strategy&
Part of the PwC network

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 new normal world, 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[1]) 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[2]** (-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.

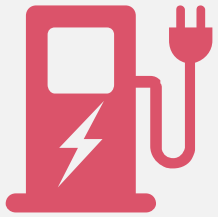
Despite consumer reluctance to share vehicles or rides during the pandemic, **smart mobility** modes beyond vehicle ownership are expected to grow in the long term. With rising number of car-subscription offerings, **shared-active** (e.g. rental, subscription) is expected to grow strongest **in Europe** (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)

1) n= 1000 GER; 1000 US; 1000 CN; 1000 JP – focus in respective section on GER; US; CN 2) Europe refers to EU 27 + Norway + Great Britain + Switzerland within this report
Note: Please refer to respective section for detailed assumptions and sources behind stated propositions

“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.

Strategy&

Source: Strategy&

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 toplines 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 becomes top priority

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; infra-structure next bottleneck

Source: Strategy&

Sustainability has become a major driver for change in auto

2021 Highlight I: Sustainability

Sustainability transformation drivers

Public perception

- **Customers** demand **genuine ESG**[1] actions
- Employer brand to **meet ESG talent expectations**
- **Higher transparency** on **social responsibility** along **supply chain**, e.g. for battery materials

73% … of customers want to change their mobility behavior to lower CO_2 emissions

86% … of employees prefer to work for firms that care about the same issues they do

Regulation

- **EU taxonomy** and **ESG reporting** standards
- **Compliance system** to fulfill new regulations, e.g. on cybersecurity
- Recalibration of **KPI systems** to ESG topics, e.g. for executive pay

41% … Ø Zero Emission Vehicle sales required for CO_2 compliance in 2030

Nr.1 …barrier to ESG effectiveness is the lack of reporting standards

Net zero CO_2 pathway

- **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**

€1T …EU Green Deal funding, of which sustainable mobility is a central pillar

55% …reduction in passenger car emissions by 2030 (EU Green Deal)

Capital markets

- Booming demand for **ESG investment classes**
- Growing relevance of top **ESG rating positions**
- Maturing **ESG investor reporting** and changing **OEM equity story**

€120bn All-time high inflows in Q1/21 for EU sustainable funds[2] (plus 18% vs. Q1/20)

6/10 … of best-performing funds in EU were related to ESG in Q1 2021

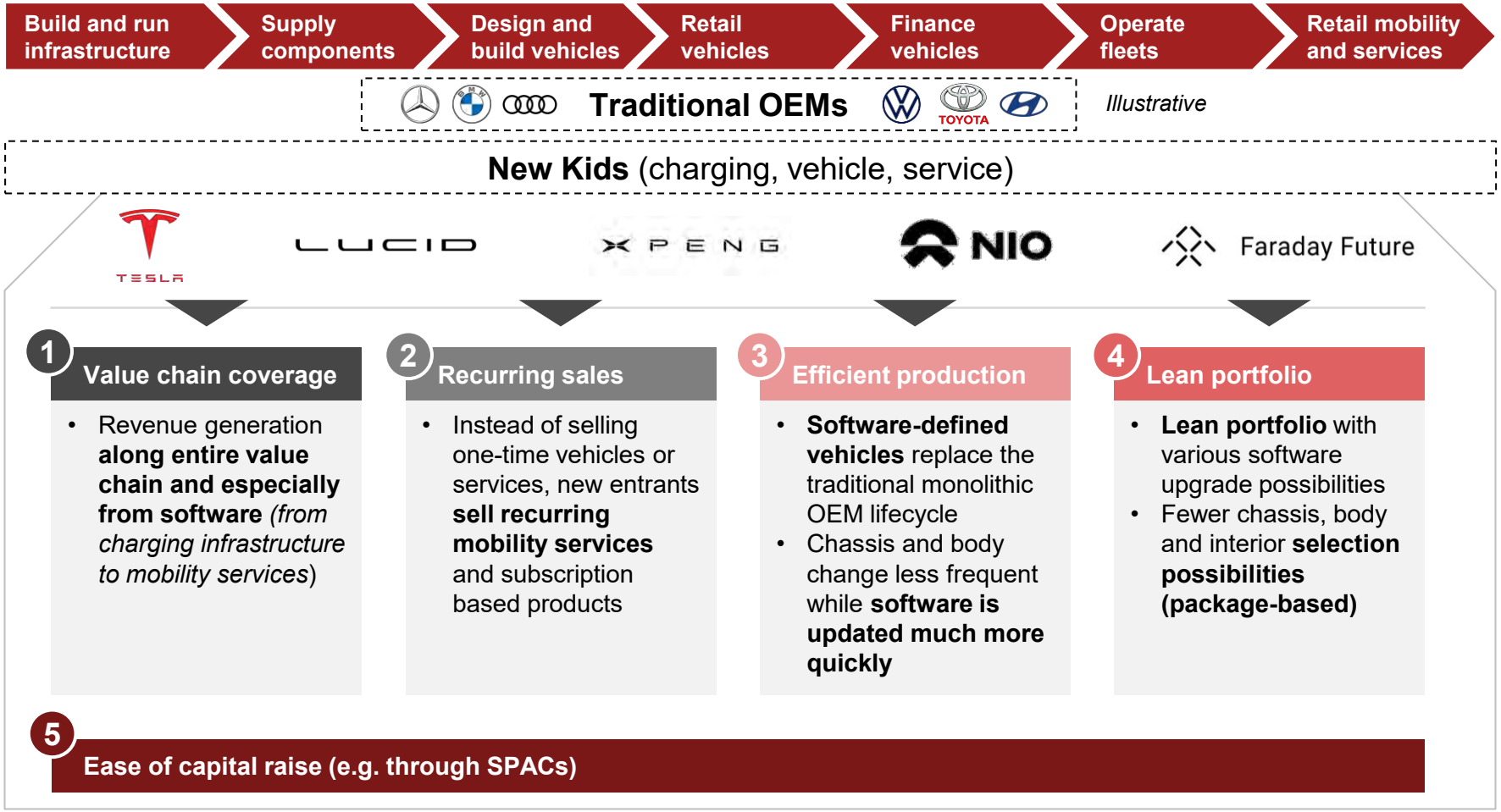
CASE implications

- 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

1) Environment, Social and Governance
2) Morningstar – European sustainable fund flows Q1 2021
Source: PwC and Strategy& analysis

New entrants redefine the rules of the automotive value game

2021 Highlight II: New kids on the block



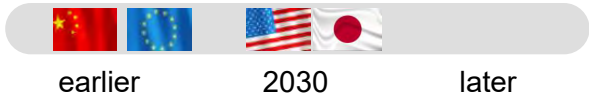
Selected key facts

1. **~45%**
   Overall profit expected to be generated from software in 2025[1)]
2. **$199**
   Tesla's monthly subscription price for full self-driving capability[2)]
3. **2024**
   Year in which BEV will achieve production cost parity with ICE[3)]
4. **~11+ vs. ~7**
   Average model runtime years Tesla Model S vs. traditional OEM models
5. **$99bn**
   Raised via automotive SPACs in 2020[4)]

1) UBS Research – EV operating profits 2) IHS Markit 3) CMBI – NEV Sales April 2021 4) SPAC figures display cash made available trough SPAC; not post-SPAC valuation
Source: Strategy&

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	• Connected service **content and UX** • Vehicle **system/EE architecture** • **Network infrastructure**	• **"Digitally savvy" share** of population • **"Freemium" segment** services	• Scope and timing of enforced **connectivity requirements** • Scope of **data sharing and privacy restrictions**	• **Indirect value capture** by OEM • **Effective end consumer pricing**	
Electric	• **Battery and powertrain performance** • EV **manufacturability and production capacity** • Charging infrastructure	• **Premium/early adopter** segment size • "**Rational green**" segment size	• **Emission target levels** • **BEV/PHEV incentives** • **Diesel/ICE bans/ restrictions** in cities	• Superior **total cost of ownership** (TCO) of BEV vs. ICE in relevant number of segments • **Additional revenues/ savings** from V2G/V2X charging	
Automated	• **ADAS** capability by use case • **Data processing** • **Driver UI** • **Network and traffic infrastructure**	• **Premium/early adopter segment** size • **Technology openness**	• Scope and timing of **enforced ADAS safety features** • Geographic **range and quantity of AV test drive/ vehicle approvals**	• **Superior TCO vs. non-AV** in first commercial cases • **Additional value capture** from riders	
Smart Mobility	• **Smartphone penetration** • **Access and fleet availability**	• **Intermodal openness** • People/**traffic density** "**Frequent** user" segment size	• **Private car restrictions**/ taxes • Passenger **transport regulation**	• **Superior TCO** vs. own vehicle • **Dynamic pricing** for opt. use and availability	

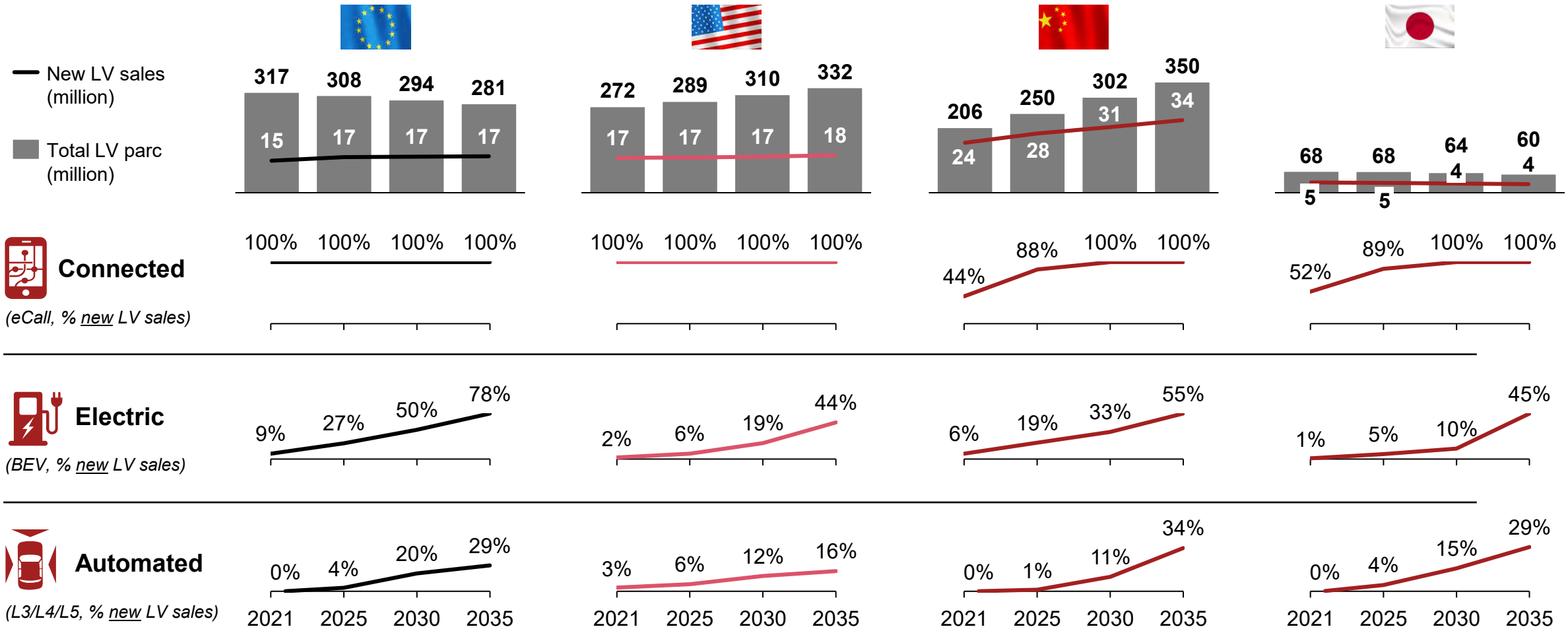
ADAS = Advanced Driver Assistance Systems; EE = Electric/electronics, V2G = Vehicle to grid, TCO = Total cost of ownership
Note: A tipping point is defined as the start of exponential growth within a segment of the mobility transformation
Source: Expert interviews, PwC AutoFacts®, Strategy&

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, %)



