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Future measures for fuel savings and GHG emission reduction of heavy-duty vehicles (FKZ 3711 96 105)

Heavy-Duty Vehicles' CO_2 emissions meeting, European Commission, Brussels 30 January 2015

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Objectives and scope

Technological energy saving and greenhouse gas reduction potentials of heavy-duty vehicles

- Standardized GHG potentials for important current or future efficiency technologies for different vehicle classes and mission profiles
- Compatible to future European CO_2 certification of heavy-duty vehicles

Costs of the investigated measures for the reduction of greenhouse gases

- Additional investment costs and fuel cost savings for vehicle operators
- Cost-efficiency of GHG reduction

Strategies to promote the introduction and establishment of energy-saving and greenhouse gas reducing technologies for heavy-duty vehicles

Vehicle classes and mission profiles

Semi-trailer truck 40 t
long-haul, regional delivery

wikimedia.org, 2007, CC BY-SA 3.0

Delivery truck 12 t
urban delivery

openswisscloud.de, 2014

Urban bus 18 t
city-bus cycle

wikipedia.org, 2006, CC BY-SA 3.0

Beispielfahrzeuge

No bias towards any manufacturer. All vehicles in the models were based on assumptions for default vehicles equipped generic technology

Fuel-saving and GHG reducing technologies

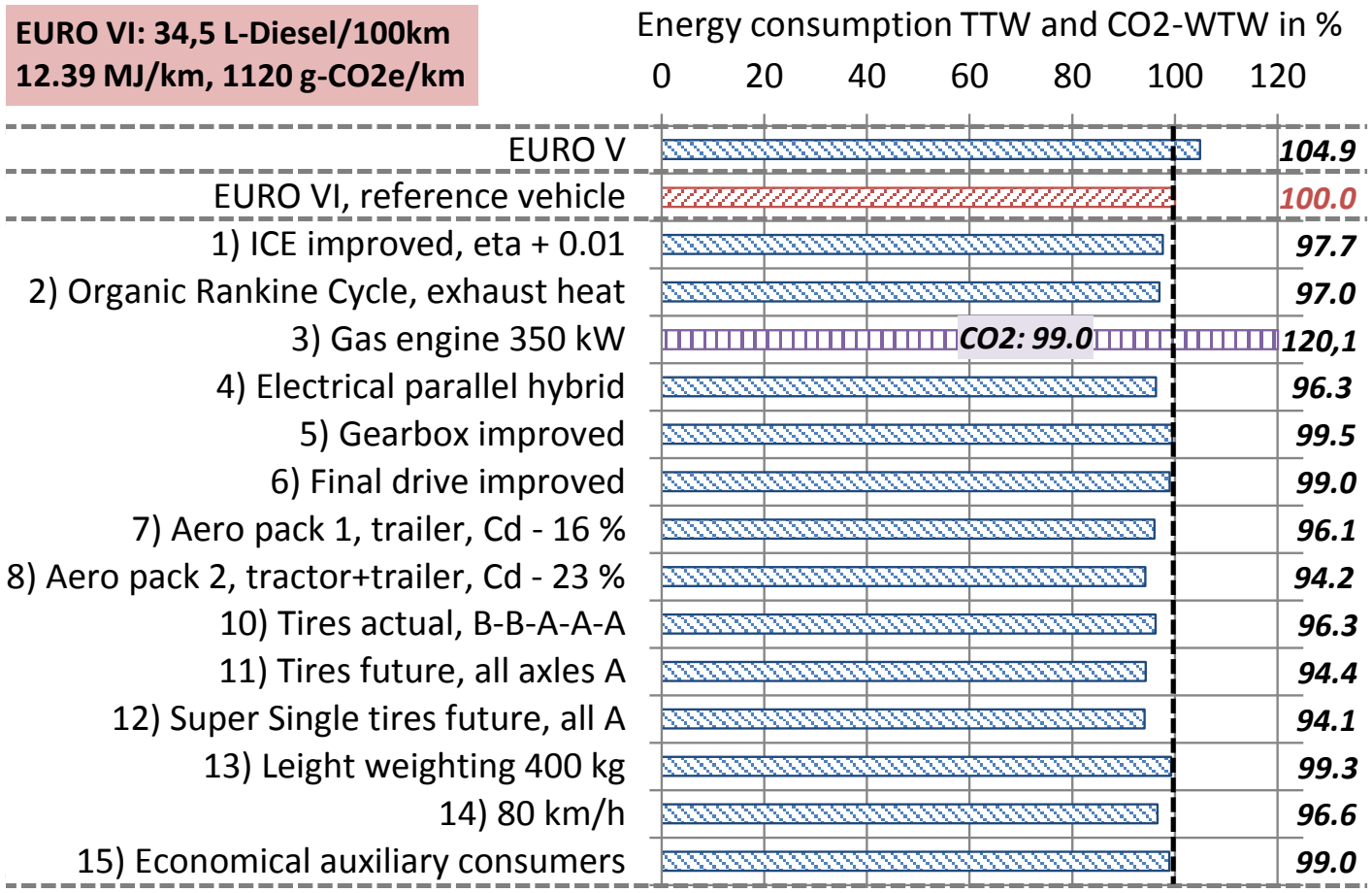
Technology	40t long-haul	40t regional	12t urban	Urban bus	Implemented in VECTO
ICE improved	Yes	Yes	Yes	Yes	Yes
Exhaust heat recovery ORC	Yes	No	No	No	Not yet
Gas engine	Yes	Yes	Yes	Yes	Yes
Electrical hybrid (parallel, serial)	Yes	Yes	Yes	Yes	Not yet
(Battery) electric	No	No	Yes	Yes	Not yet
Gearbox + final drive improved	Yes	Yes	Yes	Yes	Yes
Aerodynamics	Yes	Yes	Yes	No	Yes
Tires	Yes	Yes	Yes	Yes	Yes
Lightweighting	Yes	Yes	Yes	Yes	Yes
Speed limiter, Start/Stop	Yes	Yes	Yes	Yes	Yes
Auxiliaries improved	Yes	Yes	Yes	Yes	Yes

