

EVS 27

econnect Germany – performance and evaluation of an electrically propelled minibus for public transportation

Barcelona, 18th of November 2013

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Forschungsgesellschaft Kraftfahrwesen mbH Aachen

Agenda



- Introduction
- Test vehicles
- Test drive results
- Analysis of performance and energy costs
- Summary

Introduction



Project name: econnect Germany; predecessor project: Smartwheels
Model region: Aachen, Allgäu, Duisburg, Leipzig, Osnabrück, Sylt, Trier
Funded by: BMWi – Federal Ministry for Economics and Technology
Duration: January 2012 till December 2014
Topic: Information and Communications Technology (ICT) for Electro mobility
Consortial leader: smartlab



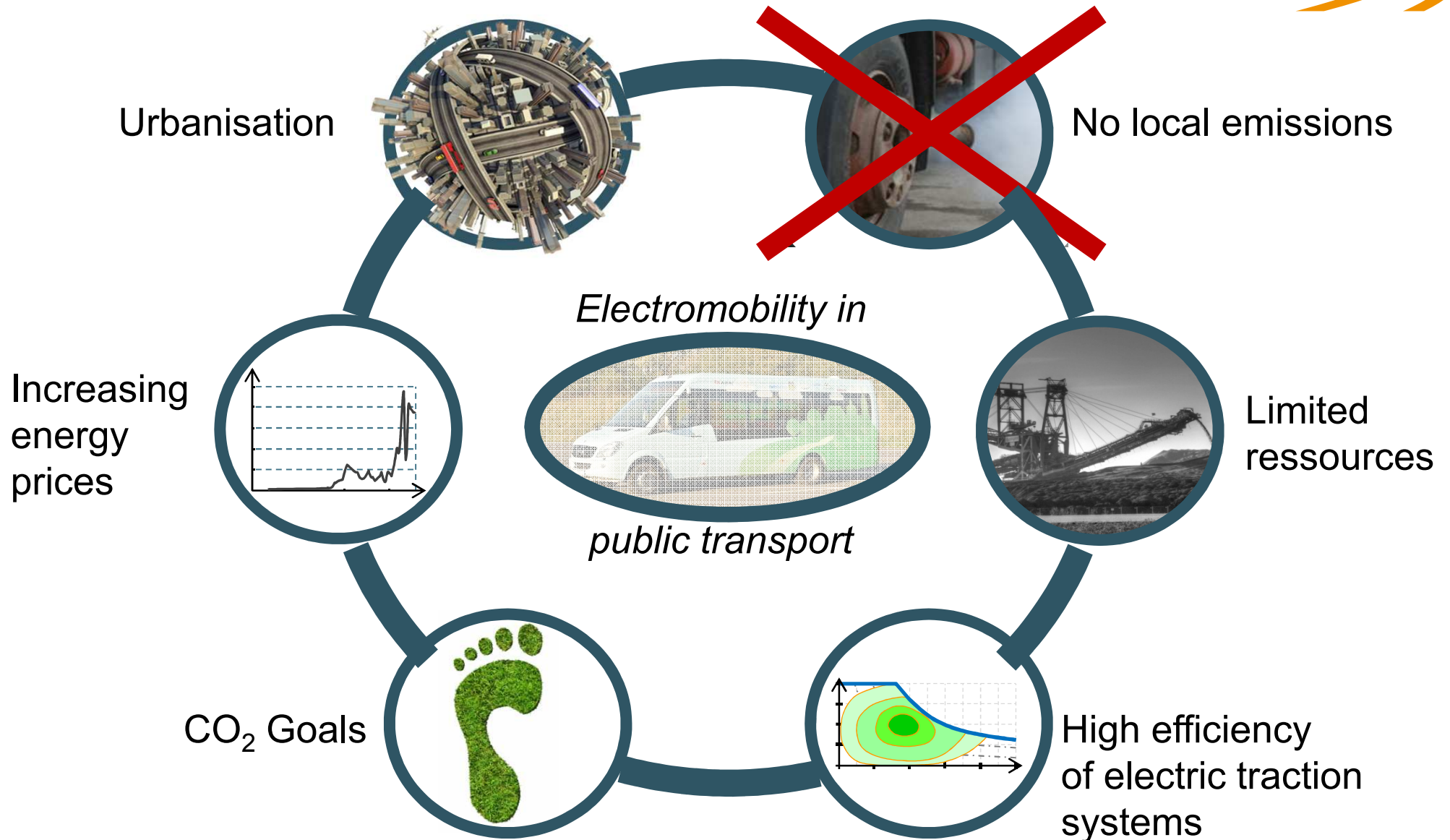
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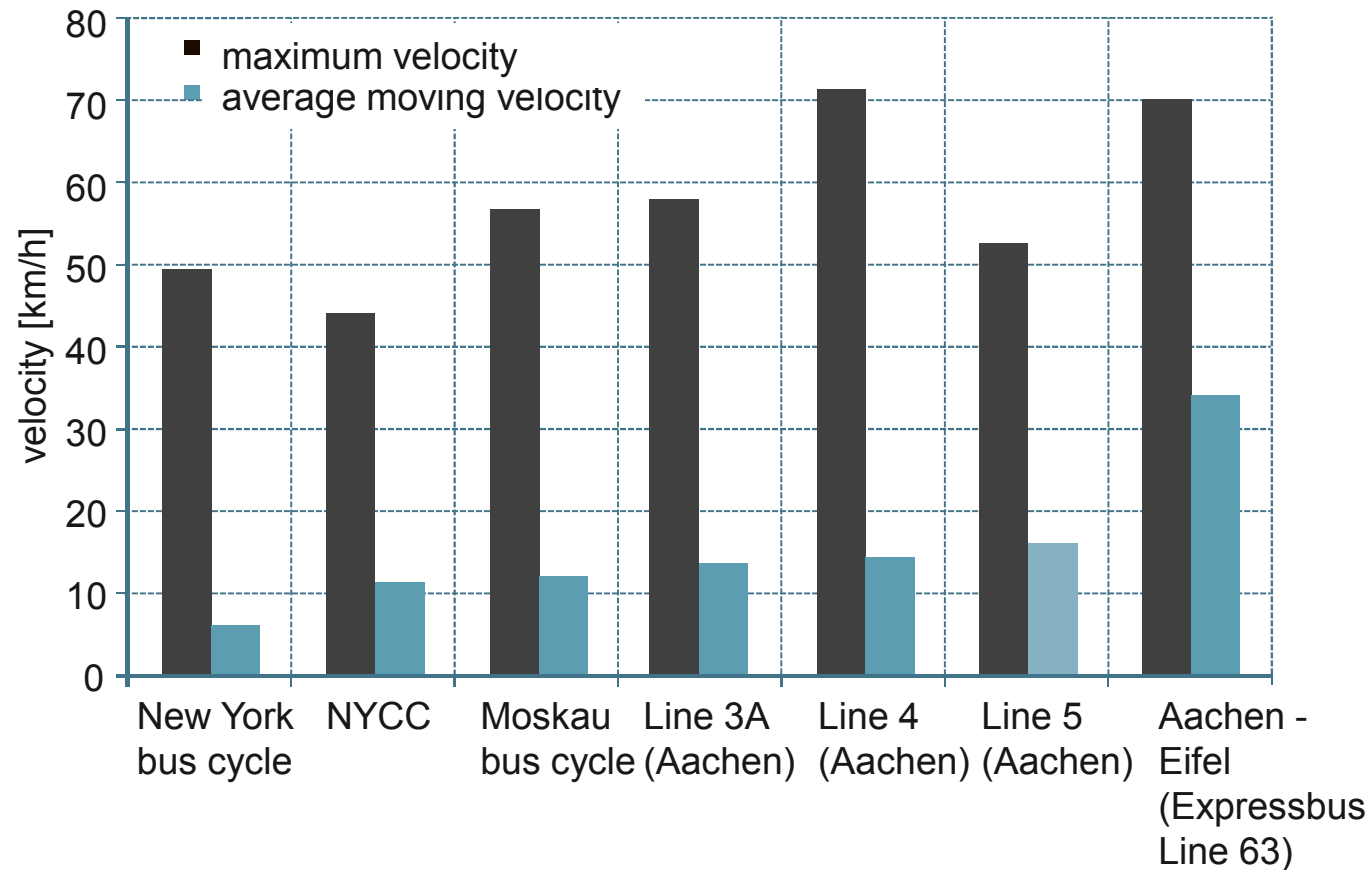
Bundesministerium
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aufgrund eines Beschlusses
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Introduction



