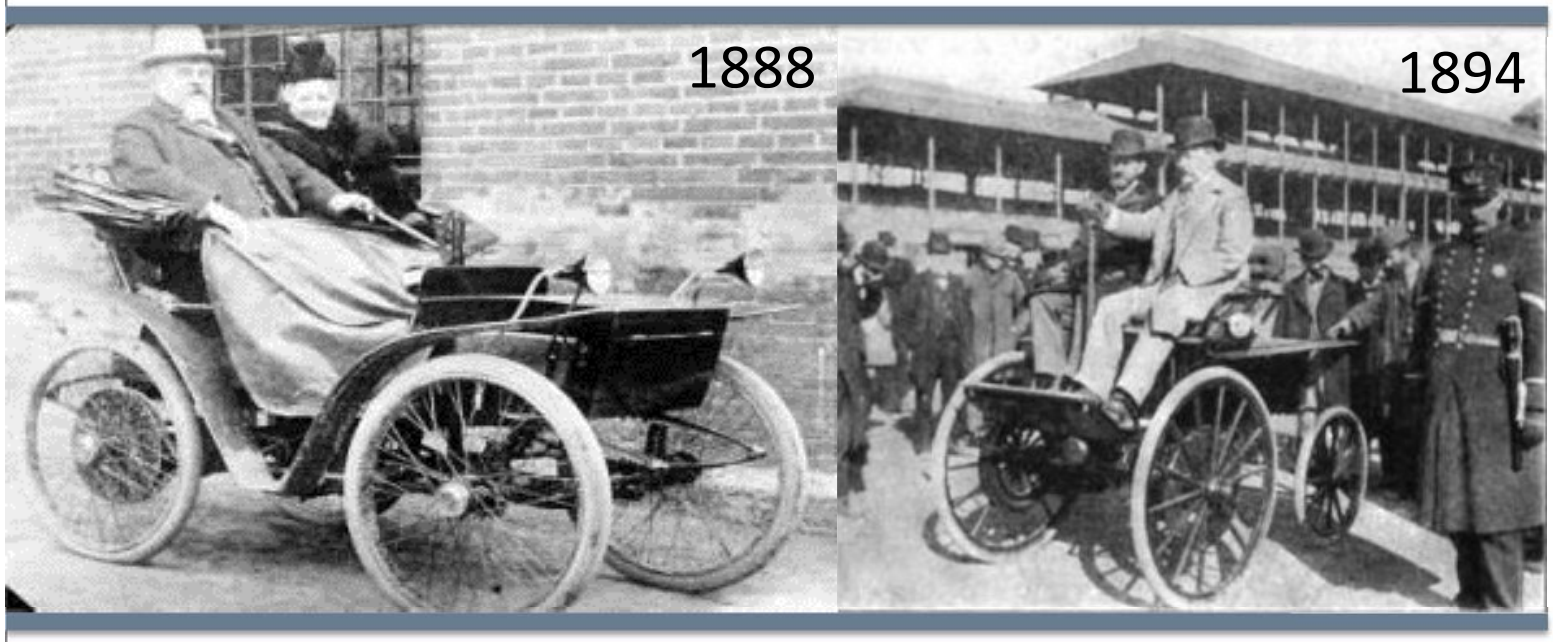
Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

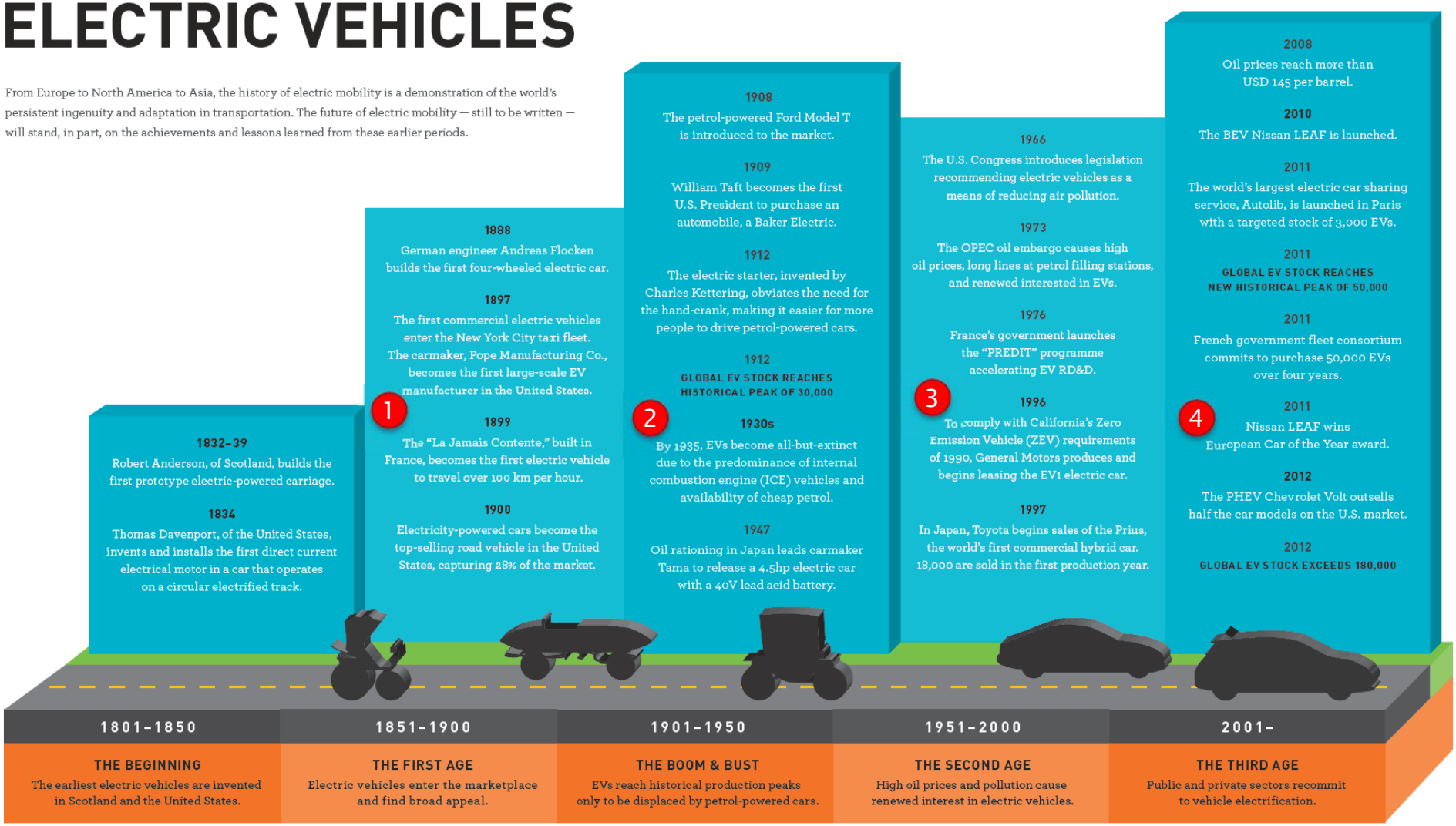


E-Vehicles, are they here to stay?

Dr. Alejandro Santis: alejandro.santis@bfh.ch
BFH-CSEM Energy Storage Research Centre: www.bfh.ch/energy

A BRIEF HISTORY OF ELECTRIC VEHICLES

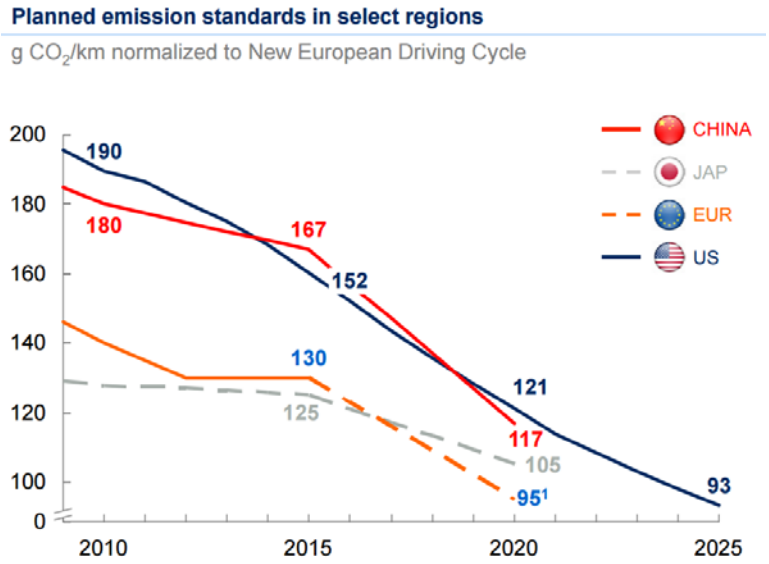
From Europe to North America to Asia, the history of electric mobility is a demonstration of the world's persistent ingenuity and adaptation in transportation. The future of electric mobility — still to be written — will stand, in part, on the achievements and lessons learned from these earlier periods.

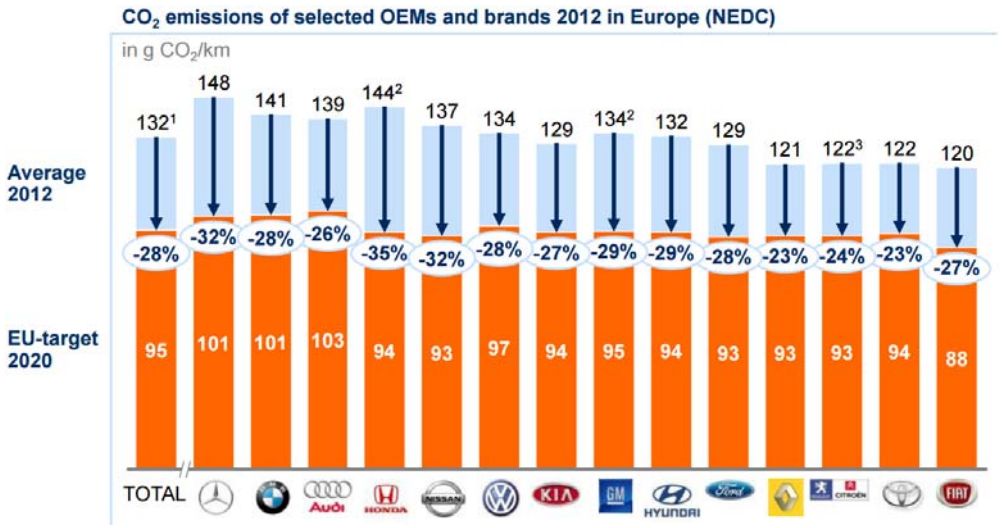


Sources: Curtis D. Anderson and Judy Anderson, *Electric and Hybrid Cars: A History*, McFarland and Company, 2012 ; burnanenergyjournal.com; pbs.org/now/shows/223/electric-car-timeline.


electric drive
Electric Drive
S VM 9200
Audi
HONDA
NISSAN
KIA
GM
HYUNDAI
Ford
CITROËN
FIAT
TESLA