Source: PwC Autofacts®, Strategy&

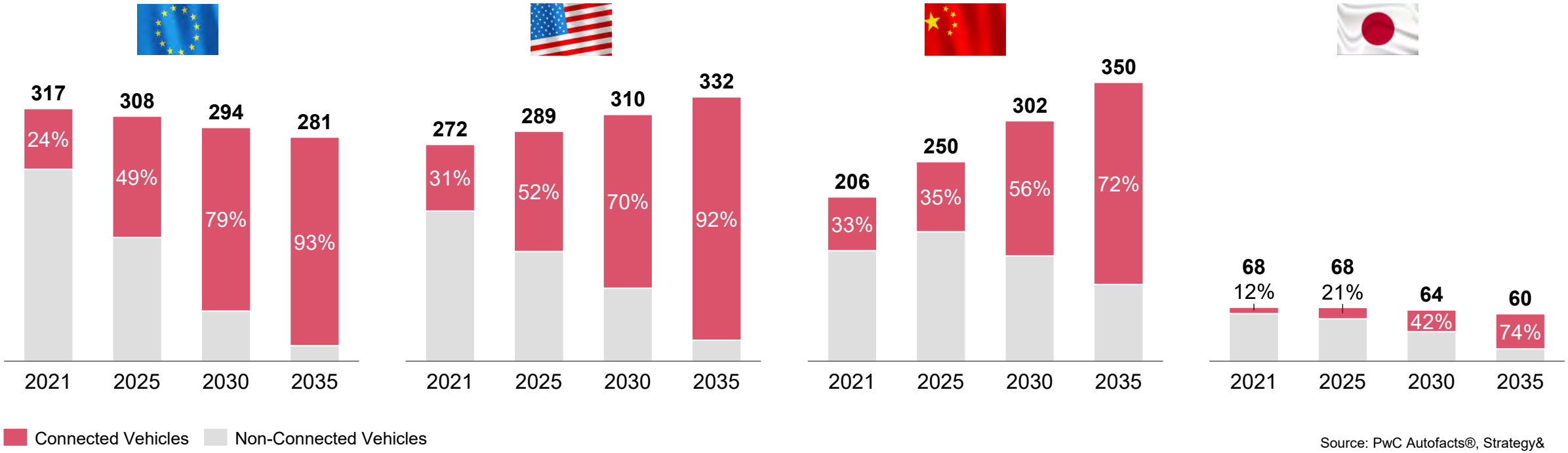
LV = Light Vehicles = Cars + Light Commercial Vehicles < 6t GVW

BEV = Battery Electric Vehicle

ICE = Internal Combustion Engine

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

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

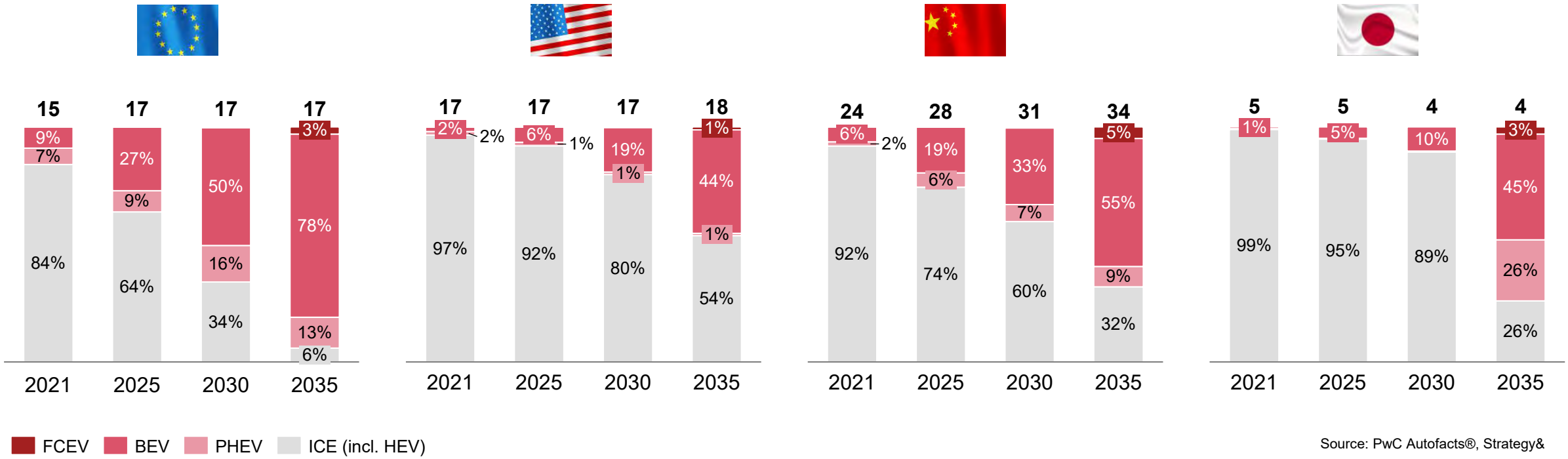


Source: PwC Autofacts®, Strategy&

> "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 faster than expected, China leads in total volume; Japan/US much slower

New vehicle sales by powertrain (in million units scaled to 100%)

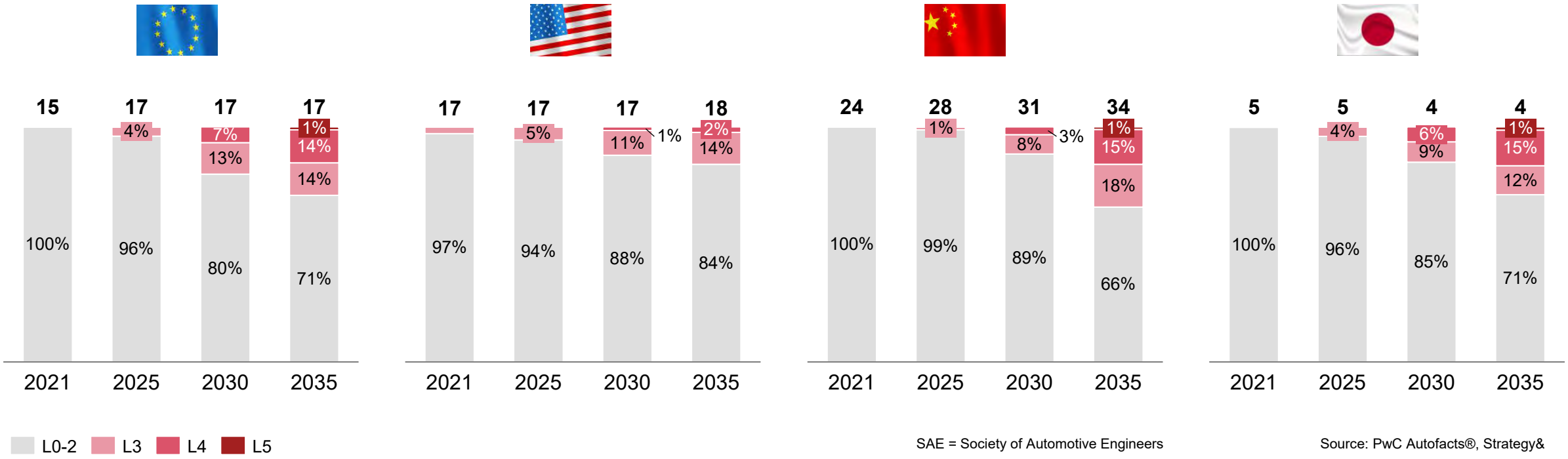


Source: PwC Autofacts®, Strategy&

> "The recently announced EU Green Deal seeks a 100% reduction in CO_2 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 units scaled to 100%)



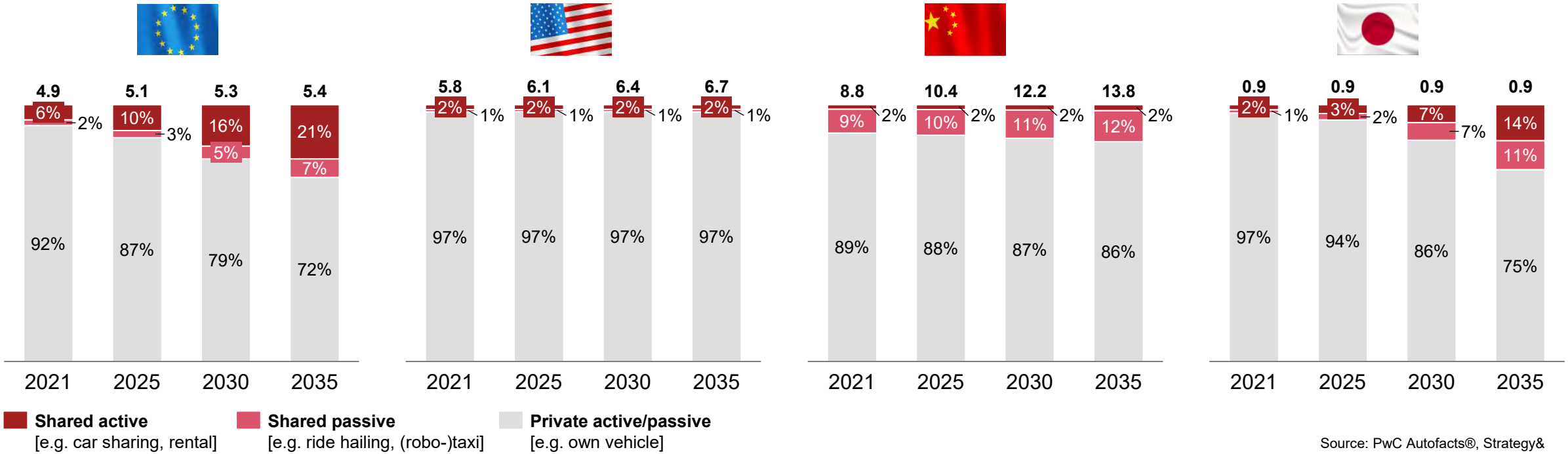
SAE = Society of Automotive Engineers

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

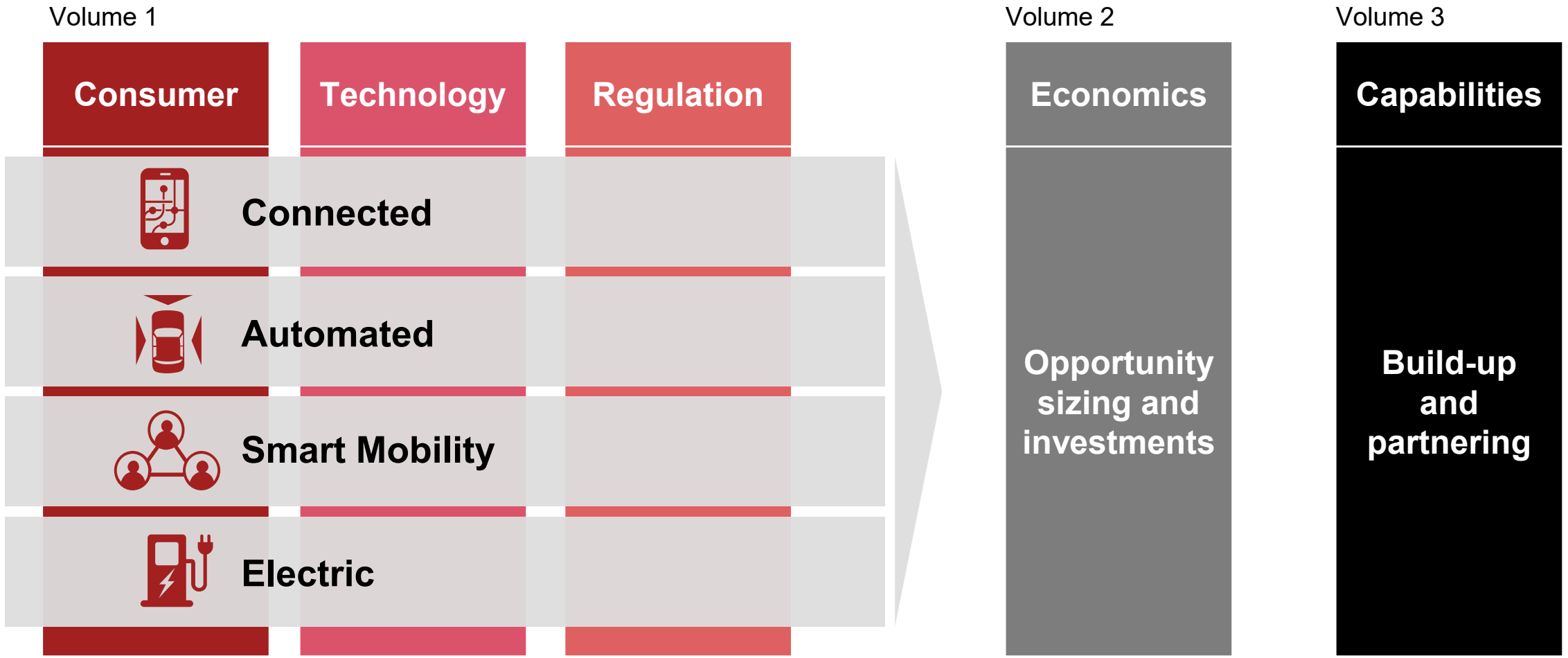
Market penetration by mobility mode (in '000 trillion person-kilometer scaled to %)



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."

