

Innovative Drivetrains for Public Transport Buses



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Wichtige Leistungsindikatoren für E-Bus Projekte *Key performance indicators for ebus projects*

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Bundesministerium
für Verkehr und
digitale Infrastruktur

Koordiniert durch:



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Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit



- 29 projects/ 32 operators/ 9 OEM/ 12 associations, research institutes, consultancies with
 - 179 Diesel Hybrid buses
 - 24 Battery electric buses
 - 12 Fuel cell Hybrid buses

- Duration: since 2013, builds on former accompanying research activities of BMVI/ BMUB (2010 – 12)

- Coordination AG Bus:



- Coordination accompanying research:



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- Jointly developed by AG Bus participants
- Analysis of hybrid electric buses as a bridging technology for buses with purely electric drivetrains in future
- Build up of data foundation on battery electric buses
- Diesel as reference technology
- AG open to other alternative drivetrain technologies
(inclusion of Fuel Cell and Trolley Hybrid buses in preparation)

Readiness of technology

Daily use

Availability buses

Availability charging infrastructure

Adjustment infrastructure
(Workshop/ Charging on bus route)

Efficiency

Fuel consumption via long term
data collection & measurements

Influence of ancillary units

Environment and climate protection

CO₂ reduction

NO_x, Particulate Matter

Noise

Economy

Life-Cycle-Costs (LCC)

Cost Break Even analysis with
reference technology

Acceptance

Publicity

Driver/ Workshop management

Technology Evaluation based on Triple Bottom Line approach of Sustainability



People

Fair and beneficial business practices toward labour and the community and region in which a organization conducts its business

