WHITE PAPER

APRIL 2020

COST-BENEFIT ANALYSIS OF EURO VI HEAVY-DUTY EMISSION STANDARDS IN ARGENTINA

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ACKNOWLEDGMENTS

This study was sponsored by the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) and its Initiative on Reducing Emissions from Heavy-Duty Vehicles and Fuels. We thank several ICCT staff: Kate Blumberg for reviewing this work, Leticia Pineda for providing inputs and data and reviewing this report, and Francisco Posada, Ray Minjares, and Stephanie Searle for providing expert advice at various stages.

ABOUT THE CCAC

The CCAC is a voluntary global partnership of governments, intergovernmental organizations, businesses, scientific institutions, and civil society organizations committed to catalyzing concrete, substantial action to reduce short-lived climate pollutants, including methane, black carbon, and many hydrofluorocarbons. The Coalition works through collaborative initiatives to raise awareness, mobilize resources, and lead transformative actions in key emitting sectors.

ABOUT THE CCAC HEAVY-DUTY VEHICLES INITIATIVE

The Coalition's Heavy-Duty Vehicles and Fuels Initiative works to virtually eliminate fine particle and black carbon emissions from new and existing heavy-duty vehicles and engines. The Initiative supports its international partners to implement a sustained technology modernization pathway toward soot-free and low-carbon solutions.

We define "soot-free" technologies as those capable of meeting Euro 6/VI-equivalent standards and reducing exhaust emissions of black carbon up to 99% compared with uncontrolled levels. For resources on soot-free transport, please visit https://theicct.org/soot-free-transport-resources.

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EXECUTIVE SUMMARY

Argentina is the third-most populous country in South America and the region's second-largest commercial vehicle market. Argentines are exposed to ambient fine particulate matter ($PM_{2.5}$) pollution levels that average 30% above the World Health Organization's annual guideline. The Organisation for Economic Co-operation and Development estimates that the annual economic costs to society from ambient $PM_{2.5}$ pollution in Argentina exceed 3.7% of gross domestic product.

The transportation sector is a substantial contributor to Argentina's health burden from $PM_{2.5}$ and ozone pollution. Exhaust emissions from vehicles and engines were conservatively associated with roughly 1,000 air pollution-related premature deaths in Argentina in 2015, along with a much greater number of air pollution-related illnesses and disabilities. Heavy-duty vehicles (HDVs), including trucks and buses, account for 3%–4% of Argentina's on-road vehicle fleet, not including motorcycles, but contribute an estimated 60% of exhaust $PM_{2.5}$ and 70% of nitrogen oxides (NO_X) emissions. NO_X emissions are a precursor to both ambient $PM_{2.5}$ and ozone.

To reduce the health impacts of HDVs, Argentina's national government has introduced progressively more stringent emission standards, up to Euro V standards in 2016. Implementing the next phase of standards, equivalent to Euro VI or U.S. 2010, would put Argentina on an equal footing with other Group of 20 (G-20) economies—including the European Union, the United States, Mexico, and Brazil—and reduce new HDV tailpipe $PM_{2.5}$ and NO_X emissions by roughly 90% compared with the current standards. In this study, we use local data on Argentina's HDV fleet to compare the costs and benefits of implementing Euro VI-equivalent standards in Argentina in 2021, 2023, or 2025. These dates reflect harmonization with Brazil and Colombia in 2023, or implementation either two years earlier or later.

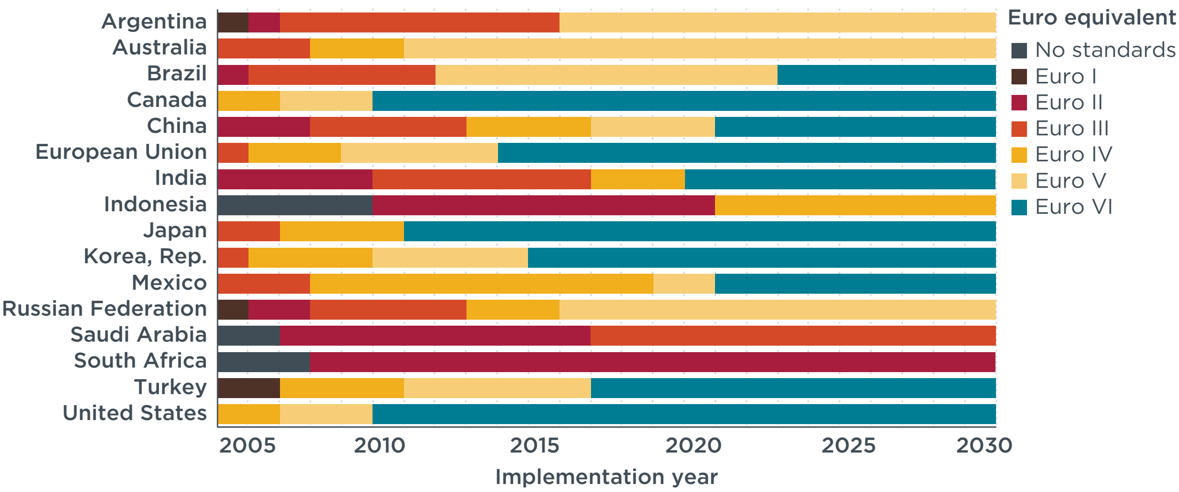

Figure ES-1. Implementation year (all sales and registrations) of heavy-duty diesel engine emission standards in G-20 economies.

We estimate that compared with the baseline scenario of Euro V standards, implementing Euro VI standards in 2023 would avoid an estimated 1,950 (836–2,870) premature deaths and 51,300 (22,000–75,600) years of life lost from 2023–2050. These estimated health benefits are conservatively low, as they exclude ozone-related premature deaths; health effects of particle number emissions; nitrogen dioxide impacts on asthma incidence among children and asthma emergency department visits; near-road health impacts; and potential health impacts of air pollution on the incidence of chronic kidney disease, preterm birth and other birth outcomes, and cognitive decline.

We find that each $1 invested to comply with Euro VI-equivalent standards will produce $3.60 in health benefits from reduced ambient $PM_{2.5}$ exposure alone over the next 30 years. Importantly, the timing of Euro VI standards in Argentina will have a temporary effect on HDV manufacturing costs but a long-term effect on air quality and health outcomes for Argentines. Compared with introducing Euro VI in 2023, doing so two years earlier would add $124 million, or 38%, of net benefits over the next 15 years. On the other hand, delaying Euro VI to 2025 would diminish the net benefits over the next 15 years by $108 million, or 33%, compared with the 2023 timeline and by $232 million, or 51%, compared with the 2021 timeline.

Table ES-1. Cumulative net benefits of Euro VI standards from 2021–2035 and 2021–2050

Net benefits over the period 2021–2035 (15 years)

Scenario	Cumulative private costs (million U.S.$)	Cumulative health benefits (million U.S.$)	Net benefits (million U.S.$)
Euro VI by 2021	325	776	451
Euro VI by 2023	267	593	327
Euro VI by 2025	213	433	219

Net benefits over the period 2021–2050 (30 years)

Scenario	Cumulative private costs (million U.S.$)	Cumulative health benefits (million U.S.$)	Net benefits (million U.S.$)
Euro VI by 2021	620	2,202	1,583
Euro VI by 2023	559	1,990	1,432
Euro VI by 2025	502	1,787	1,285

In addition to local benefits for public health, implementation of Euro VI-equivalent standards in Argentina would reduce black carbon emissions by an estimated 97% by 2050 compared with the baseline scenario, delivering toward Argentina's commitments to take meaningful action on short-lived climate pollutants as a member of the CCAC and a participant in the HDV and SNAP (Supporting National Action and Planning on Short-Lived Climate Pollutants) initiatives.

These findings underscore the societal benefits of implementing Euro VI standards in Argentina as soon as practicable. Considering the large share of new HDVs in Argentina that originate in Brazil, we recommend that Argentina consider aligning with Brazil's planned introduction of Euro VI-equivalent standards, which takes effect for new type approvals on January 1, 2022, and for all new sales and registrations on January 1, 2023.

There are several complementary actions that merit particular consideration in Argentina. Although Euro V standards have been in effect in Argentina since 2016, a large majority of the HDVs on the road are certified to Euro III and earlier standards, and approximately half of HDVs are more than 10 years old. To accelerate the benefits of Euro VI-equivalent standards, we recommend that Argentina also provide incentives for early introduction of Euro VI vehicles and accelerated fleet renewal.

This study assumes that all Euro V and VI vehicles use ultralow-sulfur fuel, as is required for the effective performance of their emission control technologies. Yet data provided by the Secretary of Energy indicate that ultralow-sulfur Grade 3 diesel is sold at a price roughly 20% higher on average than higher-sulfur Grade 2 diesel, which could lead to misfueling of Euro V and Euro VI trucks. We recommend reducing the risks of misfueling by adjusting fuel taxes to reduce or eliminate the price penalty of Grade 3 diesel and planning to transition the nationwide diesel supply to exclusively Grade 3 diesel. These actions would also reduce sulfur dioxide and $PM_{2.5}$ emissions from the in-use vehicle fleet.

Finally, we note that tailpipe $PM_{2.5}$ emissions in urban areas have disproportionate health effects because of their higher population exposure. Correspondingly, municipal policies such as low-emission zones and transitioning urban bus fleets to zero-emission technologies could have outsized health benefits, in addition to the benefits of nationwide Euro VI-equivalent standards.

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INTRODUCTION

Argentina is the third-most populous country in South America and the region's second-largest commercial vehicle market (The World Bank, 2020; Organisation Internationale des Constructeurs d'Automobiles, n.d.). Although Argentina's population is exposed to annual average amounts of ambient fine particulate matter ($PM_{2.5}$) that are relatively low compared with other South American countries, levels still average 30% above the World Health Organization's maximum for annual mean concentration (Health Effects Institute, 2019). Additionally, the Organisation for Economic Co-operation and Development (OECD) estimates that the annual economic costs to society from ambient $PM_{2.5}$ pollution in Argentina exceed 3.7% of gross domestic product (OECD.Stat, 2020).

