HDV fuel efficiency technologies

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ICCT

Decarbonising Road Freight

EXPERT WORKSHOP

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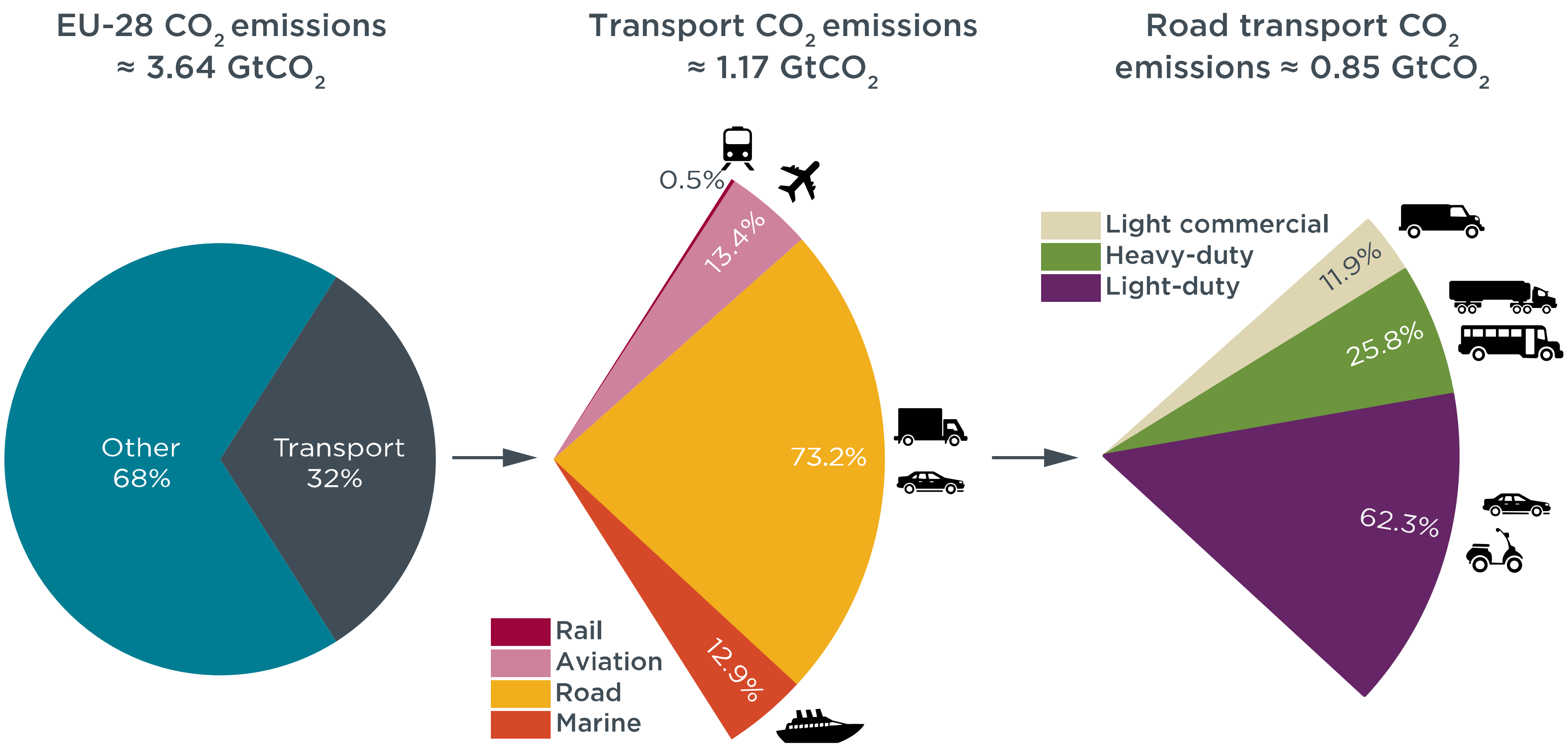
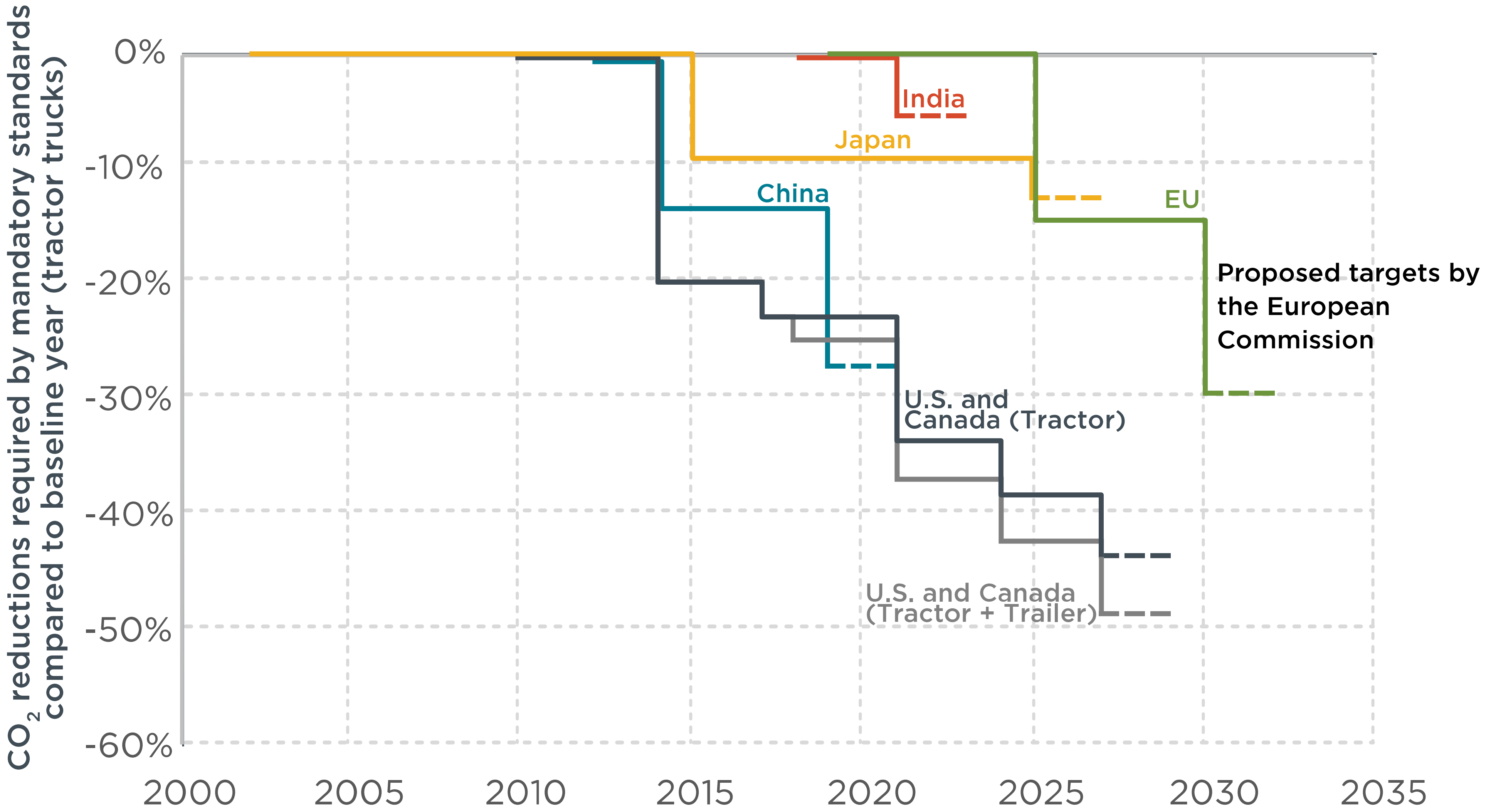
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Why policy makers should pay attention to HDVs



Delgado, Oscar, and Felipe Rodriguez. “CO2 Emissions and Fuel Consumption Standards for Heavy-Duty Vehicles in the European Union.” The International Council on Clean Transportation, May 6, 2018. https://www.theicct.org/publications/co2-emissions-and-fuel-consumption-standards-heavy-duty-vehicles-european-union.

