DLR Next Generation Train // NGT LINK
(train concept for non-electrified railway lines)

Analysis of German diesel operated regional railway lines' patterns with regard to the application of battery and fuel cell electric trains

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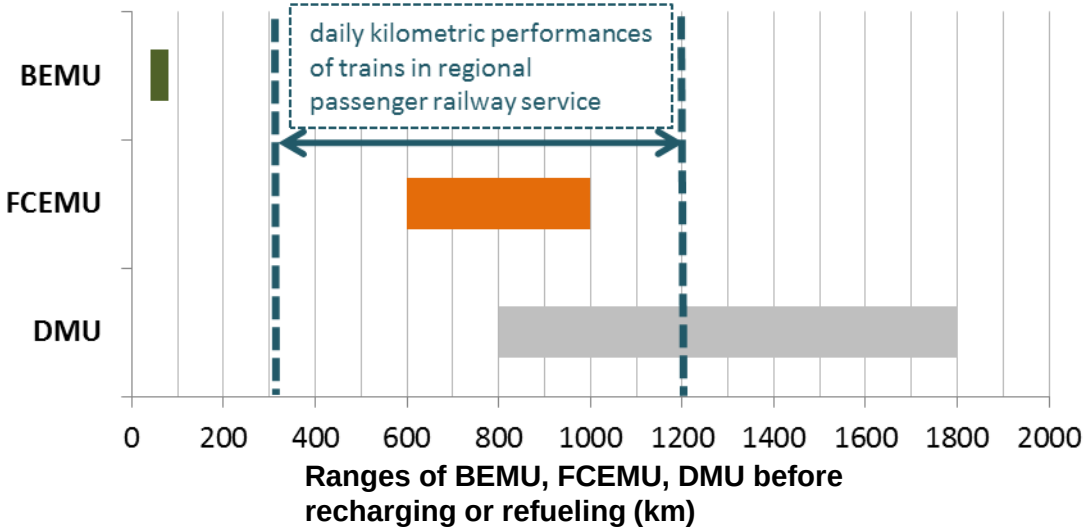
Background
FCEMU & BEMU

- In regional railway transport, BEMU (Battery Electric Multiple Units) and FCEMU (Fuel Cell Electric Multiple Units) emerge as new drivetrain alternatives to classic DMU and EMU for use on non-electrified lines

- Benefits of FCEMU/BEMU (against DMU / *EMU*):
  - Less noise, no exhaust & CO_2 emissions at point of use
  - High(er) drivetrain efficiency
  - *no trackside electrification (costs, right-of-way issues)*
- Drawbacks (to be solved):
  - No broad operational experiences gained so far
  - range-constrained (right picture)
  - Long refuelling (FCEMU) or recharging times (BEMU)

BEMU and FCEMU are adressed by industry:



Ranges of BEMU, FCEMU, DMU before recharging or refueling (km)

Aim
Assess BEMU and FCEMU suitability by means of a line analysis (for Germany)

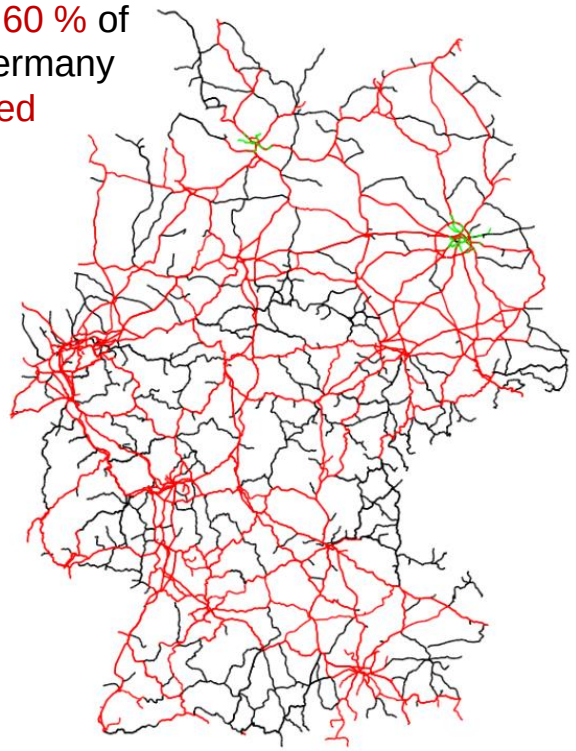
- **Why line analyis?** → A comprehensive BEMU/FCEMU comparison requires to consider technical, economical **and infrastructural aspects**.