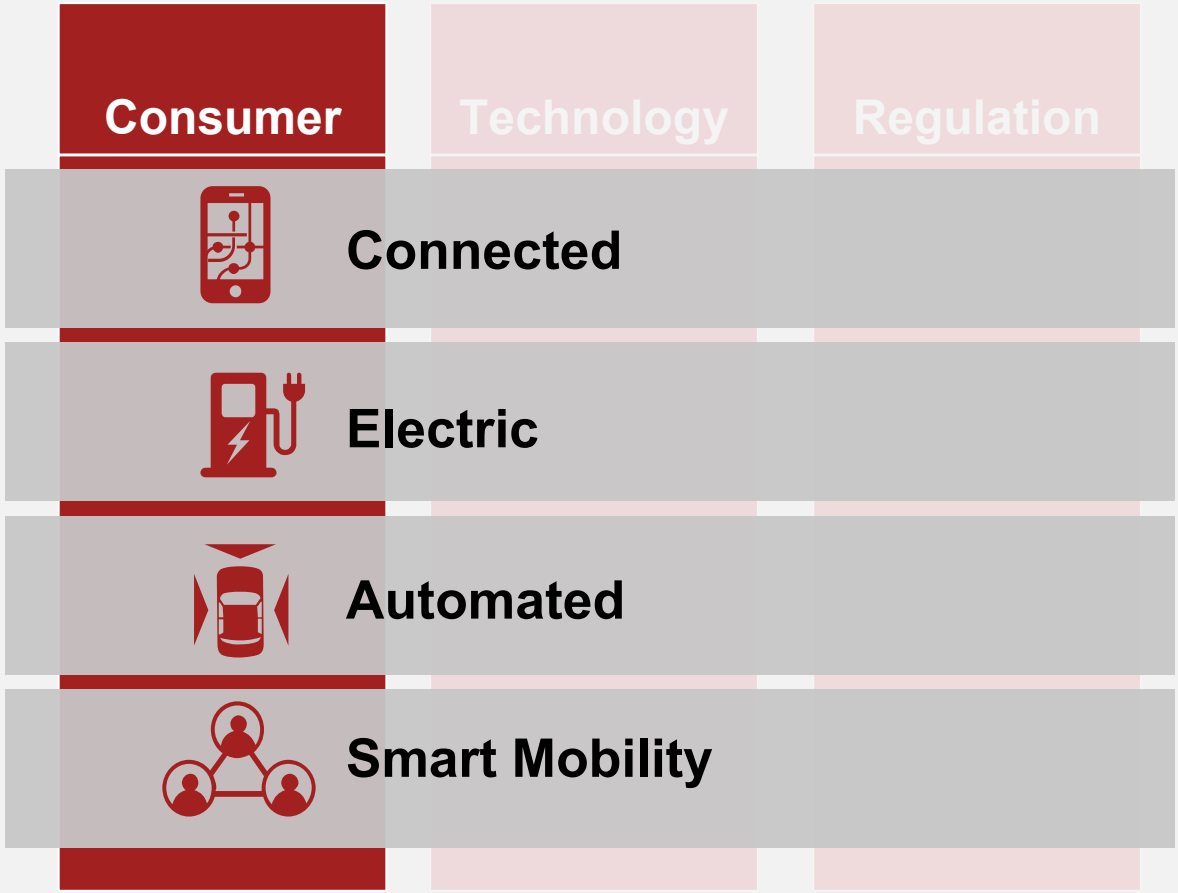
This report series is laid out in three volumes 1) CASE drivers, 2) economic opportunities, and 3) capability implications



Volume 1

Assessing global mobility market dynamics

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

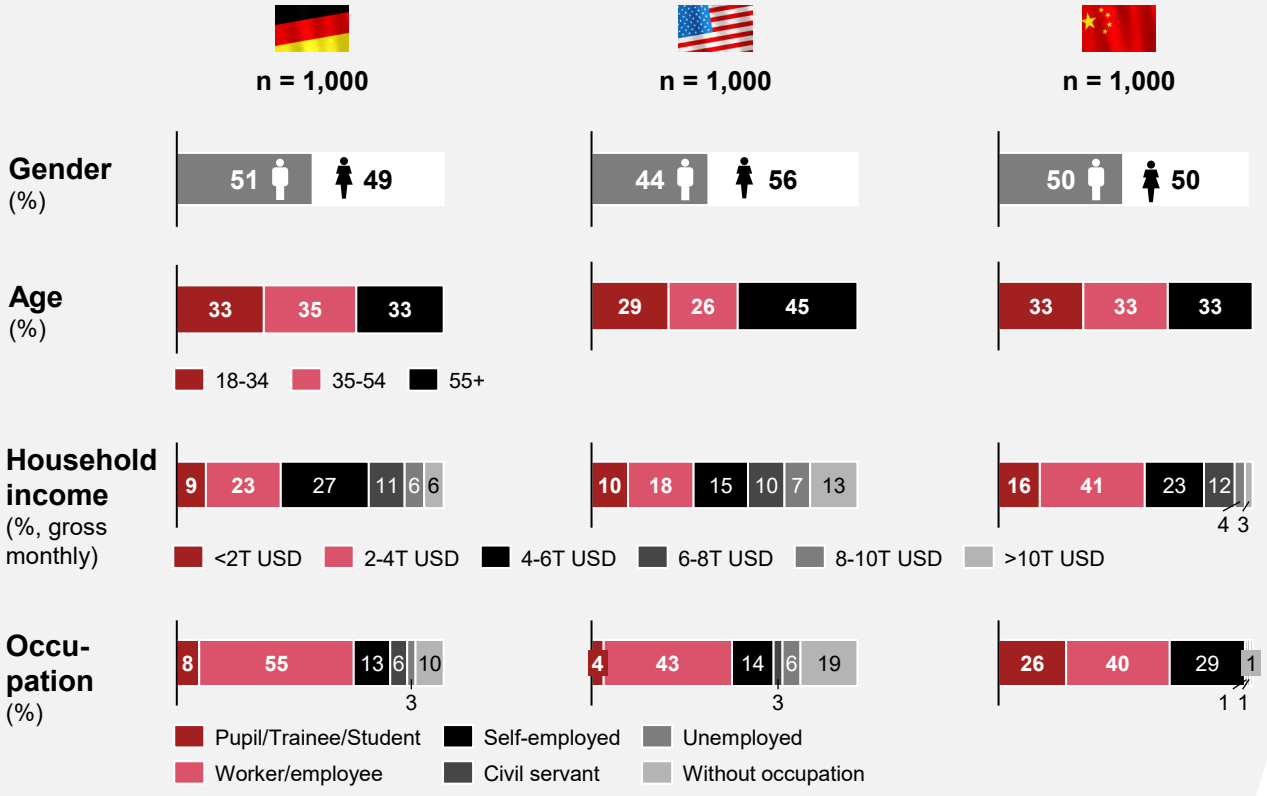


Source: Strategy&

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

Overview consumer survey

3 regions | **14 questions** | **3,000 respondents**



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**

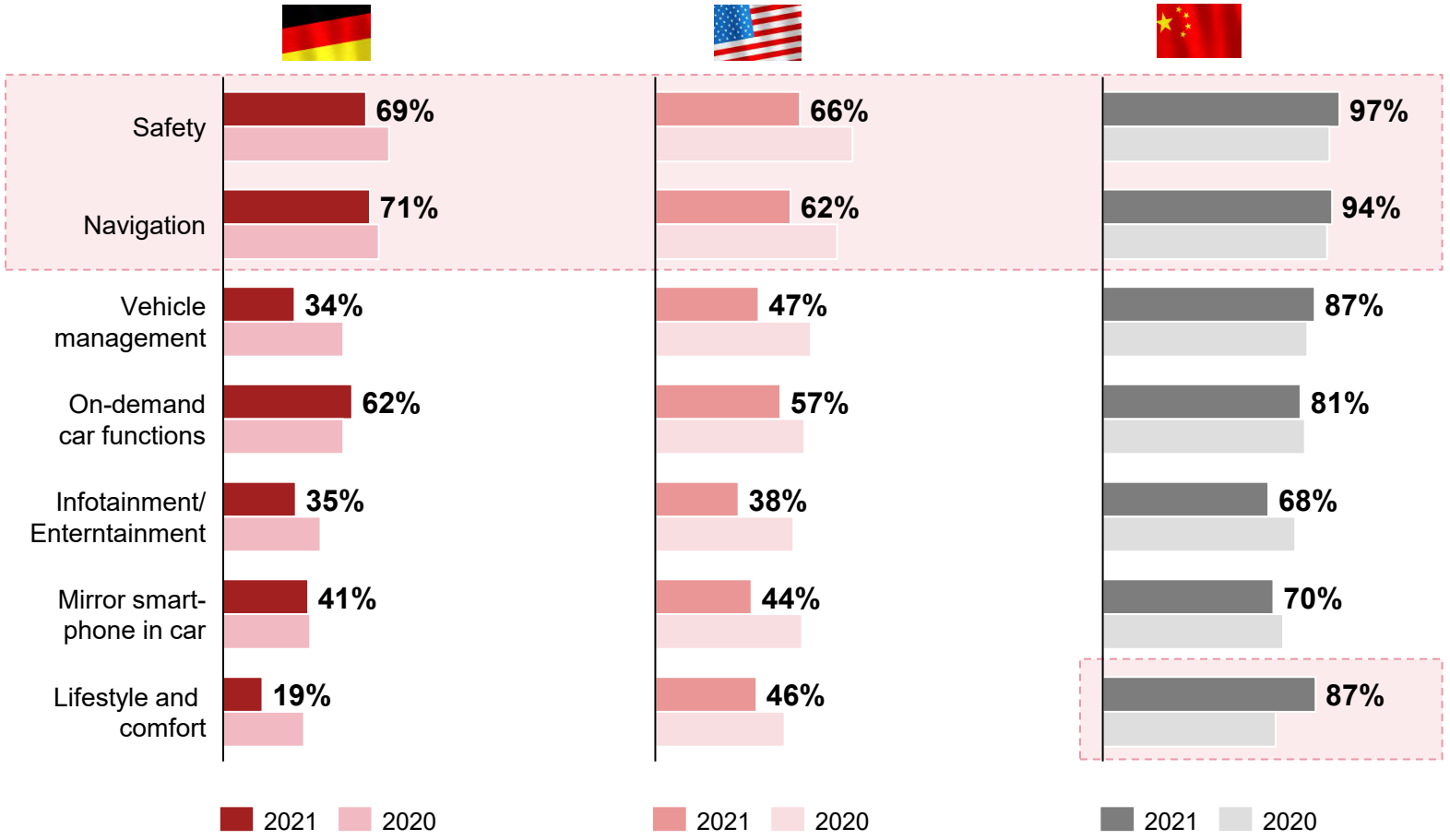
- **PHEVs** and **BEVs are most preferred** type of powertrain **only in China**; **Hydrogen gains popularity** in Germany
- **Insufficient driving range** and **concerns** about **charging options put** respondents **off** driving **electric** cars

- Respondents **indicate lower trust** in the use of **automated** cars compared to last year's survey
- **High willingness to pay** for **automated driving** among those respondents who do trust the technology

- **Moderate intention** to **purchase a new or used car**, but 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

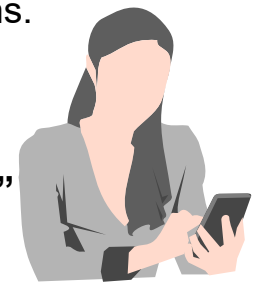
Connected services – By importance for consumers



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."**



Source: PwC Strategy& consumer research 2020; n=3,000 (1,000 DE, 1,000 US, 1,000 CN); PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

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 pay[1)]

***Ø Willingness to pay** (annual)*	*vs.*	***Reference prices of other digital & media services***		
…for a "full set" of connected services in the vehicle		Music subscription[2)]	Adobe Photoshop license	Home internet with premium/ Sport TV[3)]
$ 180 *at **69%** willingness*		**$ 142**	**$ 338**	**$ 1,300**
$ 148 *at **62%** willingness*		**$ 120**	**$ 250**	**$ 1,200**
$ 52[4)] *at **94%** willingness*		**$ 28**	**$ 138**	**$ 520**

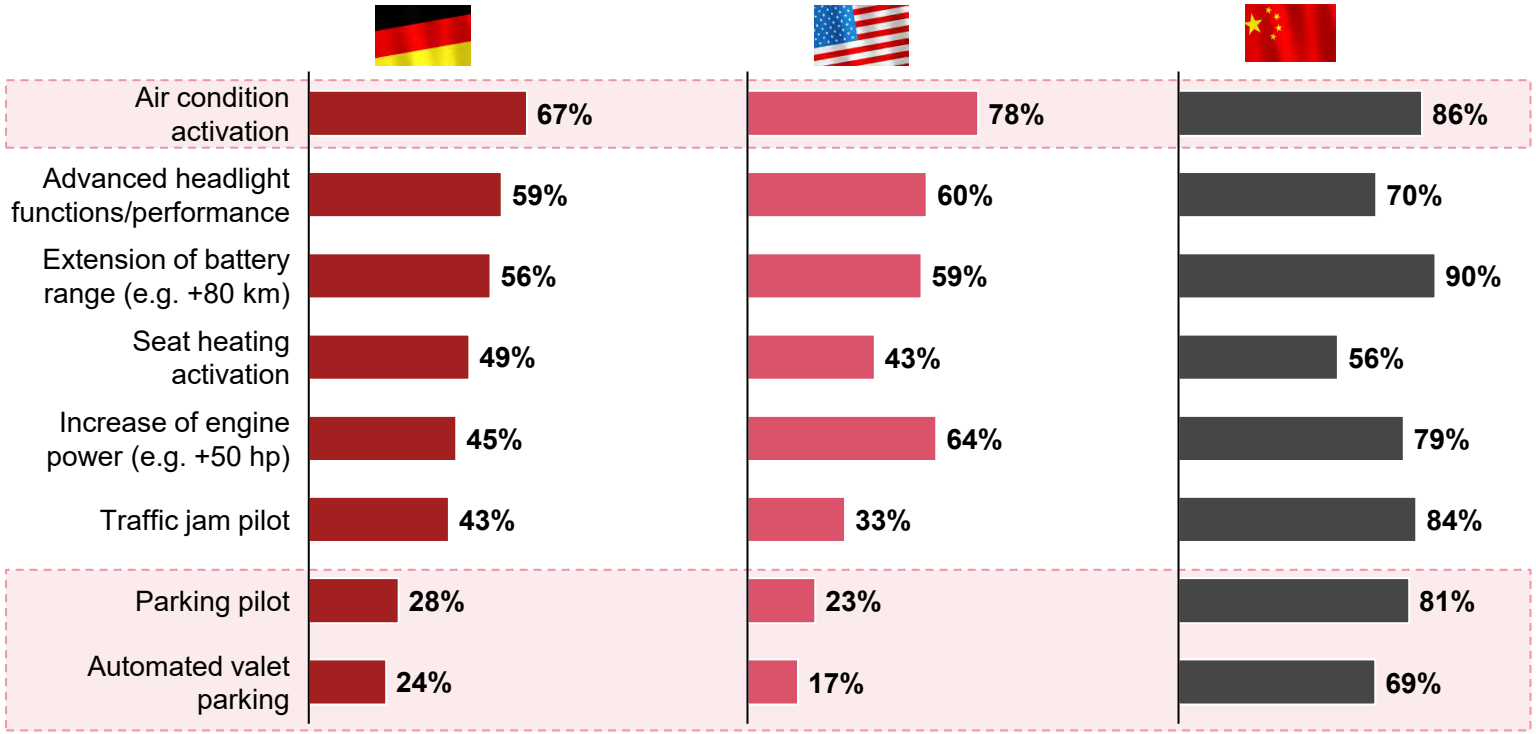
Acceptance of paying at all for connected car services **has increased across regions**

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."

