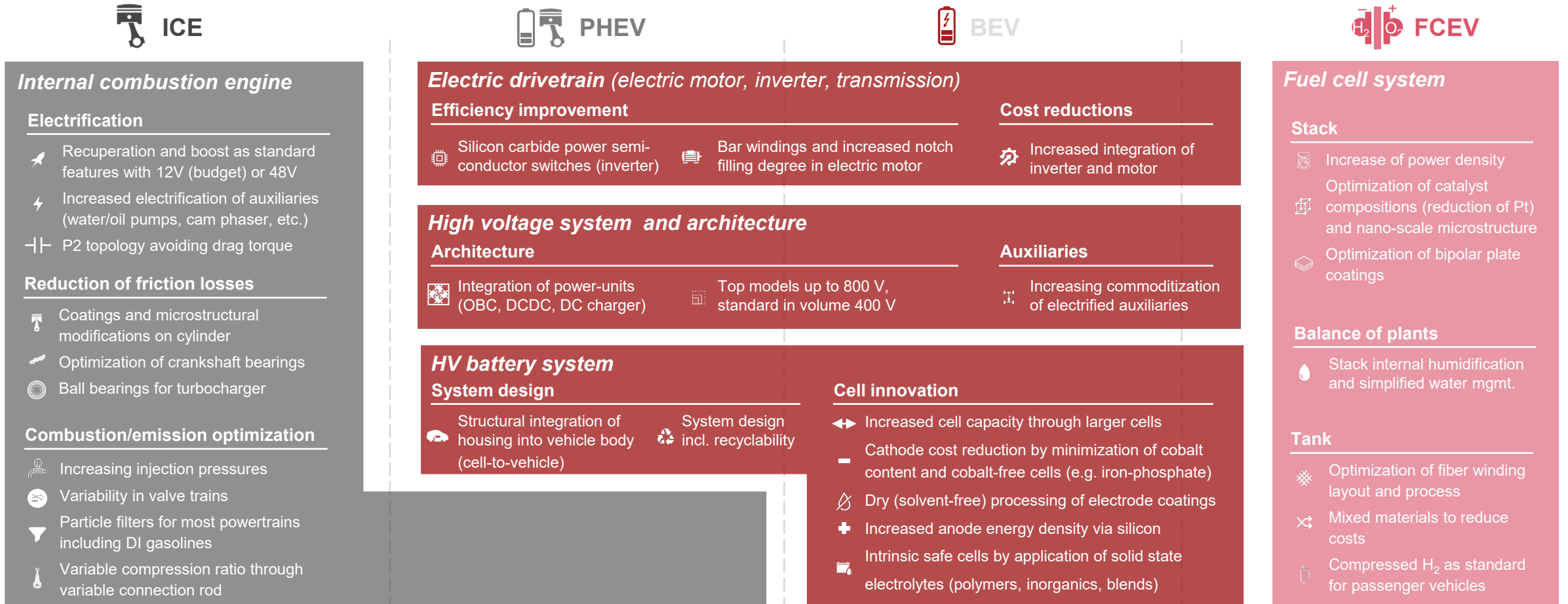
Current developments

<ul style="list-style-type: none"> Buy into cellular and satellite networks Build-up of cloud/edge infrastructures 	<ul style="list-style-type: none"> Development of own/tailed semiconductors Modular and expandable hardware architectures 	<ul style="list-style-type: none"> Development of own software stacks Build-up of own app stores 	<ul style="list-style-type: none"> Increase in automated test and compliance processes Build-up of own data/analytics platforms 	<ul style="list-style-type: none"> Expansion of cross-industry and technology alliances 	<ul style="list-style-type: none"> Centralization of sales processes Cross financing/subscription contracts
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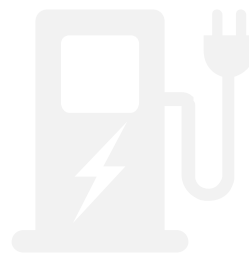
Technology progress in e-mobility must be evaluated in the context of tech trends across various alternative powertrains



