Einstecken können – wo, wie und wieviel?

Ladeinfrastruktur für Elektrofahrzeuge

Plugging in – where, how and how much?

Charging infrastructure for electric vehicles

Presentation at ika, Aachen
2019-03-14

Birger Fricke
bfricke3@ford.com
Ford Research & Innovation Center Aachen

FORD MOTOR COMPANY OVERVIEW

- 62 plants worldwide
- 200 markets
- 203,000 employees, 53,000 in Europe
- $141,5 billion revenues, $ 28,5 billion in Europe
- 6.6 million vehicle units, 1.5 million in Europe
- $ 7.3 billion expenses for engineering, research and development

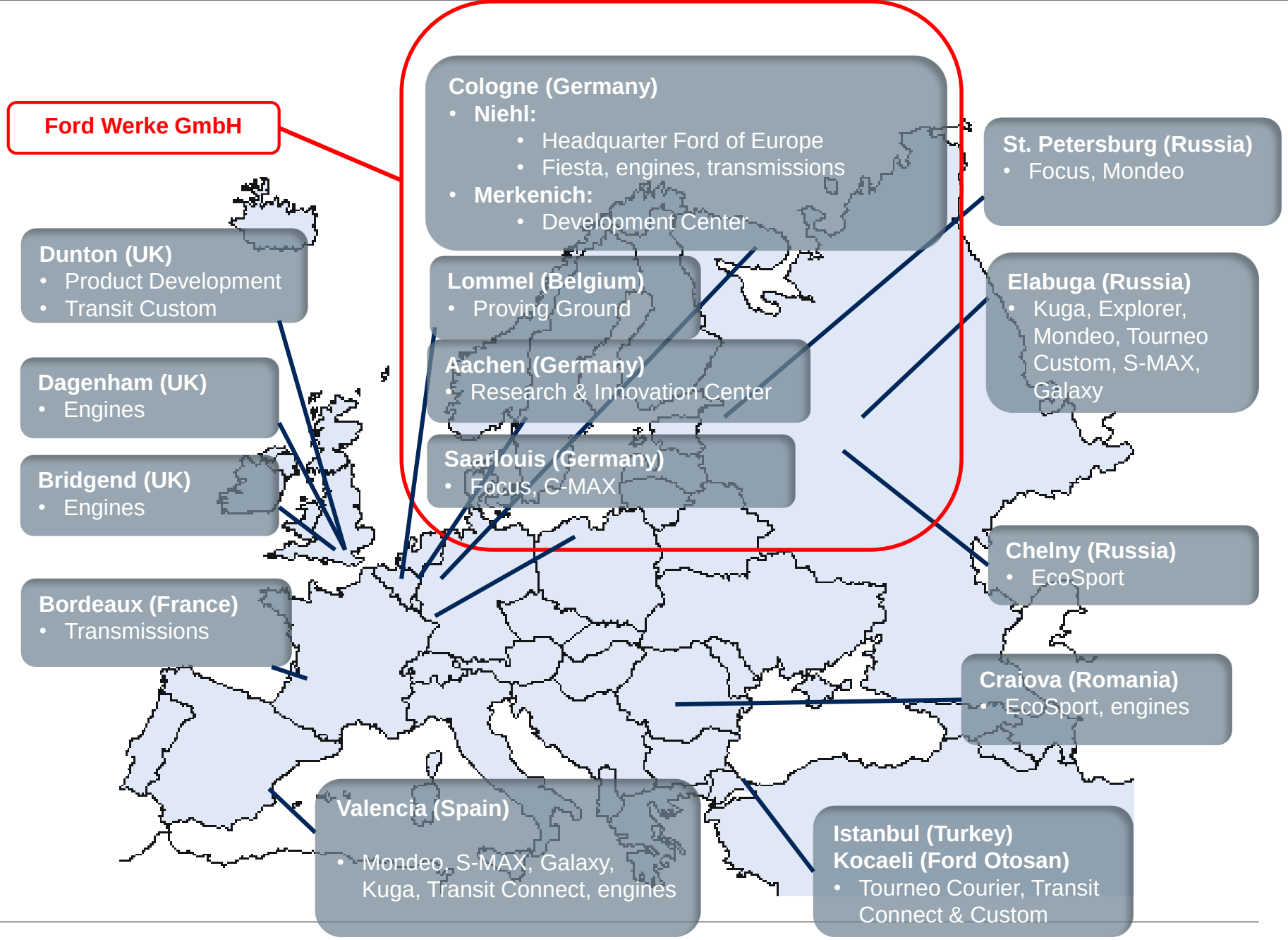
FORD OF EUROPE

- Ford Motor Company **founded 1903**
- European production started 1911
- Vehicles sold in 50 countries in Europe