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN) 1) Local currency conversion to USD
2) For GER and US "Individual" plan Spotify, for CN Kugou Music VIP membership 3) For GER Sky, for US Xfinity; for CN Tencent 4) PwC Strategy& consumer research 2020: n=1000 CN

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?"*

Ø annual willingness to pay[1)] for car that offers a full set of multiple on-demand car functions

$ 675 *at **60% willingness***

$ 760 *at **45% willingness***

n/a

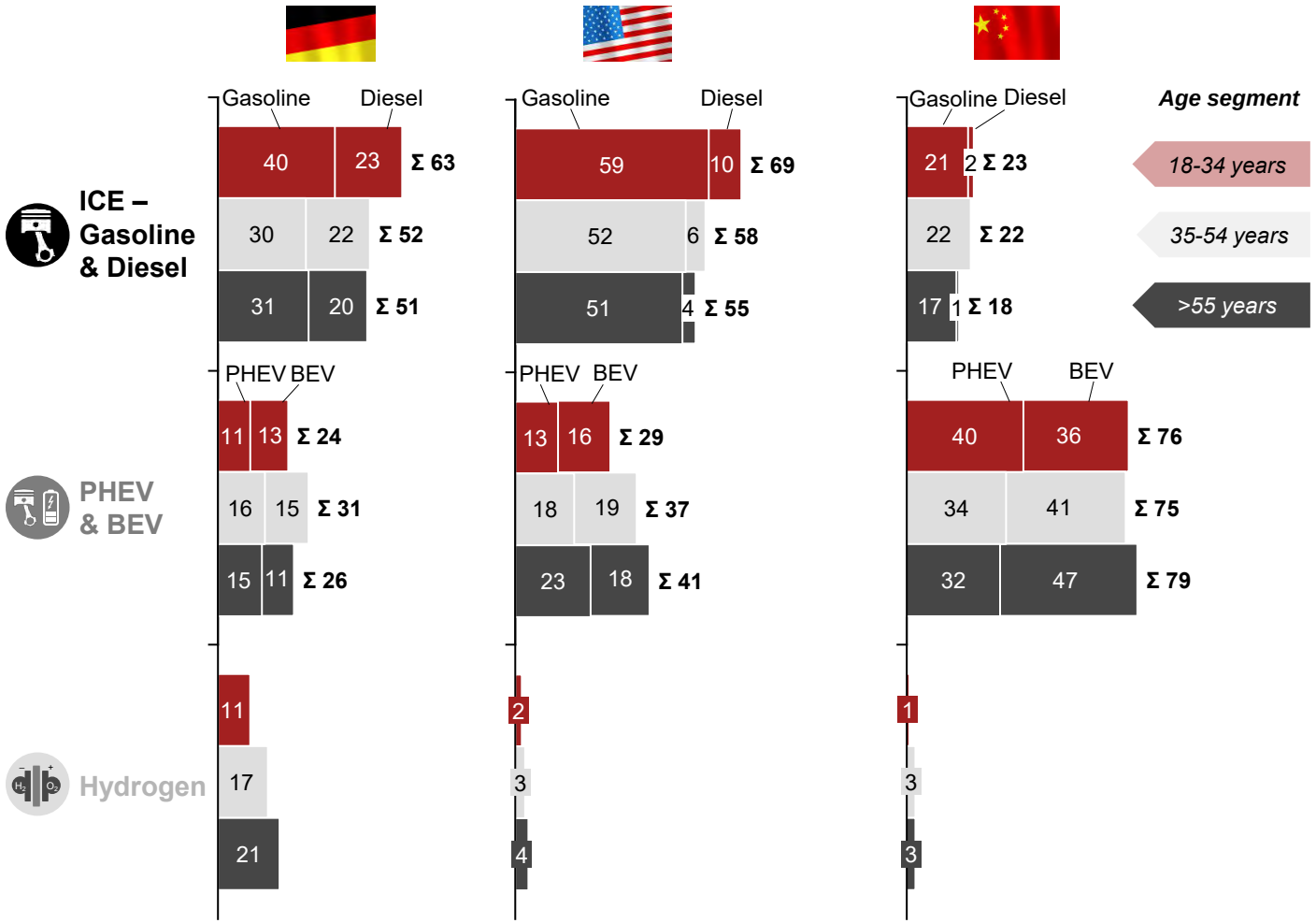
"Particularly **basic functions** like **air conditioner activation** ranked most **important,** whereas **sophisticated functions** like parking pilot or automated valet parking **do not yet seem very important** – at least in Germany and the US."

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

1) Local currency conversion to USD

>50% of US and Germany consumers retain strong preference for ICE – even young segments; Chinese 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?"*

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**.

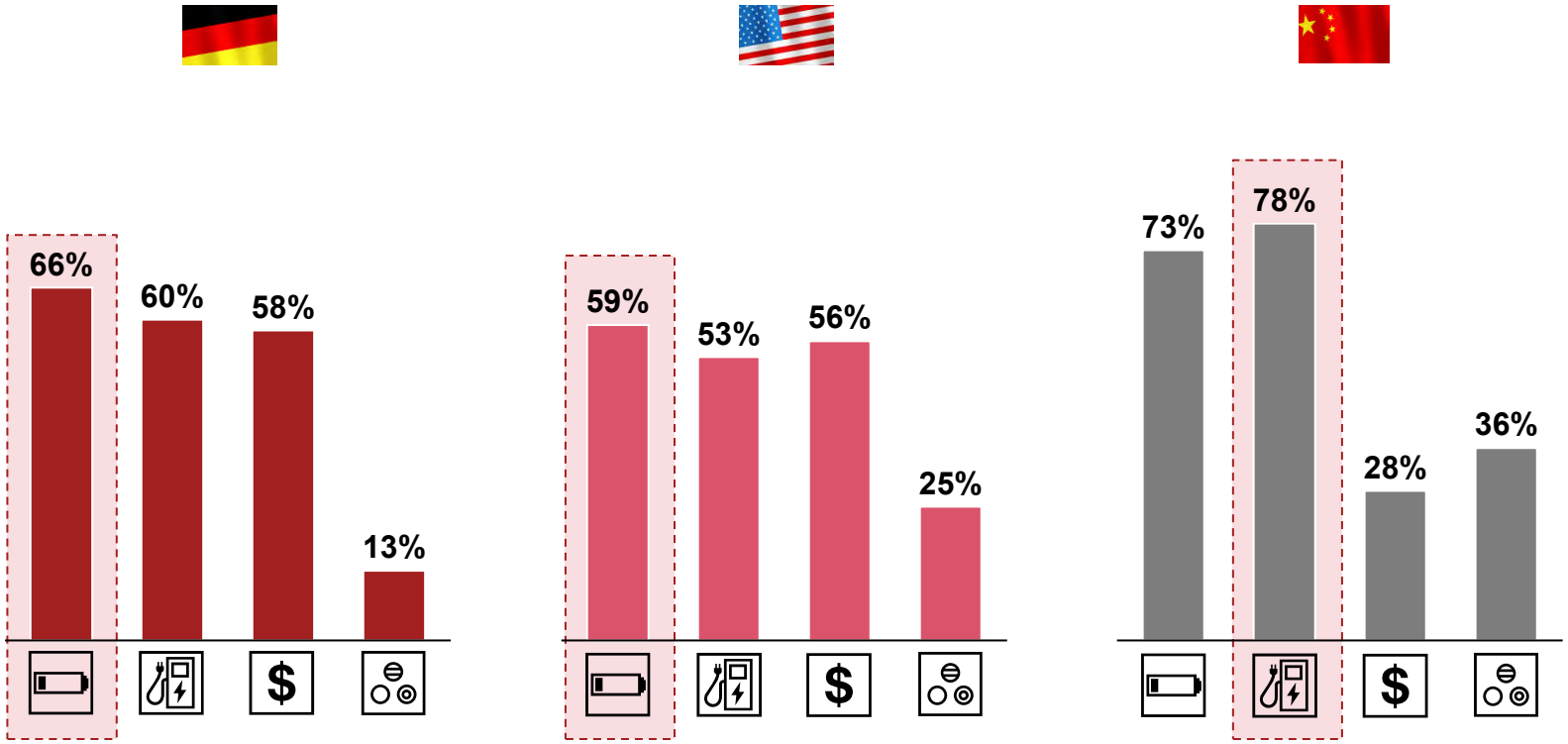
Hydrogen gains popularity in Germany – likely due to increasing press coverage and public debate."

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

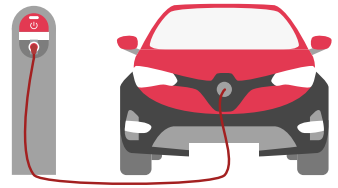
Percentages may not total 100% due to rounding

Range anxiety and charging options are major obstacles to buy an electric car – price is less of an issue, in particular 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."**

Insufficient driving range with one battery charge

Concerned about sufficient charging options/stations

$ Relatively high purchase price

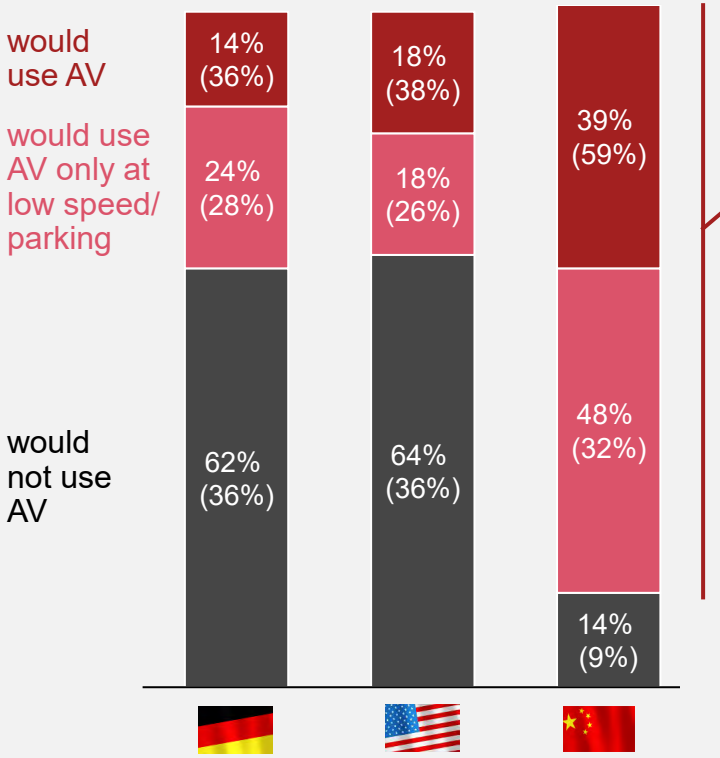
Limited choice and availability of cars

Source: PwC Strategy& consumer research 2021; n=1,897 (645 DE, 677 US, 575 CN) - respondents who are not interested in electric cars

