Cleaner and Lower Carbon Vehicles:
Global Challenges and Implications for India

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ECMA's 12th International Conference
Pune
14 November 2019

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

The International Council on Clean Transportation (ICCT)

The mission of ICCT is to dramatically improve the environmental performance and efficiency of cars, trucks, buses and transportation systems in order to protect and improve public health, the environment, and quality of life.

- Non-profit research organization
- Air Pollution and Climate Impacts
- Focus on regulatory policies and fiscal incentives
- Activity across modes including aviation and marine
- Global outreach, with special focus on largest markets
- Offices in Washington D.C., San Francisco, Berlin, Beijing

Transportation Sector Impacts

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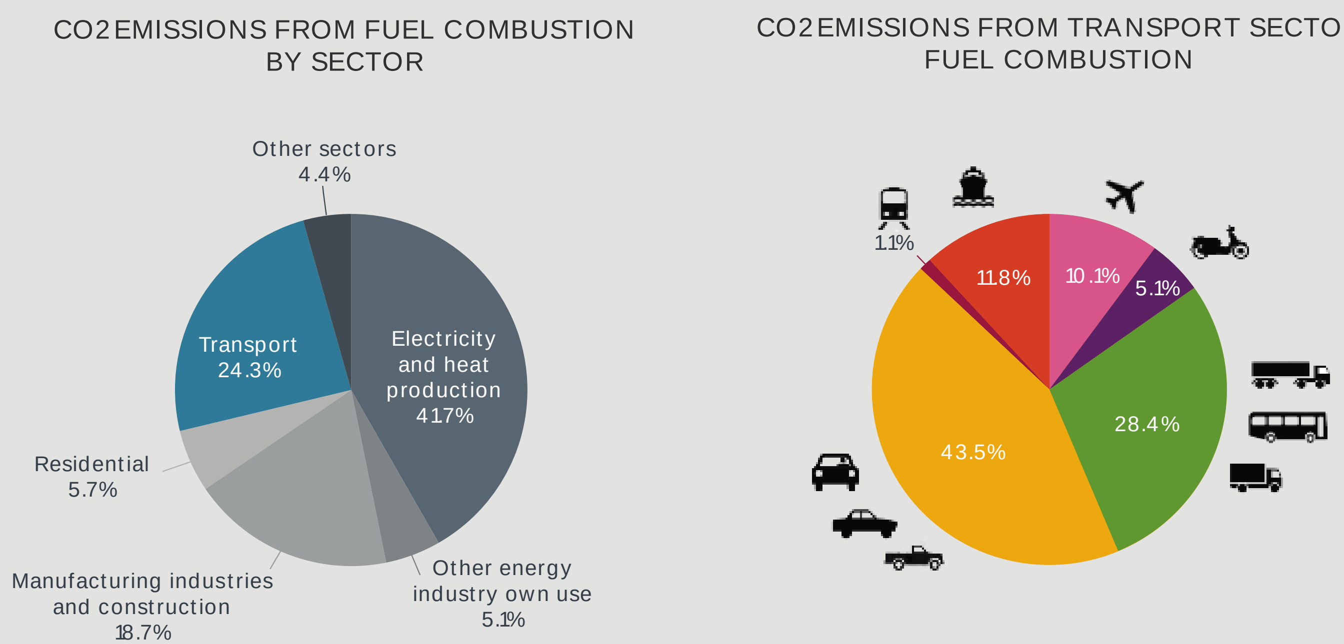
Transportation sector accounts for approximately 25% of global energy-related greenhouse gas emissions

THE TRANSPORT SECTOR
A major contributor to global anthropogenic CO_2 emissions



LEGEND

RAIL | MARINE | AVIATION | TWO- OR THREE-WHEELED VEHICLES | HEAVY-DUTY VEHICLES | LIGHT-DUTY VEHICLES

Sources:
Based on IEA data from *IEA CO2 Emissions from Fuel Combustion* © OECD/IEA 2017, www.iea.org/statistics. Licence: www.iea.org/t&c; as modified by ICCT.
Transport sector CO2 emissions are adjusted to reflect higher ICCT estimates for marine emissions: Olmer, N., Comer, B., Roy, B., Mao, X., & Rutherford, D. (2017). *Greenhouse gas emissions from global shipping, 2013–2015*. Retrieved from https://www.theicct.org/sites/default/files/publications/Global-shipping-GHG-emissions-2013-2015_ICCT-Report_17102017_vF.pdf
CO2 emissions for road transport, rail, and aviation are based on IEA data from the *Mobility Model version ETP 2017* © OECD/IEA 2017; tank-to-wheel GHG estimates by transport sub-sector (excluding marine) are adjusted to align with transport sector CO2 emissions estimates in *IEA CO2 Emissions from Fuel Combustion*.

Global air quality and health impacts of transportation tailpipe emissions in 2010 and 2015

Measure	Description	Metric	2010	2015
Transportation-attributable concentration (TAC)	How much do tailpipe emissions from transportation sources contribute to global population-weighted air pollutant concentrations? Units: depends on pollutant	annual average $PM_{2.5}$	2.9 µg/m³	3.0 µg/m³
		6-month average of the 8-hour daily maximum ozone	5.5 ppb	5.6 ppb
		annual average BC	0.2 µg/m³	0.2 µg/m³
Transportation-attributable deaths	How many premature deaths are associated with global transportation-attributable concentrations of $PM_{2.5}$ and ozone? Units: thousands (95% confidence interval)	ambient $PM_{2.5}$ deaths	312 (240–386)	330 (255–408)
		ambient ozone deaths	49 (18–76)	55 (20–85)
		total ambient $PM_{2.5}$ and ozone deaths	361 (258–462)	385 (274–493)
Transportation-attributable fraction (TAF)	What fraction of ambient air pollution deaths are attributable to tailpipe emissions from transportation sources? Units: percent	$PM_{2.5}$	11.9%	11.6%
		ozone	10.4%	10.7%
		total $PM_{2.5}$ and ozone	11.7%	11.4%
Transportation health damages	What is the welfare loss due to global transportation-attributable deaths? Units: 2015 US$	$PM_{2.5}$	$900 billion	$891 billion
		ozone	$70 billion	$85 billion
		total $PM_{2.5}$ and ozone	$970 billion	$976 billion

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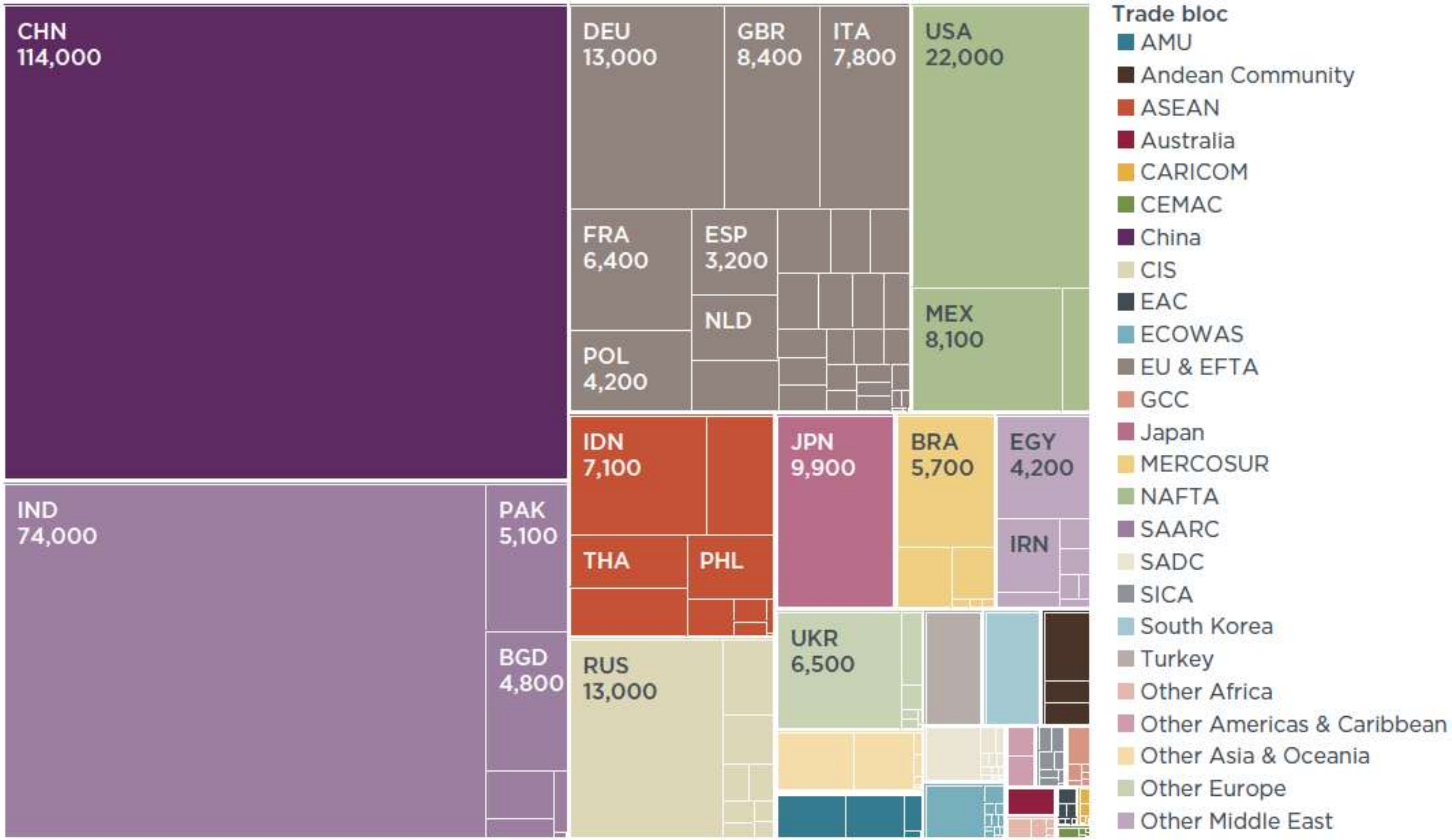
A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015
https://theicct.org/publications/health-impacts-transport-emissions-2010-2015

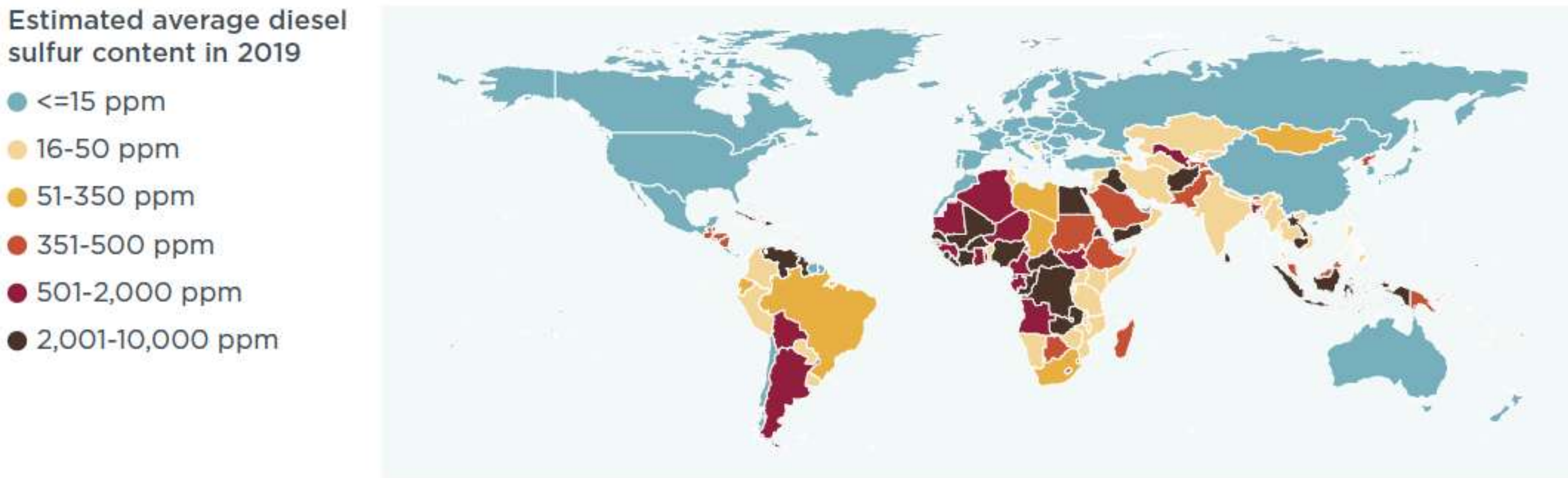
Global air quality and health impacts of transportation tailpipe emissions in 2010 and 2015

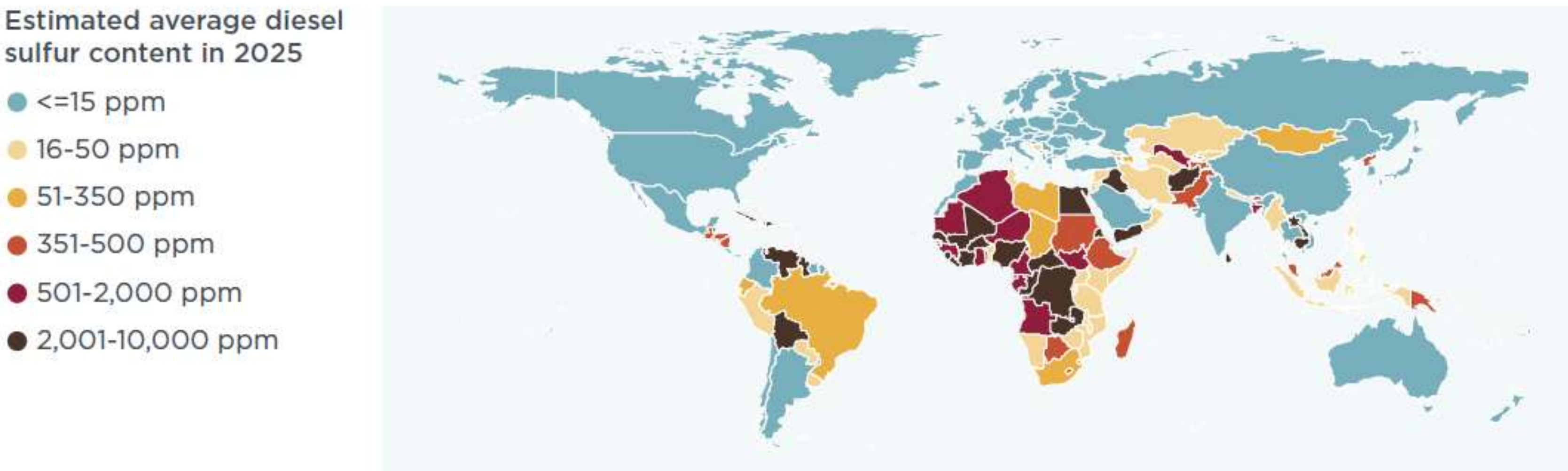


A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015
https://theicct.org/publications/health-impacts-transport-emissions-2010-2015

Global Progress Towards Soot-free Vehicles

Estimated average diesel sulfur content by country in 2019 and 2025





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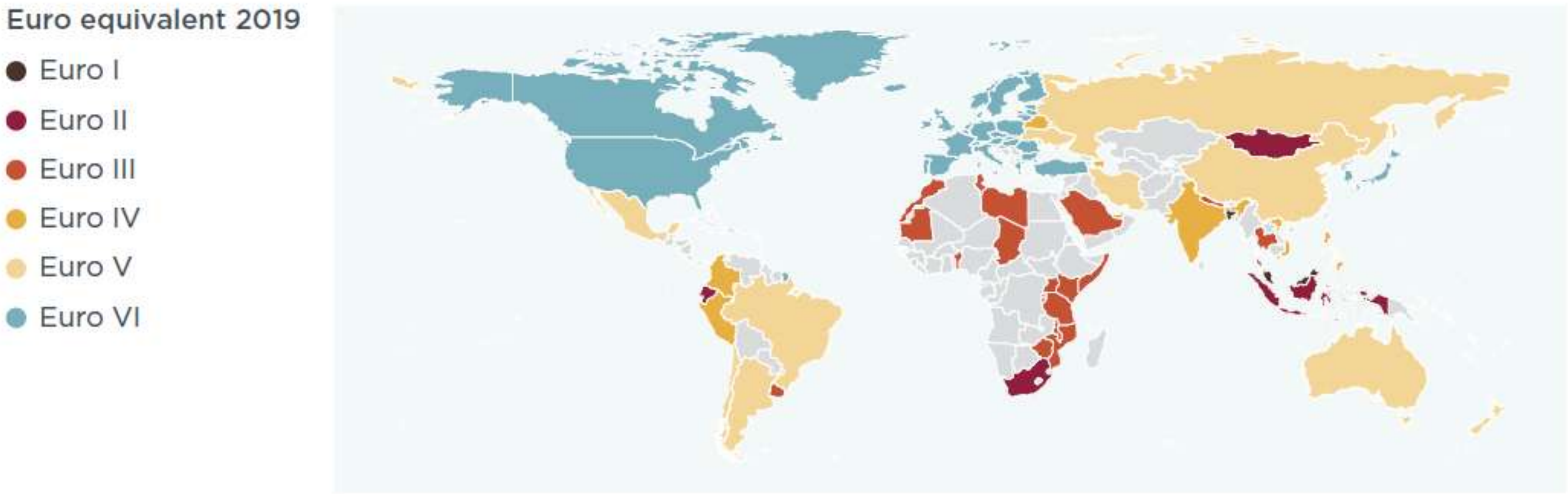
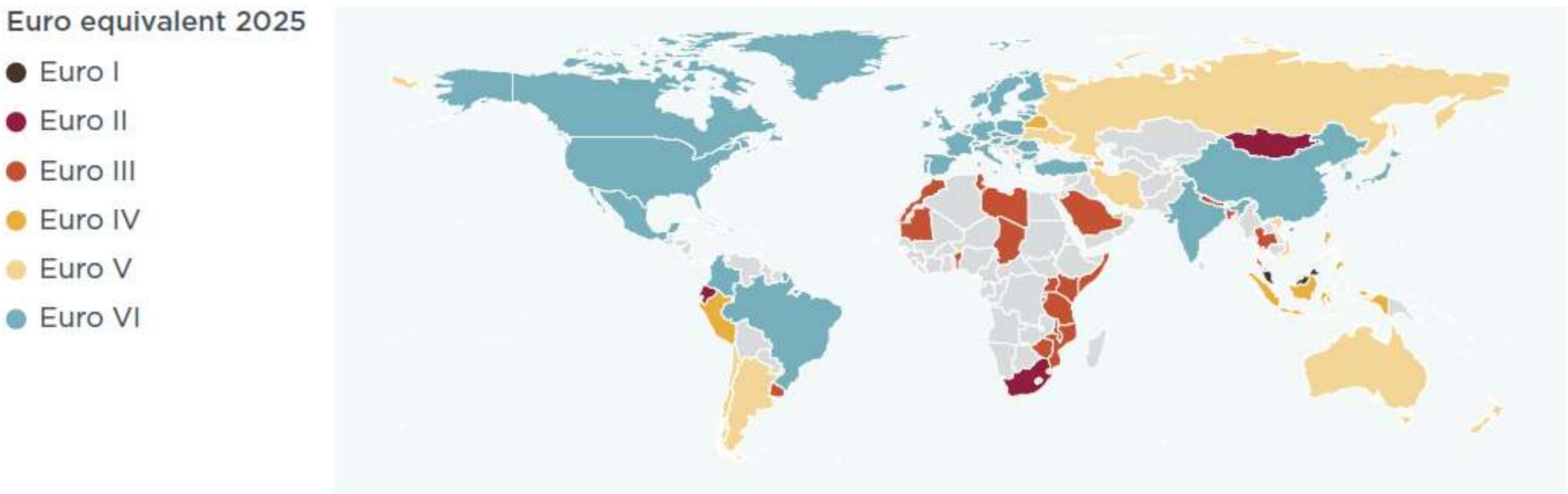
Global progress toward soot-free diesel vehicles in 2019
https://theicct.org/publications/global-progress-toward-soot-free-diesel-vehicles-2019