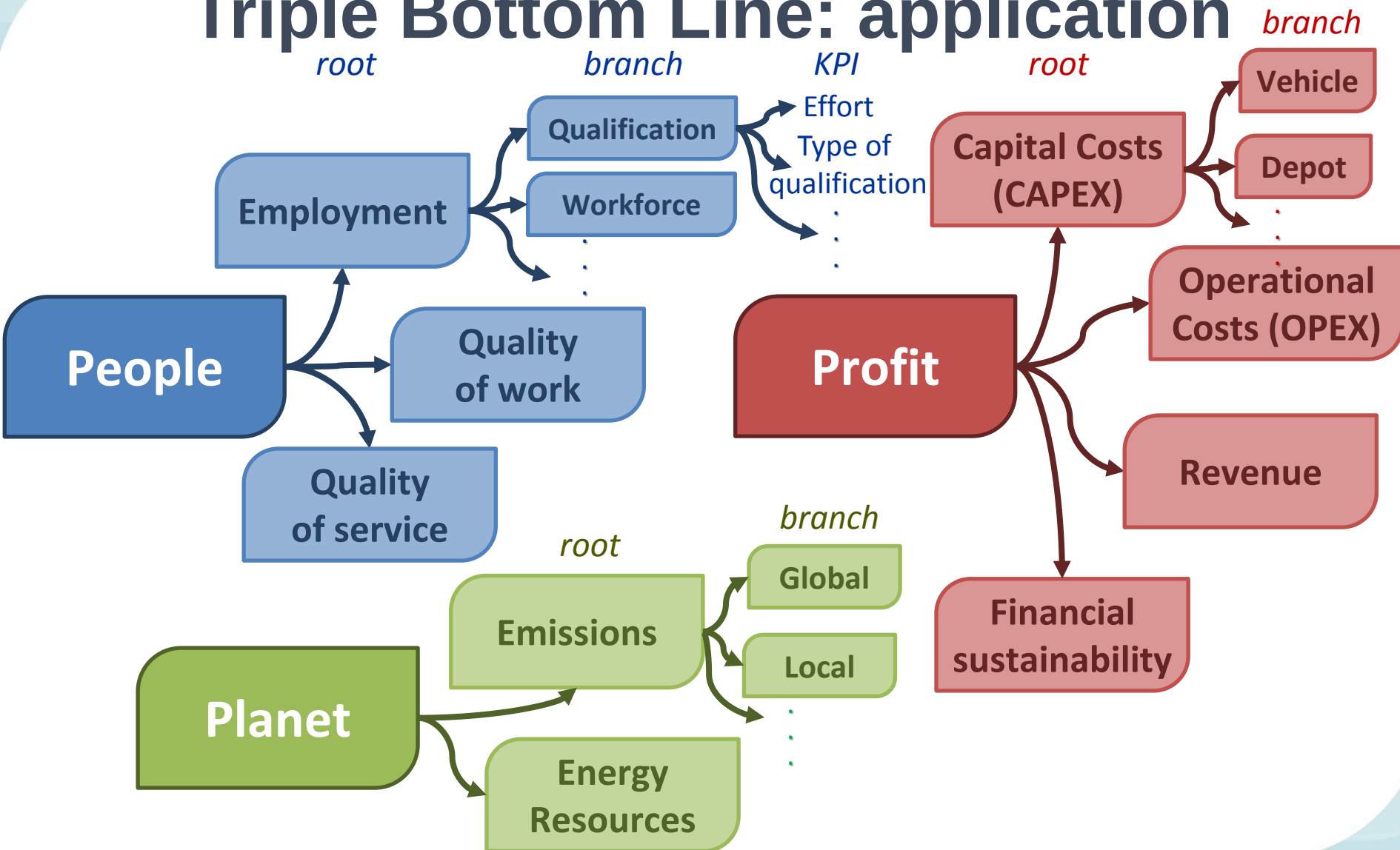
Profit

Economic value created by the organization after deducting the cost of all inputs, including the cost of the capital tied up

Planet

Sustainable environmental practices, benefit to the natural order as much as possible or at the least do no harm and minimise environmental impact