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

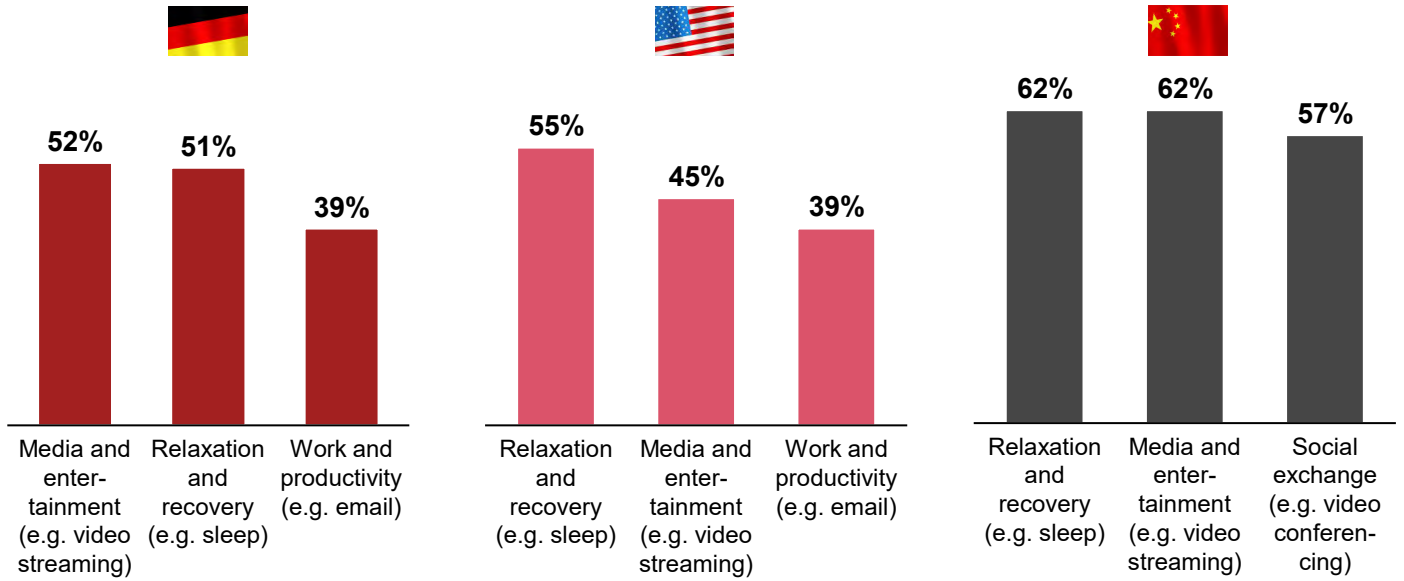
Automated driving – Consumer attitudes and usage of time gained

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** automated driving is seen as susceptible to change, and **consumer attitudes might fluctuate rapidly as** critical headlines emerge, e.g. following **accidents** and **cybersecurity threats.”**

Source: PwC Strategy& consumer research 2020; n=3,000 (1,000 DE, 1,000 US, 1,000 CN);
PwC Strategy& consumer research 2021; 1st question n=3,000 (1,000 DE, 1,000 US, 1,000 CN); 2nd question n=1604 (383 DE; 356 US, 865 CN)

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)]

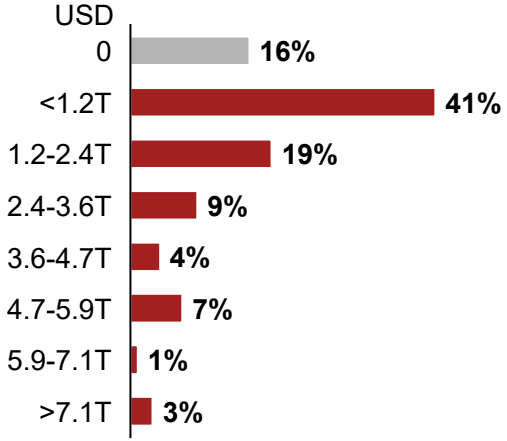
Question: *"How much would you be ready to pay on top of the regular car price to have full autonomous car functionality?"*

Premium

10 | 3 €

Base price

84%
willingness

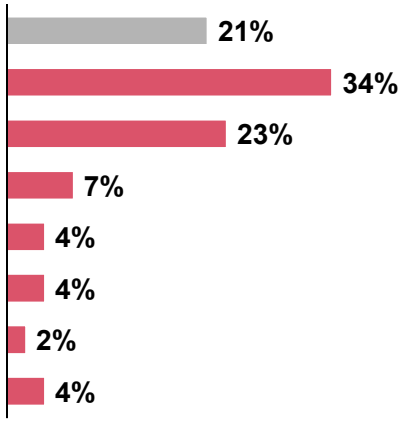


Premium

10 | 4 $

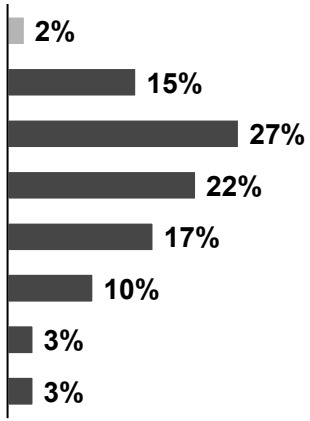
Base price

79%
willingness



n/a

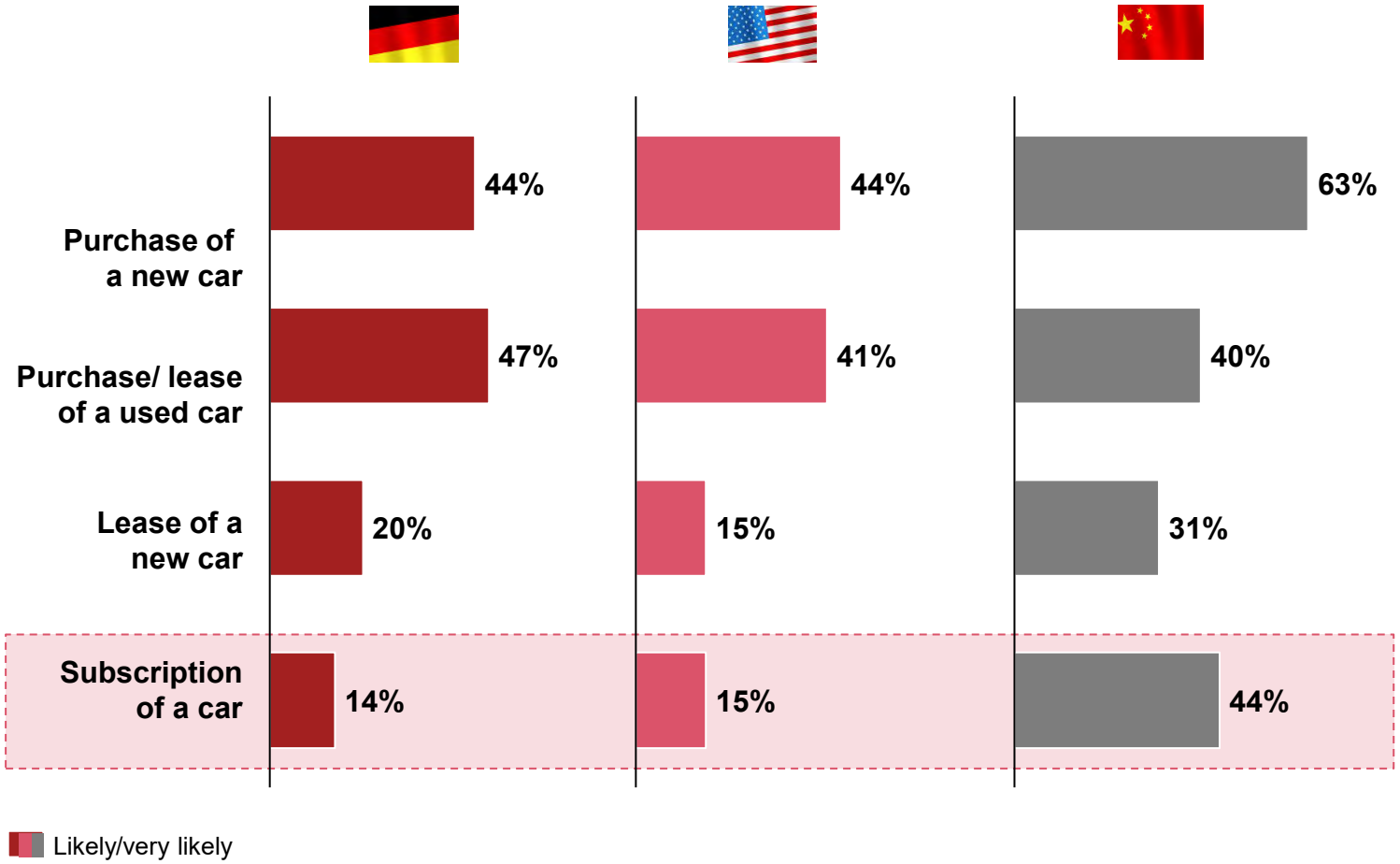
98%
willingness



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 attention

Likelihood to buy/lease/subscribe to a car



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

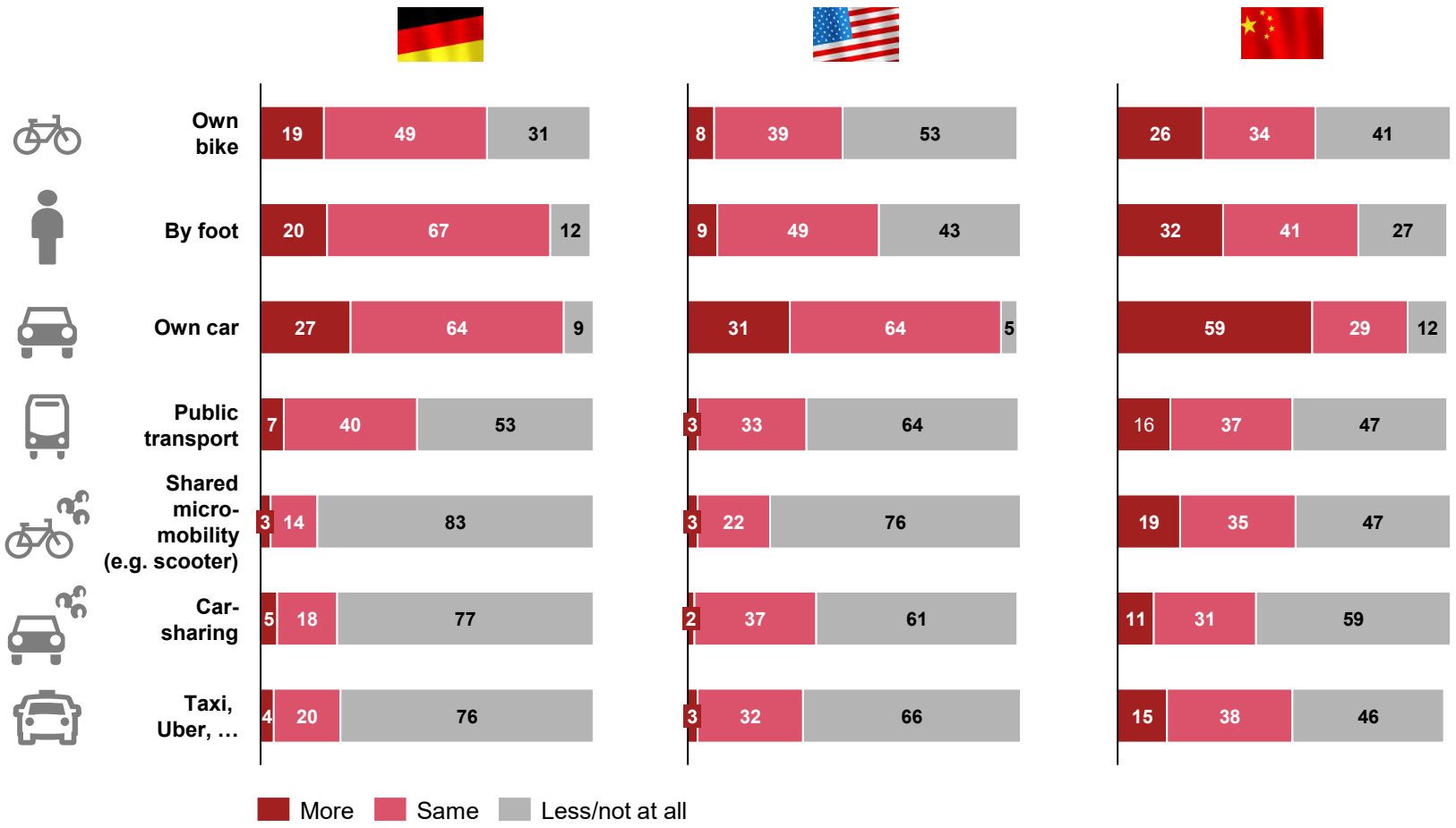
As the economic impact of COVID-19 appears to be more predictable in Germany, the **intention to get a car grew in that country** compared to last year's survey.

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)."

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN) Difference to 100%: no/low likelihood

Even as immediate COVID-19 risks decline, own car remains 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.