Implementation of heavy-duty diesel engine emission standards in 2019 and 2025





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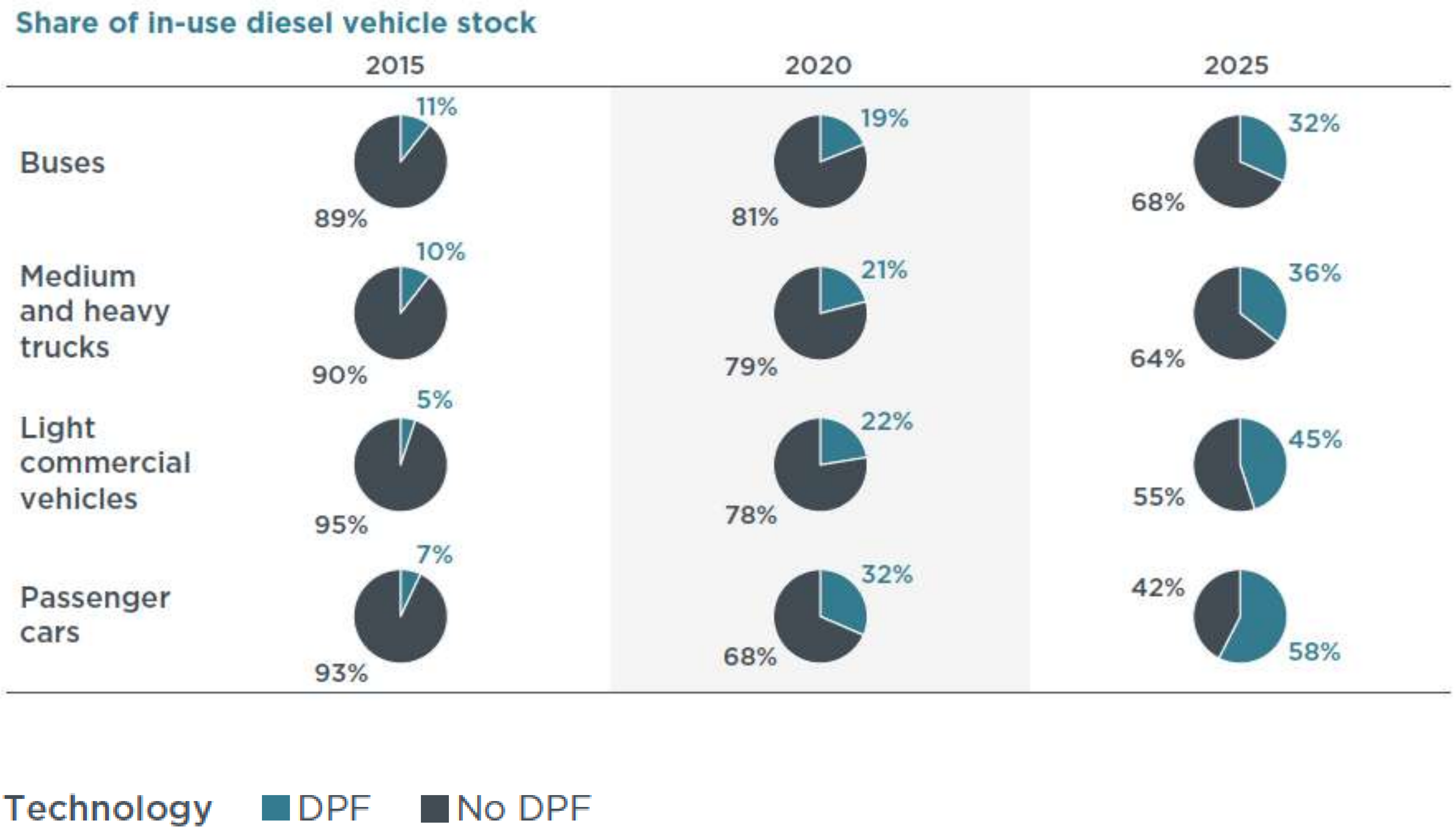
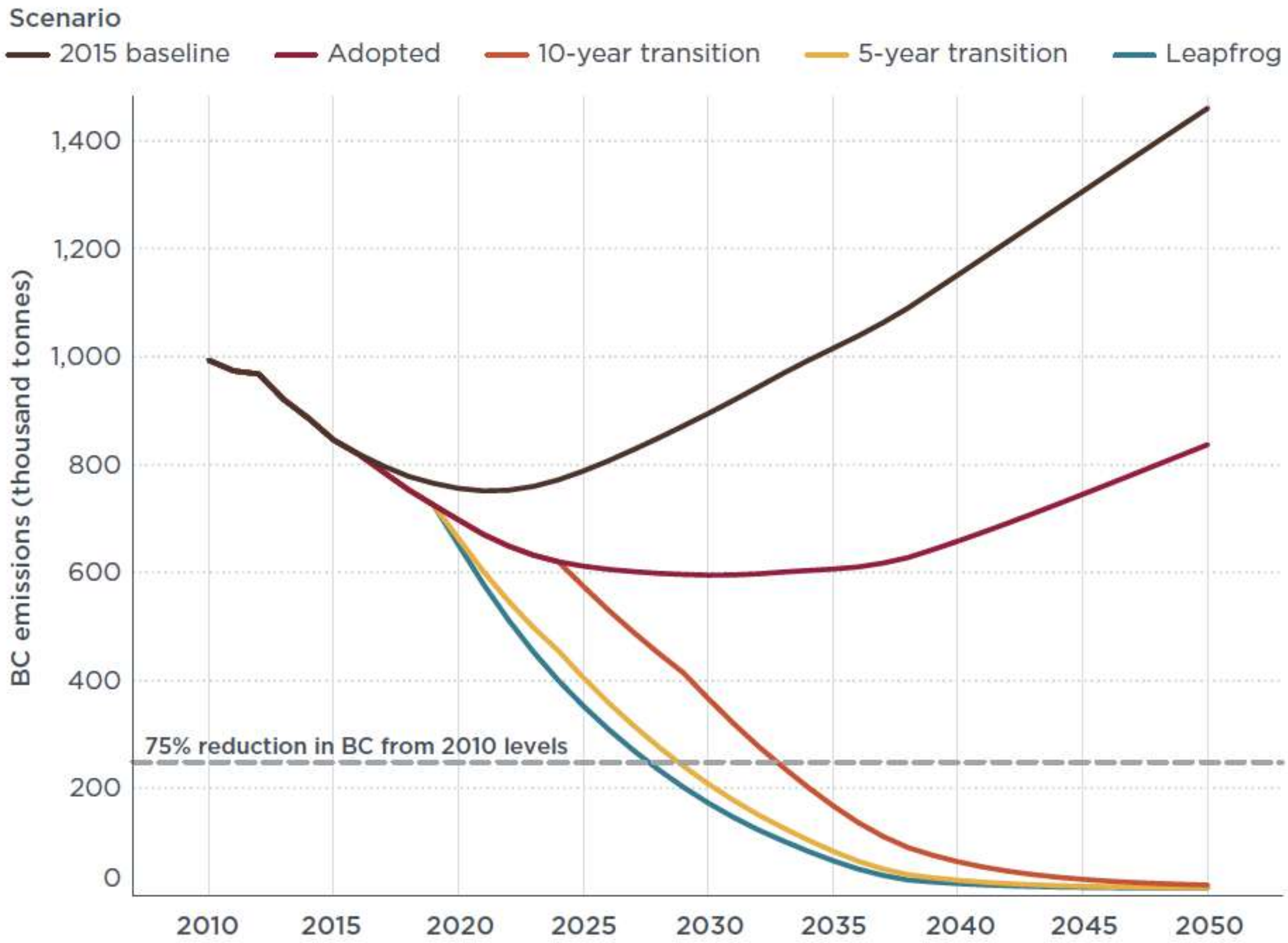
Global progress toward soot-free diesel vehicles in 2019
https://theicct.org/publications/global-progress-toward-soot-free-diesel-vehicles-2019

Estimated share of world new diesel vehicle sales and in-use stock equipped with DPFs under adopted policies in 2015, 2020, and 2025.



Global progress toward soot-free diesel vehicles in 2019
https://theicct.org/publications/global-progress-toward-soot-free-diesel-vehicles-2019

Global diesel Black Carbon emissions from light-duty and heavy-duty vehicles from 2010 to 2050

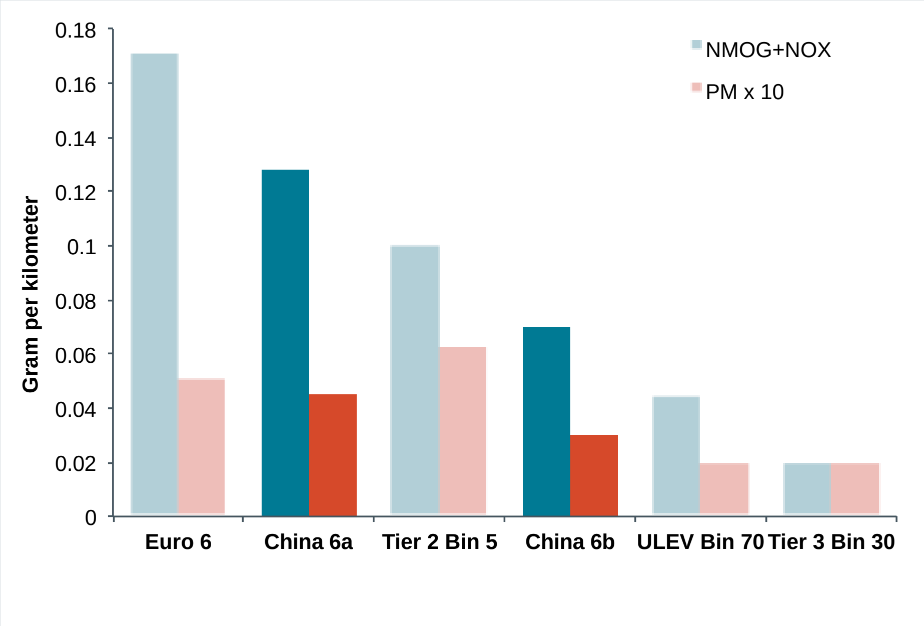


Global progress toward soot-free diesel vehicles in 2019
https://theicct.org/publications/global-progress-toward-soot-free-diesel-vehicles-2019

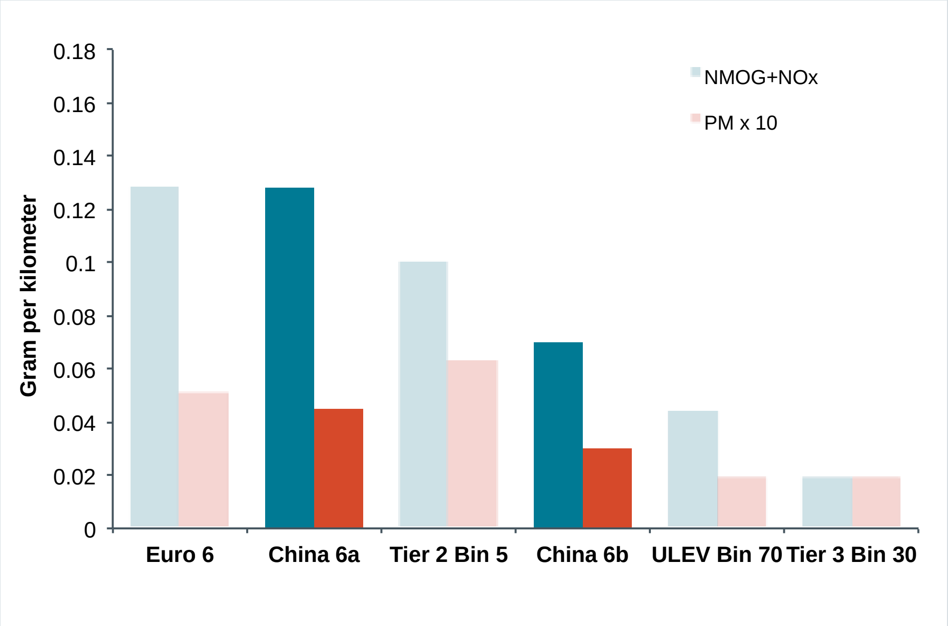
Post-Euro 6/VI standards: An opportunity for international harmonization

LDV: US and China have fuel neutral and more stringent HC/NOx limits than EU/India

Diesel Cars



Gasoline Cars



[1] Emissions limits are those for Type I test (regular temperature, cold start emission test)
[2] For diesel light-duty vehicles, Europe and China regulate HC and NOx, instead of NMOG+NOx
[3] For gasoline light-duty vehicles, Europe and China regulate NMHC and NOx, instead of NMOG+NOx
[4] This analysis simply compares direct emission limits, and does not take into consideration the differences in test cycle and procedures among various regulatory programs

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Post Euro 6/VI regulations

What to regulate	
Limits	• Introduce fuel- and technology-neutral emission limits • Tighten the emission limits to harmonize with other markets • Introduce application-neutral emission limits
Ultrafine particles	• Lower the size cutoff for particle counting from 23 nm to at least 10 nm • Develop a methodology to measure volatile and semi-volatile particles • Include emissions that occur during filter regeneration • Make particulate number (PN) standards fuel- and technology-neutral • Investigate the feasibility of PN tailpipe measurements
Unregulated pollutants	• Set limits for ammonia emissions • Set limits for CH_4 and N_2O emissions and account for them in the CO_2 standards • Set limits for aldehyde emissions • Regulate all VOCs and not just HC. • Set emission limits for brake wear particles • Consider limits for NO_2 emissions

Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union https://theicct.org/publications/recommendations-post-euro-6-eu

Post Euro 6/VI regulations

How to regulate it	
Evaporative emissions	• Tighten the evaporative emissions limit • Introduce an on-board refueling emissions standard • Increase the temperature during hot-soak, prior to the 2-day diurnal test • Introduce requirements for leak monitoring in on-board diagnostics (OBD) provisions
Low temperature test	• Low temperature emission limits should be technology-neutral • Set low temperature limits for a wider set of pollutants • Tighten the current low temperature limits • Develop a new low temperature test procedure • Monitor the greenhouse gas emissions over the low temperature test
On-road CO	• Introduce not-to-exceed limits for CO during real driving emissions (RDE) testing • Reduce the laboratory limit for CO • Introduce limitations for fuel enrichment as an auxiliary emissions strategy
Real Driving Emissions test	• Extend the upper boundary condition for RDE driving dynamics • Eliminate the lower boundary condition for RDE driving dynamics • Revise the vehicle speed requirements during RDE tests • Extend the cumulative elevation gain boundary condition • Extend the temperature range for RDE testing and revise the correction factors • Adjust trip requirements to allow shorter urban sections and cold-start driving • Remove boundary conditions that reveal that an RDE test is taking place • Eliminate the RDE evaluation factor for adjusting emissions downward

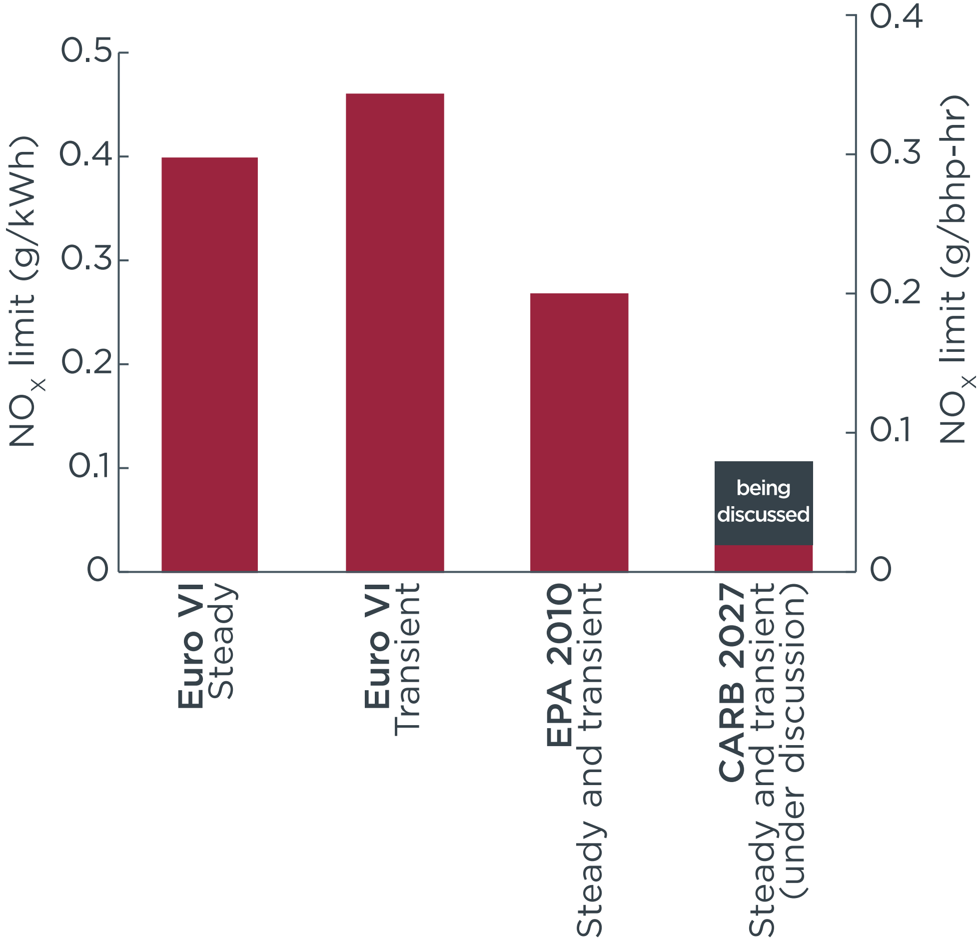
Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union https://theicct.org/publications/recommendations-post-euro-6-eu

Post Euro 6/VI regulations

How to guarantee it	
Durability	• Extend the definition of useful life for durability demonstration • Establish the whole-vehicle test as the only durability demonstration option • Extend the age/mileage requirements for in-service conformity to the full useful life • Set a minimum emission warranty program • Set an emission defect tracking and reporting program • Develop in-service conformity testing for CO_2, fuel consumption, and electric range • Develop a battery durability test
OBD and OBM	• Align on-board diagnostics (OBD) requirements with those of California and China • Introduce on-board monitoring (OBM) of pollutant emissions • Set OBD threshold limits for PN and reduce the threshold limits for other pollutants • Strengthen the anti-tampering provisions
Market surveillance	• Develop a methodology for fleet screening to identify noncompliant vehicle models • Develop a remote sensing standard and establish a database of measurements • Clarify the criteria for failure of market surveillance tests • Issue defeat device guidance • Extend the scope of market surveillance beyond pollutant emissions

Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union https://theicct.org/publications/recommendations-post-euro-6-eu

HDV: EPA'10 is cycle neutral and has lower NOx limits. CARB's plans would more than halve limits.