Discussion of all technologies and vehicle configurations with vehicle manufacturers and suppliers

Fuel-saving and GHG reducing potentials of single measures

Semi-trailer truck on long haul cycle, single measures

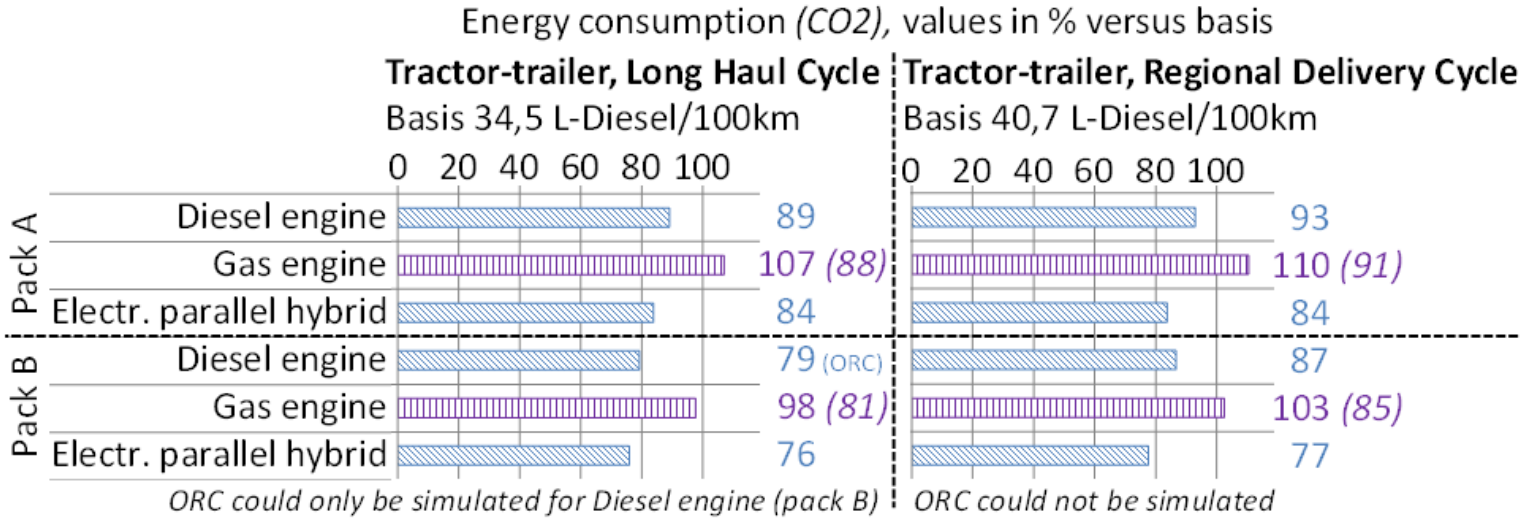
EURO VI: 34,5 L-Diesel/100km
12.39 MJ/km, 1120 g-CO2e/km



The bars in the figure show the changed final energy consumption. Differing changes of GHG emissions (CO_2e wtw) for measures with alternative energy carriers instead of diesel are indicated separately.