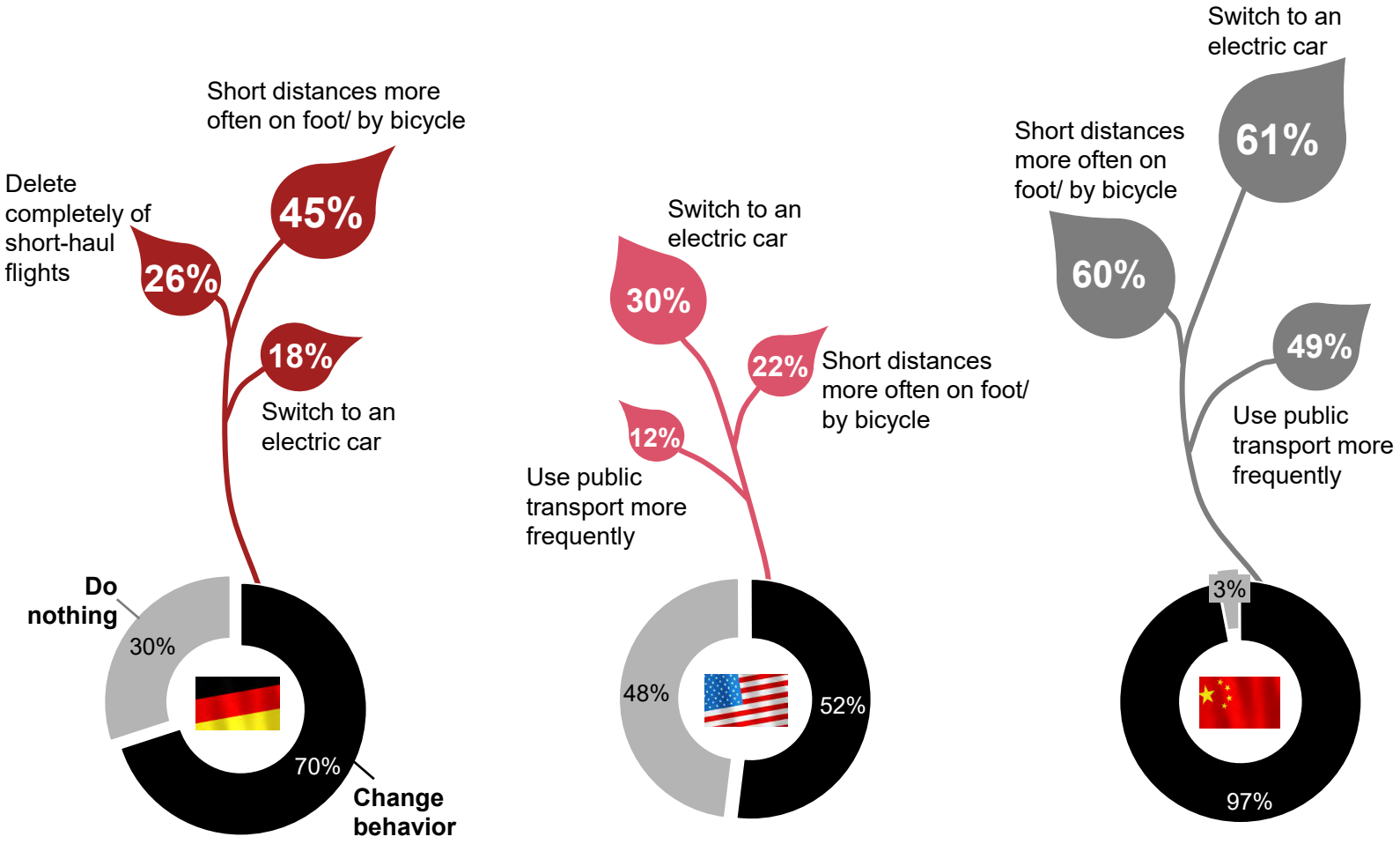
Across all regions, consumers plan reduced use of **shared modes** as well as **taxi and ride-hailing – even after the pandemic."**

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

Percentage may not total 100% due to rounding

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

Top-3 contributions to CO_2 reduction



Question: *"What major personal changes would you like to do to contribute to a reduction in CO_2 emissions?"*

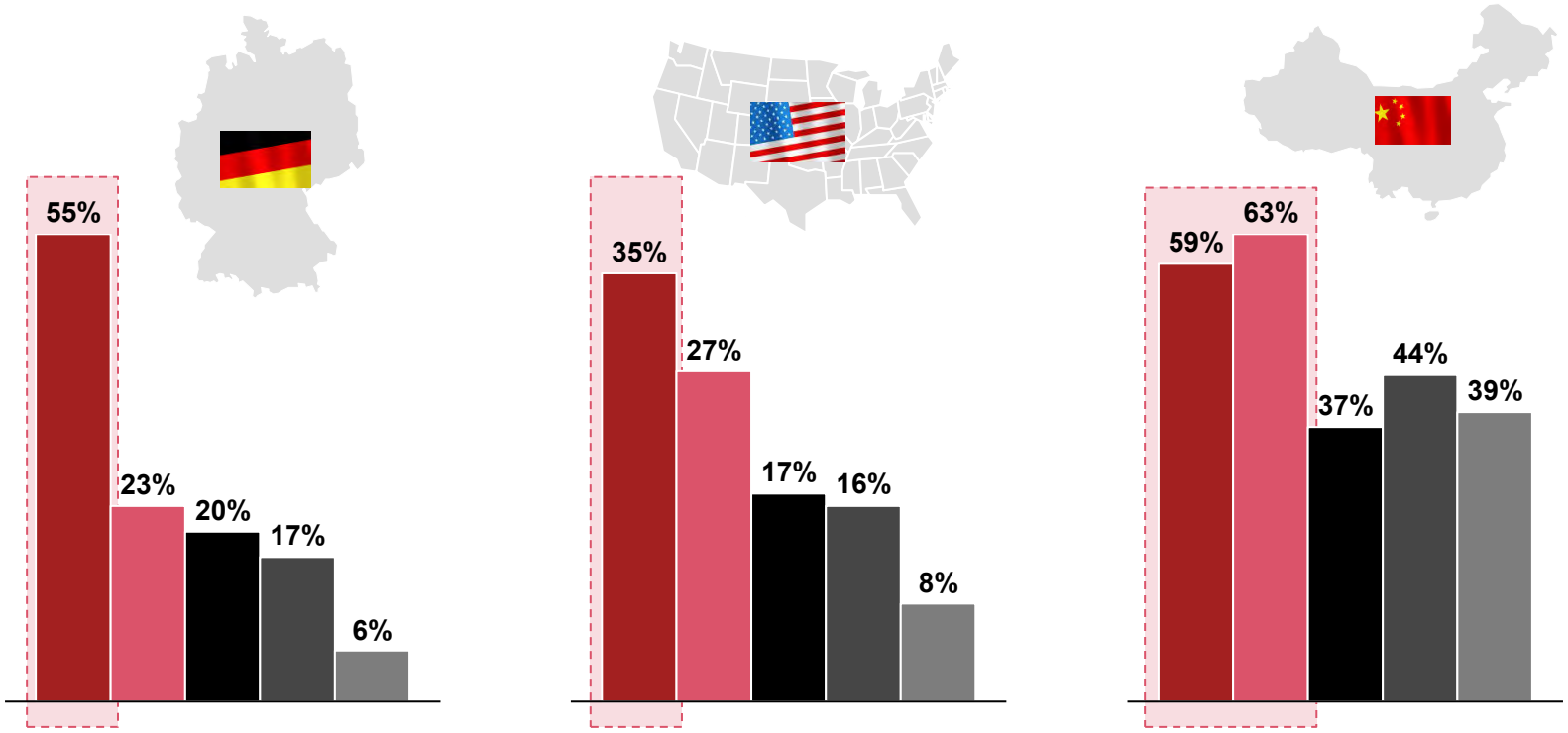
High willingness to **contribute** to **CO_2** reduction, esp. in **China** (97%) and in **Germany** (70%) whereas **US** respondents **are less willing** (52%).

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

Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

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."**

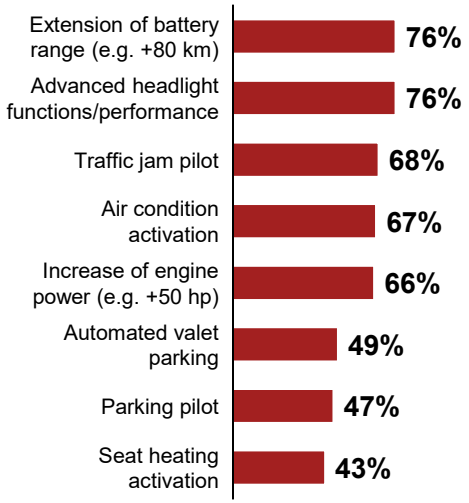
Source: PwC Strategy& consumer research 2021; n=3,000 (1,000 DE, 1,000 US, 1,000 CN)

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

Key highlights from Japanese consumer survey

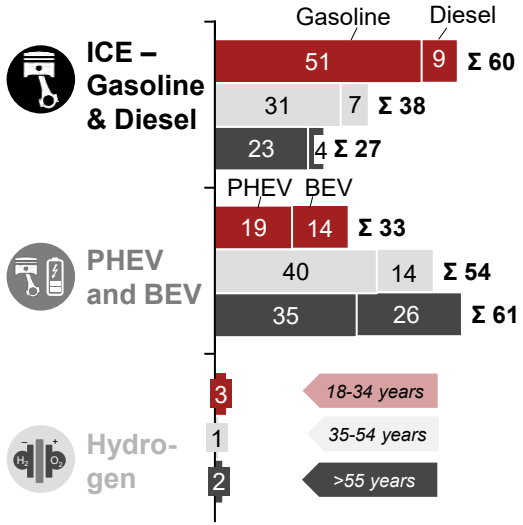
Connected

"How important would be on-demand car function [...] to you?"



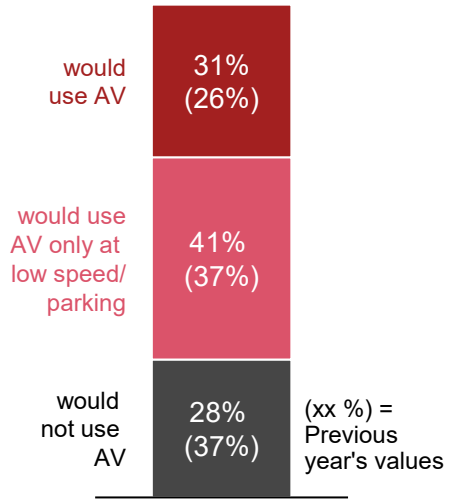
Electric

"[…] what type of engine would you like?"



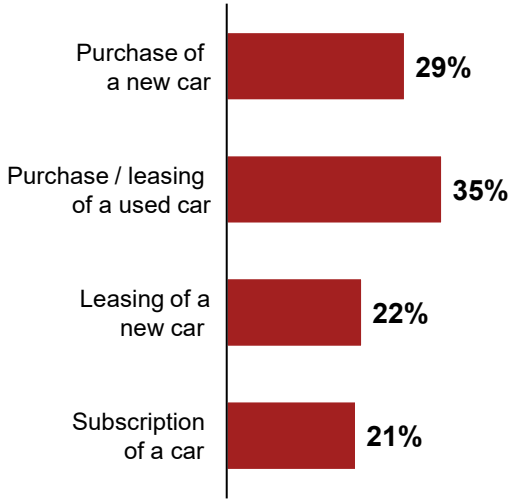
Automated vehicles

"Would you personally use a fully autonomous vehicle?"



Smart Mobility

"How likely might you purchase, lease, or subscribe to a car?"