- The US 2010 heavy-duty engine standard limits NOx emissions to 0.27 g/kWh, 30-40% lower than the Euro VI limit.
- CARB's limits are currently being discussed. Current proposal would set ~ 0.07 to 0.11 g/kWh (FTP/SET) for 2024.
- CARB's 2027 limit will depend on technical feasibility. Program initially aimed for ~0.03 g/kWh, which is the current optional low NOx limit.

HDV: There are technologies addressing NOx and CO_2 simultaneously

Negative CO_2 impact (limited to warm up/stay warm)	Neutral to positive CO_2 impact
• Backpressure driven EGR • Post injection • Fast idle • Throttling • Passive NOx absorbers • Electric cat heating • Burners • 7th injectors • Heated urea dosing	• Closed coupled SCR • SCR on filter • Improved chemistries • Dual urea dosing • EGR, turbo, CAC bypassing • Cylinder deactivation • Stop-start • VVA • Air gap manifold • Ducted fuel injection • EGR pumps • 48 Volts mHEV • Electric boosting

MECA. (2019). *Technology Feasibility For Model Year 2024 Heavy-Duty Diesel Vehicles In Meeting Lower NOx Standards*.

BS VI Regulation and Implementation

BS VI ≭ Final Euro 6/VI even after 2023

- WLTP not adopted
- On-board fuel consumption meters not included
- Real-driving emissions (RDE) proposal not consistent with Euro 6d
    - Not clear if PN will be monitored only or confirmed
    - Conformity factors not decided
    - Cold start does not appear to be included
    - Use of reference fuel, not market fuel
    - No public dissemination of RDE data
    - No in-service conformity using RDE
- Euro VI D, and E provisions (Increased share of urban driving, cold start and PN testing during in-service conformity) not included
- Relaxed emission limits for 3-wheeler NOx

Ongoing concerns about implementation of Bharat VI standards

- Consistent fuel quality across the country
- Adequate validation of aftertreatment systems
- Overall increased cost of vehicles
- On-board usage and maintenance of aftertreatment systems.
- Nationwide distribution infrastructure & Standard grade Urea availability.
- Tampering with aftertreatment systems and on-board diagnostics
- Driver/Cleaner/Owner Awareness
- Effectiveness of compliance and enforcement programs

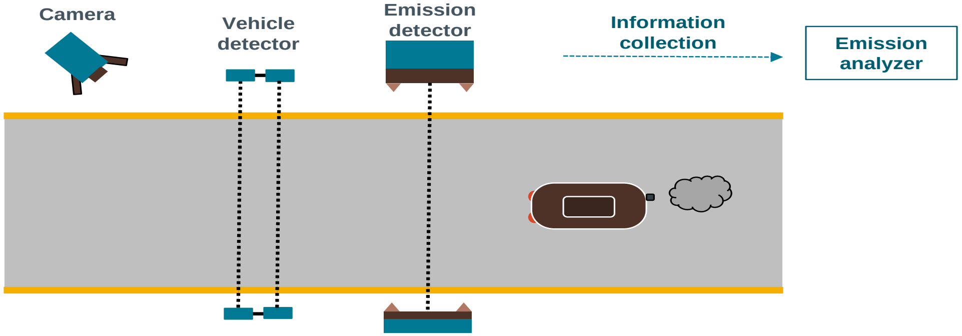
2023 and beyond agenda for vehicle emission standards in India

- WLTP should be adopted from April 2023. Compliance with RDE should be based on WLTP correlation
- Emphasis on in-use conformity and transparency needed
- Refueling evaporative emissions control needed
- Update CMVR to include use of remote sensing and OBD for in-use emissions monitoring
- Replace traditional PUC program with a combination of remote sensing, on-board emissions monitoring, and limited scale loaded tests at I&C stations
- BS VII discussions should begin now with a goal of implementation by April 2025 – National Auto Policy proposal gives a good starting point
- Target 2028 as a date for no diesel without filter through scrappage of pre-BSIV and DPF retrofits on remaining BS-IV

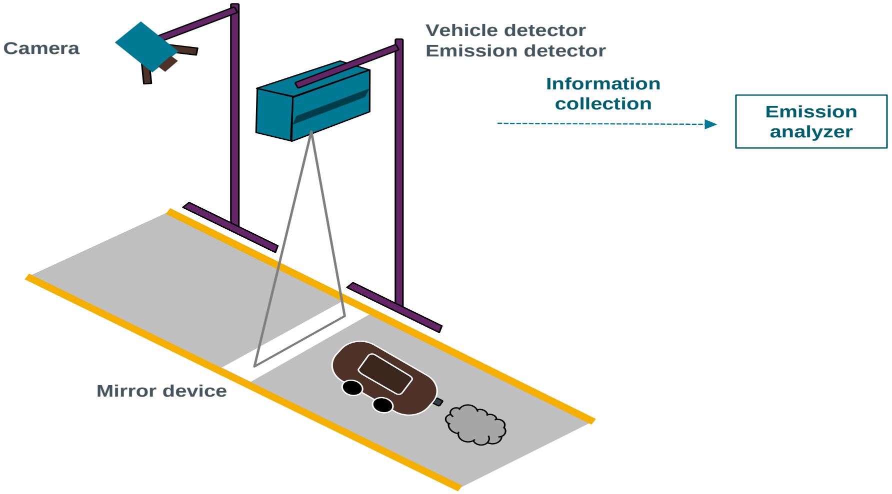
The TRUE initiative - How remote sensing technology enables cities to measure and monitor vehicle emissions

Remote sensing is a well-suited technology for unobtrusively measuring real-world emissions

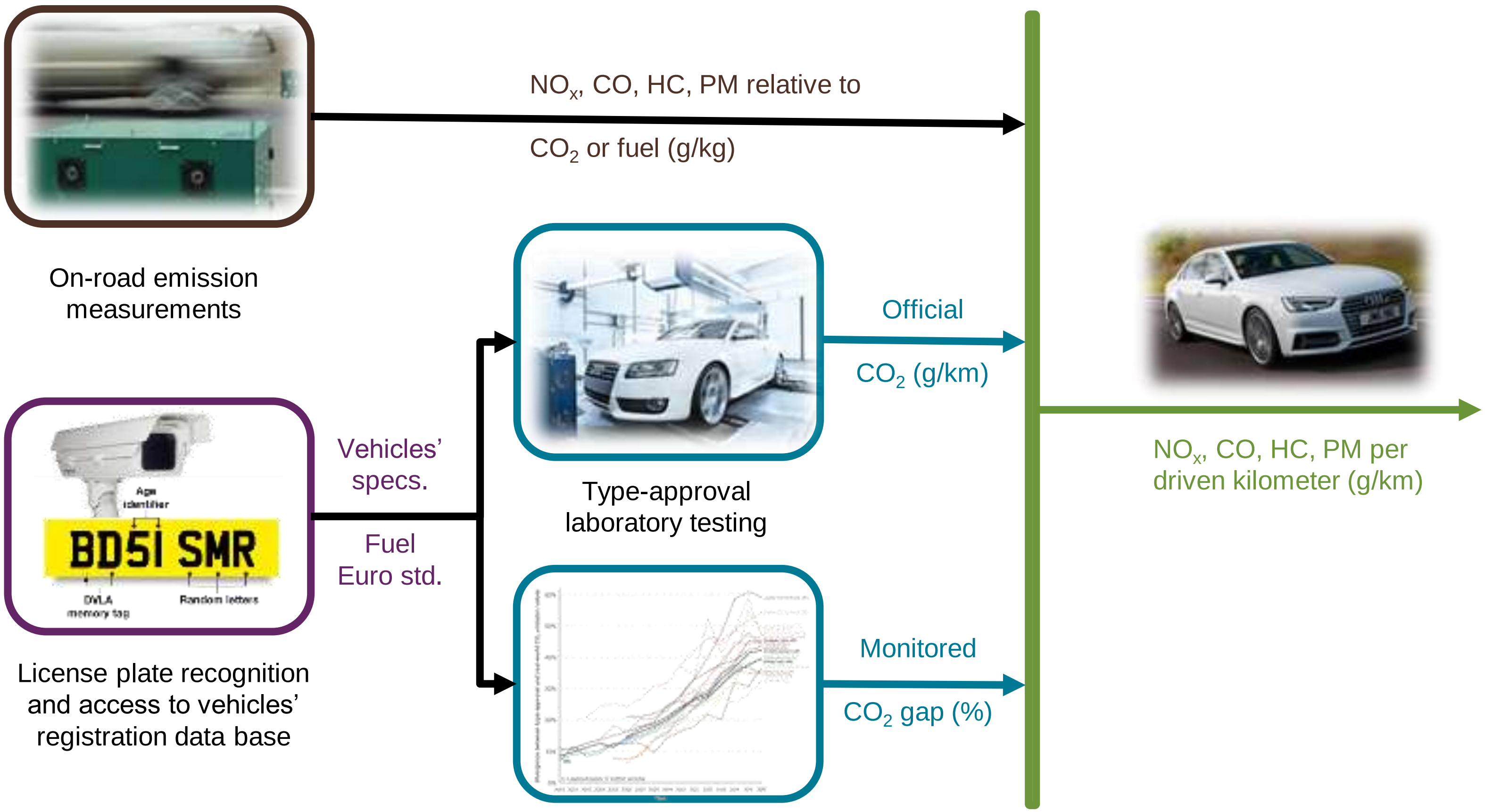
Horizontal stationary sensor



Vertical stationary sensor

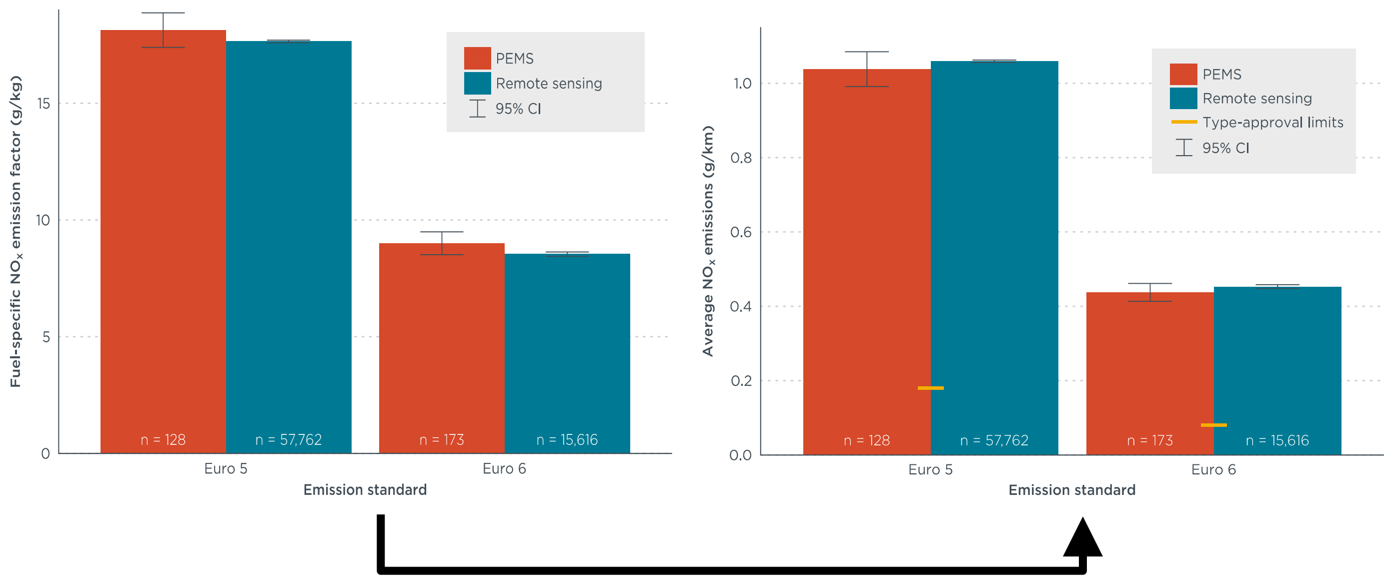


Estimation of pollutant emissions per driven kilometer with remote-sensing used in the TRUE initiative



$$pollutant\left(\frac{g}{km}\right) = mean\left(\frac{pollutant\ (g)}{fuel\ (kg)}\right) \times \frac{fuel\ (kg)}{CO_2\ (g)} \times mean\ CO_2\left(\frac{g}{km}\right) \times (1 + CO_2\ gap\ (\%))$$

Comparison of vehicle families with both PEMS and remote sensing measurements



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Fuel-specific emission factors (g/kg fuel) converted to distance-specific emission rates (g/km) using type-approval CO2 value, adjusted for real-world emissions gap

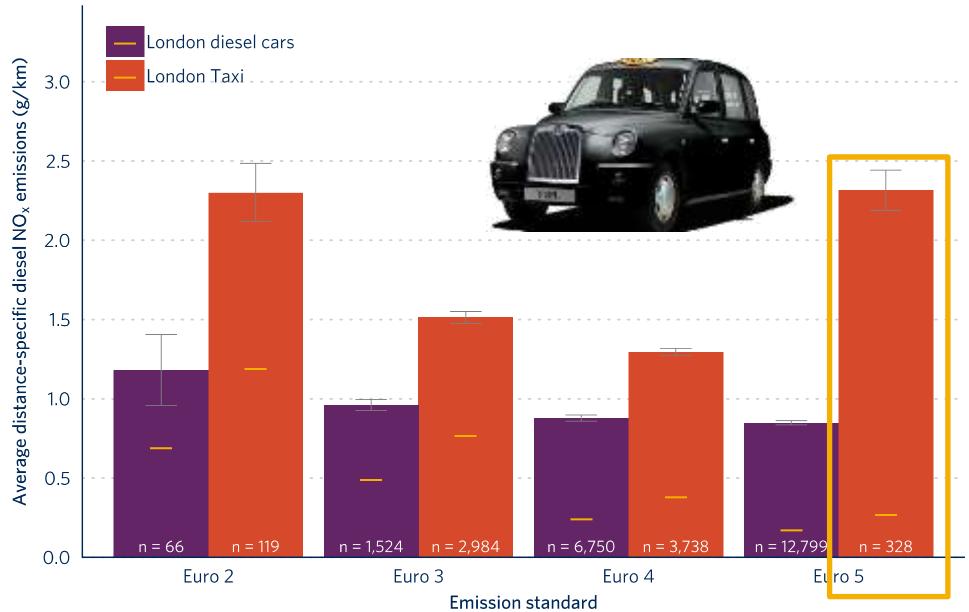
TRUE London remote sensing campaign

- Sampling over 45 days from Nov 2017 – April 2018
- 9 sampling sites throughout Greater London
- Two instruments
- Over 100,000 vehicles measured in real-world conditions

TRUE London - spotlights on special fleets

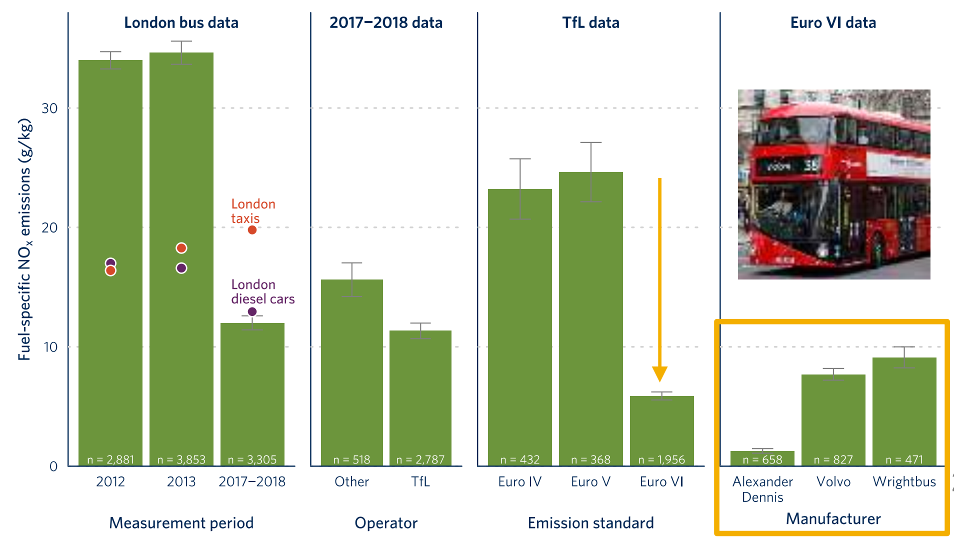
London "black" taxis

- Euro 5 NO_x are as bad as Euro 2…
- …about 10 times its type-approval value
- Similar emission level confirmed by TfL on the "London" test cycle



London buses

- Euro VI brings a 75% NO_x improvement…
- …but that varies by manufacturer
- Euro VI only are exempted from the ULEZ daily charge



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true THE REAL URBAN EMISSIONS INITIATIVE

London Mayor Sadiq Khan has announced new plans based on the TRUE study

“We know that dirty vehicles are responsible for half of our NOx air pollution – and this new data from TRUE and ICCT reveals the stark health impact of polluting diesel taxis on our streets."