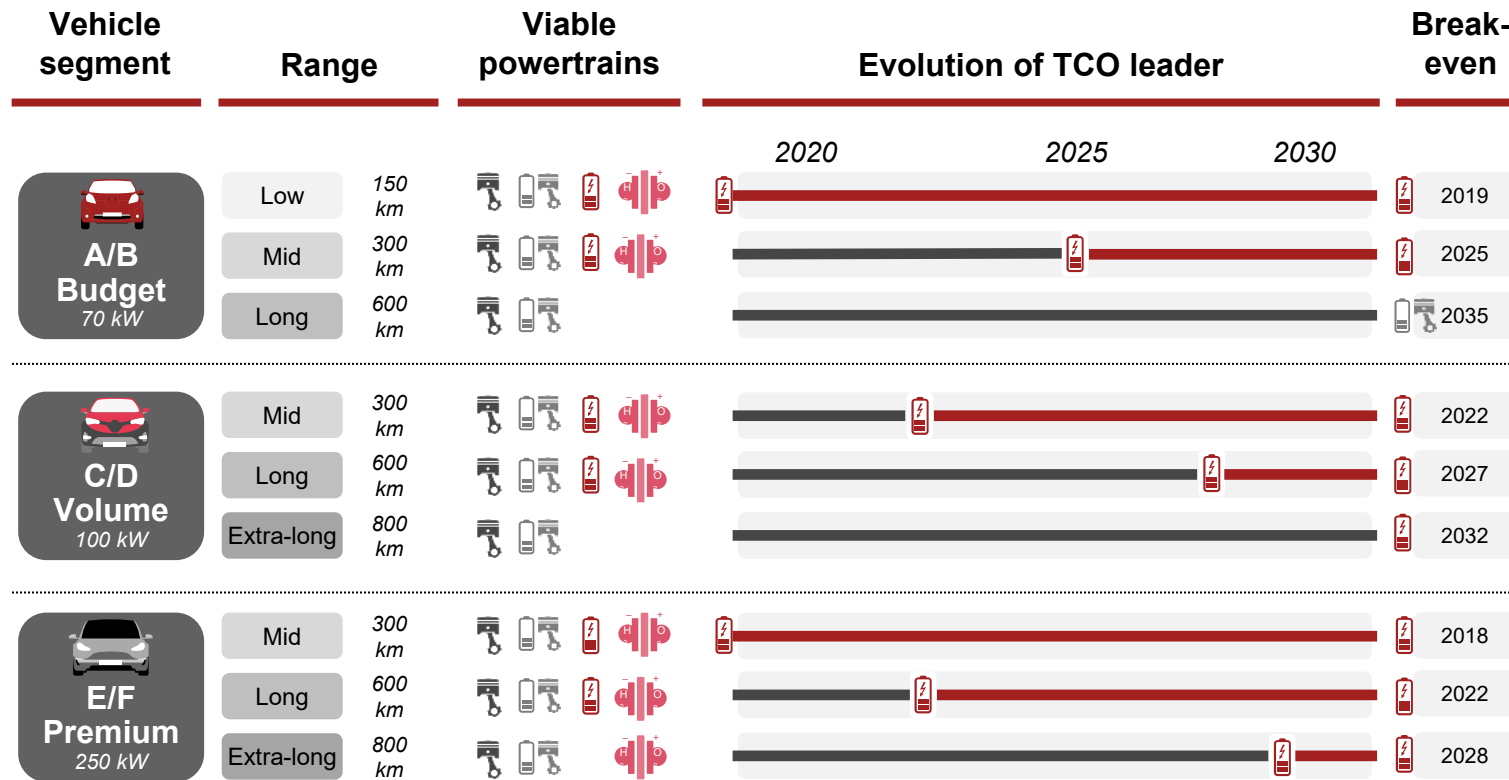
Alternative powertrain developments



By the end of the decade, BEVs will be the most economic powertrain solution for almost all segments