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%)**

Source: PwC Strategy& consumer research 2021; n=1,000 JPN

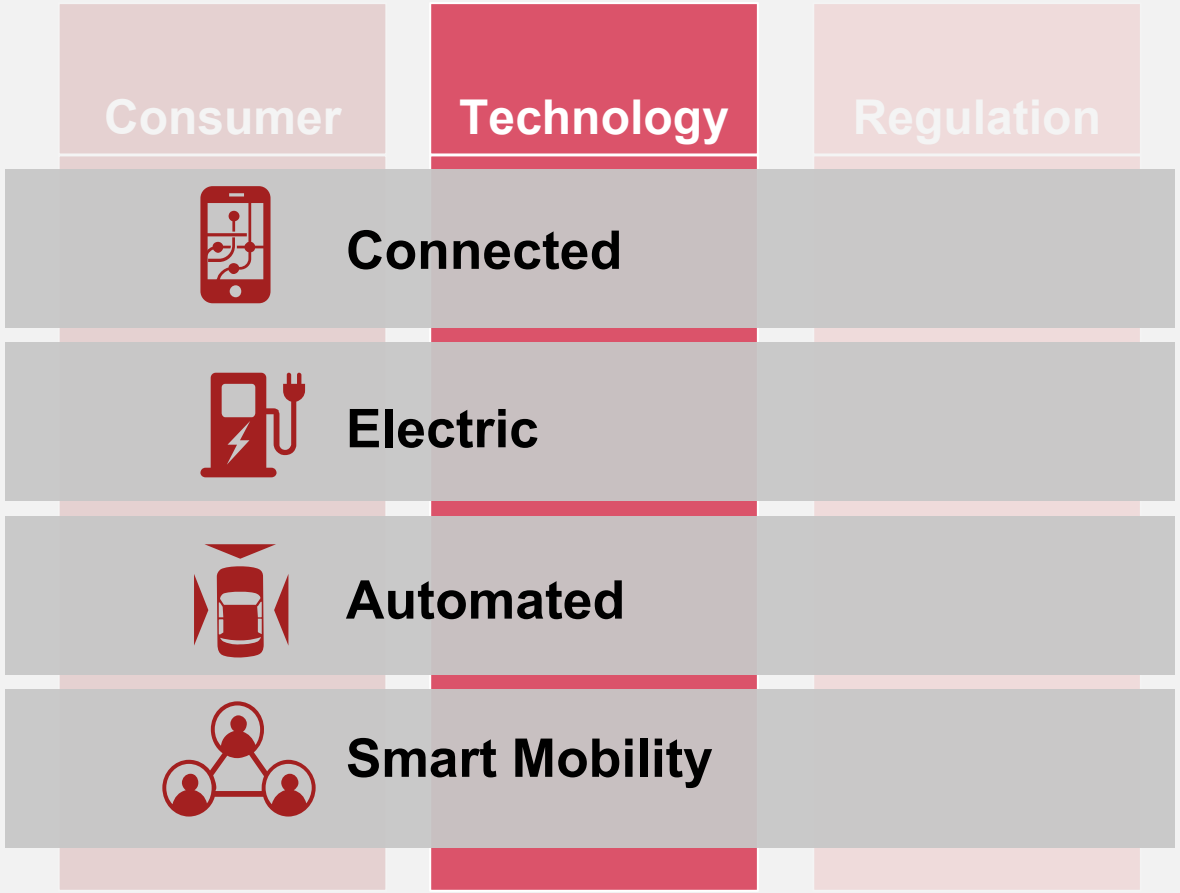
BEV = Battery Electric Vehicles

AV = Automated Vehicles

“

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

Digital Auto Report 2021 – Volume 1



Source: Strategy&

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

5th Screen Services

Value added services

Access to value-added services and revenues

Vehicle-Centric Connected Services

Automated driving

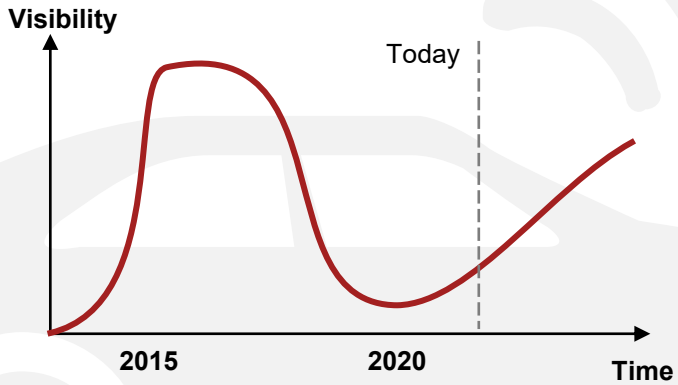
Cloud-supported situation analytics and driving assistance

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



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

Vehicle Features as a Service

Feature activation

Dynamic activation/ deactivation of paid add-on services

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

Source: Strategy&

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

Connected service components of a software-defined vehicle

	Enabler	Hardware	Software	Data / Integration	Content/Service	Sales and CRM
	Plan – Build – Ship – Update – Sunset					
Key value blocks	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	3rd party content and services	Customer support
Current limitations	• Regional regulations • Cybersecurity concerns • MNO costs	• Transformation of E/E architecture • Semiconductor availability	• Software capabilities • Development processes • Cybersecurity regulations	• System test capabilities • Decision on closed vs. open systems • Certifications	• Data ownership • Revenue models	• Customer access/ identification • Data privacy
Current develop-ments	• Buy into cellular and satellite networks • Build-up of cloud/edge infrastructures	• Development of own/ tailored semiconductors • Modular and expandable hardware architectures	• Development of own software stacks • Build-up of own app stores	• Increase in automated test and compliance processes • Build-up of own data/ analytics platforms	• Expansion of cross-industry and technology alliances	• Centralization of sales processes • Cross financing/ subscription contracts

Source: Strategy&
V2x: Vehicle-to-everything I/O: Input/ Output E/E: Electric/Electronic HW: Hardware SW: Software Crucial value blocks

Technology progress in e-mobility must be evaluated in the context of tech trends across various alternative powertrains

Alternative powertrain developments

ICE

Internal combustion engine

Electrification

- Recuperation and boost as standard features with 12V (budget) or 48V
- Increased electrification of auxiliaries (water/oil pumps, cam phaser, etc.)
- P2 topology avoiding drag torque

Reduction of friction losses

- Coatings and microstructural modifications on cylinder
- Optimization of crankshaft bearings
- Ball bearings for turbocharger

Combustion/emission optimization

- Increasing injection pressures
- Variability in valve trains
- Particle filters for most powertrains including DI gasolines
- Variable compression ratio through variable connection rod

PHEV

***Electric drivetrain** (electric motor, inverter, transmission)*

Efficiency improvement

- Silicon carbide power semi-conductor switches (inverter)
- Bar windings and increased notch filling degree in electric motor

Cost reductions

- Increased integration of inverter and motor

High voltage system and architecture

Architecture

- Integration of power-units (OBC, DCDC, DC charger)
- Top models up to 800 V, standard in volume 400 V

Auxiliaries

- Increasing commoditization of electrified auxiliaries

HV battery system

System design

- Structural integration of housing into vehicle body (cell-to-vehicle)
- System design incl. recyclability

Cell innovation

- Increased cell capacity through larger cells
- Cathode cost reduction by minimization of cobalt content and cobalt-free cells (e.g. iron-phosphate)
- Dry (solvent-free) processing of electrode coatings
- Increased anode energy density via silicon
- Intrinsic safe cells by application of solid state electrolytes (polymers, inorganics, blends)

BEV

FCEV

Fuel cell system

Stack

- Increase of power density
- Optimization of catalyst compositions (reduction of Pt) and nano-scale microstructure
- Optimization of bipolar plate coatings

Balance of plants

- Stack internal humidification and simplified water mgmt.

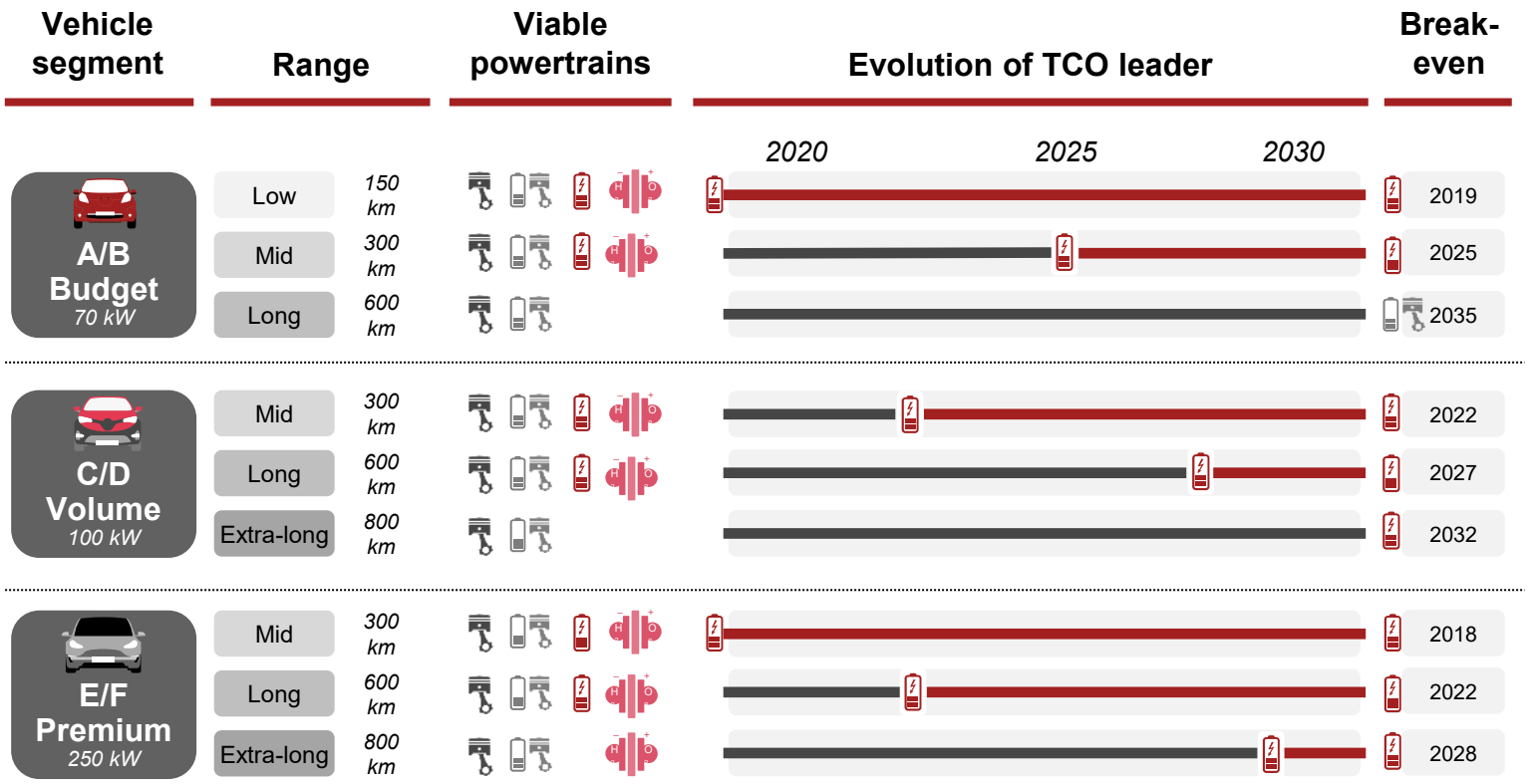
Tank

- Optimization of fiber winding layout and process
- Mixed materials to reduce costs
- Compressed H_2 as standard for passenger vehicles

Source: Strategy&

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)



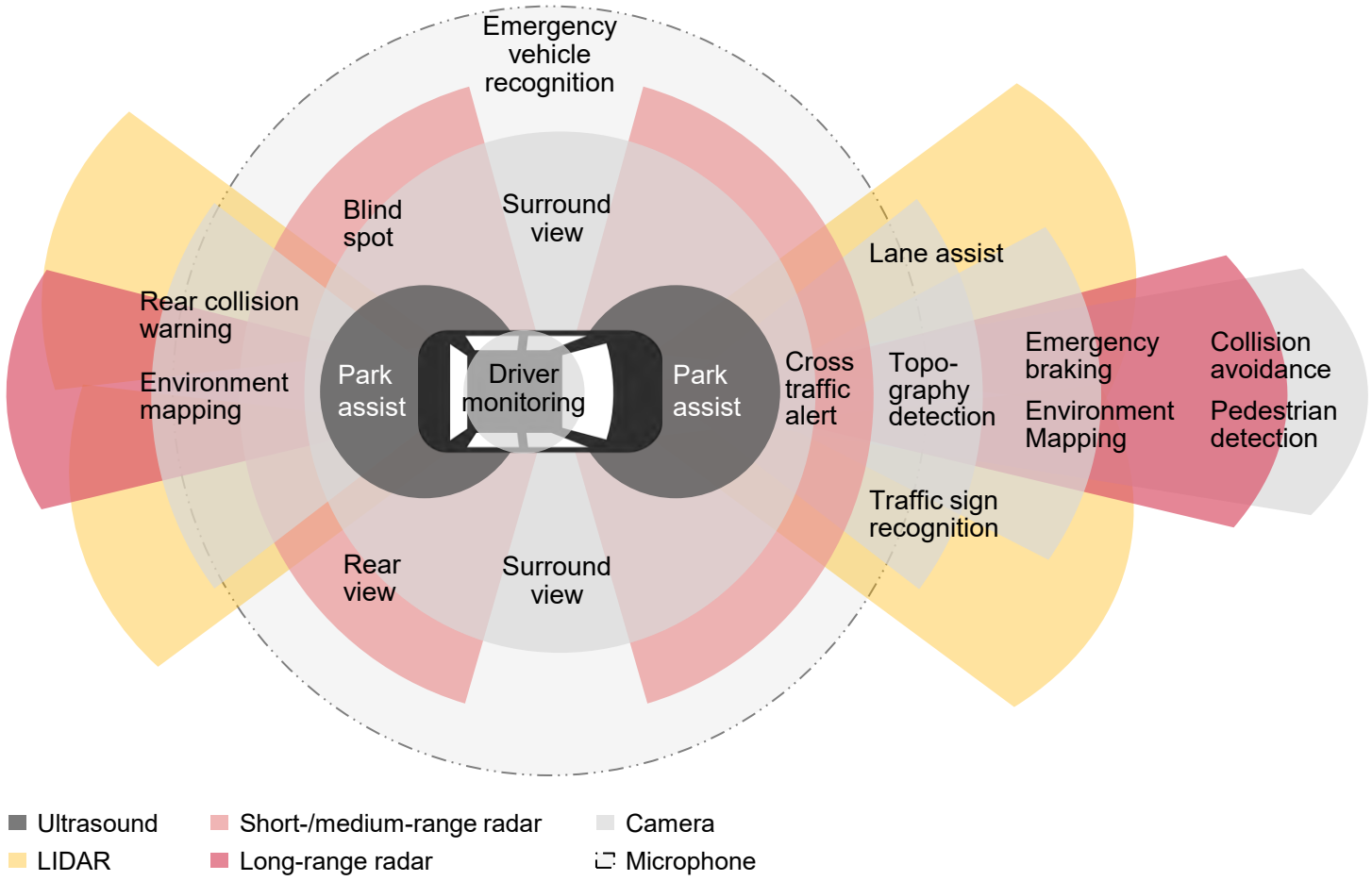
"There is **no fixed point** in time **when battery electric vehicles will** offer an operating **cost advantage over internal combustion engines** – it depends on factors such as the vehicle segment and range"

