WELCOME!

2nd E-Mobility Forum

DIGITAL MOBILITY

E-Mobility Cloud Center

5G R&D and Test Center for autonomous vehicles and drones

SAJAM ENERGETIKE I 05 OKTOBAR 2018

E-MOBILITY GAME CHANGERS:
autonomous driving & e-cars, new mobility services and e-infrastructure

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Faculty of Electrical Engineering

Mobility revolution is visibly gaining momentum across many areas in both private and public sectors

Private sector

Electric car

Infineon, DELPHI, TESLA, National Electric Vehicle Sweden, SAAB, KARMA

Autonomous car

Microsoft, DELPHI, MOBILEYE, NOVARIANT, UBER, Google

Car sharing

TURO, Enterprise CarShare, 易到用车 yongche.com, GREEN GO, zipcar, e代驾, DAIMLER

Carpooling/Ride-sharing

BlaBlaCar, Side·car, GM

E-Hailing/Hailing services

UBER, GRABTAXI, lyft, OLA, DiDi

Advanced Driver Assistance

MAGNA, HELLA, ZF, FICOSA International

Connected car

HARMAN, Jasper, Vodafone Automotive, Continental, verizon

Navigation systems

here, TOMTOM, INRIX, 高德地图 amap.com, NAVINFO 四维图新

Public sector

OSLOCITY

"Oslo moves to ban cars from city center within four years"

City of Gothenburg

"100 **self-driving cars** set to hit Sweden's public roads in 2017"

DUBAI

"25% of all transportation in Dubai will be smart and **driverless** by 2030"

City of Boston

"Boston is currently testing **autonomous vehicle** scenarios with the support of BCG."

BEVERLY HILLS

"**Driverless buses** are coming to public-transit-phobic Beverly Hills"

SINGAPORE

"Singapore is getting the world's first fully **autonomous taxi service**"

1. Selected examples of relevant companies with investment activity
Source: BCG Analysis, World Economic Forum, Quid.com, Press search

There are 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure

There are 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure

1 Autonomous vehicles are taking off – first cars with self-driving features are already on the road

Selected self-driving vehicle pilots – ongoing or announced in 2016

Self-driving cars

Gothenburg, Volvo
"Drive Me" project with 100 SDVs in Gothenburg in 2017

California/Texas, Google
1.5 million miles driven on modified Lexus SUVs and prototype vehicles

Pittsburgh, Uber
100 SDVs provided by Volvo and Ford in 2016

Fujisawa, Robo Taxi
Field test for driverless Toyota taxis, roll-out planned for Olympics 2020

Self-driving (mini-)buses and pods

Amsterdam, Daimler
Autonomous bus pilot on dedicated lane at Amsterdam airport

Singapore
Several projects underway, e.g., in cooperation with EasyMile

Sion, Navya
Self-driving inner-city mini buses operated by PostBus

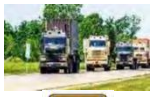
Milton Keynes, RDM
Driverless 2-seater trial pods since 2015, 100 pods in 2017

Self-driving trucks

Platooning challenge
DAF, Daimler, MAN, IVECO, Scania and Volvo platooning on public roads

California, Otto
Test fleet of five trucks equipped with self-driving kits on public highways

Boliden, Volvo
Driverless trucks test in Kristineberg mine



Michigan, US Army
Driverless military truck convoy on public highways

Source: Press research, BCG analysis

1 Further use cases will emerge for autonomous e-vehicles in different mobility segments in the short term

Passenger car: Shared e-car connected to traffic systems

Detail 1

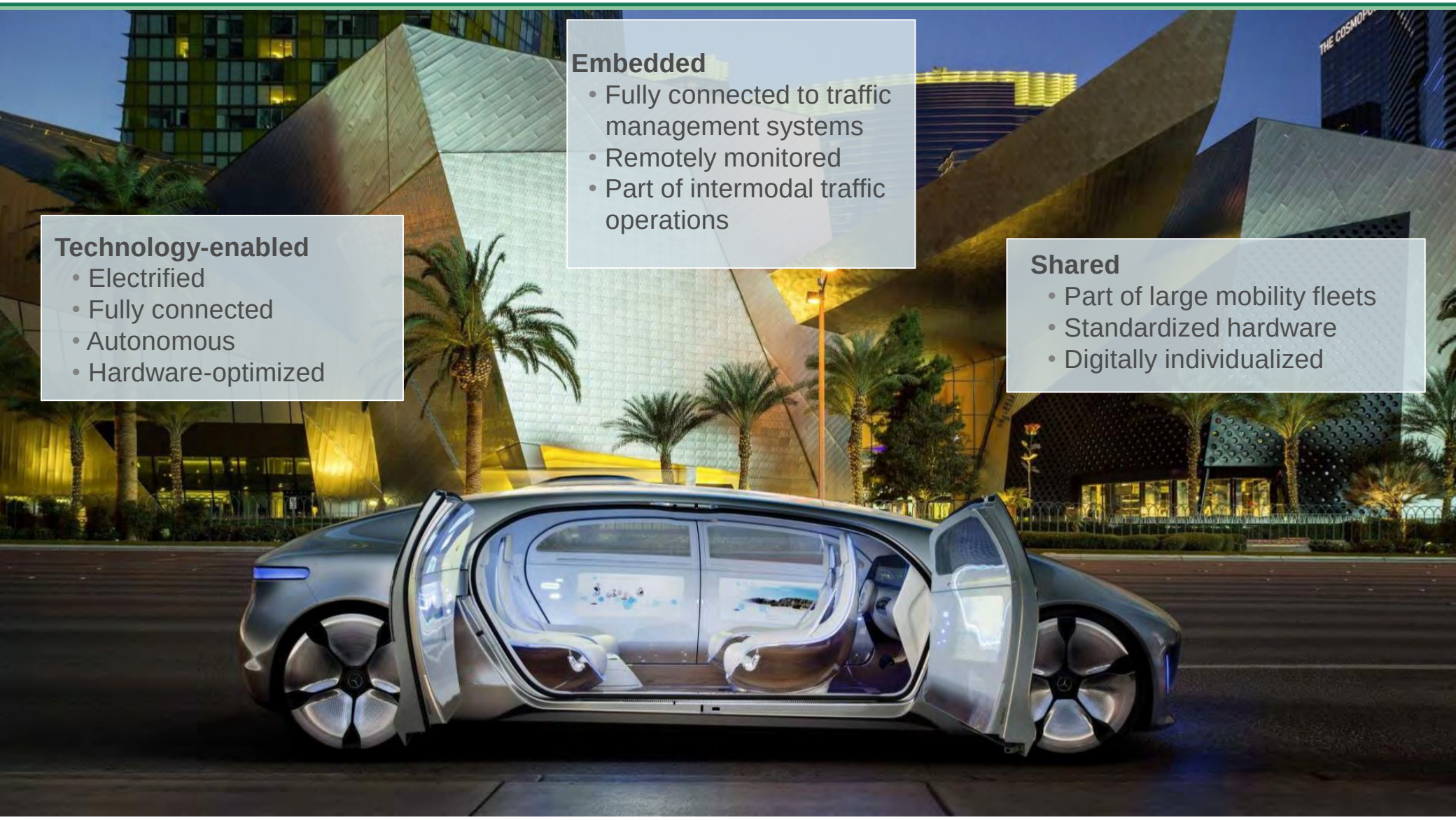
Buses: Self-driving electric (mini-)buses

