Elektromobilita
Stav a vývoj – Globální trendy

10. března 2017
The Boston Consulting Group (BCG) is a major international strategic consultancy and global thought leader on e-mobility

1. **BCG**
   - We are **leading global strategic consultancy**
   - Founded in 1963, BCG is the leading strategic consultancy with 85 offices in 48 countries, ~1,000 expert partners and $5B annual revenues

2. **Our opinion is independent and unbiased**
   - We are an independent consultancy with no direct financial stake in the game
   - Our opinion is unbiased as we are not trying to sell any e-mobility product or service

3. **We are global e-mobility thought shaper**
   - We have helped to shape the e-mobility industry from the very start
   - We have 'seat at the table' at major global e-mobility events including the World Economic Forum in Davos

4. **We have extensive hands-on experience**
   - We are the consultant of choice for leading private and public sector players for e-mobility strategy projects
   - We supported almost 40 e-mobility projects over the last 3 years

5. **We have global reach and international experts**
   - We are a truly global company with dedicated e-mobility experts across geographies and industry practice areas including automotive, utilities and public sector
Mobility revolution is visibly gaining momentum across many areas in both private and public sectors

**Private sector**

- **Electric car**
  - infineon
  - DELPHI
  - National Electric Vehicle Sweden
  - SAAB
  - KARMA
- **Autonomous car**
  - Microsoft
  - Mobileye
  - Novariant
  - Google
  - Uber
- **Car sharing**
  - TURO
  - Enterprise CarShare
  - Go
  - Zipcar
  - Bytemobius
  - DAIMLER
- **Carpooling/Ride-sharing**
  - Side-car
  - GM
- **E-Hailing/Hailing services**
  - Uber
  - OLA
  - DiDi
  - GrabTaxi
  - Lyft
  - Magna
- **Advanced Driver Assistance**
  - Continental
  - Vodafone Automotive
  - HARMAN
  - Jasper
  - verizon
- **Connected car**
  - Vodafone
  - Automotive
  - Vodafone
  - Continental
  - TomTom

**Public sector**

- **City of Gothenburg**
  - "100 self-driving cars set to hit Sweden’s public roads in 2017"
- **City of 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."
- **City of Beverly Hills**
  - "Driverless buses are coming to public-transit-phobic Beverly Hills"
- **City of 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

Draft—for discussion only
Our recent project experience shows the breadth of e-mobility topics and sectors involved across geographies

<table>
<thead>
<tr>
<th>Geography</th>
<th>Client</th>
<th>Short project description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major city in the Netherlands</td>
<td>Developed <strong>driverless vehicle / autonomous driving strategy</strong> for a Dutch municipality</td>
<td></td>
</tr>
<tr>
<td>World Economic Forum</td>
<td>Conducted comprehensive analysis of <strong>self-driving vehicles and urban mobility</strong></td>
<td></td>
</tr>
<tr>
<td>Premium car OEM</td>
<td>Built <strong>new e-mobility business concept</strong> at intersection of vehicle connectivity, autonomous driving, sharing, and electric drive</td>
<td></td>
</tr>
<tr>
<td>Operator of parking garages</td>
<td>Conducted strategic review and proposed new <strong>smart parking strategy</strong></td>
<td></td>
</tr>
<tr>
<td>Public transport company</td>
<td>Created the <strong>2020 strategy focused on e-mobility</strong> for a public transport company</td>
<td></td>
</tr>
<tr>
<td>Multinational technology company</td>
<td>Reviewed the <strong>future mobility landscape</strong> with focus on autonomous driving, e-mobility and car sharing</td>
<td></td>
</tr>
<tr>
<td>Japanese car manufacturer</td>
<td>Supported developing a <strong>smart city strategy for sustainable mobility</strong>, with focus on electric vehicle infrastructure</td>
<td></td>
</tr>
<tr>
<td>Global mobility solutions provider</td>
<td>Analyzed technology solutions landscape around <strong>autonomous vehicles</strong> and determined client way forward on traffic mgmt.</td>
<td></td>
</tr>
<tr>
<td>Leading energy utility</td>
<td>Assessed robustness of <strong>e-mobility strategy</strong> at a European energy utility</td>
<td></td>
</tr>
<tr>
<td>Global automotive company</td>
<td>Provided support in launching a <strong>car sharing pilot</strong> in the US for a global automotive company's new electric vehicle</td>
<td></td>
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</tbody>
</table>

Over the last three years we supported almost 40 e-mobility related projects for major private and public sector players
We see 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure.
We see 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure.
Autonomous vehicles are taking off – first cars with self-driving features already on the road

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

### Self-driving cars
- **Gothenburg, Volvo**
  "Drive Me" project to launch 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 to be provided by Volvo and Ford by end of 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 planned by 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

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**The Boston Consulting Group**

Draft—for discussion only
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

**Buses:** Self-driving electric (mini-)buses

**Trucks:** Autonomous, optimized long-haul trucks

*Source: BCG, Daimler, Freightliner, Google, LocalMotors*
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
Detail 2: Trucks of the future will be technology-enabled, remotely-managed with fully optimized load-patterns

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

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

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

Source: Daimler, BCG
Price of batteries will fall to ~1/2 by 2025 making electric cars more competitive

Battery price in $ / kWh, pack-level

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

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

% of total respondents

- Hybrid: 37%
- Electric: 29%
- I don't know: 15%
- Trad. combustion: 9%
- Fuel cell: 9%

"It has to be an e-car, everything else wouldn't be state of the art!"