Introduction



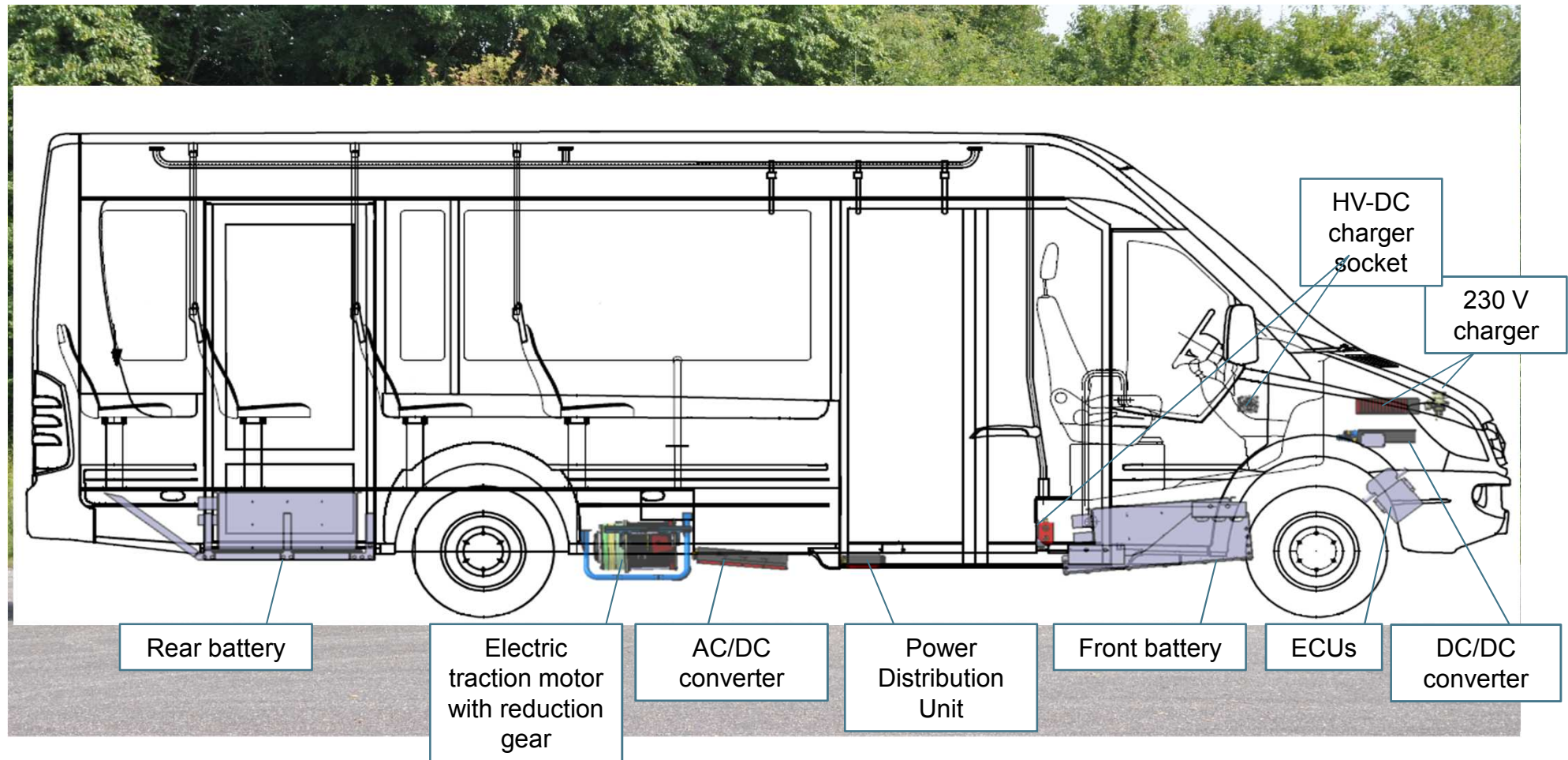
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Test vehicles