Trucks: Autonomous, optimized long-haul trucks

Detail 2

Source: BCG, Daimler, Freightliner, Google, LocalMotors

1 Detail 1: The passenger car of the future will be electric, connected, and embedded in inner-city traffic management



Technology-enabled
- Electrified
- Fully connected
- Autonomous
- Hardware-optimized

Embedded
- Fully connected to traffic management systems
- Remotely monitored
- Part of intermodal traffic operations

Shared
- Part of large mobility fleets
- Standardized hardware
- Digitally individualized

Source: Daimler, BCG

1

Detail 2: Trucks of the future will be technology-enabled, remotely-managed with fully optimized load-patterns

Remotely-managed
- Integrated in remote monitoring, virtual maintenance systems
- Optimized operations, full fuel efficiency in all use cases

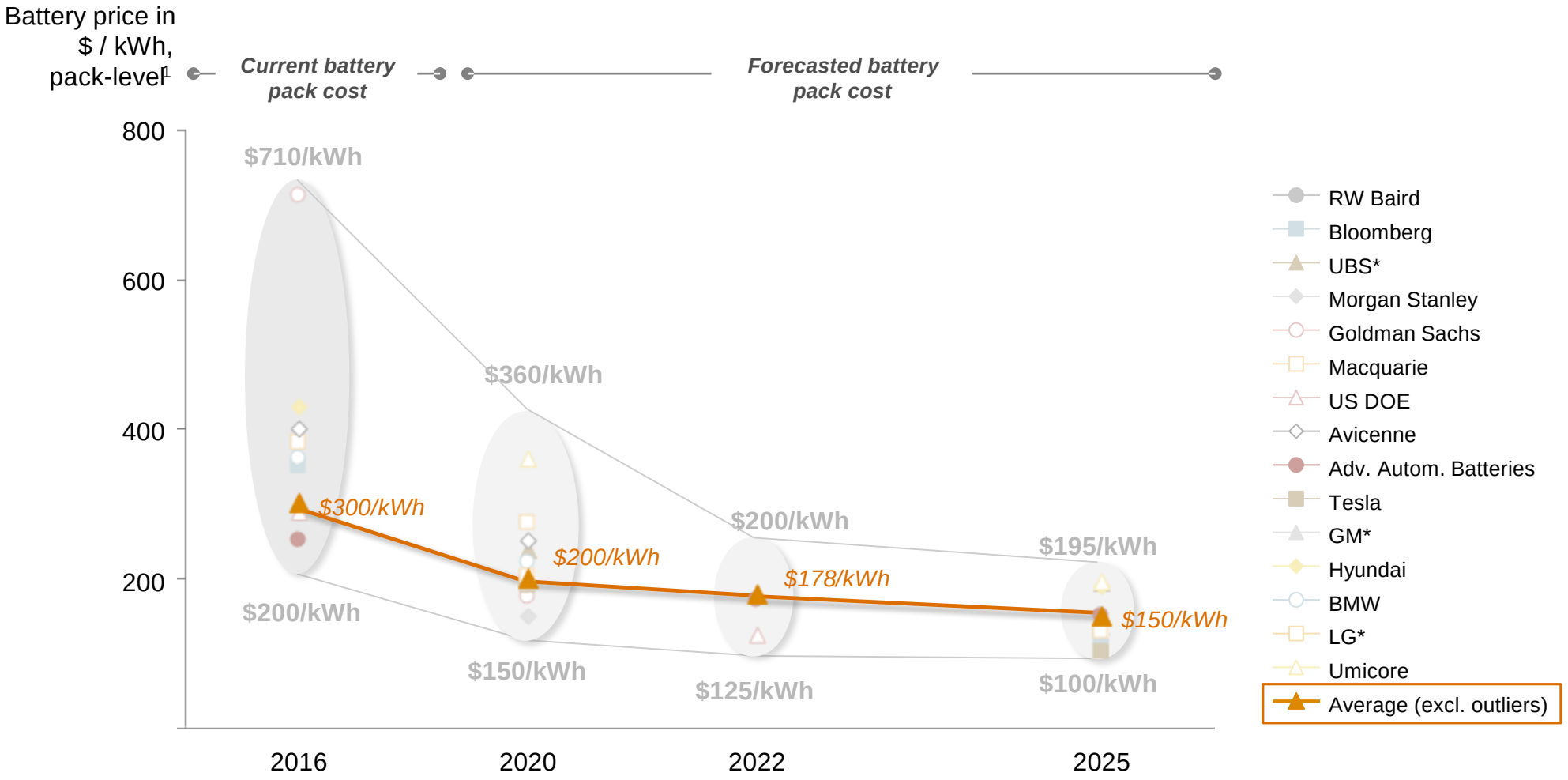
Shared resources
- Optimized load patterns
- Full transparency over capacity utilization

Technology-enabled
- Partly electrified (electric auxiliaries
- Fully connected
- Autonomous
- Hardware-optimized (aerodynamics, rolling resistance)

These trucks will have ~50% lower operating cost and almost 100% utilization – compared to today's maximum ~60% stipulated by law