Fuel-saving and GHG reducing potentials of measure packs

Semi-trailer truck on Long Haul and Regional Delivery Cycle, measure packages



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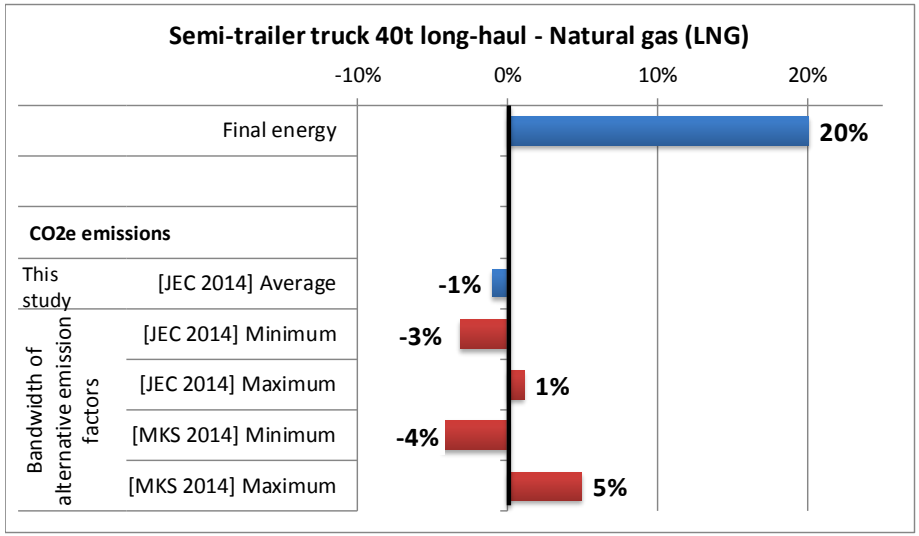
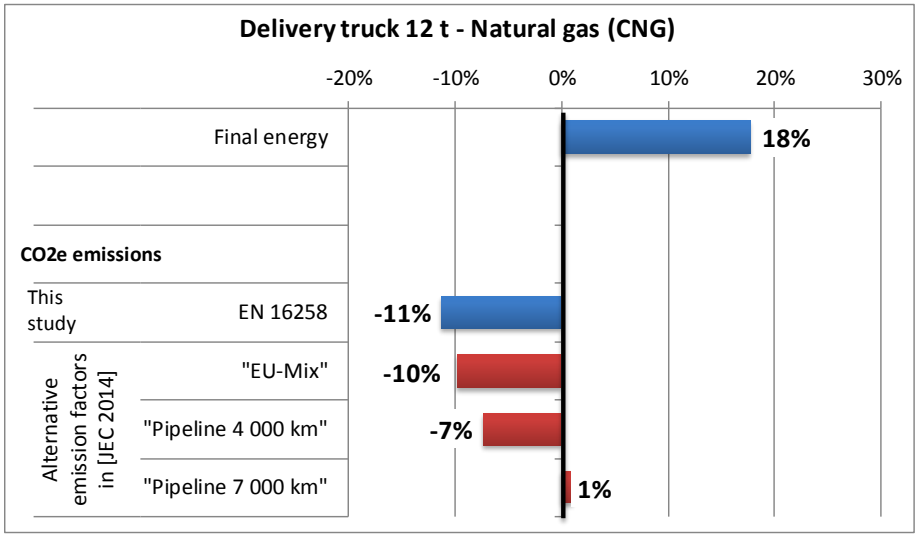
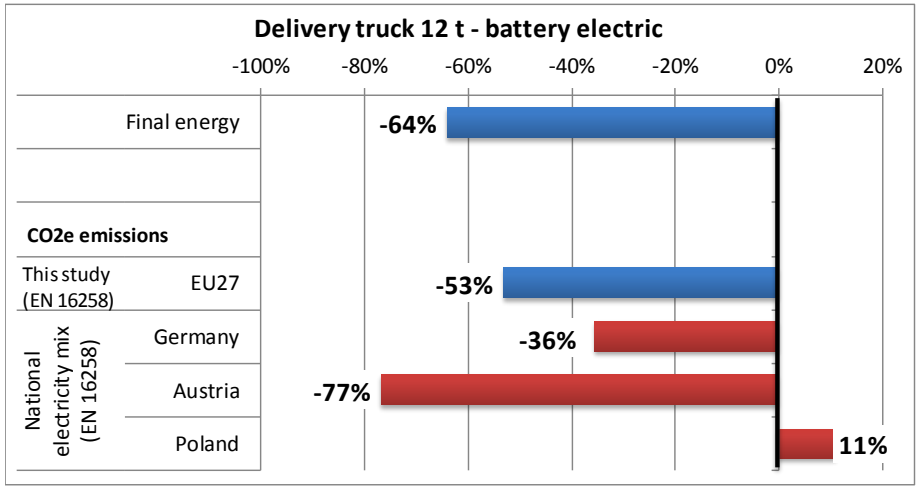
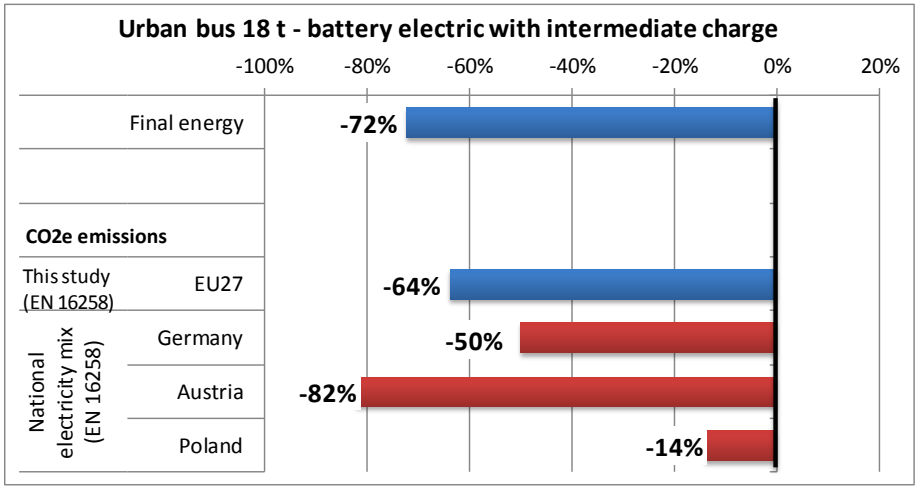
Importance of well-to-wheel GHG emission factors









Vehicle cost changes with fuel-saving technologies

Additional investment costs and changes in running costs

- Current prices for available technologies from public information sources
- Market entry prices for new technologies from scientific research
- Changes in running costs (e.g. AdBlue, oil and tire changes, maintenance)
- Discussion of all additional vehicle costs with OEMs and suppliers