Long-haul tractor-truck CO_2 standards around the globe



4 key barriers delay technology uptake

Uncertain return on investment

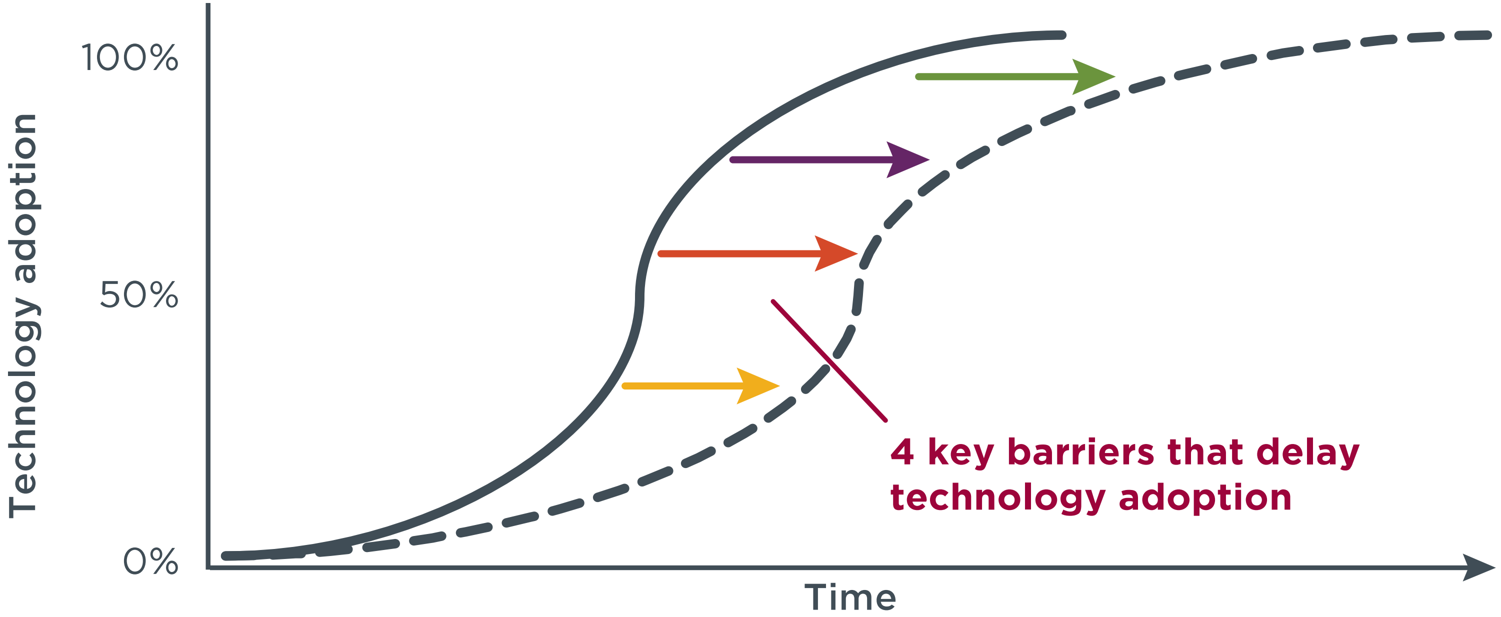
Will the technologies perform as expected?

What will fuel prices be in the future?

Capital cost constraints

Can the fleet get access to additional capital?

Sharpe, B. (2017). Barriers to the adoption of fuel-saving technologies in the trucking sector. [http://theicct.org/barriers-to-fuel saving-technologies-trucking-sector](http://theicct.org/barriers-to-fuel-saving-technologies-trucking-sector)



Split incentives

Are the equipment owner and operator different entities with different motivations?

Who makes the technology purchase vs. who pays for fuel?

Lack of technology availability

Are the technologies available in the market?

Are they available from a preferred supplier?

Why regulate HD efficiency?

Drivers for CO_2 emissions from on-road freight and market barriers

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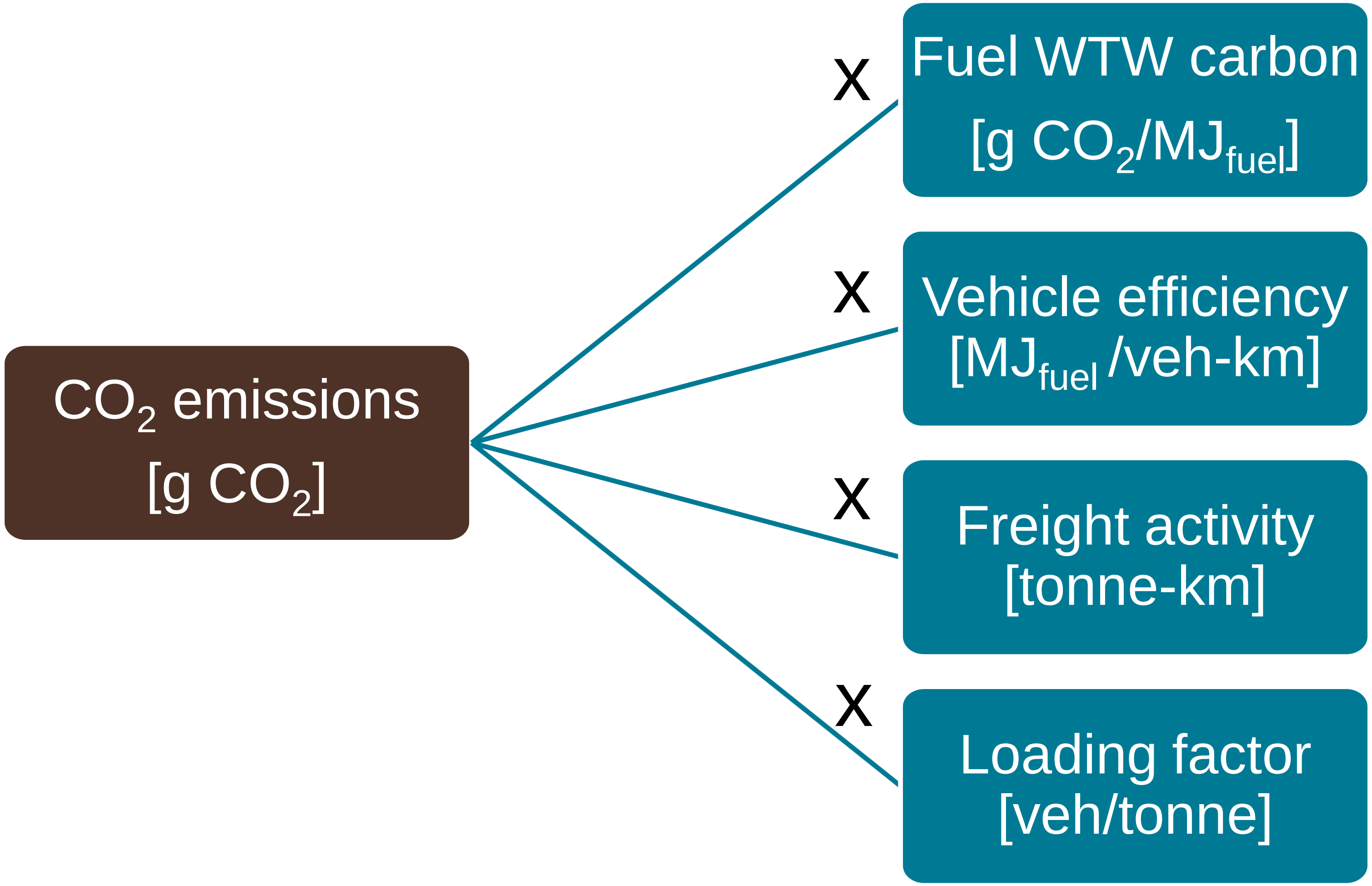
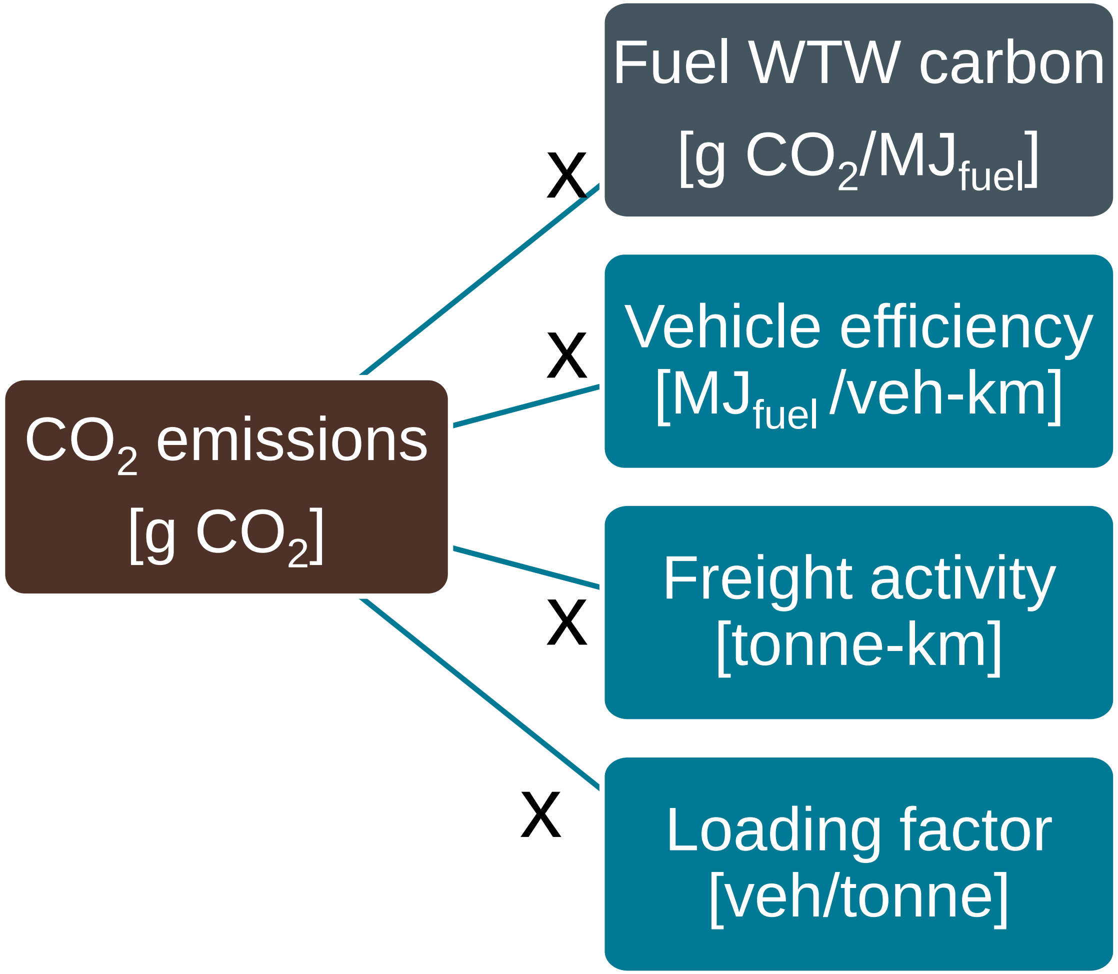
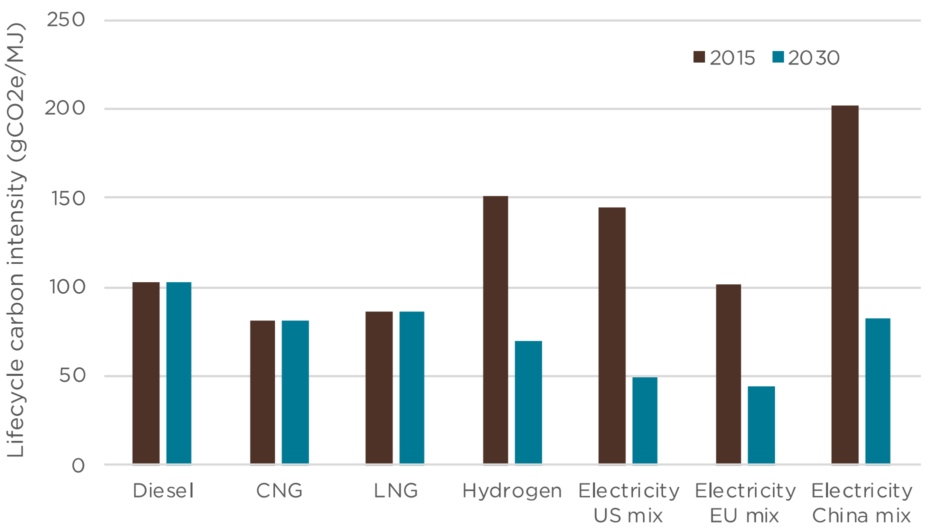
Drivers for tailpipe CO_2 emissions from road freight transport