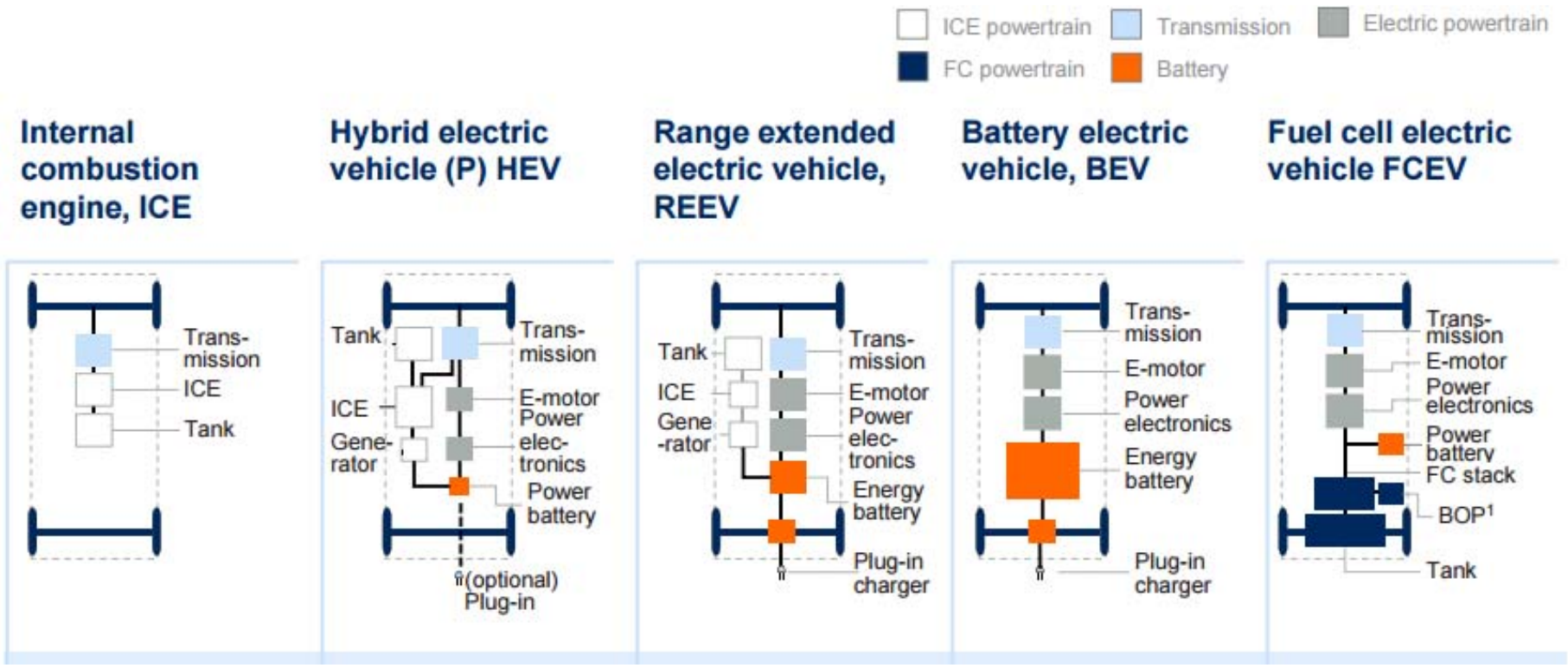
Governments around the world are setting ambitious targets for light vehicle CO_2 emissions





- EU target of 130 g CO_2/km effective as of 2012, with a moderate phase-in allowed until 2015
- Long-term EU proposal of 95 g CO_2/km for 2020; 2025 initial proposal 68-78 g but decision postponed
- In the US, fleets must improve to 93 g CO_2/km in 2025 from the 152 g CO_2/km threshold in 2016

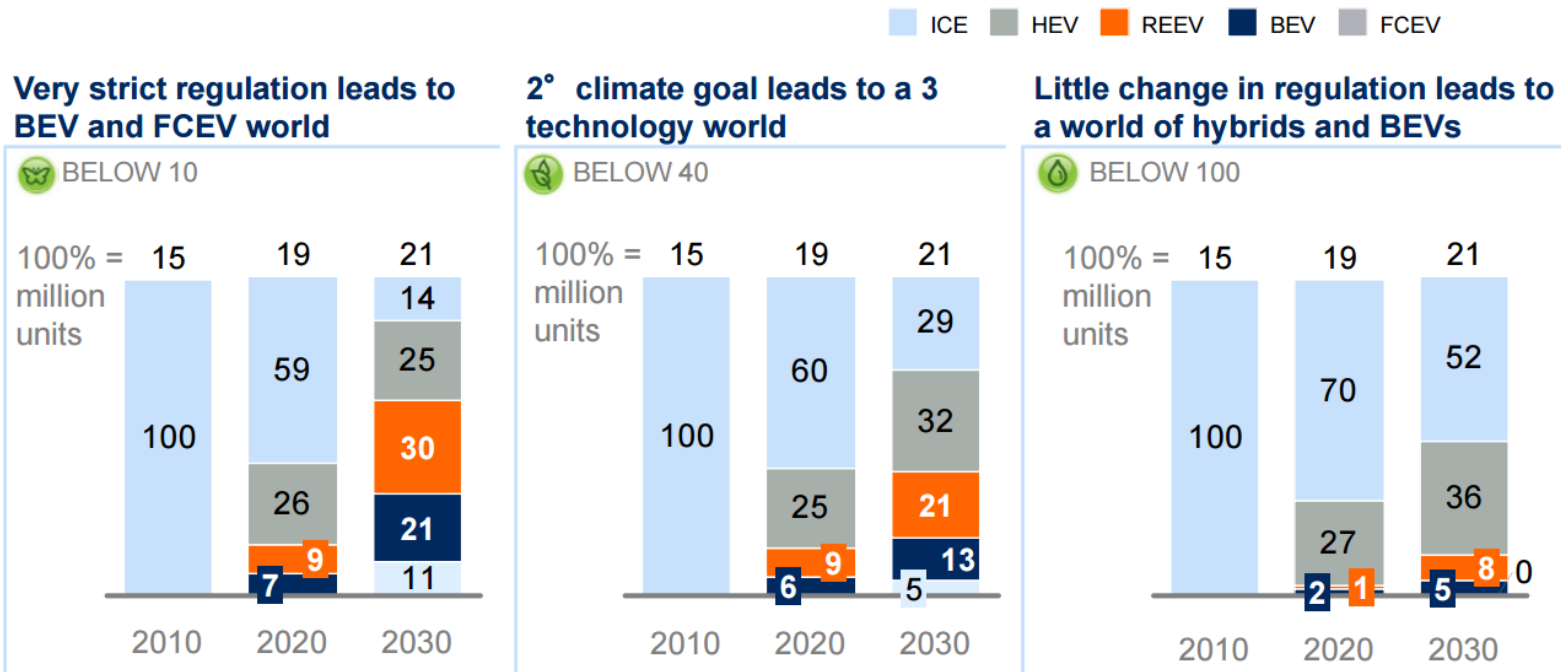
ICE and the different types of EVs



ICE primary source of propulsion

ELECTRIC MOTOR primary source of propulsion

In the long-term EV adoption remains uncertain, driven by regulation (Europe)



Very strict CO_2 emission reduction to 10 g/km in 2050, representing the global warming goal of a maximum increase of 2 degrees Celsius transferred to the transportation industry[1]

Strong CO_2 emission reduction to 40 g/km in 2050 – a scenario that foresees a continuation of increasingly restrictive emission standards[1]

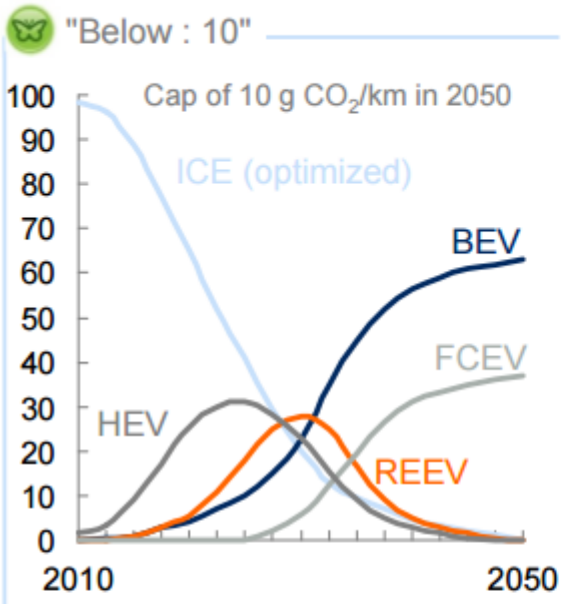
Moderate CO_2 emission reduction to 95 g CO_2/km in 2050. This would imply that regulation as of 2020 will not get much tighter. Only the tank-to-wheel standard will shift to a well-to-wheel standard[1]

1 For further details on scenarios, refer to Appendix 1

SOURCE: McKinsey – Boost! Powertrain KIP

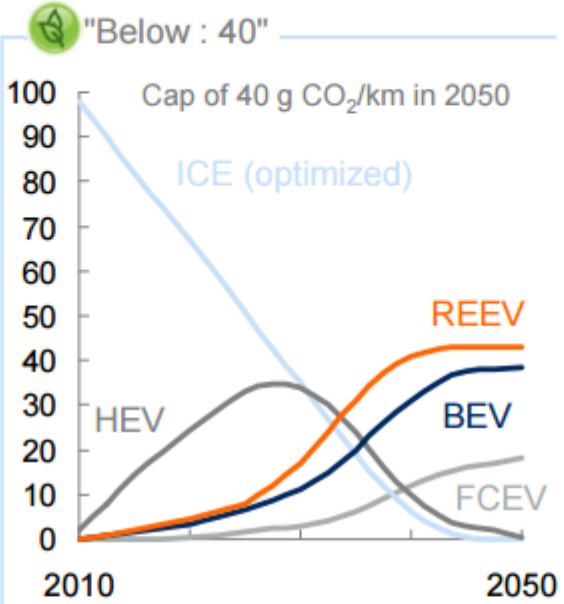
In the long-term EV adoption remains uncertain, driven by regulation (Europe)

Very strict regulation leads to BEV and FCEV world



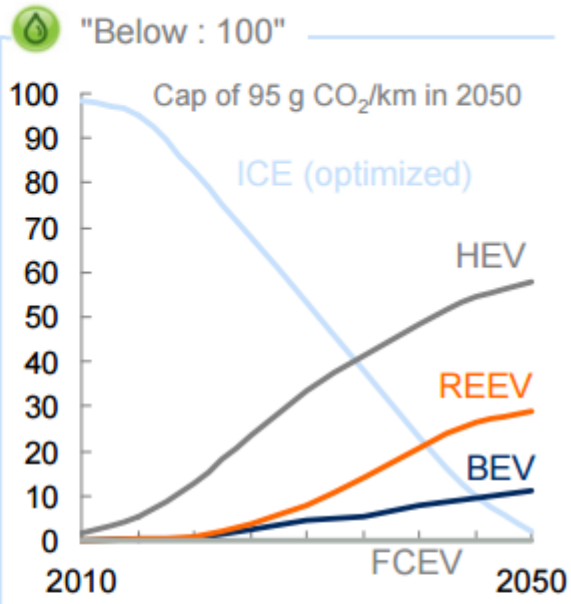
- ICE remains dominant until 2025, but loses market share to xEVs
- In the long run, BEVs dominate smaller vehicles and FCEV larger vehicles
- HEV / REEV as bridging technology

2° climate goal leads to a 3 technology world



- ICE remains dominant until 2025 but loses market share to xEVs
- Over time, BEVs, REEVs and FCEVs dominate small, medium and large vehicles, respectively
- xEVs lead to singular drivetrain scenario