Electric powertrain operating cost break-even timeline (vs. ICE)



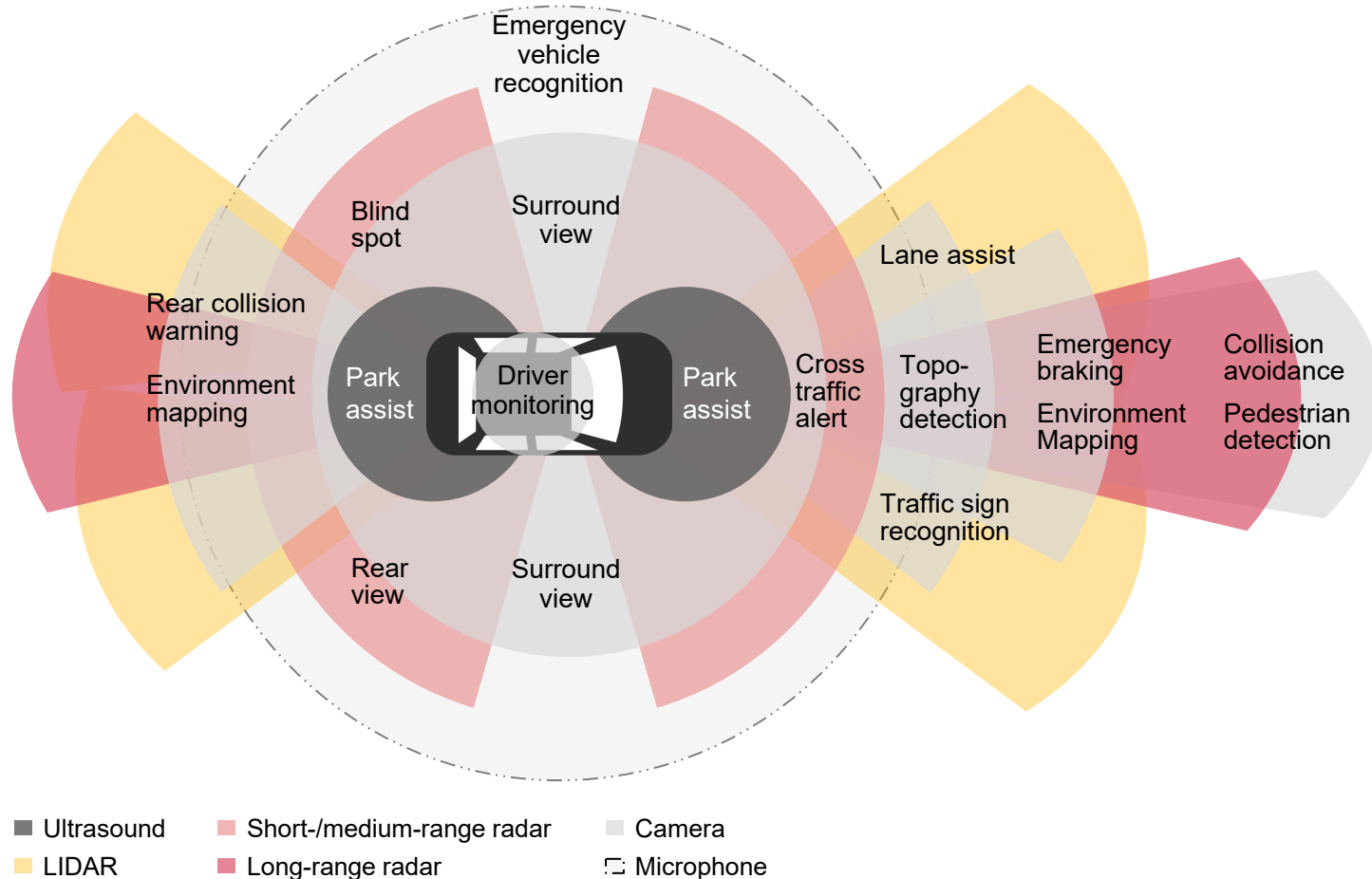
”