- Designing, engineering, building, selling and servicing Ford brand vehicles in Europe
- **Headquarters in Cologne**, Germany

- **54.000 employees**
- 69.000 people incl. joint ventures

- **24 manufacturing facilities**, 16 wholly-owned
- 8 unconsolidated joint venture facilities


Ford Werke GmbH
Cologne (Germany)
• Niehl:
• Headquarter Ford of Europe
• Fiesta, engines, transmissions
• Merkenich:
• Development Center
St. Petersburg (Russia)
• Focus, Mondeo
Dunton (UK)
• Product Development
• Transit Custom
Lommel (Belgium)
• Proving Ground
Elabuga (Russia)
• Kuga, Explorer, Mondeo, Tourneo Custom, S-MAX, Galaxy
Dagenham (UK)
• Engines
Aachen (Germany)
• Research & Innovation Center
Saarlouis (Germany)
• Focus, C-MAX
Bridgend (UK)
• Engines
Chelny (Russia)
• EcoSport
Bordeaux (France)
• Transmissions
Craiova (Romania)
• EcoSport, engines
Valencia (Spain)
• Mondeo, S-MAX, Galaxy, Kuga, Transit Connect, engines
Istanbul (Turkey)
Kocaeli (Ford Otosan)
• Tourneo Courier, Transit Connect & Custom

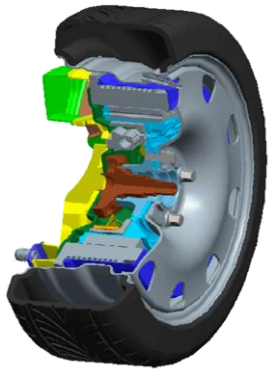
FORD RESEARCH & INNOVATION CENTER AACHEN

- 1995 founded, only research facility of Ford outside the US
- 350 employees from 28 different nations (US: approx. 1200)
- Locations: Aachen, Cologne, Lommel (test track, Belgium)

ADVANCED POWERTRAINS AND ELECTRIFICATION

Advanced powertrains to meet future CO_2 and tailpipe emission targets by:

- Increasing efficiency of combustion engines
- Enhanced aftertreatment systems
- Increased electrification
  - 40 highly electrified vehicles until 2022
  - Mild hybridization (48V)
  - From 2017: co-development with Streetscooter
  - 2020: Launch of all-new small utility BEV
  - IONITY
- New (Bio-)Fuels
- Fuel Cell Technology



PLUG-IN ELECTRIC VEHICLES BY FORD

- Historical
- Focus BEV
- C-Max PHEV
- Ford Transit PHEV

OVERVIEW

- Ford
- Why?
- Fundamentals
  - Types of plugin electric vehicles
  - Energy consumption (How much?)
  - Range extension
  - Charging systems (How?)
  - Where?
- High-power charging
- User Behaviour and Smart Charging
- Automatic charging
- Historical comparison
- Government regulations and funding
- Behind the scenes: Interoperability
- Summary

WHY?

- „Start with why“
- Why electric vehicles?
  - CO2 targets
  - Limited supply of fossil fuels
  - Great acceleration
  - Low noise
- Why this presentation?
  - Plug-in electric vehicles need to be charged.
  - Present status quo and future of charging infrastructure
  - Basis for further discussion

TYPES OF PLUGIN ELECTRIC VEHICLES

- Short range
  - ~100 km range, sufficient for daily trips
  - fast charging for range anxiety
- „somewhere in the middle“
  - fast charging for occasional long-distance travel
- Long range
  - >500 km range
  - fast charging or high-power charging for range extension

- Plugin hybrid
  - electric range for typical daily trips
  - gasoline for faster acceleration, higher top speed, longer range

How much range is needed?