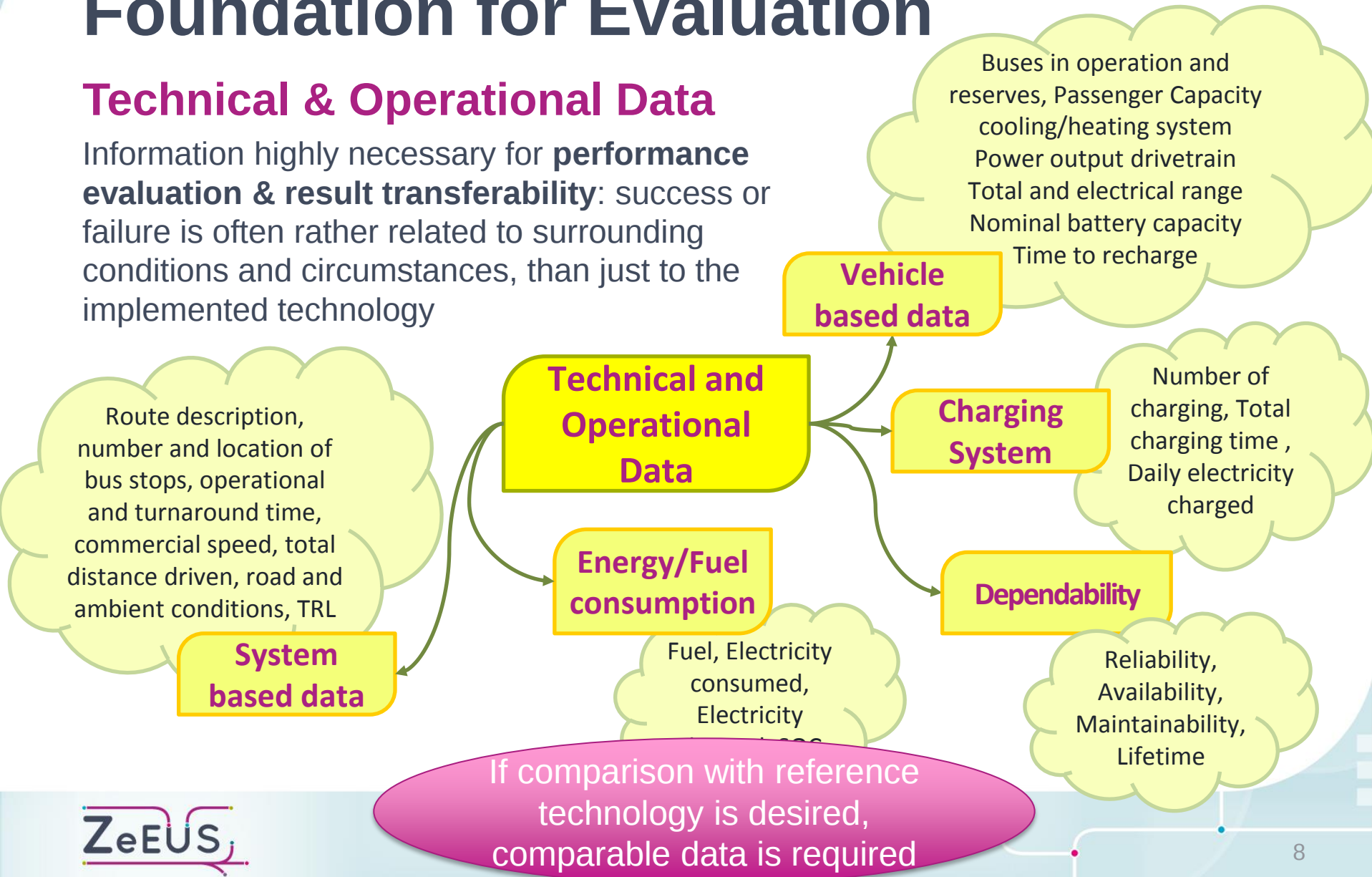
Triple Bottom Line: application



Foundation for Evaluation

Technical & Operational Data

Information highly necessary for **performance evaluation & result transferability**: success or failure is often rather related to surrounding conditions and circumstances, than just to the implemented technology



Overview of KPI's per Bottom Line

People

Root	Branch	Sub-Branch	KPI #
Employment	Amount of Workforce		3
	Qualification of workforce	Driver	2
		Maintenance personnel	2
		Planning/ management	2
Quality of Work	Safety	Driver	4
		Maintenance personnel	4
	Health		3
	Perception of technology		3
Quality of Service	Safety	Passenger	2
		Other road users	2
	Security		2
	Perception of technology		5
TOTAL			34

Planet

Root	Branch	Sub-Branch	KPI #
Emissions	Global		3
	Local		7
Resources	Building resources		2
	Energy resources	Renewable energy	4
		Non-renewable energy	3
	Materials		2
TOTAL			21

Profit

Technical & operational data

Technical & operational data

Root	Branch	Sub-Branch	KPI #
Capital cost (CAPEX)	Vehicles		3
	Depot facilities		3
	Recharging infrastructure		5
	Adjustments to current practices		4
	Assumed depreciation period		1
	Decommissioning costs		1
	Personal cost		4
Root	Branch	Sub-Branch	KPI #
System base data			17
	Route description		2
	Total distance driven		3
	Technology Readiness Level		3
Vehicle base data			13
Energy / Fuel consumption	Fuel consumption		6
		Fuel consumed per day	5
	Electricity consumption		8
Charging			8
RAM (Dependability)	Reliability (MTBF)		3
	Availability		5
		Time in Service	2
	Maintainability (MTTR)		2
	Lifetime		4
TOTAL			81