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

Automated driving technology developments



Current status and limitations

Hardware
e.g. sensors

- **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**

Software
e.g. smart data usage

- **Test and validation not** yet **mature**
- **Motion prediction** still **not** completely **solved**
- Very **large amounts** of **test data complicate** traditional **analytics**

Infrastructure
e.g. 5G

- 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)

Source: Strategy&

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

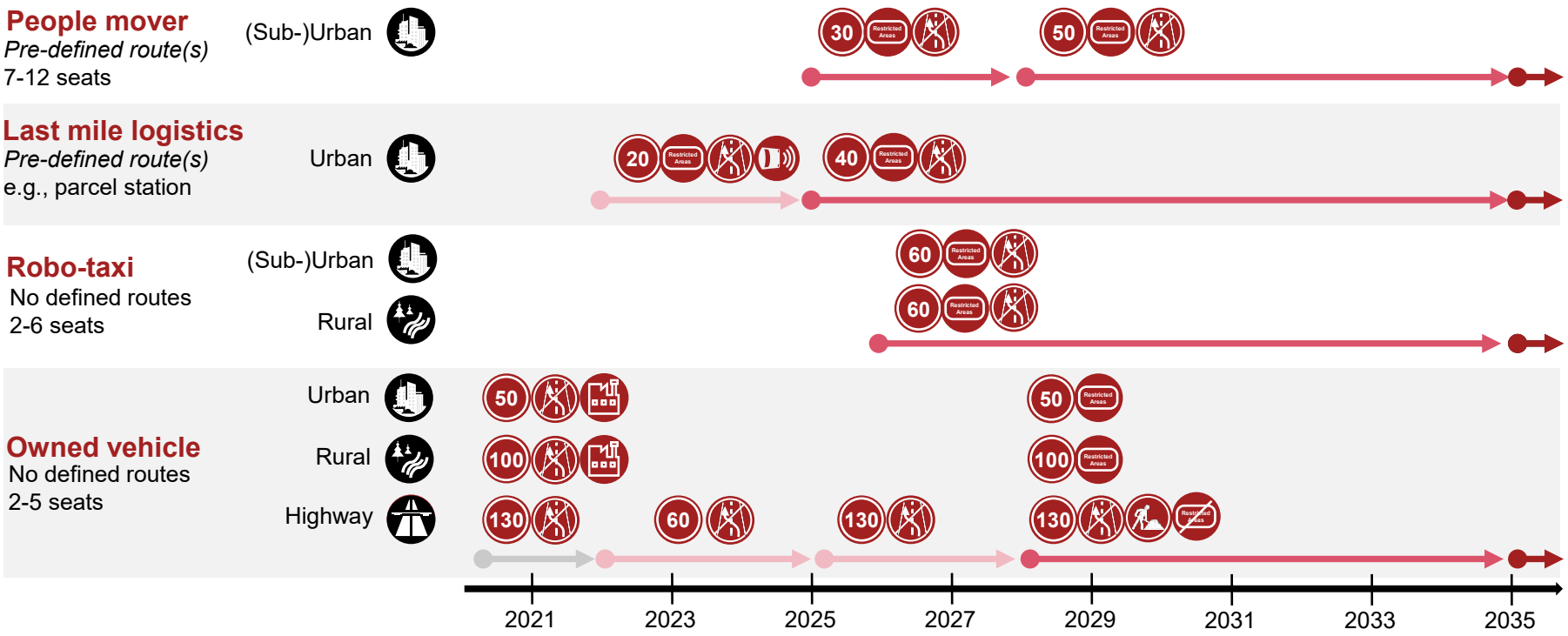
HIGH ↑ AUTOMATION ↓ LOW

SAE level	Narrative definition		Vehicle control	Environment monitoring and user interface	Fallback for dynamic driving task	System capability	Exemplary AD functionalities
5 Full driving automation	The **system performs all aspects of dynamic driving** (driving-mode specific)…	…under **all environmental and road conditions** that can be managed by a human driver (not ODD specific	System	System	System	All driving modes	• 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		Most driving modes	• Urban/rural/highway pilot with multi-lane change • Robo-taxi and automated people-mover • Urban last-mile delivery • Automated valet parking
3 Conditional driving automation		…**expecting the human driver to respond appropriately** to an intervention request (ODD specific)			Human	Some driving modes	• Urban/rural/highway assistant (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 system**…	…executes both **steering and acceleration/deceleration** (driving-mode specific and depending on ODD)…		Human			• Adaptive cruise control • Remote/key parking assistant • Lane change assistant
1 Driver assistance		…executes **either steering or acceleration/deceleration** (driving-mode specific and depending on ODD)	Human and System	Conventional user interface			• 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	• Pre-/forward- collision braking • Front/rear cross-traffic alert with braking

Source: "SAE International Standard J3016", SAE; Strategy& ODD = Operational design domain

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



Commercial availability (beyond pilot projects)[2)]

Level 2+ · Level 3 · Level 4 · Level 5

Max. speed · Area restriction · Construction area capable · Automated lane changes · Closed compounds · 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*

Current developments

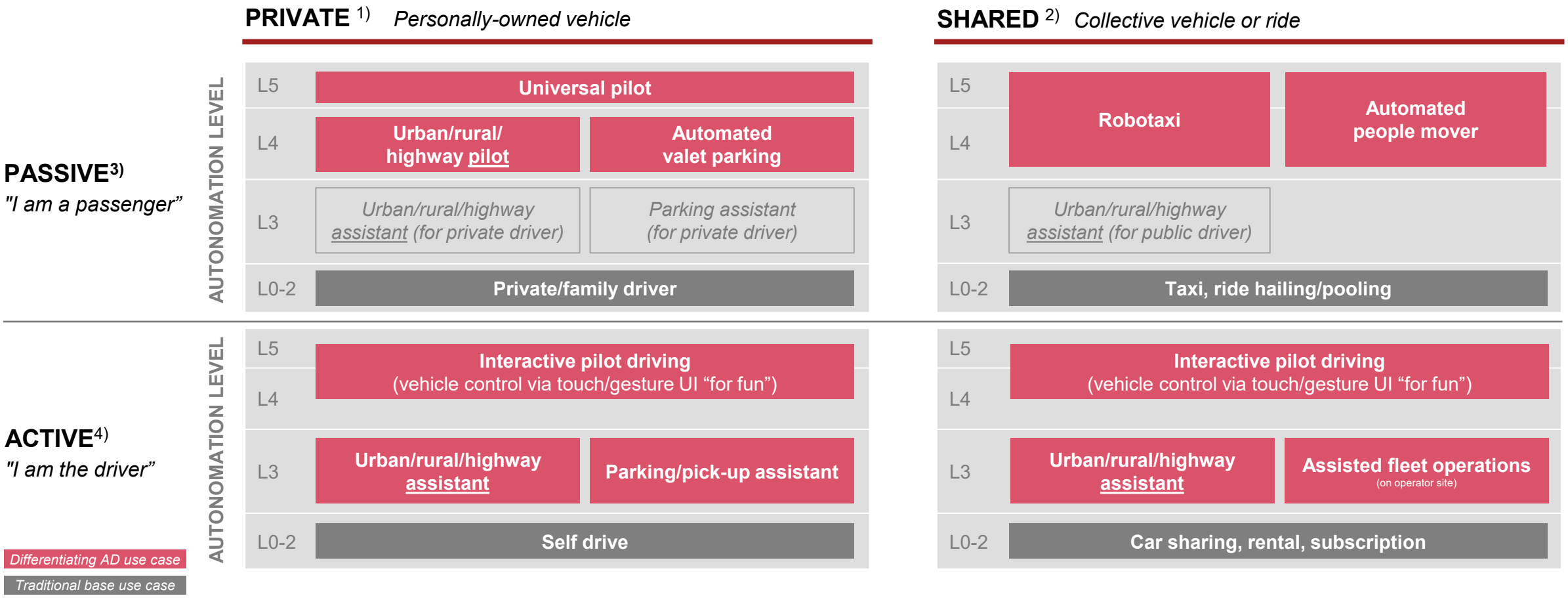
- ADAS[1)] technologies require **higher development cost** and efforts than anticipated
- ADAS **sensors** still far **above target cost**, due to small production volumes and sensor fusion/ recognition challenges
- **Regulation** is advancing, with UN/ECE technical framework being finalized and e.g. 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**

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

Source: Strategy&

Individual mobility divides into private vs. shared and active vs. passive driving modes, 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

Charging and battery management
- Energy demand prediction
- Charge point management
- Battery replacement and recycling

Internal Business Operations
- Customer acquisition/ marketing
- Finance and controlling, risk and legal, HR, ..
- IT mgmt (IoT, data and analytics, cyber, ..)

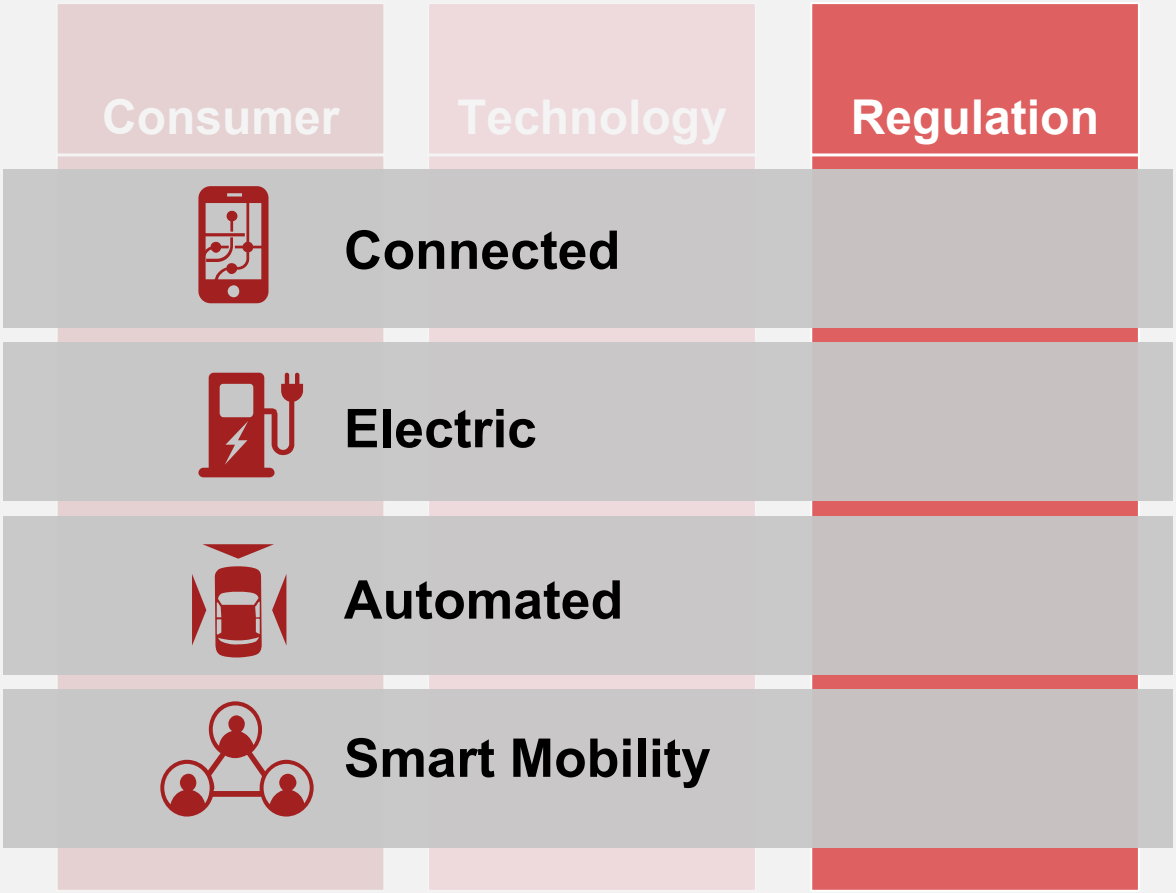
Partner integration (API) and external data sourcing

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

Source: Strategy&

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



Source: Strategy&

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

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**

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. CO_2 emission standards[1] (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 released[2] (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**

Positive expert sentiment **Neutral** expert sentiment **Negative** expert sentiment

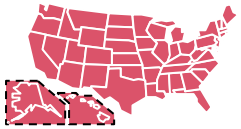
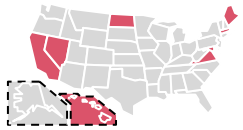
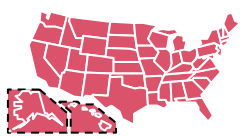
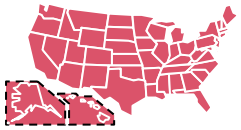
Note: (1) average emissions of new cars to come down by 55% from 2030 and 100% from 2035 compared to 2021 levels (2) 1: improve capacity for technology innovation; 2: build an NEV industry ecosystem; 3: advance industrial integration and development; 4: build a sound infrastructure system; and 5: increase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

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 inter-mediaries 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 publica-tion 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

Source: Strategy&

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