



Energy Technologies Area

Lawrence Berkeley National Laboratory

Improved Heavy-Duty Vehicle Fuel Efficiency in India: Benefits, Costs and CO₂ Impacts

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The International Council on Clean Transportation



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Project scope of work

- Vehicles included in the analysis: HDVs > 12 tonnes
- Focus on diesel-powered trucks and buses
- Fuel efficiency technologies that can be commercialized over the next 10 years
- Time horizon: 2000 – 2050 (model calibrated against historical data for 2000-2014)



- Baseline technology characterization
- Fuel consumption reduction potential
- Per-vehicle technology costs



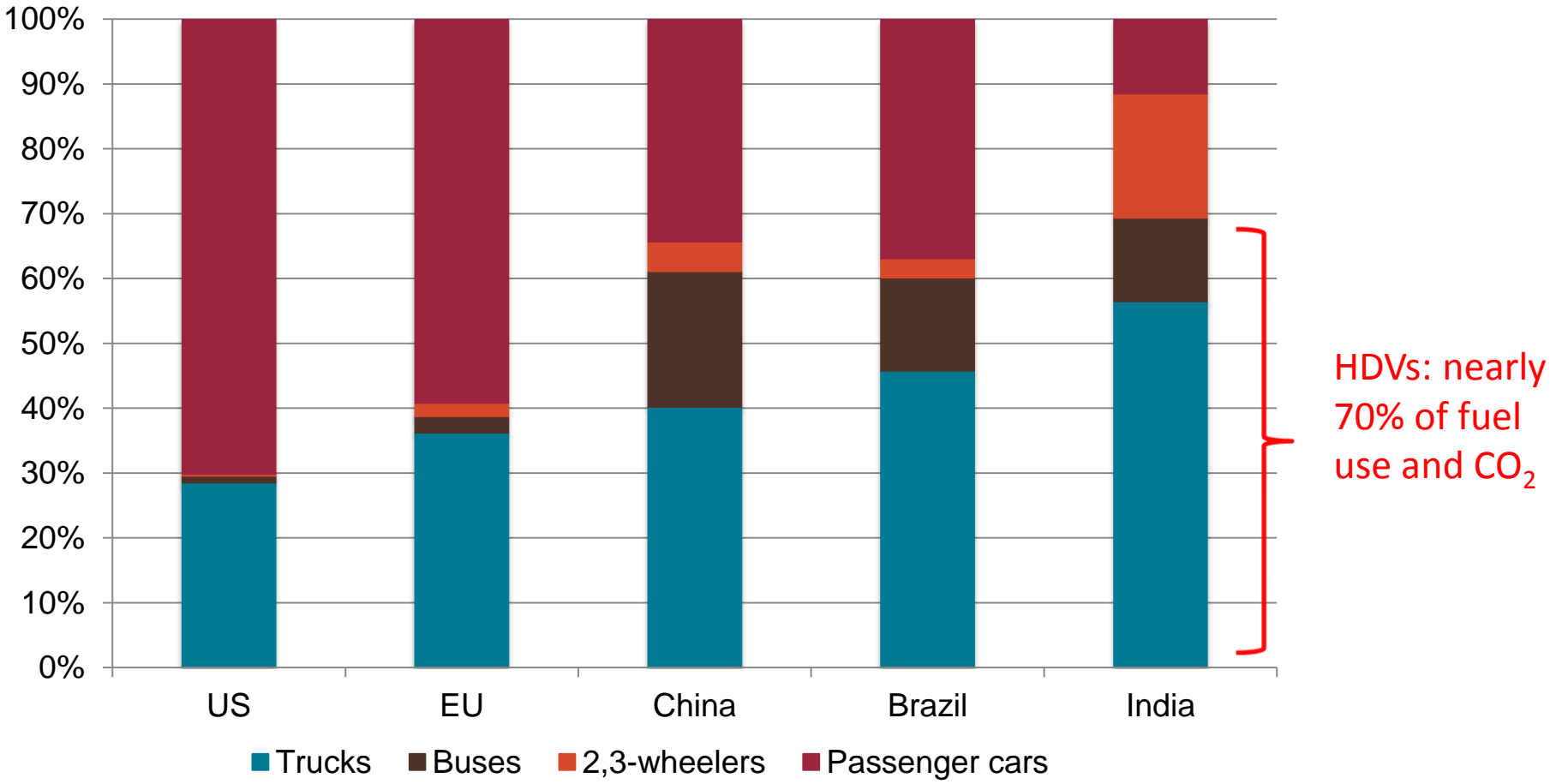
- HDV stock turnover model
- Total fleet fuel consumption impacts
- Total fleet cost impacts

Fuel consumption reduction potential and cost-benefit impacts of various technology deployment scenarios

HDVs in India consume larger share of on-road fuel than in other major markets








Share of fuel consumption and CO₂ emissions in 2015

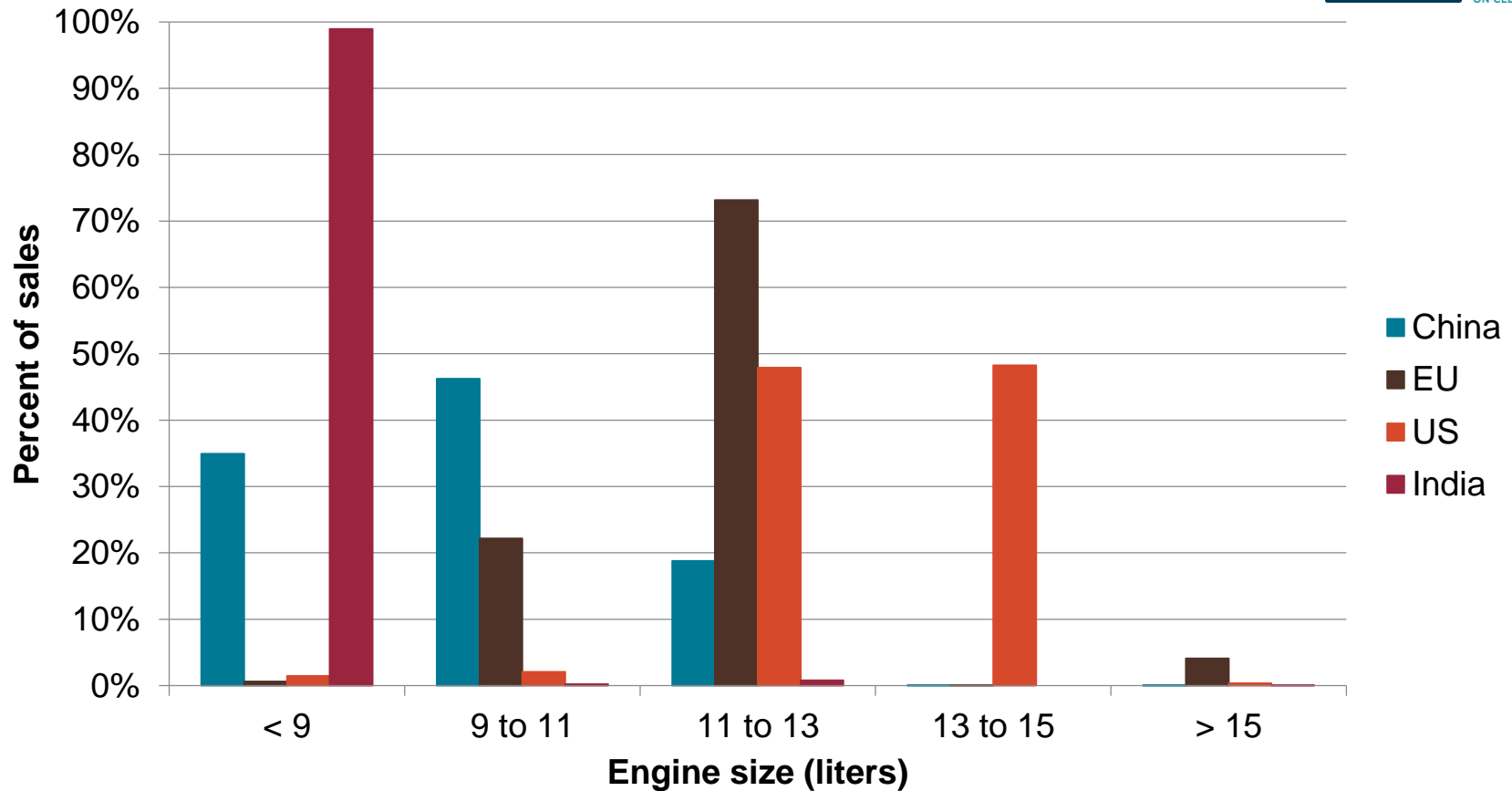


<http://www.theicct.org/global-transportation-roadmap-model>

HDV characteristics differ across regions

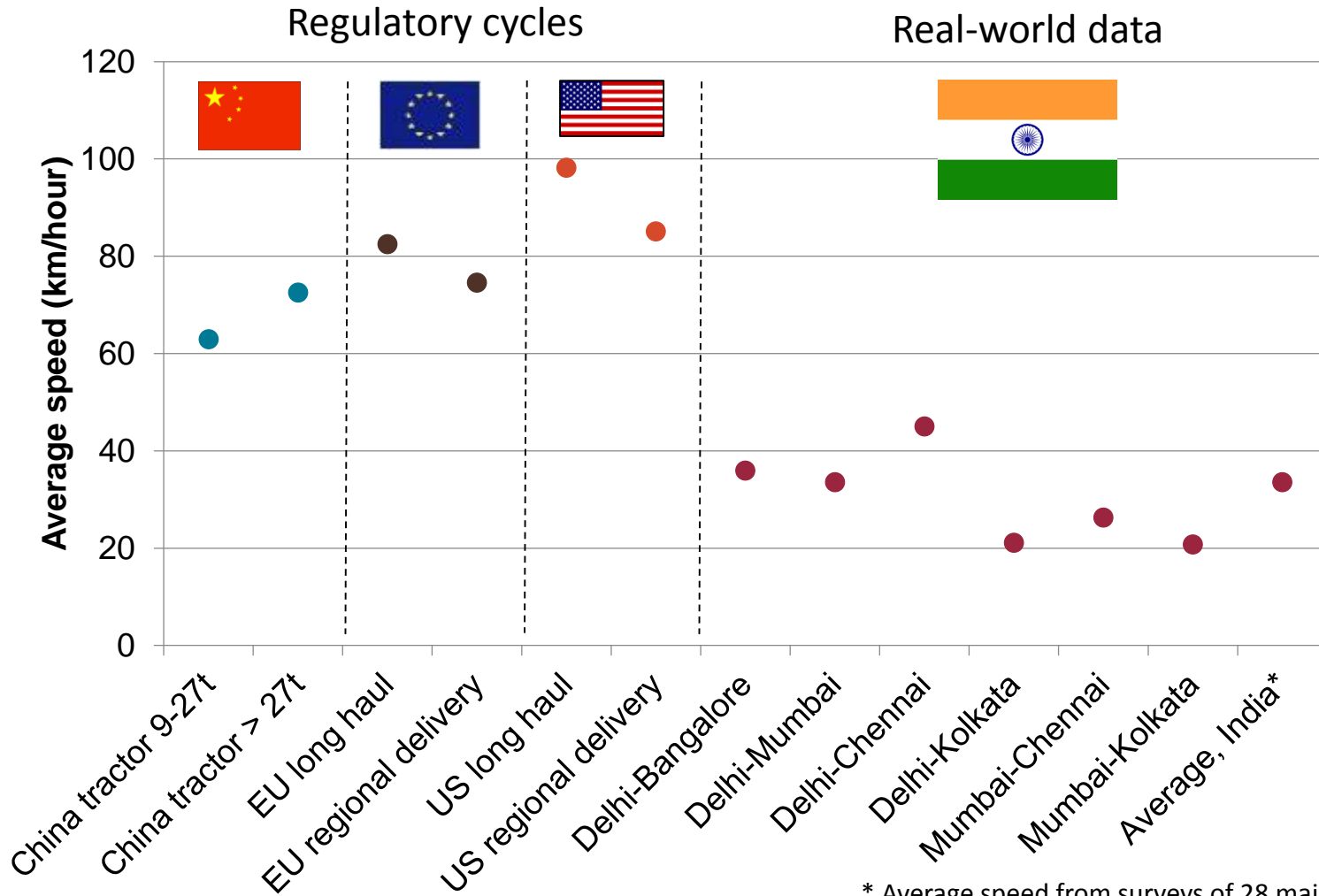
	Brazil	China	EU	India	US
					
Axle config.	6x2	6x4	4x2	4x2	6x4
Tractor weight	9.7t	10t	7t	6t	8t
GVW	35t	33t	40t	40t	36t
Transm.	Manual	Manual	12-speed AMT	6-speed manual	10-speed manual
Engine displ.	13 liter	< 11 liter	13 liter	< 6 liter	15 liter
Engine power	~ 325kW	~ 260kW	~ 325kW	~ 135kW	~ 340kW
Emission level	Proconve 7	China IV	Euro VI	Bharat III	US EPA 2010

HDV engine size and power are much smaller in India than other major markets



<http://www.theicct.org/market-analysis-heavy-duty-vehicles-india>

Average speeds are much lower in India than other major markets



* Average speed from surveys of 28 major trucking routes in India

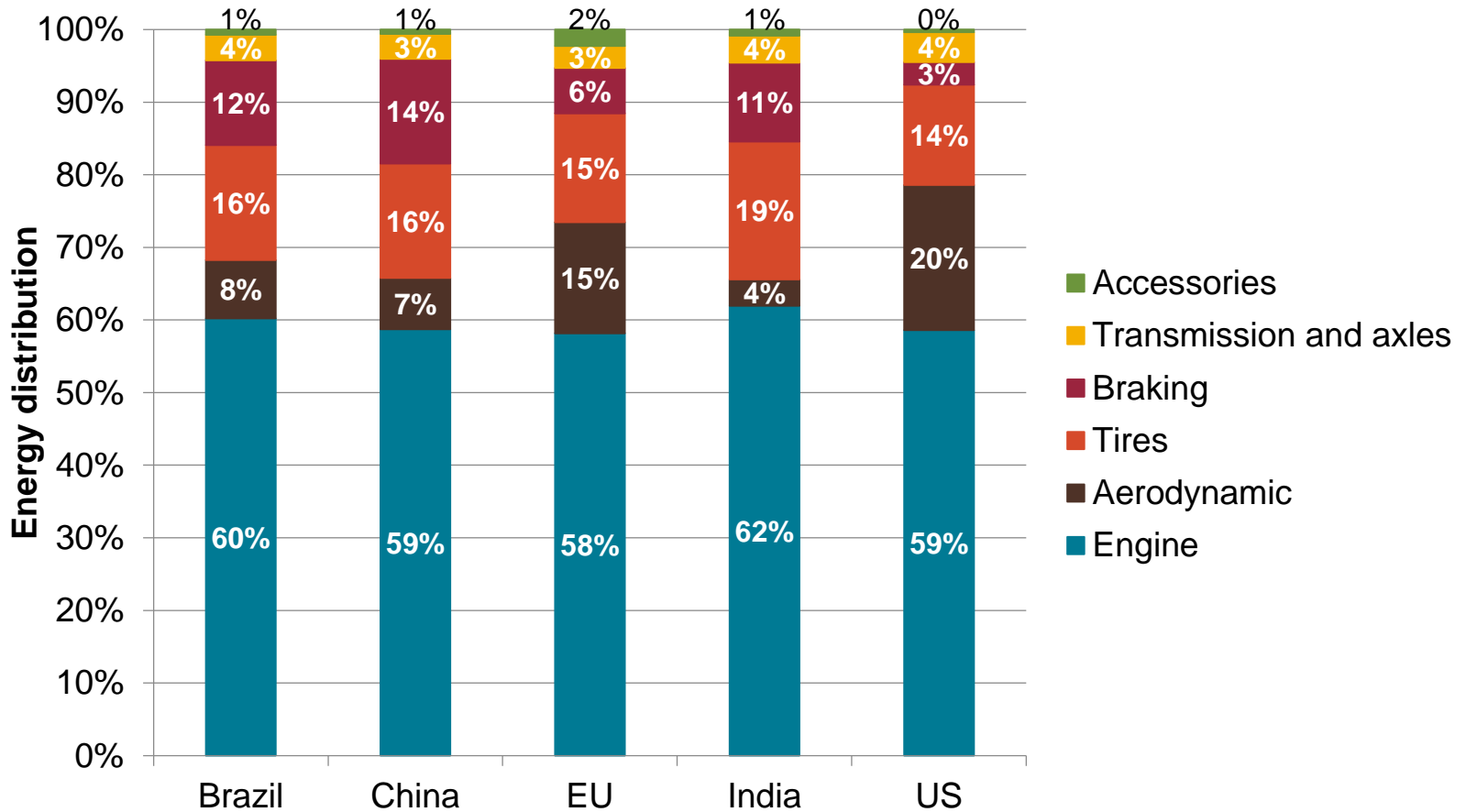
Source: TCI-IIMC (2016) Operational efficiency of freight transportation by road in India. 3rd edition.

http://www.tcil.com/tcil/study_report.html

Together, engines and tires represent 80% or more of energy losses for Indian HDVs