- The concrete **line and electrification profile** largely determines the suitability of BEMU and FCEMU:
  - Electrification degree
  - number of electrified start & terminus stations
  - position and length of non-electrified sections

  } Adressed in this presentation

  - Dwelling times at start/terminus stations
  - Operational profile (timetable, trains per hour/direction)
  - Local H_2 production potential
  - Potential to equip further electrification islands/sections

Only about 60 % of tracks in Germany are electrified



Electrified (AC 15 kV, 16.7 Hz)

Electrified (DC, 3rd rail)

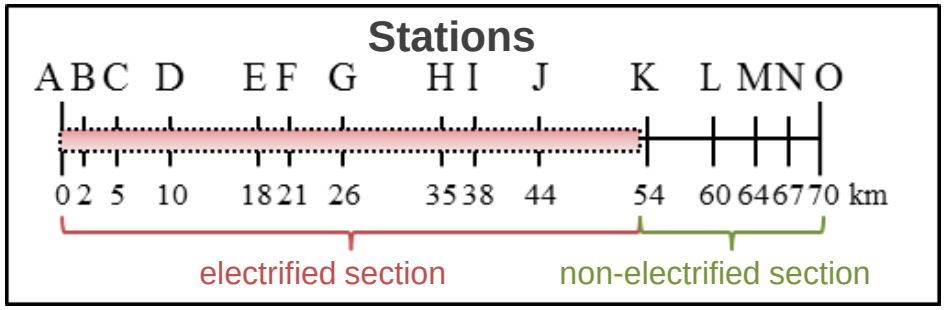
Non-electrified

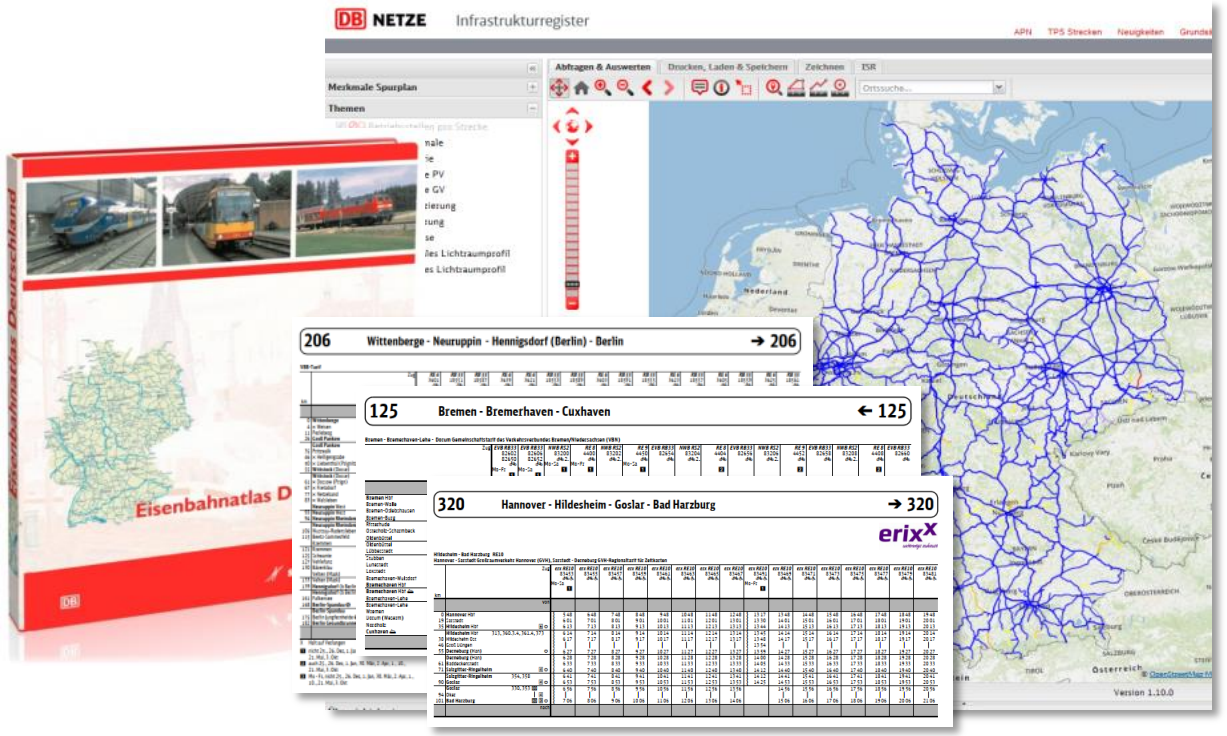
Source: https://geovdbn.deutschebahn.com/isr