- average travel distance: 30 to 37 km/d (MiD 2017)

ENERGY CONSUMPTION

Input:

- 15 kWh / 100 km (actual value varies)
- 15 000 km/a (MiD 2017: 14653 km/a)

Calculation:

- Consumption of one vehicle: 2250 kWh/a
- Average power for charging one EV:
  2250 kWh / 8760 h ≈ 250 W
- 1 million EVs => 2,25 TWh, 0,25 GW
- 40 million EVs => 90 TWh, 10 GW

Comparison (Germany):

- Average consumption of one household:
  3200 kWh/a
- Production of electricity (2018):
  > 600 TWh/a, ~ 100 GW base, ~ 200 GW peak

Short term effect: Local increase of consumption
Long term effect: Opportunity to make use of peak production

RANGE EXTENSION

- Rule of thumb:
  Charge power P in kW ≈ Range extension in km within 10 minutes
- 50 kW · 0,9 · 10min / (15 kWh/100km) = 50 km
- However:
  - Vehicle efficiency can differ from 15 kWh/100 km.
  - Charging efficiency can be worse than 0,9.
  - Increased duration due to limited charge acceptance, e.g. when battery is hot/cold.
  - Increased duration due to consumption of other consumers while slow-charging.

$$P \text{ 👍 } \Delta s$$

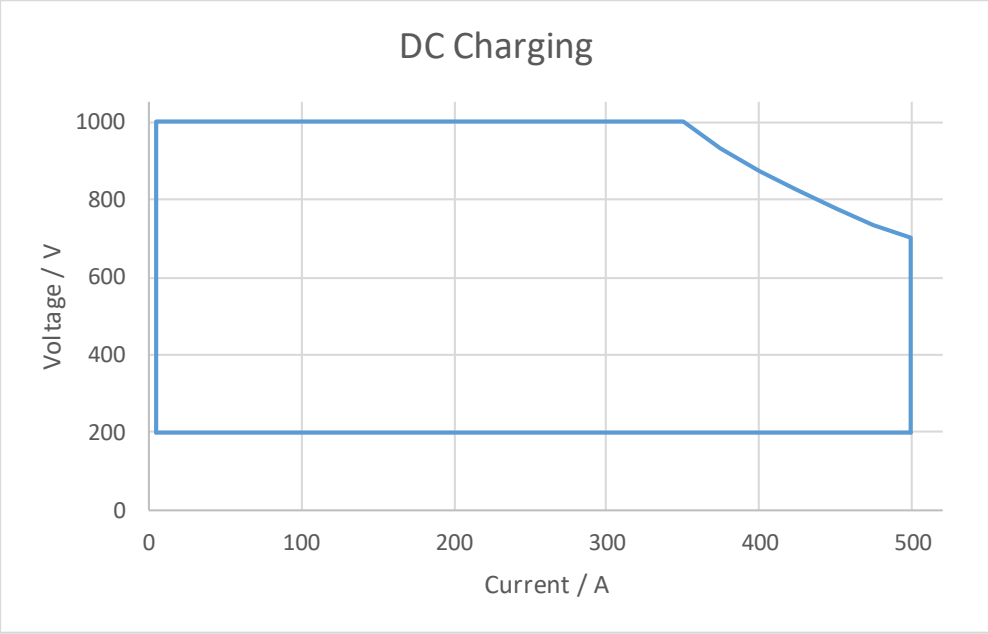
Rule of thumb is not precise but useful for quick assessment of needs and capabilities.

CHARGING SYSTEMS

- AC:
  - Household socket-outlet: ~ 2 kW
  - Charging station: 3, 7, 11, 22 kW (max 43 kW)
  - IEC 62196-2 Type 2

- DC:
  - 50 kW (fast charging)
  - 350 kW (high power charging)
  - actual power depends on battery
  - IEC 62196-3 Configuration FF („Combo 2“)

- WPT:
  - ~ 11 kW
  - Under preparation



WHERE?

- Slow charging: Where vehicle is parked for a long time and installation is cheap. (Home / work)
- Fast charging: Easy accessibility (Near major roads), things to do (e.g. short rest, eat, ...)
- Different solutions apply for fleet operators.