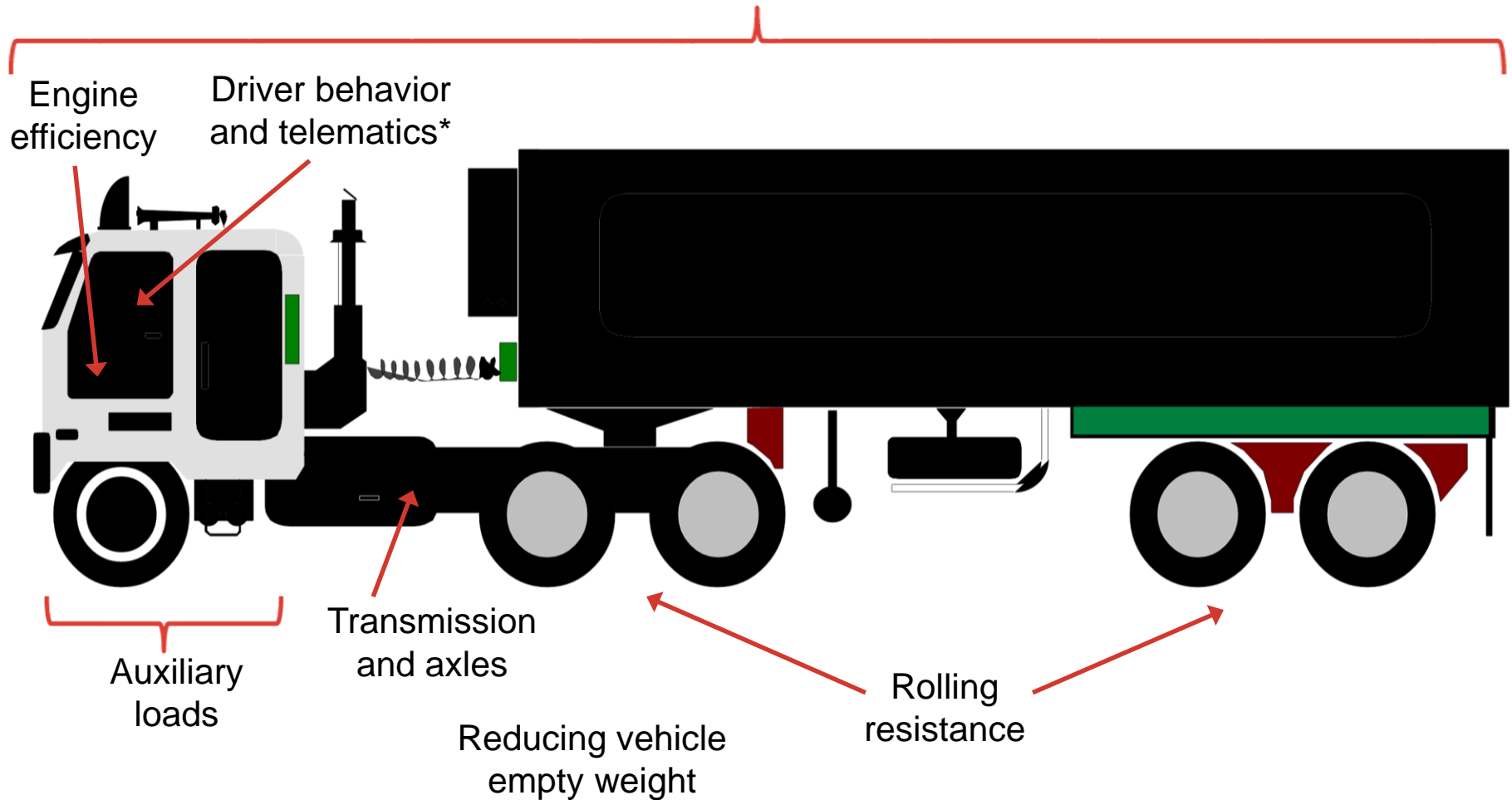


Tractor-trailers operating with regionally-specific drive cycles and payloads.



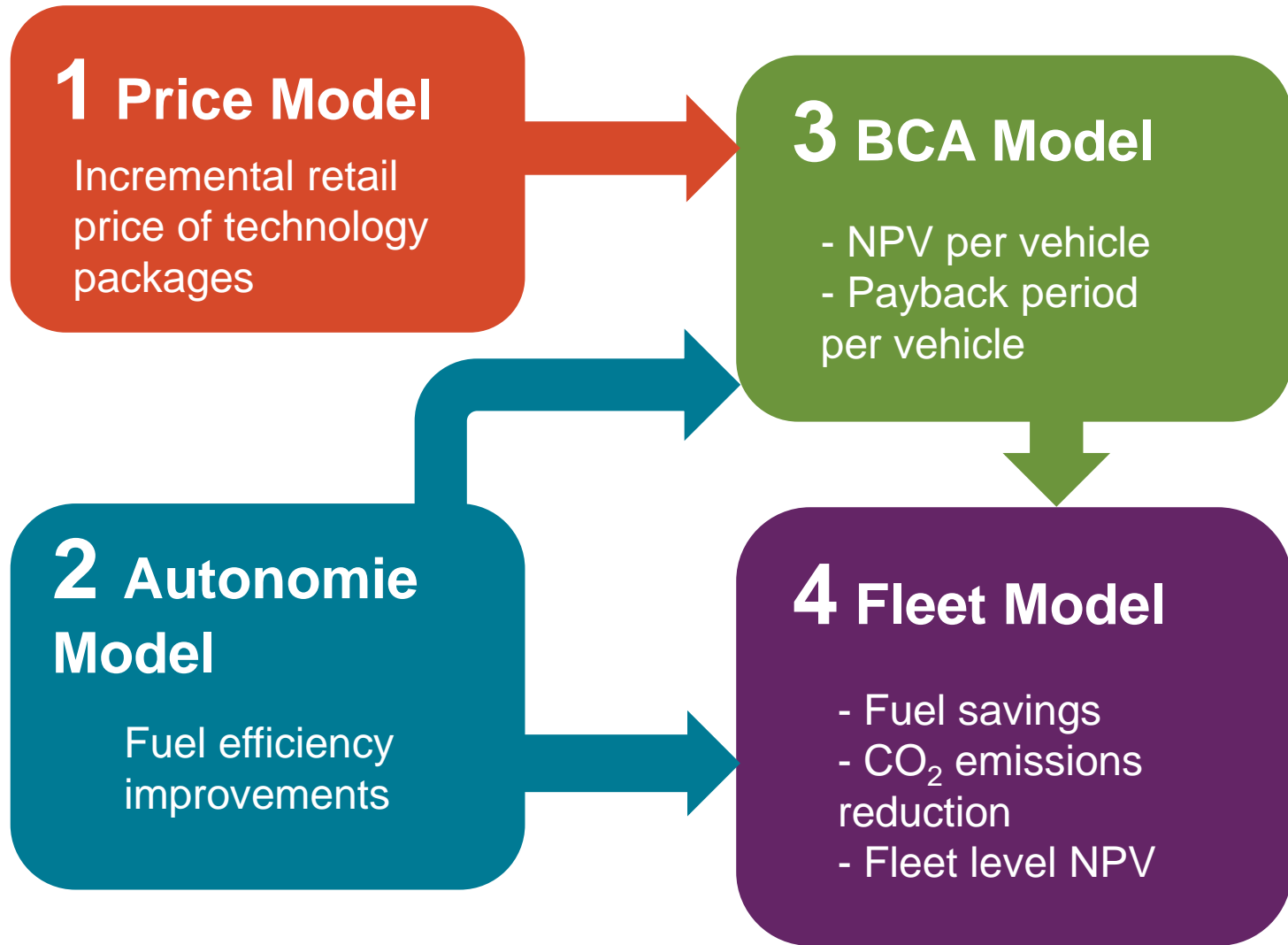
<http://www.theicct.org/estimating-fe-tech-potential-hdvs-gfei-wp14>

Truck and trailer aerodynamics



* Not investigated as part of this analysis

Summary of methodology






Summary of analysis

- Identified HDV baseline and efficiency improving technologies that can be commercial in India within 10 years for 3 vehicle categories over 12 tonnes in GVW
- Full vehicle simulations to estimate fuel efficiency of baseline and technology packages
- Incremental retail price of vehicles fitted with each technology package
- Economic analysis of HDV technology packages – payback period and NPV
- Crude oil, diesel, CO₂ implications at the fleet level out to 2050
- Fleet level economic benefits

Per-vehicle fuel efficiency potential and costs: methodology and results

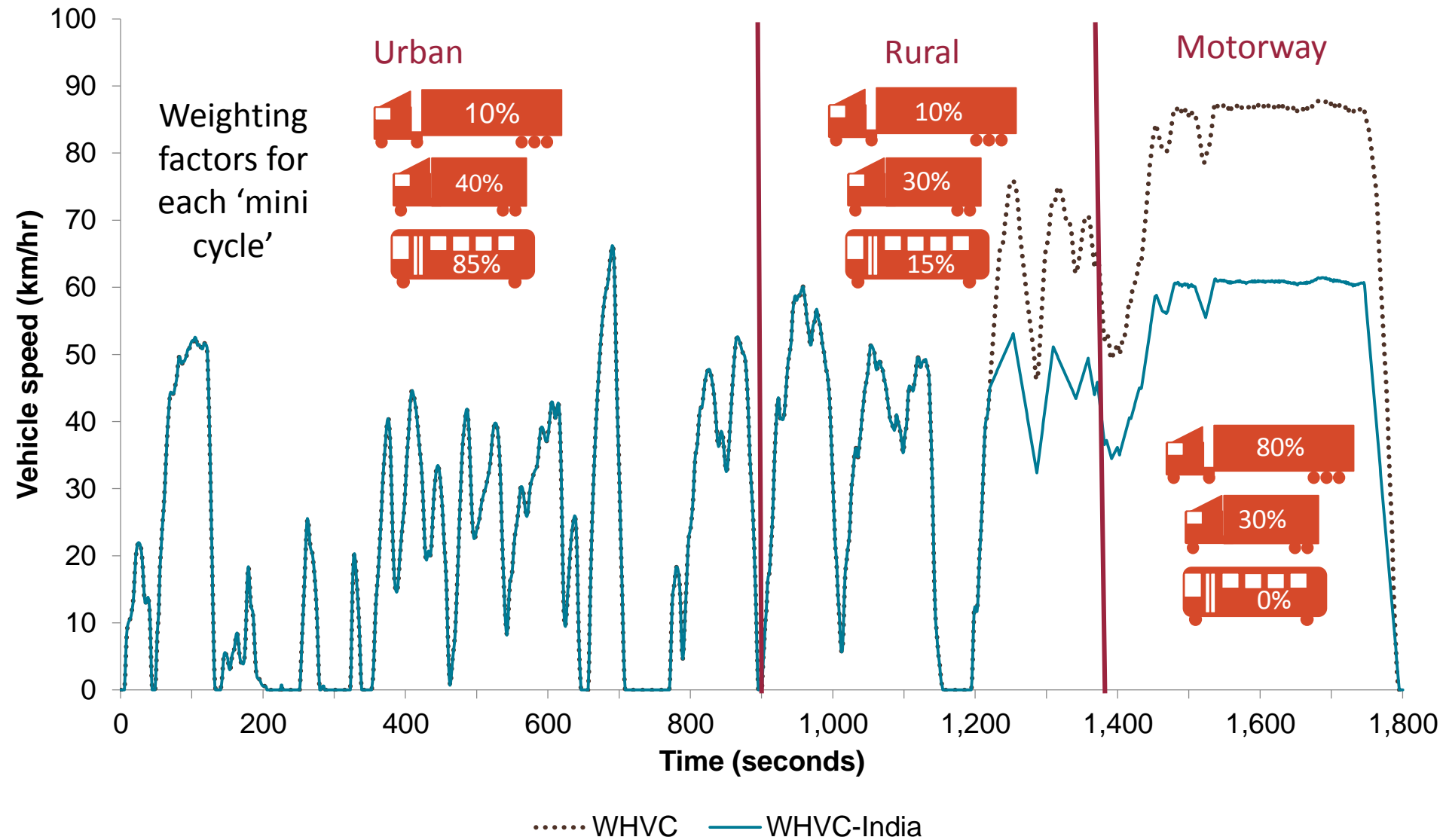
Our analysis to determine fuel-saving technology potential uses simulation modeling

	 Tractor-trailer	 Rigid truck	 Transit bus
Engine	Bharat Stage IV, 5.9 liter, 134 kW		
Transmission (gear ratios: 1 st , 2 nd , ..., 6 th)	6 speed manual (9.2, 5, 3, 1.9, 1.4, 1)	6 speed manual (9.2, 5, 3, 1.9, 1.4, 1)	6 speed manual (6.6, 3.8, 2.3, 1.5, 1, 0.8)
Payload	13,615 kg	9,245 kg	1,837 kg
Gross vehicle weight	40,200 kg	25,000 kg	16,200 kg
Aerodynamic drag coefficient	0.7		
Frontal area	7.2 m ²	6.8 m ²	7.5 m ²
Coefficient of rolling resistance	0.008		
Final drive ratio	6.8	6.1	6.1

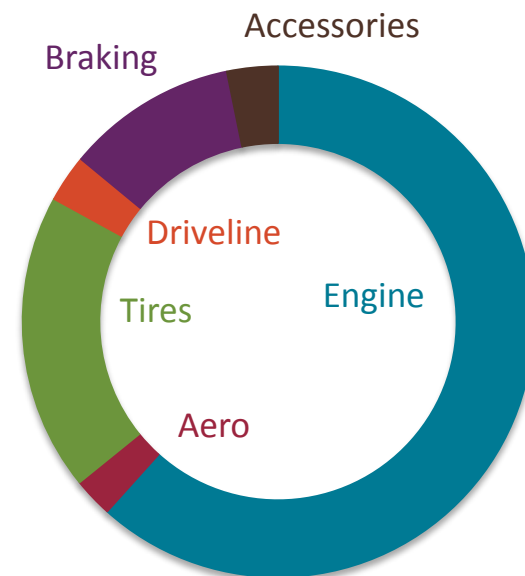
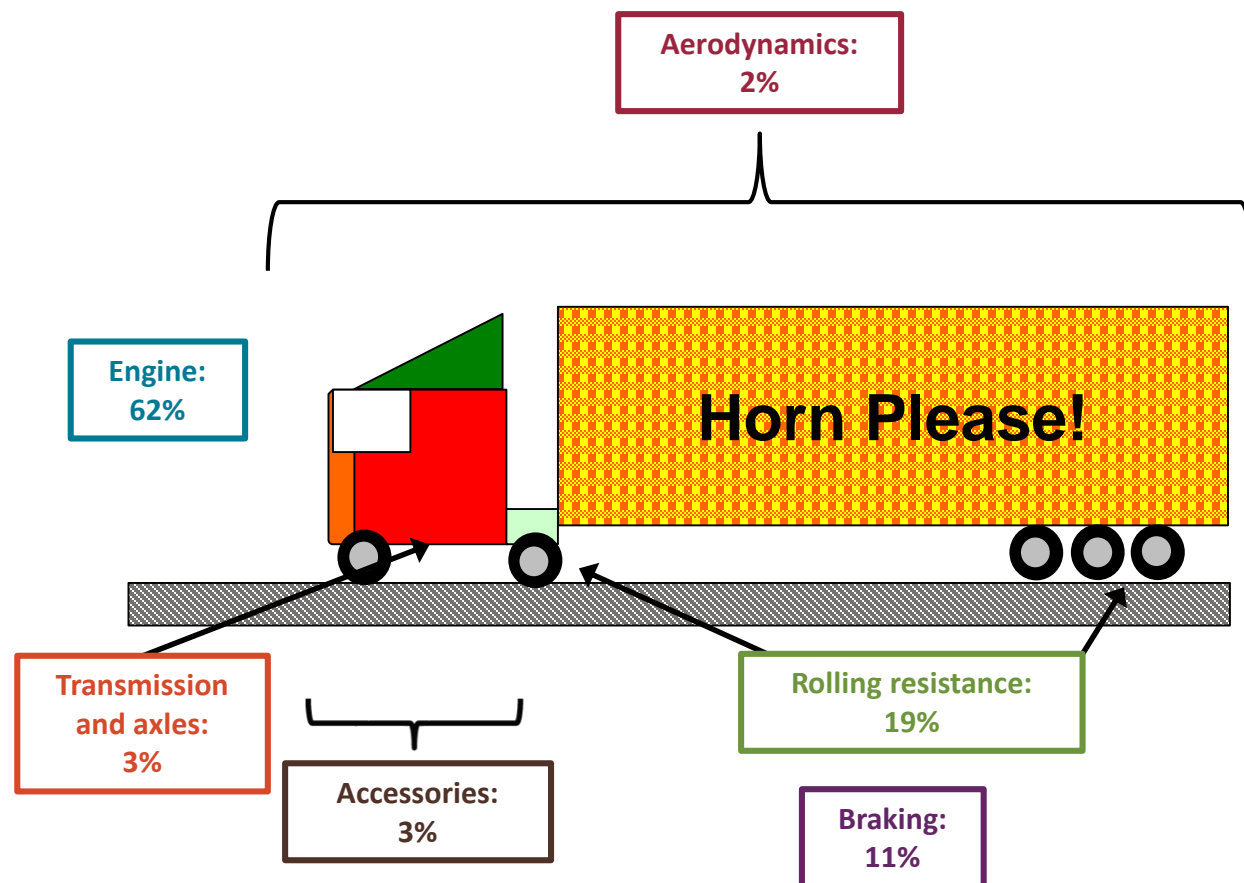


<http://www.autonomie.net>

WHVC-India cycle created to better represent HDV driving in India



Engine and tire rolling resistance losses dominate in cycles with low average speeds



Energy balance for a tractor-trailer over the WHVC-India cycle and 27,200 kg payload

Source: Sharpe and Delgado (2016)