Methods

- Data on **469 German regional railway lines** which are **diesel operated today** were used
- **Line definition:** Train running once from <u>start to terminus station</u> on a regional railway operated route
- Data derived from publicly available sources (Streda.X Infrastrukturregister, railway atlas, electronic timetable, public transport authorities,…)
- Derived data:

Example line:





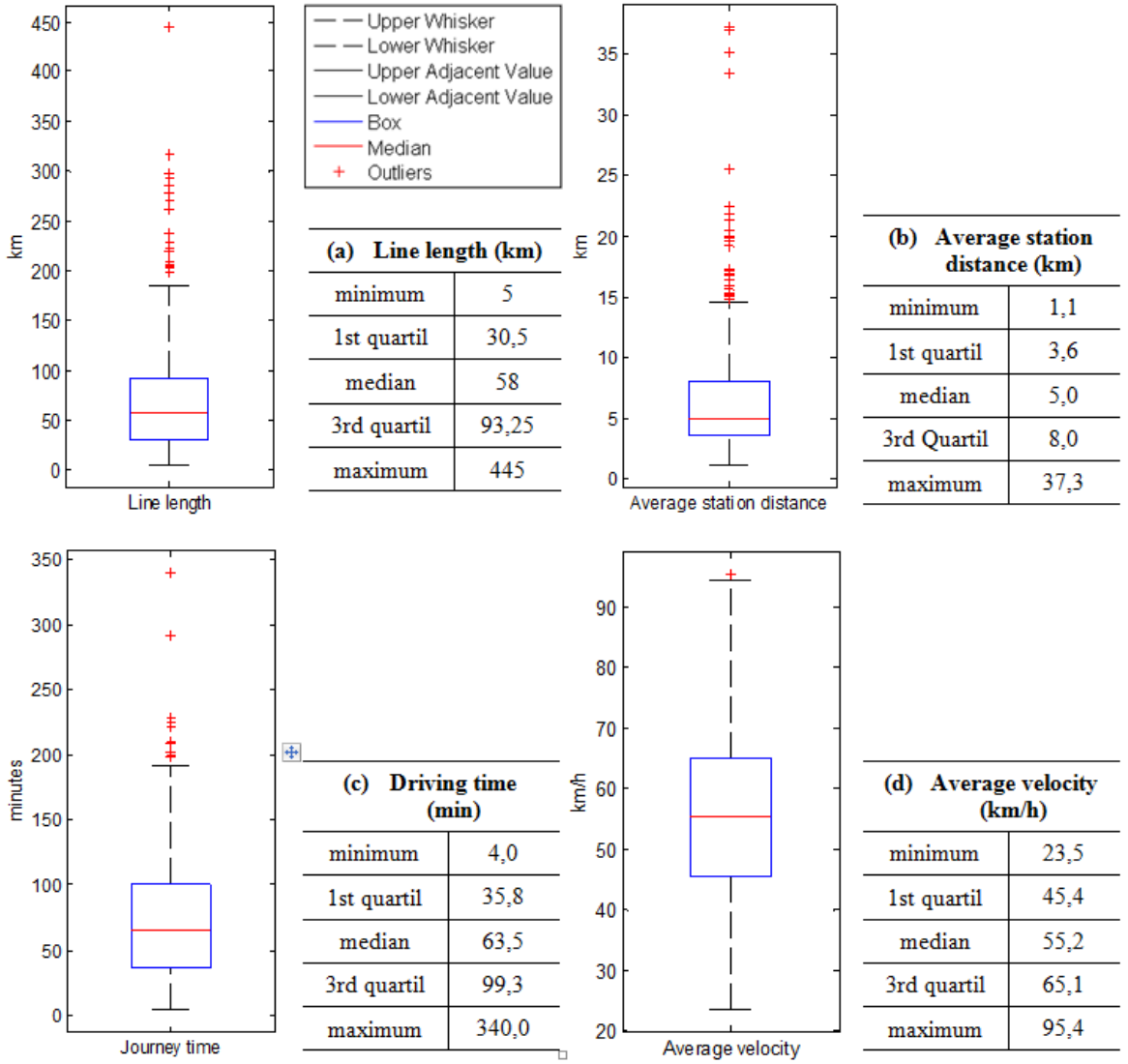
Attributes and characteristic values	
Basic line and route data - federal state in charge - diesel line subnetwork affiliation - route number (German: Kursbuchstrecke) - number of RB (regional train) / RE (regional express train) service - name of start and terminus station, itinerary - line length (km) - max. velocity (km/h)	Stations - number of stations - average distance between stations (km) Timetable - driving time (min) - dwell time at terminus station* (min) Operations (current) - railway operator - railway class in service - train kilometer/a[a] (km/a)
Electrification - position of electrified line sections (km) - electrification degree by line - start or terminus station electrified	[a] incomplete due to partly missing data