Source: Daimler, BCG

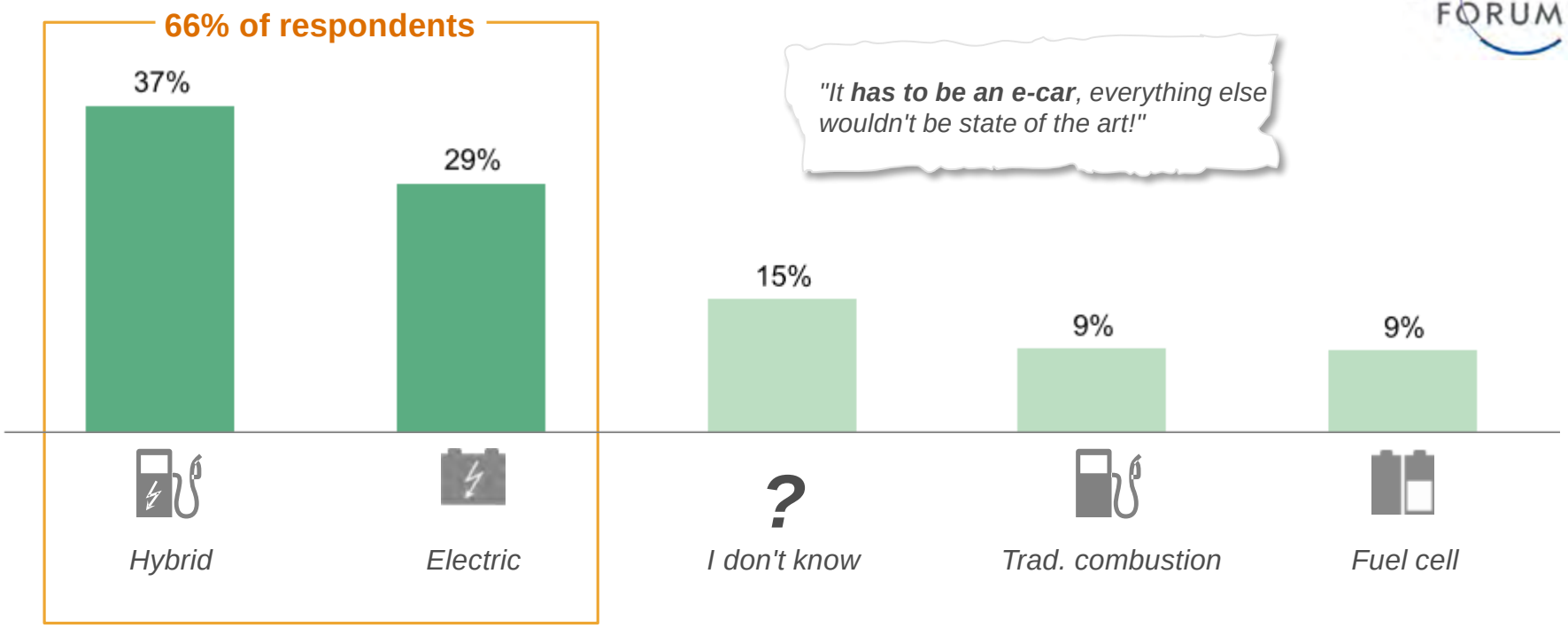
1 Price of batteries will fall to ~1/2 by 2025 making electric cars more competitive



1. To convert cell price to pack price, 35% of cell price is added 2. $250/kWh was the target derived by U.S. DoE in Nov 2009, where it's believed that TCO becomes competitive to that of the ICE (assuming gas is priced at $2.27/gal)
Source: Analysts reports, expert interviews, BCG analysis

1 The change is already in consumer minds: Self-driving cars will be electric or hybrid rather than traditional combustion

% of total respondents



Q: What **type of engine** do you think self-driving vehicles will primarily have?

n = 5,635

Source: World Economic Forum; BCG analysis, consumer survey August 2015

1 It is cities that trigger major changes in the mobility systems around the world

Observations

From 2014 to 2030, more than 1bn people will move to urban areas

Already today, urban infrastructure is saturated globally

- In North America, 0.7% GDP growth are estimated to be lost in traffic jams

Global air pollution levels continue to rise with many cities exceeding maximum concentration levels 5-10x, mostly caused by traffic

- China's air pollution-related health cost 2016 estimated at 6.5 ppt of national GDP

Implications

Life situation of billions of people calls for radically new mobility systems

Smart new infrastructure is needed across countries

Enabling technology fosters accelerated transition from traditional individual mobility to...

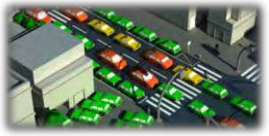
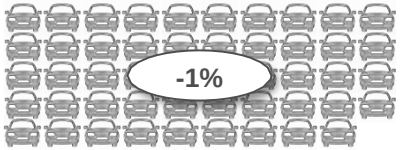
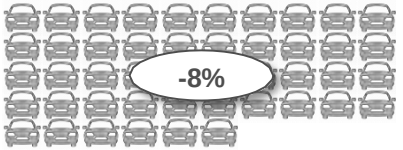
- Electric driving
- Connected driving
- Autonomous driving

Demand for car-sharing, embedded in seamless mobility, will increase dramatically

Source: CNBC, UN, The Texas Transportation Institute, BCG

1

Depending on the scenario for autonomous e-vehicle penetration, the future of city traffic will change dramatically

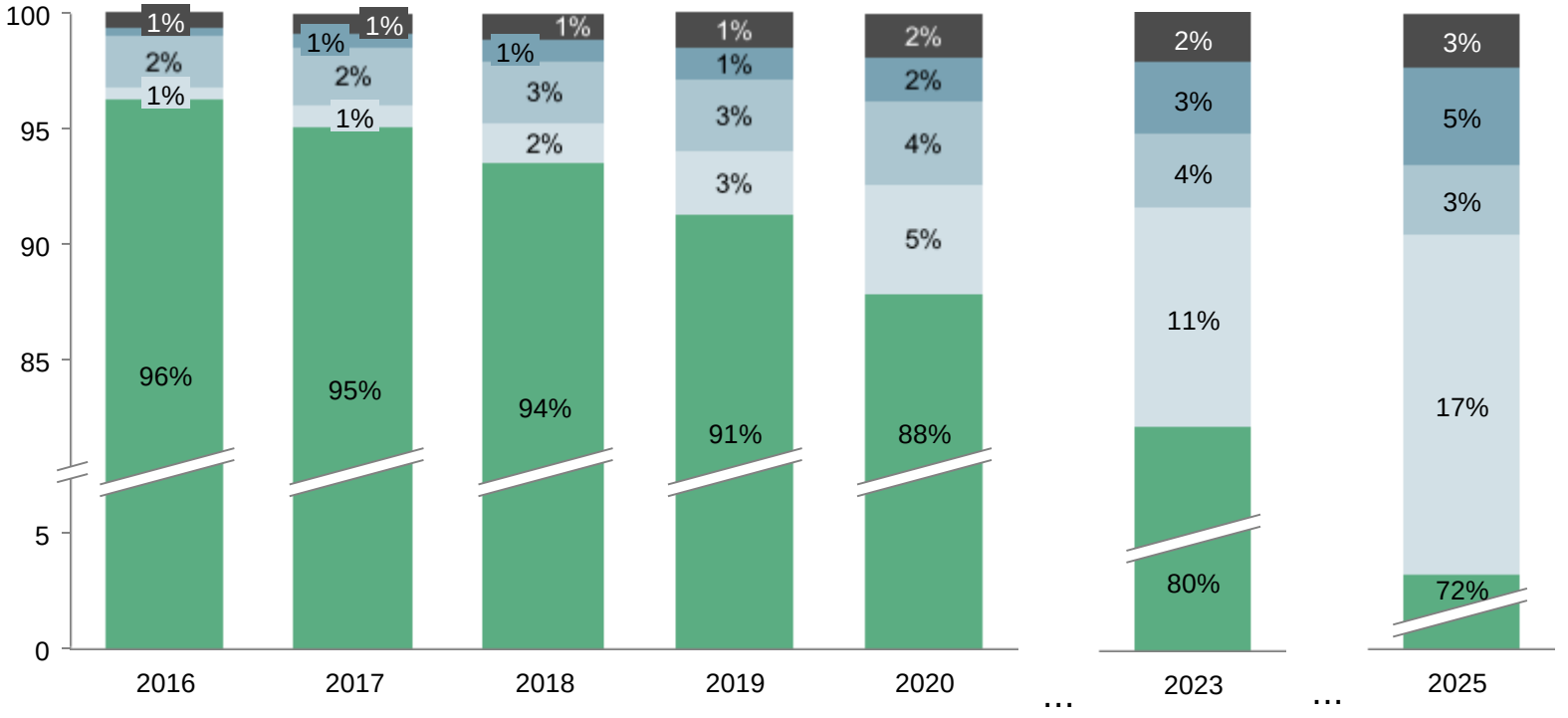
	1 The premium car drives itself	2 Autonomous vehicles rule the streets	3 Self-driving taxi revolution	4 Ride-shared self-driving taxi revolution
Scenario	 Autonomous vehicles complement existing mobility offer	 Autonomous vehicles replace most traditional cars	 Self-driving taxis are primary mobility option	 Ride-sharing self-driving taxis are primary mobility option
Vehicle population	 -1%	 -8%	 -46%	 -59%
Impact[1]	Limited city and consumer benefits CO_2 -9% P 0% -19% -28%	Some city and consumer benefits CO_2 -23% P -5% -55% -43%	Sizable benefits, but not without costs CO_2 -81% P -39% -86% -23%	Highest benefits for city and consumer CO_2 -85% P -54% -87% -55%