The transportation sector is a substantial contributor to Argentina's health burden from $PM_{2.5}$ and ozone pollution. A conservative estimate attributed roughly 1,000 premature deaths annually to transportation tailpipe emissions in 2015 (Anenberg, Miller, Henze, Minjares, & Achakulwisut, 2019). Among transportation sources, the two subsectors with the greatest contributions to air pollution in Argentina are on-road diesel vehicles and nonroad mobile sources. Despite constituting only 3%–4% of Argentina's on-road vehicle fleet excluding motorcycles, heavy-duty trucks and buses contribute an estimated 60% of exhaust $PM_{2.5}$ and 70% of nitrogen oxides (NO_X) emissions. NO_X emissions are a precursor to both ambient $PM_{2.5}$ and ozone.

To address air pollution from on-road vehicles, the national government of Argentina has followed the regulatory pathway originated by the European Union by implementing progressively more stringent standards for vehicles, engines, and fuels. Argentina put in place Euro V-equivalent standards for new heavy-duty engines in 2016. Implementing the next phase of standards, equivalent to Euro VI or U.S. 2010, would put Argentina on an equal footing with the European Union and the United States and reduce tailpipe $PM_{2.5}$ and NO_X emissions by roughly 90% compared with Euro V levels (Miller & Jin, 2019).

A transition to "soot-free" Euro VI-equivalent standards for heavy-duty vehicles (HDVs) is already taking place among many of the countries in the G-20 and in South America. Mexico is set to become the first country in Latin America to require world-class HDV emission standards nationwide, and these will apply to all new sales starting January 1, 2021 (Blumberg, 2018). Brazil and Colombia have adopted Euro VI-equivalent standards that will apply to all new diesel HDV sales and registrations by 2023 (Miller & Jin, 2019). Euro VI has been mandatory for new buses in Santiago, Chile, since 2017, and negotiations have begun to apply Euro VI standards to new HDVs nationwide.

In September 2018, the government of Argentina convened stakeholders from national trucking and automotive associations, industry and academia, and international experts and regulators from other South American countries to discuss both a regional transition to soot-free and zero-emissions transportation and improved compliance and enforcement programs (Posada, Delgado, Miller, & Minjares, 2019). These discussions identified a need for further studies comparing the benefits of soot-free standards in the region with the costs of complying.

This study addresses that need by assessing the potential costs and benefits of soot-free standards for HDVs in Argentina. It follows similar studies conducted for Brazil and Mexico, which found that the societal benefits of Euro VI-equivalent standards outweigh the compliance costs for the industry by an order of magnitude or greater (Miller & Façanha, 2016; Miller, Blumberg, & Sharpe, 2014). This study uses local data on Argentina's HDV fleet to compare the costs and benefits of implementing Euro VI-equivalent standards in 2021, 2023, or 2025—reflecting either harmonization with the timelines of Brazil and Colombia, or implementation two years earlier or later.

The paper is organized as follows. First, we provide more details on the history of vehicle and fuel standards in Argentina and their current status compared with other G-20 and South American countries. Next, we define the scenarios evaluated in this study, describe the data sources and methods used to characterize emissions from Argentina's HDV fleet, and present our emissions estimates for each scenario. We then evaluate the health impacts that are expected to result from HDV tailpipe emissions under each scenario. Following that, we compare the value of health benefits from Euro VI-equivalent standards with the expected costs for truck and bus manufacturers to comply; these are mainly the incremental costs of new vehicle emission controls. We conclude with a discussion of policy implications and recommendations for a path forward.

CURRENT SITUATION AND SCENARIO DEFINITIONS

Since 1995, Argentina has progressively tightened emission standards for new vehicles and engines following the regulatory pathway of the Euro standards developed by the European Union. The Secretary of Environment and Sustainable Development of Argentina first introduced Euro II standards for new HDV models in 2004; this is illustrated in Figure 1, which also shows that Euro III standards were introduced in 2006, Euro IV in 2009, and Euro V in 2016 (Vassallo, 2018). However, these standards were not applied to all new HDV sales and registrations until slightly later. All new HDV sales were required to meet Euro II in 2006 and Euro III in 2007. Certifications for Euro III vehicles were originally scheduled to be succeeded by Euro IV for all new HDVs in 2011 (Res. 731/2005) but were instead extended to the end of 2015 (Res. 1464/2014). As a result, auto dealers imported Euro III trucks through 2015 and switched to importing Euro V trucks starting in 2016.

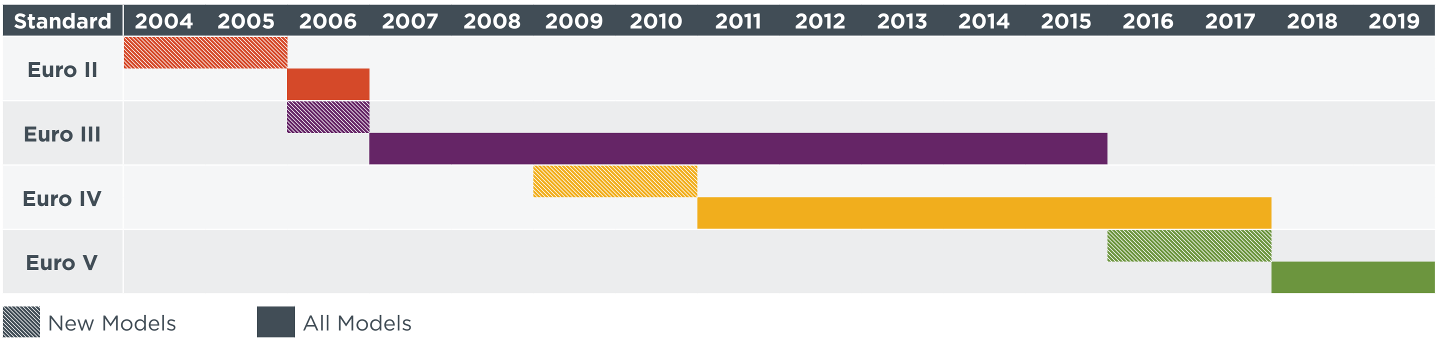

Figure 1. Timeline for implementation of nationwide emission standards for diesel HDVs. The bars show the years in which each standard was required, with hatched portions representing only new models. Note that from 2011 through 2015, both Euro III and Euro IV certifications were allowed.

Figure 2 shows the implementation of heavy-duty diesel engine emission standards in G-20 economies. In practice, the jump in Argentina from Euro III to Euro V standards mirrored implementation in Brazil, where a delay in implementation of Euro IV standards also resulted in a jump from Euro III-equivalent P-5 standards to P-7 standards, which are generally equivalent to Euro V.[1] The HDV market in Argentina is closely tied to Brazil's: Nearly 75% of HDVs in Argentina's current fleet were manufactured in Brazil (Promotive SA, 2019).

With interest in soot-free standards from both regulators and industry stakeholders, Argentina is poised to follow regional and economic peers and begin planning for Euro VI standards. Euro VI-equivalent standards are already in place in the United States, Canada, the European Union, Japan, South Korea, and Turkey. India has implemented Euro VI-equivalent standards beginning April 1, 2020, and China and Mexico will do so in 2021. Brazil's P-8 (Euro VI-equivalent) standards apply to new models January 1, 2022, and all new HDV sales and registrations on January 1, 2023. Euro VI models can be certified before these dates on a voluntary basis (Miller & Posada, 2019). Elsewhere in South America, Colombia has committed to enforcing Euro VI-equivalent standards for all new HDVs in 2023, as well as accelerating the retirement of older vehicles (Ministry of Health and Social Protection, the Republic of Colombia, 2019).

1 P-7 included several notable deviations from Euro V standards with respect to the requirements for on-board diagnostic systems. See Cristiano Façanha, *Deficiencies in the Brazilian PROCONVE P-7 and the case for P-8 standards*, (ICCT: Washington, DC, 2016), https://theicct.org/publications/deficiencies-brazilian-proconve-p-7-and-case-p-8-standards.

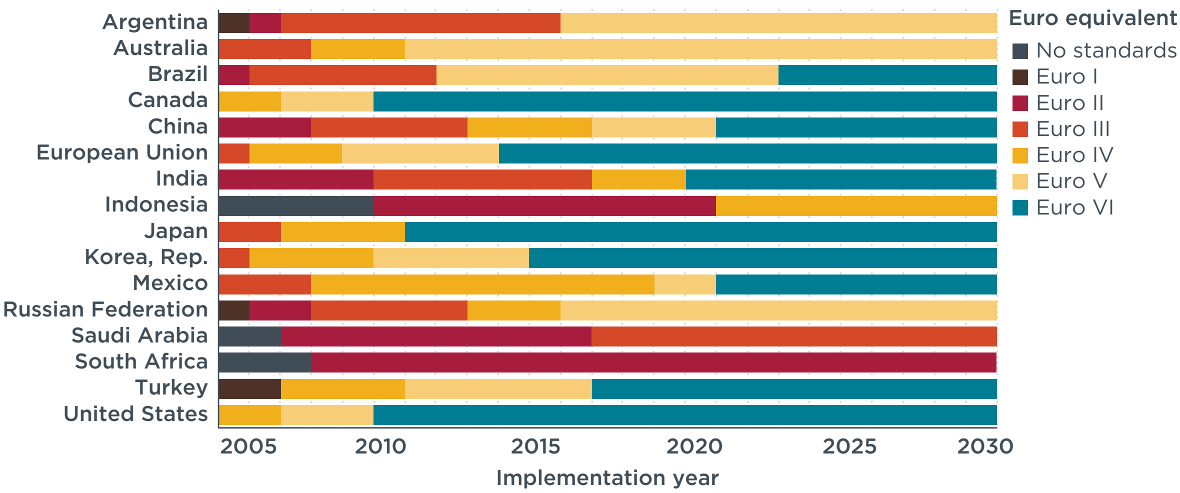

Figure 2. Implementation year (all sales and registrations) of heavy-duty diesel engine emission standards in G-20 economies. Adapted from Miller & Jin (2019).

The emissions control technologies used to reduce air pollutant emissions to the low levels required by Euro V and Euro VI standards are designed to function with ultralow-sulfur fuel, which contains a maximum of 10–15 parts per million (ppm) of sulfur. Two grades of diesel fuel for on-road vehicles are currently permitted for sale in Argentina. Grade 2 diesel contains a maximum sulfur content of 500 ppm in major cities and 800 ppm outside major cities. Under Res. 558/2019, Grade 2 diesel will be capped at 350 ppm sulfur as of January 1, 2024. Grade 3 diesel contains a maximum of 10 ppm sulfur and is currently widely available across Argentina.