Results (I) – General line patterns

Attributes analysed and exemplary observations

- Diverse pattern in terms of
  - Line length
  - Average station distances
  - Journey/(Driving time) time
  - Average velocity

- 75 % of lines:
  - Line lengths: shorter than 93 km
  - Station distances: less than 8,0 km
  - Driving times: less than 99,3 min
  - Average velocities: lower than 65,1 km/h



(a) Line length (km)	
minimum	5
1st quartil	30,5
median	58
3rd quartil	93,25
maximum	445

(b) Average station distance (km)	
minimum	1,1
1st quartil	3,6
median	5,0
3rd Quartil	8,0
maximum	37,3

(c) Driving time (min)	
minimum	4,0
1st quartil	35,8
median	63,5
3rd quartil	99,3
maximum	340,0

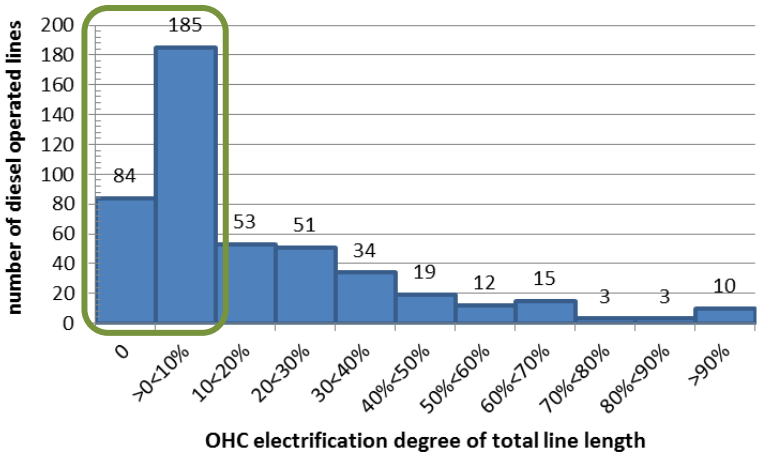
(d) Average velocity (km/h)	
minimum	23,5
1st quartil	45,4
median	55,2
3rd quartil	65,1
maximum	95,4

Exemplary results of diesel line analysis (469 lines)