Little change in regulation leads to a world of hybrids and BEVs



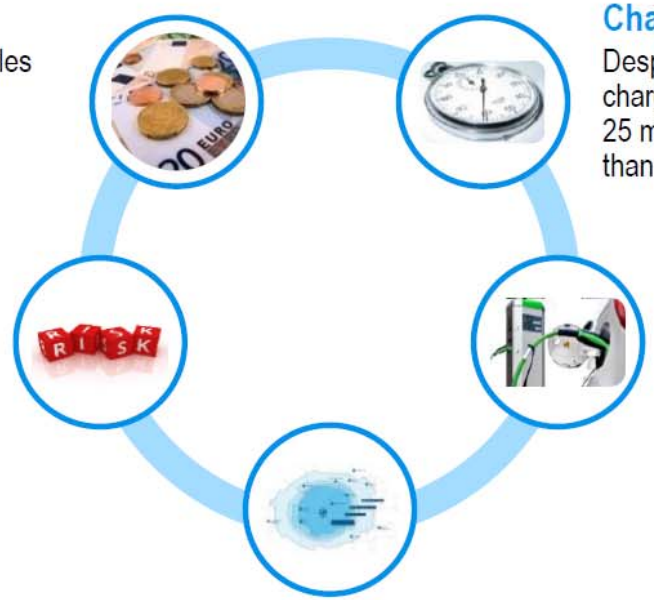
- ICE remains dominant until 2035+
- BEV will only become economically competitive post-2030, no infrastructure for FCEV is built
- Long-term HEV and REEV / BEV existence leads to a dual powertrain scenario

SOURCE: McKinsey – Boost! Powertrain KIP

Main hurdles for e-mobility: All Battery related!

Purchase price
The current purchase price of electric vehicles is significantly higher compared to vehicles equipped with conventional powertrains

Charging time
Despite existing rapid-charging stations, the charging of a battery electric vehicle takes 20-25 minutes and therefore significantly longer than fueling of a conventional car



Risk
Recent accidents (e.g. burning battery of a Tesla Model S) lead to security concerns, e.g. regarding maturity of the technology

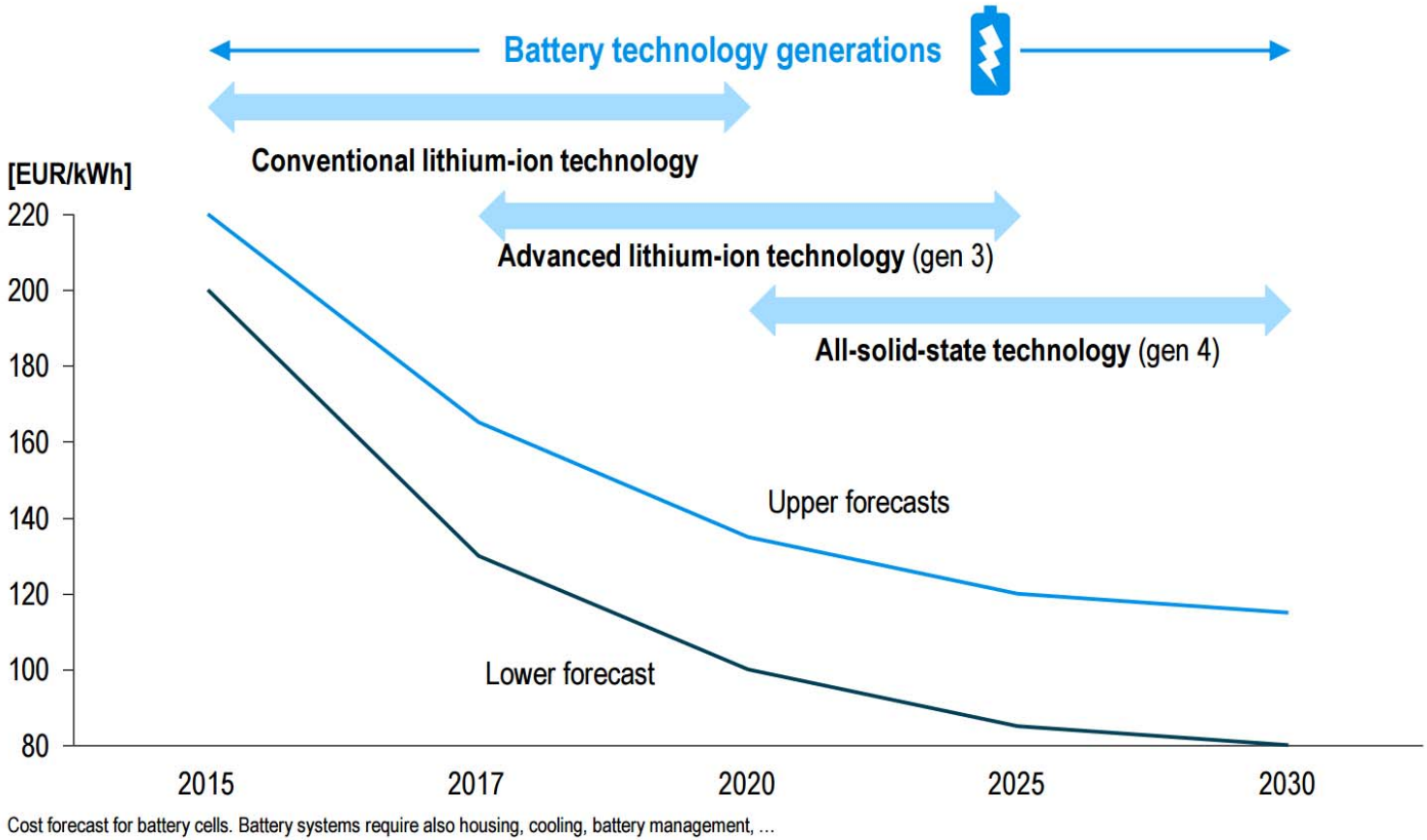
Infrastructure
The current density of charging stations is low compared to conventional gas stations and therefore leads to a different usage behavior for electric vehicles (e.g. ~2,000 charging stations vs. ~14,000 gas stations in Germany)

Vehicle range
Due to limited battery capacity, the maximum range of a electric vehicle is significantly lower compared to a vehicle with conventional powertrain

Source: Roland Berger, Integrated fuels and vehicles to 2030 and beyond, 2016

Price development of battery cells [EUR/kWh]

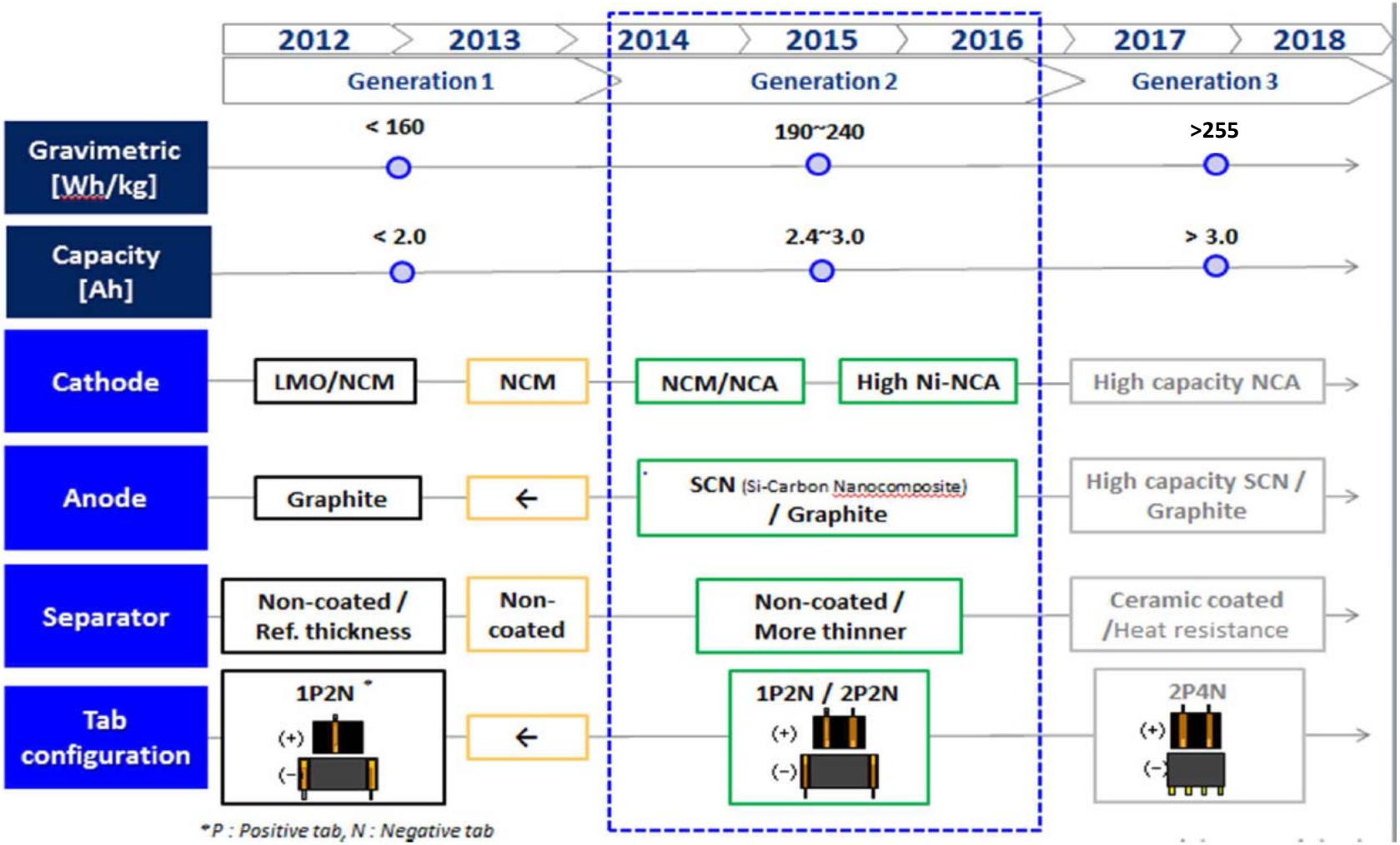
Batteries make up a third of the cost of an electric vehicle
As battery cell costs continue to fall, demand for EV's will rise



Cost forecast for battery cells. Battery systems require also housing, cooling, battery management, …