Table 1 shows the sulfur limit and sales shares of these diesel fuel grades. As more Euro 5/V or Euro 6/VI vehicles enter the market, the supply of Grade 3 diesel will need to increase to accommodate them. Data provided by the Secretary of Energy (Secretary of Energy, 2017) indicate that Grade 3 diesel is sold at a price roughly 20% higher on average than Grade 2 diesel, which could lead to some misfueling of Euro V and Euro VI trucks. Since this analysis addresses the impacts of Euro VI standards in comparison with Euro V, we assume that in all scenarios, all Euro V and Euro VI HDVs use the appropriate Grade 3 diesel fuel.

Table 1. Estimated sulfur content and sales share of on-road diesel fuel grades, 2014–2024.

Diesel grade	Sulfur content (ppm)			Share of on-road diesel fuel sales (%)			
	2014–2019	2020	2024	2014	2019	2020	2024
Grade 2 (Rural)	1,000	800	350	61%	52%	Based on pre-Euro V trucks fuel demand, assuming the same split between urban and rural as in 2019	
Grade 2 (Urban)	500	500	350	18%	14%		
Grade 3	10	10	10	21%	34%	Based on Euro V–VI trucks fuel demand	

Grade 2 diesel sold in urban areas—cities with a population of more than 90,000—is subject to a 500 ppm sulfur limit. A limit of 800 ppm sulfur applies outside urban areas.

In this analysis, we evaluate the costs and benefits of three scenarios and corresponding implementation timelines for a transition to Euro VI-equivalent standards in Argentina: an accelerated transition (2021), a transition aligned with Brazil's P-8 standards (2023), and a delayed transition (2025). These three scenarios are compared with a baseline scenario in which the current standards remain in place with no change.

» Baseline: Assumes Euro V standards remain in effect for all new HDVs.
» Euro VI by 2021: Assumes an accelerated transition to Euro VI standards, with all new vehicles meeting Euro VI requirements by 2021.
» Euro VI by 2023: Assumes a transition to Euro VI standards aligned with Brazil's P-8 standards, with all new vehicles meeting Euro VI requirements by 2023.
» Euro VI by 2025: Assumes a delayed transition to Euro VI standards, with all new vehicles meeting Euro VI requirements by 2025.

BASELINE FLEET AND EMISSIONS

HDVs play a crucial role in Argentina's passenger and freight systems. In 2018, trucks transported 93% of domestic freight and moved a total of 536 million tonnes (National Directorate of Cargo Transportation Planning and Logistics, 2019). In densely populated areas, buses are essential to urban mobility, and in the metropolitan region of Buenos Aires alone, passengers take more than 1.5 billion rides per year (General Directorate of Statistics and Census, 2015).

In this analysis, we utilize fleet data obtained from automotive associations, government agencies, and academic institutions in Argentina to characterize the current fleet of on-road HDVs in the country. The automotive consulting company Promotive provided information on more than 400,000 HDVs currently in circulation (Promotive SA, 2019). We used this fleet database in combination with other data sources to construct a detailed emissions inventory of Argentina's HDV fleet and to project how these emissions are likely to evolve under various policy scenarios. In this section, we describe our methods for characterizing the fleet of HDVs in Argentina and quantifying associated emissions. We then present our estimates of current and projected emissions for each scenario, with particular attention to those pollutants with the greatest impacts on public health.

CURRENT VEHICLE FLEET

In 2018, HDVs made up 3%–4% of on-road vehicles in Argentina excluding motorcycles. Estimates of the size of the HDV stock of circulating vehicles range from 310,000 (ONDaT, 2016, 2017) to 760,000 (Asociación de Fábricas de Automotores [ADEFA], 2018). The divergent estimates reflect differences in underlying data sources, turnover assumptions, and vehicle classifications. For this analysis, HDV stock estimates were derived using standard international vehicle categories as shown in Table 2, and information on vehicle types, gross vehicle weights, and ages provided by Promotive (Promotive SA, 2019). The Promotive dataset is based on information from manufacturers, fleet information from the National Directorate for the Registration of Motor Vehicles and Loans (DNRPA), and registrations and claims from insurance companies.

Table 2. Definition of vehicle categories by vehicle type and gross vehicle weight.

Category	Vehicle type	Definition
LDV	Passenger Cars	Passenger vehicles ≤ 3,500 kg
	Light Commercial Vehicles	Freight vehicles ≤ 3,500 kg
HDV	Buses	Passenger vehicles > 3,500 kg
	Medium-Duty Trucks	Freight vehicles > 3,500 kg and ≤ 15,000 kg
	Heavy-Duty Trucks	Freight vehicles > 15,000 kg

As shown in Table 3, Argentina's HDV fleet consists of approximately 80,000 buses, 100,000 medium-duty trucks (MDTs), and 220,000 heavy-duty trucks (HDTs). While HDVs constitute a small fraction of the total vehicle fleet, they are driven substantially more than passenger cars or light commercial vehicles (LCVs) and account for about 12% of all vehicle-kilometers traveled (VKT) in Argentina. HDVs also consume more fuel per unit of distance traveled compared with light-duty vehicles. From 2006–2018, the size of Argentina's HDV fleet increased by 60%, and growth has leveled in the past few years (ADEFA, 2018).

Table 3. Stock estimates and share by fuel type in Argentina, 2018 (Asociación de Fábricas Argentinas de Componentes, 2018).

Vehicle type	Stock	Share of stock by fuel type (%)		
	(#)	Diesel	Gasoline	CNG
PC	11,900,000	14.0%	71.7%	14.3%
LCV	1,560,000	66.2%	29.7%	4.0%
HDT	219,000	100%	0%	0%
MDT	102,000	100%	0%	0%
Buses	80,000	100%	0%	0%

As Table 3 also details, all of the HDVs in the Promotive database have diesel engines. Alternative technologies are currently being pilot-tested, including liquefied natural gas trucks (Resolution 42/2019) and electric buses (Resolución 284/2019). While these programs suggest new fuels could play a role in the future HDV fleet, they are not evaluated in this analysis because they are still limited in scope.

Figure 3 shows the share of HDVs by age and emissions standard in 2018, as estimated from the Promotive database (Promotive SA, 2019). To determine the share of HDVs by emissions standard, we matched the age of each vehicle model in the Promotive database with the timeline for when each standard applied to all sales and registrations. Argentina's HDV fleet has a median age of approximately 10 years. Euro V standards, which have been in effect since 2016, were estimated to account for only 15% of the HDV fleet in 2018. An additional 47% were certified to Euro III, and the rest of the fleet to earlier standards or no standards. More than a 10th of Argentina's HDV fleet in 2018 is considered "pre-Euro," indicating vehicles with uncontrolled emissions. The high proportion of vehicles certified to Euro III standards and earlier underscores a need for complementary programs that encourage the replacement of older vehicles in conjunction with new vehicle standards such as Euro VI.

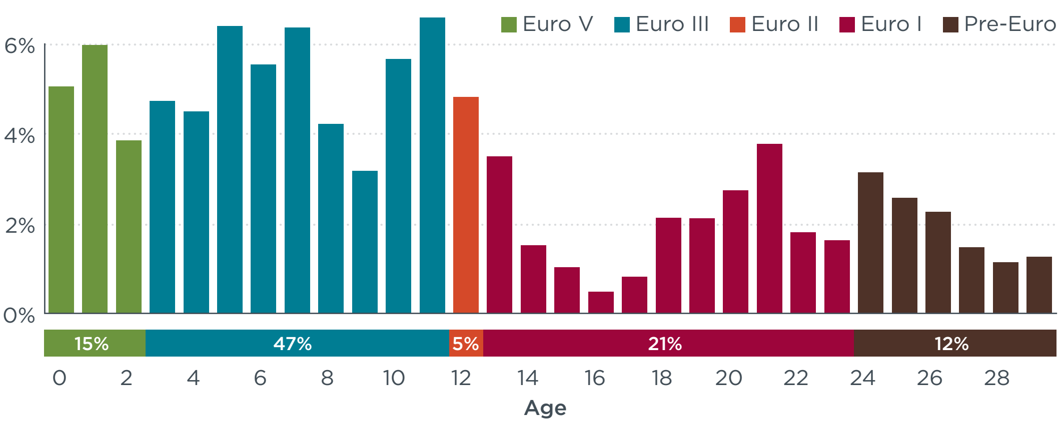

Figure 3. Share of HDVs by age and equivalent Euro standard in Argentina, 2018. "Pre-Euro" represents vehicles not certified to a Euro standard.

PROJECTION OF VEHICLE SALES

For this analysis, assumptions of projected growth in HDV sales were based on the International Energy Agency's (IEA) Mobility Model (IEA, 2017). HDV sales are assumed to grow at a slow pace through 2030, with truck sales increasing slightly and bus sales remaining constant (Table 4). From 2030–2040, sales are assumed to grow at a faster rate of 2%–4% per year. For this analysis, which focuses on the costs and benefits of Euro VI standards compared with Euro V standards, we assume that new HDV sales continue to rely on diesel engines in all scenarios. While it is outside the scope of this study, we expect that certain HDV types such as urban buses could be transitioned to zero-emission technologies such as battery-electric buses with concerted action at the national and local levels. Such actions could further reduce the air pollution-related health impacts associated with HDVs in Argentina.

Table 4. HDV sales and projected annual growth rates, 2018–2040. Sales growth rates are based on IEA (2017).

		Trucks	
	Buses	**MDT**	**HDT**
Vehicle sales in 2018	2,900	4,100	13,400
Growth rate 2018–2030	0.0%	1.8%	1.3%
Growth rate 2030–2040	3.4%	2.8%	3.6%

EMISSIONS MODELING METHODOLOGY

Tailpipe air pollutant emissions were estimated using an updated version of the ICCT's global on-road vehicle emissions model (Miller & Jin, 2018). We updated the model with extensive historical data on the Argentinian vehicle fleet, including new vehicle sales, fuel sales, and fleet characteristics. We characterized the 2018 vehicle fleet using the Promotive database (Promotive SA, 2019) in combination with assumptions for annual vehicle mileage, fuel efficiency, and changes in mileage by vehicle age (Miller & Jin, 2018). Next, we estimated vehicle retirement curves for each vehicle type such that bottom-up estimates of vehicle stock based on cumulative vehicle sales and estimated retirements aligned with the 2018 stock data. We then calibrated annual vehicle mileage assumptions to align our on-road energy consumption estimates with national fuel sales data (Ministerio de Energía y Minería, 2017).