New measures proposed by the Mayor and TfL:

- An enhanced delicensing fund, providing up to £10,000 for drivers who trade in their older, dirtier vehicles early
- A £2.5M fund to help drivers of newer Euro 5 taxis to convert to much cleaner LPG fuel
- A consultation early next year on a phased reduction in maximum taxi age limits for the dirtiest vehicles from 15 years to 12 years by 2022

TRUE Paris remote-sensing campaign

- Sampling over 20 days in June and July 2018
- HEAT EDAR instrument (x2)
- > 200,000 emissions measurements
- > 5,000 measurements per equipment per day

Euro 5 and 6 diesel cars account for more than 60% of total NO_x from passenger cars in Paris

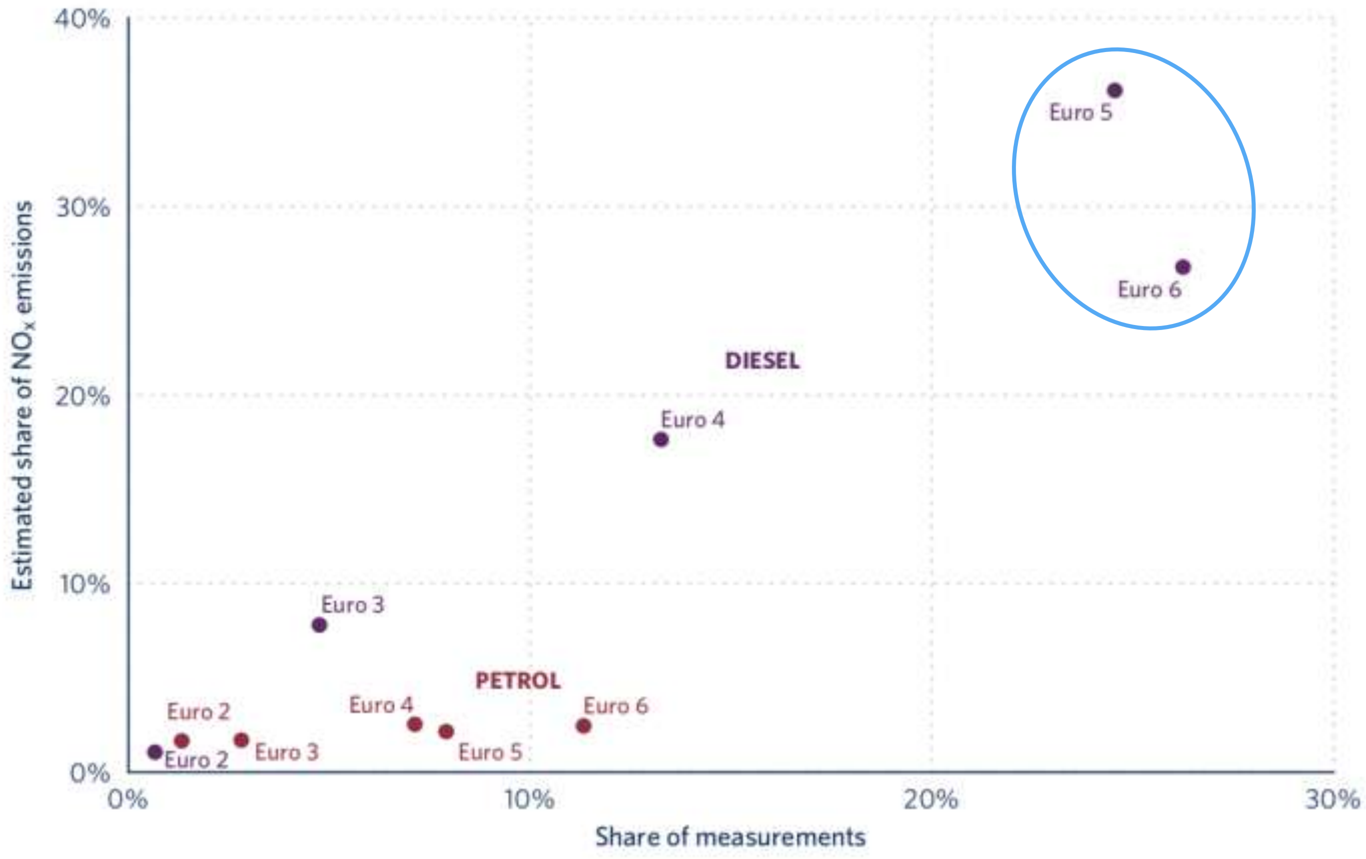

Figure 11. Estimated share of annual NO_x emissions from passenger cars and respective share of remote sensing measurements in Paris, differentiated by Euro standard and fuel type.

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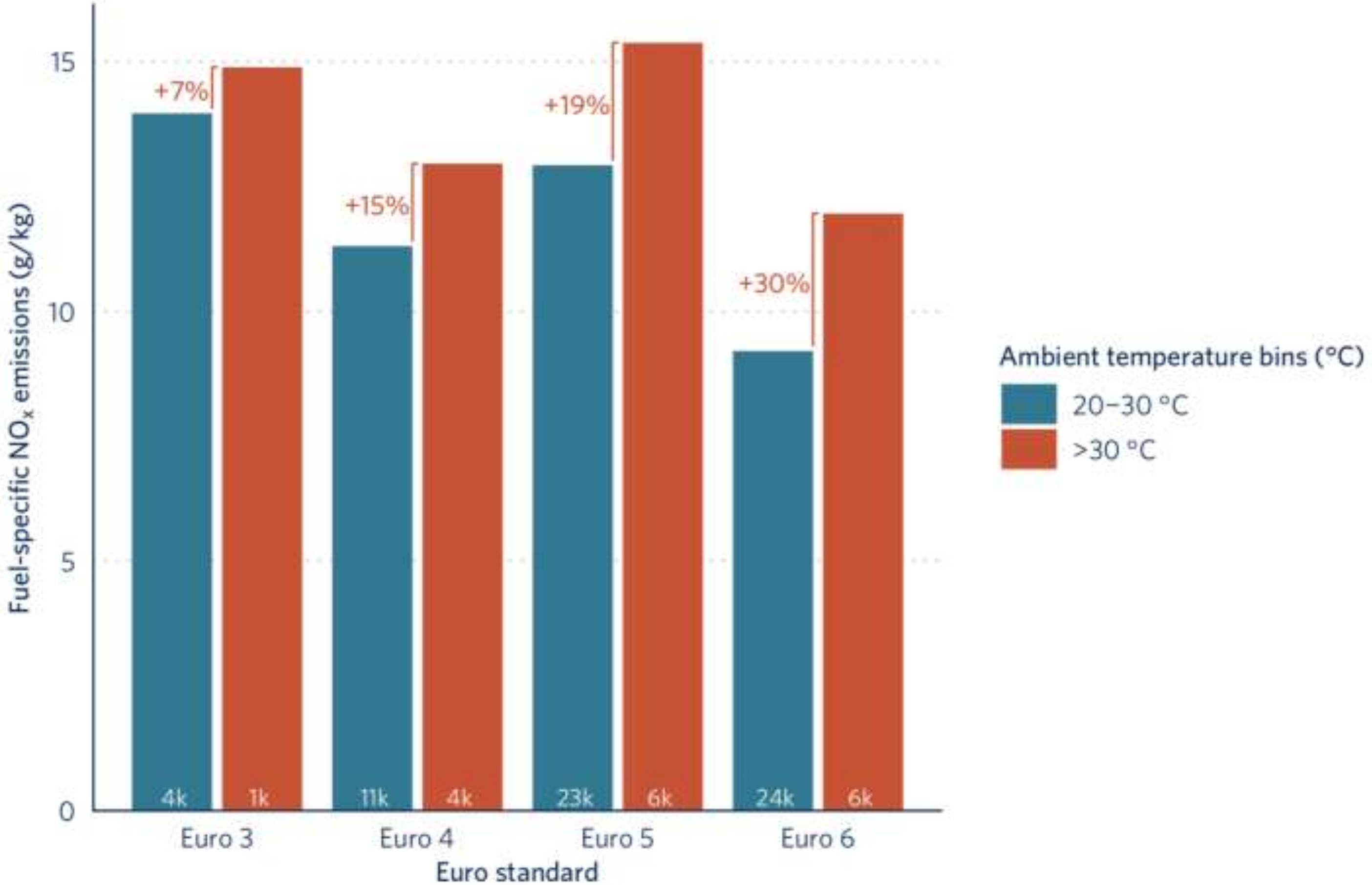
“Remote sensing of motor vehicle emissions in Paris”
www.theicct.org/publications/on-road-emissions-paris-201909

NO_x emissions from diesel passenger cars increase significantly above 30℃



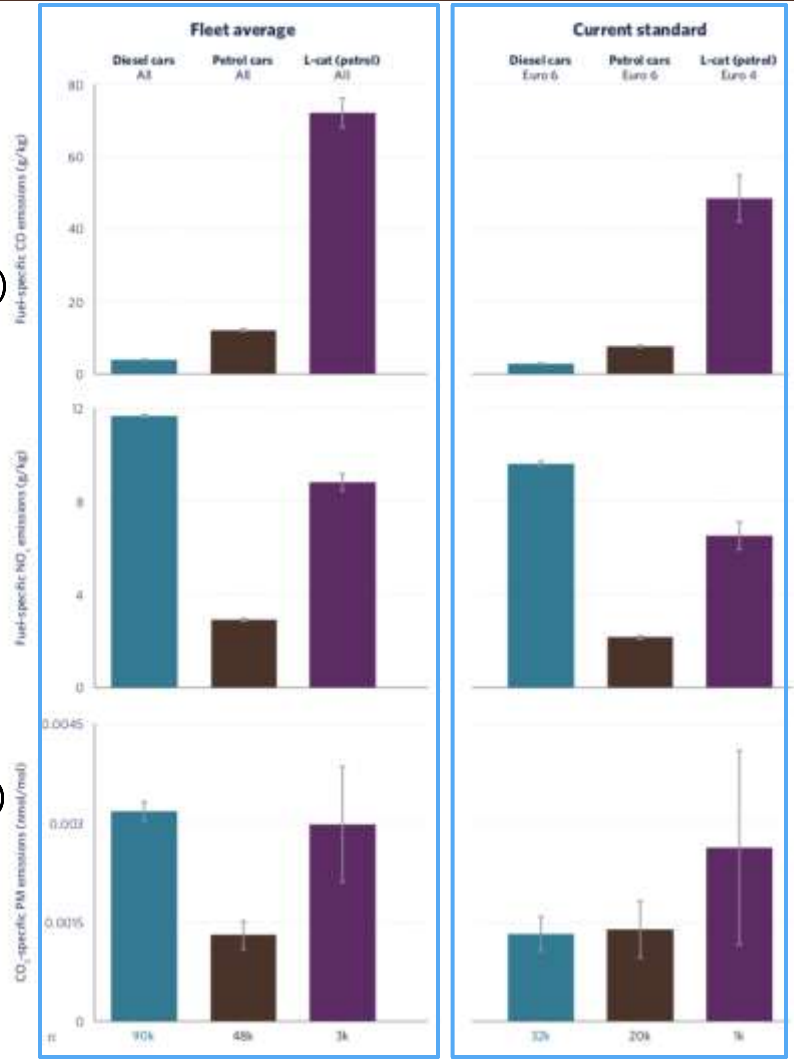
Average NOx emissions from diesel cars, in grams per kilo of fuel consumed. In hot weather, NOx emissions from Euro 6 cars were worse than emissions from Euro 4 cars at milder temperatures. The gap between in-use NOx emissions measured at ambient temperatures between 20 and 30 °C, which is the type-approval test range, and above 30 °C increases with every Euro standard, as type-approval NOx limits become more stringent.

Pollutant emissions from mopeds, motorcycles, three wheelers, and other category "L" vehicles in Paris

Carbon monoxide (CO)

Nitrogen oxides (NO_x)

Particulate matter (PM)



For a given quantity of fuel burnt

- Fleet-average emissions
  - far exceed those of diesel or petrol passenger cars (PC)
  - for NO_x and PM are closer to diesel PC than for gasoline

- The average emissions of the most recent Euro 4 standard
  - for CO are nearly 10x higher than for Euro 6 PC
  - for NO_x approximately 3x higher than those of gasoline PC

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State of the electric vehicle market

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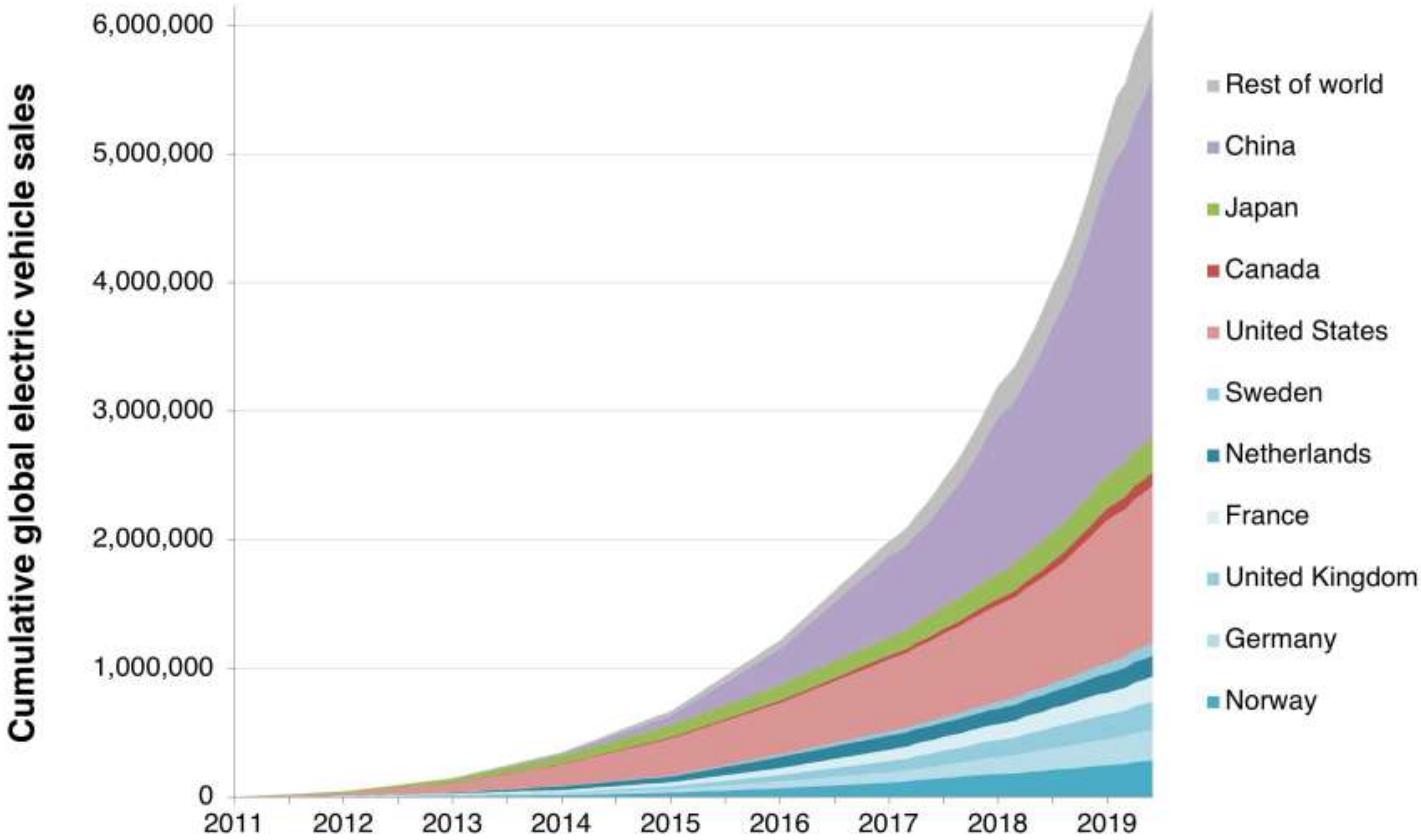
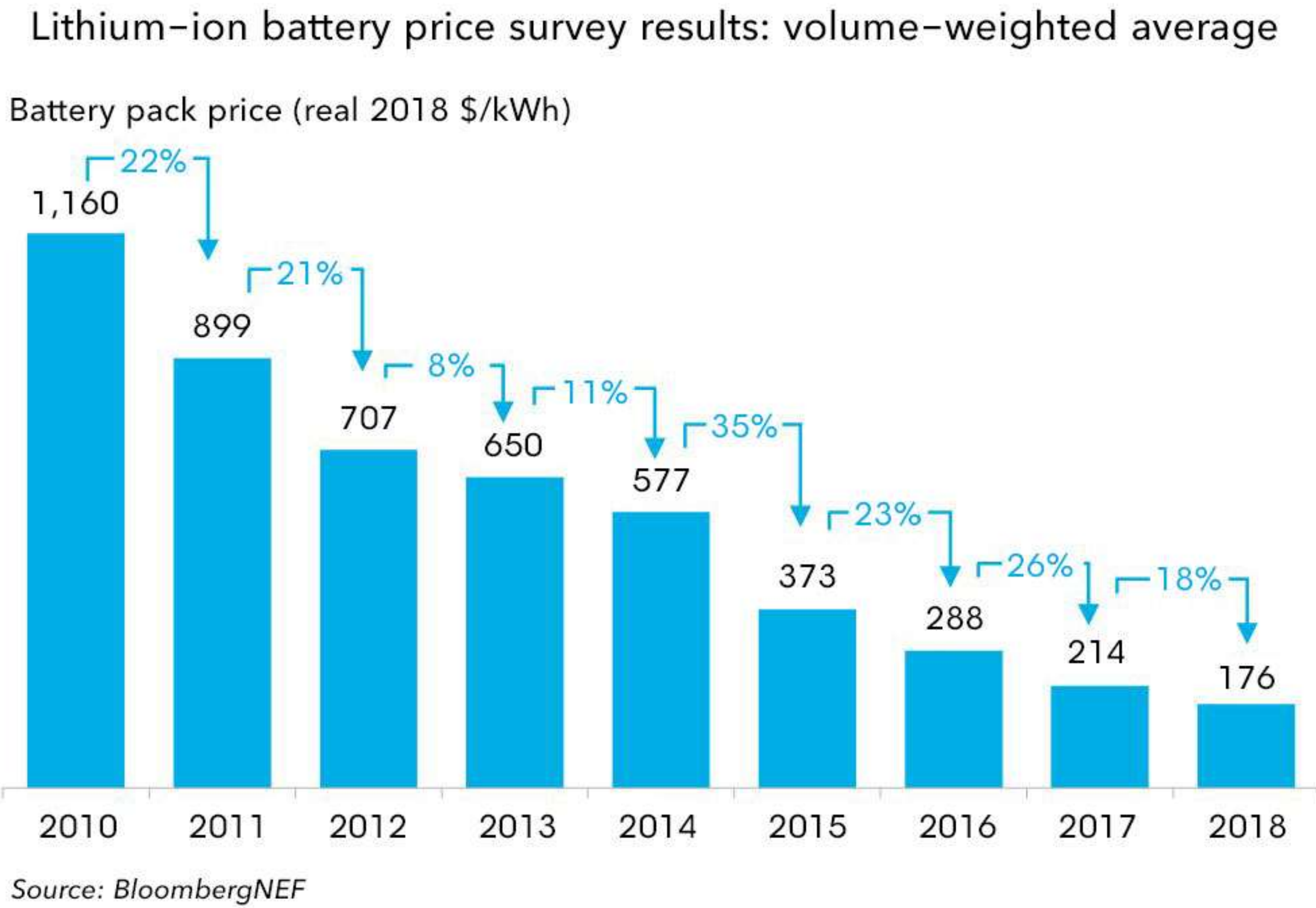
Annual electric vehicle sales jumped 80% in 2018. Cumulative EV sales are now above 6 million.