CO_2 Emissions Accidents P Parking space Mobility cost

Source: World Economic Forum; BCG analysis 1. In year 10; Note: calculations based on model city with tidal-style traffic and approx. 5M inhabitants and 1.34M taxis and private vehicles, modeled

1 Which will lead to an increase of electric and hybrid vehicles on new production from ~3% in 2016 to ~30% in 2025

Global vehicle production (% of total)



Note: Other analysts' 2020 EV base case scenarios (as of 2016): (a) HSBC – 2.2%, (b) JP Morgan – 1.0%, (c) Morgan Stanley – 2.9% 2. Distribution based on 20-'23 CAGRs
Source: IHS, HSBC, JP Morgan, Morgan Stanely

There are 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure

1

AUTONOMOUS DRIVING & E-CARS

3

E-MOBILITY INFRASTRUCTURE

2 New mobility opens door to disruptive business models in B2B and B2C segments

Vehicle-centered

Ride hailing

Detail 1

- Taxi
- "Black car"
- Robo taxi

Car sharing

Detail 2

- B2C & B2B sharing
- P2P sharing
- Community sharing
- Bike & scooter sharing

Ride sharing

- B2C sharing
- B2B load capacity sharing
- P2P sharing
- Shuttle services

Micro transit

- Area-to-area
- Point-to-point
- Flexible vs. fix routes
- Self-driving mini bus

IT-centered

Multimodal platforms

- Multimodal
- Mono-modal
- Life assistants
- Data brokerage

Mapping and navigation

- Navigation services
- Mapping services
- Data brokerage

Infrastructure-centered

Smart parking

Detail 3

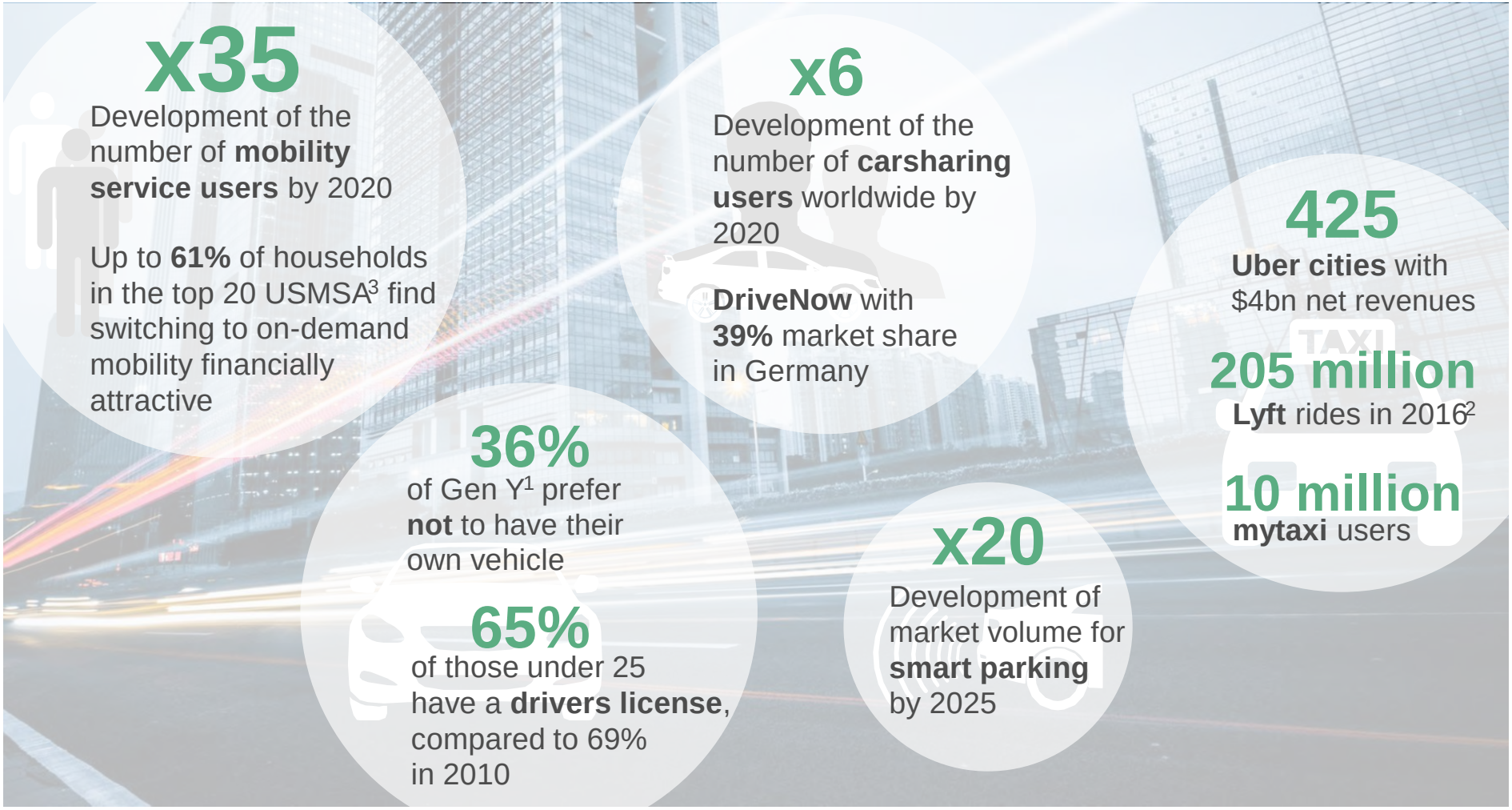
- Off-street parking
- On-street parking
- P2P parking space share
- Data brokerage