This detailed, bottom-up representation of the vehicle fleet was combined with historical and assumed future timelines of new vehicle emission standards and fuel quality improvements. Finally, we applied technology-specific tailpipe emission factors for local air pollutants such as $PM_{2.5}$ and NO_X. These emission factors were derived from established models, weighted by the vehicle subcategories in Argentina's fleet and adjusted using data on real-world performance for NO_X emissions. The resulting emission estimates were compared against several other on-road emission inventories to check for consistency. The following subsections provide additional details about several of these methodological components.

Fleet turnover

Fleet turnover in future years was modeled using survival curves specific to each vehicle type. We calibrated these survival curves using historical HDV sales data from the Association of Automotive Dealers of Argentina (2017). These HDV sales data were scaled down by 15% to match estimates of HDV sales in recent years implied by the Promotive database (Promotive SA, 2019). The difference in HDV sales totals most likely results from variances in underlying vehicle definitions. The estimated average retirement ages are 20 years for MDTs, 16 years for HDTs, and 30 years for buses. The particularly high average retirement age for buses is in line with recent new bus sales, which were roughly a 30^{th} of the total stock in 2018.

Energy consumption

Figure 4 compares several data sources for historical diesel and gasoline consumption in Argentina. The national energy balances (Secretary of Energy, 2019) include all transportation modes, whereas the IEA statistics (IEA, 2017) and national fuel sales data (Secretary of Energy, 2017) include only on-road vehicles. We calibrated our model to match the national fuel sales data. For this analysis, we evaluate future changes in HDV energy consumption based on assumptions of future HDV sales and fleet growth. We did not evaluate potential changes in annual VKT per vehicle or HDV fuel efficiency. While outside the scope of this analysis, complementary policies to improve HDV efficiency could potentially yield proportional reductions in emissions of certain pollutants such as NO_x.

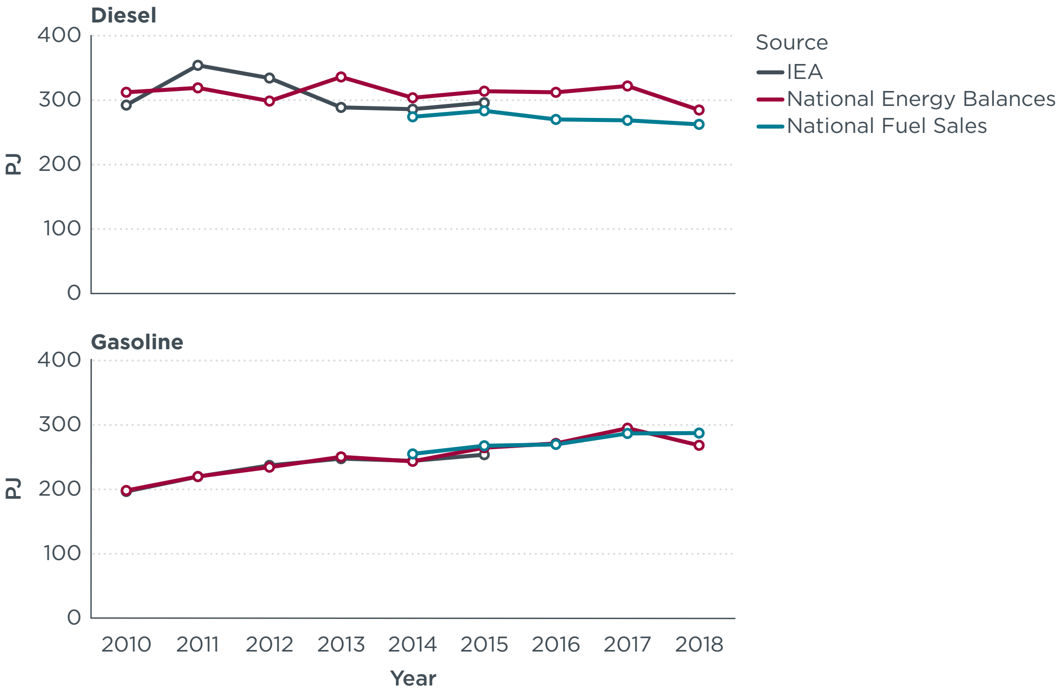

Figure 4. Transport sector and on-road diesel and gasoline consumption in Argentina, 2010–2018.

Emission factors

Technology-specific emission factors were adapted from the European Environment Agency's (EEA, 2019) air pollutant emissions inventory guidebook. This analysis differentiates two classes of freight trucks, MDT and HDT, whereas the guidebook provides emission factors for four weight classes: trucks with a gross vehicle weight of less than 7.5 tonnes, trucks 7.5–16 tonnes, trucks 16–32 tonnes, and trucks more than 32 tonnes. To match the guidebook's values to our classifications, we applied the emission factors for trucks weighing less than 16 tonnes to MDTs and those above 16 tonnes to HDTs. Within those categories, the guidebook emission factors were weighted to reflect the share of trucks within each weight category in Argentina (Promotive SA, 2019). Similarly, the guidebook provides emission factors for urban buses and coach buses. As done for trucks, the guidebook emission factors were weighted to reflect the share of urban buses and coach buses in Argentina (Promotive SA, 2019). These shares are given in Table 5. In all cases, the resulting emission factors are still differentiated by vehicle type, fuel type, and emissions standard.

Table 5. Shares for computing weighted-average emission factors

Vehicle type	Vehicle subcategory	Share of vehicle type
MDT	Diesel 7.5–16 tonnes	79.3%
	Diesel ≤ 7.5 tonnes	20.7%
HDT	Diesel 16–32 tonnes	97.3%
	Diesel >32 tonnes	2.7%
Bus	Coaches	50.4%
	Urban Buses	49.6%

Further adjustments were applied to the NO_x emission factors of diesel vehicles to better reflect the observed discrepancy between real-world emissions performance and certification limits. For MDTs and HDTs, NO_x emission factors for Euro III, Euro IV, Euro V, and Euro VI trucks were sourced from Anenberg et al. (2017). Pre-Euro III emission factors for trucks were taken from the guidebook and scaled to maintain consistency with the adjusted Euro III and later values. NO_x emission factors for buses were derived from the Handbook Emission Factors for Road Transport (HBEFA), as described in Dallmann (2019), and we accounted for the different sizes and driving conditions of urban buses and coach buses.

The resulting distance-specific emission factors applied in this analysis are given for $PM_{2.5}$ in Figure 5 and for NO_x in Figure 6. As shown, Euro VI vehicles are expected to emit 95% less $PM_{2.5}$ and 84%–89% less NO_x than their Euro V counterparts.

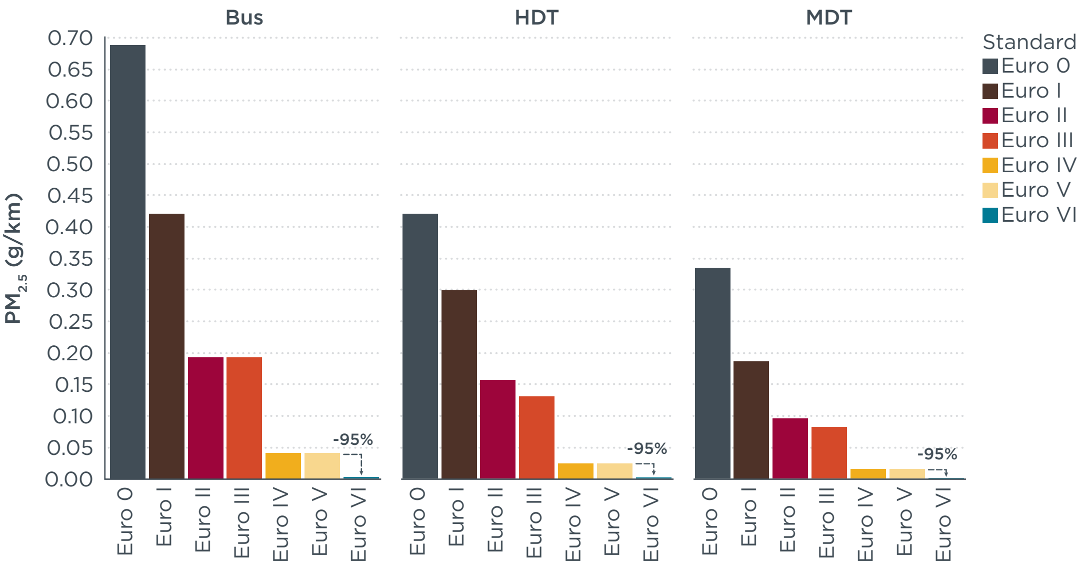

Figure 5. Distance-specific $PM_{2.5}$ emission factors for HDVs by vehicle type and emission standard

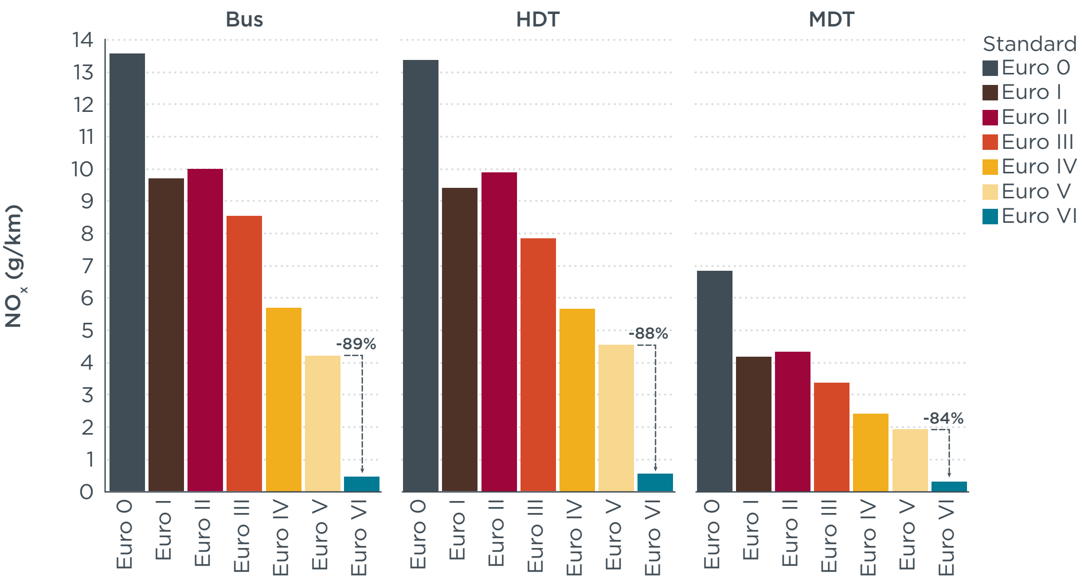

Figure 6. Distance-specific NO_x emission factors for HDVs by vehicle type and emission standard

As a final step before inputting to the model, distance-specific emission factors for each vehicle type, fuel type, and emissions standard were converted to fuel-specific emission factors using the energy consumption (MJ/km) values in Table 3-27 of the guidebook (EEA, 2019). The reason for this step is that fuel-specific emission factors are better suited to emissions inventory analyses in which the distribution of VKT among different HDV types is unknown, since there is less variation among HDV types than for distance-specific emission factors (Miller & Jin, 2018).