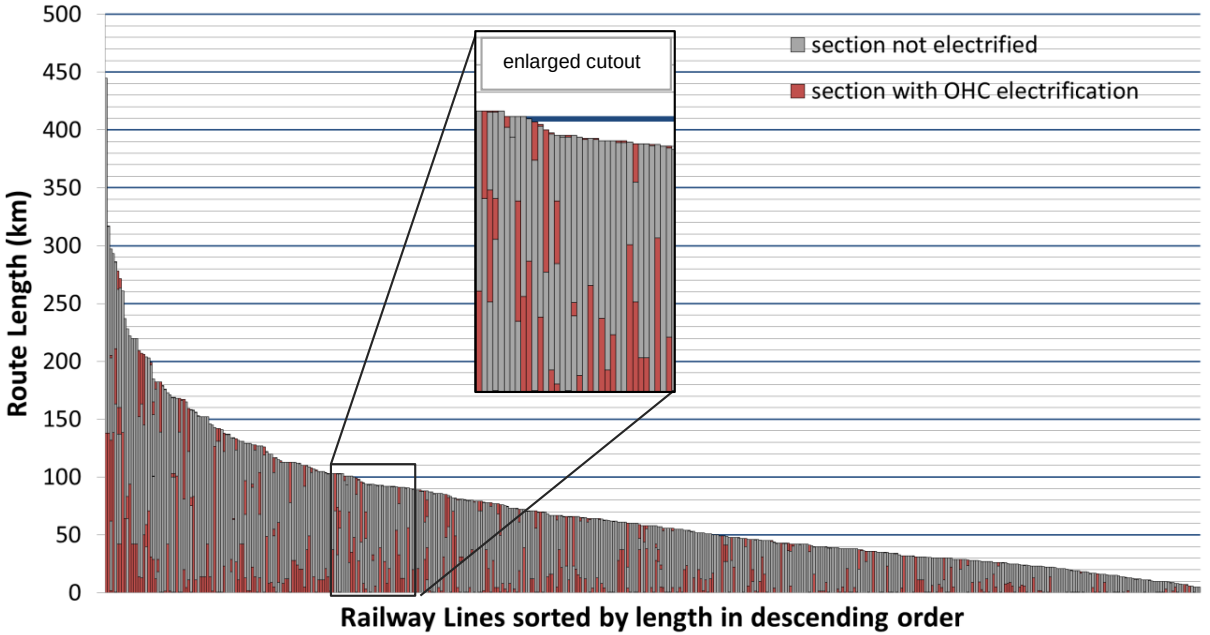
Results (II) – Electrification patterns

- OHC (overhead catenary) electrified sections (red) are concentrated mainly around start and terminus stations (top right figure) →

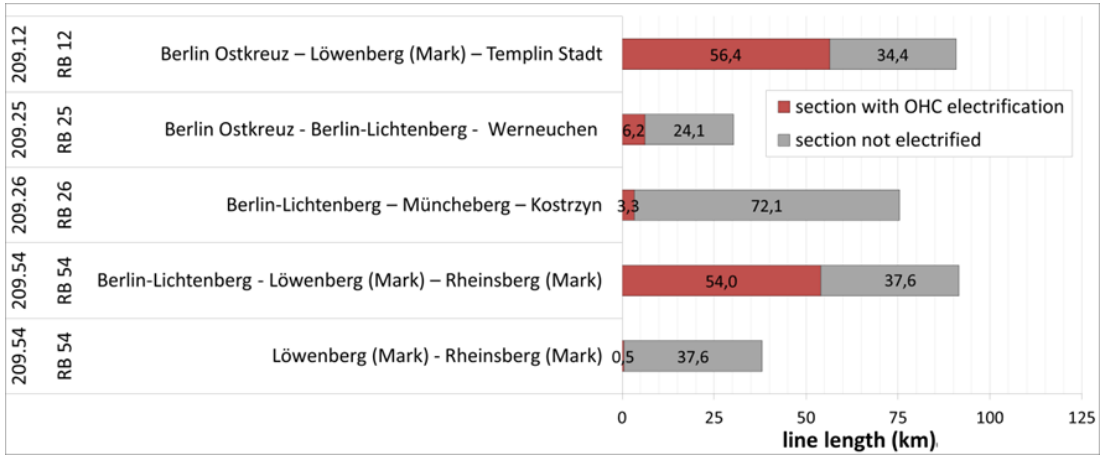
- 57 % of all lines (269) are electrified by less than 1/10 (bottom left figure) ↓