Charging

- Public charging
- Fast charging
- Corporate charging
- P2P charging

Source: BCG analysis

2 These new mobility services will be launched at ever-increasing speed

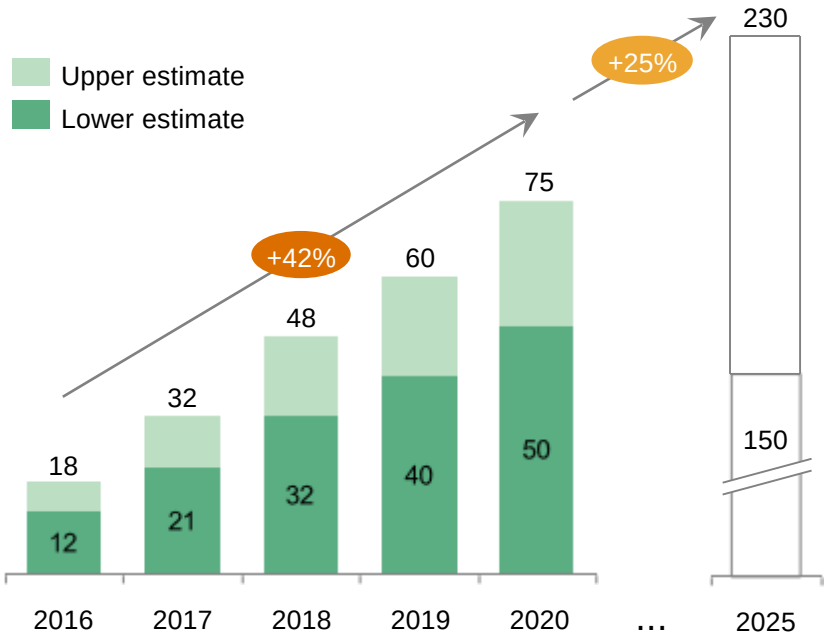


1. Currently age 22-34 2. Lyft forecast 3. United States Metropolitan Statistical Area Note: Market estimates in this chapter generally from consumer perspective (i.e., total value of mobility services booked Source: Deutsche Bank; McKinsey; Web Recherche; mytaxi; BCG analysis

2 Detail 1: The ride hailing market is expected to grow by ~40% p.a. championed by companies such as Uber

Ride-hailing: market value of gross bookings expected to grow by ~40% p.a.

Global gross bookings[1], €B



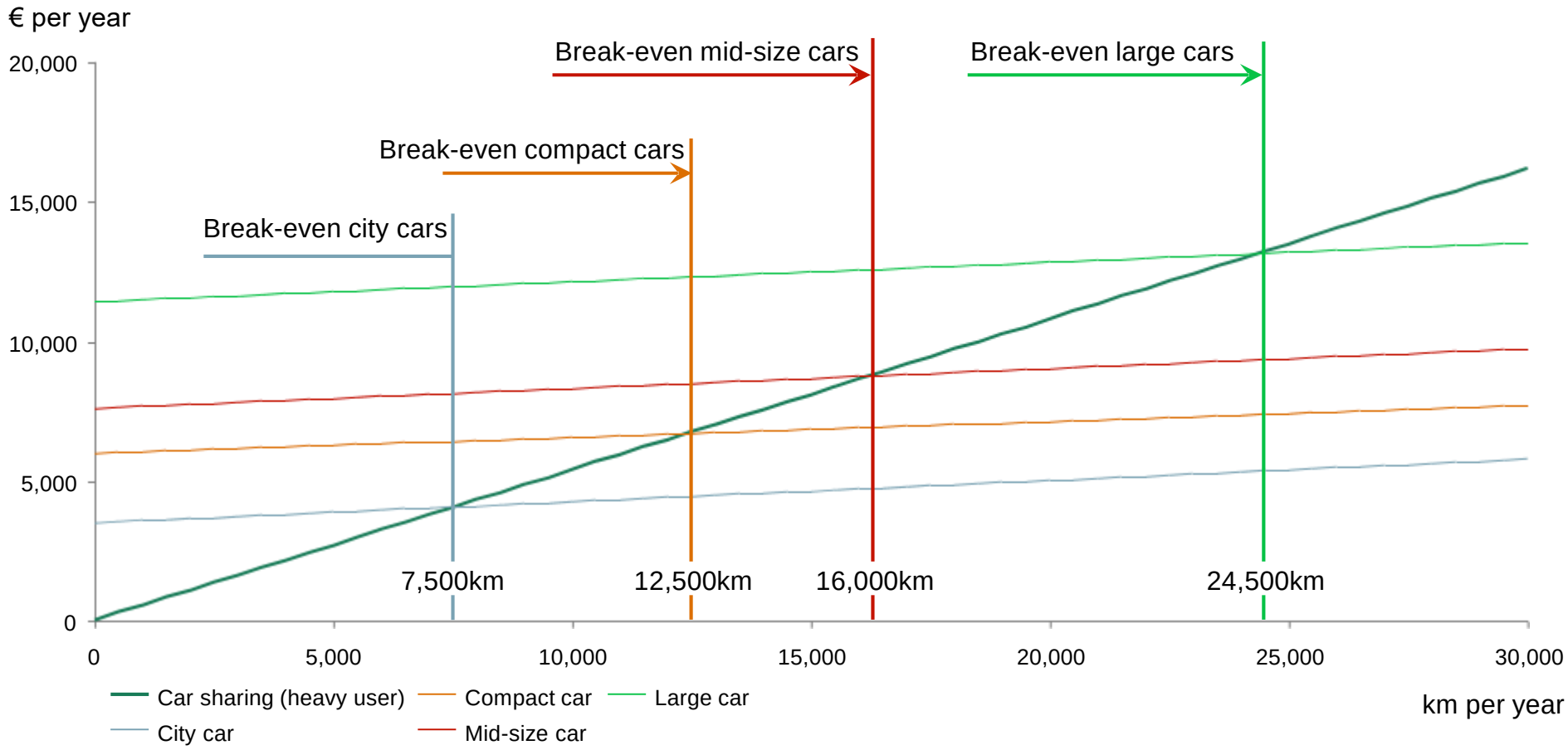
Top 10 "ride-on-demand" apps

Multiple of Uber app dowloads

1	Uber	1.00
2	Kuadi	0.71
3	Didi	0.14
4	BlaBlaCar	0.11
5	Shenzou Zhuanche	0.10
6	Kakao Taxi	0.10
7	Lyft	0.09
8	GrabTaxi	0.07
9	Easy Taxi	0.06
10	Yongche	0.06

1. UBS, 2015, Could "ride-on-demand" end car ownership? Key model assumptions: Average monthly revenue generated by each driver for the "ride-on-demand" operator is €1,000 (average of San Francisco, NYC, Paris, London, HK) on the basis of a shift of 8 hours and an idle time between trips of 15 minutes 2. Estimate based on 2015 revenues of Uber, Lyft, Gett and Didi (C4 ratio: 80%, CAGR 15'-17': 30%)
Source: UBS, Project Armstrong, BCG analysis