<http://www.theicct.org/engine-and-tire-tech-hdvs-india-201602>

- Baseline and efficient technologies determined based on our expert understanding of global markets and discussions with Indian industry and government
- Commercial in India within 10 years
 - Most technologies we chose will be feasible much sooner
- We know India is different
 - Price sensitive market
 - Much smaller capacity engines

Technology packages (TPs): tractor-trailer

Engine



Transmission



Tires



Aerodynamics



Weight reduction



Baseline

TP1

TP2

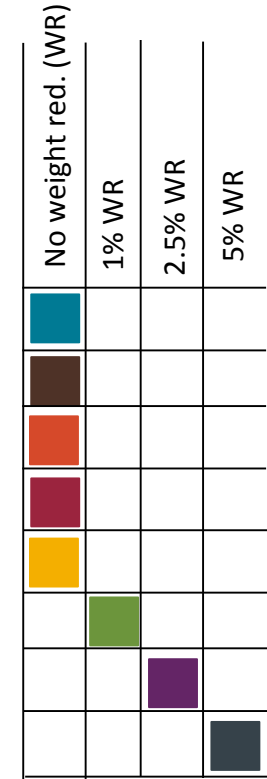
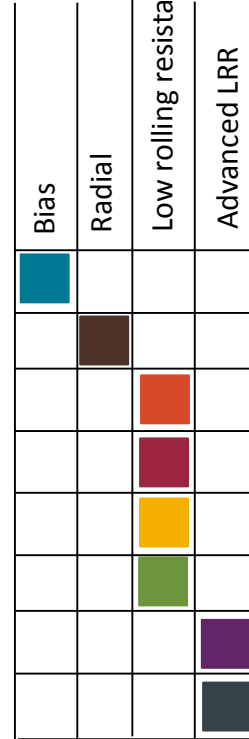
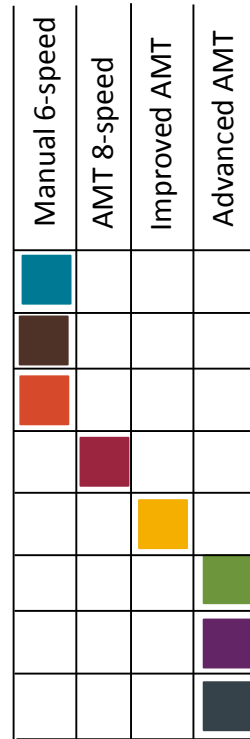
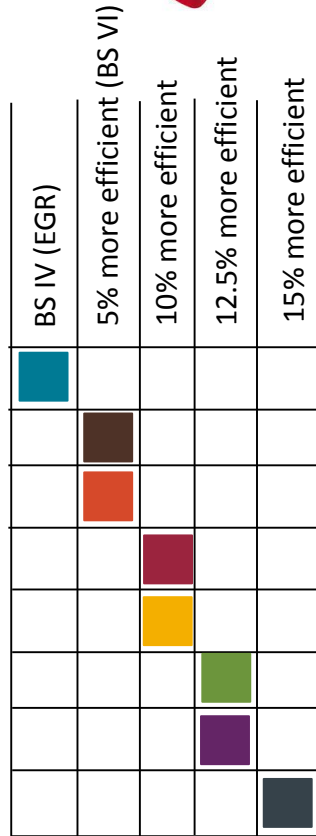
TP3

TP4

TP5

TP6

TP7



Increasingly efficient technologies, moving left to right

Technology packages (TPs): rigid truck

Engine



Transmission



Tires



Aerodynamics

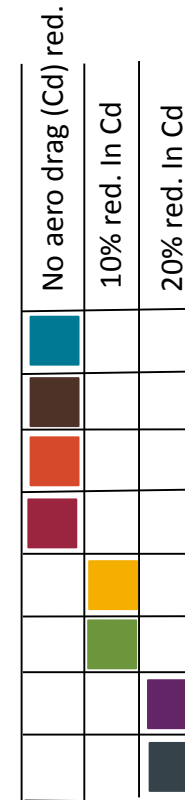
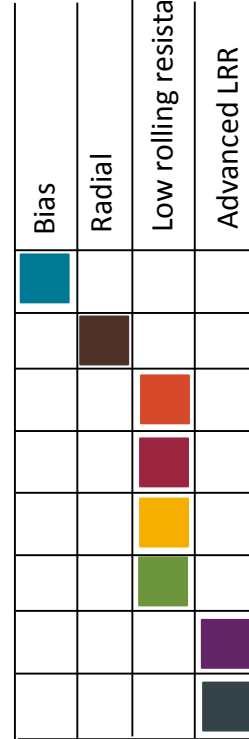
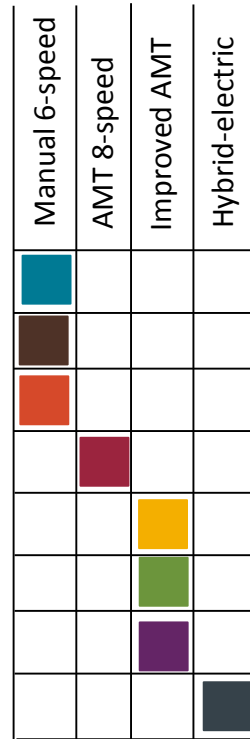
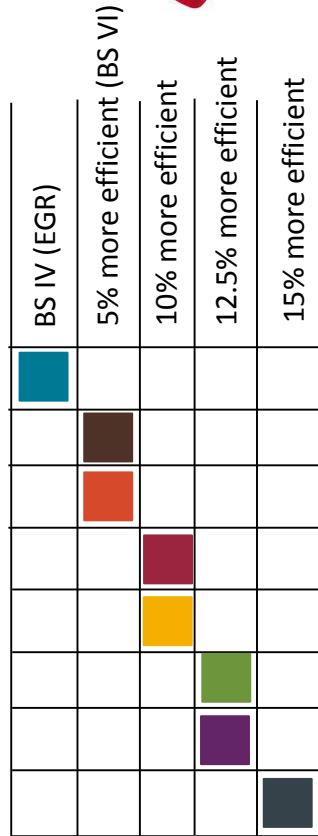


Weight reduction



Baseline

TP1
TP2
TP3
TP4
TP5
TP6
TP7



Increasingly efficient technologies, moving left to right

Technology packages (TPs): transit bus

Engine



Transmission



Tires



Aerodynamics

Weight reduction



Baseline

TP1

TP2

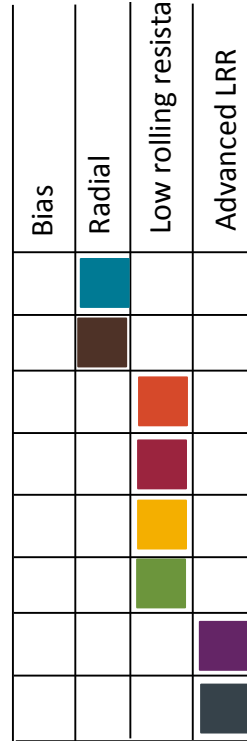
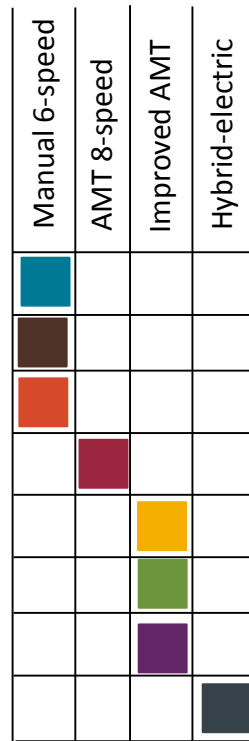
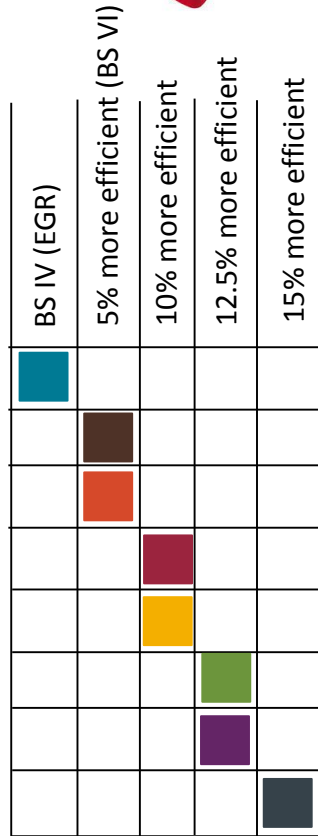
TP3