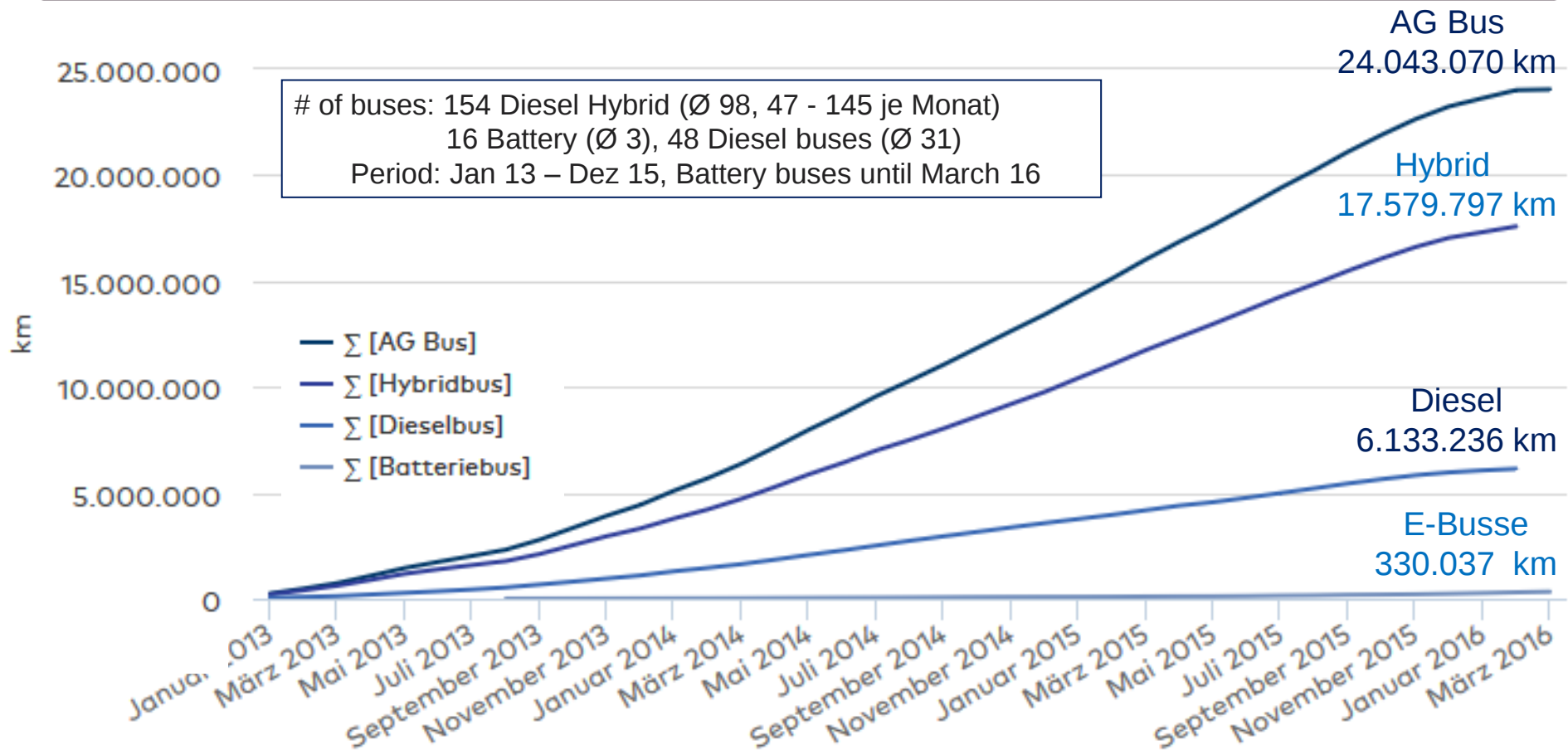
Number of available indicators: People: 34, Profit: 41, Planet: 21, T&O: 81
operator specific selection of KPI's, ZeEUS demo's selected 53 – 152 indicators

Exemplary results

Total driven distance German AG Bus



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- Total distance driven : ~**24 Mio. km** (32x to the moon and back)
- Increased data basis compared to former accompanying research
- Build up of data basis for electric buses started