Modification of the basic vehicle



Test vehicles

Comparison of diesel and electric bus



	Series vehicle	Electric prototype	Unit
Seats	12 + 1 (Driver)		-
Stance	18	10 to 15	-
L x W x H	7700 x 1993 x 2845		mm
Max. Weight	5650		kg
Motor power	120	150 (peak)	kW
Maximum Speed	80 (electronically limited)	78	km/h
Max. Torque (at rpm)	360 (1200 - 2400)	300 (0 - 4500)	Nm
Max. rpm	4000	12 500	rpm
Gearbox	6-speed automatic	Fixed planetary gearbox	-
Battery capacity (gross)	-	45	kWh
Usable SOC window	-	15 – 95	%
Peak discharging current	-	400	A
Peak charging current	-	160	A
Charging time @230 V (max. 3,6 kW)	-	12	h
Charging time @400 V DC (max. 64 kW)	-	ca. 0,5	h
Motortype	4-cylinder Diesel	Hybrid-synchron-motor	-

Agenda



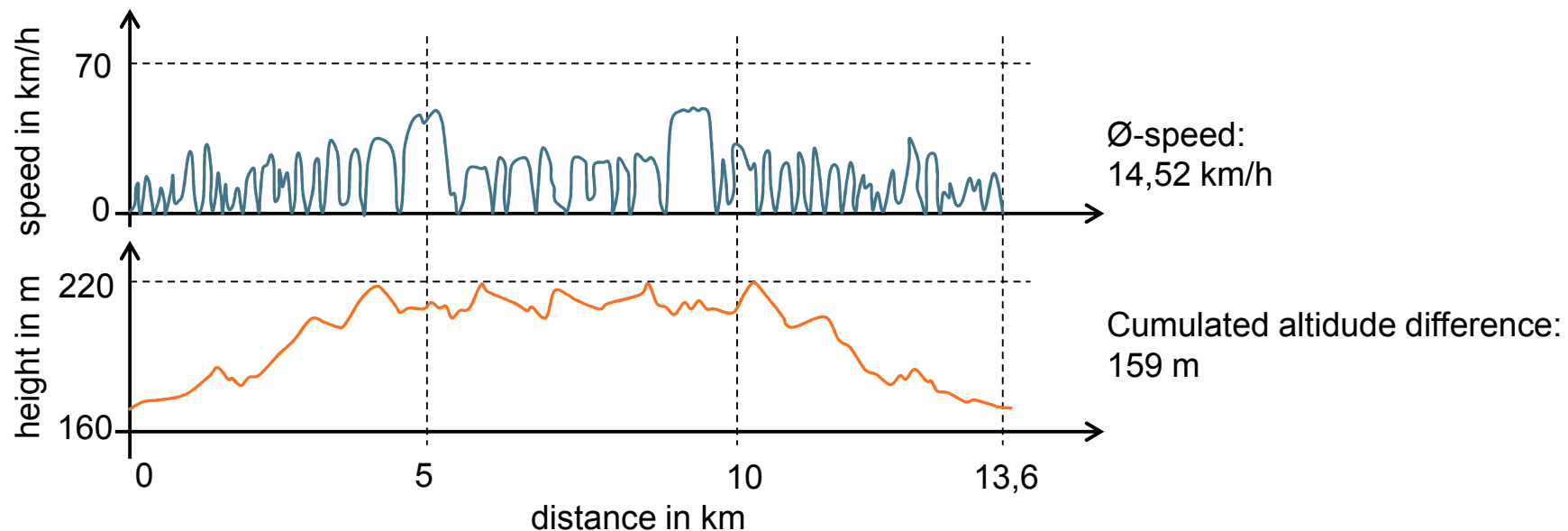
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Test drive results

Electric bus - Line 4

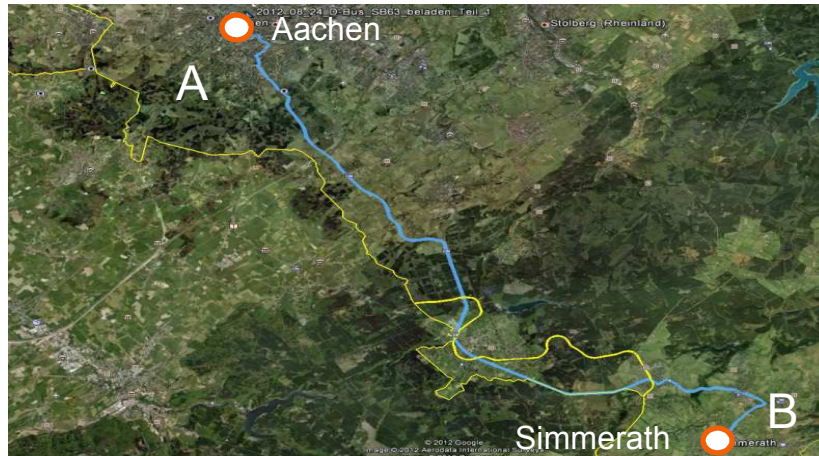


	Unit	Min. payload (300 kg)	max. payload (1500 kg)
Energy demand	kWh/100km	41,4	60,2
Recuperation / Drive energy	-	0,20	0,19
Range with 35 kWh available energy	km	84,5	58
Charging time for 100 km with 26 kW charger	h	1,77	2,57