There is **no fixed point** in time when **battery electric vehicles will offer an operating cost advantage over internal combustion engines** – it depends on factors such as the vehicle segment and range”

Main assumptions: electricity and fuel prices as for Germany 2020; H2 price 5€/kg; PHEV driving modes 40% EV mode/60% ICE mode; FCEV driving modes 40% EV mode/60% FC mode
One-time buying incentives not considered
Source: Strategy&

Hardware, software and infrastructure of automated driving are improving, but still not reached level necessary for scaling up

Automated driving technology developments



Current status and limitations

- Existing radar and camera technology will be improved to achieve better resolution. LiDAR technology has still not reached the cost point
- The appropriate sensor setting for future Level 3/4 vehicles has not yet been finally defined. Ongoing discussions between camera-only solution and other solutions
- New ADAS computers based on low power tech are under development
- Different driver assistant systems mandatory beginning 2022 in EU



Hardware
e.g. sensors



Software
e.g. smart data usage




Infrastructure
e.g. 5G

- Test and validation not yet mature
- Motion prediction still not completely solved
- Very large amounts of test data complicate traditional analytics
- So far, there are only a few test tracks that are fully developed for automated driving
- Expansion of 4G by 2022 for motorways in GER as basis for 5G
- For the time being only pseudo 5G based on 4G (non stand-alone)

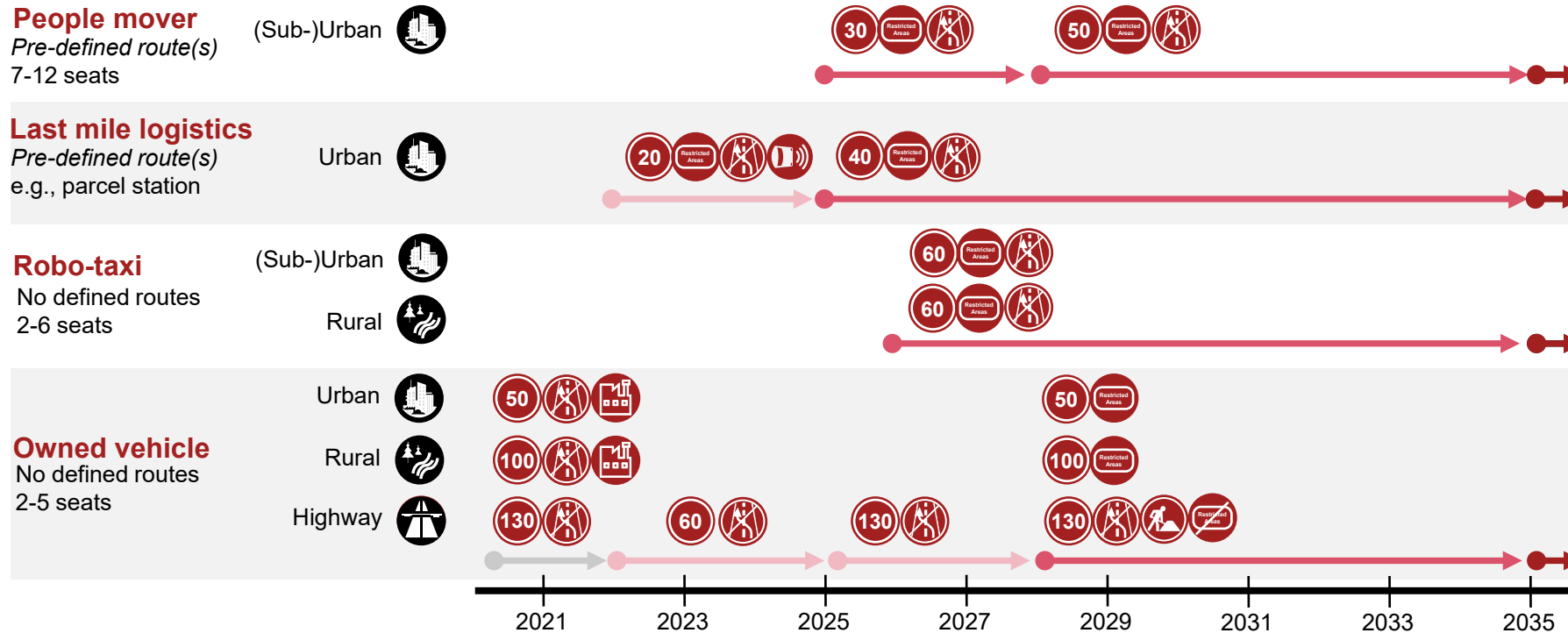
Once reaching maturity at L3 with broad use case deployment, rapid breakthrough of L4 technologies expected soon after