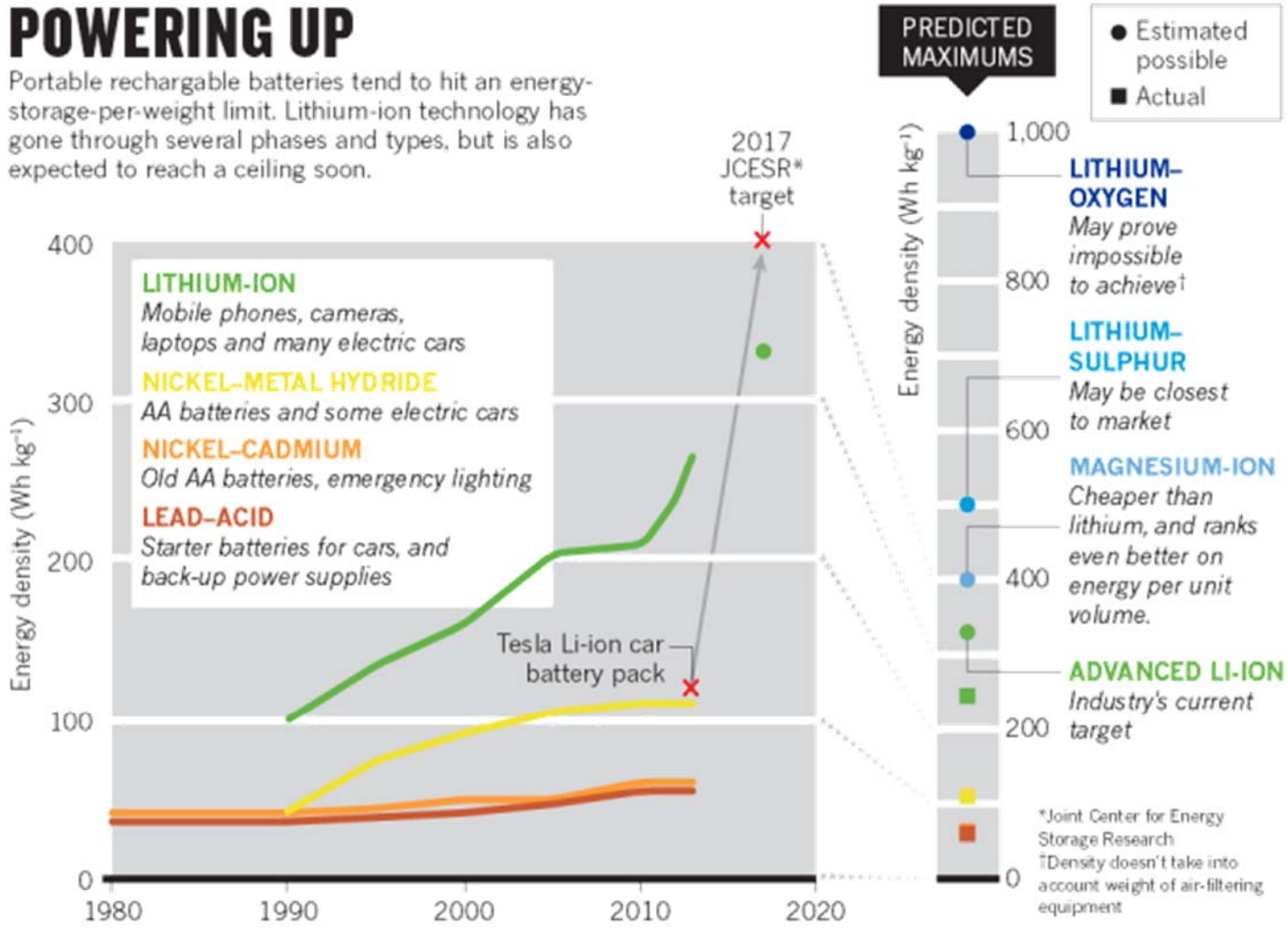
Source: Roland Berger

Li-Ion Technology Roadmap 18650 & 21700



Source: BMZ, 2016

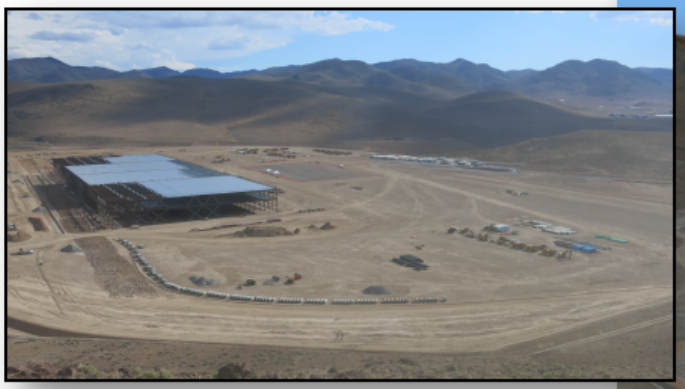
Advanced and Post Lithium-ion



Source: IDTechEX, Advanced and Post Lithium-ion Batteries 2016-2026: Technologies, Markets, Forecasts , 2015

TESLA's 150 GWh (?) Battery Factory (Gigafactory)

Gigafactory 1.0



- $4-5 Billion investment
- Under construction in Reno, NV
- 6,500 full-time jobs
- First battery packs mid-2016

- Currently only approximately 20 percent of its 1-million-square-foot facility is already up and running.
- Its projected capacity for 2018 is 50 GWh/yr of battery packs and its final capacity upon completion of entire factory is 150 GWh/yr. This would enable Tesla to produce 1,500,000 cars per year (2020 ?)

Source: Tesla Motors JB Straubel – CTO, co-founder 2015 EIA Conference June 15, 2015 Washington, D.C.

Tesla's 150 GWh Gigafactory - Synopsis

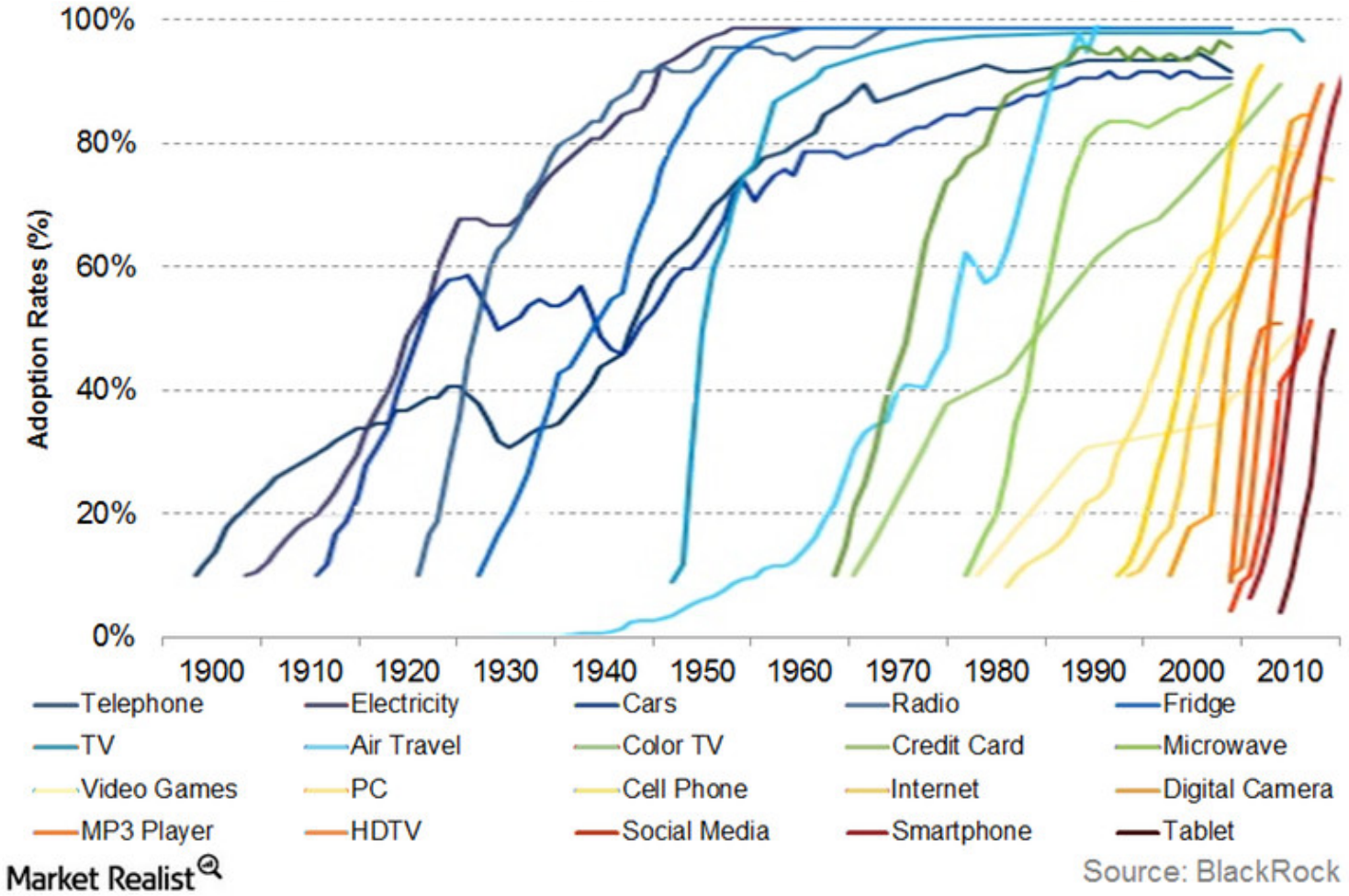
- Tesla suggests that it will put up half of the $5 billion investment, with Panasonic investing on the order of $1-1.5 billion, but unconfirmed reports from Japan suggest that Panasonic only committed to about $200M in 2017
- Pack cost much below $200/kWh is unlikely before 2020, which brings the cost of the proposed 70 kWh pack for a 240 mile D class EV to $14'000 (or higher).
- If 50 GWh are indeed installed and utilized, initial assessments shows that pack pricing for the 2025 time scale could be as low as $167/kWh, $8,400 for a 50 kWh battery and $11'700 for a 70 kWh pack
- Other automotive and utility customers for the factory are possible but far from assured
- The chosen site outside Reno, Nevada offer lower labor and utility cost than Japan sites and short supply lines to the Fremont Tesla car factory

Source: Copyright 2014 Total Battery Consulting, Inc

Game Changer

- As of April 7, 2016, one week after the event, Tesla Motors reported over 325,000 reservations, more than triple the 107,000 Model S cars Tesla had sold by the end of 2015.
- Tesla reported the number of net reservations totaled about 373,000 as of 15 May 2016 after about 8,000 customer cancellations and about 4,200 reservations canceled by the automaker because these appeared to be duplicates from speculators.
- According to http://model3counter.com/, there are now (June 2017) 538'632 reservations.