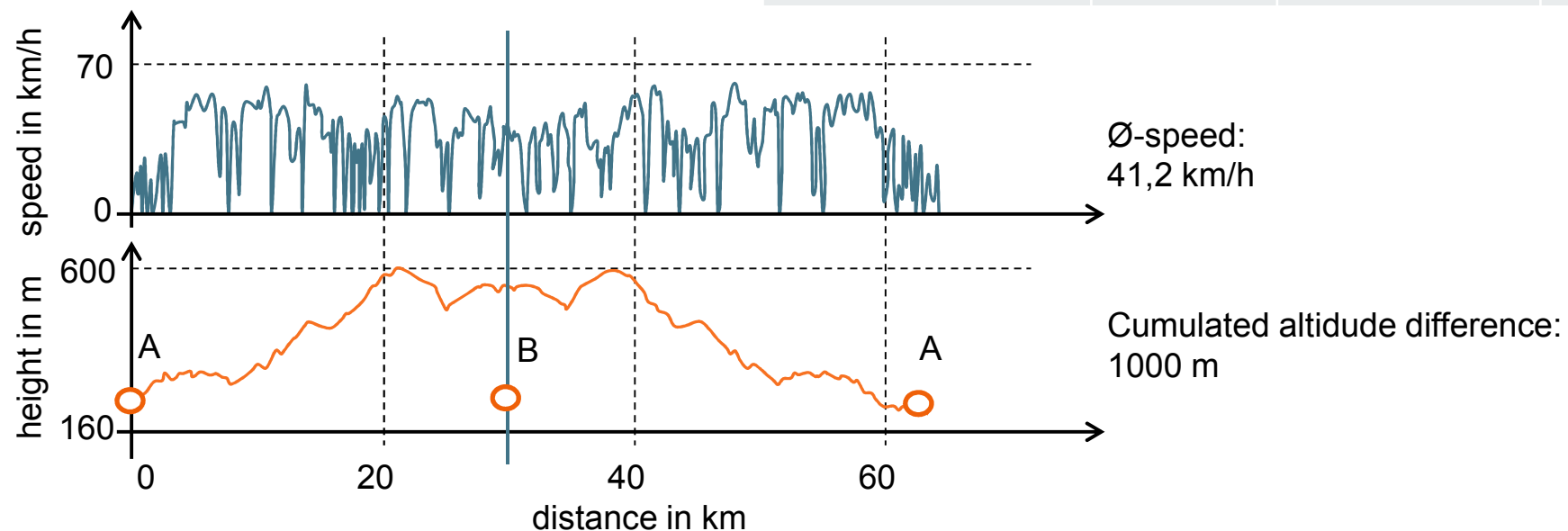


Test drive results

Electric bus - Line 63 (extra-urban express bus)