Automated driving SAE levels and AD function mapping

			Vehicle control	Environment monitoring and user interface	Fallback for dynamic driving task	System capability	Exemplary AD functionalities
 <p style="text-align: center;">AUTOMATION</p> <p style="text-align: center;">↑ HIGH</p> <p style="text-align: center;">↓ LOW</p>	5 Full driving automation	The system performs all aspects of dynamic driving (driving-mode specific)...	System	System	System	All driving modes	<ul style="list-style-type: none"> • Universal pilot (full autonomy) • Interactive pilot driving (control via touch/gesture UI) • Robo-taxi and automated people-mover (all conditions)
	4 High driving automation			...even if a human driver does not respond appropriately to a request to intervene (ODD specific)	Alternative or conventional user interface	System	Most driving modes
	3 Conditional driving automation	... expecting the human driver to respond appropriately to an intervention request (ODD specific)	System	Human	Human	Some driving modes	<ul style="list-style-type: none"> • Urban/rural/highway <u>assistant</u> (e.g. hands-off traffic jam, intersection movement, single lane change) • Parking chauffeur • Assisted fleet operations (on-site, off-highway)
	d Partial Driving automation	The human driver performs remaining aspects of dynamic driving, while the systemexecutes both steering and acceleration/deceleration (driving-mode specific and depending on ODD)...					Human
	1 Driver assistance	...executes either steering or acceleration/deceleration (driving-mode specific and depending on ODD)	Human and System	Conventional user interface	Human	Some driving modes	<ul style="list-style-type: none"> • Adaptive cruise control • Driver assisted parking assistant • Lane keeping assistant (system steers) • Blind spot monitoring rear/side (system steers)
	0 No driving automation	The human driver performs all aspects of dynamic driving, potentially “enhanced” by warning or intervention systems	Human			n/a	<ul style="list-style-type: none"> • Pre-/forward- collision braking • Front/rear cross-traffic alert with braking

Commercially viable automated driving applications at L3 and beyond will start becoming available for specific use cases first

Automated driving timeline of commercial road availability



Current developments

- ADAS¹⁾ technologies require **higher development cost** and efforts than anticipated
- ADAS **sensors** still far **above target cost**, due to small production volumes and sensor fusion/recognition challenges
- **Regulation** is advancing, with UN/ECE technical framework being finalized and e.g. German law for automated and autonomous driving already in place
- First **L3 vehicle** is already approved up to 60 km/h according to **UNECE ALKS**. **Further vehicles** expected for **2021/22**