Diesel fuel in Argentina contains a mandated 10% blend of biodiesel (Res. 1283/2006), which is slightly higher than the 7% blend of biodiesel specified as the EU reference fuel for Euro VI standards. Tests of different biodiesel blends in Brazil have found that the use of a 10% blend does not have a significant effect on emissions of gaseous pollutants and particulates, nor does it affect the proper functioning of advanced aftertreatment systems (Dallmann, 2018). These findings agree with the results of international testing, which show that Euro VI engine technologies reduce regulated emissions to such low levels that any fuel effects are negligible (IEA-AMF, 2016). In other words, biofuels should not be considered as a substitute for Euro VI-equivalent standards. Whether higher biodiesel blends of 20% or 100% would impair proper functioning of emission controls or advanced vehicle systems is an area of ongoing research. This analysis does not attempt to account for these effects.

Although not a determining factor for the cost-benefit analysis, emissions of specific components of $PM_{2.5}$ such as black carbon (BC) were estimated using the speciation profiles developed for the U.S. Environmental Protection Agency's (EPA) MOVES2014 model (2015), which distinguishes between diesel vehicles with and without diesel particulate filters (DPFs). Speciation profiles for diesel vehicles with DPFs were applied starting at Euro VI for HDVs.

Euro VI standards include a particle number (PN) emissions limit, which effectively requires diesel particulate filters. This has been shown to reduce PN emissions from diesel HDVs by greater than 99.5% compared with vehicles that do not have such filters (Giechaskiel, 2018). Ultrafine particles are hypothesized to be even more harmful to human health than larger particles; however, the specific impacts are uncertain and were not included in our evaluation (Ohlwein et al., 2019).

PROJECTED TAILPIPE EMISSIONS BY SCENARIO

Figure 7 and Figure 8 show projected HDV tailpipe emissions of $PM_{2.5}$ and NO_X for each scenario over the period 2020–2050. In the baseline scenario, $PM_{2.5}$ and NO_X emissions are projected to decrease over the next 10–15 years as Euro V vehicles continue to replace Euro III and pre-Euro III vehicles. Yet over the longer term, $PM_{2.5}$ and NO_X emissions would start to increase as growth in passenger and freight demand offsets the emission reductions achieved by Euro V vehicles. In contrast, under the Euro VI scenarios, $PM_{2.5}$ and NO_X emissions would be reduced at substantially faster rates over the next 10–15 years. Compared with projected baseline emissions in 2050, Euro VI-equivalent standards under all scenarios would reduce annual tailpipe emissions of $PM_{2.5}$ by ~90%, NO_X by ~87%, and BC by ~97%.

The timing impacts of Euro VI-equivalent standards is particularly noticeable when comparing the cumulative emission benefits. Considering the period 2021–2035, introducing Euro VI in 2021 rather than 2023 would prevent emissions of ~100,000 tonnes of NO_X and ~1,000 tonnes of $PM_{2.5}$. Conversely, introducing Euro VI in 2025 instead of 2023 would increase cumulative emissions from 2021–2035 by similar amounts. As discussed later, these differences in emissions have substantial effects on the net benefits of each Euro VI scenario.

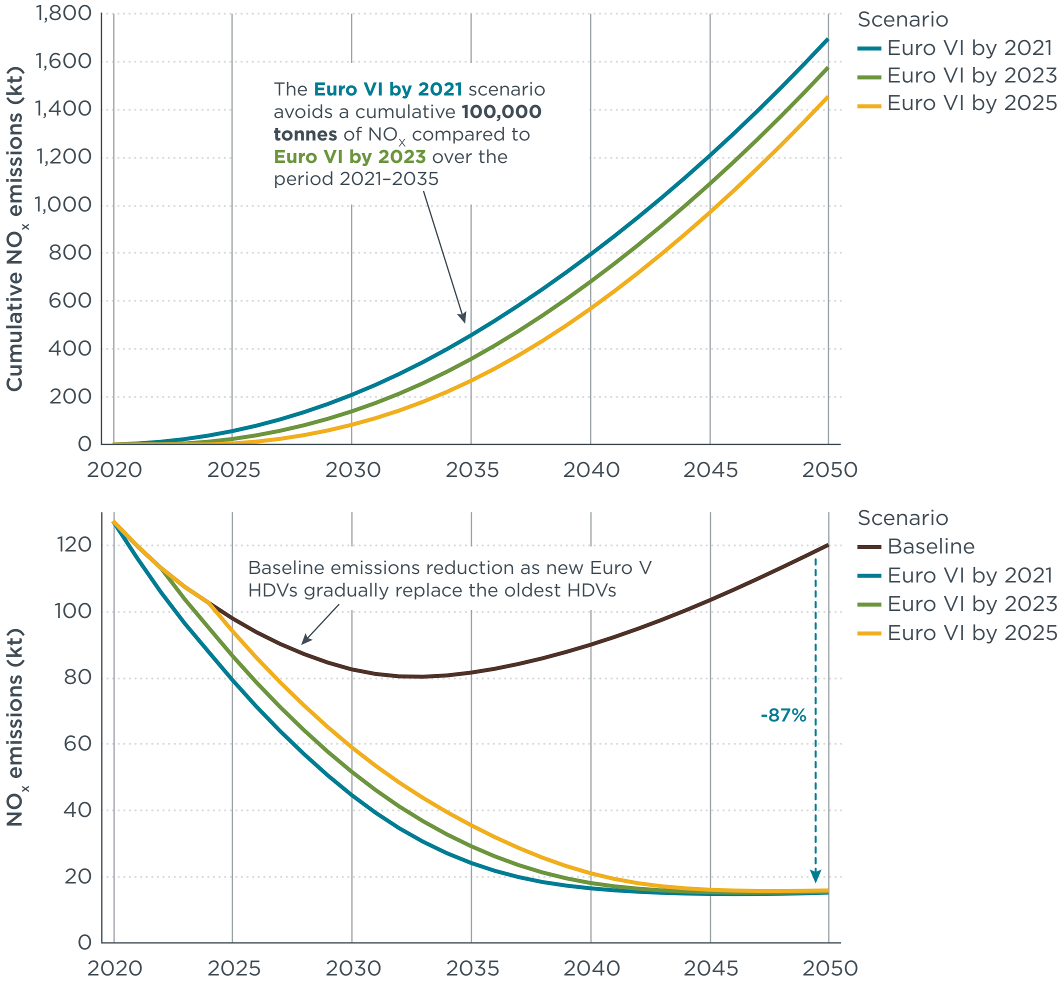

Figure 7. Top panel: Projected cumulative HDV NO_x emissions avoided by Euro VI scenarios compared with the baseline. Bottom panel: Annual HDV NO_x emissions by scenario, 2020–2050

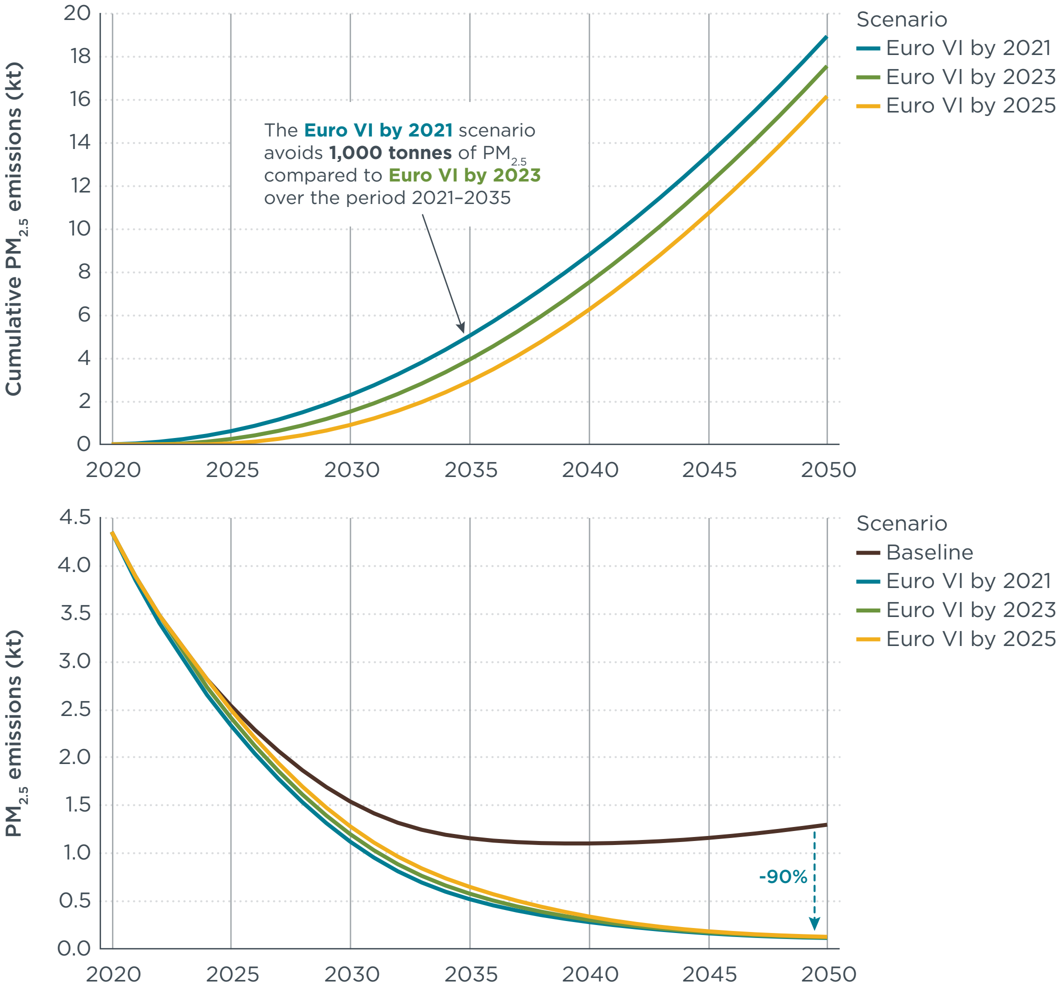

Figure 8. Top panel: Projected cumulative HDV $PM_{2.5}$ emissions avoided by Euro VI scenarios compared with the baseline. Bottom panel: Annual HDV $PM_{2.5}$ emissions by scenario, 2020–2050