Source: World Economic Forum; BCG analysis, consumer survey August 2015
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
Depending on the scenario for autonomous e-vehicle penetration, the future of city traffic will change dramatically.

1. The premium car drives itself: Autonomous vehicles complement existing mobility offer

2. Autonomous vehicles rule the streets: Autonomous vehicles replace most traditional cars

3. Self-driving taxi revolution: Self-driving taxis are primary mobility option

4. Ride-shared self-driving taxi revolution: Ride-sharing self-driving taxis are primary mobility option

Impact:

- **Limited city and consumer benefits**: Limited city and consumer benefits
  - Emissions: -9%
  - Accidents: -19%
  - Parking space: -28%

- **Some city and consumer benefits**: Some city and consumer benefits
  - Emissions: -23%
  - Accidents: -55%
  - Parking space: -43%

- **Sizable benefits, but not without costs**: Sizable benefits, but not without costs
  - Emissions: -81%
  - Accidents: -86%
  - Parking space: -23%

- **Highest benefits for city and consumer**: Highest benefits for city and consumer
  - Emissions: -85%
  - Accidents: -87%
  - Parking space: -55%

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 over a 10 year horizon; assumes no powertrain mix shift; Source: World Economic Forum; BCG analysis.
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
We see 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure.
New mobility opens door to disruptive business models in B2B and B2C segments

### Vehicle-centered
- **Ride hailing**
  - Taxi
  - "Black car"
  - Robo taxi
- **Car sharing**
  - B2C & B2B sharing
  - P2P sharing
  - Community sharing
  - Bike & scooter sharing

### IT-centered
- **Multimodal platforms**
  - Multimodal
  - Mono-modal
  - Life assistants
  - Data brokerage

### Infrastructure-centered
- **Smart parking**
  - Off-street parking
  - On-street parking
  - P2P parking space share
  - Data brokerage

### New mobility services
- **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
- **Mapping and navigation**
  - Navigation services
  - Mapping services
  - Data brokerage
- **Charging**
  - Public charging
  - Fast charging
  - Corporate charging
  - P2P charging

Source: BCG analysis

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

**x35**
Development of the number of mobility service users by 2020

Up to 61% of households in the top 20 USMSA³ find switching to on-demand mobility financially attractive

**x6**
Development of the number of carsharing users worldwide by 2020

DriveNow with 39% market share in Germany

**425**
Uber cities with $4bn net revenues

**205 million**
Lyft rides in 2016²

**x20**
Development of market volume for smart parking by 2025

**10 million**
mytaxi users

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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
Detail 1: We expect the ride hailing market 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.

Top 10 "ride-on-demand" apps

<table>
<thead>
<tr>
<th>Rank</th>
<th>App</th>
<th>Multiple of Uber app downloads</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Uber</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Kuadi</td>
<td>0.71</td>
</tr>
<tr>
<td>3</td>
<td>Didi</td>
<td>0.14</td>
</tr>
<tr>
<td>4</td>
<td>BlaBlaCar</td>
<td>0.11</td>
</tr>
<tr>
<td>5</td>
<td>Shenzou Zhanche</td>
<td>0.10</td>
</tr>
<tr>
<td>6</td>
<td>Kakao Taxi</td>
<td>0.10</td>
</tr>
<tr>
<td>7</td>
<td>Lyft</td>
<td>0.09</td>
</tr>
<tr>
<td>8</td>
<td>GrabTaxi</td>
<td>0.07</td>
</tr>
<tr>
<td>9</td>
<td>Easy Taxi</td>
<td>0.06</td>
</tr>
<tr>
<td>10</td>
<td>Yongche</td>
<td>0.06</td>
</tr>
</tbody>
</table>

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.
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.
Detail 2: We expect that by 2021 ~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.
Detail 2: B2C mobility platforms expand beyond car sharing also to other vehicle types – for example eScooters
**Detail 3: Smart parking has potential to dramatically change the way we park; we see four innovative models in the market**