Commercial availability (beyond pilot projects)²⁾

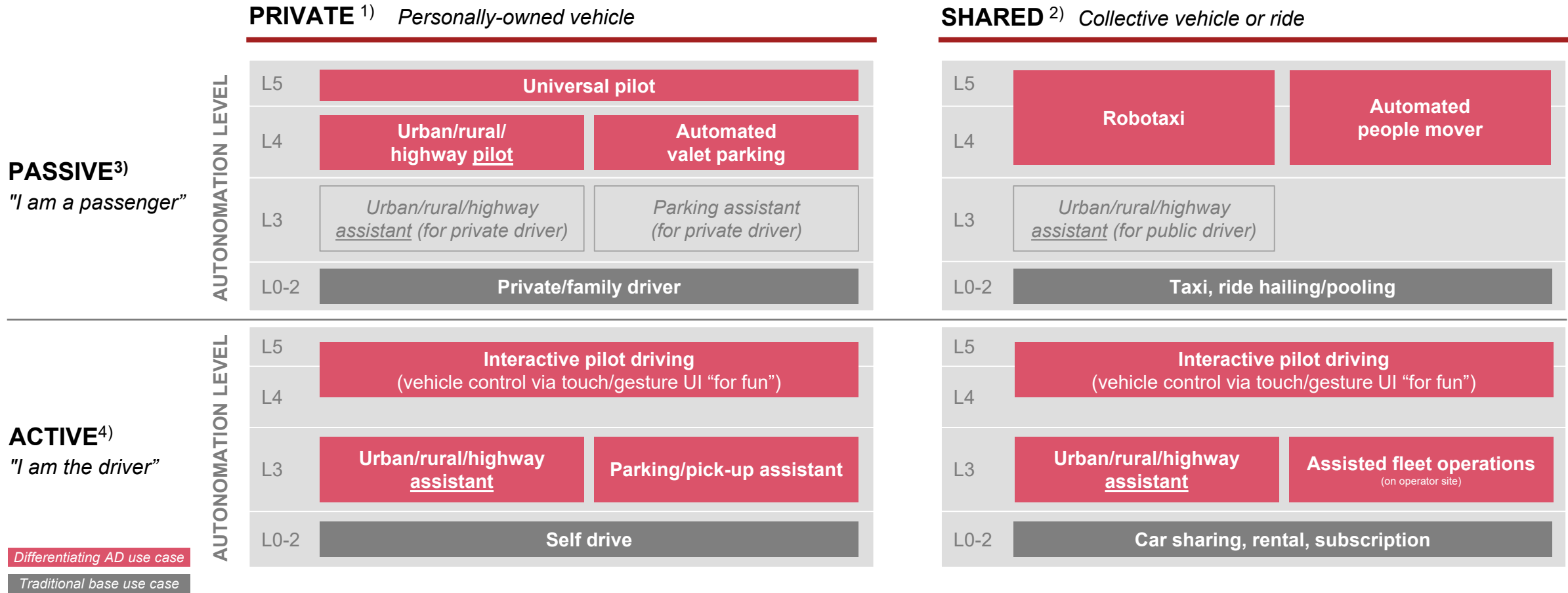
●→ Level 2+ ●→ Level 3 ●→ Level 4 ●→ Level 5
 ⓧ Max. speed ⓧ Construction area capable ⓧ Closed compounds
 ⓧ Area restriction ⓧ Automated lane changes ⓧ Vehicle follows user

Urban: Traffic situations with many traffic interactions and low speeds
Sub-Urban: Traffic situations with moderate traffic interactions and moderate speeds
Rural: Traffic situations with few traffic interactions and higher speeds

1) ADAS = Advanced Driver Assistance Systems
 2) Indicating start of availability. Tipping points of significant adoption expected significantly later in certain fields

Individual mobility divides into four modes of private vs. shared and active vs. passive driving, each with increasing automation

Private/shared mobility modes with selected automated driving use cases





1) Includes self-owned, family-owned, credit-financed, long-term leased, personal company car 2) Includes rental, subscription (up to 1 year), ride-hailing, ride-sharing, car sharing, pool car, car club
 3) "Passenger" determines mobility purpose / destination and selects means of transport with certain expected time of arrival; "mobility system" determines detailed routing and actual time/place of arrival
 4) "Driver" determines mobility purpose / target and selects means of transport with certain arrival time; "driver" determines detailed routing and actual time / place of arrival through User Interface (UI)
 Source: PwC AutoFacts®, Strategy&