HIGH-POWER CHARGING

- Liquid-cooled charge cables support up to 500 A
- Output voltage up to 1000 V
- Ionity: Joint venture of BMW, Daimler, Ford, VAG
  - 350 kW per charge pole
  - More than 400 sites in Europe with 4 to 6 charge poles
- Other companies are planning additional sites.

- Well suited for range extension of long-distance vehicles.

USER BEHAVIOUR AND SMART CHARGING

- Vehicles need to be plugged in – to support flexible charging.
- Users are lazy and only plug in when needed.
- If every vehicle is plugged in every day, low probability of simultaneous load. First full before last is plugged in. However, this is changing with larger batteries and lazy users.
- High peak loads create problems for the grid.
- Countermeasures:
  - Load management
  - Financial incentives (cheaper electricity for flexible loads)
  - Stationary battery buffers
  - Automatic charging

Lazy users are a problem for smart charging.
Technical solutions needed.

AUTOMATIC CHARGING

- Wireless charging (limited power, frequency assignment)
- Battery swapping(?)
- Automatic plugging
  - Pantograph (buses)
  - Robotized conventional coupler
  - From bottom of vehicle

HISTORICAL COMPARISON

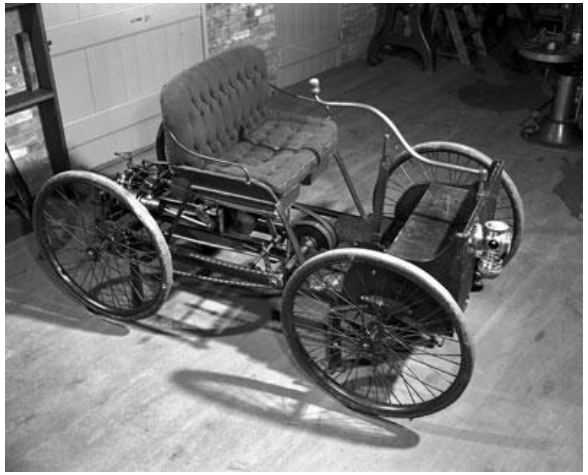
- 1888: First cross-country automobile journey by Bertha Benz
  - Fuel infrastructure: Three liters of ligroin (Leichtbenzin) from pharmacy
- 1909: More than 2500 drugstores, general stores, hotels etc. sell gasoline in Germany.
- 1913: First drive-in gas station in Pittsburgh
- 1922: First gas station in Hannover, Germany.

Public Domain

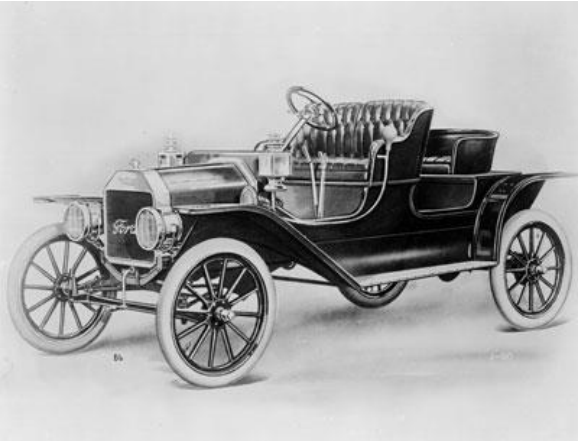
Worldwide production of automobiles:

- 1909: 200k
- 1913: 600k
- 1922: 2.8M (incl. 1.3M Model T)
- 2017: >1M EVs
- 2018: >2M EVs

Slow start, fast ramp-up?