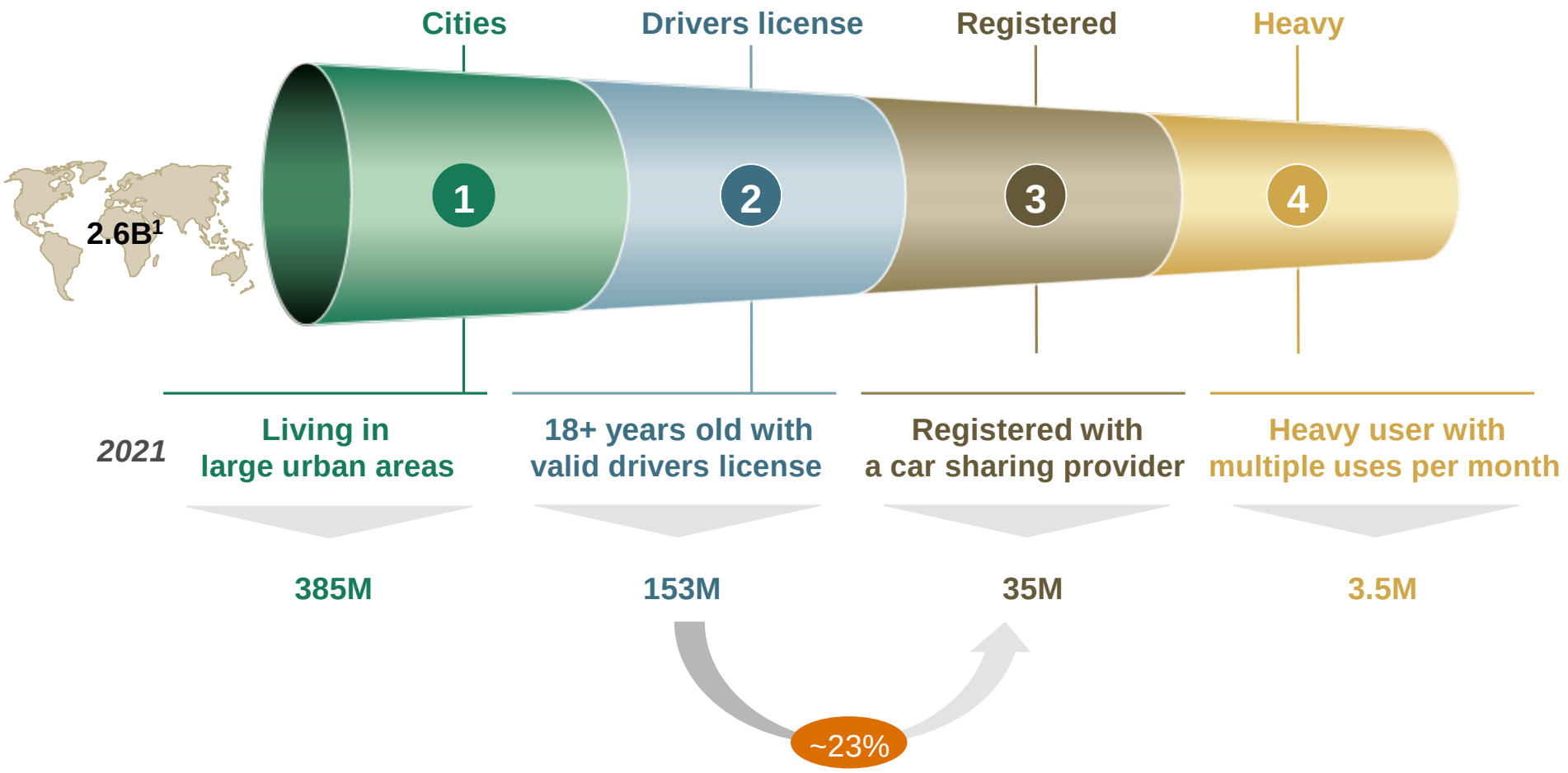
2 Detail 2: At low mileages, car sharing has lower total cost of ownership than standard car car ownership



For compact car owners driving less than 12,500km, car sharing has a lower total cost of ownership

Note: Cost analysis for Europe
Source: ADAC; Car sharing companies; BCG analysis

2 Detail 2: By 2021 is expected that ~23% of drivers living in large urban areas will be registered with car sharing providers



1. Only includes countries where we expect car sharing to be offered: Australia, Canada, China, Europe (including Russia and Turkey), Hong Kong, Japan, Malaysia, New Zealand, Singapore, South Korea, Taiwan, and the U.S.
Source: Statista; BCG analysis

2 Detail 3: Smart parking has potential to dramatically change the way we park; there are four innovative models in the market

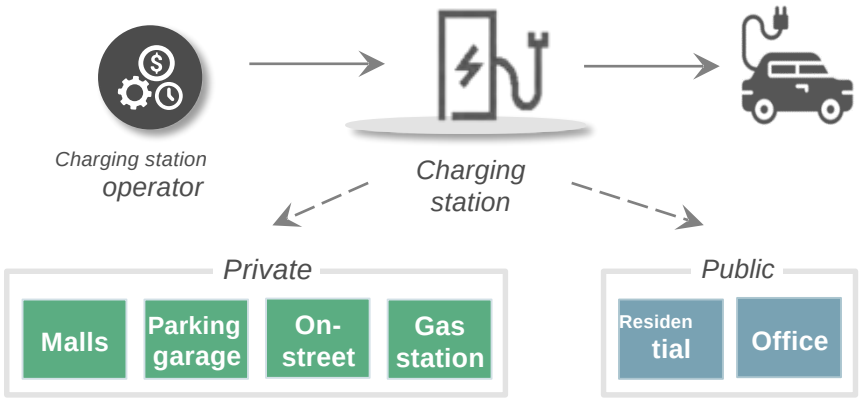
	1 Off-street parking reservation & payment	2 On-street parking space locator & mobile metering	3 Peer-2-peer parking space sharing	4 Data brokerage for on-street parking data
				
Use case	• **Reservation** of off-street parking spaces • **Navigation** to available space • **Online payment** of parking fees	• **Search engine for free on-street parking** spaces nearby • Remote **extension of parking ticket** • **Online payment** of parking fees	• Private individuals **rent out own parking** spots to others • Hourly, daily or monthly periods possible	• Data aggregator purchases proprietary vehicle data to **locate free on-street parking** spaces
Value proposition	• **To user:** Relieves need for lengthy parking space search • **To operator:** Allows variable pricing to improve space utilization	• **To user:** Relieves customer from meter payments/space search • **To operator:** Enables digital control of parking tickets	• **To user:** Private parking space often cheaper than dedicated lots • **To owner:** Additional revenue to parking space owner	• **To aggregator:** Additional data points for service • **To user:** Location of free parking spaces via aggregator service
	ParkNow, ParkingPanda	Parkmobile	PARK CIRCA, ParkingPanda	INRIX