HEALTH IMPACTS AND VALUATION METHODS

Ambient air pollution is the leading environmental health risk factor worldwide (Stanaway et al., 2018). Transportation sources contribute to ambient air pollution via directly emitted $PM_{2.5}$ and nitrogen dioxide (NO_2), and via emissions of precursors to secondary $PM_{2.5}$ and ozone, which include NO_X, sulfur dioxide (SO_2), and volatile organic compounds. Worldwide, transportation tailpipe emissions were associated with nearly 400,000 premature deaths from ambient $PM_{2.5}$ and ozone in 2015 (Anenberg et al., 2019). The same study conservatively estimated that transportation tailpipe emissions in Argentina resulted in nearly 1,000 premature deaths and $2.1 billion in health damage in 2015, of which 38% were associated with on-road diesel vehicles.

The human health impacts of vehicle emissions are influenced by many factors, including the composition of emissions, their contribution to primary and secondary ambient air pollution, and the proximity and characteristics of the exposed population. For this study, we evaluate the health benefits in Argentina associated with a reduction in vehicle emissions of primary $PM_{2.5}$ and precursors to secondary $PM_{2.5}$. We use literature-derived estimates of intake fractions and effect factors (Table 6). Intake fractions indicate the amount of $PM_{2.5}$ in milligrams inhaled for each kilogram of emissions of primary $PM_{2.5}$ or precursor pollutants such as SO_2, NO_X, or NH_3. These intake fractions are measured in ppm. The effect factors indicate the number of disability-adjusted life years associated with each kilogram of inhaled $PM_{2.5}$.

The applied intake fractions for primary $PM_{2.5}$ take into account data on population, area, linear population density, population-weighted average ambient $PM_{2.5}$ concentrations, and meteorology for 28 cities in Argentina with greater than 100,000 population. The applied effect factors similarly take into account population-weighted data for the same cities, considering $PM_{2.5}$ exposure, ambient $PM_{2.5}$ concentrations, and mortality rates from air pollution-related diseases. The applied intake fractions for secondary $PM_{2.5}$ are not specific to Argentina and are subject to a higher level of uncertainty.

Intake fractions and effect factors can be combined with emission estimates to calculate the associated health impacts, measured in disability-adjusted life years (DALYs) as in this formula:

$$DALYs = Emissions \times Intake\ fraction \times Effect\ factor$$

Emissions are in kilograms (kg); intake fractions are in milligrams (mg) of $PM_{2.5}$ inhaled per kg of $PM_{2.5}$ or precursor; and effect factors are in DALYs per kg of inhaled $PM_{2.5}$ (Humbert et al., 2011).

We applied this equation to estimate the number of DALYs that could be avoided through potential reductions of vehicle emissions in Argentina. Additionally, we calculated the associated number of avoidable premature deaths by dividing estimated DALYs by the same average severity factor as used in Fantke et al. (2019), or 26.3 DALYs per death.

We calculated the value of health damages avoided by multiplying the number of premature deaths by the value of a statistical life (VSL). We applied a VSL of $2.1 million for Argentina in 2015, which was calculated using the benefit-transfer approach (Anenberg, Miller, Henze, & Minjares, 2019). To monetize health benefits in future years, we assume an annualized per-capita income growth rate of 1.87% from 2015 to 2050 (UN Population Division, 2019; OECD, 2018) and a social discount rate of 5% (Miller & Façanha, 2016).

For the application of intake fractions for primary $PM_{2.5}$ and secondary $PM_{2.5}$ precursors emitted in urban and rural areas, we apportioned our national vehicle emissions estimates to urban and rural areas. We assume 36.5% of HDV emissions occur in urban areas and the remainder in rural areas. See the Discussion section, below for implications of the uncertainties regarding this assumption. This share takes vehicle NO_X emissions as a proxy for all pollutant emissions and is based on the results of a high-resolution road transport emissions inventory for Argentina (Puliafito et al., 2017). We assume no change in spatial distribution from the 2014 inventory presented in that study.

We apply the same intake fractions and effect factors for all years of the analysis without attempting to adjust for potential changes in population size, demographics, population density, or baseline rates of air pollution-related diseases. For this reason, we consider the estimated health benefits in this study to be conservatively low.

Table 6. Intake fractions and effect factors applied in this study

Parameter	Geography	Value	Source
Intake fractions for primary $PM_{2.5}$ emitted outdoors at ground level in urban and rural areas[a]	Urban areas	$PM_{2.5}$: 26.4 ppm	Population-weighted values for Argentinian cities in supporting information of Fantke et al. (2017)
	Rural areas	$PM_{2.5}$: 0.24 ppm	
Intake fractions for secondary $PM_{2.5}$ derived from precursor emissions in urban and rural areas[b]	Urban areas	SO_2: 0.99 ppm NO_X: 0.2 ppm NH_3: 1.7 ppm	Recommended intake fractions in Table 3 of Humbert et al. (2011)
	Rural areas	SO_2: 0.79 ppm NO_X: 0.17 ppm NH_3: 1.7 ppm	
Effect factors for $PM_{2.5}$ exposure[c]	Cities in Argentina+	112 (48–165)	Average slope effect factor for cities in Argentina+ in Table 1 of Fantke et al. (2019)

Notes
[a] Intake fractions for primary $PM_{2.5}$, measured in parts per million (ppm), indicate mg $PM_{2.5}$ inhaled per kg $PM_{2.5}$ emitted.
[b] Intake fractions for secondary $PM_{2.5}$, measured in ppm, indicate mg $PM_{2.5}$ inhaled per kg precursor (i.e. SO_2, NO_X, or NH_3) emitted.
[c] Effect factors indicate the number of disability-adjusted life years (DALYs) per kg $PM_{2.5}$ inhaled.

We estimate that compared with the baseline scenario of Euro V standards, implementing Euro VI standards in 2023 would avoid an estimated 1,950 (836–2,870) premature deaths and 51,300 (22,000–75,600) years of life lost from 2023–2050. The numbers in parentheses represent the lower and upper bounds associated with the effect factors in Table 6. Implementing Euro VI standards two years earlier would avoid an additional 150 (64-221) premature deaths and 3,950 (1,690–5,820) years of life lost, whereas a two-year delay would result in 150 (65–225) more premature deaths and 4,020 (1,720–5,920) years of life lost compared with the 2023 scenario for Euro VI.

COSTS AND BENEFITS

INCREMENTAL TECHNOLOGY COSTS

Euro VI standards require the application of stringent emission controls for diesel engines that demonstrate effective performance over a broad range of driving situations and over the useful life of the engine (Williams & Minjares, 2016). Strict limits on PM and PN effectively require Euro VI diesel engines to be equipped with DPFs. NO_x emissions are primarily controlled using exhaust gas recirculation systems and selective catalytic reduction (SCR) systems. In this analysis, we consider the incremental costs of improvements to SCR systems from Euro V to Euro VI, DPF installation and maintenance, and improved sensors designed to prevent tampering.

In addition to the cost of new technologies, SCR systems require the reagent urea, which assists in the decomposition of NO_x into less harmful gases. Although urea is consumed at only a small fraction of the rate of diesel, the operating cost can be non-negligible over the course of a vehicle's lifetime. To compensate for these costs, manufacturers have improved the fuel efficiency of Euro VI engines compared with Euro V engines. In Europe, where urea is cheaper than diesel, the fuel savings have more than offset the costs of additional urea consumption (Posada et al., 2019). In this analysis, we similarly assume that the costs of increased urea consumption of Euro VI engines compared with Euro V engines are offset by their improved fuel efficiency. This study addresses only the avoided health costs associated with Euro VI standards. However, the social benefits would be even greater if the economic value of reducing greenhouse gases and short-lived climate pollutants such as BC were considered. The introduction of complementary policies such as HDV efficiency standards could support reaching national climate targets while guaranteeing greater fuel savings that translate to operational savings.

As in cost-benefit analyses of Euro VI standards for other countries (Miller & Façanha, 2016; Miller et al., 2014), we applied estimates of incremental technology costs derived from a bottom-up engineering cost analysis. The ICCT has conducted such analyses for light-duty vehicles (Posada et al., 2012), HDVs (Posada et al., 2016), and nonroad equipment (Dallmann et al., 2018). The costs applied in this analysis account for direct costs to manufacturers, including fixed costs and costs that vary with engine size; we also used a multiplier for indirect costs.

Indirect costs include costs of research and development, marketing, shipping, corporate operations, facility operations, and warranties. Indirect cost multipliers (ICMs) are commonly selected based on technology complexity and production timeframe (Rogozhin et al., 2009). We consider diesel aftertreatment technology to be low complexity, as research and development of SCR and DPF technologies and their integration with engines has already been solved in Europe and other leading markets, and no new materials must be developed. Similarly, we selected an ICM based on long-term costs, since Euro VI-equivalent technologies have already been manufactured for more than a decade. The ICM applied in this analysis is 1.125, based on the total warranty plus nonwarranty long-term ICMs for diesel engines (EPA, 2016).[2]

This analysis considers recent changes in the costs of several components since the publication of the previous cost studies. First, prices of the precious group metals platinum and palladium have been updated to reflect average prices over the past six months. Suppliers of NO_x sensors and temperature sensors for automotive applications have substantially lowered their prices as China and India have begun to require these technologies in their latest new vehicle models. Similarly, the costs of DPFs have come

2 See Table 2-119 of the regulatory impact assessment.

down as their widespread deployment in the United States, Europe, and China has resulted in the commodification of DPF substrates.