ZEV Alliance Based on ev-sales.blogspot.com and http://www.ev-volumes.com

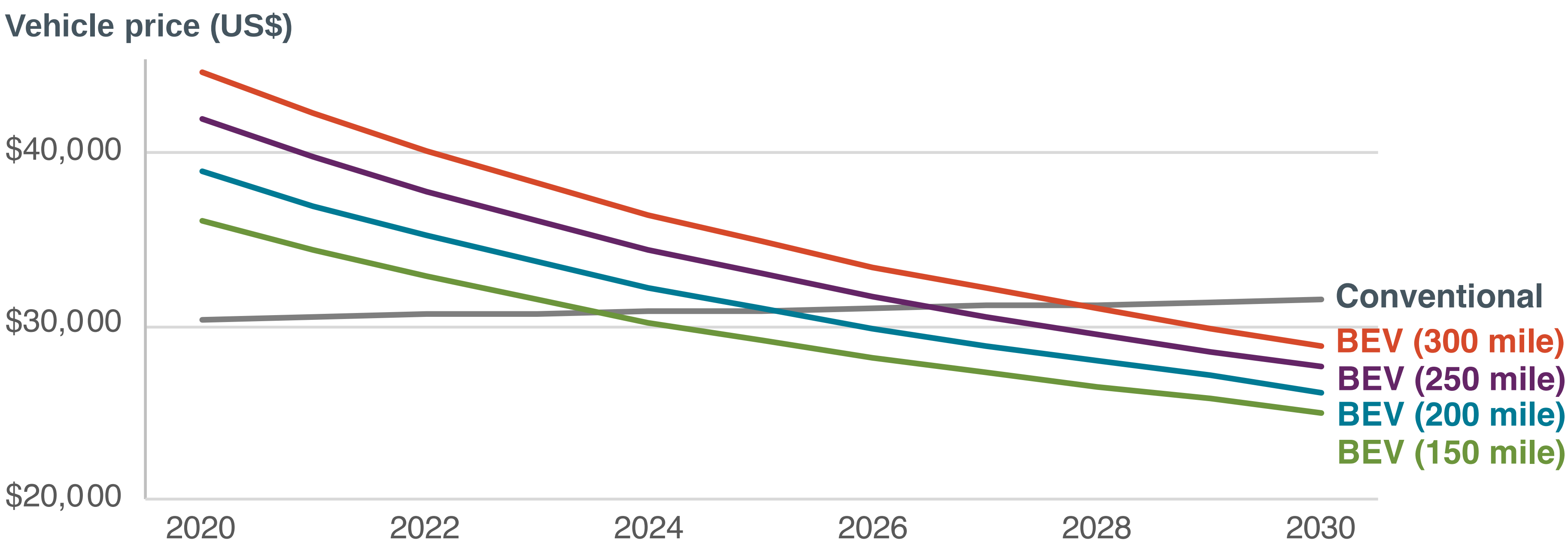
Li-ion battery prices have come down by ~80% in the last decade



https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Declining EV cost: Critical time for sustained policy

- Cost reduction → NEV "cost parity"
  - 2024-2029 for 150-300-miles electric range; Crossover/SUV parity several years later in the US context



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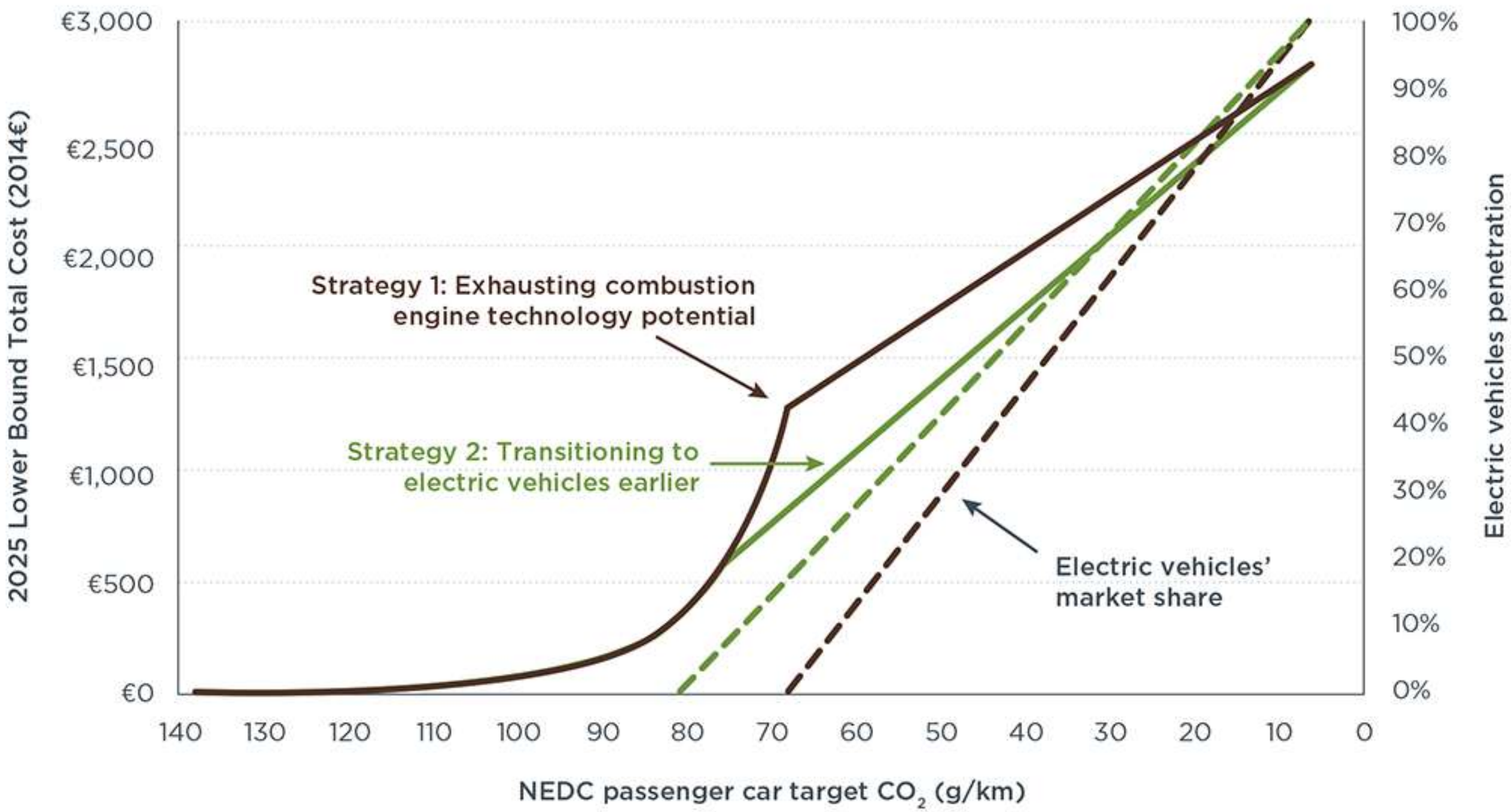
Based on ICCT, 2019. Update on electric vehicle costs in the United States through 2030.
https://www.theicct.org/publications/update-US-2030-electric-vehicle-cost

EU 2025-2030 CO_2 standards can be achieved cheaper if transitioning to electric vehicles earlier



CO_2 target (NEDC)	Total cost (2014€)		Electric vehicles' market share
	2025	2030	
80 g/km	€300 - €1,350	€250 - €1,100	4 - 17%
70 g/km	€650 - €1,900	€500 - €1,550	17 - 28%
60 g/km	€1,000 - €2,450	€750 - €1,950	30 - 39%
50 g/km	€1,300 - €2,950	€1,000 - €2,350	43 - 51%
40 g/km	€1,650 - €3,500	€1,250 - €2,750	56 - 62%

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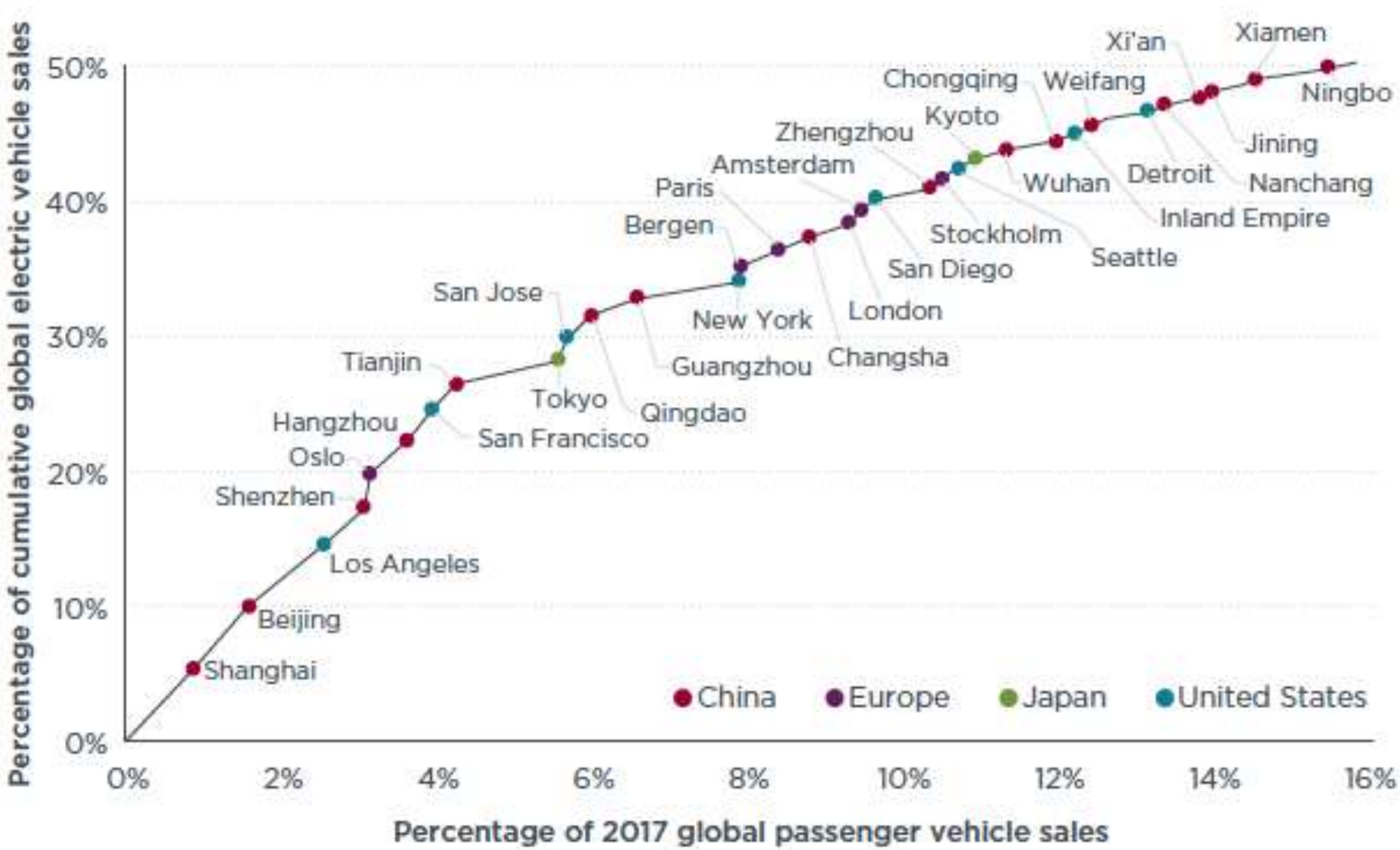
Source: http://www.theicct.org/2020-2030-co2-standards-cars-lcvs-eu-briefing-nov2016

Passenger vehicle ZEV mandates spread around the world

Government	Target year	Percentage of EV credits	ICCT estimate of percent EV sales
China	2020 2023	12% 18%	3 – 4% 5 – 7%
California (+ Sec. 177 states)	2025	22%	8 – 10%
Quebec	2025	22%	10%
Europe	2025 2030	15% 30%	5 – 10% 15 – 20%

Top 30 cities accounted for half of all passenger EV sales in 2017 (top 25 accounted for 42% in 2018)



Electric vehicle capitals: Accelerating the global transition to electric drive.
https://www.theicct.org/publications/ev-capitals-of-the-world-2018

Electric mobility landscape in India

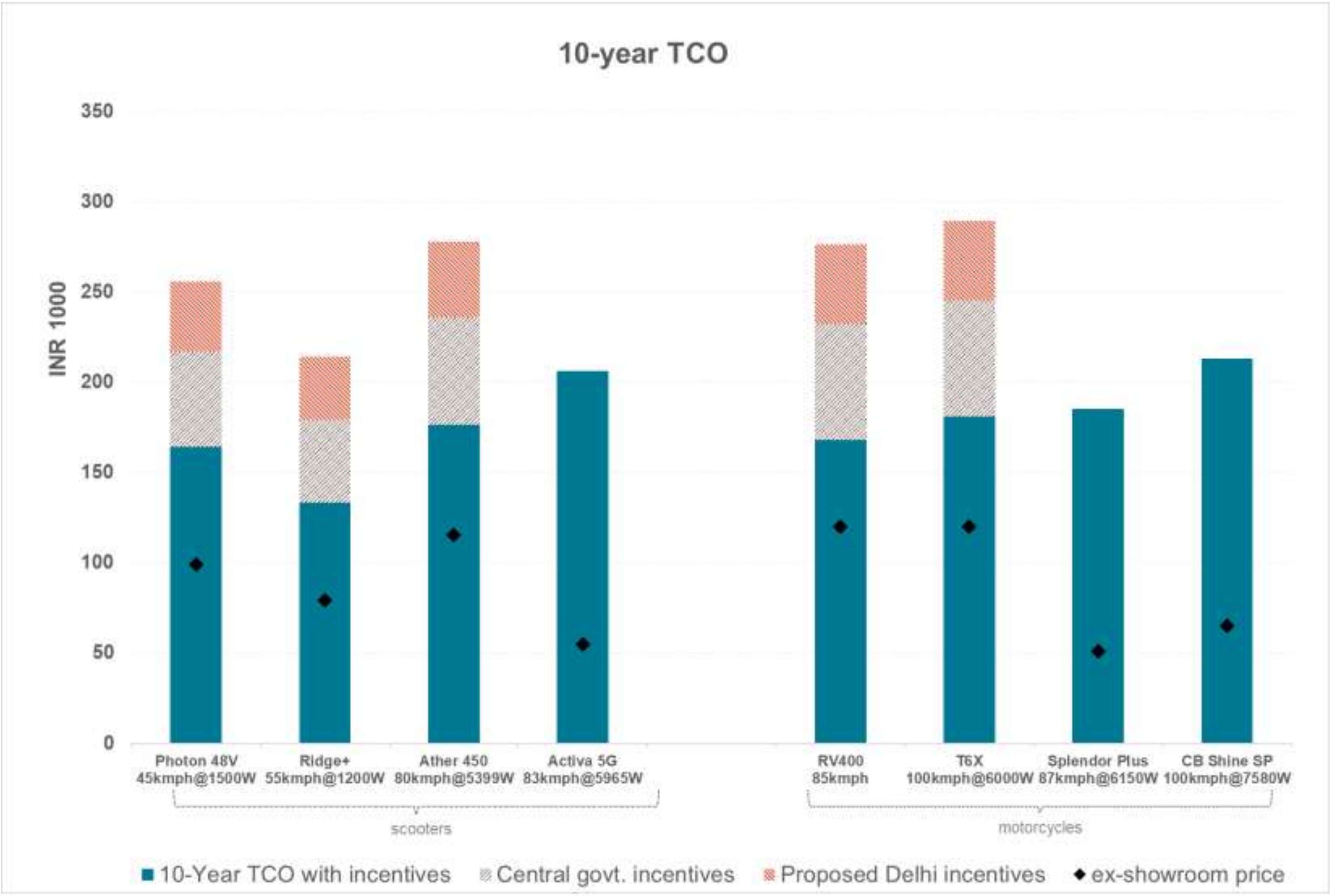
Measurable progress has been made on policies to promote vehicle electrification in India