Source: BCG analysis

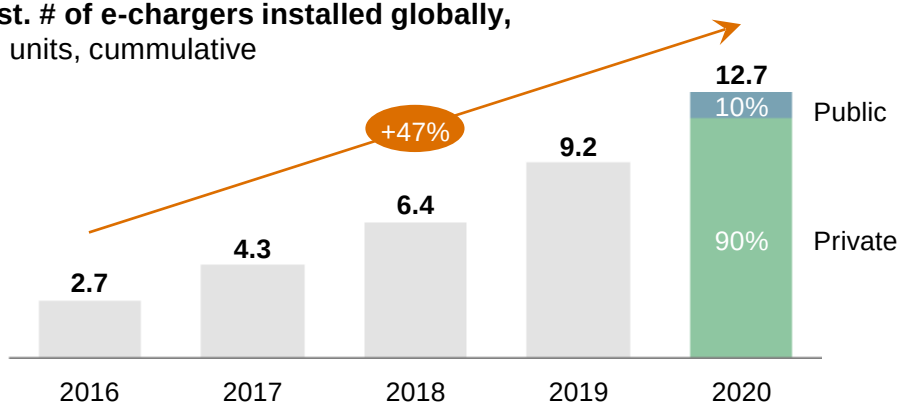
There are 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure

3 Public charging points will remain the infrastructural bottleneck in the development of e-mobility

of e-chargers will grow by ~50% p.a., but only 10% will be public

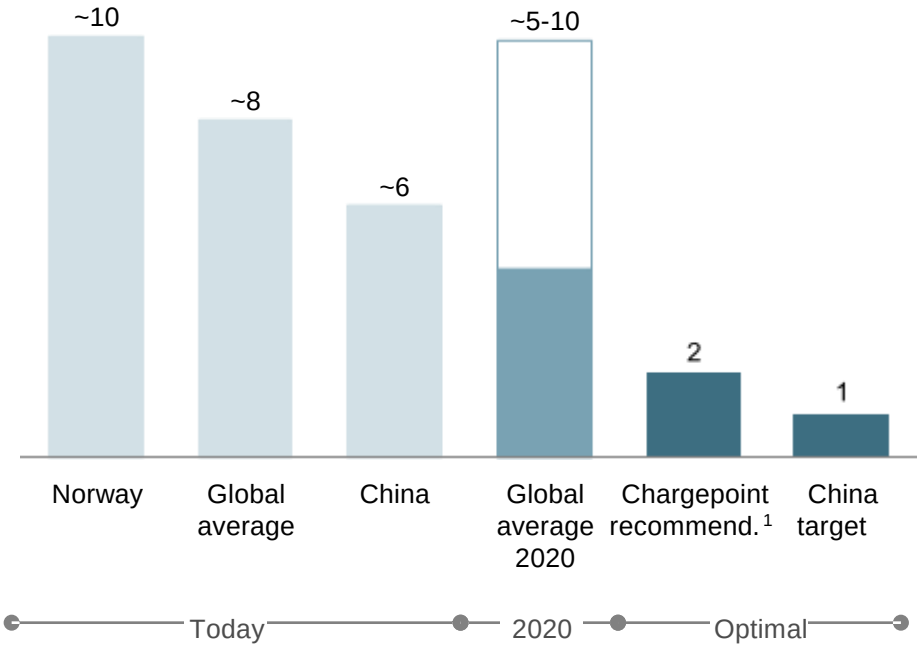


Est. # of e-chargers installed globally,
M units, cummulative



Public e-infrastructure will continue to be bottleneck of e-mobility

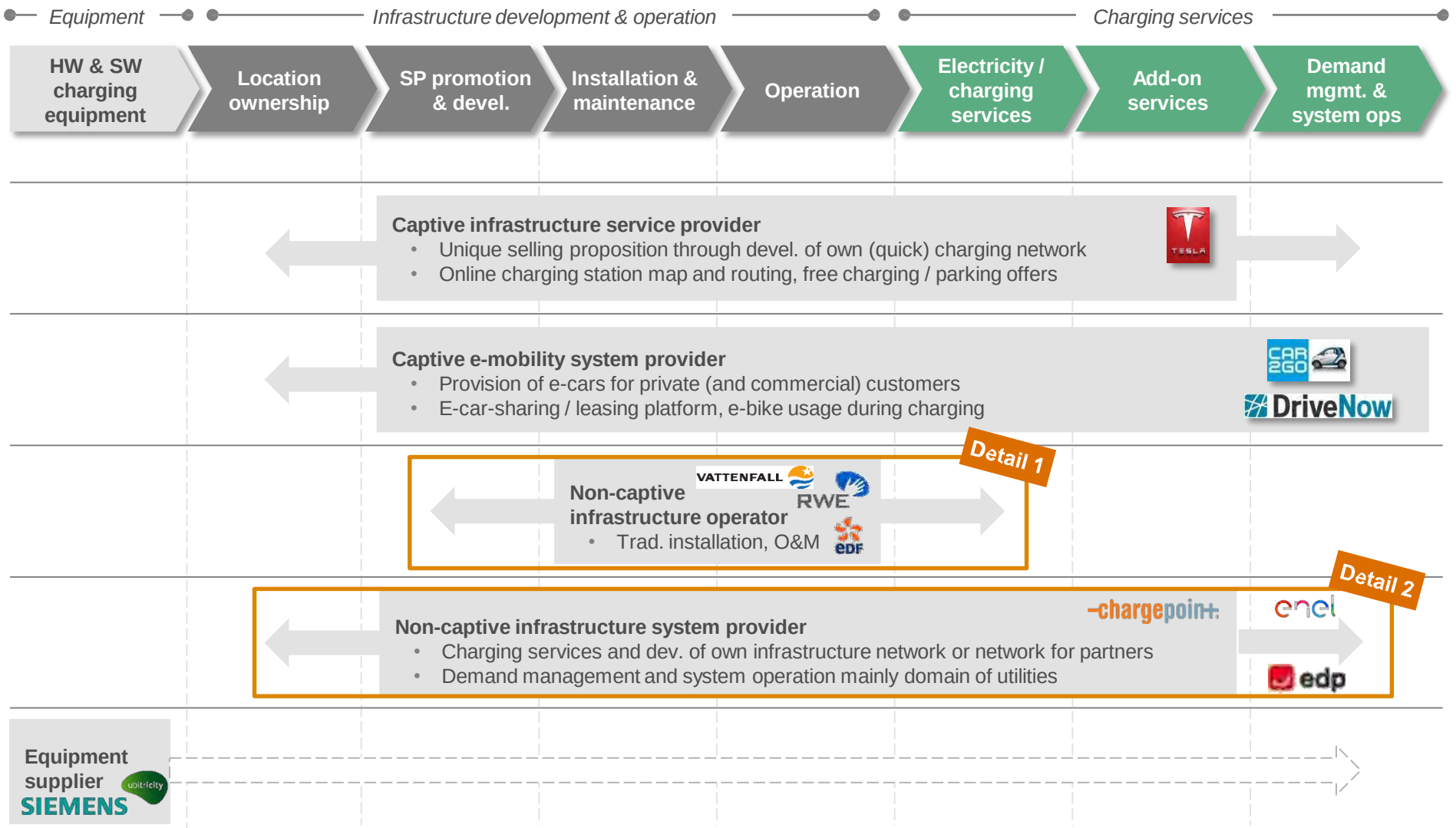
# of electric and hybrid vehicles per public charging outlet