In addition to capturing recent international market developments in this analysis, we adjusted these estimates of incremental technology costs to account for the average engine sizes of HDVs in Argentina. Engine displacement is an important determinant of technology costs, since aftertreatment systems are sized to treat the exhaust traveling through the tailpipe. We grouped HDVs in Argentina into three segments, then calculated the average engine size for each segment using market data from Promotive (Figure 9).

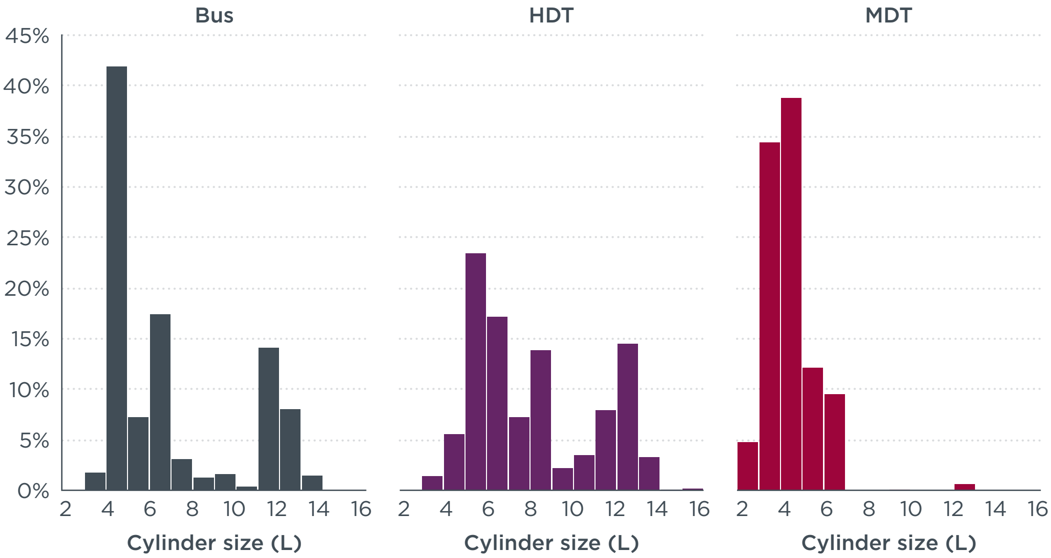

Figure 9. Share of HDV stock by engine size for each vehicle type

Estimated per-vehicle incremental technology costs to comply with Euro VI are shown for each HDV segment in Figure 10. We estimate the costs for manufacturers to comply with Euro VI standards instead of Euro V average $1,000–$1,500 per vehicle, with lower costs for smaller engines and higher costs for larger engines. These estimates are given in U.S. dollars as the price in Argentine pesos depends on the exchange rate and manufacturing location. The largest costs compared with Euro V engines are the addition of the DPF and improvements to the SCR system, which account for more than half of all incremental costs. Further costs are incurred from the addition of technologies to control the engine's air-fuel ratio and to improve combustion. On-board diagnostics and emission sensors account for the remainder of direct manufacturing costs. In addition, we apply an adjustment for indirect costs as discussed above.

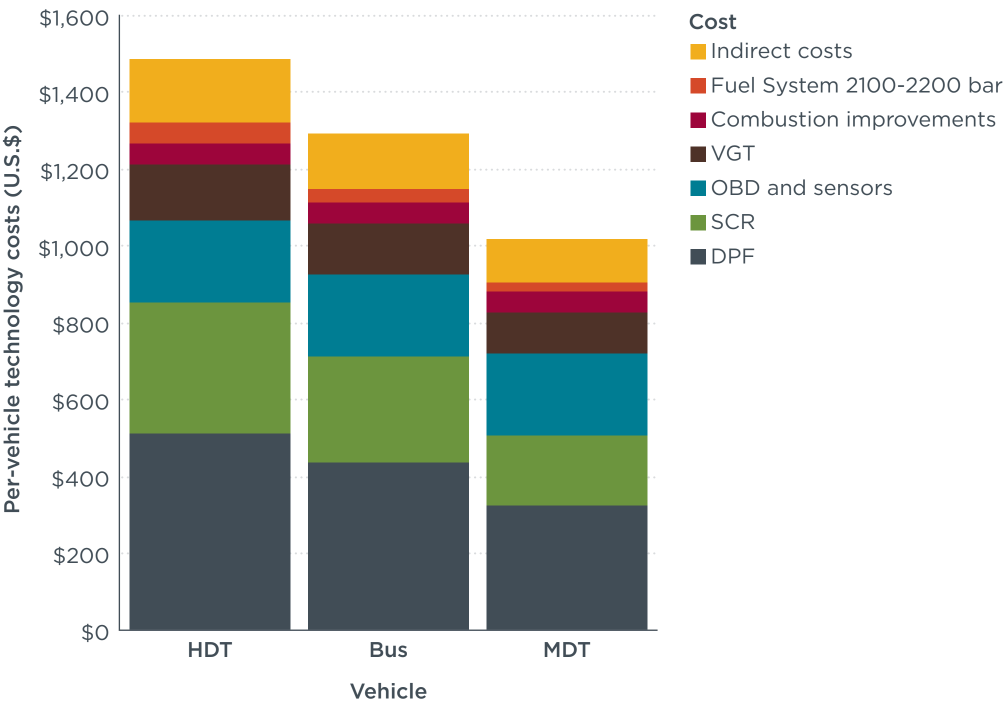

Figure 10. Per-vehicle technology costs to comply with Euro VI compared with Euro V. VGT, variable-geometry turbocharger; OBD, on-board diagnostics; SCR, selective catalytic reduction; DPF, diesel particulate filter.

Fleetwide incremental technology costs were calculated by multiplying per-vehicle costs for each HDV segment by the volume of projected vehicle sales in each calendar year, starting with the year when Euro VI-equivalent standards are assumed to apply to all new HDV sales and registrations in Argentina. As shown in Figure 11, the total incremental costs to HDV manufacturers are estimated to be approximately $30 million a year based on the current level of HDV sales. Varying assumptions of the projected volume of HDV sales would affect the magnitude of estimated benefits and costs but is not expected to affect which scenario yields the greatest net benefits.

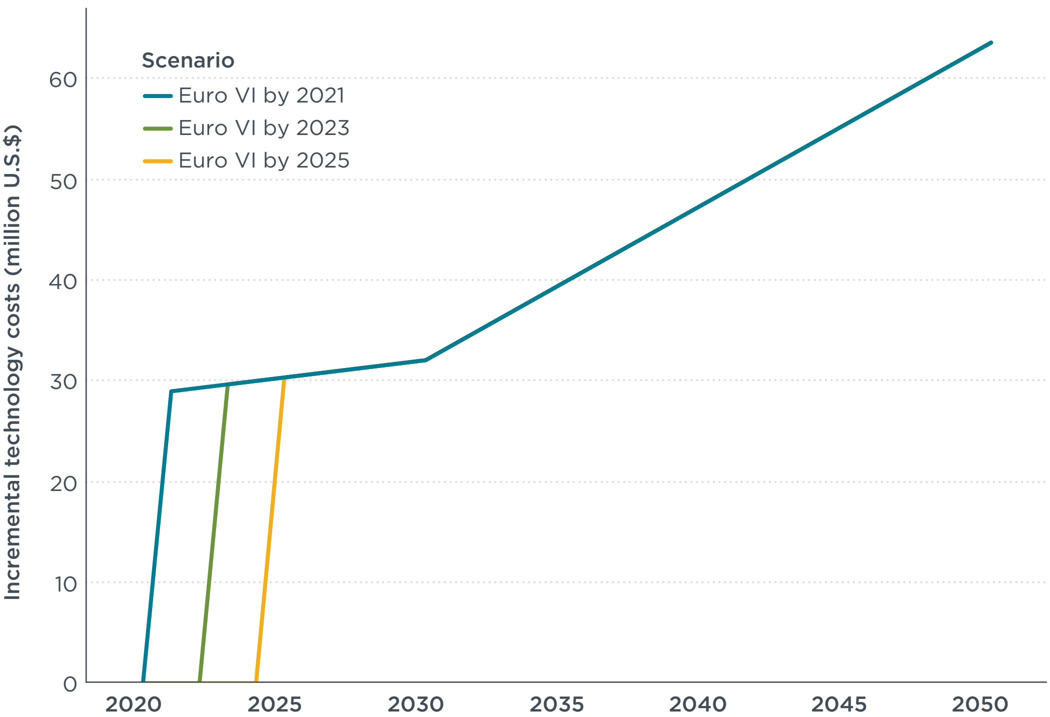

Figure 11. Annual incremental technology costs of Euro VI standards, 2020–2050

VALUE OF HEALTH BENEFITS

Figure 12 shows the estimated value of health benefits of Euro VI-equivalent standards over the period 2020–2050. Because these vehicles will remain on the road for many years, the differences in health benefits are observed over a period of more than 20 years, in contrast to technology costs, which are differentiated over only a four-year period. In other words, beyond the decision about whether to adopt Euro VI-equivalent standards, near-term policy decisions regarding accelerating or delaying their implementation will have a temporary effect on HDV technology costs but a long-term effect on air quality and health outcomes for Argentines. The comparison of costs and benefits is further detailed in the next section.