TP4

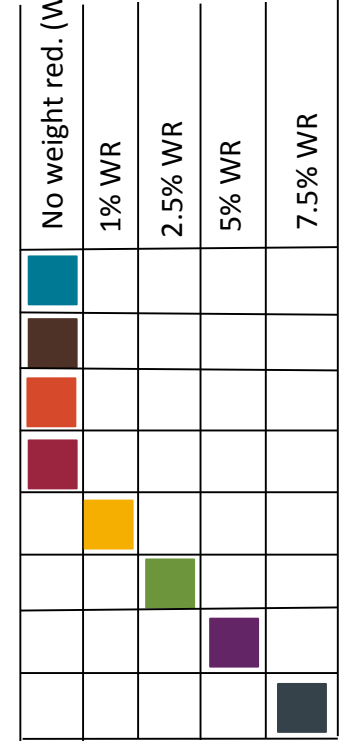
TP5

TP6

TP7

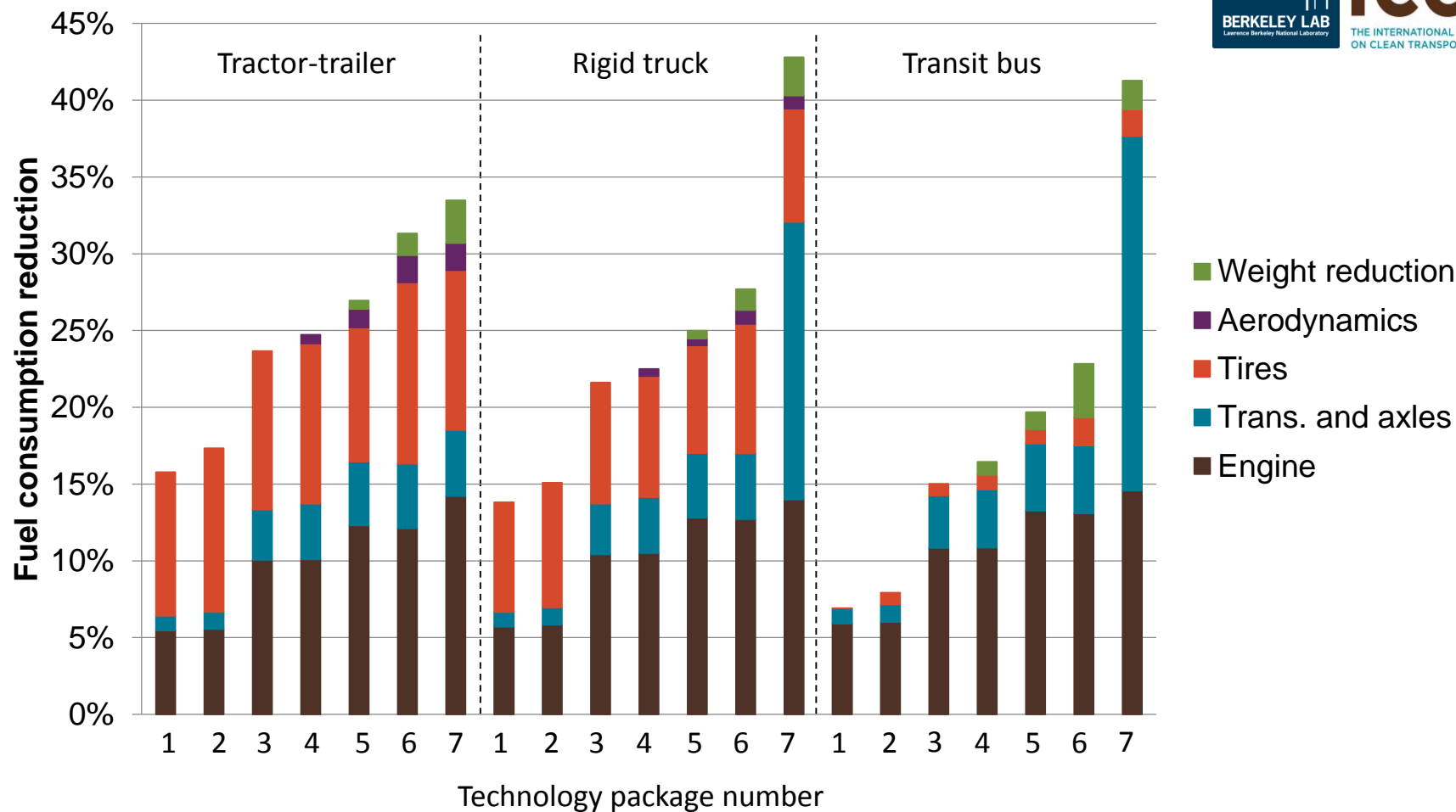


We assume no aerodynamic improvements for the transit bus

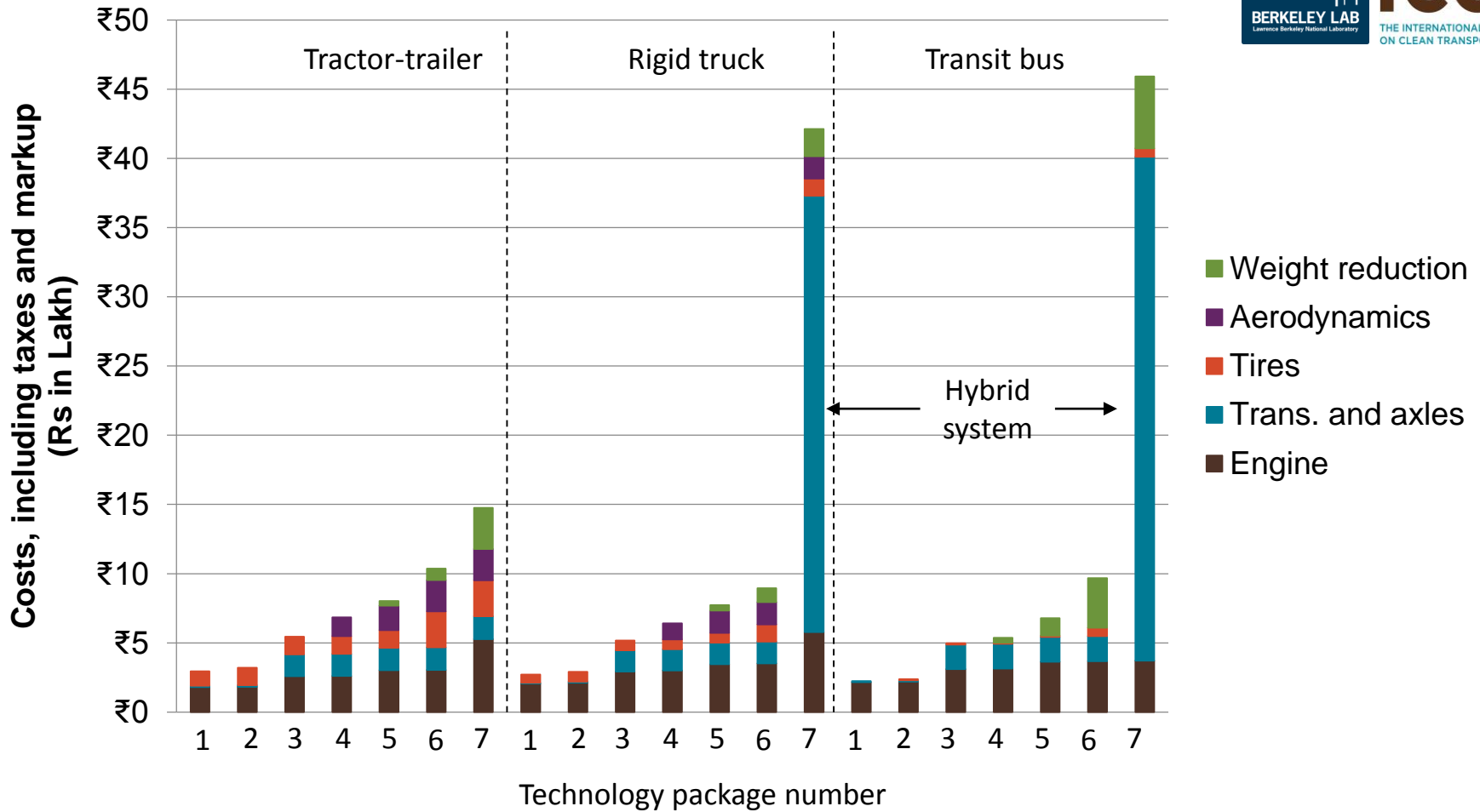


Increasingly efficient technologies, moving left to right

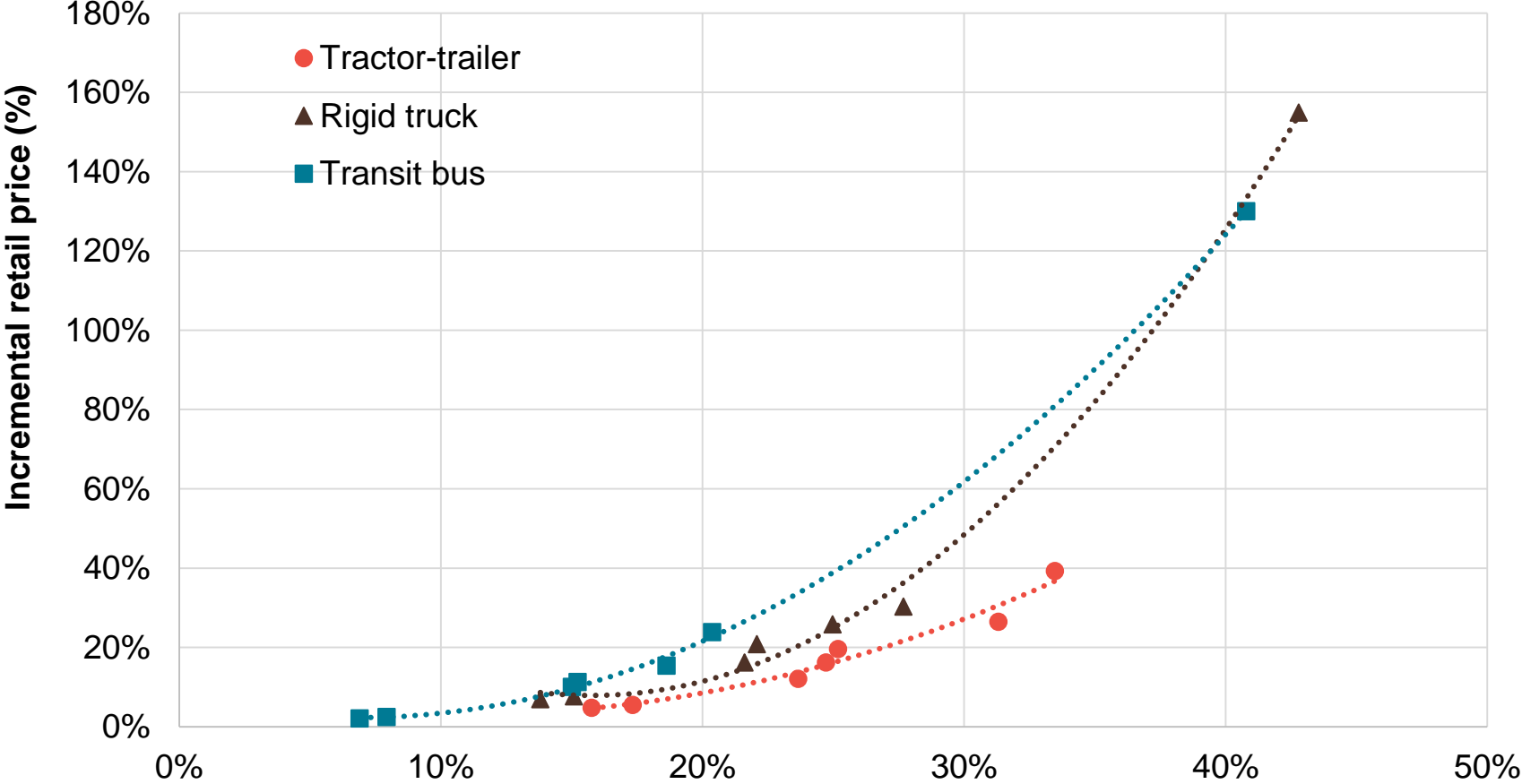
Engine, transmission, and tire technologies represent the large majority of total fuel savings



Cost breakdown for each technology package



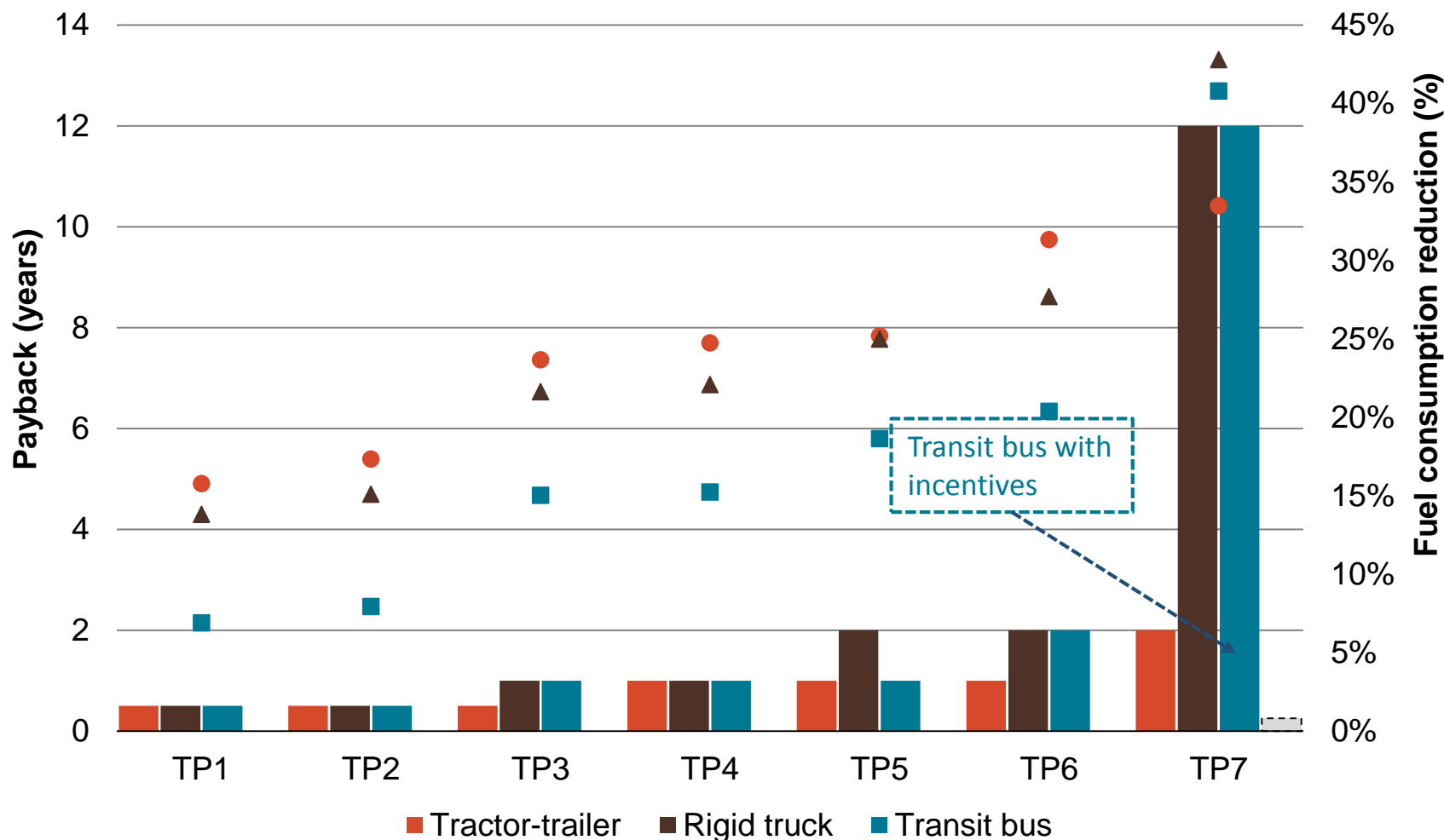
Incremental retail price versus fuel consumption reduction



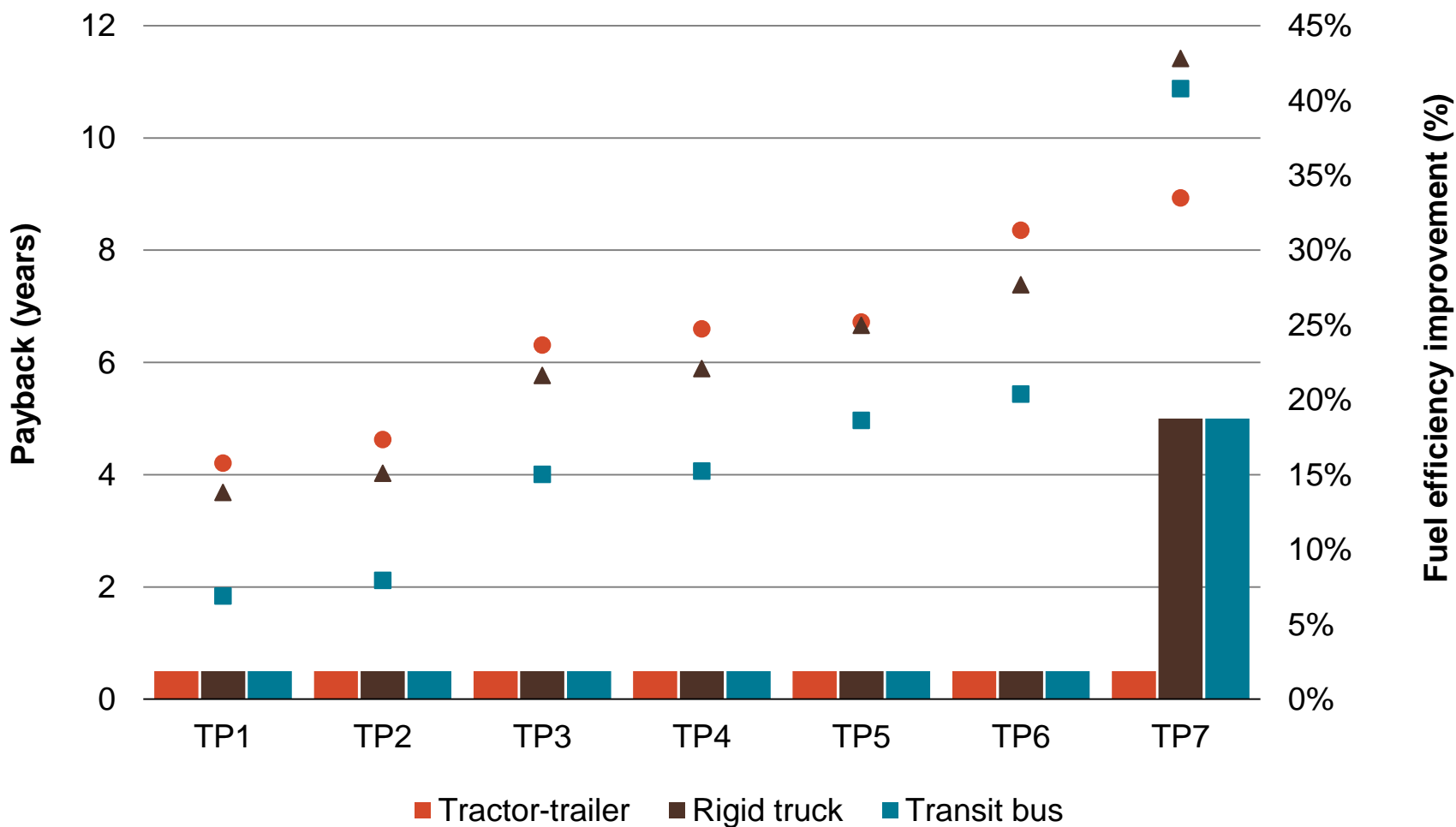
Reduction in fuel consumption versus the Baseline
Note: Incremental retail price includes manufacturing cost, tax, and markup.

Economic, oil, and greenhouse gas impacts: methodology and results

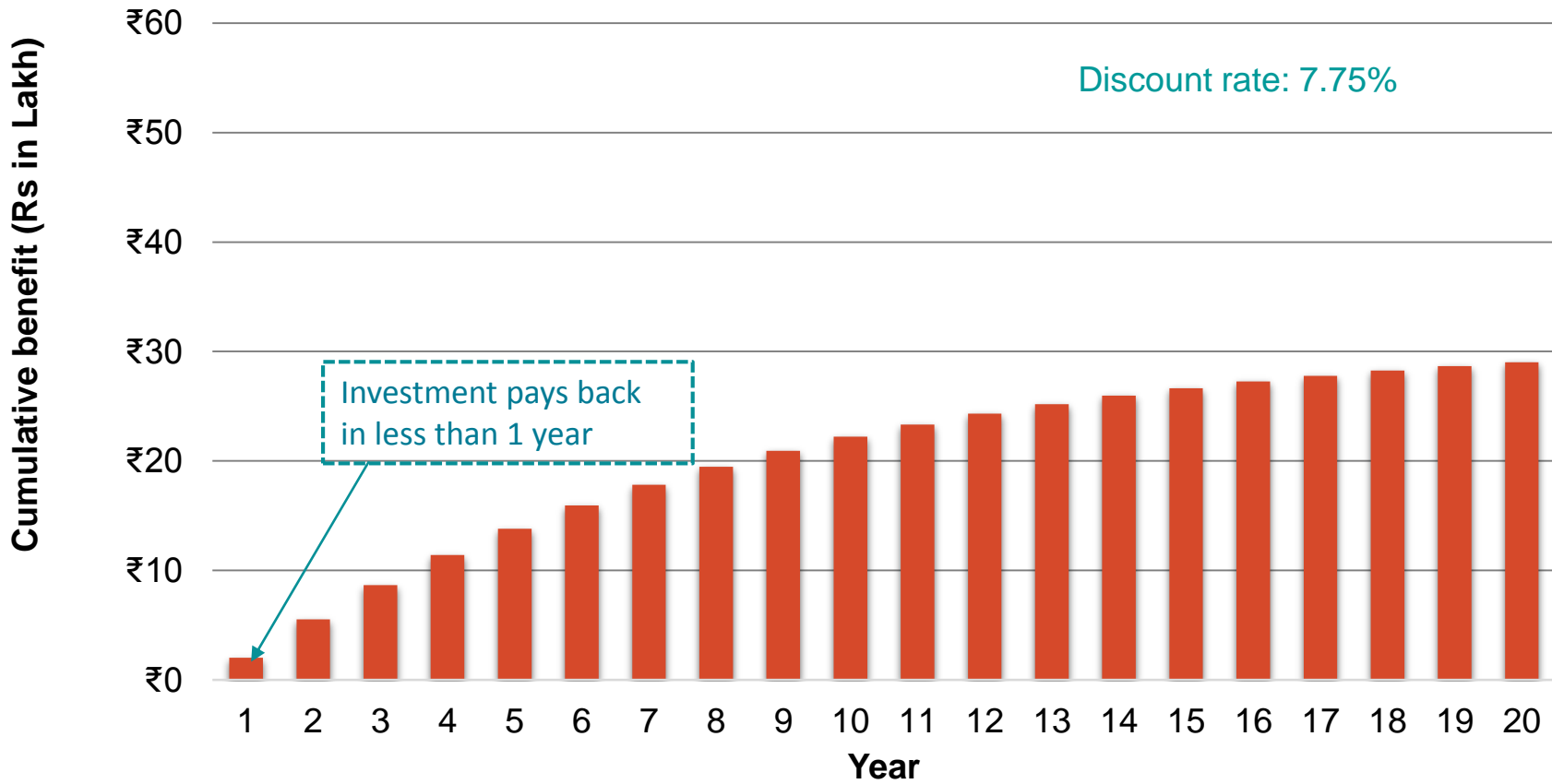
Payback period is within 2 years for nearly all of the technology packages



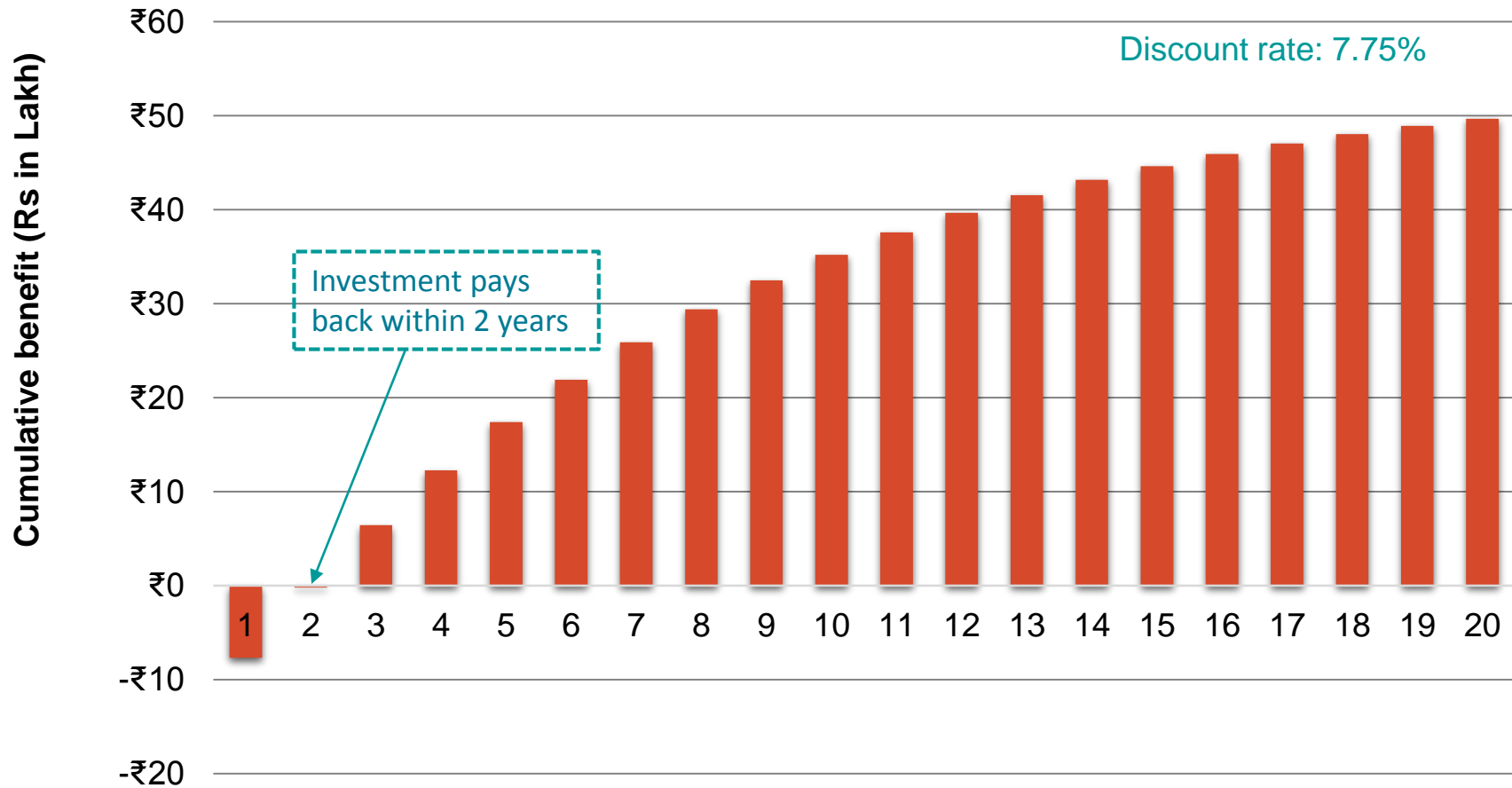
Assuming a 5-year loan, payback time is even more attractive