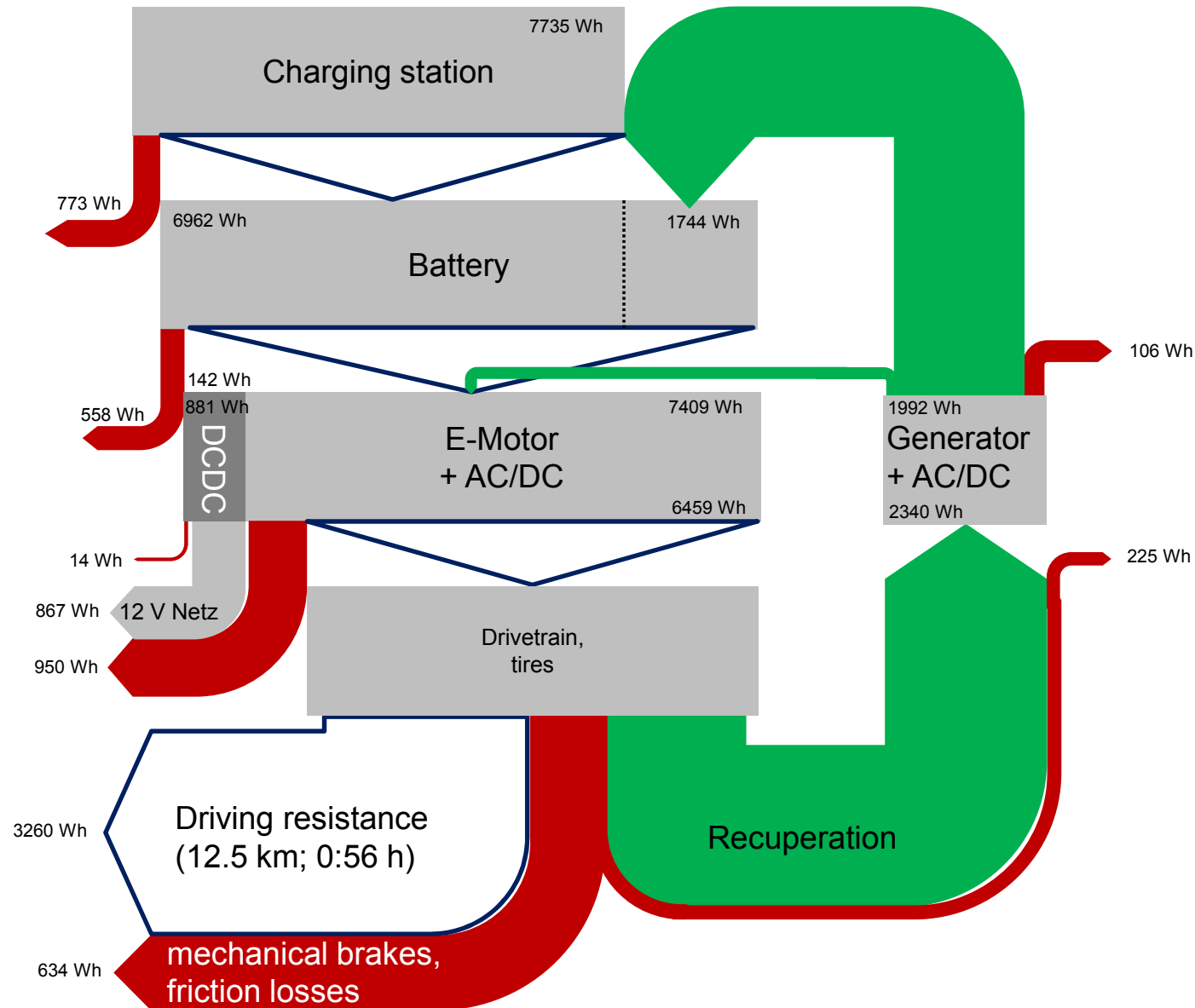


	Unit	Min. payload (300 kg)	max. payload (1500 kg)
Energy demand	kWh/100km	37,9 – 39,2	42,2 – 44,6
Recuperation / Drive energy	-	0,17 (0,08 uphill; 0,26 downhill)	0,18 (0,07 uphill; 0,29 downhill)
Range with 35 kWh available energy	km	92,2	78,5
Charging time for 100 km with 26 kW charger	h	1,62	1,9

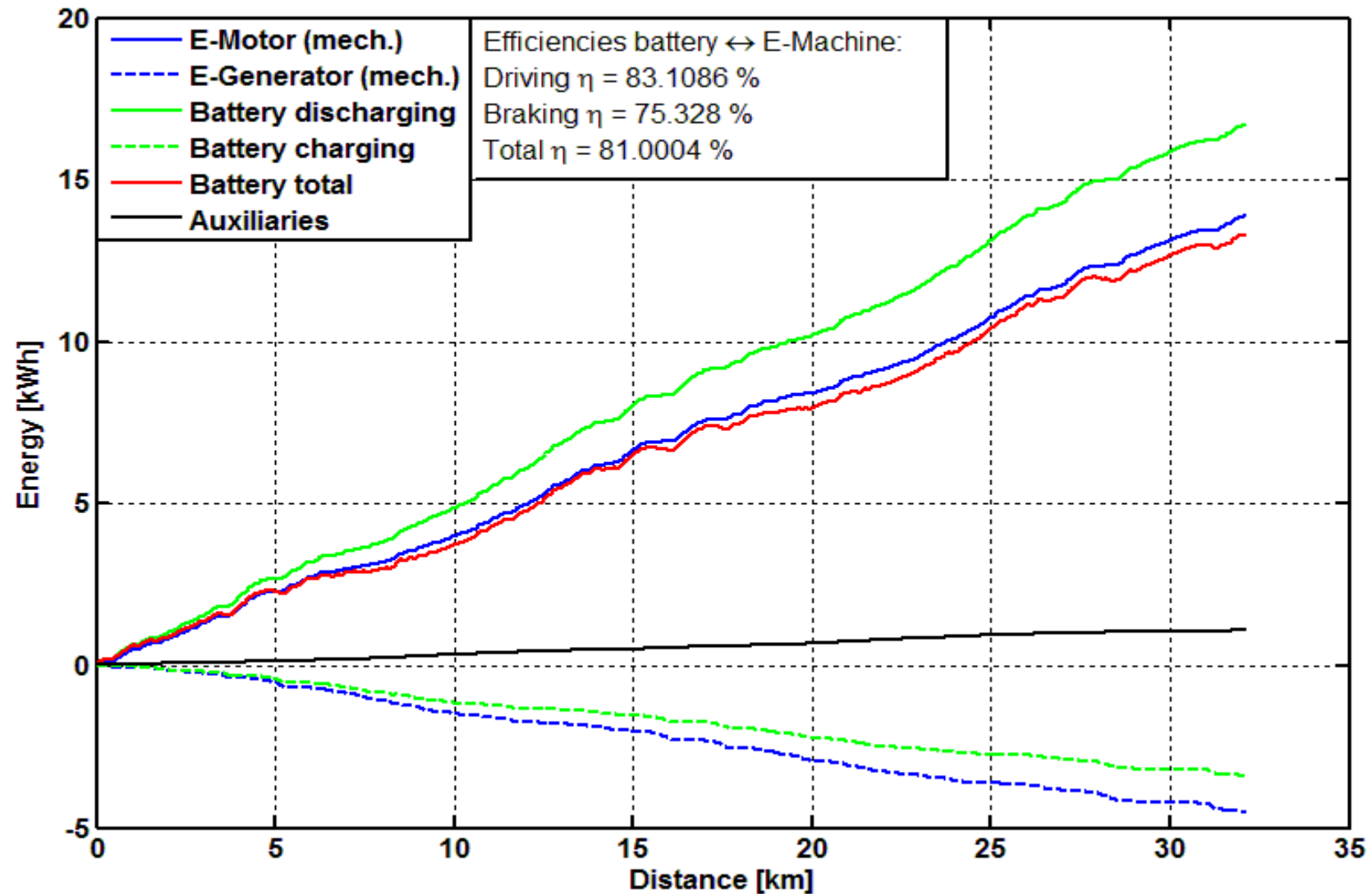


Energy diagram for electric bus – Line 4

55,7 kWh / 100 km at battery; 61,9 kWh / 100 km at grid



Resulting energy demand (line 4)