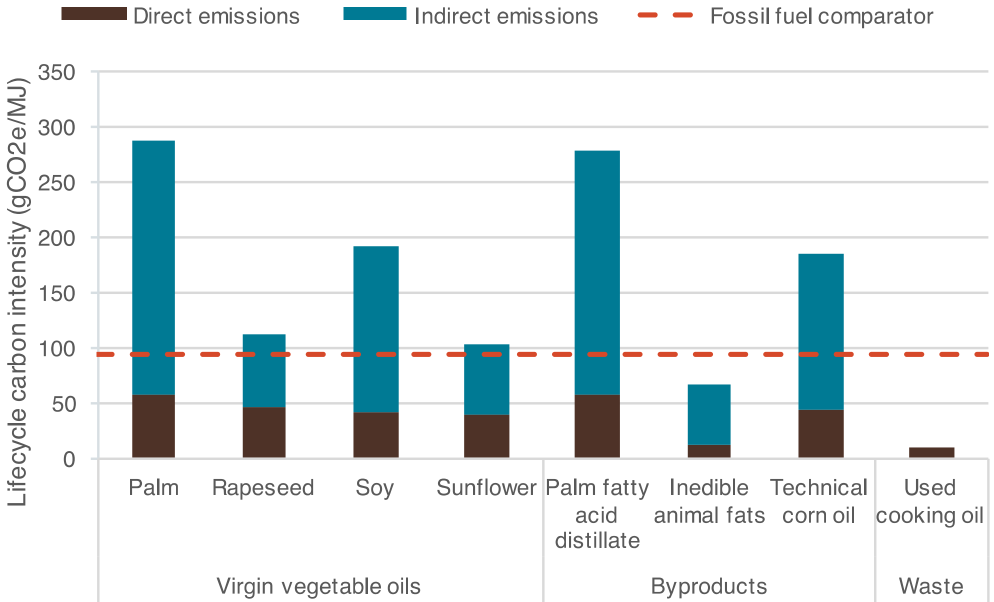


Life-cycle carbon intensity of different fuels



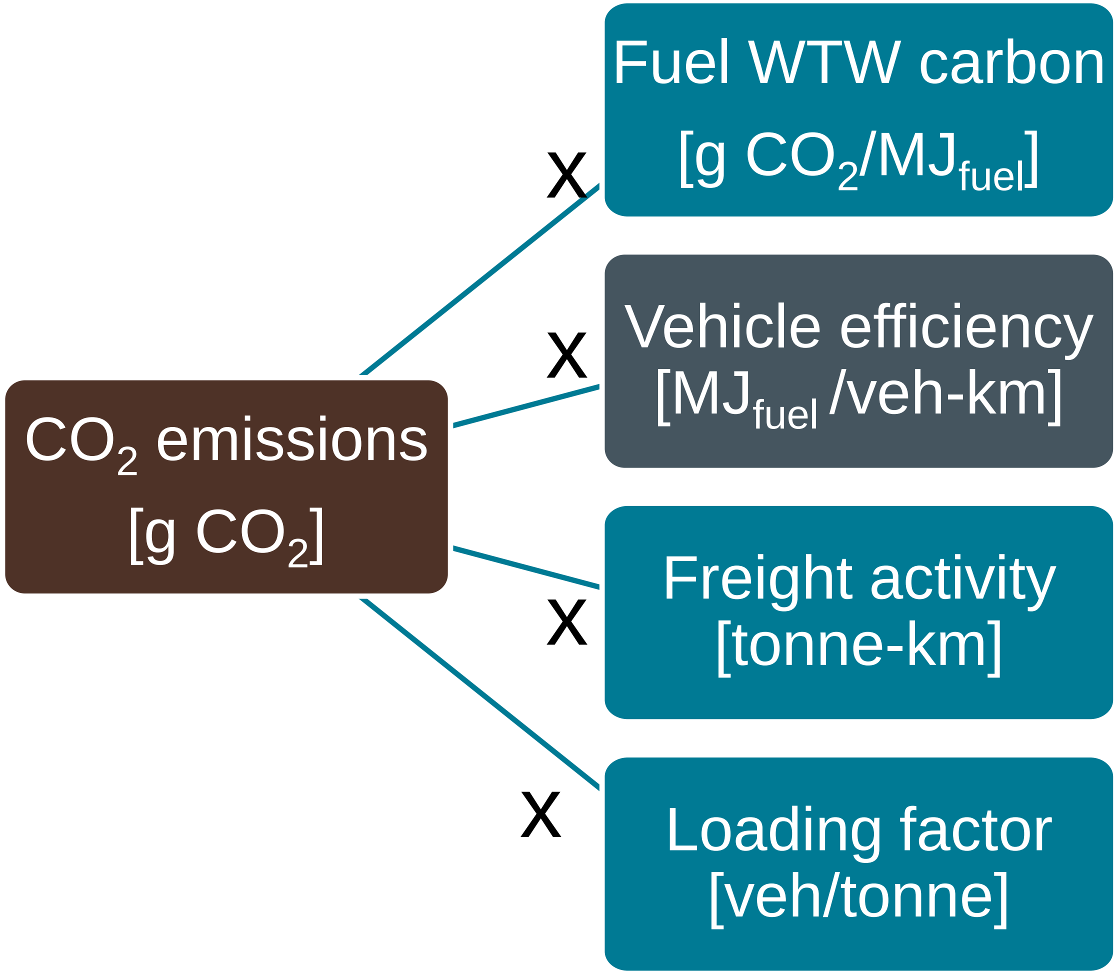


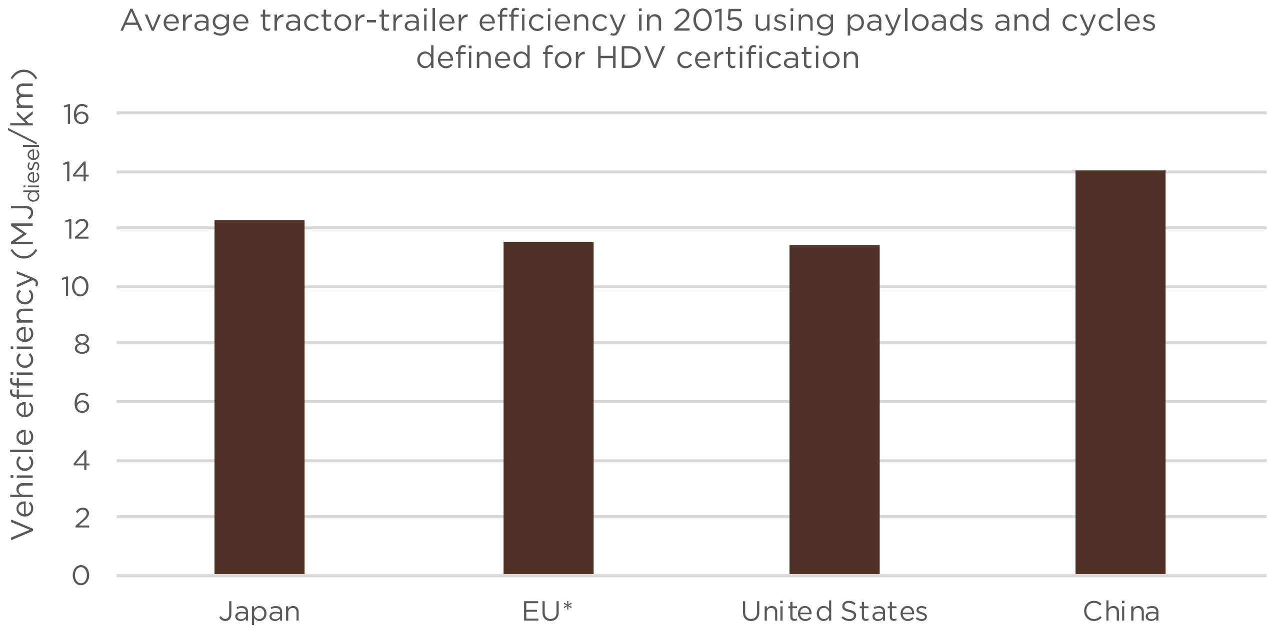
Data source: Moultak, Marissa, Nic Lutsey, and Dale Hall. 2017. “Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.” The International Council on Clean Transportation https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles