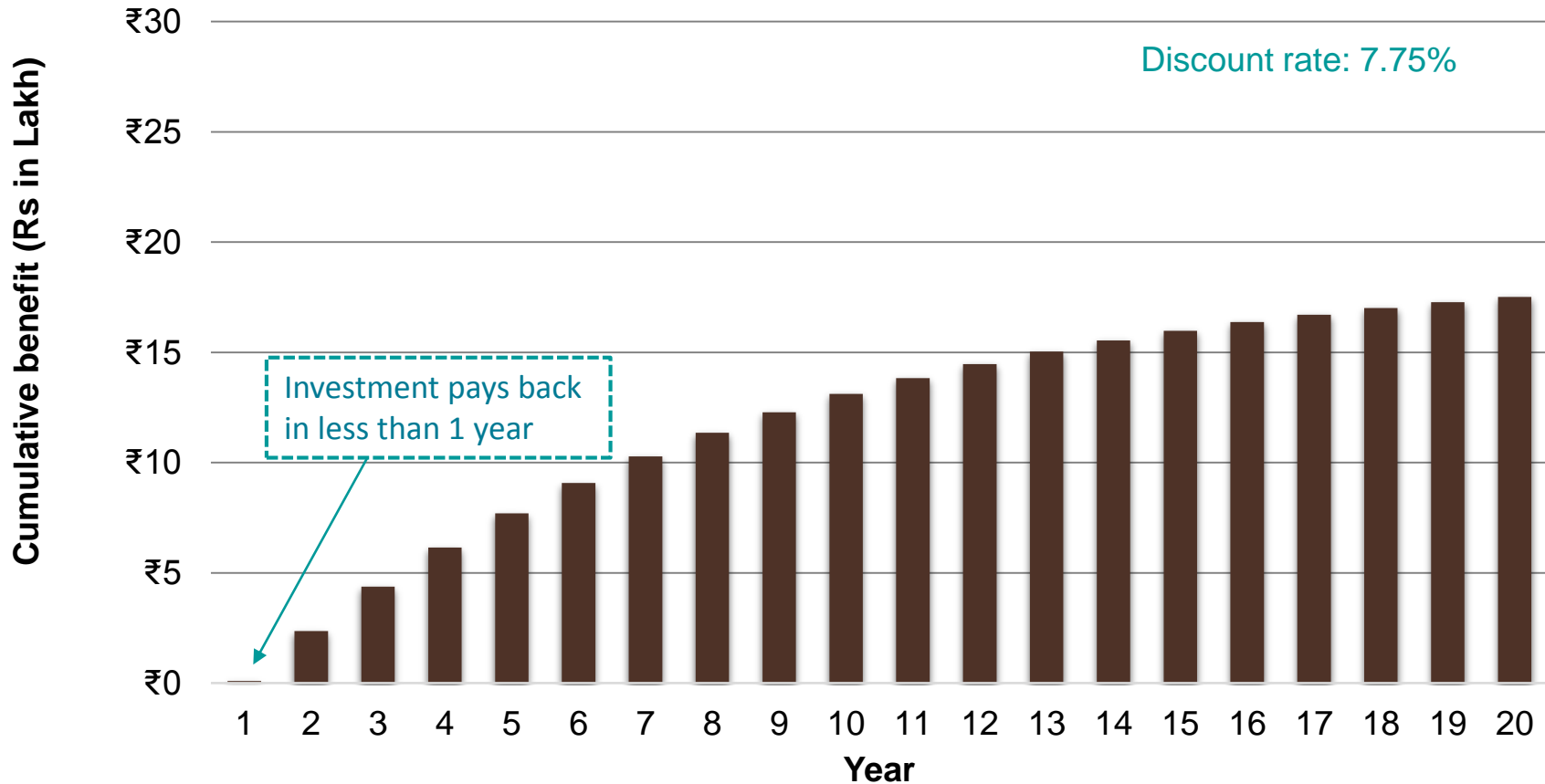
Cumulative benefit for tractor-trailer with TP1, assuming one-time upfront payment



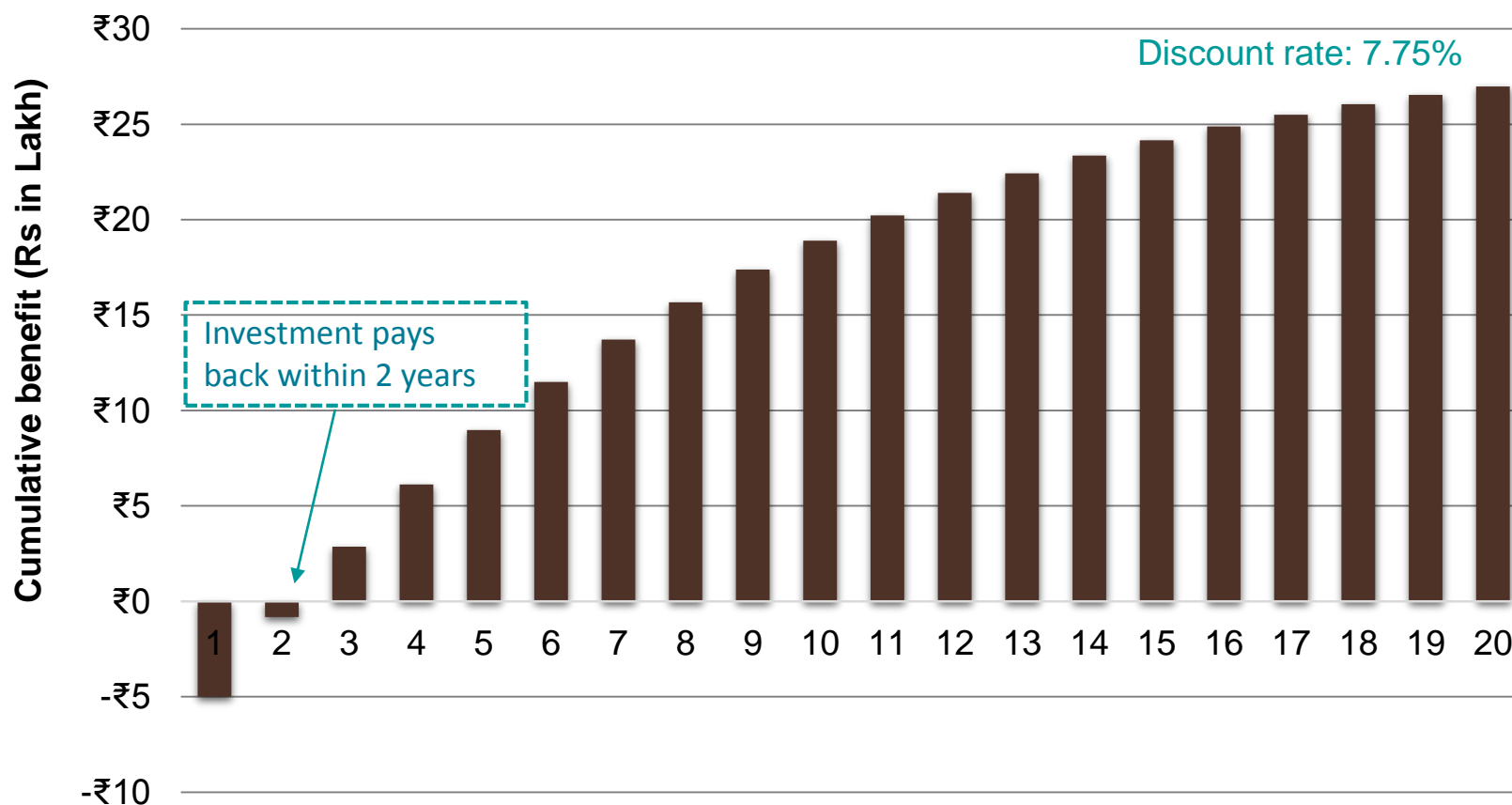
Cumulative benefit for tractor-trailer with TP7, assuming one-time upfront payment



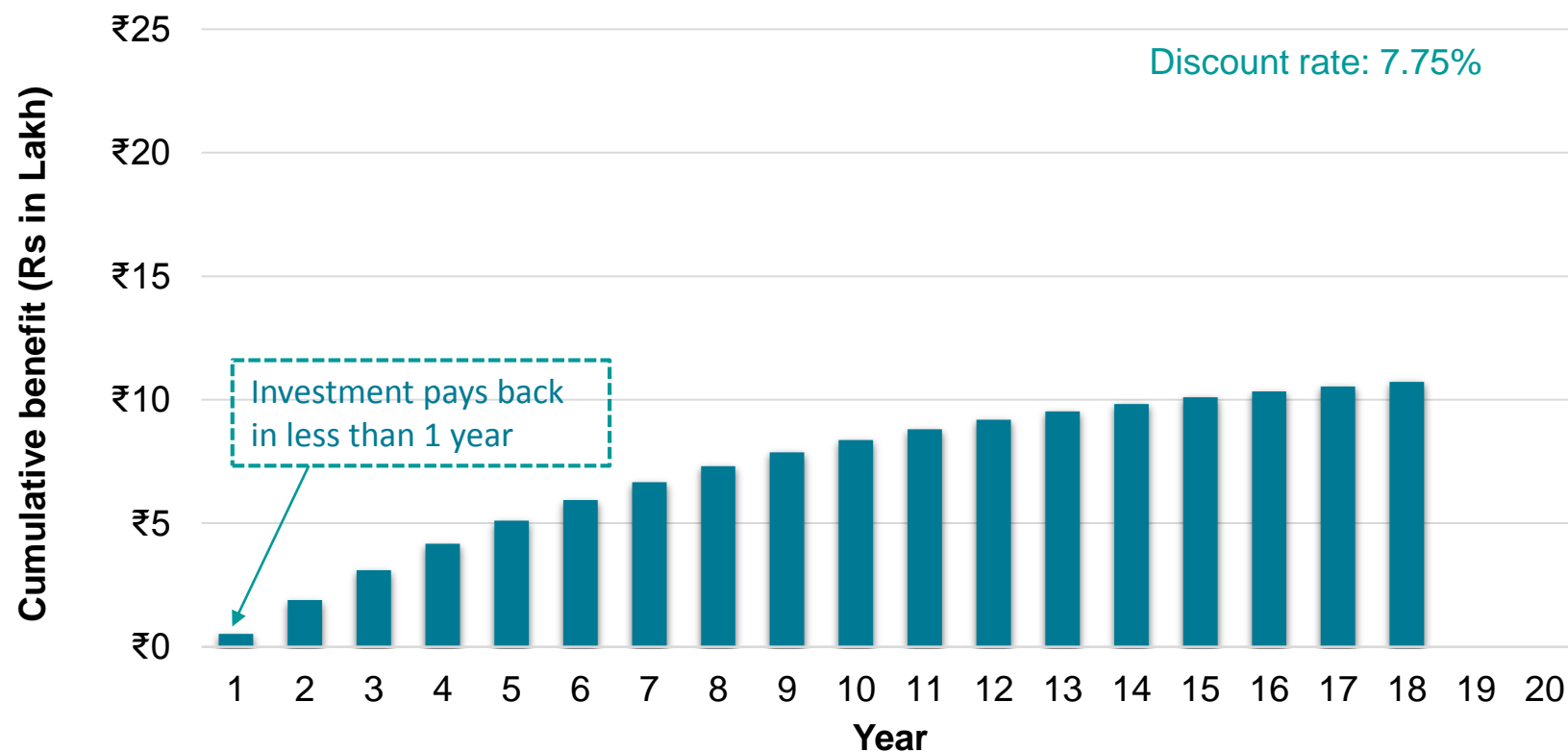
Cumulative benefit for rigid truck with TP2, assuming one-time upfront payment



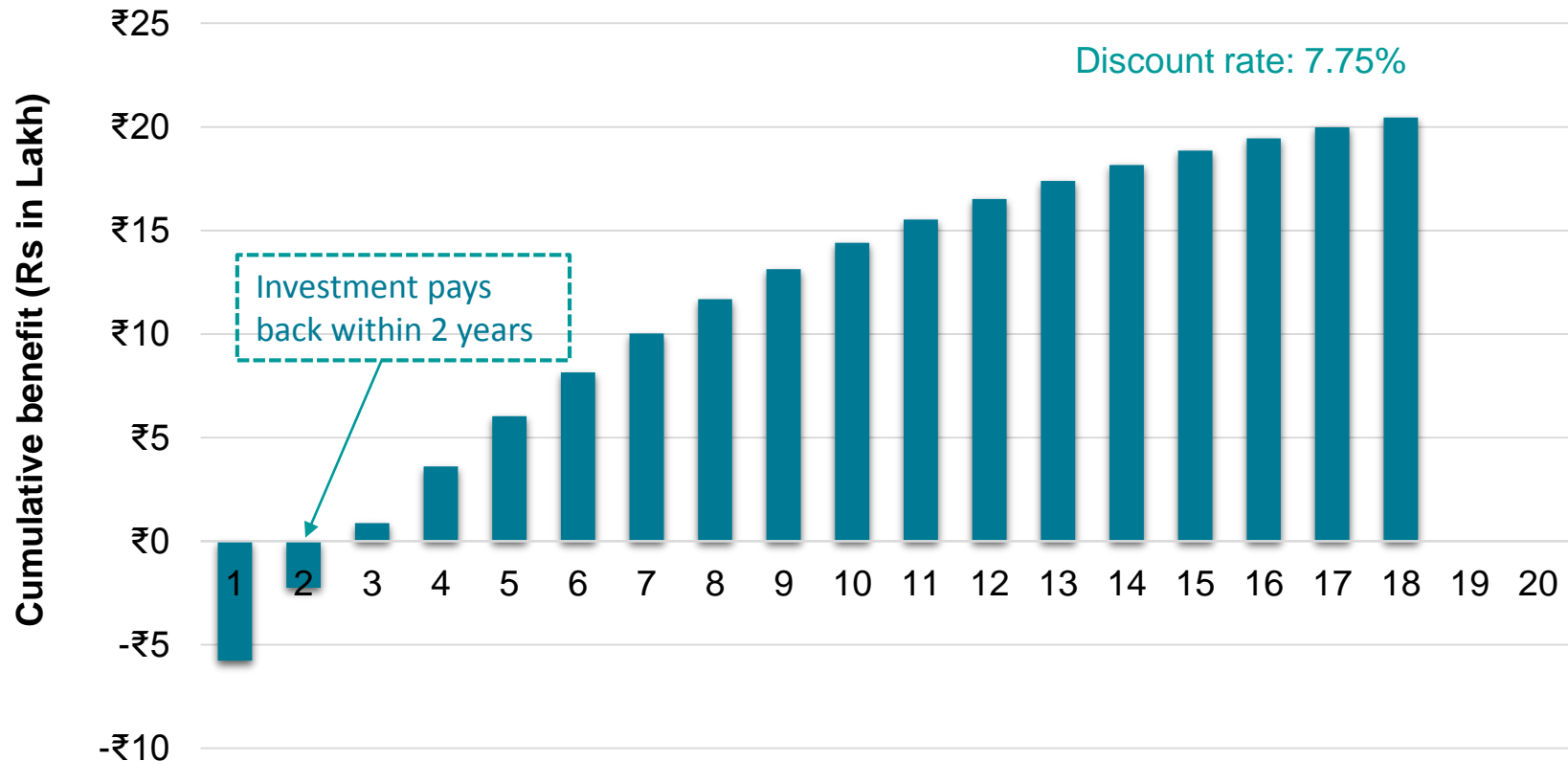
Cumulative benefit for rigid truck with TP6, assuming one-time upfront payment