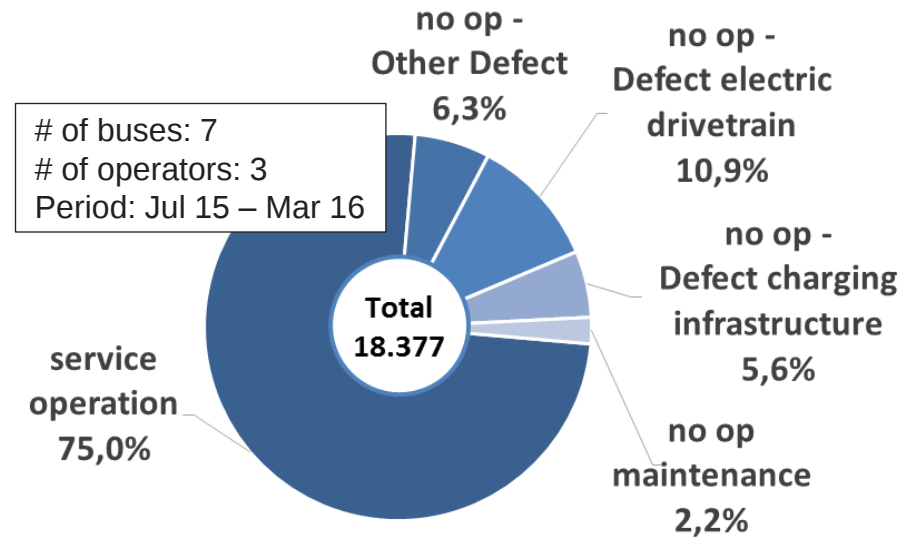


Readiness of Technology

Availability Battery Electric Bus

- Technology at start of learning curve
- First trend after 9 months of operation
12/18 m buses (opportunity charging)
Availability: ~ 75%
(comparable to Diesel-hybrid introduction in 2009/10, some operators better)
- 4 Midi buses (Oct 14 - Dec 15): ~8
(since Aug 13: Ø 72%)
- Increasing complexity of system, vital importance of charging infrastructure
- Utilisation of existing infrastructure sometimes challenging
- Next step: Demonstration of transferability from single line to (partial) network

Availability 12/ 18 m opportunity charging



Charging infrastructure Dresden:

Month (2015)	Jun	Jul	Aug	Sep	Oct	Nov
Availability	88 %	95 %	100 %	99 %	94 %	68 %

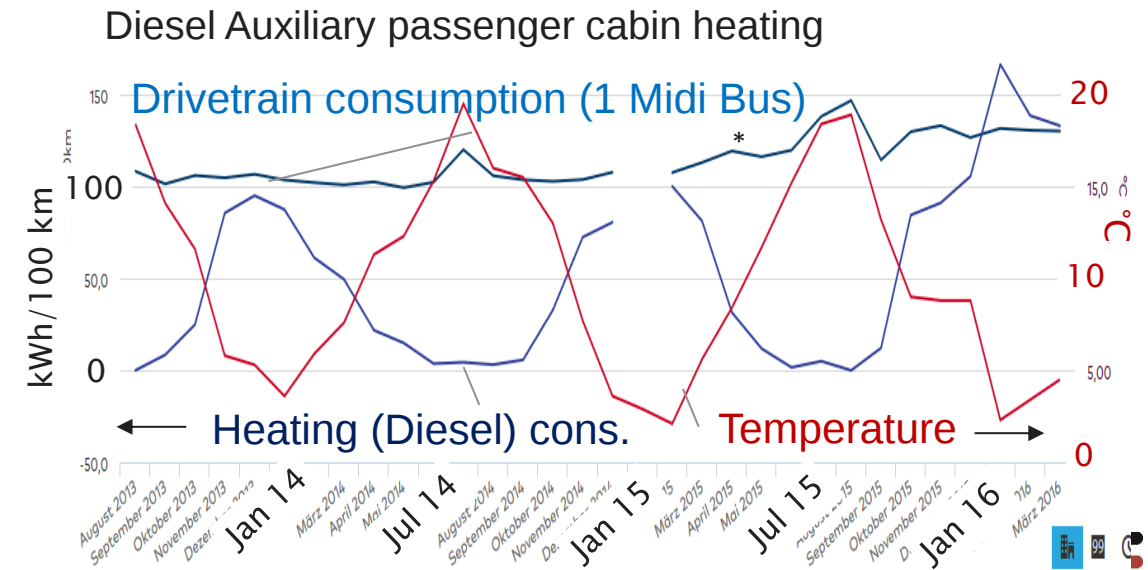
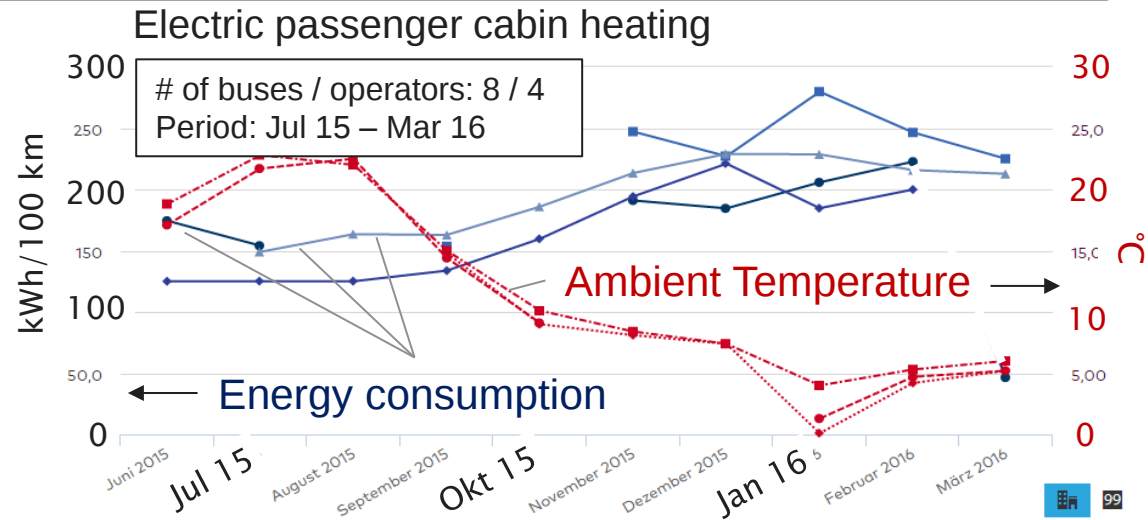
since January 16 close > 95%