Data sources: European Commission proposal for recast Renewable Energy Directive to 2030; Valin et al. (2015); Searle et al. (2017); Malins, C. (2017)

Tractor-trailer efficiency for different regions in the year 2015

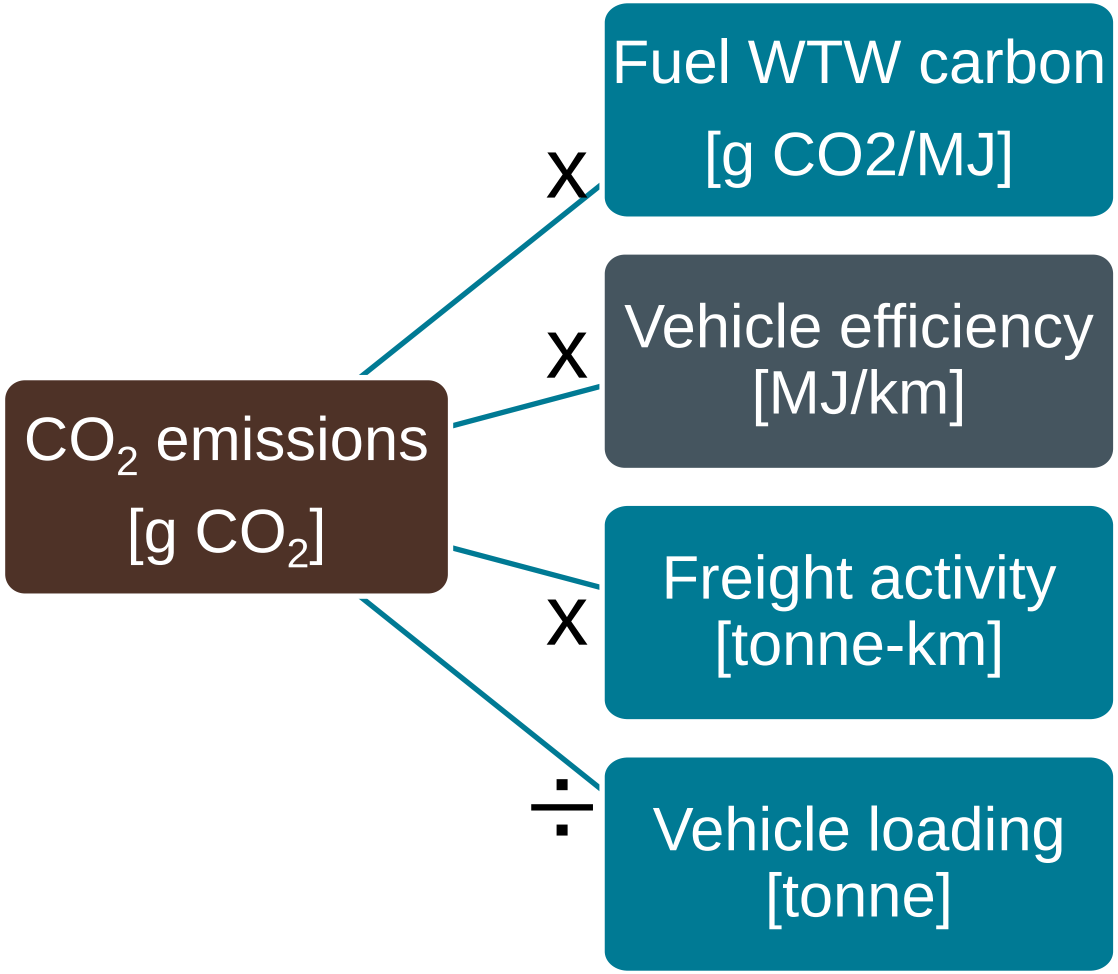


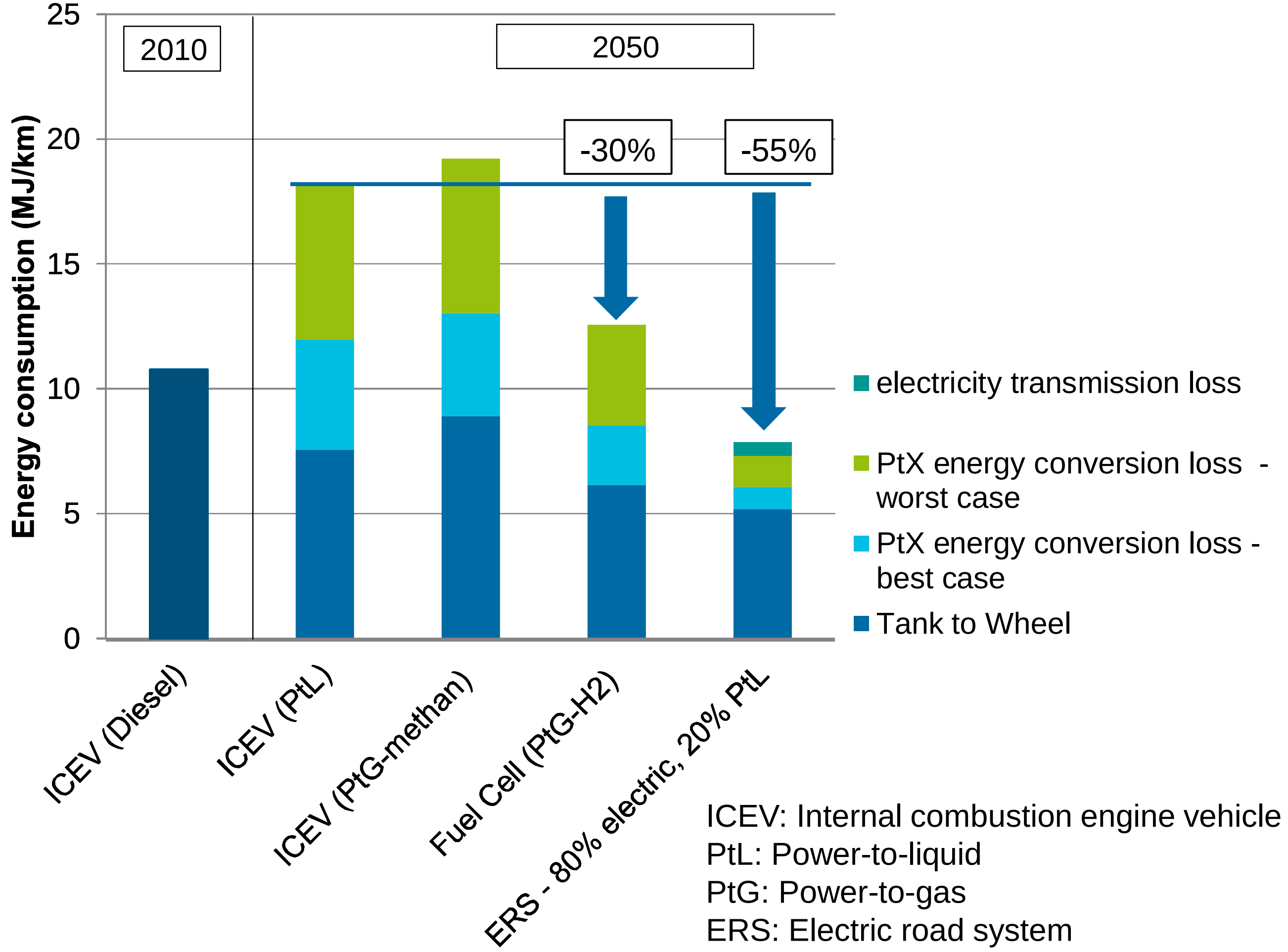


	2015 fuel consumption in region's metric*	Notes on cycle and payload
Japan	2.84 km/L	GCVW = 38 t, Payload = 50% loading (~10 t). Cycle: JE05 (55%), 80 km/h (45%)
EU	33.1 L/100km	GCVW = 40 t, Payload = 19.3 t, Cycle: Long Haul
U.S.	7.3 gal/1000 ton-mi	GCVW = 36 t, Payload = 17.2 t, Cycle: 95% constant speed cycles
China	40 L/100km	GCVW = 40 t, 100% loading (~24 t), Cycle: C-WTVC (90% motorway)

* With the exception of the EU, the fuel consumption corresponds to the mandatory limits set in HDV standards. The EU vehicle efficiency is based on ICCT's own work. The EU will propose HDV CO_2 standards in May 2018.