Grouped frequency of OHC electrification degrees



Electrification patterns of all 469 DMU operated lines



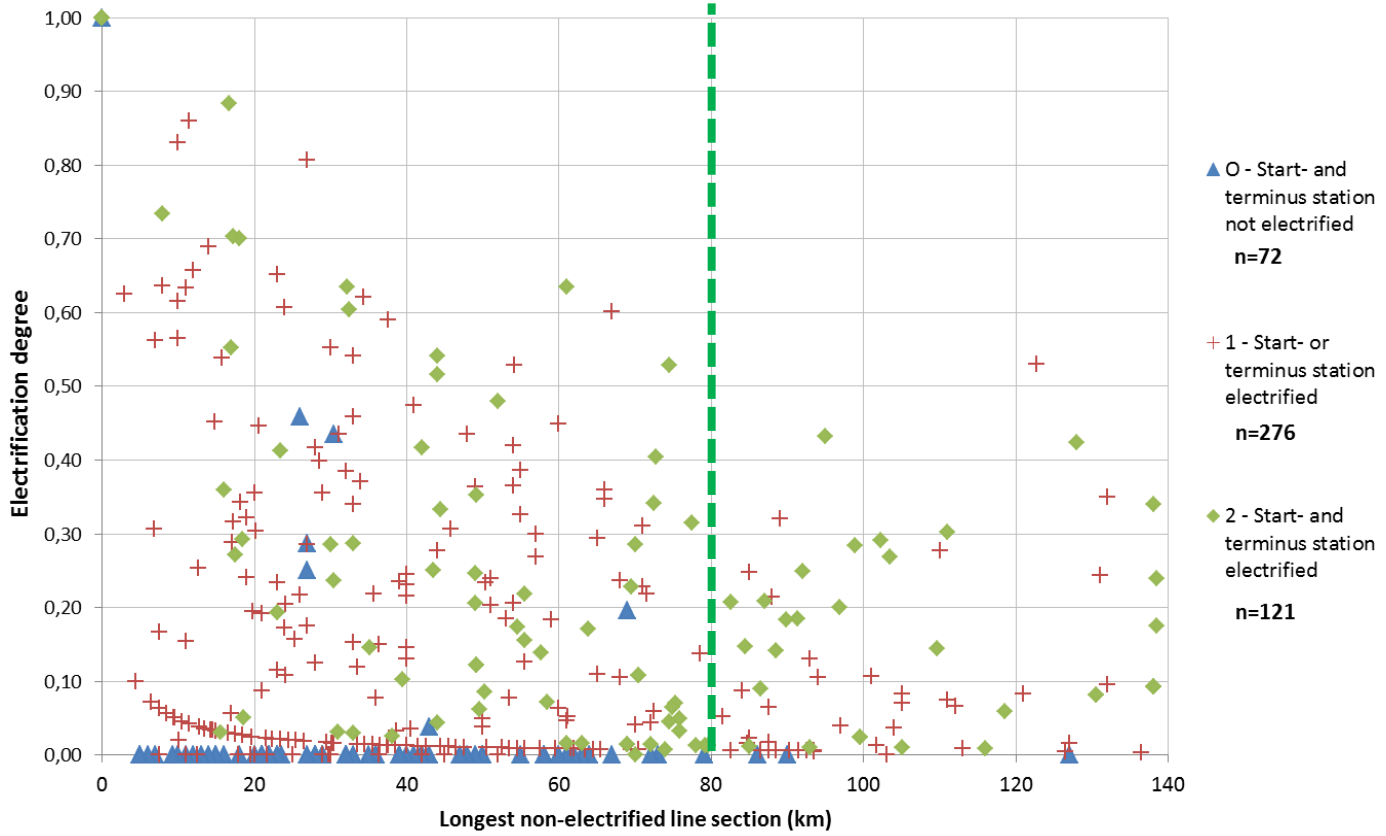
Example of a diesel sub-network (East Brandenburg Lot 2)

Results (III) – Electrification degree vs. length of longest non-electr. section

- Line classification by number of start and terminus stations equipped with overhead catenary (0 ▲, 1 +, 2 ◆)

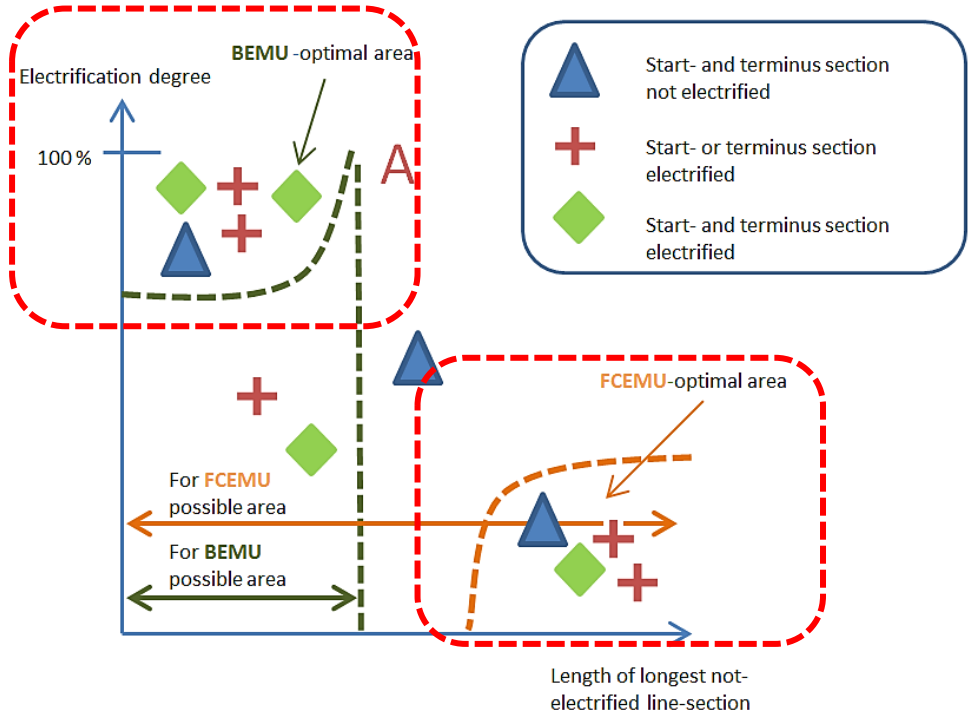
- 77 % of lines have maximum non-electrified sections lengths of < 80 km