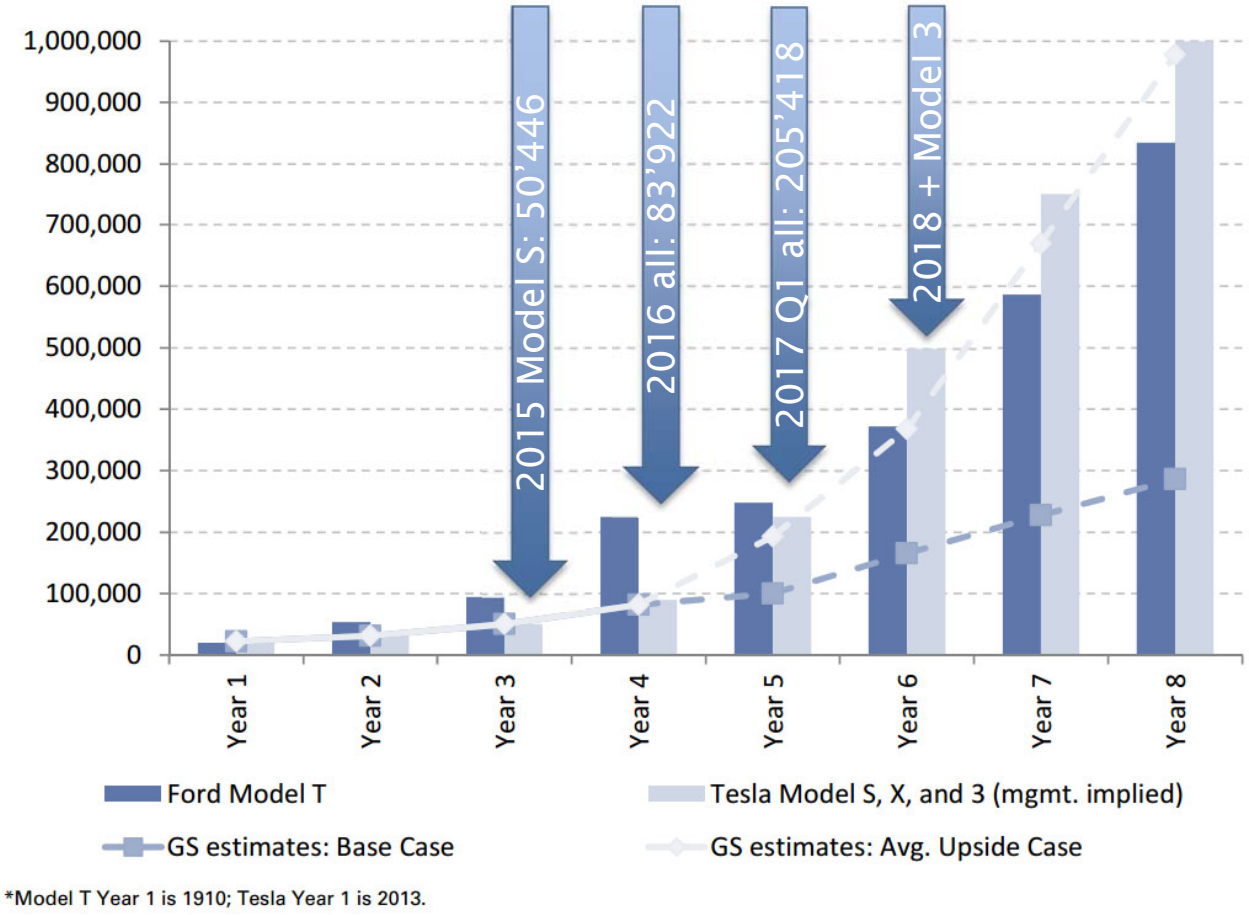
Adoption of technology in the US (1900 to present)



Game Changer

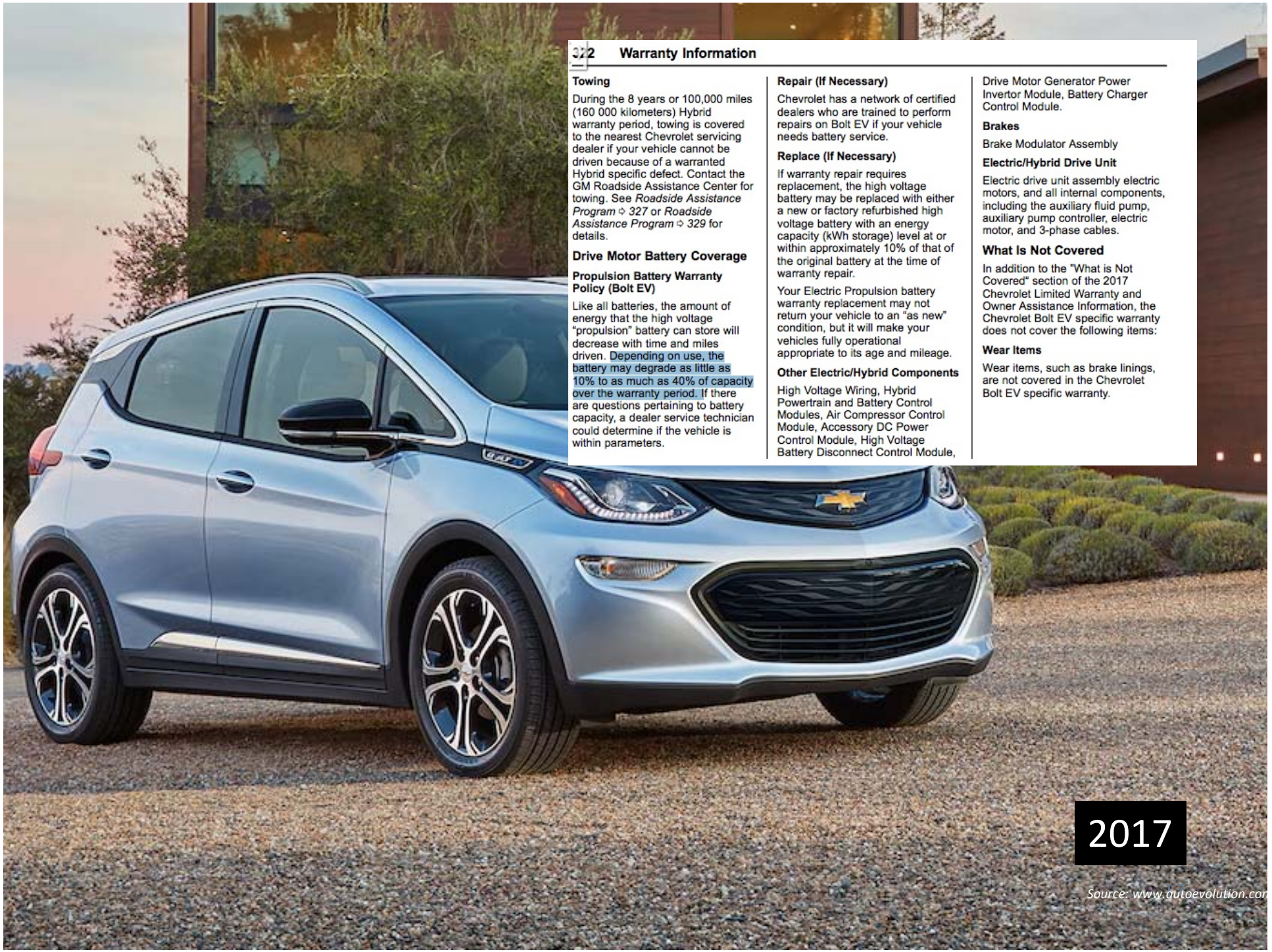
Comparing Elon Musk's Tesla vehicles with Henry Ford's iconic Model T

Exhibit 10: Tesla's estimated production ramp is very similar to that of Ford's Model T 100 years ago
Tesla vehicle deliveries vs. Ford's Model T



*Model T Year 1 is 1910; Tesla Year 1 is 2013.

Source: Company data, Goldman Sachs Global Investment Research.



Towing

During the 8 years or 100,000 miles (160 000 kilometers) Hybrid warranty period, towing is covered to the nearest Chevrolet servicing dealer if your vehicle cannot be driven because of a warranted Hybrid specific defect. Contact the GM Roadside Assistance Center for towing. See *Roadside Assistance Program* ⇨ *327* or *Roadside Assistance Program* ⇨ *329* for details.

Drive Motor Battery Coverage

Propulsion Battery Warranty Policy (Bolt EV)

Like all batteries, the amount of energy that the high voltage "propulsion" battery can store will decrease with time and miles driven. Depending on use, the battery may degrade as little as 10% to as much as 40% of capacity over the warranty period. If there are questions pertaining to battery capacity, a dealer service technician could determine if the vehicle is within parameters.

Repair (If Necessary)

Chevrolet has a network of certified dealers who are trained to perform repairs on Bolt EV if your vehicle needs battery service.

Replace (If Necessary)

If warranty repair requires replacement, the high voltage battery may be replaced with either a new or factory refurbished high voltage battery with an energy capacity (kWh storage) level at or within approximately 10% of that of the original battery at the time of warranty repair.

Your Electric Propulsion battery warranty replacement may not return your vehicle to an "as new" condition, but it will make your vehicles fully operational appropriate to its age and mileage.

Other Electric/Hybrid Components

High Voltage Wiring, Hybrid Powertrain and Battery Control Modules, Air Compressor Control Module, Accessory DC Power Control Module, High Voltage Battery Disconnect Control Module, Drive Motor Generator Power Invertor Module, Battery Charger Control Module.

Brakes

Brake Modulator Assembly

Electric/Hybrid Drive Unit

Electric drive unit assembly electric motors, and all internal components, including the auxiliary fluid pump, auxiliary pump controller, electric motor, and 3-phase cables.

What Is Not Covered

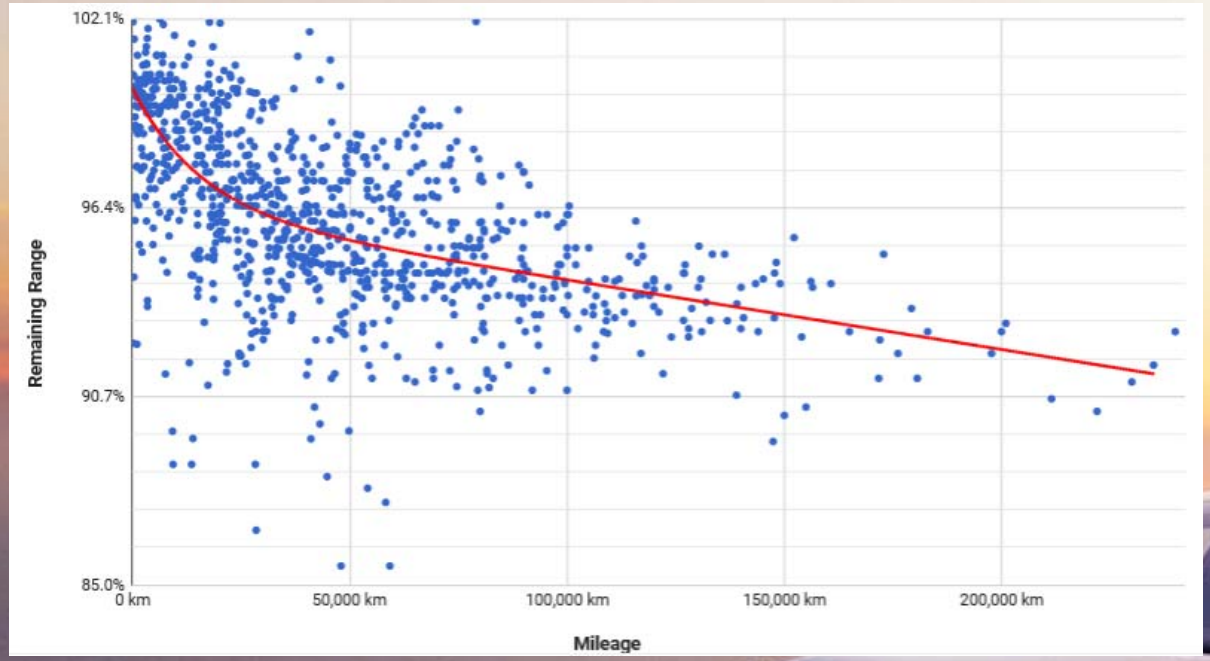
In addition to the "What is Not Covered" section of the 2017 Chevrolet Limited Warranty and Owner Assistance Information, the Chevrolet Bolt EV specific warranty does not cover the following items:

Wear Items

Wear items, such as brake linings, are not covered in the Chevrolet Bolt EV specific warranty.