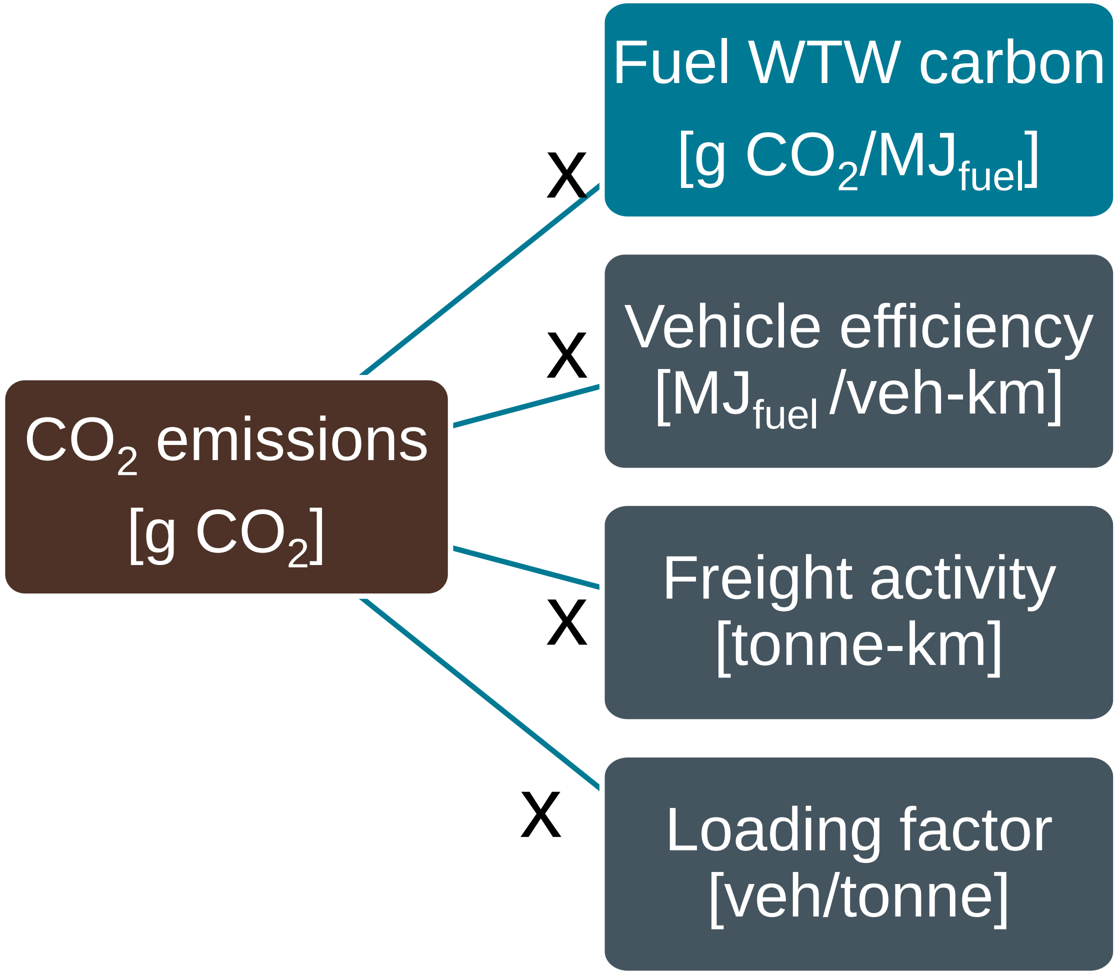
Direct use of electricity has benefits on the vehicle efficiency, and results in a lower overall energy consumption