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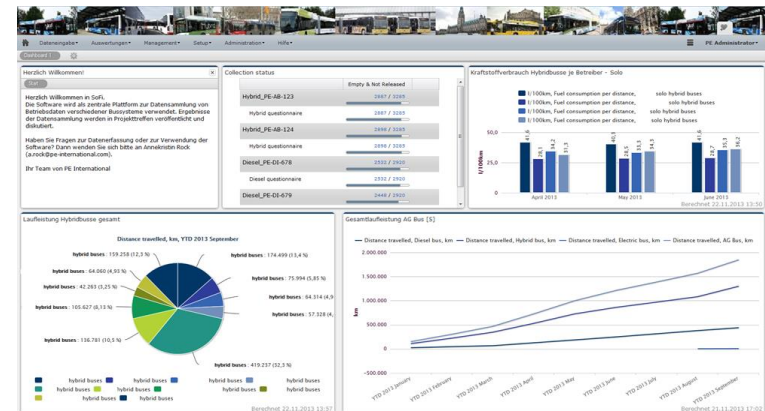
- Data collection period: 9 months
- Consumption (measured at grid level !):
12 m (different lines):
1,2 - 2,85 kWh/km
18 m: 2,5 - 3,4 kWh/km
- Charging efficiency:
- inductive: ~ 90%
- conductive: 92-95%
- First indications: topography of minor relevance (recuperation), ambient temperature dominates
- 2 heating concepts:
- Electric heating: Jul to Dec 16:
+ 60% energy consumption
- Diesel heating: during heating period energy demand comparable to drivetrain
- Energy demand heating over 12 months: Ø ~40% of drivetrain energy demand



* Increase in drive train energy consumption due to new routing of line

SUMMARY

- For meaningful performance evaluation robust data base on operational data needs to be build up
- Well-structured KPI tree was drafted in collaborative process between Joint Evaluation Team and Liaison Bodies of different demonstrators
- It follows closely Triple Bottom-Line (TBL) via “People, Profit, and Planet”, a.k.a. Three Pillars of Sustainability.
- Next step for battery electric buses: operation of multiple routes/ network to evaluate operational stability & flexibility
- Public transport well suited lighthouse for introducing innovative Zero-Emission drivetrains



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Thank you!

- For your attention
- Supporting federal ministries and European Commission
- Partners for collaboration and providing the data

- Further information available:

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https://www.now-gmbh.de/content/5-service/4-publikationen/1-begleitforschung/now_abschlussbericht_bus_web.pdf

<http://zeeus.eu/>

<https://www.vdv.de/ebus-projekt.aspx>



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