2017

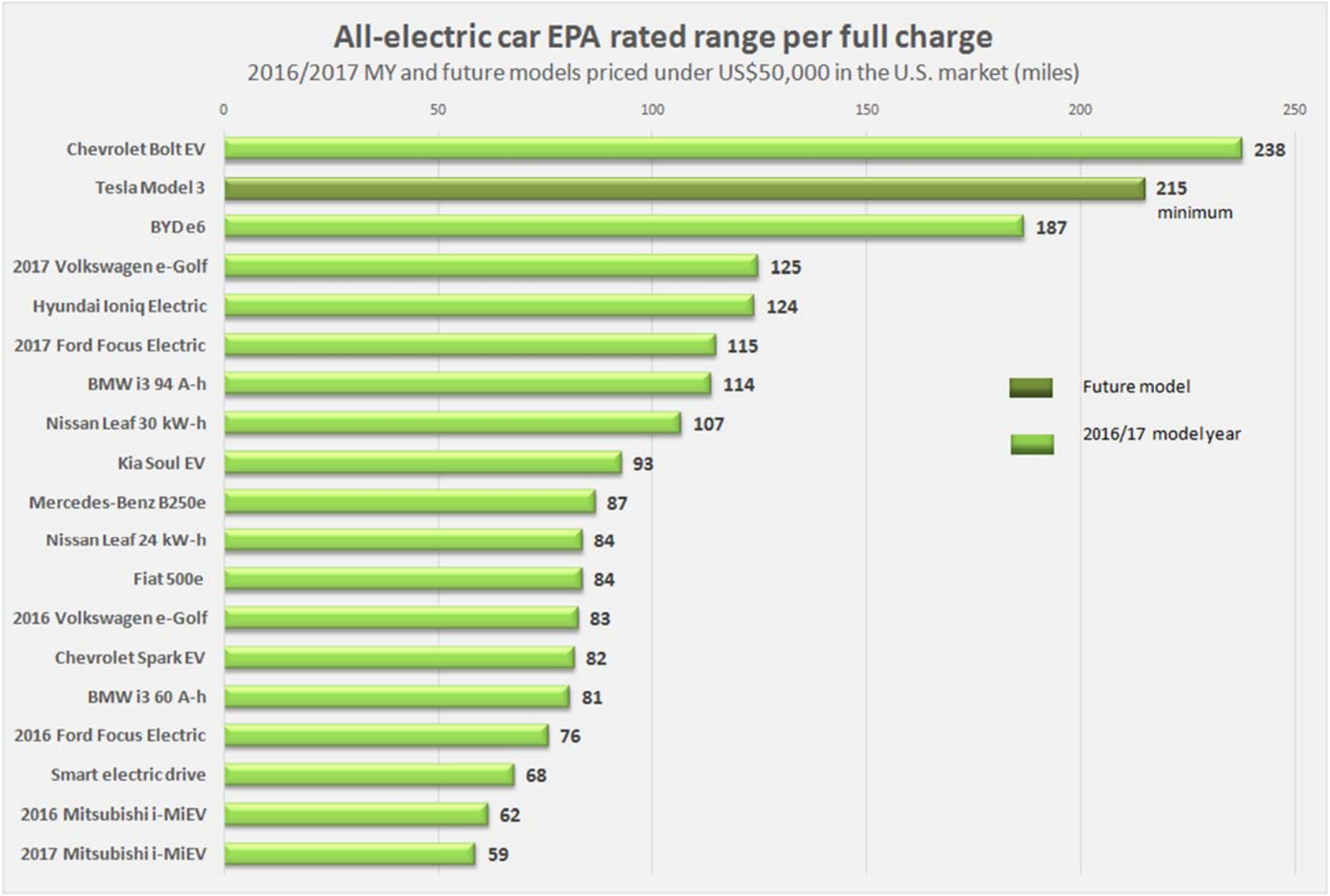
Source: www.autoevolution.com



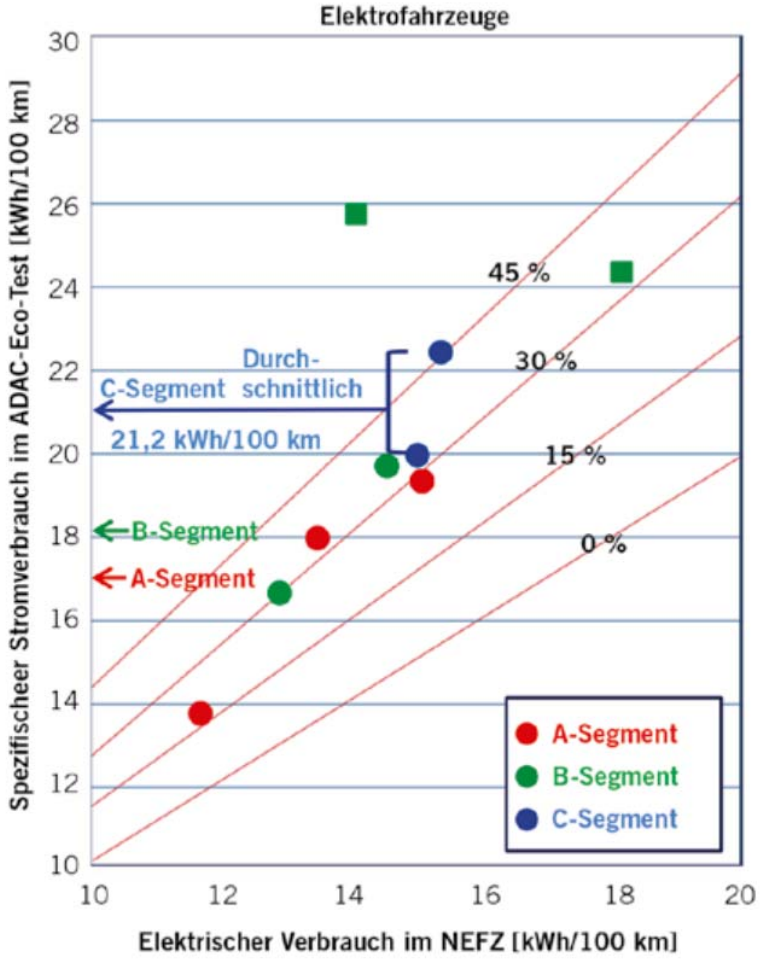
Source: www.teslarati.com

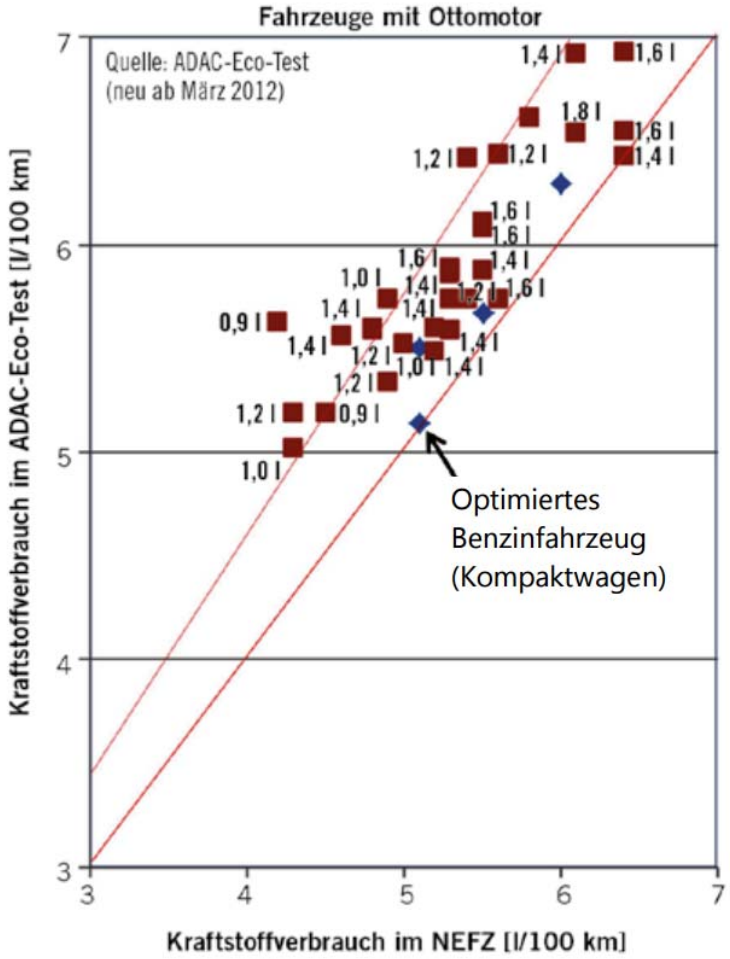
2012 – 2016+

Range of E-Vehicles priced under USD 50'000



Range: energy consumption in kWh/100km



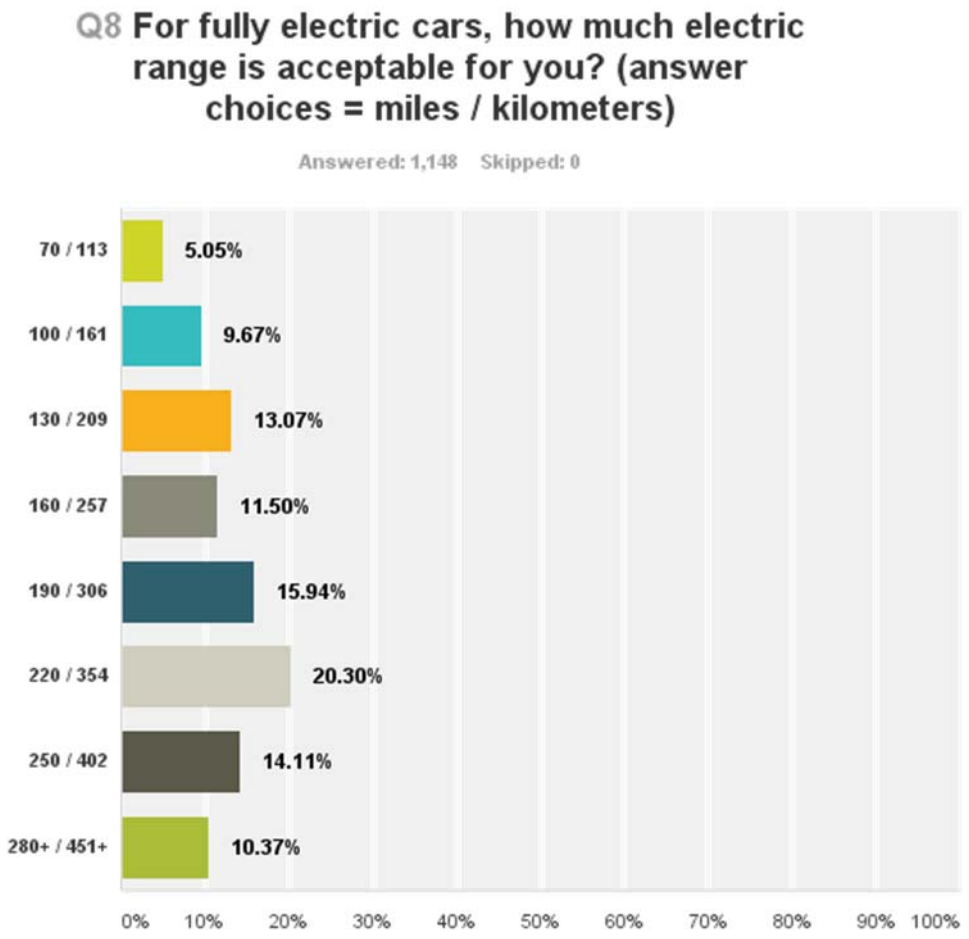


Source: «Mazdas Weg zu effizienteren Verbrennungsmotoren», MTZ 05/2016

Range, what consumers want

- 28% Don't Need >130 Miles of Range
- 55% Don't Need >190 Miles of Range
- 75% Don't Need >220 Miles of Range

- Among non-owners, 45% responded that they needed 220 or more miles of range on a single charge.