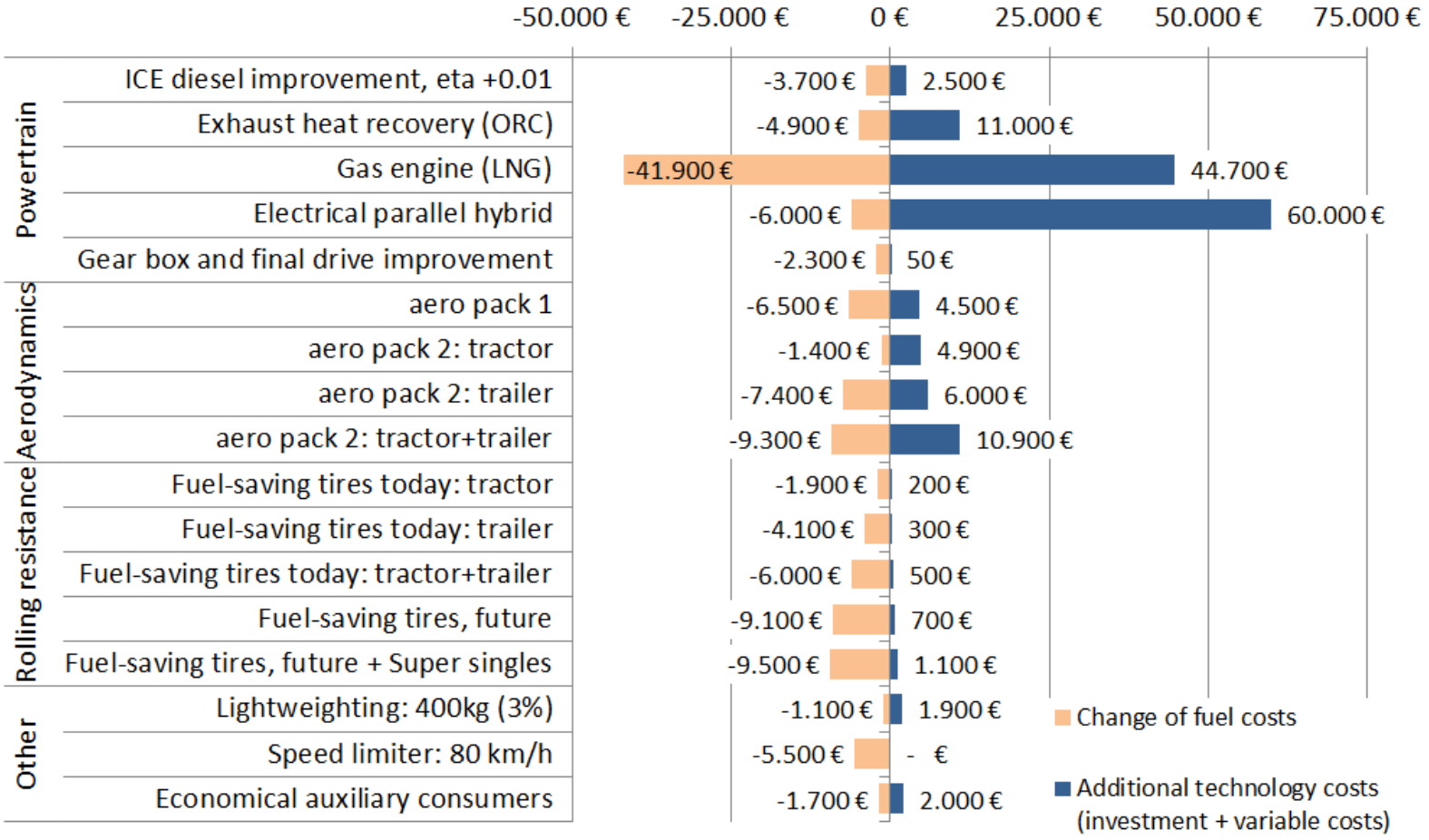
Fuel cost savings

- Annual fuel savings with average annual mileage per vehicle segment
- German fuel prices, end of 2014 (diesel, natural gas, electricity)
- Fuel cost savings for different time periods and average vehicle service life

Comparison of additional vehicle operating costs and fuel cost savings for different time periods, calculation of payback periods

Change in costs per vehicle within 3 years

Change in costs per vehicle in the first 3 years for a semi-trailer truck in long-haul transport