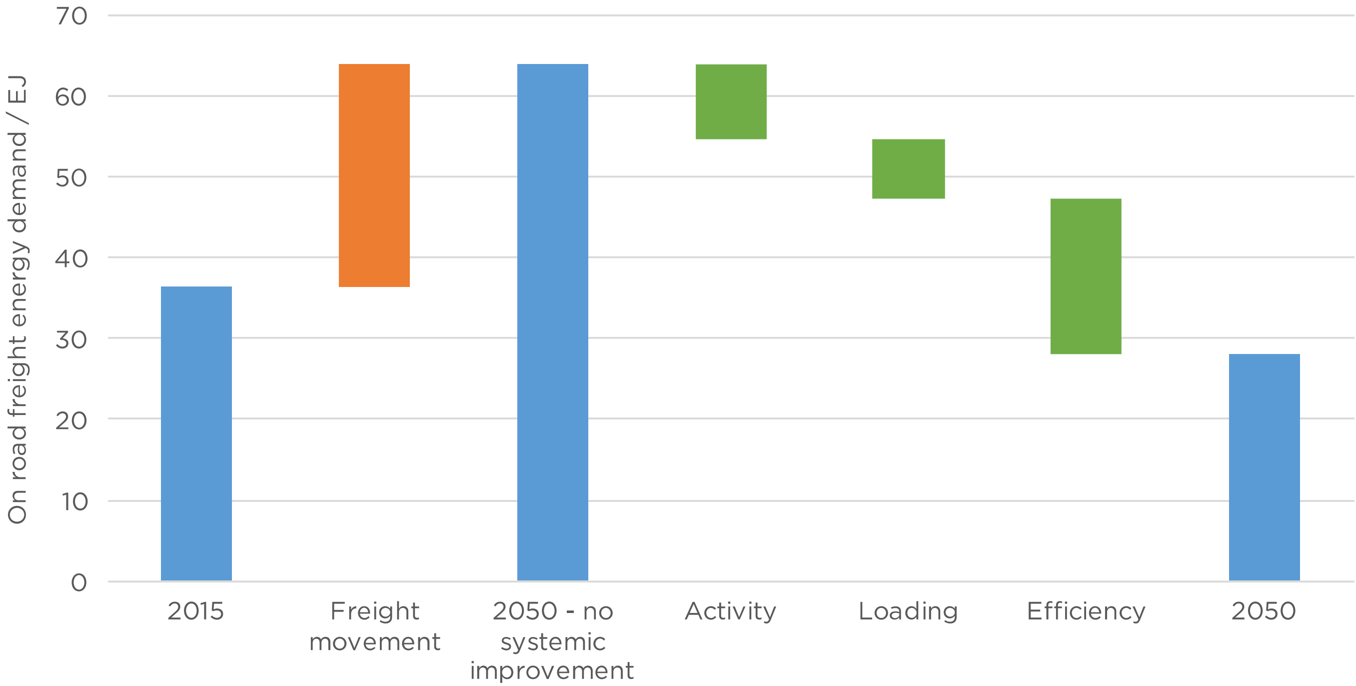




Sources: Öko-Institut (2016). Decarbonisation of road transport. Webinar

Vehicle efficiency is the biggest lever to reduce freight's energy demand

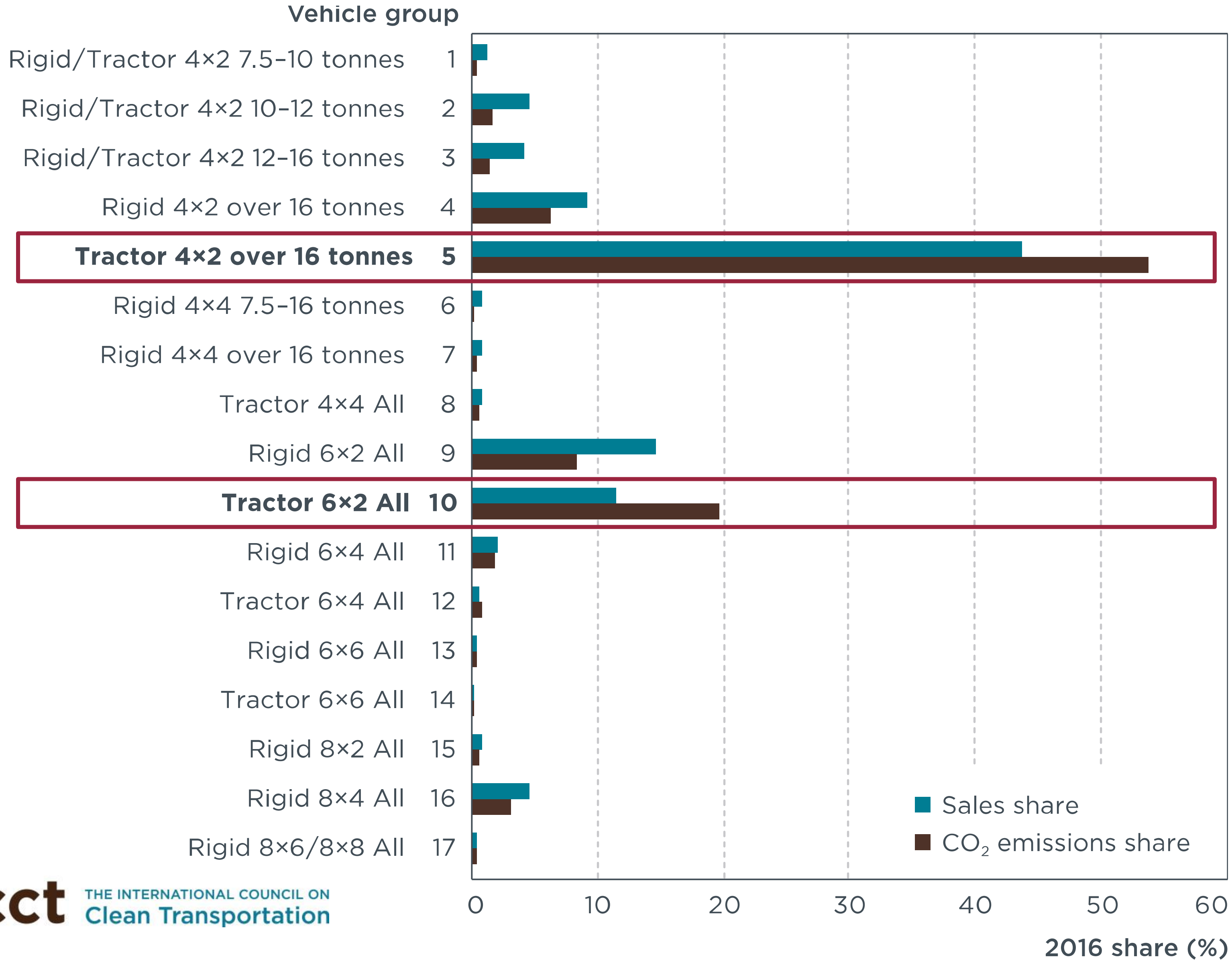




Data source: International Energy Agency. (2017). *The Future of Trucks. Implications for energy and the environment*.

Cost-effective technology potential

Tractor-trailers account for the majority of HDV CO_2 emissions



Vehicle groups 5 and 10 (i.e., tractor-trailers) account for over 70% on the CO_2 emissions of on-road HDVs

Source: Delgado, O., Rodríguez, F., & Muncrief, R. (2017). *Fuel Efficiency Technology in European Heavy-Duty Vehicles: Baseline and Potential for the 2020–2030 Time Frame*. International Council on Clean Transportation.

http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030

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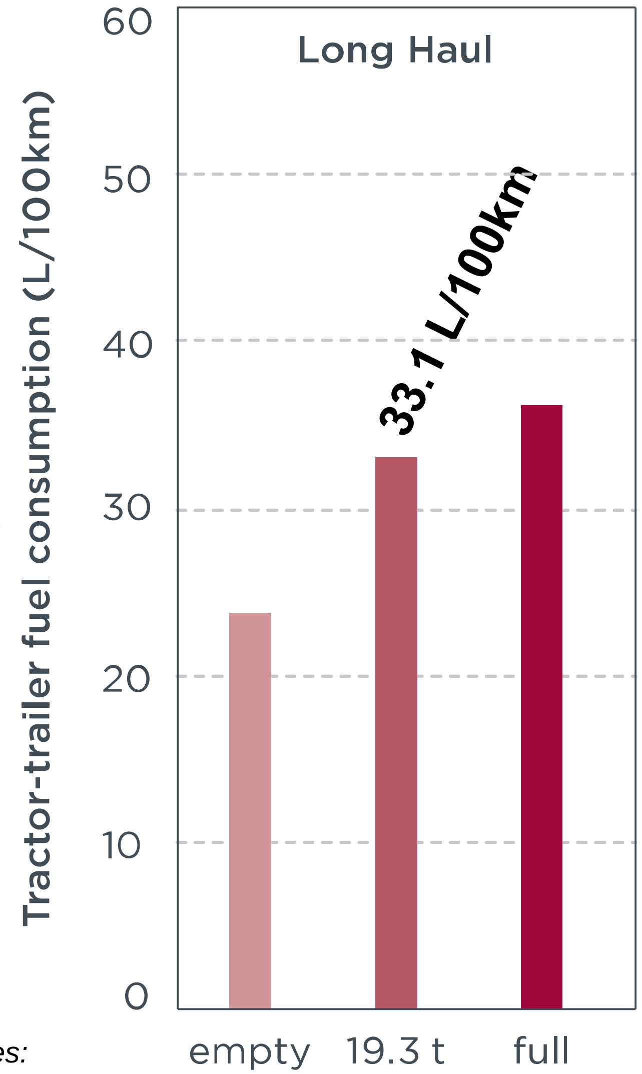
Reference 2015 tractor-trailer used for our analysis

Baseline specifications	Tractor-trailer
Gross vehicle weight (t)	40
Vehicle curb weight (t)	14.4
Axle configuration	4×2
Aerodynamic drag area (m^2)	6.0
Tire rolling resistance (N/kN)	5.5
Engine emissions	Euro VI
Engine displacement (L)	12.8
Engine power (kW)	350
Engine peak BTE (%)	44.8
Transmission type	AMT
Transmission gear number	12
Transmission gear ratios	14.93–1.0
Rear axle ratio	2.64
Accessory power (kW)	5.6

→ Vehicle Simulation →



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List of technologies considered in analysis

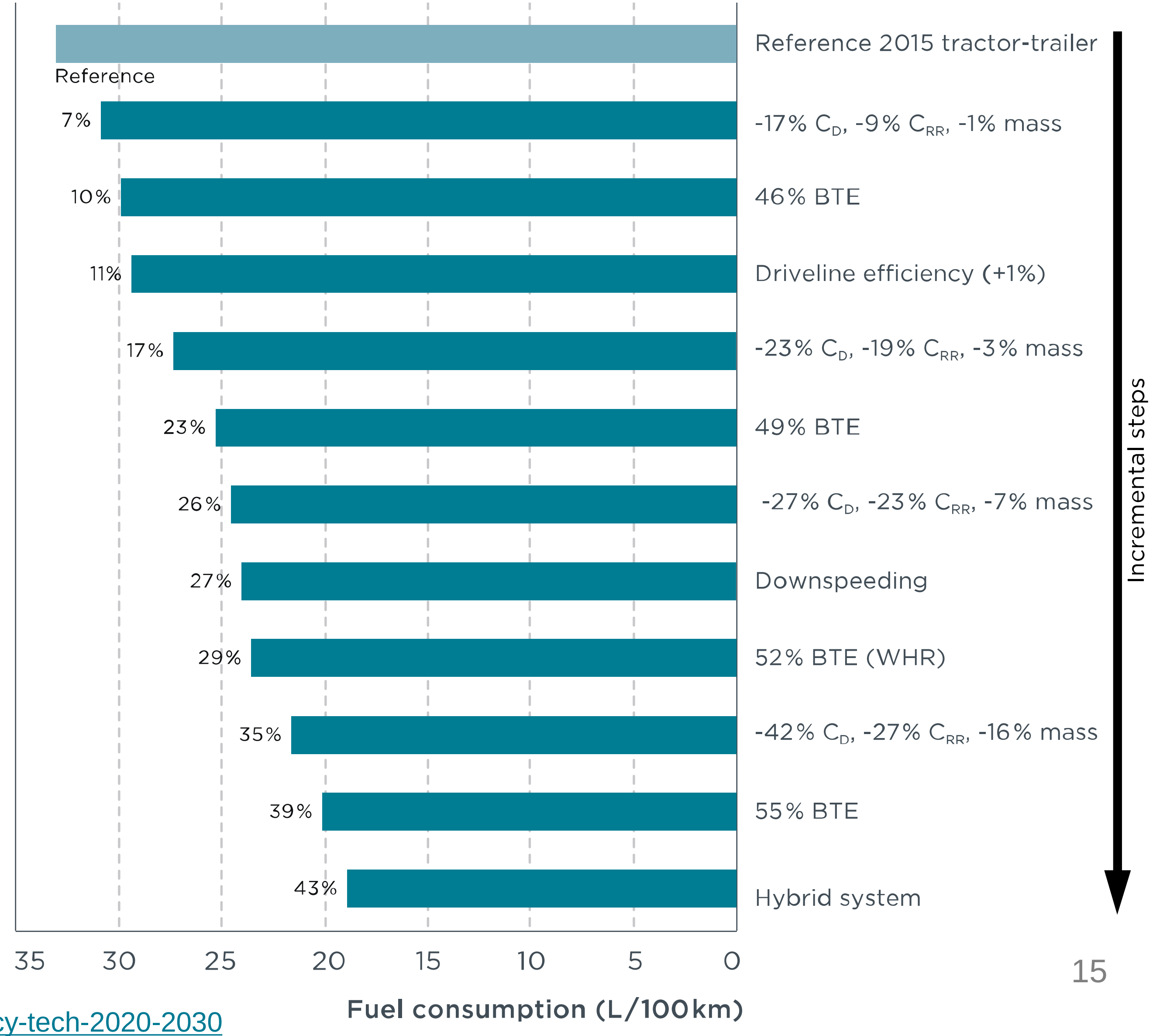
Engine	Aerodynamics	Rolling resistance	Mass reduction area / system	Driveline / Transmission	Auxiliaries	Driver assistance systems	Hybridization
Combustion optimization	Roof spoiler	Low rolling resistance tires	Engine	Automated man. transmission	Variable speed cooling fan	Stop-start / idle reduction	Integrated Mild Hybrid
Advanced turbocharging	Cabin side turning vanes	Single wide tires	Coolant circuit	Dual clutch transmission	Variable/clutched air compressor	Eco-roll	Parallel hybrid
EGR reduction / advanced SCR	Tractor/truck side skirts	Tire pressure monitoring	Fuel circuit	Downspeeding	LED lighting	Speed limiter	48-V electric architecture
Friction reduction	Active grille shutter	Automatic tire inflation	Exhaust system	Improved mech. efficiency	Electro-hydraulic power steering	Predictive cruise control	24-V brake energy recovery
On demand / improved pumps	Cabin underbody devices		Transmission	Top-torque control	High efficiency HVAC	Adaptive cruise control	
Turbocompound	Rearview cameras		Electrical system	Engine/trans. deep-integration	High efficiency alternator		
Waste heat recovery	Air dam		Chassis				
	Tractor side panels		Suspension				
	Wheel covers		Braking				
	Vented mud-flaps		Wheels				
	Trailer side skirts		Cabin				
	Trailer rear-end device		Trailer Body				
	Trailer underbody devices						

Not captured by VECTO	Partially captured by VECTO	Captured by VECTO

43% CO_2 reduction possible for long-haul tractor-trailers by 2030

How efficient can diesel long-haul tractor trailers be in the future?