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Analysis of performance and energy costs

Overview



	Unit	With minimal payload						With maximal payload					
Bus line	-	3	4	5	13	63	Ø	3	4	5	13	63	Ø
Distance (ring or end-to-end)	km	11,2	13,6	25	6,3	62	-	11,2	13,6	25	6,3	62	-
Ø – Speed	km/h	16,9	14,5	15,8	14,9	41,2	-	16,9	14,5	15,8	14,9	41,2	-
Altitude difference (cumulated)	m	132	159	268	80	1000	-	132	159	268	80	1000	-
Ø – energy consumption at battery	kWh/100km	41,3	45,7	40,2	42,3	38,6	41,6	57,1	60,2	52,5	60	43,4	54,6
Ø – energy consumption at grid	kWh/100km	45,4	50,3	44,2	46,5	42,5	45,8	62,8	66,2	57,8	66	47,7	60,1
Recuperation / drive energy	-	0,21	0,2	0,18	0,18	0,18	0,19	0,16	0,2	0,19	0,17	0,17	0,18
Ø – range	km	89,8	84,5	90,4	85,6	92,2	88,5	60	58	66,7	56,3	78,5	63,9
Ø – charging time* for 100 km	h	1,7	1,8	1,7	1,8	1,6	1,7	2,5	2,6	2,2	2,7	1,9	2,4
Ø – Diesel consumption	l/100km	16	16,2	16	17	14,5	15,9	22,5	20,6	19,4	21,4	16,9	20,2

* The charging power was 27 kW. It can be boosted up to almost 60 kW, which would half the needed charging time, but also increase the losses while charging.

Energy costs for both vehicles for different price scenarios



Electric bus

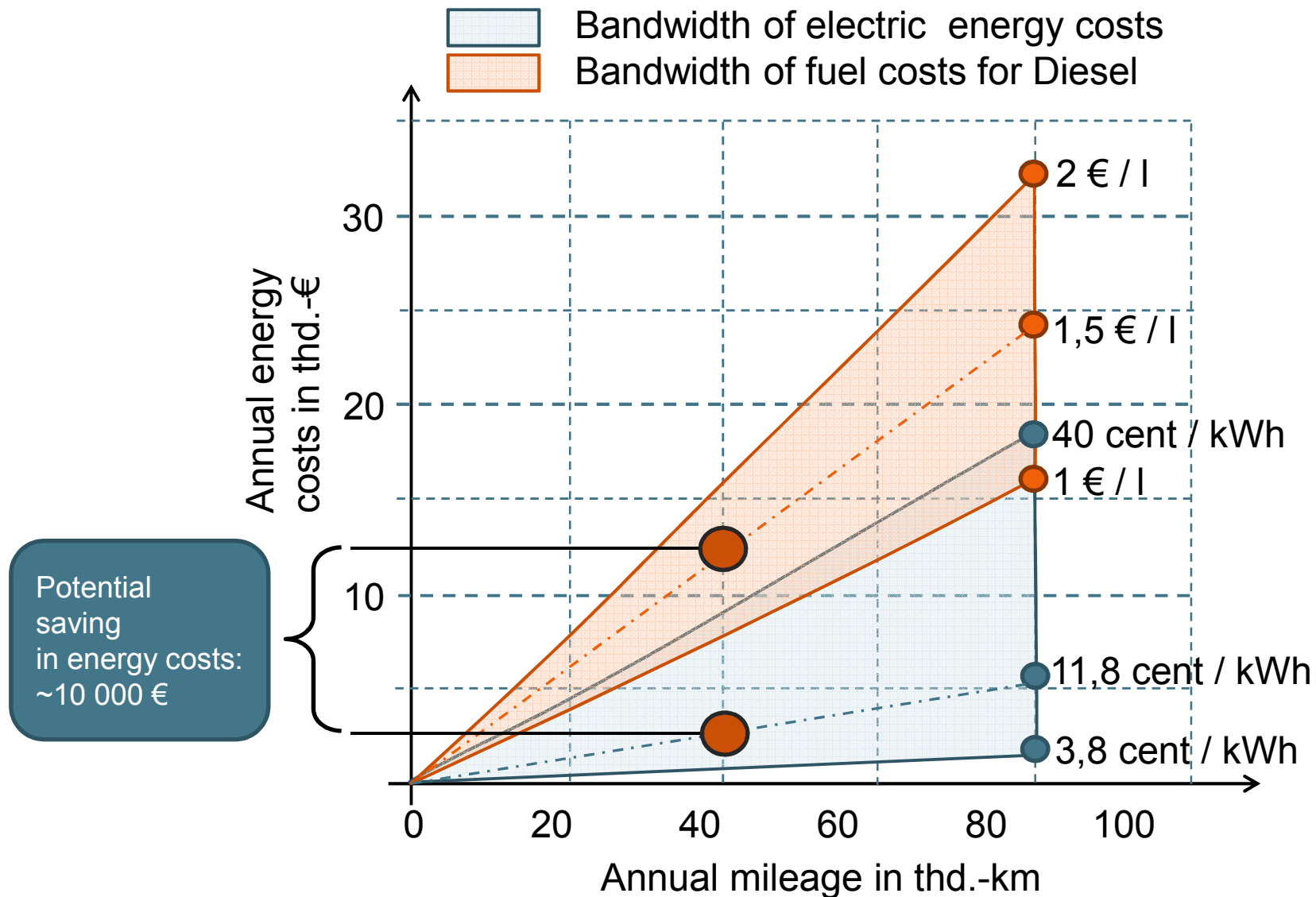
Price scenario	Price for electricity [€/MWh]	Energy costs [€/100km]	
		With minimal payload (45,8 kWh/100 km)	With maximal payload (60,1 kWh/100 km)
Low (average EEX price in Germany and Austria)	37,71	1,73	2,28
Medium (Average price in EA-17 for industrial consumers, 500 – 2000 MWh/a)*	118	5,40	7,09
High (assumed price for scenario with high costs for electric energy)	400	18,32	24,04