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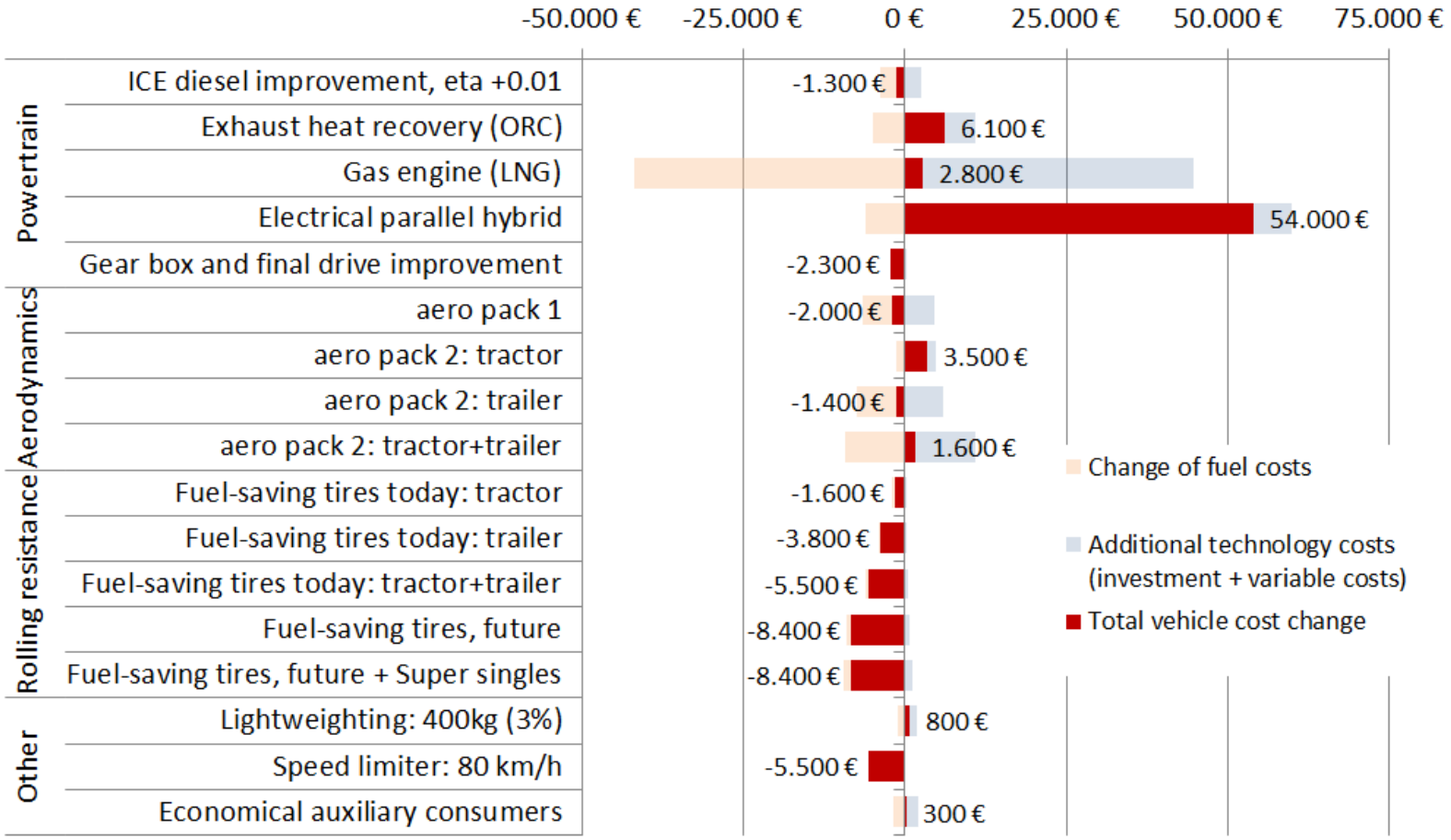


Several technologies with payback within the first 3 years

Payback periods with today's costs

		Semi-trailer truck 40t long-haul	Semi-trailer truck 40t regional deliv.	Delivery truck 12t urban delivery	Urban bus 18t
Powertrain	ICE improved +1 %	0.9	2.0	3.5	0.7
	Exhaus heat recovery	6.8	-	-	-
	Gas engine	3.2	6.5	3.4	5.3
	Parallel hybrid	30.0	27.2	40.2	22
	Serial hybrid	-	-	-	14.8
	Electric	-	-	25.7	14.4
	Electric with intermediate charge	-	-	-	10.7
	Gearbox and final drive improved	0.1	0.1	0.4	0.1
Aero-dynamics	Aero 1	2.1	6.2	19.7	-
	Aero 2: tractor	10.7	25.6	-	-
	Aero 2: trailer	2.4	7.3	-	-
	Aero 2: tractor+trailer	3.5	10.7	35.3	-
Rolling resistance	Fuel-saving tires: actual	0.1	0.3	0.7	0.3
	Fuel-saving tires: future	0.1	0.2	0.8	0.3
	Fuel-saving tires: future + supersingles	0.2	0.5	-	
Others	Lightweighting: 3 % weight reduction	5.2	9.8	7.9	3.1
	Speed limiter 80 km/h	0.0	0.0	-	
	Start-Stop system + speed limiter	-	-	3.1	6.7
	Optimized auxiliaries	3.5	10.4	11.8	4.9

Legend of payback periods	≤3 years	›3-6 years	›6 years, but within vehicle service life	Not within vehicle service life