- Engine: 55% peak efficiency
- Aerodynamic drag: 0.35
- Rolling resistance: 4 N / kN
- Lightweighting: -2300 kg
- Hybrid: P2, 120 kW, 2 kWh



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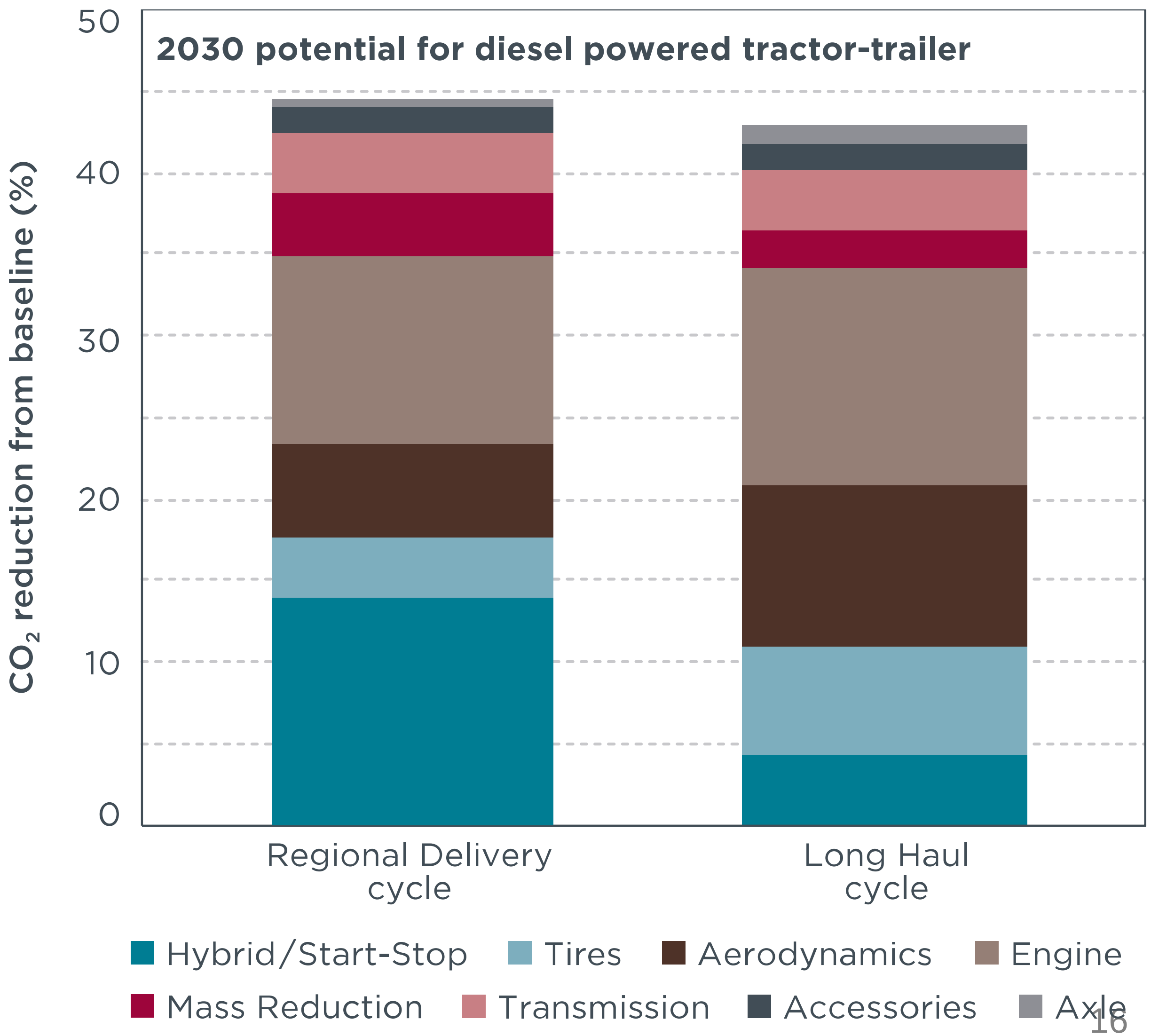

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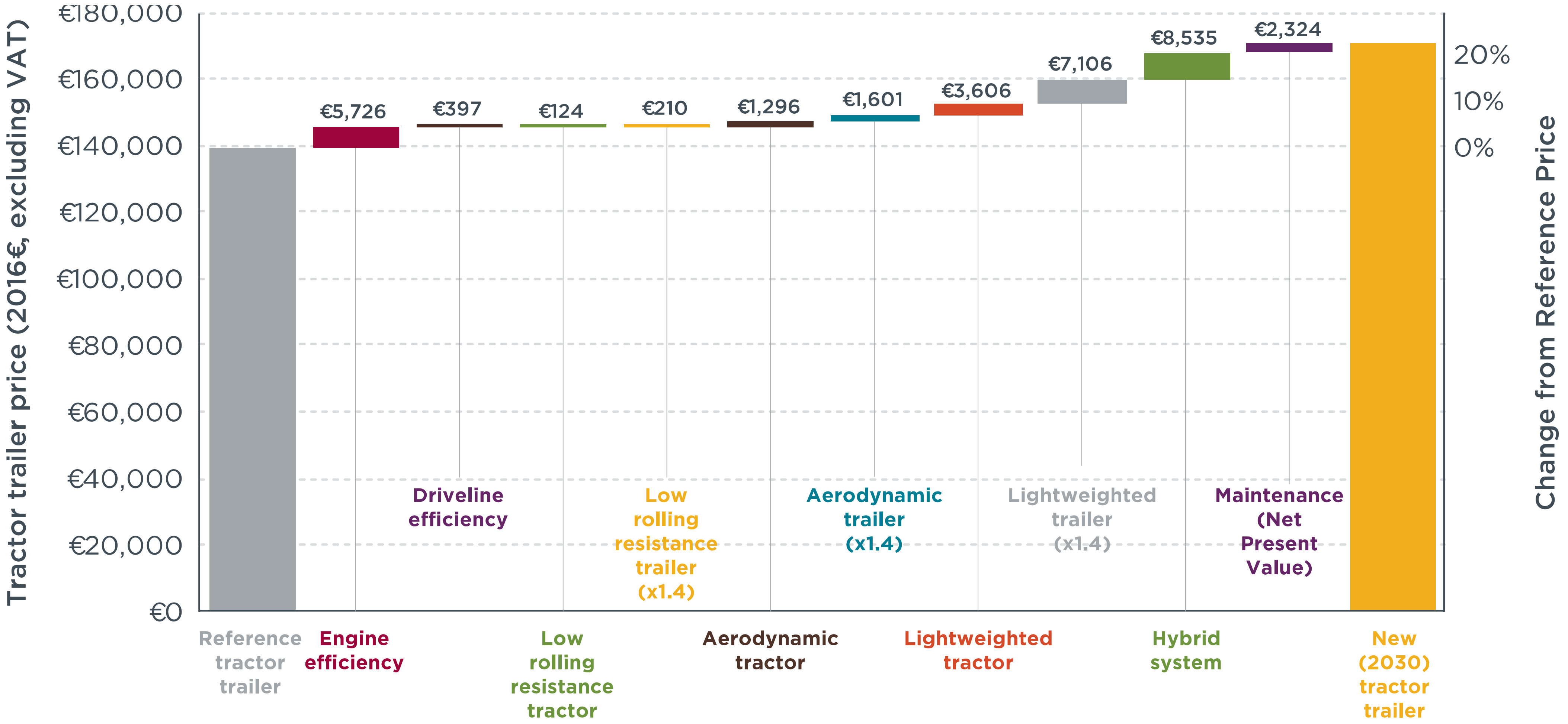
Engine: 55% peak efficiency

The Supertruck II program from the US department of energy aims to show pathway to **55**% brake thermal efficiency. Participants include Cummins, Daimler, Navistar (VW), Volvo, Paccar (DAF).

Daimler, Cummins, Navistar, and Volvo already demonstrated 50%+ peak eff.