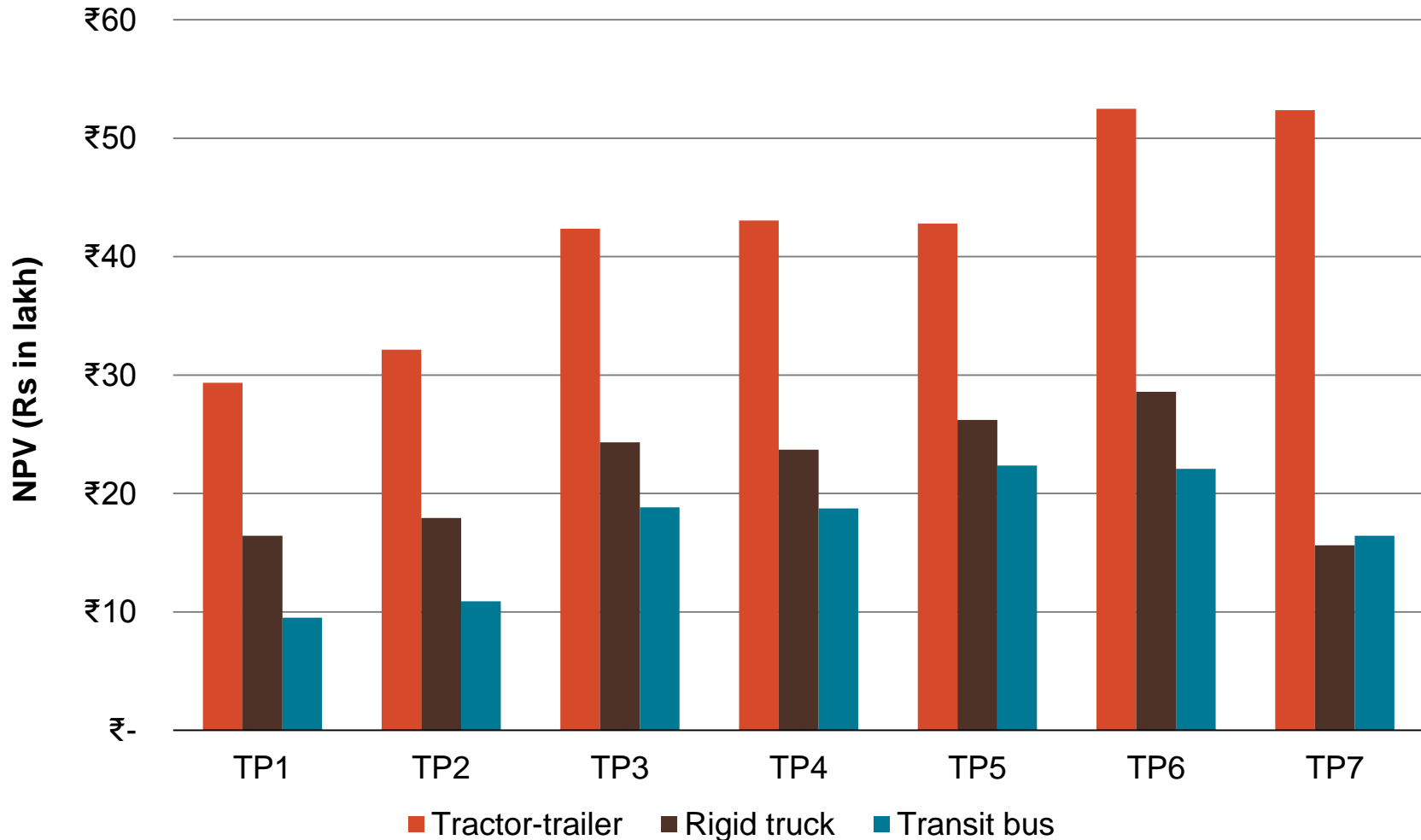
Cumulative benefit for transit bus with TP2, assuming one-time upfront payment



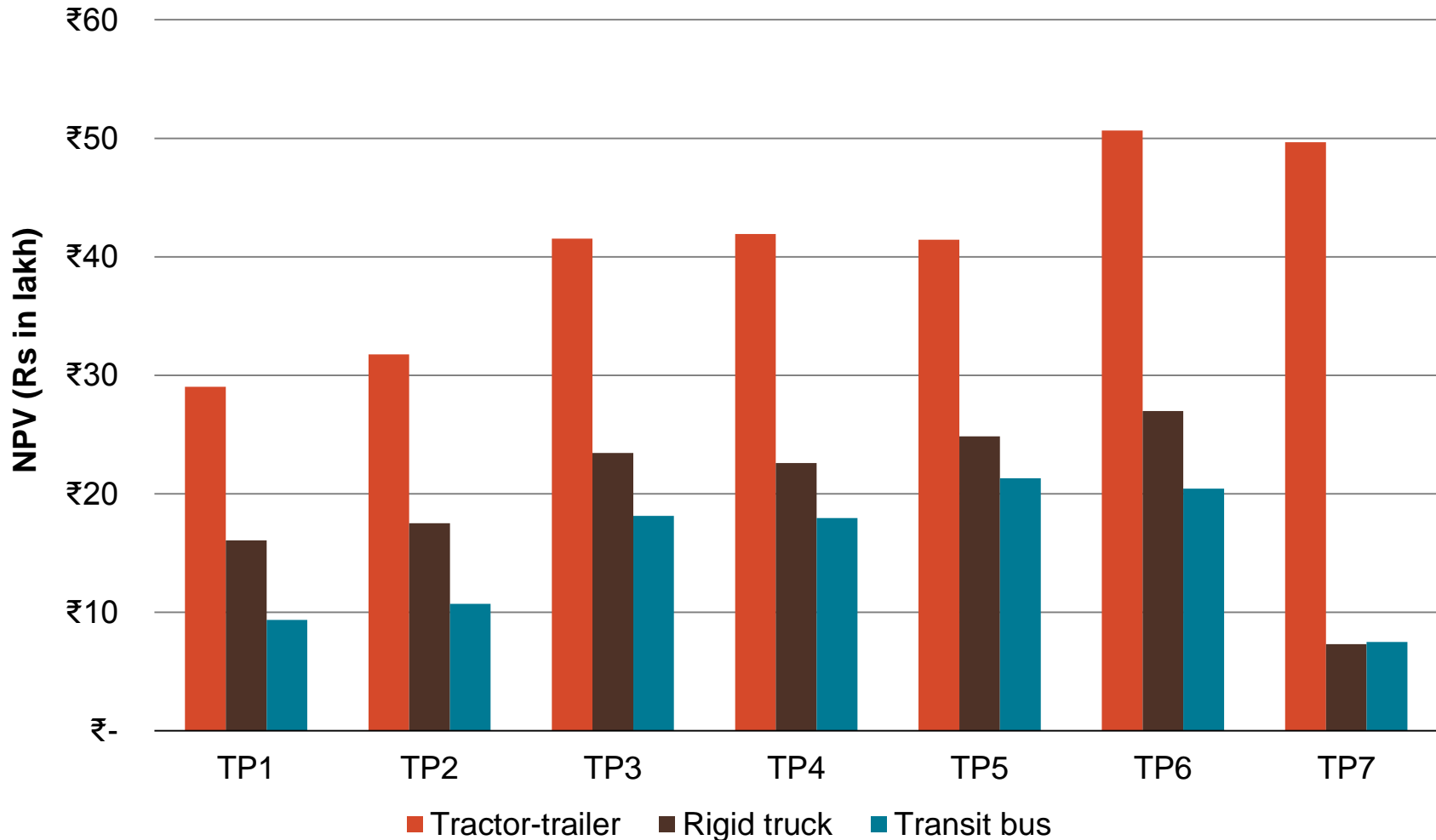
Cumulative benefit for transit bus with TP6, assuming one-time upfront payment



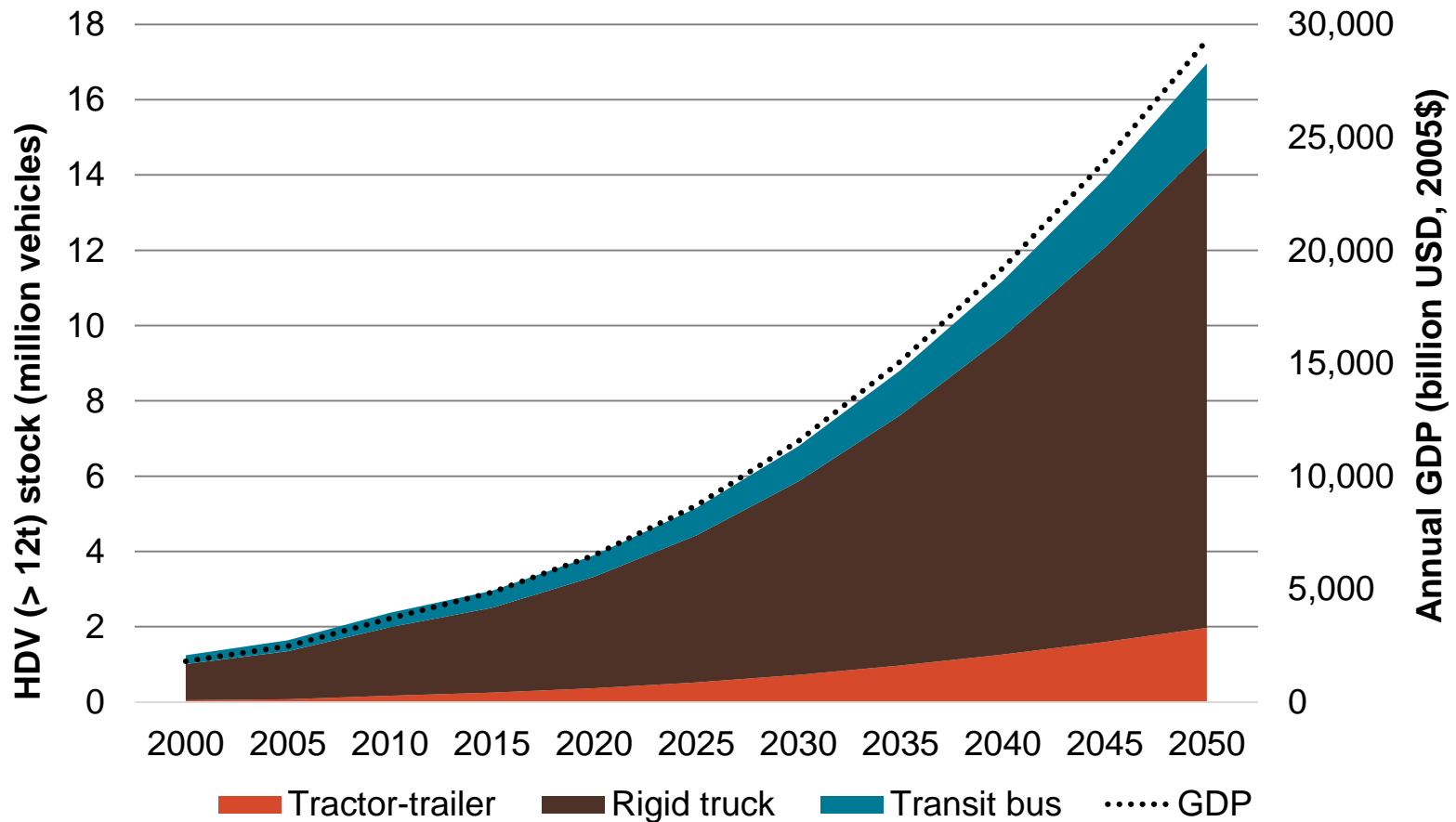
Net present value (NPV), assuming one-time upfront payment



Net present value (NPV), assuming 5-year loan

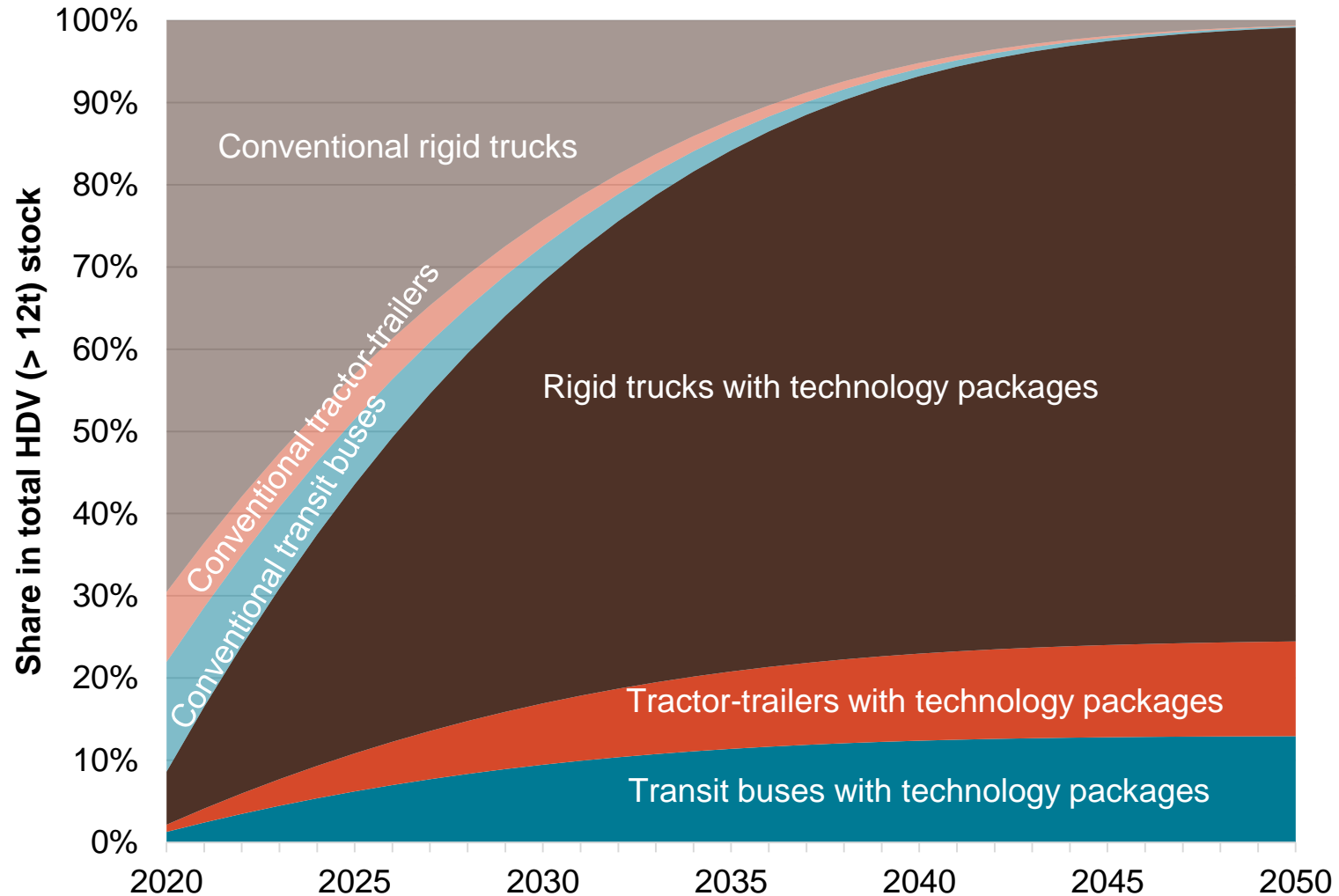


HDV stock growth model results

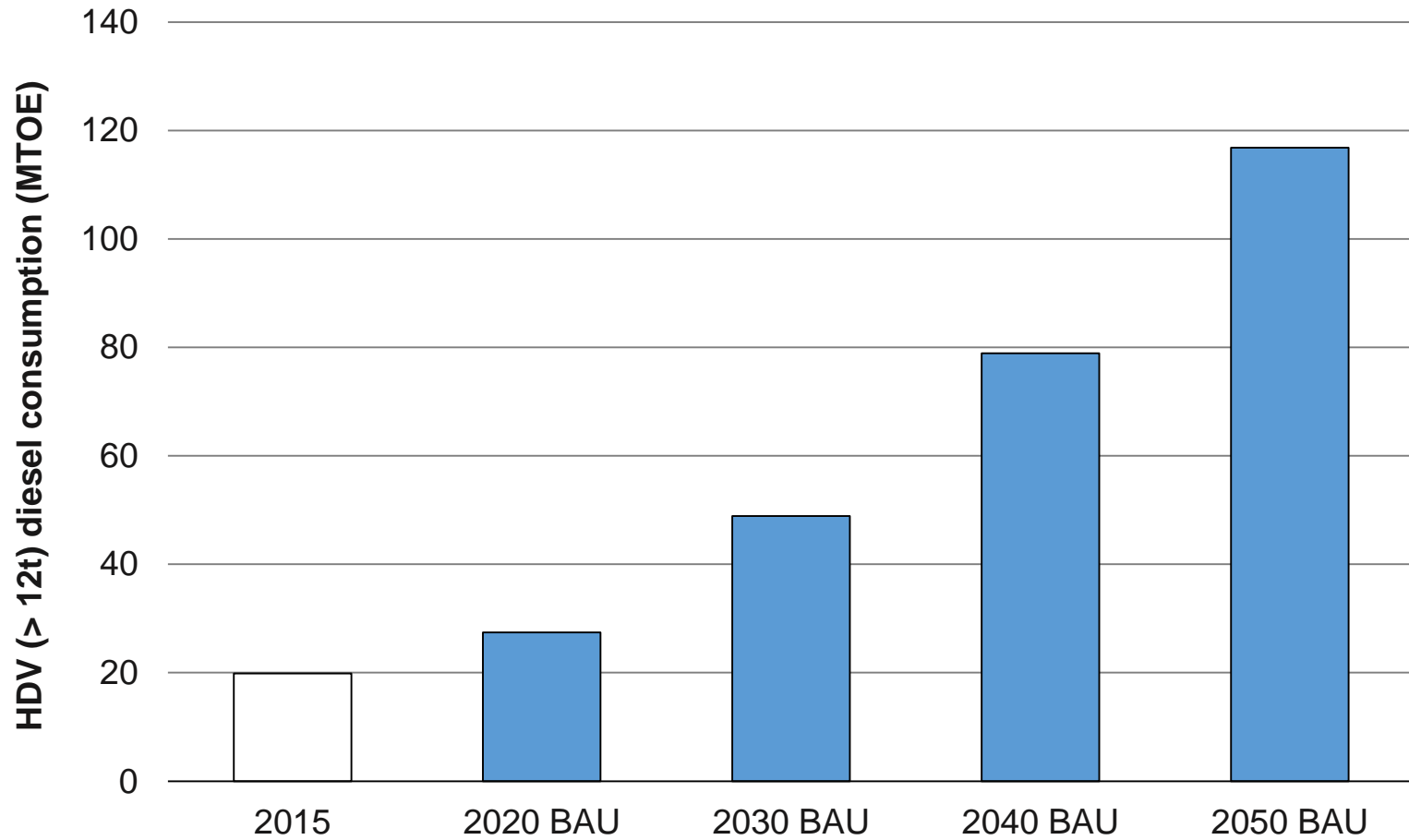


Note: GDP growth is based on the World Bank forecasts.