- Fiscal incentives
  - Faster Adoption and Manufacturing of Electric Vehicles (FAME-II) -- $ 1.4 billion over three years
  - Goods and service tax (GST) on EVs, chargers, and charging stations reduced to 5%
  - Exemption from additional compensation cess (1% to 15% for conventional vehicles)
  - Import duty on critical EV components such as on-board chargers has been waived
  - Income tax deductions up-to INR 1.5 lakh (~$2100) on interest paid on EV loans
  - 15% discount in comparison to conventional vehicles towards mandatory third-party insurance
  - Waiver in registration fees for EVs proposed
  - Road tax waiver and additional fiscal incentives proposed in several states including attractive electricity tariffs for EV chrging stations

Measurable progress has been made on policies to promote vehicle electrification in India

- Non-fiscal incentives
  - Central Electricity Act amendments to allow resale of electricity by third party at charging stations
  - Green license plates for EVs
  - Waiver from permit requirements for commercial applications
  - Amendments to model building by-laws of 2016 to assist states to incorporate adequate EV charging infrastructure into respective byelaws
  - National Mission on Transformative Mobility and Battery Storage to support localization of entire EV value chain
  - Multiple states offering priority allotment of land for EV-component manufacturing, R&D support, and development of vocational training programs

Total cost of ownership (TCO)
Electric scooters and motorcycles vs. conventional models



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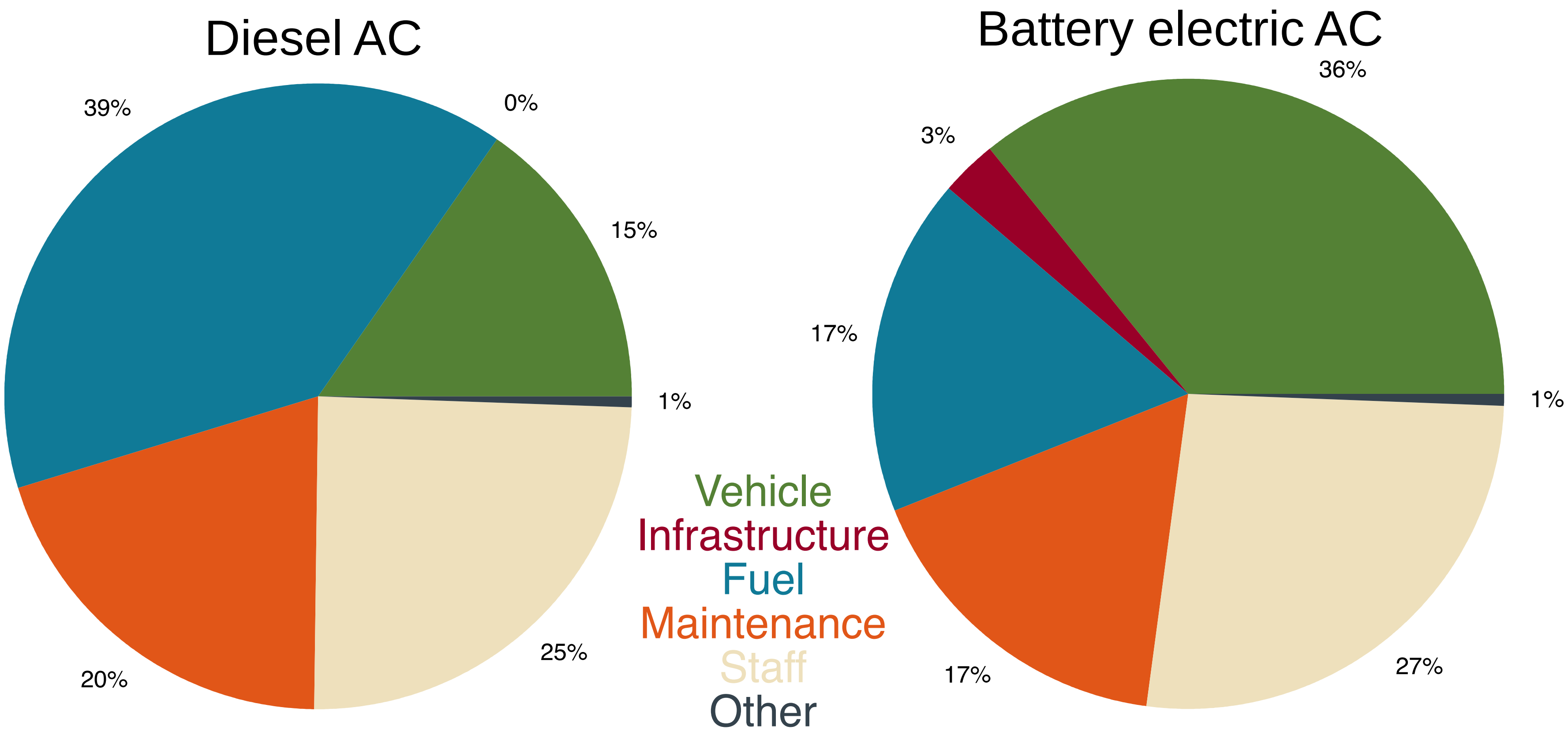
Cost breakdown for representative bus route



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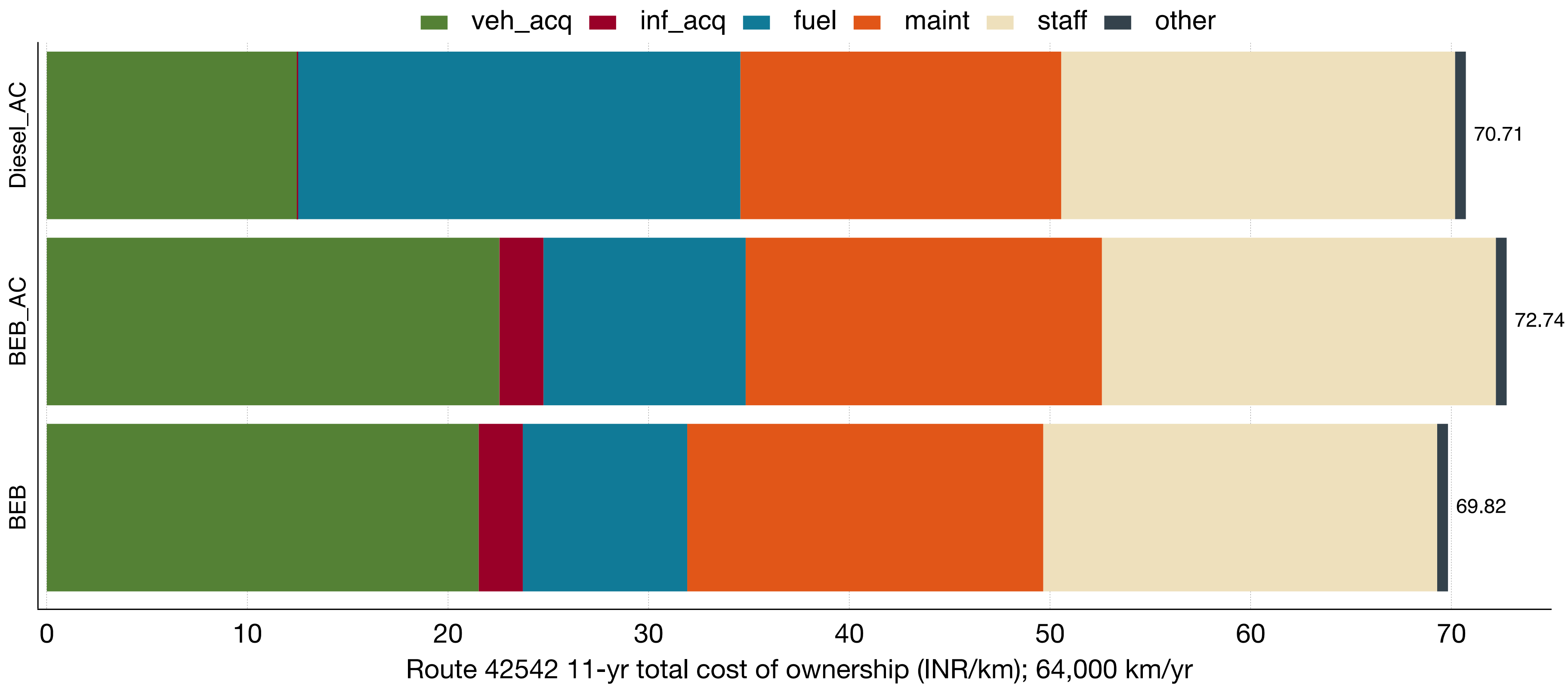
Electric buses are beginning to reach total cost of ownership (TCO) parity already



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Scenarios for transport decarbonization in India

Current status of policies to reduce GHG emissions from road transport

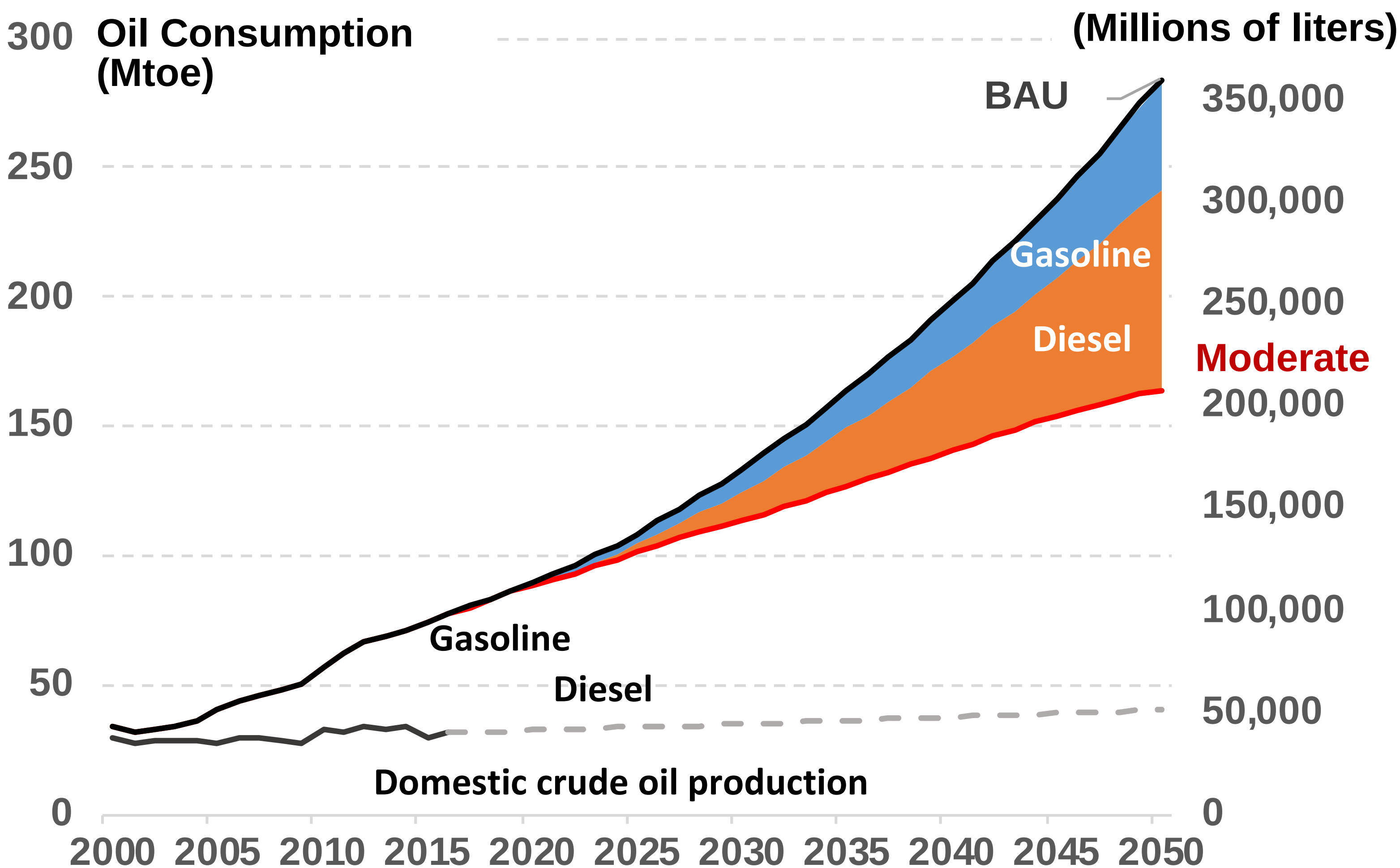
Policy		Progress
Vehicle fuel efficiency standards	The first PV fuel efficiency standards: 130 gCO_2/km in 2017-18 and 113 gCO_2/km in 2022-23	2017-18 new vehicle average fuel efficiency: 5.1 l/100km or 121 gCO_2/km; on par with EU-28 due to smaller, lighter, and less powerful vehicles
	The first HDV round of fuel efficiency standards adopted on 2017-2018, but not being implemented	Current new vehicle average fuel efficiency: 650+ gCO_2/km
Electric vehicles	Lower GST[1] rates for EVs	A 5% tax rate for EVs (compared with 28% plus cess (1% to 15%) for petrol and diesel cars and hybrid vehicles)
	FAME[2] scheme for hybrid and electric vehicles	More than 278,701 vehicles participated (by mid-April 2019) FAME-II until 2021-22, with a total of 10,000 Rs Crore funding ($1.4 billion)
	Central government's leading actions	Several hundred EVs are purchased for government cars, with potential to expand Waiving registration fees and permitting requirements for EVs
Energy diversity	20% bioethanol blending targets 5% biodiesel blending targets	The ethanol blending percentage in petrol is ~ 5.8% (~$3 billion revenue in 2019), and biodiesel blending percentage in diesel is ~0.14%
	CNG fleet	More than 3.3 million CNG vehicles reported as of April 2019

1. GST: goods and services tax
2. FAME: Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles

Key assumptions in two plausible scenarios

	BAU	Moderate	Ambitious
Fuel efficiency（FE)	PV FE standard adopted HDV FE standard adopted	1-2% annual improvement between 2020-2050	1-5% annual improvement between 2020-2050
Zero emission vehicles (ZEVs)	<1% in 2017	Up to 50% ZEV share in 2050	Up to 100% ZEV share in 2050
Biofuel blending[1]	2.5% bioethanol 0.5% biodiesel	10% bioethanol in 2030-50 1.5% biodiesel in 2030-50	20% bioethanol in 2050 5% biodiesel in 2050
Electrical grid upgrade	820 gCO_2/kWh	500 CO_2g/kWh in 2030	266 CO_2g/kWh in 2050
1. The biofuel blending targets are set based on the sustainable feedstock capacity			

Transport oil demand doubles in moderate scenario



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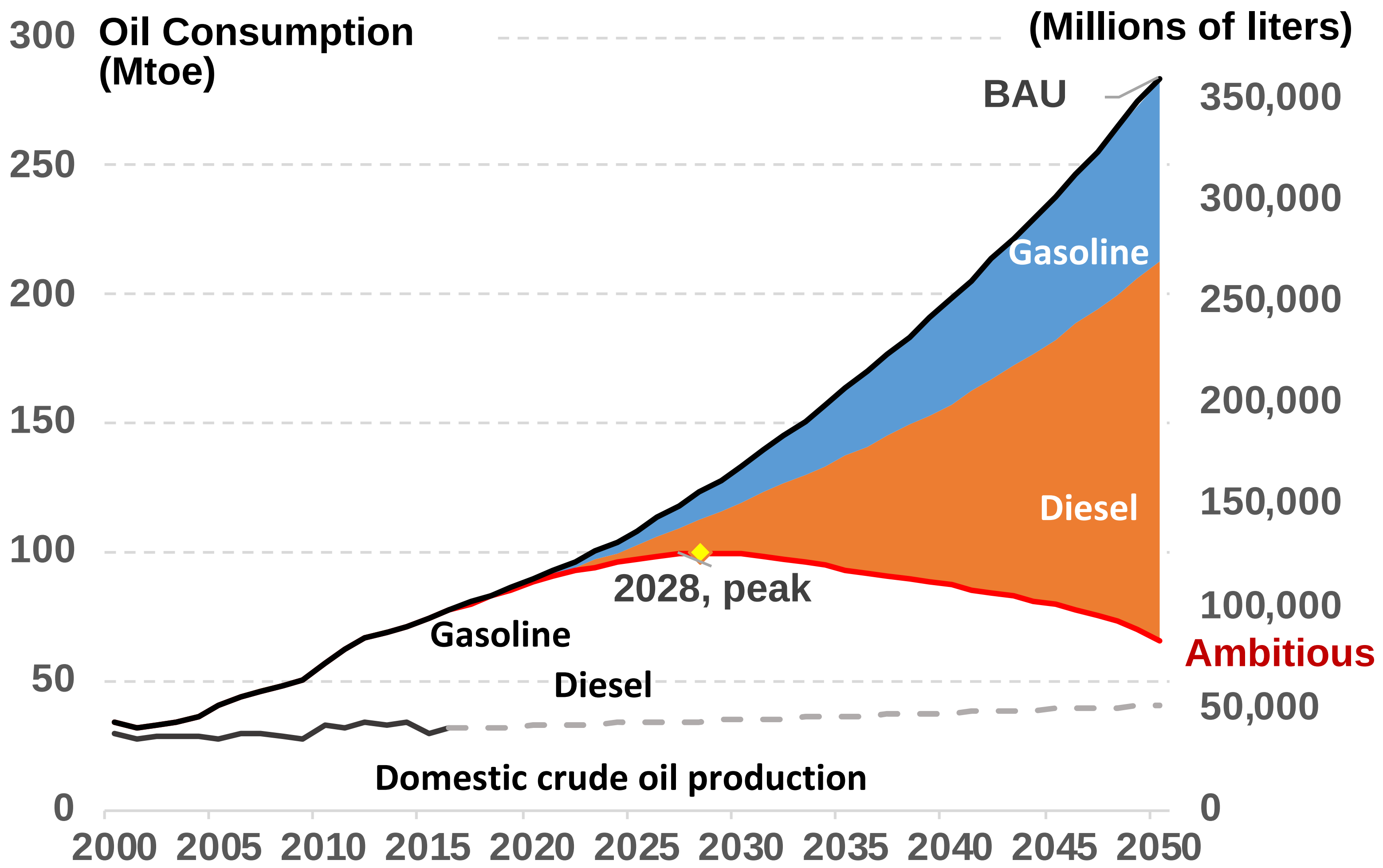
Transport oil demand can peak within a decade with ambitious action