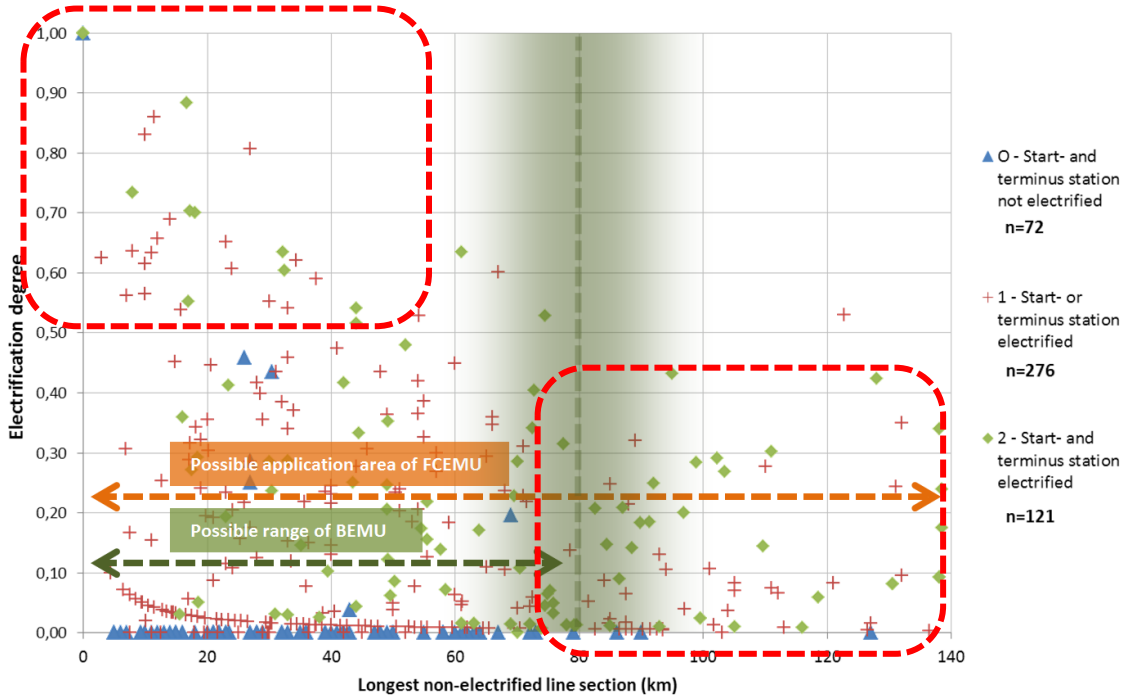
[The falling red dot curve indicates cases where a non-electrified secondary line leads into an electrified line at start/terminus station (500 m electrified length assumed in general)]



All lines' OHC electrification degree and length of longest non-electrified section of each line (n=469)