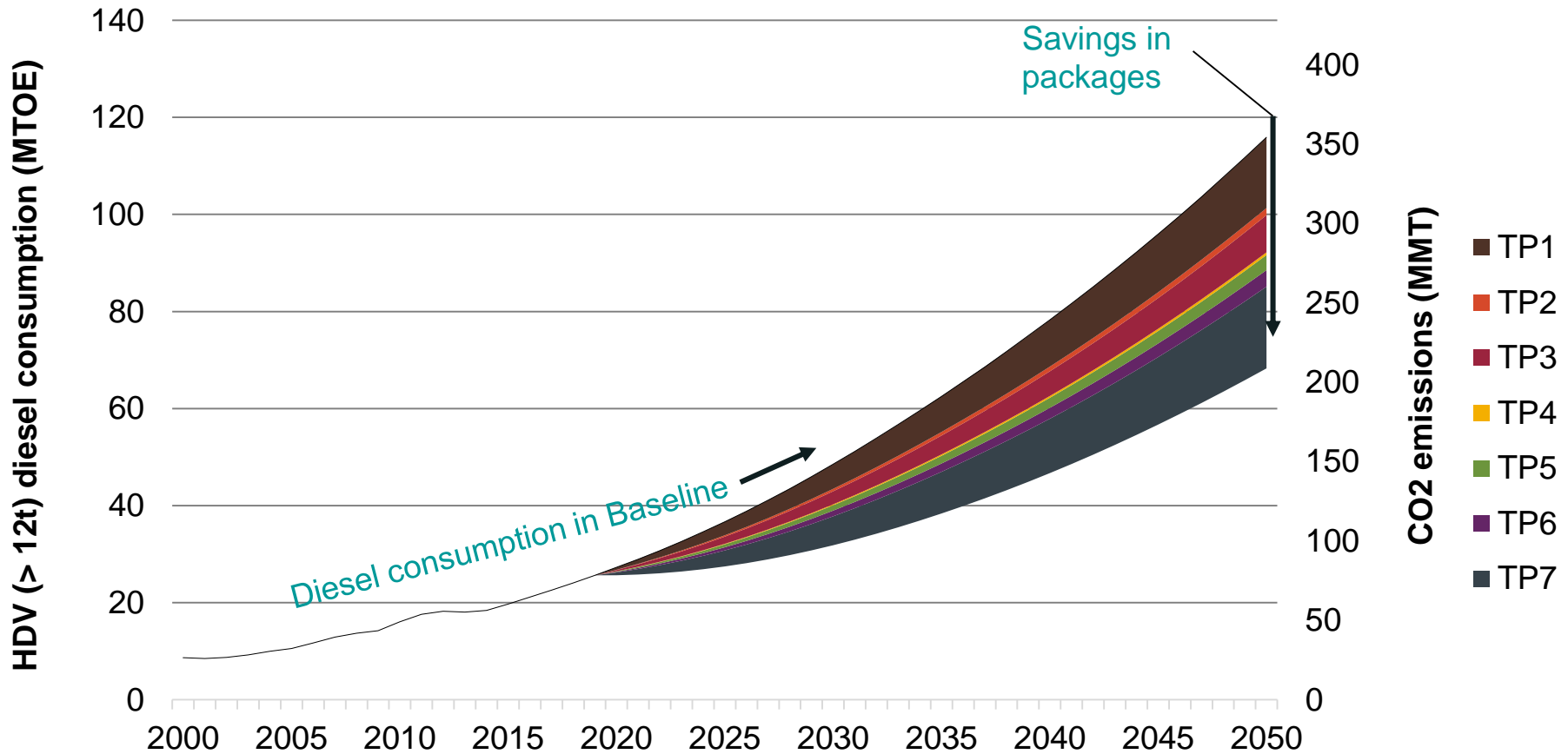
Penetration of technology packages



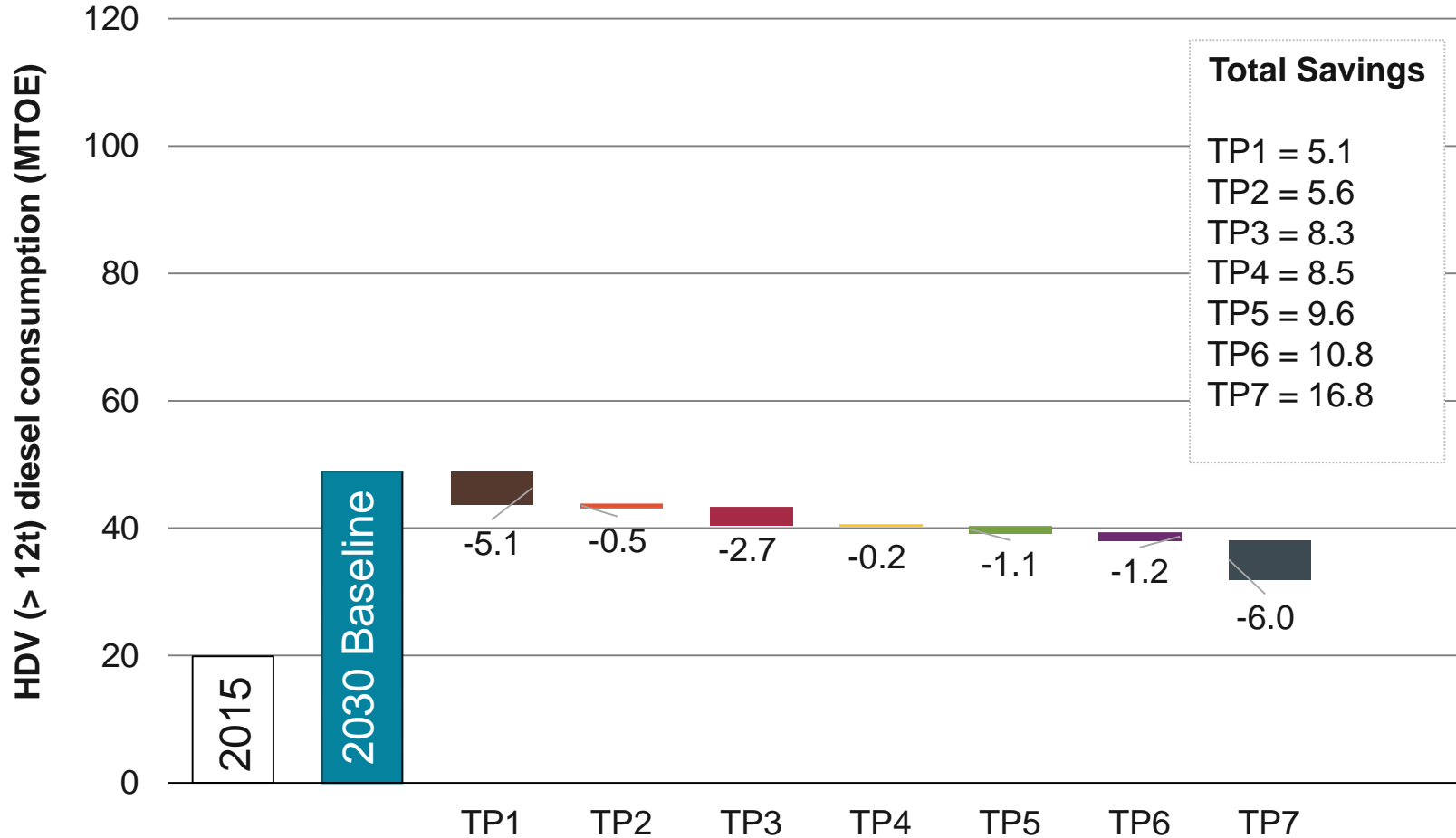
Baseline HDV diesel consumption



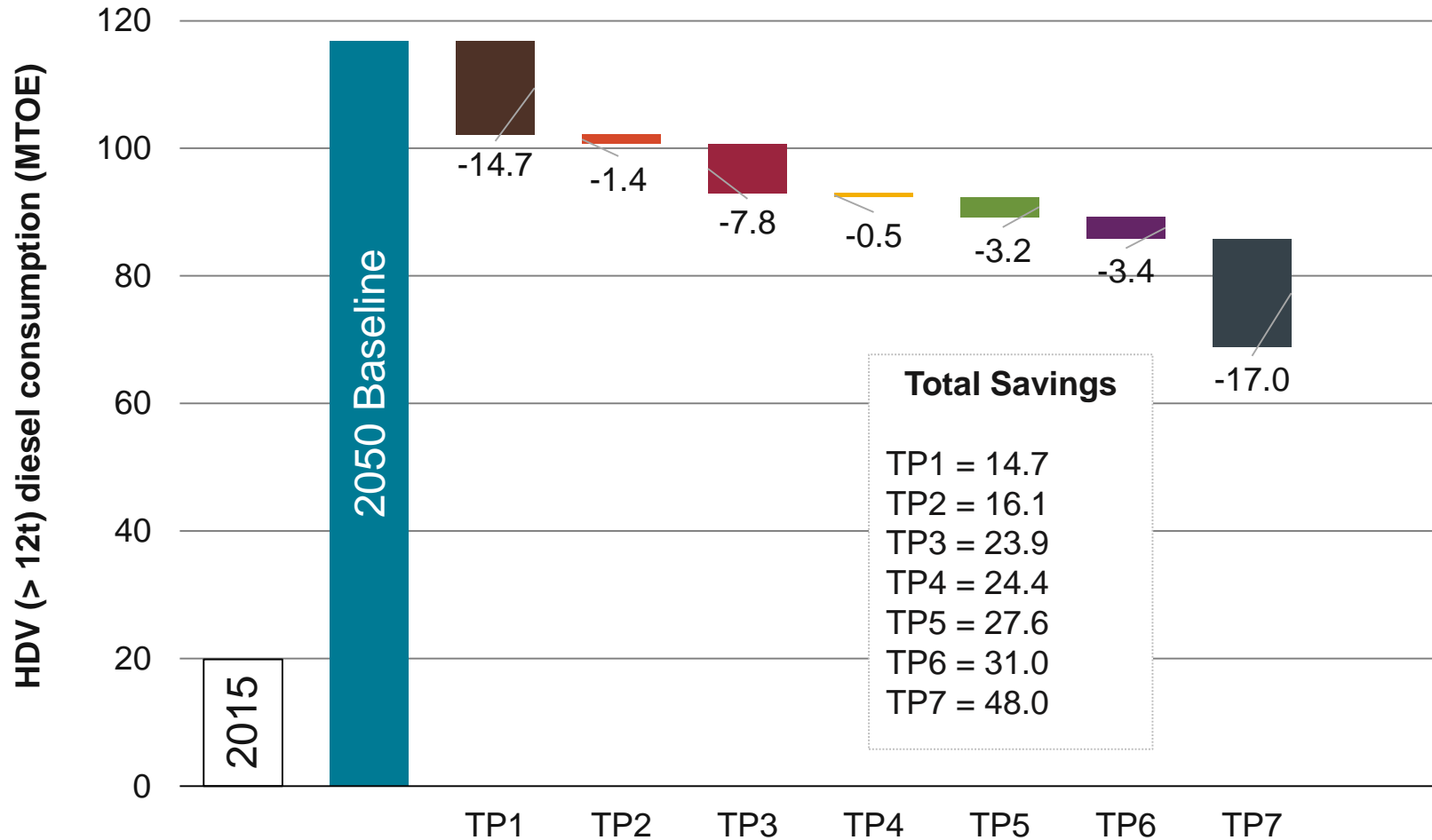
Technology packages provide substantial diesel and CO₂ savings