Specific GHG abatement costs of single technologies

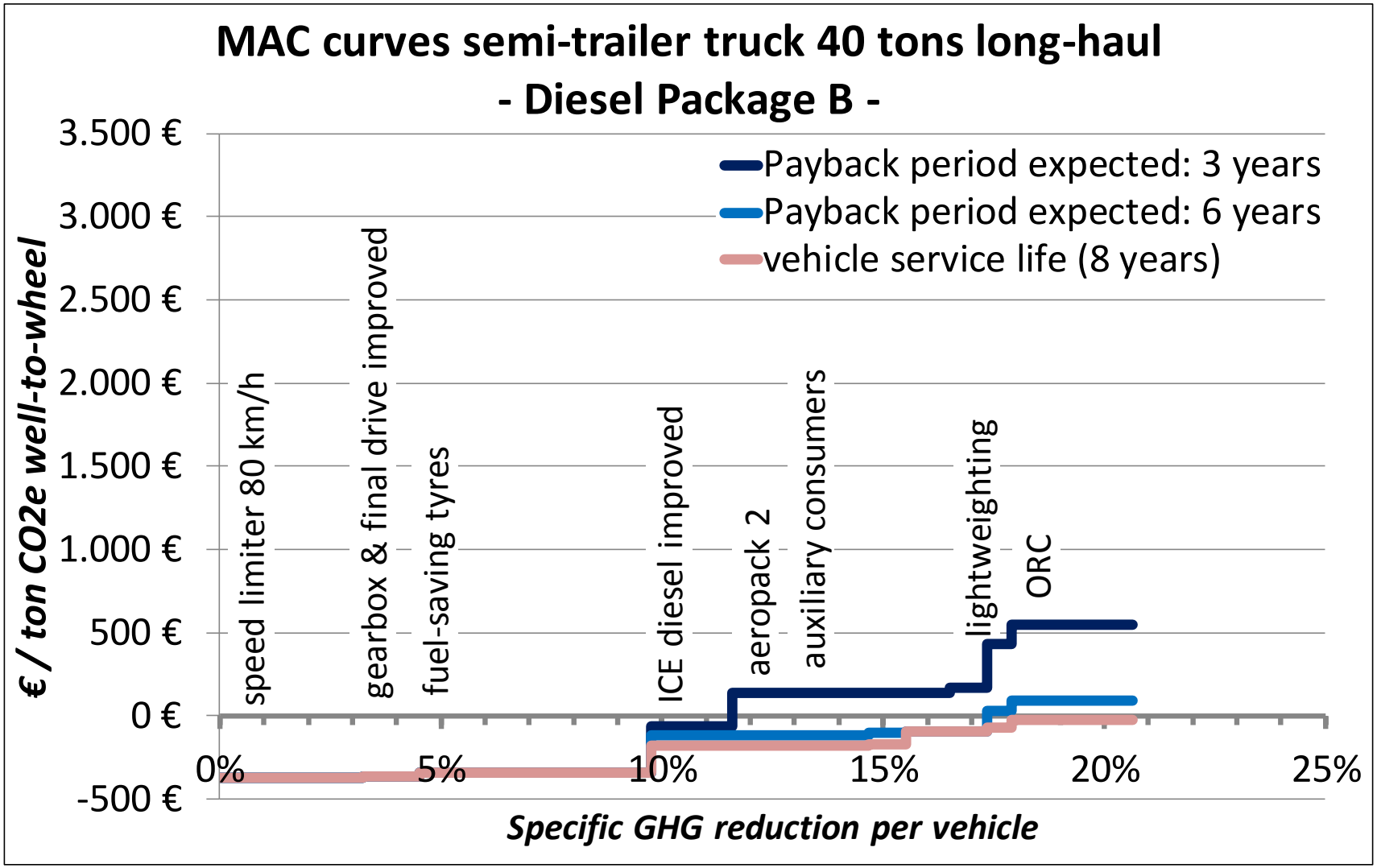
$$GHG\ abatement\ costs\ \left(\frac{€}{tons\ CO2e}\right) = \frac{[additional\ technology\ costs\ (€)] - [fuel\ costs\ savings\ (€)]}{[GHG\ emission\ reduction\ (tons\ CO2e)]}$$

Specific GHG abatement costs of technological measures for a semi-trailer truck in long-haul transport depending on the reference period

	3 years	Euro / t CO2e	6 years	Euro / t CO2e	vehicle service life (8 years)	Euro / t CO2e
1	Speed limiter 80 km/h	-370 €	Gas engine (LNG)	-3.756 €	Gas engine (LNG)	-4.849 €
2	Gearbox and final drive improved	-363 €	Speed limiter 80 km/h	-370 €	Speed limiter 80 km/h	-370 €
3	Fuel-saving tyres today: trailer	-342 €	Gearbox and final drive improved	-363 €	Gearbox and final drive improved	-363 €
4	Fuel-saving tyres future	-341 €	Fuel-saving tyres today: trailer	-342 €	Fuel-saving tyres today: trailer	-342 €
5	Fuel-saving tyres today: all axles	-338 €	Fuel-saving tyres future	-341 €	Fuel-saving tyres future	-341 €
6	Fuel-saving tyres today: tractor	-329 €	Fuel-saving tyres today: all axles	-338 €	Fuel-saving tyres today: all axles	-338 €
7	Fuel-saving tyres future + supersingles	-327 €	Fuel-saving tyres future + supersingles	-335 €	Fuel-saving tyres future + supersingles	-336 €
8	ICE diesel improved	-124 €	Fuel-saving tyres today: tractor	-329 €	Fuel-saving tyres today: tractor	-329 €
9	Aero pack 1	-115 €	Aero pack 1	-243 €	Aero pack 1	-275 €
10	Aero pack 2: trailer	-70 €	Aero pack 2: trailer	-220 €	Aero pack 2: trailer	-258 €
11	Aero pack 2: tractor+trailer	66 €	Aero pack 2: tractor+trailer	-152 €	Aero pack 2: tractor+trailer	-207 €
12	Economical auxiliary consumers	66 €	Economical auxiliary consumers	-152 €	Economical auxiliary consumers	-207 €
13	Lightweighting	276 €	ICE diesel improved	-147 €	ICE diesel improved	-153 €
14	Exhaust heat recovery with ORC	467 €	Lightweighting	-47 €	Lightweighting	-128 €
15	Gas engine (LNG)	617 €	Exhaust heat recovery with ORC	48 €	Exhaust heat recovery with ORC	-57 €
16	Aero pack 2: tractor	946 €	Aero pack 2: tractor	288 €	Aero pack 2: tractor	123 €
17	Electric parallel hybrid	3.340 €	Electric parallel hybrid	1.485 €	Electric parallel hybrid	1.021 €