<table>
<thead>
<tr>
<th></th>
<th>Off-street parking reservation &amp; payment</th>
<th>On-street parking space locator &amp; mobile metering</th>
<th>Peer-2-peer parking space sharing</th>
<th>Data brokerage for on-street parking data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reservation of off-street parking spaces</td>
<td>Search engine for free on-street parking spaces nearby</td>
<td>Private individuals <strong>rent out own parking</strong> spots to others</td>
<td>Data aggregator purchases proprietary vehicle data to <strong>locate free on-street parking</strong> spaces</td>
</tr>
<tr>
<td></td>
<td>Navigation to available space</td>
<td>Remote <strong>extension of parking ticket</strong></td>
<td>Hourly, daily or monthly periods possible</td>
<td>To aggregator: Additional data points for service</td>
</tr>
<tr>
<td></td>
<td>Online payment of parking fees</td>
<td><strong>Online payment</strong> of parking fees</td>
<td>To user: Additional revenue to parking space owner</td>
<td>To user: Location of free parking spaces via aggregator service</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use case</th>
<th>Value proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To user:</strong> Relieves need for lengthy parking space search</td>
<td><strong>To user:</strong> Relieves customer from meter payments/space search</td>
</tr>
<tr>
<td><strong>To operator:</strong> Allows variable pricing to improve space utilization</td>
<td><strong>To operator:</strong> Enables digital control of parking tickets</td>
</tr>
<tr>
<td><strong>To user:</strong> Private parking space often cheaper than dedicated lots</td>
<td><strong>To owner:</strong> Additional revenue to parking space owner</td>
</tr>
<tr>
<td><strong>To operator:</strong> Allows variable pricing to improve space utilization</td>
<td><strong>To aggregator:</strong> Additional data points for service</td>
</tr>
<tr>
<td><strong>To user:</strong> Location of free parking spaces via aggregator service</td>
<td><strong>To user:</strong> Location of free parking spaces via aggregator service</td>
</tr>
</tbody>
</table>

*Source: BCG analysis*
We see 3 interrelated e-mobility game-changers: autonomous driving & e-cars, new mobility services and e-infrastructure.
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

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

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Infrastructure development &amp; operation</th>
<th>Charging services</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW &amp; SW charging equipment</td>
<td>Location ownership</td>
<td>SP promotion &amp; devel.</td>
</tr>
<tr>
<td>Installation &amp; maintenance</td>
<td>Operation</td>
<td>Electricity / charging services</td>
</tr>
<tr>
<td>Add-on services</td>
<td>Demand mgmt. &amp; system ops</td>
<td></td>
</tr>
</tbody>
</table>

**Captive infrastructure service provider**
- Unique selling proposition through devel. of own (quick) charging network
- Online charging station map and routing, free charging / parking offers

**Captive e-mobility system provider**
- Provision of e-cars for private (and commercial) customers
- E-car-sharing / leasing platform, e-bike usage during charging

**Non-captive infrastructure operator**
- Trad. installation, O&M

**Non-captive infrastructure system provider**
- Charging services and dev. of own infrastructure network or network for partners
- Demand management and system operation mainly domain of utilities

Source: BCG analysis
**Detail 1: Vattenfall builds, owns and operates the first wireless charging infrastructure for electric buses**

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

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Source: BCG analysis

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

Chargepoint operates the largest charging network worldwide without investing in infrastructure. Chargepoint currently has approximately 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
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)

1. PG&E contacts BMW server (OpenADR 2.0b) to request lead drop

2. Server

3. Monitoring equipment verifies that total desired load drop is achieved

- **100 kW**
- **BMW selects vehicles for charging delay** based upon owner preferences and notifies customers, who can opt out as desired. Stationary battery provides additional power as needed

### 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

Includes also vehicle-to-home functionality (PV-charged battery = ~2 days of household electricity)

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*Note: ESS = energy storage system, V2G = vehicle-to-grid*

*Source: Press search, BCG analysis*
### E-Mobility Infrastructure

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Purchase subsidies</th>
<th>Registration tax benefits</th>
<th>Ownership tax benefits</th>
<th>Local incentives</th>
<th>Infrastructure incentives</th>
<th>Examples</th>
</tr>
</thead>
</table>
| 🇩🇪 Germany | ✓ | ✓ | ✓ | ✓ | ✓ | - Tax rebate on installation of home chargers of up to 12,000 DKK  
- Connection charge reduced by 50% for public charging station |
| 🇫🇷 France | ✓ | ✓ | ✓ | ✓ | ✓ | - Free Parking  
- Reserved Parking spots  
- Bus lane use |
| 🇳🇴 Norway | ✓ | ✓ | ✓ | ✓ | ✓ | - Urban toll exemption  
- Highway toll exemption  
- Free Parking  
- Bus lane use  
- Funding in some cities for normal charging stations |
| 🇸🇪 Sweden | ✓ | ✓ | ✓ | ✓ | ✓ | - 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
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