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**

<table>
<thead>
<tr>
<th><strong>54,000 employees</strong></th>
<th><strong>24 manufacturing facilities, 16 wholly-owned</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>69,000 people incl. joint ventures</strong></td>
<td><strong>8 unconsolidated joint venture facilities</strong></td>
</tr>
</tbody>
</table>
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 CO₂ 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 $\approx$ Range extension in km within 10 minutes
  
  $50 \text{ kW} \cdot 0.9 \cdot 10\text{min} / (15 \text{ kWh}/100\text{km}) = 50 \text{ km}$

- 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.

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.
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.

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?
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
- German subsidies for installation of charging stations.

Government is pushing for fast adoption.
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)
  - ..

$m \times n$ 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.

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