1896: Ford Quadricycle



1908 – 1927: Ford Model T

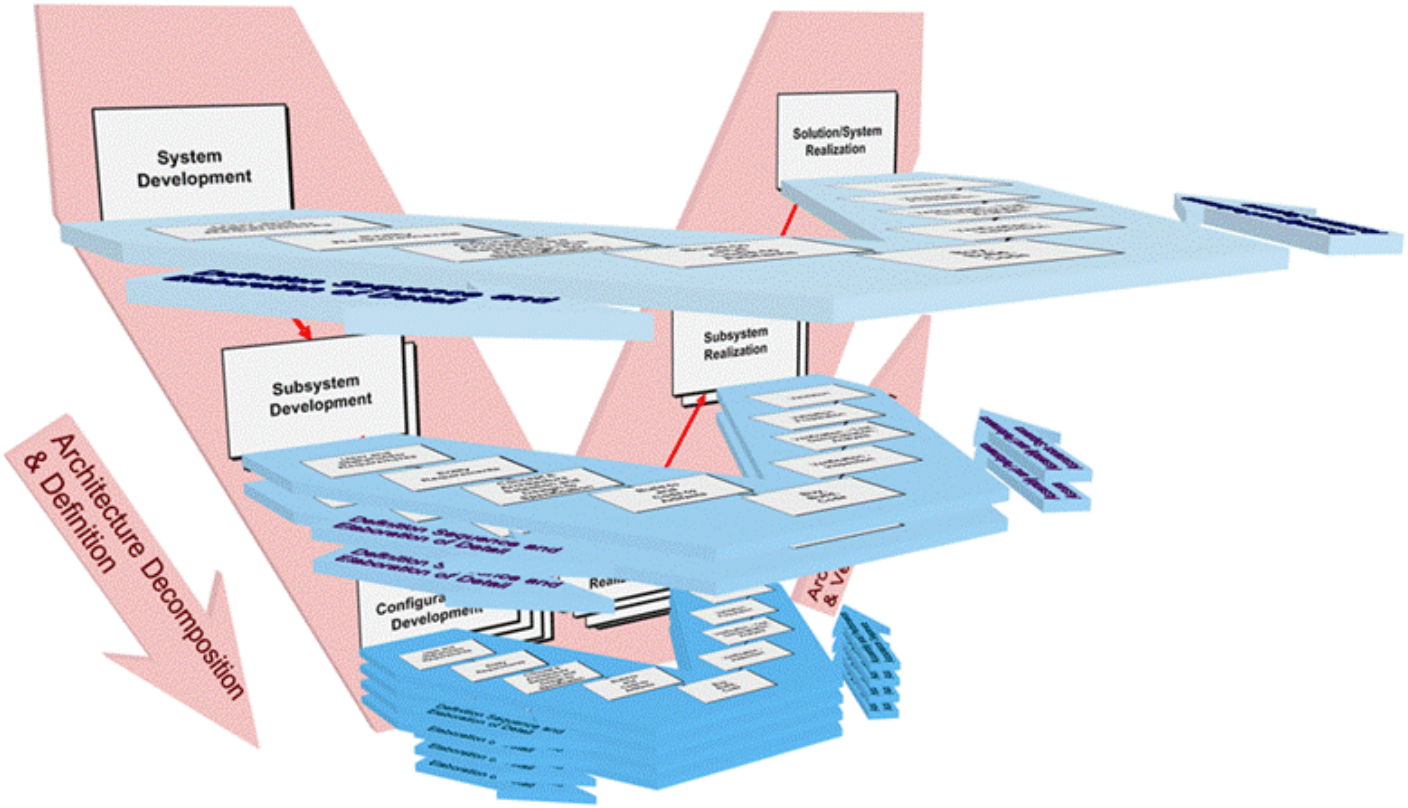
GOVERNMENT REGULATIONS AND FUNDING

- EU Directive on Alternative Fuels Infrastructure 2014/94/EU: Public charging stations shall be equipped with Type 2 and Combo 2
- EU Directive on Energy Performance of Buildings (EU) 2018/844: New buildings shall be prepared for installation of charging stations.
- German subsidies for installation of charging stations.

Government is pushing for fast adoption.

BEHIND THE SCENES: INTEROPERABILITY

- Charging systems cross traditional system boundaries, require participation of many stakeholders.
- “Dual Vee model” of development process.
  - System: Complete charging system
  - Subsystems:
    - EVs (from several manufacturers)
    - Charging stations (from several manufacturers)
    - ..
- m x n validation is only possible while m and n are very small.
- Validation tests were carried out by OEMs and at JRC Ispra.
- Standards are updated to prevent problems.



Source: Kevin Forsberg and Hal Mooz 2006 (CC-by-3.0)

Robustness requires a lot of work.

SUMMARY

- Ford
- Fundamentals
- State-of-the-art solutions (e.g. high-power charging)
- Future solutions (e.g. automatic charging)
- Ramp-up
- Robustness