Diesel bus

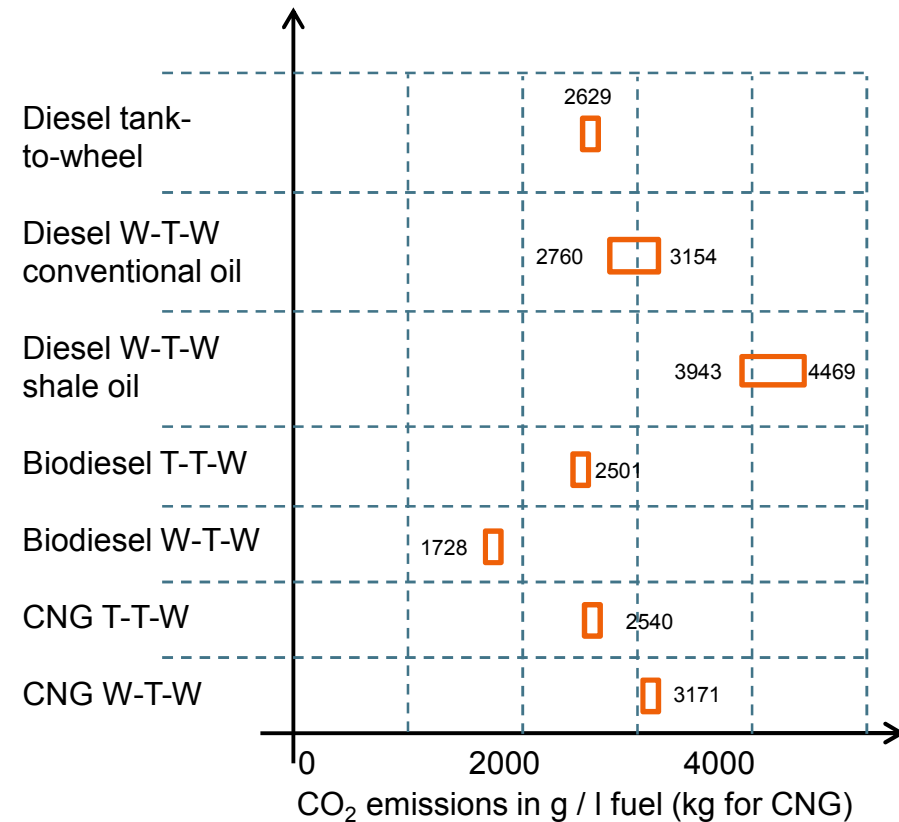
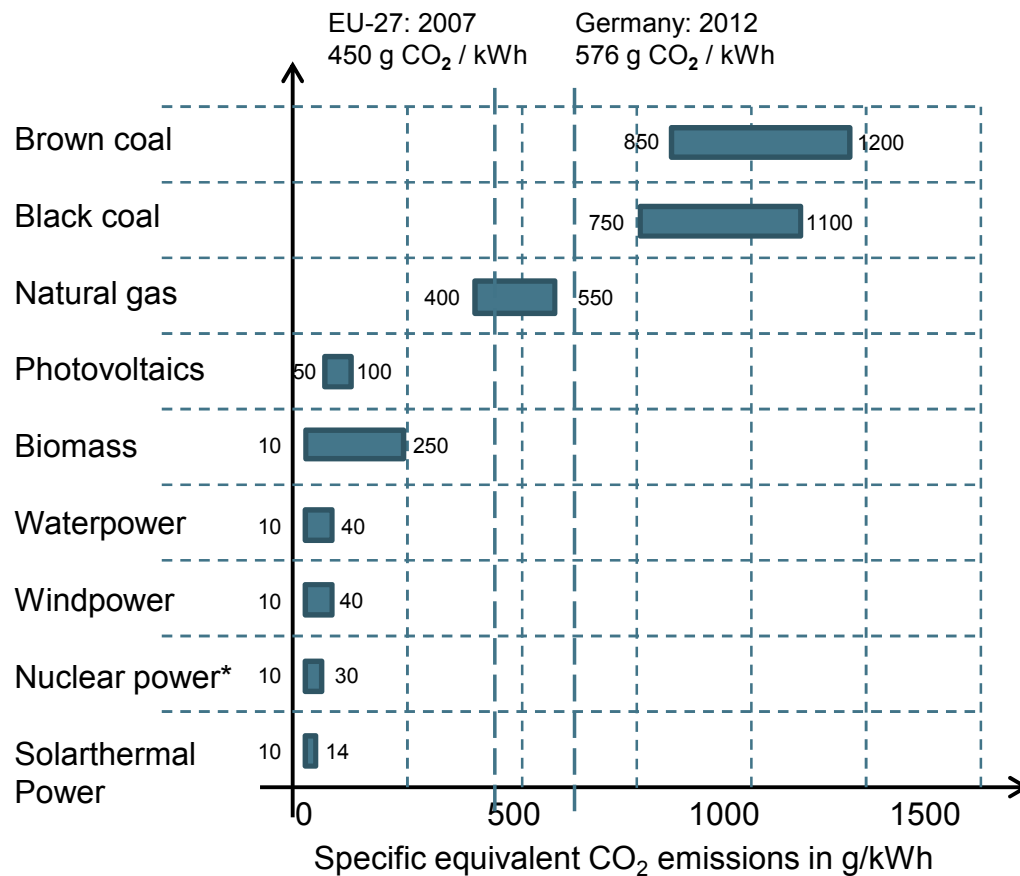
Price scenario	Price for Diesel [€/l]	Energy costs [€/100km]	
		With minimal payload (15,9 l/100 km)	With maximal payload (20,2 l/100 km)
Low	1,00	15,93	20,17
Medium	1,50	23,90	30,26
High	2,00	31,86	40,34