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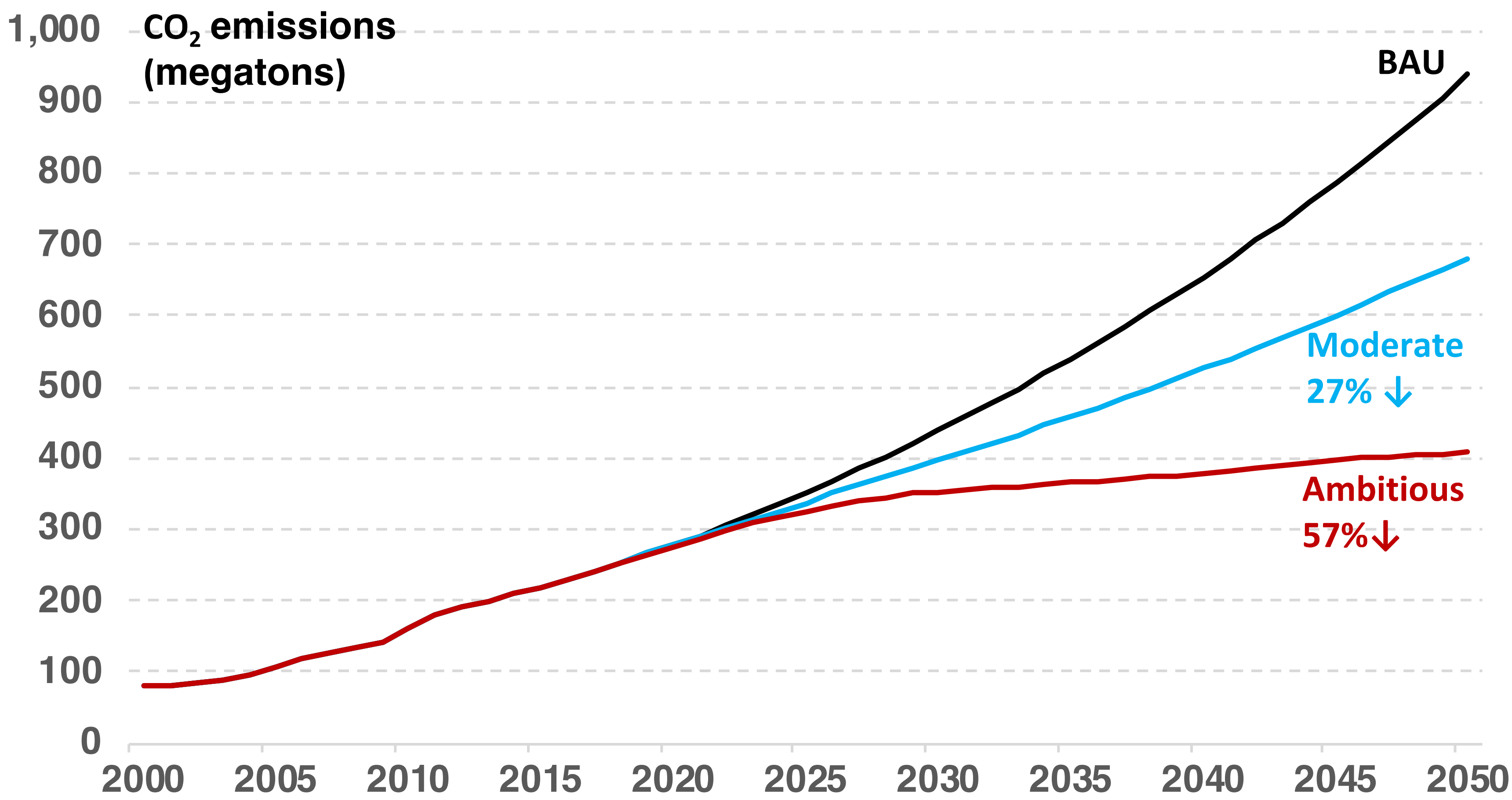
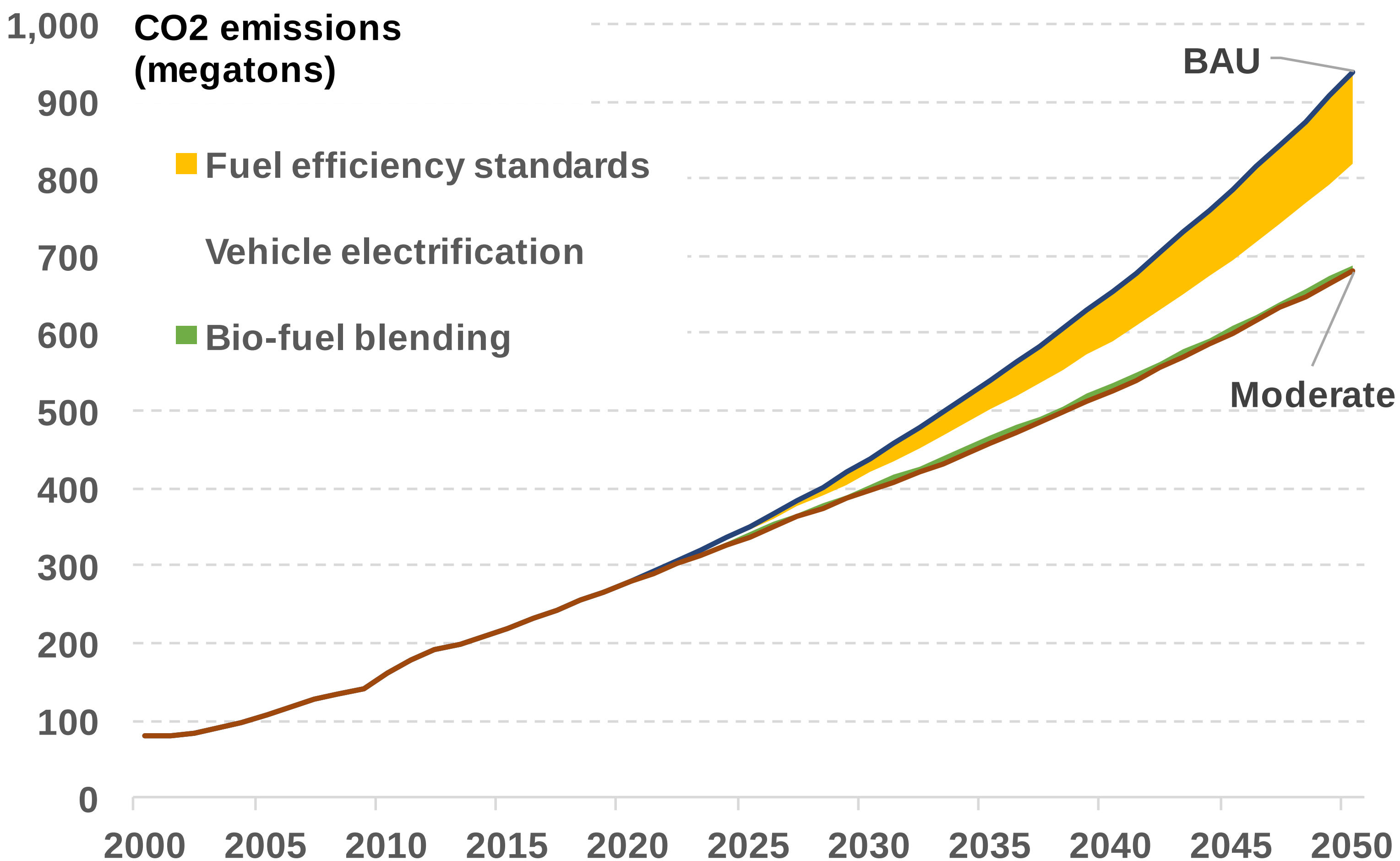
India's CO_2 emission could stabilize in mid-century with aggressive action



Fuel efficiency standards and vehicle electrification work together in India's sustainable energy trajectory (Moderate Scenario)



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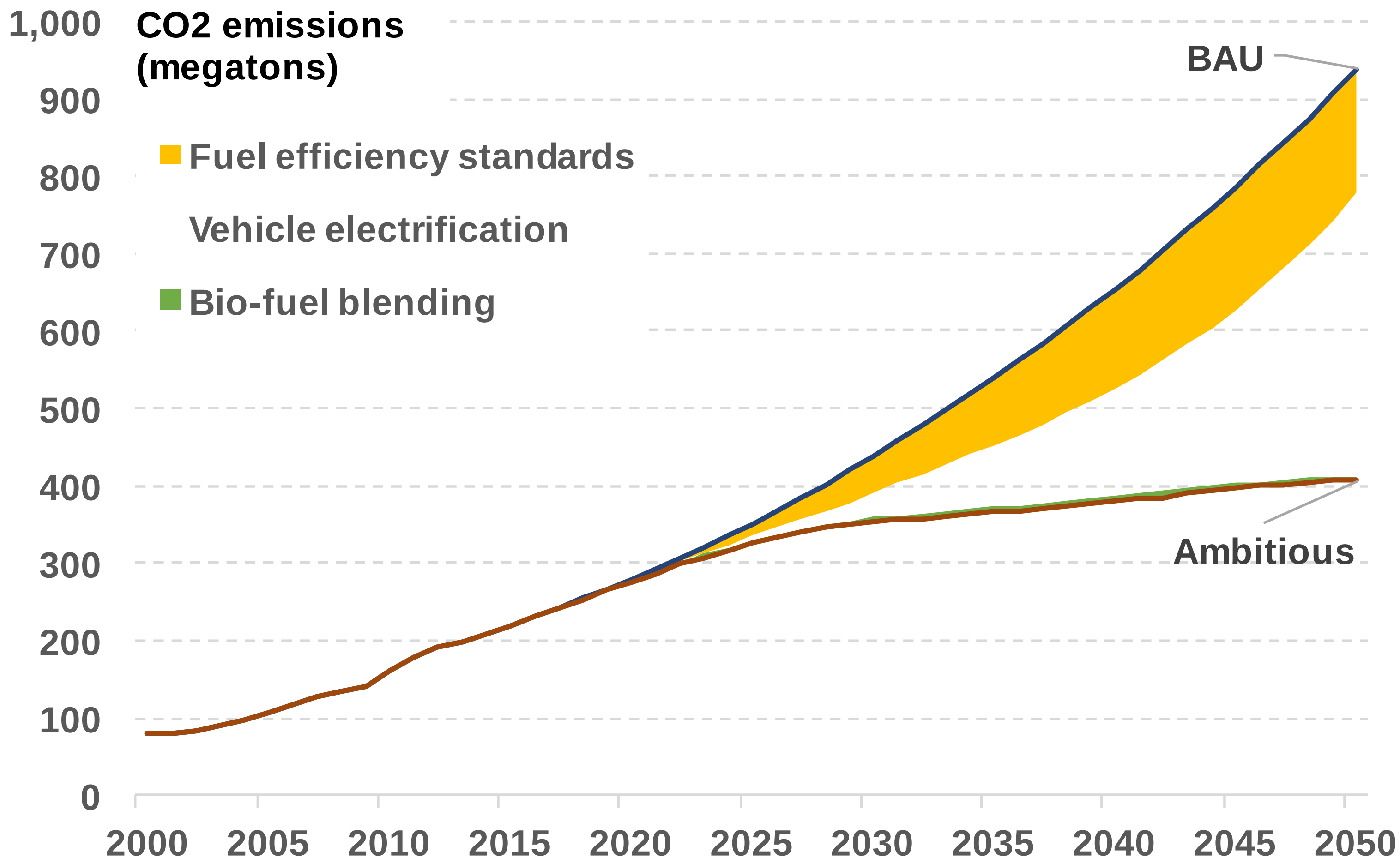
EVs play a critical role in containing India's transport GHG emissions (Ambitious scenario)



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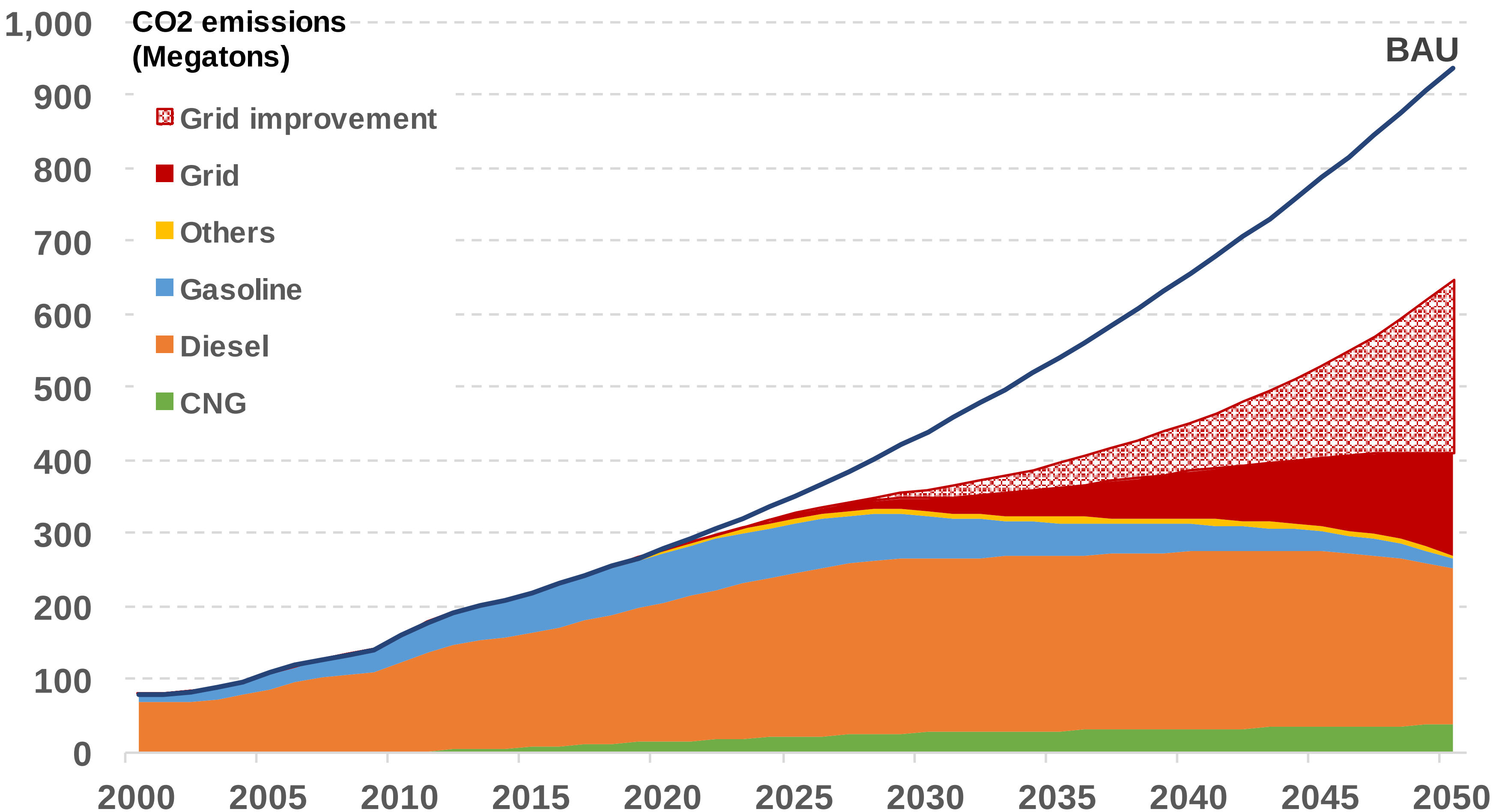
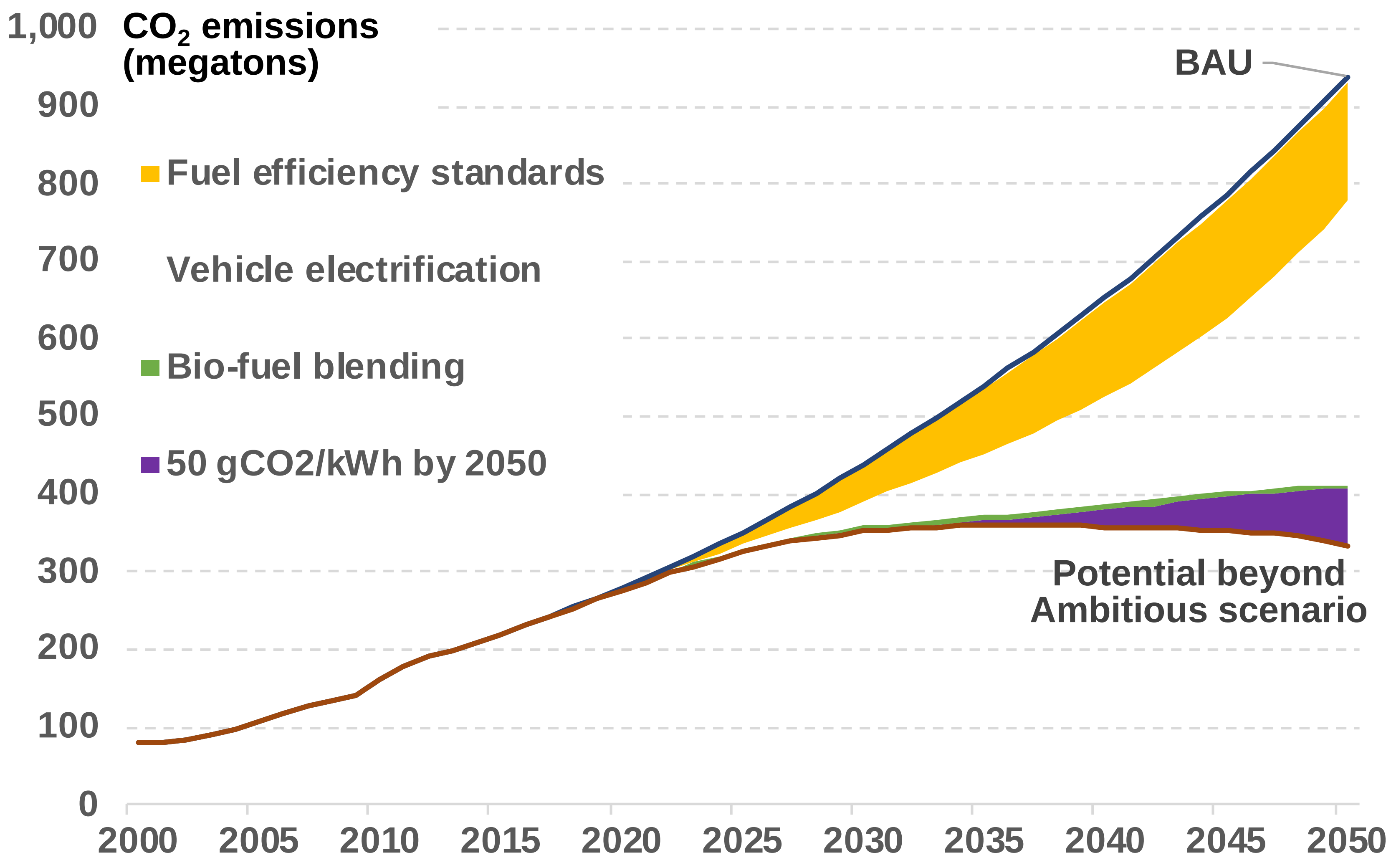
Decarbonization of the grid plays a key role in the success of vehicle electrification