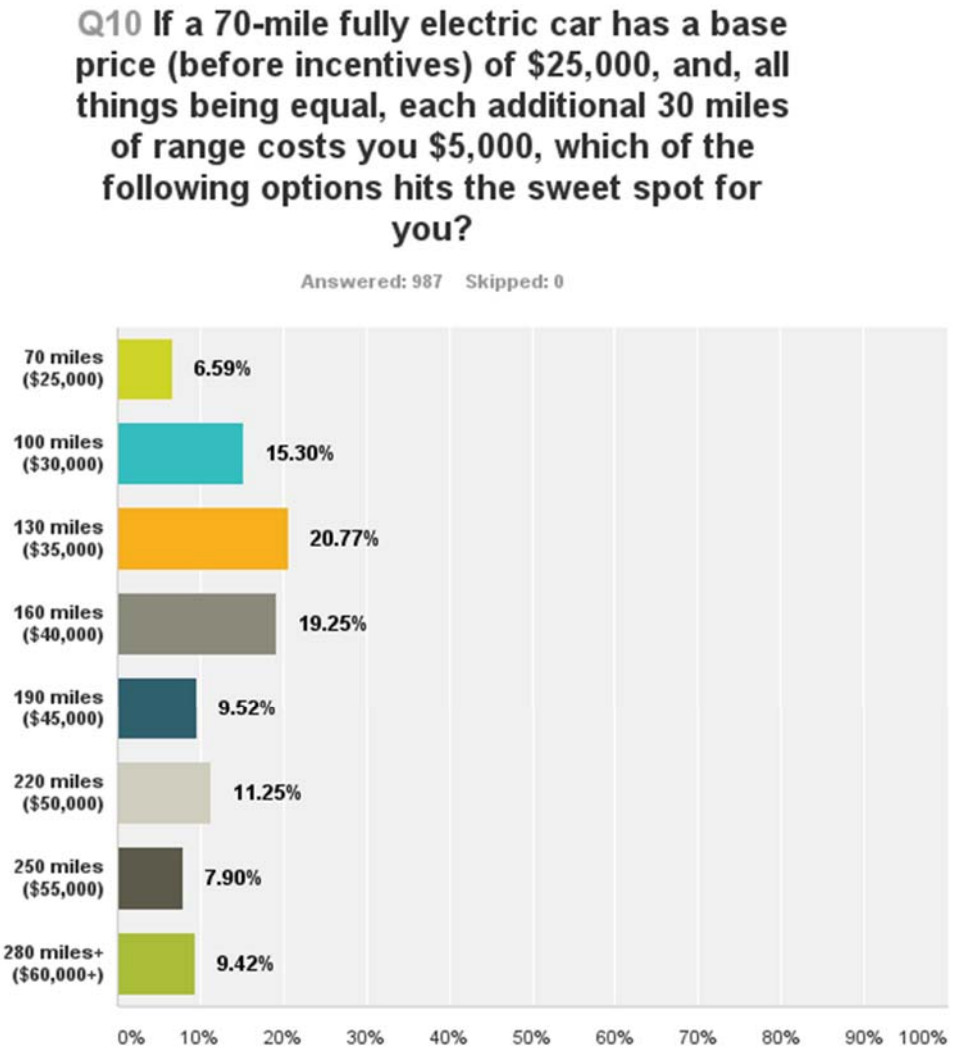
Source: "Electric Cars: What Early Adopters And First Followers Want", CleanTechnica; 2016

Range: how much consumers are willing to pay

- 43% Don't Need >130 Miles of Range (before 28%)
- 60% Don't Need >190 Miles of Range (before 55%)
- 70% Don't Need >220 Miles of Range (before 75%)

- Additional 150 Miles (241km) for 25'000 USD equals a price of 489 USD/kWh based on average consumption of 21.2kWh/100km[1]

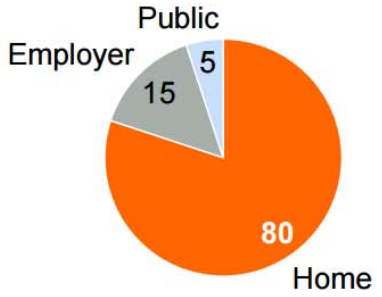
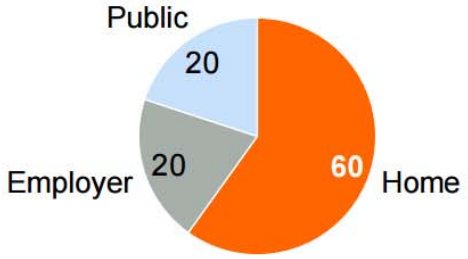
[1] Assuming 100% DOD



Source: "Electric Cars: What Early Adopters And First Followers Want", CleanTechnica; 2016

Implications for charging infrastructure:

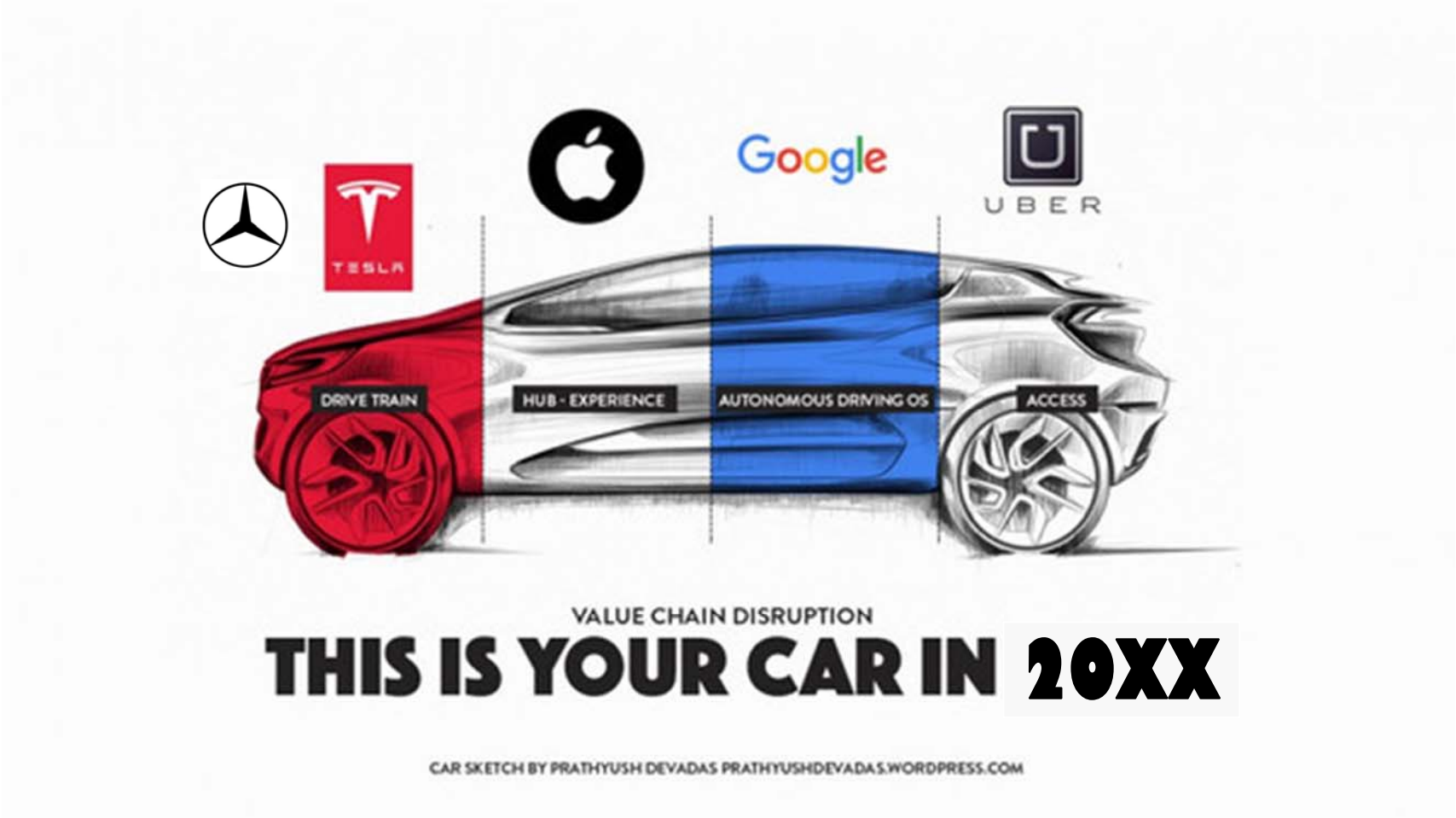
Basic belief from interviews and pilot results: In the first years, home charging will dominate

	Early adopters	"Mass rollout"
	Home charging and semipublic dominates	Rise of public infrastructure
Distribution of charge-points for private		
Home and semipublic	▪ Home and corporate charging dominate; cars are mostly **charged at home or at corporate locations**	▪ Share of **semipublic** charging increases, dominated by **long-term parking** at work and car parks
Public	▪ Public infrastructure will **not be built up densely**; first installations mostly triggered by public authorities	▪ Accelerated rollout as **share of EVs** and customers **without own garages** increases

SOURCE: McKinsey

Game Changer: CASE

Connected, **A**utonomous, **S**hared & **S**ervice and **E**lectric Drive



New Players

- The Apple Car effort, known as Project Titan, now employs over a thousand engineers
- The Google self-driving cars have clocked more than 1.1 million miles since 2009
- Teslas 'gigafactory' has the potential to not only serve Tesla's growing demand for lithium-ion batteries, but also to be a major source for the entire electric car and off-the-grid power industries.
- Uber CEO Travis Kalanick has long envisioned a future where his company's cars operate autonomously and is now deploying a test vehicle in Pittsburgh

From ownership to mobility as a service

- The long-term vision of the self-driving car involves moving from an ownership model to a service model, in which large numbers of people simply call cars whenever they want them. The new business model from Google favors the Robo-Taxi model, where car rides will be provided on demand. Google also wants to dominate the market for providing maps and software for the self-driving car.