The pathway to 55% peak efficiency could include the use of waste heat recovery (WHR), variable valve timing, back-pressure reduction, low EGR/high SCR concepts, low high peak combustion pressures, optimized combustion bowl, optimized injector, closed-loop injection rate shaping, reduced heat transfer, reduced friction in piston ring pack and bearings, opposed piston architecture, low temperature combustion, among others.

The technologies for 43% reduction increase the tractor-trailer cost by approximately 20%



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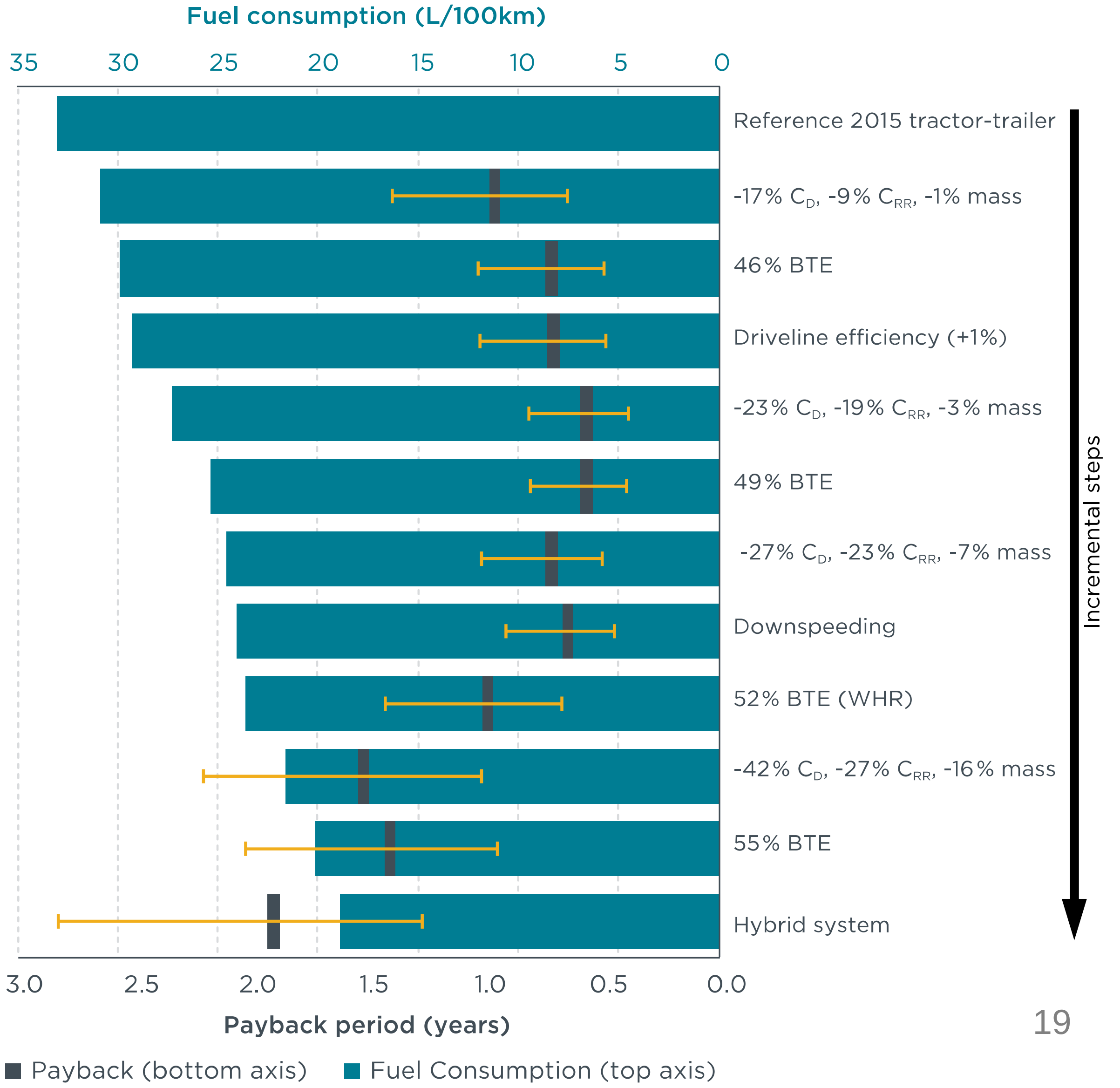
Source: Meszler, D., Delgado, O., Rodriguez, F., & Muncrief, R. (2018). *European Heavy-Duty Vehicles – Cost effectiveness of fuel efficiency technologies for long-haul tractor-trailers in the 2025-2030 timeframe*. International Council on Clean Transportation.

http://theicct.org/publications/cost-effectiveness-of-fuel-efficiency-tech-tractor-trailers

The technologies for 43% reduction will have a payback between 1.4 to 2.7 years in 2030

Main study assumptions:

- Fuel price: 0.7 to 1.4 €/L
- Discount rates: 4% to 10%
- Evaluation years: 2025 and 2030
- Trailers per tractor: 1.4
- Vehicle lifetime: ~1 M km
- First owner annual use: ~110k km



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HD ZEV freight

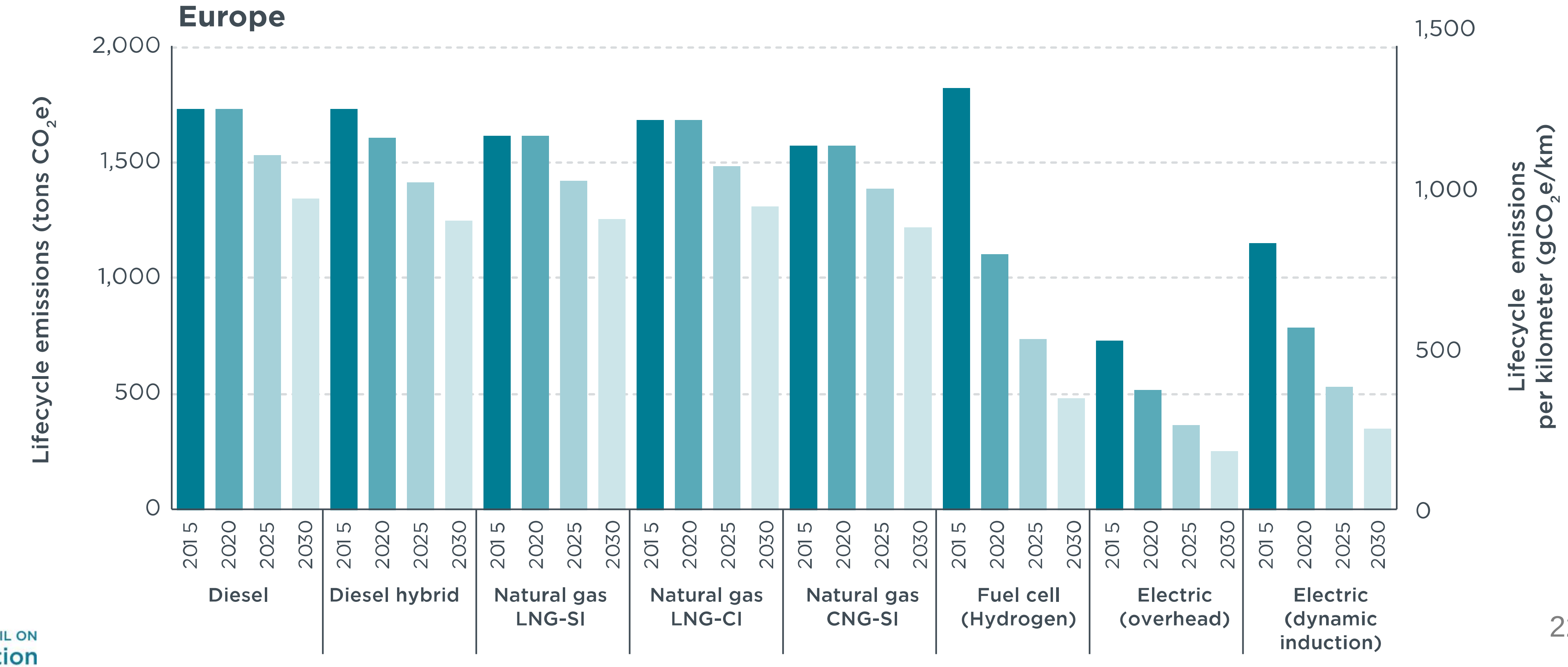
HD ZEV freight: Long-haul is simultaneously the most important and most challenging segment

Segments		Definition	Duty Cycle	Range	Payload Requirements	Battery/ Hydrogen Requirements	Infrastructure Requirements	CO_2 Footprint	Current Availability
Freight	**Urban Delivery**	• Medium Duty rigid (straight) trucks and vans	Low speed, transient	<200km/ day	<5 ton	<100kWh <10kg H_2	Limited	10-15%	>20 models
	Drayage	• Transport freight from ports • Travel high volume freight corridors							
	Regional Delivery	• Return to base • Mix of urban and highway							
	Long Haul	• Mostly tractor-trailers	High speed, constant	>500km/ day	>20 ton	>800kWh >30kg H_2	Extensive	65-75%	None

Lifecycle CO_2 emissions over by vehicle technology type for Europe

Fuel WTW carbon [g CO2/MJ_{fuel}]

The carbon intensity of the fuels is the only lever available for full decarbonization of on-road freight. Direct use of electricity results in the lowest CO_2 emissions



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Questions? Contact the HDV team at the ICCT

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