Results (IV) - Implications to the suitability of BEMU and FCEMU

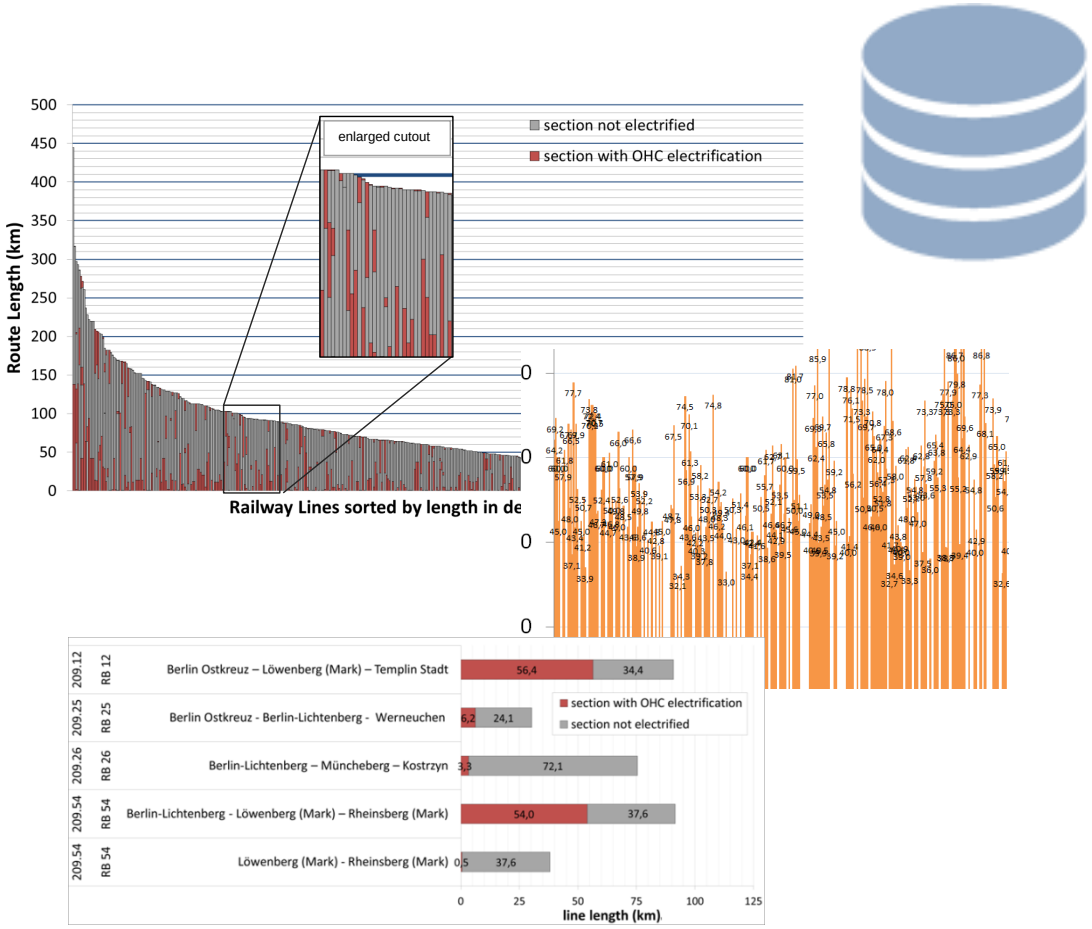


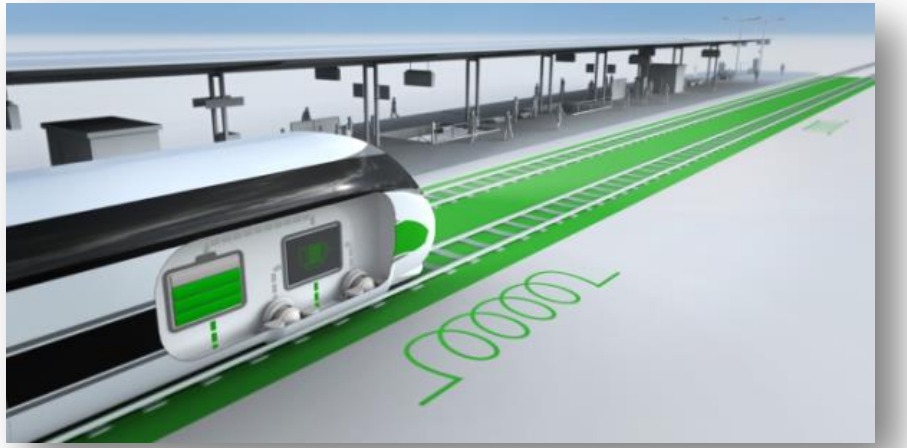


- Lines with < 80 km non-electrified single section: generally suited to BEMU, but full battery recharging must be possible
- 26 % of lines have both start and terminus stations electrified (and offer therefore good premises for BEMU)
- FCEMU (currently 600 – 1000 km range) can be deployed on all investigated lines
  (provided, the timetable allows refueling during daytime if required)
- Future outlook: BEMU-tailored new direct lines (EMU with battery operation on short non-electrified branches)

Conclusions

- Dataset of 469 currently German diesel operated lines was set up
- Line and electrification patterns were analysed
- BEMU and FCEMU based line suitability criteria can be investigated line by line and diesel (sub-)network by network
- Diverse pattern in terms of line lengths (5-445 km), electrification degree (80 % electrified by < 30%) and electrification patterns
- Outlook: Further parameters to be included (e.g. track-profile, energy demand, detailed rosters)





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Thank you for your attention.

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