Car sharing/subscription platforms rely on micro-mobility technology stacks when migrating towards electric car fleets


Smart mobility technology platform building blocks – Example of e-vehicle fleet provider


Key benefits

 *Intuitive digital user experience*

 *Easy electric vehicle access*

 *High vehicle availability*

 *Reliable & fast charging*

 *Efficient business operations*

Technical platform capabilities

User interface and apps
(drivers, fleet operators, partners)

Customer operations

Onboarding (identity, access, ...)	Charging and maintenance	Incident management
Calculation and contracting		Billing and payment

Asset and fleet management

Vehicle condition monitoring/telematics	Asset lifecycle management	Maintenance and repair management
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Charging and battery management

Energy demand prediction	Charge point management	Battery replacement and recycling
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Internal Business Operations

Customer acquisition/marketing	Finance and controlling, risk and legal, HR, ..	IT mgmt (IoT, data and analytics, cyber, ..)
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Partner integration (API) and external data sourcing





Current developments

- Providing a seamless electric vehicle sharing/subscription experience, requires a holistic **technology architecture and IT platform approach** covering functionalities on five levels
- The IT platforms need to address very **different performance requirements** (e.g. operating telematics/fleet monitoring vs. managing back-end billing processes)
- To enable fast scale-up in multiple cities, **API/open standards/interfaces are key** to swift onboarding of **external partners** and **adoption of local** (regulatory) requirements
- **Cloud-based systems** ensure high reliability/scale-up flexibility, while supporting efficient process execution

“

Regulation is aiming to accelerate the mobility transformation – but various regions have followed very different approaches”

Digital Auto Report 2021 – Volume 1

Consumer	Technology	Regulation
	Connected	
	Electric	
	Automated	
	Smart Mobility	


China and EU leads regulatory discussions on CASE trends – EV penetration and AV enablement are leading focus areas

Latest regulatory initiatives and discussions (excerpt)




USA


- AUTOMATED** U.S. Department of Transportation released Automated Vehicles Comprehensive Plan laying out **strategy for safe integration of Automated Driving Systems** (01/2021)
- AUTOMATED** NHTSA issued a Standing General Order to **report crashes of L2-L5 vehicles** to identify safety issues emerging from automated vehicles (06/2021)
- ELECTRIC** Several measures from Biden administration to **accelerate deployment of EV charging infrastructure** (04/2021)

 **Lagging behind other regions; New impulses from Biden administration particularly for EVs expected**


EU

- AUTOMATED** Germany is first country to pass **regulation for completely driverless vehicles** allowing commercial deployment of L4 AV use-cases with focus on MaaS (05/2021)
 - AUTOMATED** France to allow **future use of vehicles controlled by automated driving systems** on predefined routes or zones starting from 09/2022 (07/2021)
 - ELECTRIC** EC adopted a package under **European Green Deal** incl. CO₂ emission standards¹⁾ (07/2021)
 - ELECTRIC** EC promoting deployment of **alternative fuels infrastructure** with directive revision and **Strategic Rollout Action Plan**
-  **EU states with a siloed / bottom-up approach towards CASE regulation**

China

- AUTOMATED** Draft to amend Road Traffic Safety Law clarifying **requirements for AV road testing** and regulating liabilities for traffic violations and accidents (03/2021)
 - AUTOMATED** Guide for Admission of Intelligent and Connected Vehicle Manufacturers and Products drafted **regulation of safety requirements for AV manufacturers** (04/2021)
 - ELECTRIC** **New Energy Vehicle Industrial Development Plan for 2021 to 2035** with 5 strategic tasks released²⁾ (10/2020)
 - ELECTRIC** Regulations on Recall of Motor Vehicle Emissions **extending original safety recalls to emission recalls** (07/2021)
-  **Top-down approach based on long-term strategy with positive impact on CASE**