Number of technologies with negative GHG abatement costs increases with longer reference periods

Marginal abatement costs (MAC)

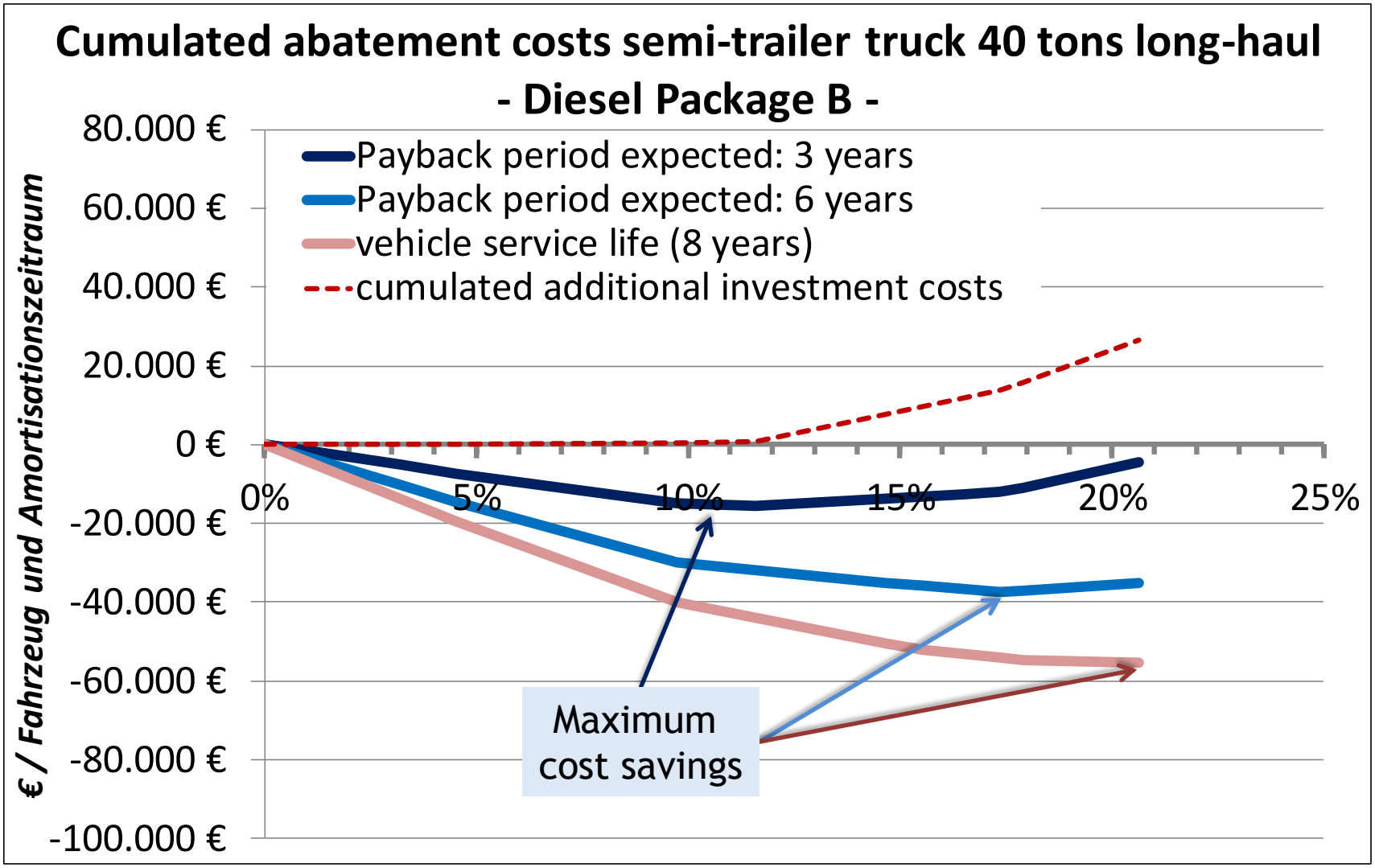


GHG savings potentials with negative abatement costs

Vehicle class and mission profile	Measure package	Combined GHG mitigation potential of the package	Partial GHG mitigation potentials of individual measures in the package with negative GHG abatement costs		
			After 3 years	After 6 years	Within vehicle service life
Semi-trailer truck 40 t, long haul cycle	Diesel A	11%	10%	+1%	+0%
	Natural gas (LNG) A	12%	10%	+2%	+0%
	Parallel hybrid A	16%	10%	+1%	+0%
	Diesel B	21%	12%	+6%	+3%
	Natural gas (LNG) B	19%	10%	+9%	+1%
	Parallel hybrid B	24%	12%	+6%	+1%

High relevance of considered reference period for GHG savings potentials without additional abatement costs

Cumulated abatement costs



Thank you for your attention!