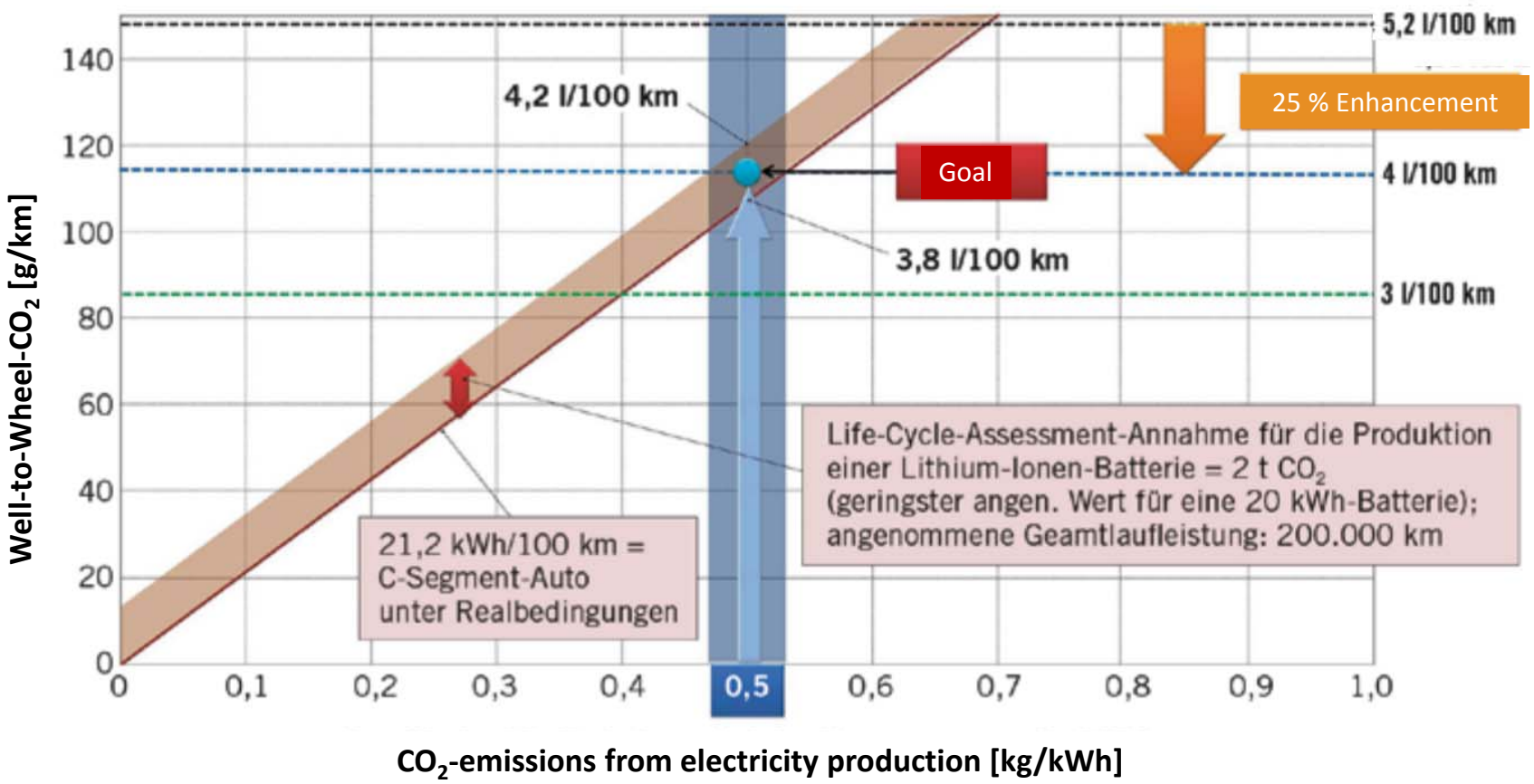
Winners

- Semi And Fully Autonomous Car Adopters
- Component Suppliers And Sensor Manufacturers
- Rental & Ride Sharing Companies

Losers

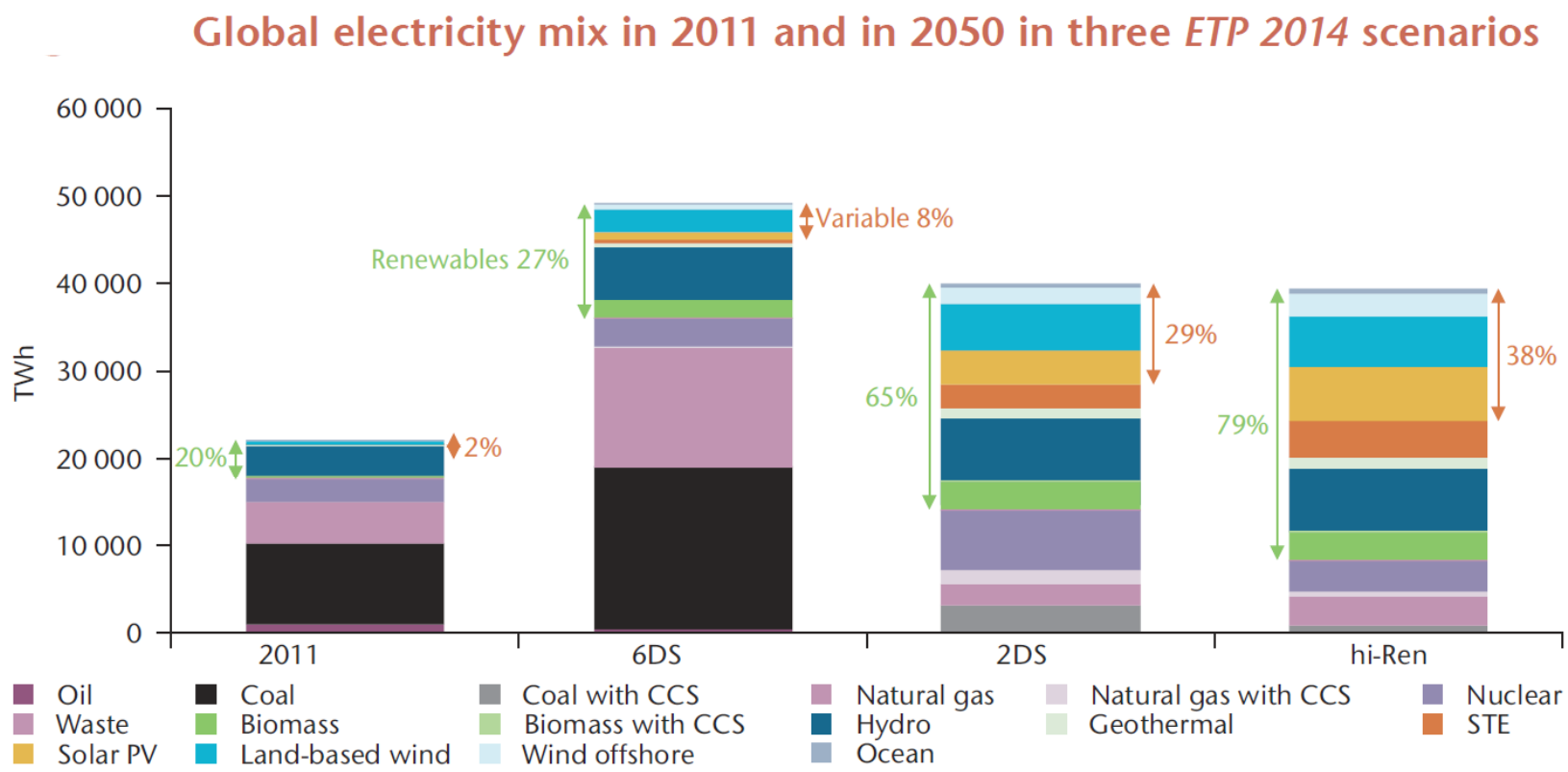
- Traditional Auto Manufacturers
- Taxi Services And Professional Drivers
- Auto Insurance Companies
- Auto Service Industry

CO_2-Emissions from Electric Vehicles



Source: «Mazdas Weg zu effizienteren Verbrennungsmotoren», MTZ 05/2016

Global electricity mix in 2011and in 2050



KEY POINT: in the hi-Ren Scenario, renewables provide 79% of global electricity by 2050, variable renewables provide 38%, and PV provides 16%.

Source: IEA, Technology Roadmap Solar photovoltaic energy, 2014

Summary

- The development in battery technology and the scaling up of production capacities make tomorrows EV's cost competitive.
- Electric Vehicle sales and production numbers continue to increase aggressively over the next years but will reach 35% of all new sales only in 2040.
- Range is for most users no longer an issue; with long range batteries electric vehicles should reach over 350km (220 Miles) within 5 years
- Connected Autonomous Shared Electric (CASE) vehicles will reshape mobility behavior as well as the mobility industry
- Analysts have predicted that the autonomous car technology will be sufficiently reliable for mass-market use by the middle of the next decade. But before a lot needs to change – particularly around regulation and technology improvements.
- An increasing renewable energy production makes EVs an ideal solution to reduce CO_2 emissions.

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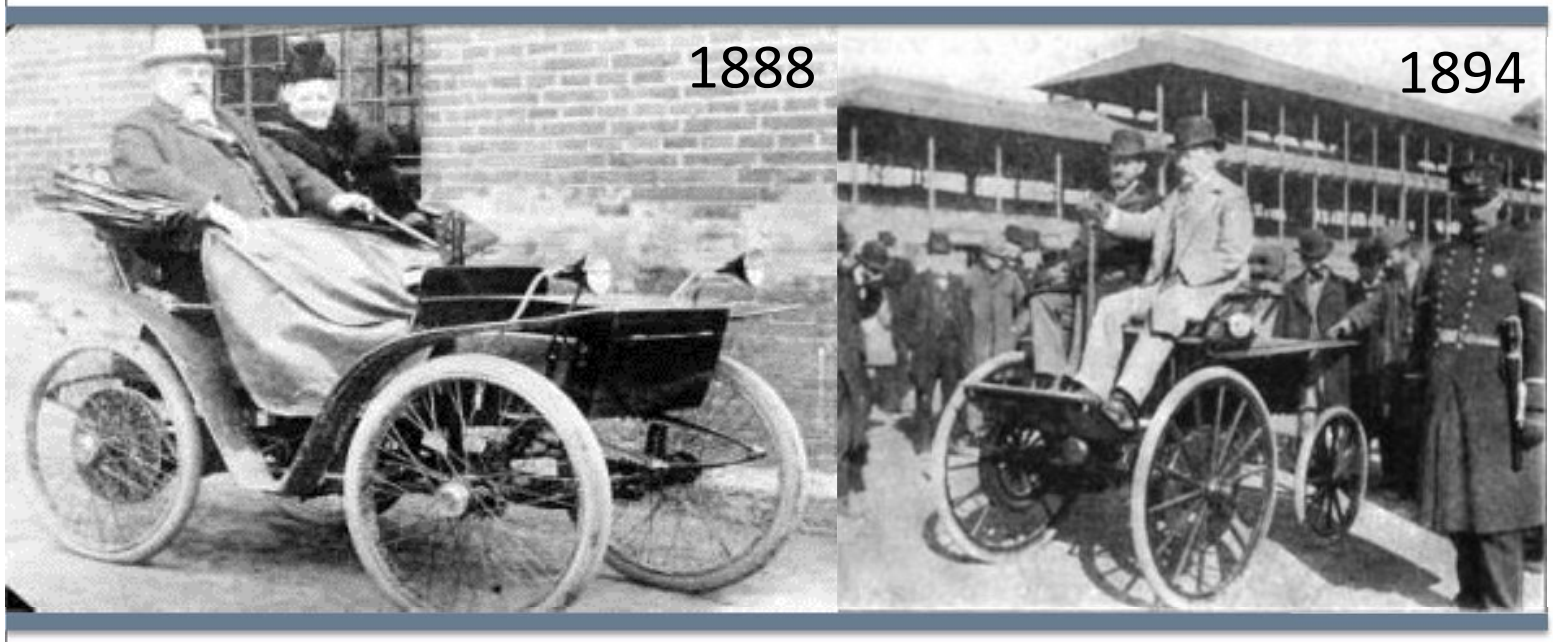

Questions?

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