Ultra-low carbon grid by 2050 offers even greater GHG reduction opportunity in transport sector



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One plausible scenario of decarbonization in India

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India Low Carbon Growth Scenario

	BAU	Low Carbon Growth
Fuel efficiency (FE)	PV FE standard adopted HDV FE standard adopted	1-5% annual improvement between 2020-2050
Zero emission vehicles (ZEVs)	<1% in 2019	Up to 100% ZEV share in 2050
Biofuel blending[1]	2.5% bioethanol by 2030 0.5% biodiesel by 2030	20% bioethanol in 2050 5% biodiesel in 2050
Electrical grid upgrade	820 gCO_2/kWh	266 CO_2g/kWh in 2050

1. The biofuel blending targets are set based on the sustainable feedstock capacity

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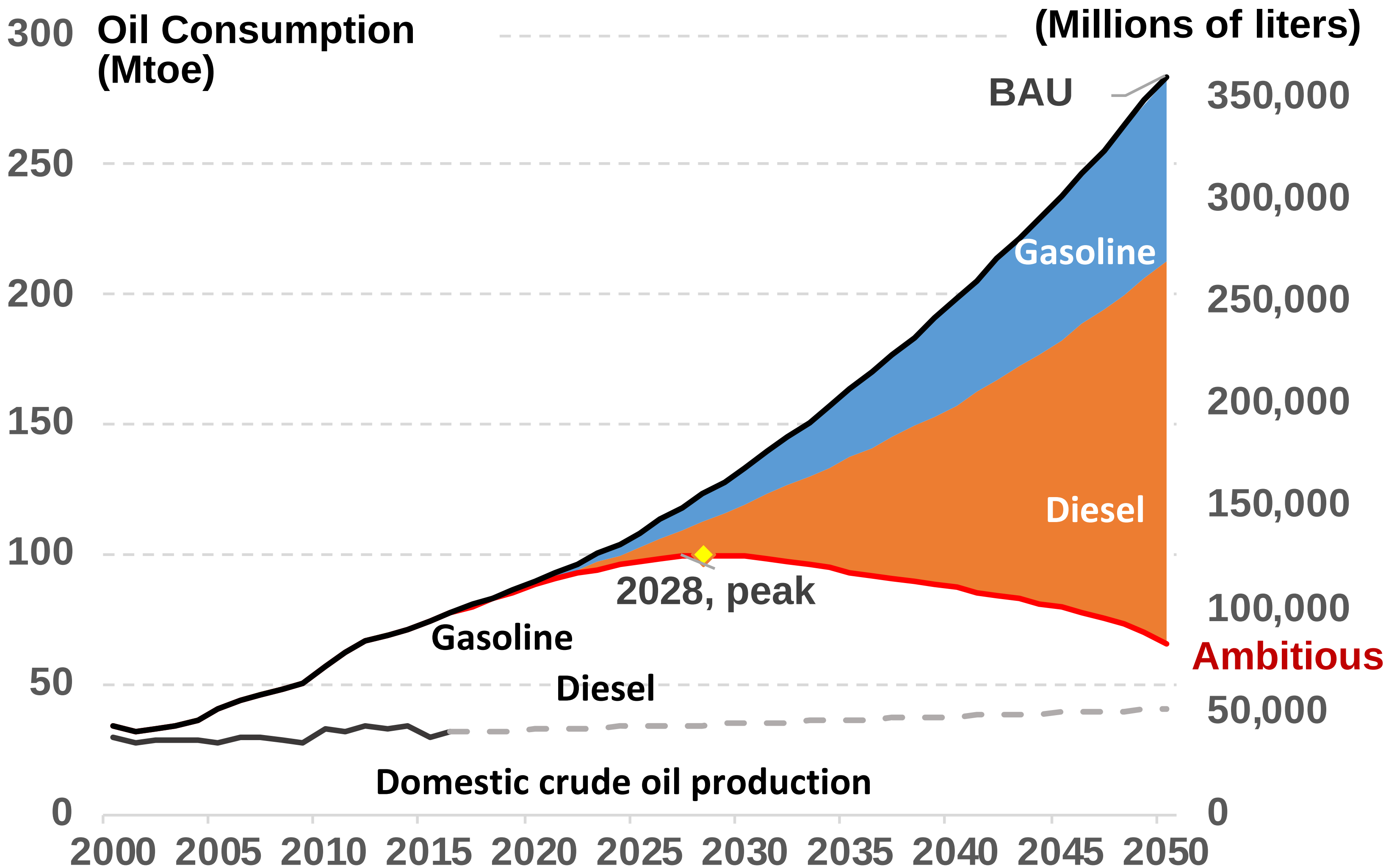
Transport oil demand can peak within a decade with ambitious action



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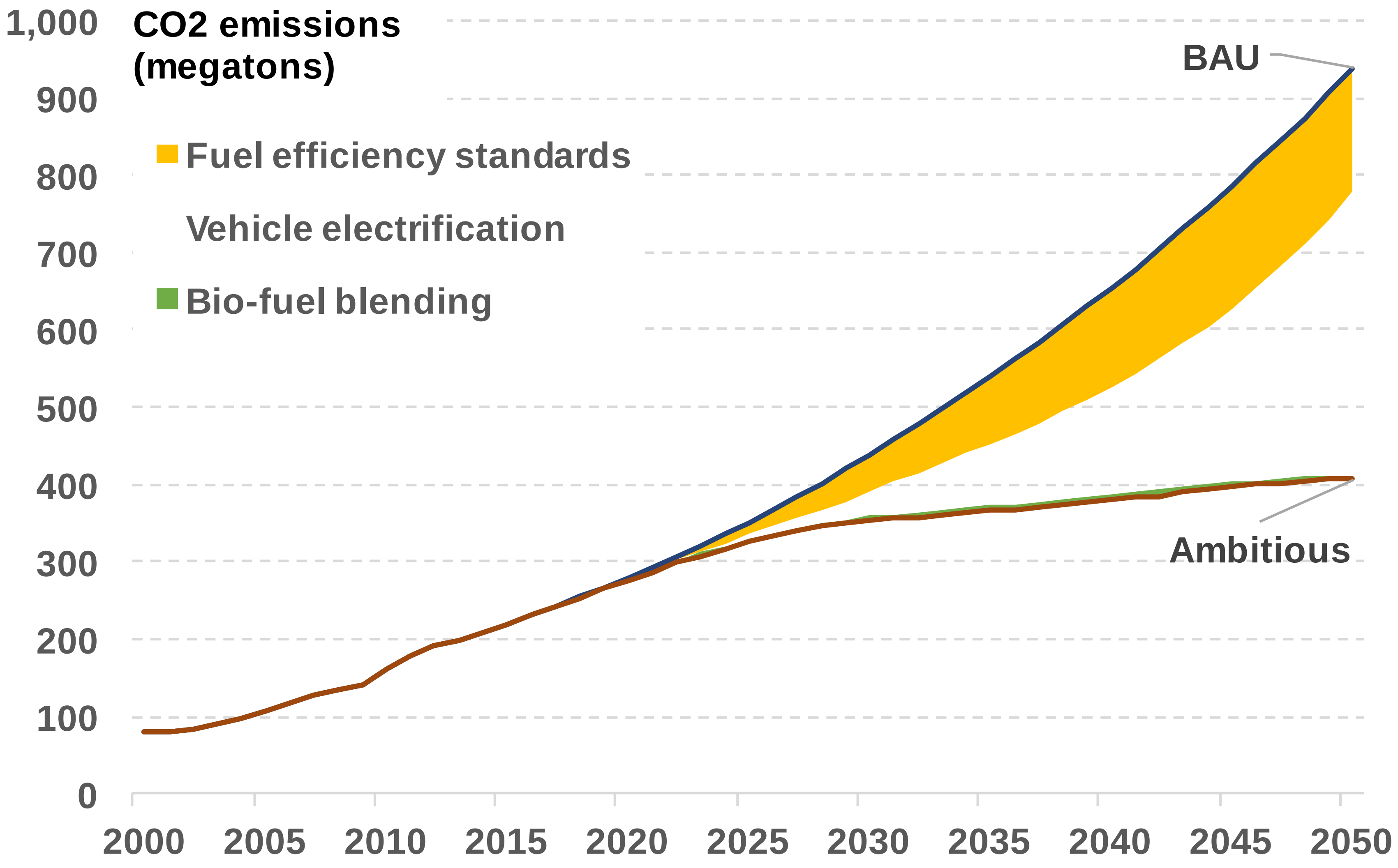
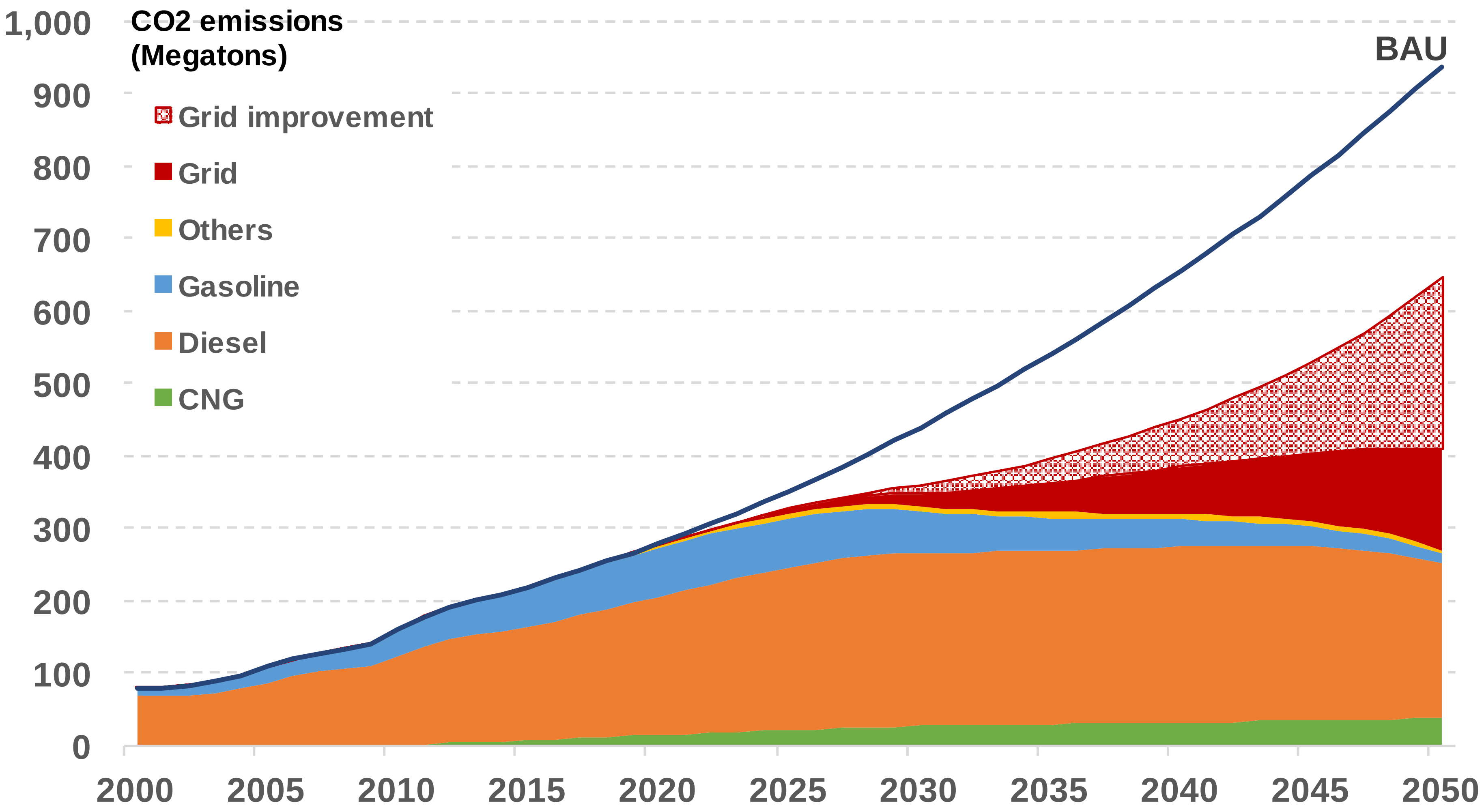
Vehicle Electrification plays a leading role in India's sustainable energy trajectory for long-term



Decarbonization of the grid plays a key role in the success of vehicle electrification



Summary

Transportation Air Pollution and GHG Challenge is daunting, but is creating many opportunities.

- Tremendous progress in ultra-low sulfur fuel availability around the world – Euro 6/VI equivalent norms following
- Major opportunities to reduce vehicle emissions (tailpipe, evaporative, brake and tire wear) still remain, and leading policies around the world (US Tier 3, EU Post Euro 6, CARB HDV Low NOx) being proposed or adopted
- Major compliance and enforcement challenge still remaining in much of the world including United States and EU
- Vehicle electrification is progressing faster than most of us expected just a few years ago – embrace the change
- Stronger fuel efficiency standards needed to mitigate near term GHG and oil usage; stringent efficiency standards ultimately promote electrification as well
- Technology opportunities to address India’s petroleum use, vehicular air pollution are plentiful – good for business, good for the economy, and good for environment and public health.

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Implementation status of soot-free heavy-duty engine standards by country as of July 2019

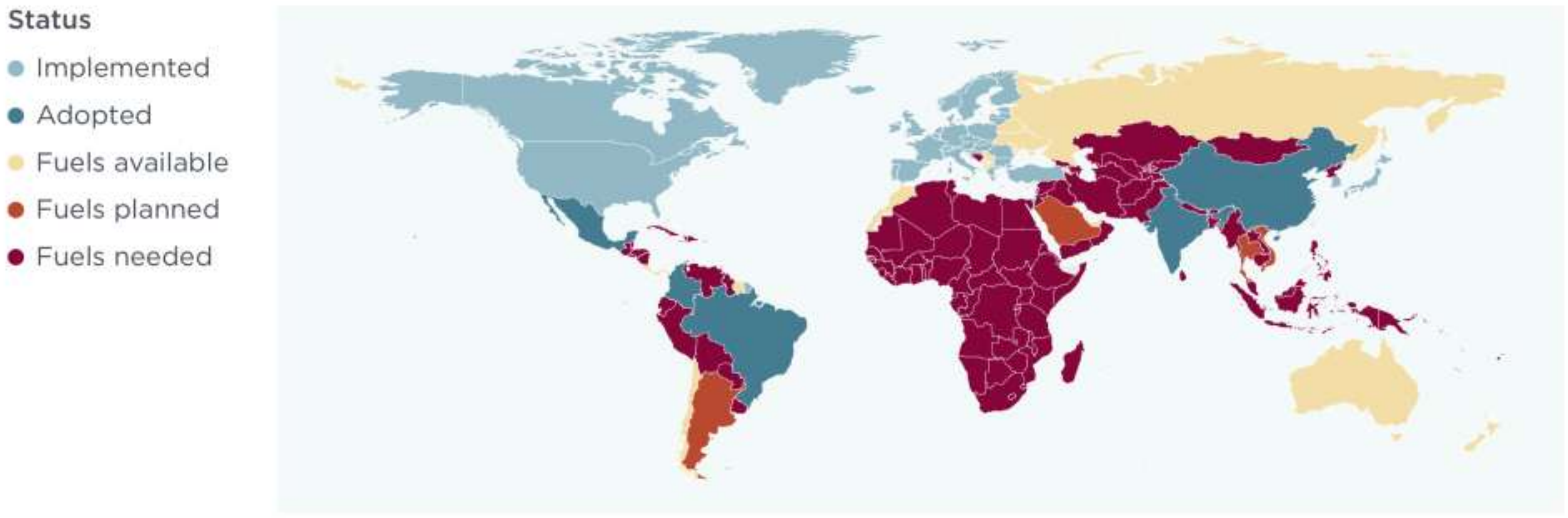

Figure ES-1. Implementation status of soot-free heavy-duty engine standards and ultralow-sulfur diesel by country as of July 2019. Recently adopted standards will take effect between 2020 and 2023, depending on the country. Fuels available or planned means soot-free engine standards are not yet adopted. Fuels needed means fuel sulfur reductions are needed to enable implementation of soot-free engine standards.

A combination of regulatory tools and incentives is necessary to reduce transport emissions

New Vehicle Policies

- ❑ Stringent tailpipe emission standards
  - ✓ BS VI for on-road vehicles
  - ✓ Stage V for non-road vehicles
- ❑ Stringent evaporative emission standards
- ❑ Strong compliance and enforcement program
- ❑ Promotion of electric drive

Clean Fuel Policies

- ✓ Ultra-low sulfur fuels
- ❑ Stage I and II evaporative controls

In-use vehicle emission control

- ❑ On-board diagnostics (OBD) based inspection and maintenance program
- ❑ Remote sensing or other in-use emissions testing program
- ❑ Scrappage of old (especially diesel) vehicles
- ❑ Diesel particulate filter (DPF) retrofits for BS III/IV vehicles

Demand management

- ❑ Restrictions on use of older/more polluting vehicles
- ❑ Additional fees for older/more polluting vehicles
- ❑ Low Emission zones (LEZ)