Questions?

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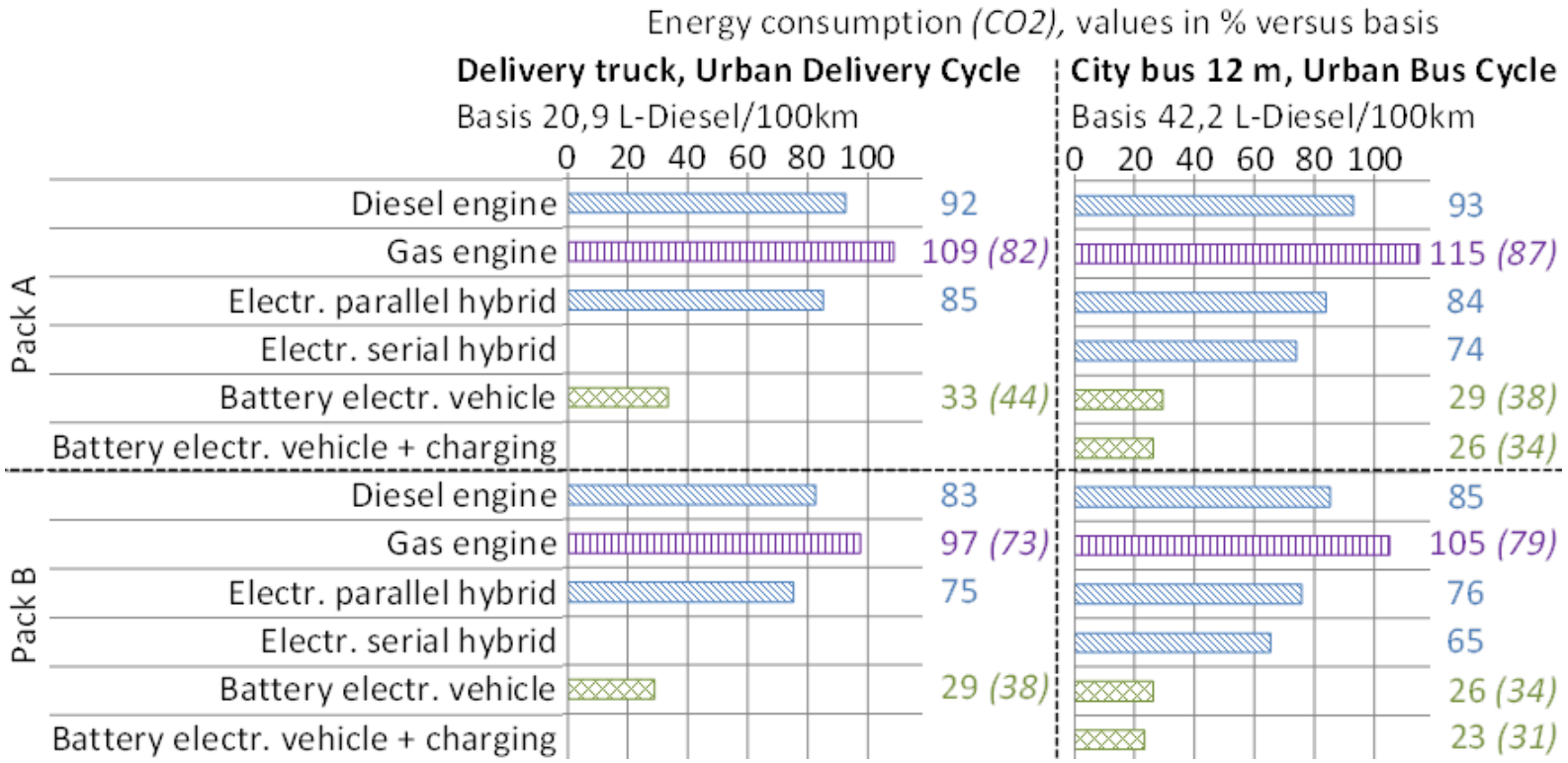
Fuel-saving and GHG reducing potentials of measure packs

Delivery truck and city bus, measure packages



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Scenarios of future payback periods

Average payback periods in years		with today's costs	with future costs in 10 years	
			scenario A	scenario B
Semi-trailer truck 40 t long-haul	parallel hybrid - with battery replacement	30.0	15.0	8.8
	parallel hybrid - without battery replacement		10.0	5.8
Semi-trailer truck 40 t regional delivery	parallel hybrid - with battery replacement	27.2	13.6	7.9
	parallel hybrid - without battery replacement		9.1	5.3
Delivery truck 12 t	parallel hybrid - with battery replacement	40.2	20.1	11.7
	parallel hybrid - without battery replacement		14.4	8.4
	electric	25.7	12.8	7.5
Urban bus 18 t	parallel hybrid - with battery replacement	22.0	11.0	6.4
	parallel hybrid - without battery replacement		8.5	5.0
	serial hybrid	14.8	7.4	4.3
	electric	14.4	7.2	4.2
	electric with intermediate charge	10.7	5.3	3.1

Legend of payback periods	≤3 years	>3-6 years	>6 years, but within vehicle service life	Not within vehicle service life

Hybrid and electric vehicles become economically viable if investment costs can be reduced considerably in future