GLOBAL

- CONNECTED** International regulation on **cybersecurity and software updates** as well as their respective management systems enacted by UNECE (01/2021)
 - AUTOMATED** UNECE establishing uniform provisions concerning **approval of vehicles with regard to Automated Lane Keeping Systems (ALKS)** (03/2021)
 - AUTOMATED** Release of new **ISO 22737** defining minimum requirements & test procedures for low-speed autonomous driving (LSAD) systems (designed to operate L4 automation) (07/2021)
-  **Recently introduced regulations at UN level with positive impact on CASE adoption, further steps required**

 Positive expert sentiment  Neutral expert sentiment  Negative expert sentiment

Note: (1) average emissions of new cars to come down by 55% from 2030 and 100% from 2035 compared to 2021 levels (2) 1: improve capacity for technology innovation; 2: build an NEV industry ecosystem; 3: advance industrial integration and development; 4: build a sound infrastructure system; and 5: increase openness and deepen international cooperation

AV = Automated vehicle; EC = European Commission; NCAP = New Car Assessment Program; NHTSA = National Highway Traffic Safety Administration; UNECE = United Nations Economic Commission for Europe

Developing capabilities to comply with data regulation is vital if OEMs are to exploit CASE opportunities fully

Major data regulations (excerpt)



Objective

	Data governance act	Strengthen data sharing mechanisms
	Trade secret protection act	Define and protect trade secrets
	Digital markets act	Regulate gatekeeper platforms
	Digital services act	Regulate online intermediaries and platforms
	GDPR	Ensure data protection and privacy
	Further regulations accelerating data sharing	Facilitate data sharing among public and private bodies

Framework for data sharing/ usage under ultimate premise of protecting customers privacy and data rights



Objective

	Federal privacy laws	Domain and sector specific regulations for privacy protection
	State-level privacy laws	Grant rights for data privacy protection
	Federal gov data publication laws	Make government-held information accessible to public
	Driver's Privacy Protection Act	Governs privacy and disclosure of personal information

Heterogeneous regulation across states, balancing privacy concerns and adoption of new technologies



Objective

	Civil code	Specify right of privacy of natural persons
	China cybersecurity law	Protect data e.g. by storage of personal and important data within the PRC
	Provisions on management of automotive data security	Regulate handling of personal and important data in automotive
	Multiple national standards	Foster measures to protect data and prevent unauthorized access and abuse

Increasing complexity and requirements to meet privacy requirements as well as national interests
 → need for China-specific data solutions

Network contacts



Jörg Krings

joerg.krings@
strategyand.de.pwc.com

Automotive Europe



Andreas Gissler

andreas.gissler@
strategyand.de.pwc.com

Digital Transformation



Jonas Seyfferth

jonas.seyfferth@
strategyand.de.pwc.com

Connected & Smart Mobility



Hartmut Güthner

hartmut.guethner@
strategyand.de.pwc.com

Automated Driving



Jörn Neuhausen

joern.neuhausen@
strategyand.de.pwc.com

Alternative Powertrains



Claus Gruber

claus.gruber@
strategyand.de.pwc.com

Software Development



Akshay Singh

akshay.singh@
pwc.com

Automotive US



Steven Jiang

steven.jiang@
strategyand.cn.pwc.com

Automotive China



Kentaro Abe

kentaro.abe@
pwc.com

Automotive Japan

Contributors

Felix Andre

Kunal Arora

Steven van Arsdale

Thilo Bühnen

Christoph Faller

Andrew Higashi

Steffen Hoppe

Sebastian Jursch

Tobias Killmeier

Felix Kuhnert

Anil Khurana

Patrick Lill

Nicola Schudnagies