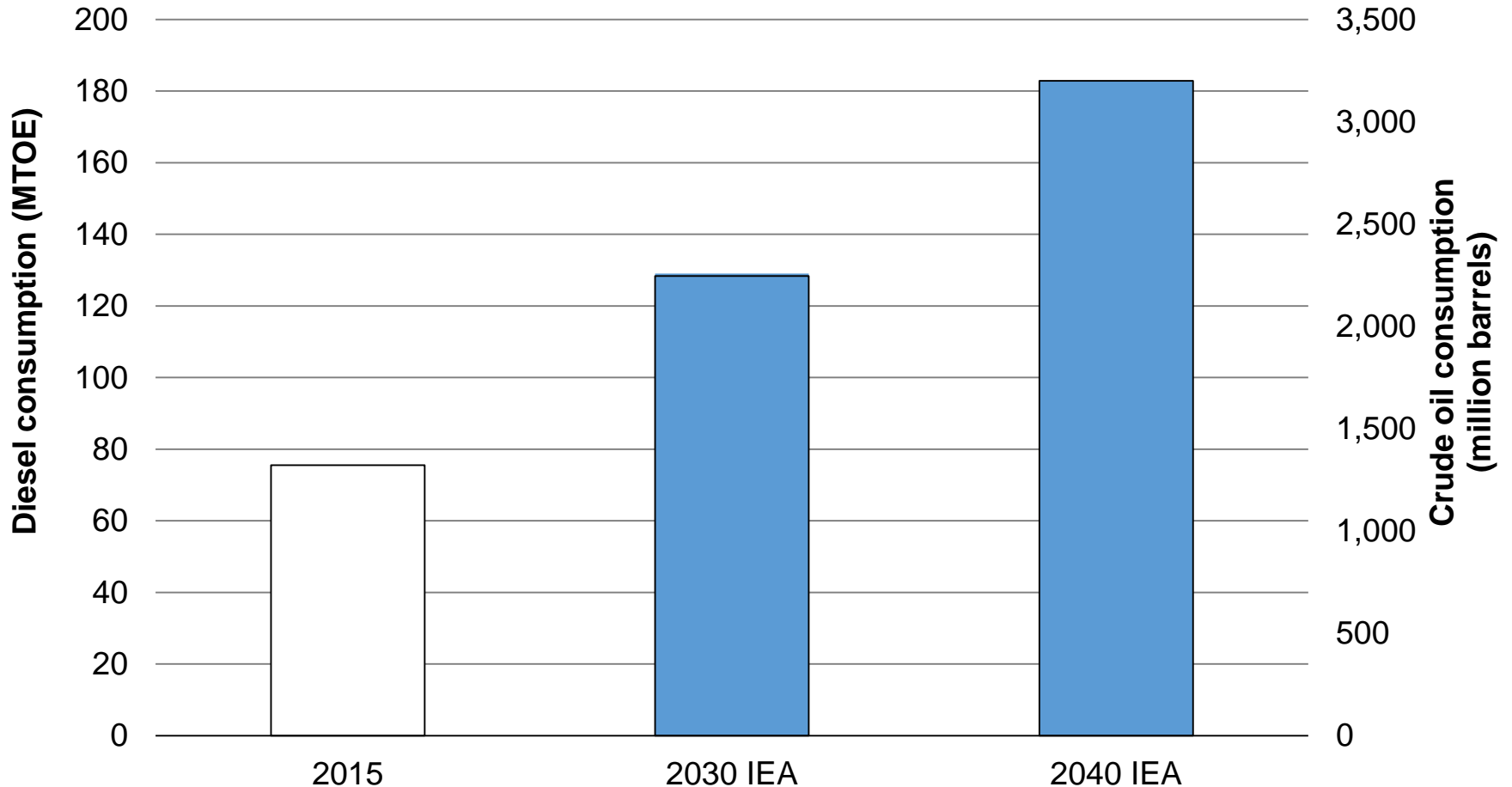
HDV fleet diesel consumption in 2030



HDV fleet diesel consumption in 2050

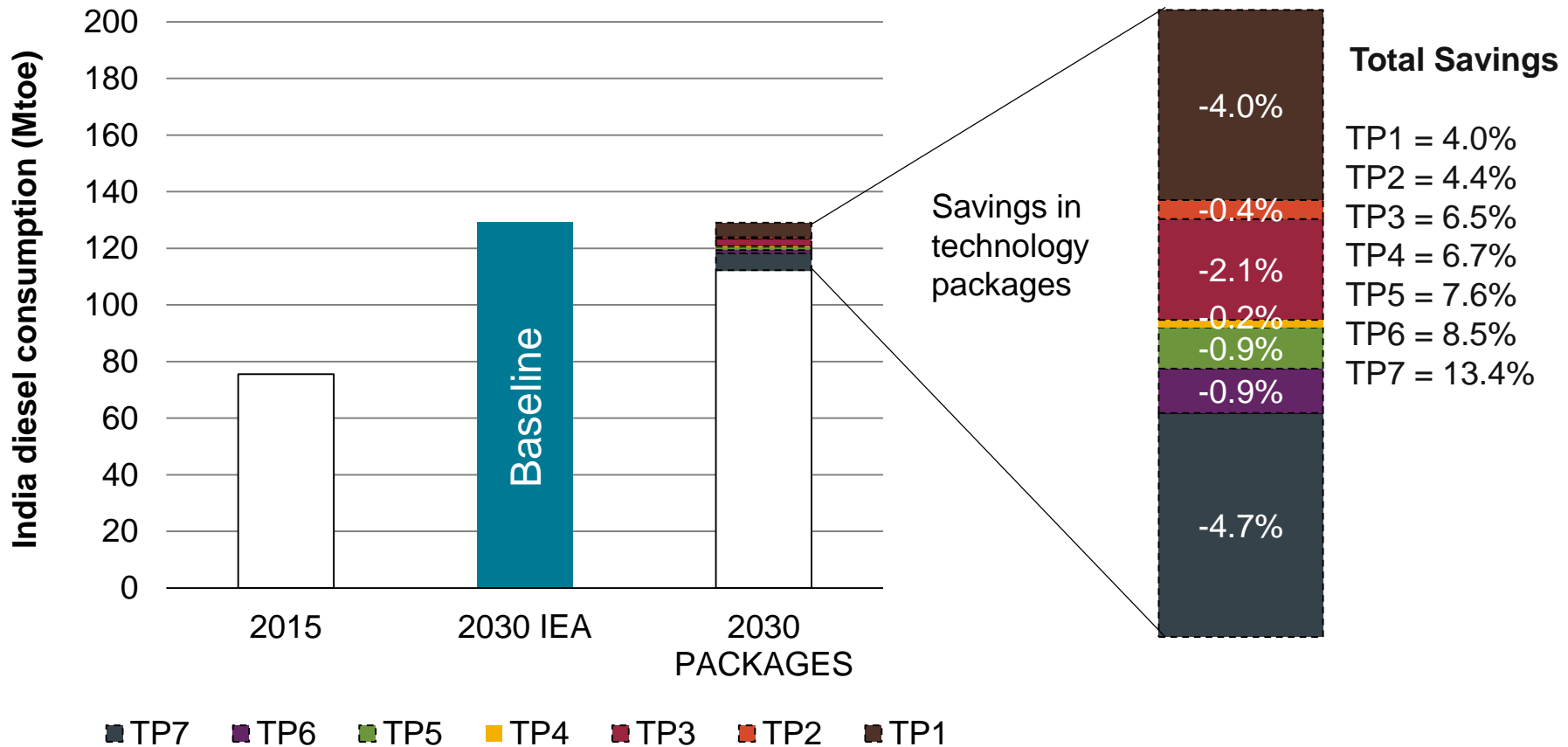


Total national diesel and oil consumption

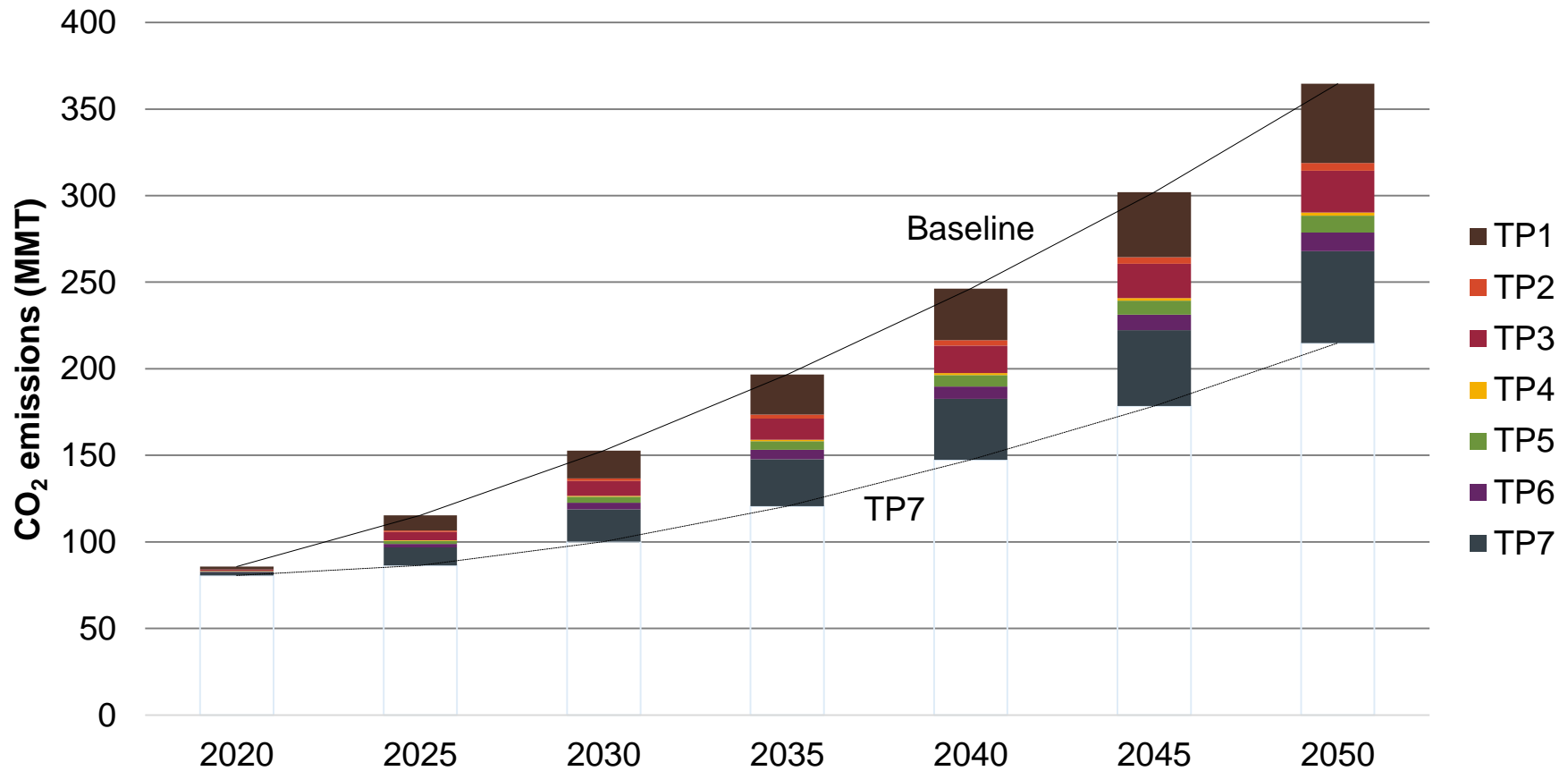


Source: India Energy Outlook, International Energy Agency. 2015
https://www.iea.org/publications/freepublications/publication/IndiaEnergyOutlook_WEO2015.pdf

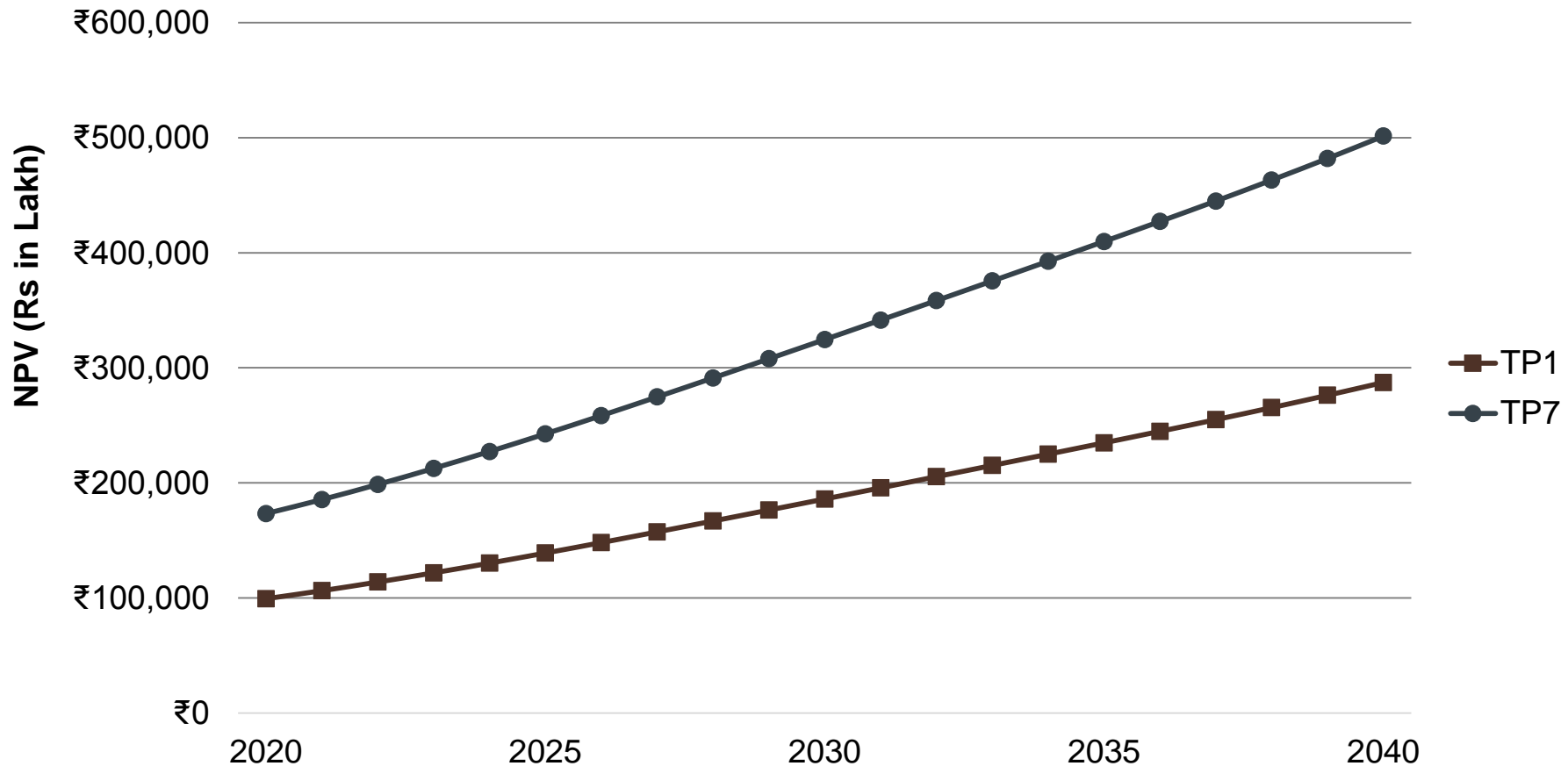
2030 HDV diesel savings relative to total Indian consumption; more savings needed



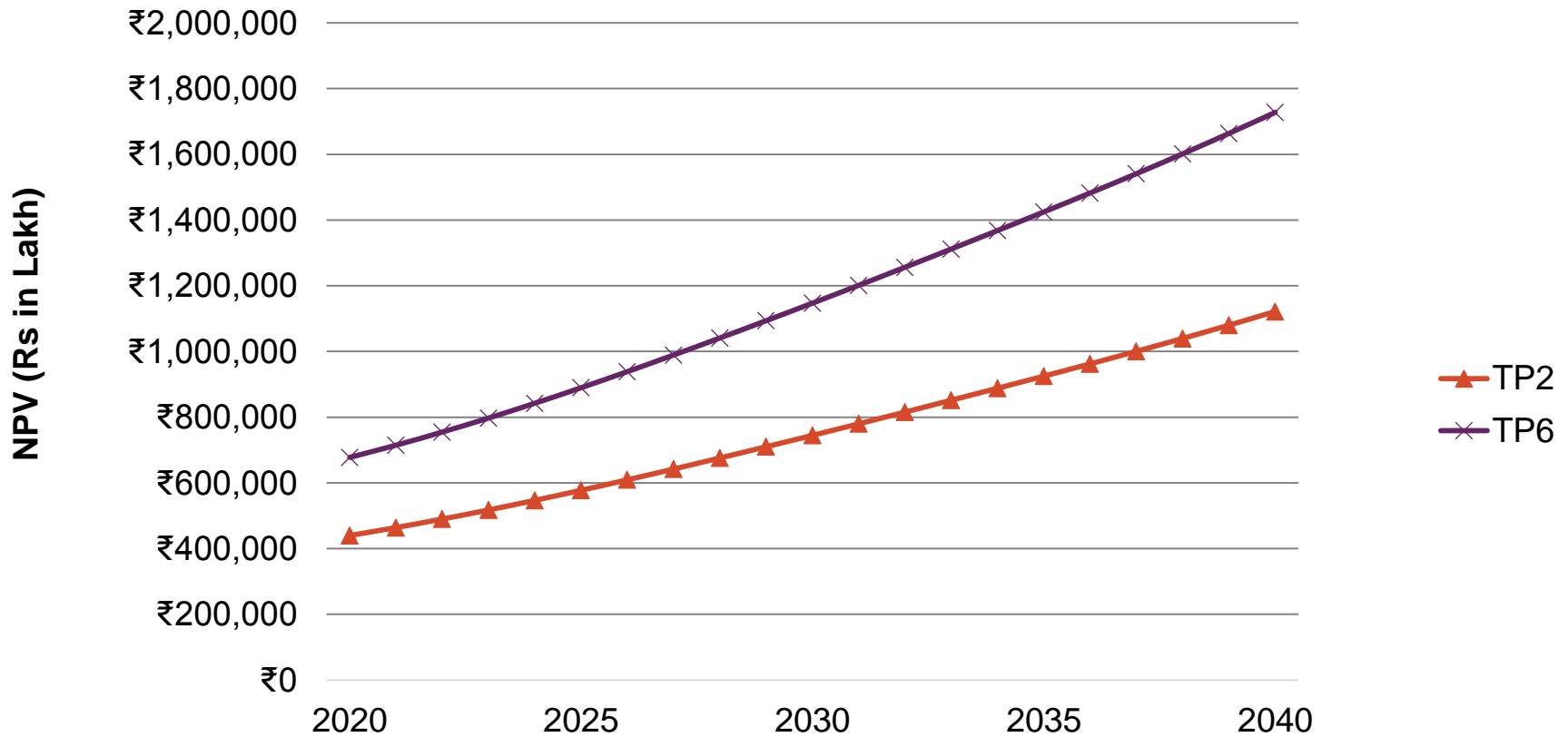
CO₂ emissions savings



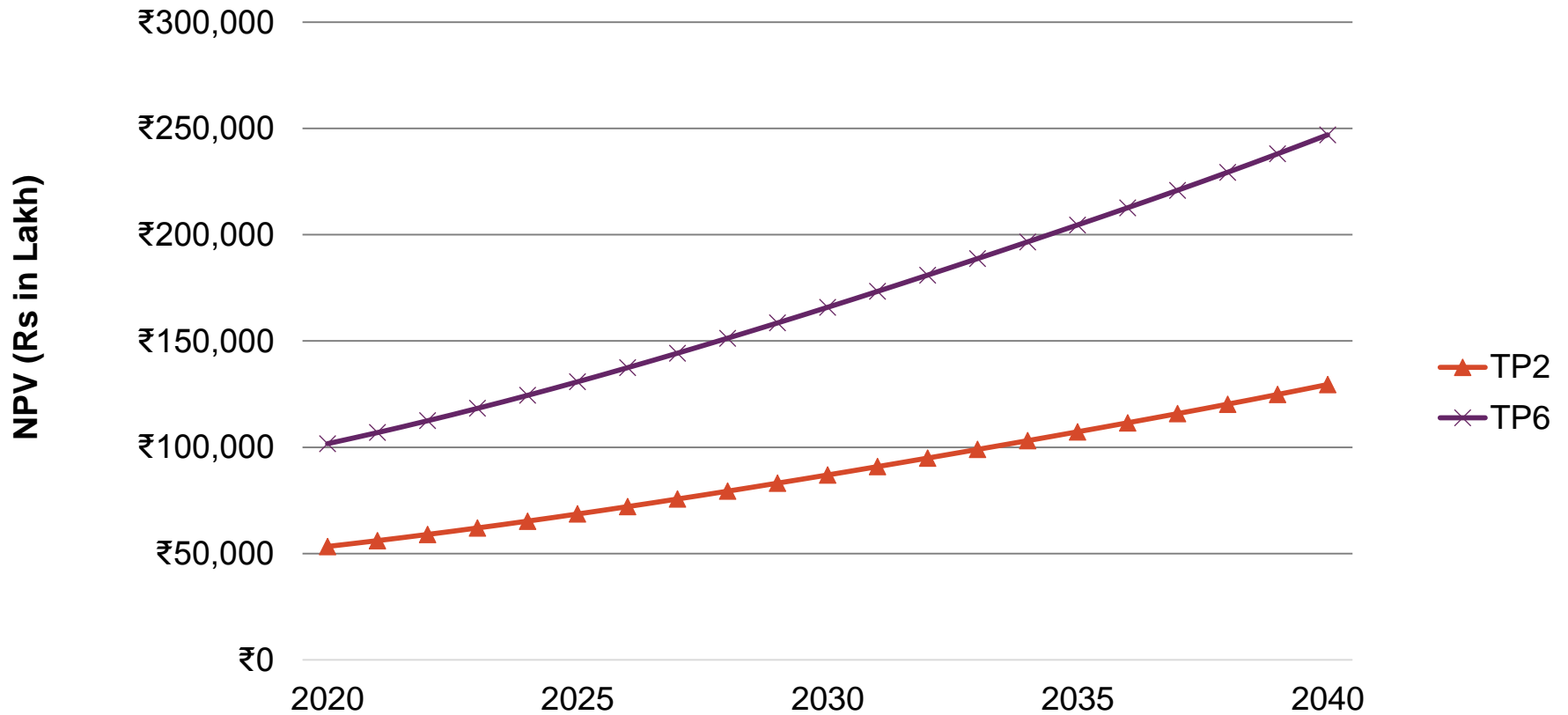
Total fleet NPV for tractor-trailer fleet



Total fleet NPV for rigid truck fleet



Total fleet NPV for transit bus fleet



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