1. Currently largest charging network in the world, with approx. 30,000 charging spots in North America, Europe, Asia, and Australia
Source: BCG analysis, IHS, Navigant, Technavio, Markets&Markets, IEA

3

Major players develop different business models along the e-infrastructure value chain



Source: BCG analysis

3 Detail 1: Vattenfall builds, owns and operates the first wireless charging infrastructure for electric buses

VATTENFALL

Vattenfall involved in a number of development and demonstration projects around the **electrification of buses, trucks and electric cars** including inductive charging

First wireless e-bus charging system in Sweden joint venture between Vattenfall, Scania, KTH, and the public transport operator for the Stockholm region SL

Key system specifications

- **Hybrid electric bus** which can cover most of the 10 km route on electricity only – biodiesel engine for longer rides without charging
- **Inductive battery charging time:** 6 to 7 minutes

*"Vattenfall also owns the charging infrastructure and will **connect it to our IT platform for charging services, which will enable active monitoring and remote control.** Operational reliability will be crucial if there is to be a large-scale transition to electric transport."*

Director E-Mobility Vattenfall

Source: BCG analysis

3 Detail 2: Chargepoint operates largest charging network worldwide without investing in infrastructure

chargepoint®

Currently largest charging network in the world, with approx. 30,000 charging spots in North America, Europe, Asia, and Australia

Core business: construction and maintenance of charging infrastructure for 3rd parties (e.g., company parking lots, shopping malls, parking garages, public parking lots)

Extensive partnering

- High benefit for EV drivers through **partnerships with various stakeholders in EV market**, including OEMs (e.g. BMW, VW, GM), charger manufacturers, power companies and government organizations

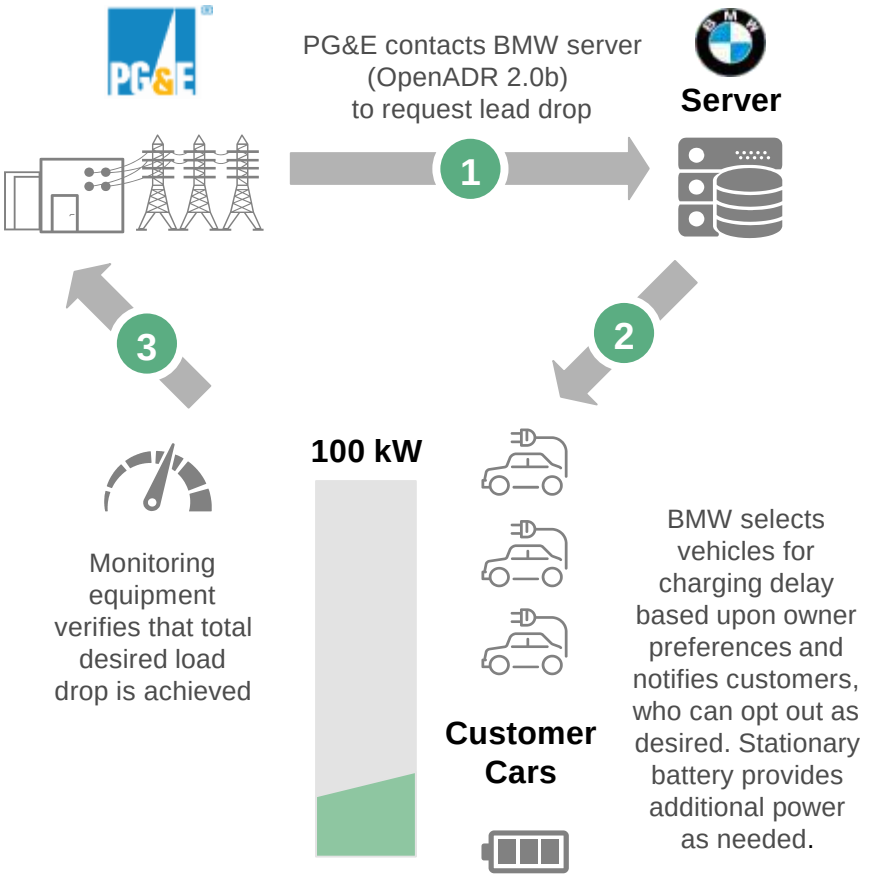
Customized service offer for B2B and B2C

- **B2B:** Minimization of operating costs with monitoring, notifications, diagnosis, and station controlling
- **B2C:** Round-the-clock driver support, station searches, station availability information, navigation support, and reservation by app

Source: BCG analysis

3 Electric vehicles will also play an important role in ensuring a stable electricity network through vehicle-to-grid (V2G)

BMW/PG&E V2G pilot (100 BMW i3)



Nissan/Enel V2G partnership

"We see Nissan electric vehicles as being the mobile energy hubs of the future, pioneering a self-sustaining energy infrastructure that will help solve the capacity issues of the future."

Chairman Nissan Europe

- First fully **commercial V2G Hub in Denmark** launched in January 2016 comprising 40 V2G units
- First **V2G trial in the UK** announced in May 2016 with 100 V2G units

Note: ESS = energy storage system, V2G = vehicle-to-grid
Source: Press search, BCG analysis

3 Favorable legislation and public incentives are crucial for development of e-mobility and e-car penetration

Country	Purchase subsidies	Registration tax benefits	Ownership tax benefits	Local incentives	Infrastructure incentives
Austria	✓	✓	✓	✓	✗
Czech Republic	✗	✓	✓	✗	✗
Denmark	✓	✓	✗	✓	✓
France	✓	✓	✓	✓	✗
Germany	✓	✗	✓	✓	✗
Hungary	✗	✓	✓	✓	✗
Italy	✓	✗	✓	✗	✓
Norway	✗	✓	✓	✓	✓
Poland	✗	✗	✗	✗	✗
Slovakia	✗	✗	✗	✗	✗
Spain	✓	✓	✓	✓	✓
Sweden	✓	✗	✓	✗	✗
United Kingdom	✓	✓	✓	✓	✓

Examples

- Tax rebate on installation of home charger of up to ____ EUR
- Connection charge reduced by 50% for public charging station

- Free Parking
- Reserved Parking spots
- Bus lane use

- Urban toll exemption
- Highway toll exemption
- Free Parking
- Bus lane use
- Funding in some cities for normal charging stations

- Public funding for fast charging stations every 50 km on main roads.

- Electric vehicles exempt from London congestion zone charge

Source: European Alternative Fuels Observatory; BCG analysis