*Prices for 2011

Bandwidth of price scenarios for diesel and electric bus



CO₂ emissions for electric energy production and fossil fuels

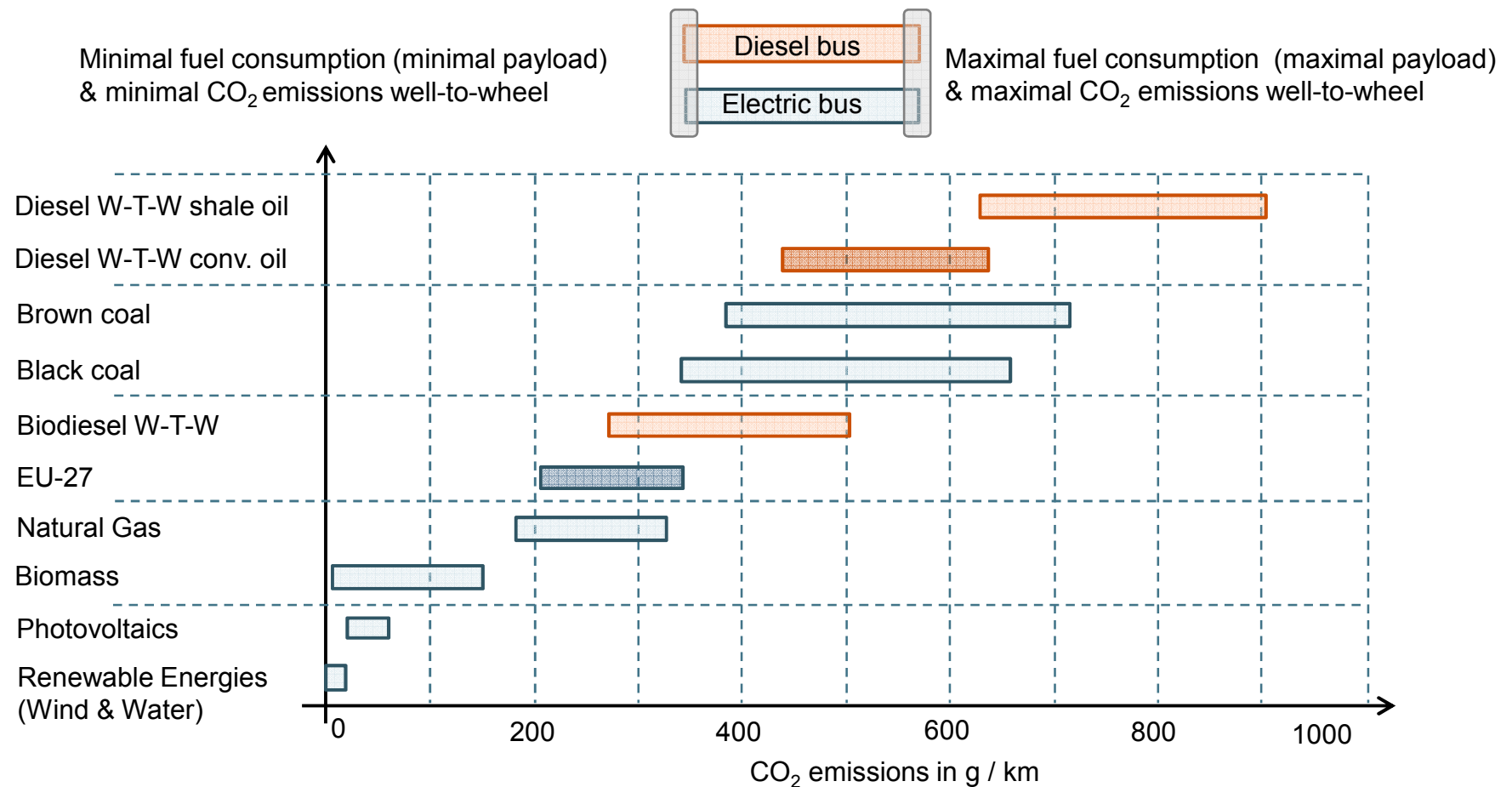


*assumed efficiency of nuclear powerplant: 33 %;
energy demand for nuclear waste disposal is not included

Sources: Bochum University;
Institute of energy systems and economics;

Verkehrsrundschau 51-52/2010

Comparison of CO₂ emissions from diesel and electric bus (well-to-wheel)



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Summary



- The electric bus with a gross weight of 5.65 tons, a passenger capacity of 25 persons and a battery with a usable energy content of 35 kWh has a range of at least 60 km and maximum 95 km.
- With a DC highpower charger (ca. 25 kW) a charging time between 1,6 h and 2,7 h is necessary to recharge the battery for 100 km.
- The high efficiency of the electric drive train reduces the energy costs significantly, especially if the prices for energy are continuously rising.
- The CO₂ emissions can be significantly lowered by using electric traction systems.
- With the average CO₂ emissions in the EU made from electricity production the electric bus has emissions between 200 and 350 g CO₂ / km, while a diesel bus with fossil fuels from conventional oil-wells produces emissions between 440 and 640 g CO₂ / km.

Contact



Thank you for your attention!

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