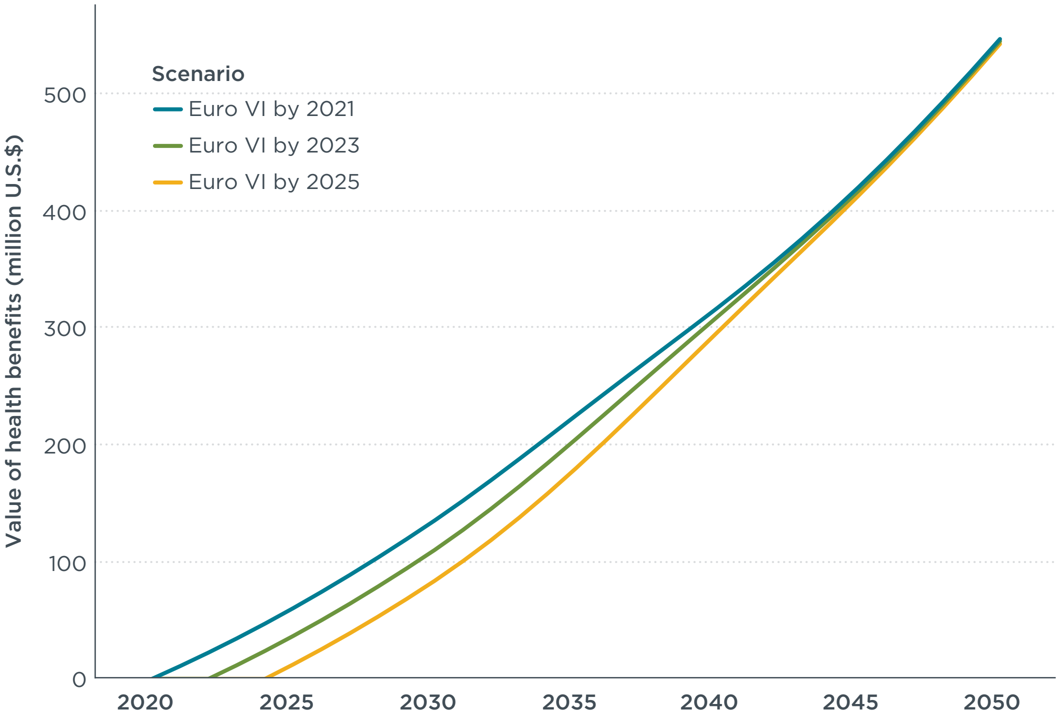

Figure 12. Annual value of health benefits of Euro VI standards, 2020–2050

COMPARISON OF COSTS AND BENEFITS

Table 7 compares the cumulative private costs, health benefits, and net benefits of Euro VI standards over two periods: 2021–2035 and 2021–2050. In all three scenarios, the health benefits of Euro VI standards would substantially exceed the costs of compliance over both periods. Compared with introducing Euro VI in 2023, doing so two years earlier would add $124 million, or 38%, to net benefits over the next 15 years. Conversely, delaying Euro VI to 2025 would diminish the net benefits over the next 15 years by $108 million, or 33%, compared with the 2023 timeline and by $232 million, or 51%, compared with the 2021 timeline.

Compared with the 15-year time period, the net benefits of Euro VI standards are roughly three to six times greater when looking out to 2050, reflecting the continued divergence of emission trajectories under Euro V versus Euro VI. Over a 30-year horizon, in all three scenarios each $1 invested to comply with the standards would produce $3.60 in health benefits.

Table 7. Cumulative net benefits of Euro VI standards from 2021–2035 and 2021–2050

Net benefits over the period 2021–2035 (15 years)

Scenario	Cumulative private costs (million U.S.$)	Cumulative health benefits (million U.S.$)	Net benefits (million U.S.$)
Euro VI by 2021	325	776	451
Euro VI by 2023	267	593	327
Euro VI by 2025	213	433	219

Net benefits over the period 2021–2050 (30 years)

Scenario	Cumulative private costs (million U.S.$)	Cumulative health benefits (million U.S.$)	Net benefits (million U.S.$)
Euro VI by 2021	620	2,202	1,583
Euro VI by 2023	559	1,990	1,432
Euro VI by 2025	502	1,787	1,285

DISCUSSION

Although we characterized emissions from Argentina's current HDV fleet using data representing more than 400,000 HDVs in circulation, there remain uncertainties regarding how annual mileage and fuel efficiencies vary among HDV types, applications, and ages. Further efforts to improve national vehicle registration databases and collect information from fleet operators could help to mitigate these uncertainties. Although these factors could have a substantial effect on estimated current HDV emissions, they are expected to have a smaller effect on the comparison of Euro V and Euro VI standards.

We estimated technology-specific emission factors for HDVs in Argentina using emission factors from European data sources. While these emission factors are reasonable because Argentina has followed the European regulatory pathway for HDV emissions, there are several factors that could cause the emissions performance of HDVs in Argentina to deviate from European HDVs certified to similar standards. Notably, most of the HDVs in Argentina originate in Brazil, where compliance issues associated with PROCONVE P-7 (Euro V equivalent) standards have led to inadequate urea usage and higher-than-expected NO_x emissions (Façanha, 2016). To the extent that similar issues are present for Euro V trucks in Argentina, this would strengthen the case for transitioning to Euro VI standards with stronger safeguards for compliance that are particularly important for real-world control of NO_x emissions (Williams & Minjares, 2016). This also underscores the importance of strengthening compliance and enforcement programs as an essential component of implementing more-stringent standards.

This study assumes that all Euro V and VI vehicles use ultralow-sulfur fuel, as is required for the effective performance of their emission control technologies. Yet data provided by the Secretary of Energy indicate that the retail price of Grade 3 diesel (10 ppm sulfur) is roughly 20% higher on average than Grade 2 diesel, which encourages misfueling of Euro V and Euro VI trucks. Misfueling could lead to increased levels of SO_2 and sulfate emissions and interfere with the reduction of other pollutants such as NO_x. Several available policy options could reduce or eliminate the risks of misfueling. One option would be to introduce differential fuel taxes that bring the retail price of Grade 3 diesel closer to or slightly lower than the price of Grade 2 diesel. Such tax differentials at the pump have been successful in accelerating transitions to cleaner fuels in the United Kingdom, Germany, and Hong Kong (He, 2013). A second option would be to set a regulatory timeline to transition Argentina's diesel supply to meet Grade 3 specifications. Such an approach is consistent with international best practices applied in the United States, Canada, the European Union, Japan, South Korea, and other leading regulatory markets (Miller & Jin, 2019).

We evaluated the health benefits associated with potential reductions in vehicle exhaust emissions using literature-derived estimates of intake fractions and effect factors. Considering that the average intake fraction for tailpipe $PM_{2.5}$ is nearly 100 times higher in urban areas of Argentina than in rural areas, potential developments such as growth in truck and bus traffic in urban areas could have outsized impacts on urban air quality and public health. Our assumption that 36.5% of activity occurs in urban areas is based on an inventory of all vehicle types and may misrepresent the spatial distribution of HDV activity. The estimate is likely to be too low for buses, as these include coaches and urban buses, and is uncertain for trucks, which highlights a need for further detailed transportation emission inventories. Because of the higher exposure in urban areas, municipal policies such as low-emission zones and transitioning urban bus fleets to zero-emission technologies could have correspondingly outsized health benefits in addition to the benefits of nationwide Euro VI standards.

Argentina has already begun to explore potential local applications of electric buses. In May 2019, a one-year electric bus pilot program was initiated in Buenos Aires (Resolución 284/2019). Although the acquisition and operation of the buses were handled by private entities, the Ministry of Transportation is overseeing the experiment and has provided an import tax exemption for these buses. In Brazil, an ICCT analysis of São Paulo's bus fleet found that electric buses could achieve the greatest reductions in emissions of local air pollutants and carbon dioxide and at lower total costs of ownership than current Euro V diesel buses (Dallmann, 2019). As the global market for electric buses continues to expand, reductions in manufacturing costs are expected to make electric buses an increasingly viable option for urban bus fleets worldwide (Miller et al., 2017). Moreover, the fuel life-cycle carbon dioxide emission benefits of battery electric vehicles can be further enhanced with complementary actions to clean up the electricity grid, such as renewable energy policies.

Several health outcomes are not evaluated in this analysis. Excluded outcomes are ozone-related premature deaths; NO_2 impacts on asthma incidence among children and asthma emergency department visits; near-road health impacts; potential health effects of PN emissions; and potential health impacts of air pollution on the incidence of chronic kidney disease, preterm birth and other birth outcomes, and cognitive decline (Anenberg et al., 2019). Consideration of these health outcomes would increase the estimated net benefits of Euro VI standards.

This analysis considered the costs and benefits of Euro VI standards for HDVs with diesel engines, since diesel is currently the principal fuel for trucks and buses in Argentina. We did not evaluate the costs and benefits of these standards for positive-ignition (gasoline or gas-fueled) engines. Additionally, while most first-generation biodiesel feedstocks do not confer substantial benefits from a greenhouse gas or environmental perspective when fuel life-cycle emissions are taken into account (Searle, 2019), we also do not expect that current biodiesel blends in Argentina will impair the functioning of Euro VI (Dallmann, 2018). As a result, we did not consider biodiesel blends in this analysis. For positive-ignition engines, cost-effective technologies are available to enable compliance with Euro VI emission levels (Posada, 2010; Rodríguez, 2019). Introducing Euro VI-equivalent standards for positive-ignition engines in addition to compression-ignition, or diesel, engines would safeguard against potential increases in methane and PN emissions in the event that the market share of HDVs with gas engines increases.

This study found that although Euro V standards have been in effect in Argentina since 2016, a large majority of the HDVs on the road are certified to Euro III and earlier standards, and approximately half of HDVs are more than 10 years old. Since emission standards such as Euro V and Euro VI generally apply only to new vehicles, complementary actions to support fleet renewal could play an important role in accelerating the health benefits of Euro VI standards. Fleet renewal has been identified as an important area for further research among G-20 economies, with particular relevance for countries that have recently introduced or are planning to introduce more-stringent emission standards (Miller, 2020).

CONCLUSION

This study coincides with an accelerating global transition to soot-free vehicles and fuel standards. More and more countries are taking action to reduce the health effects of motor vehicle exhaust and to mitigate the impacts of short-lived climate pollutants, including BC from diesel engines. It also follows similar studies conducted for Brazil, Mexico, and other countries, all of which found that the societal benefits of Euro VI-equivalent standards substantially outweigh the costs for the industry to comply. We utilized local data on Argentina's HDV fleet to compare the costs and benefits of implementing Euro VI-equivalent standards in Argentina in 2021, 2023, or 2025; these dates reflect harmonization with Brazil and Colombia in 2023, or implementation either two years earlier or later.

We estimate that each $1 invested to comply with Euro VI-equivalent standards will produce approximately $3.60 in health benefits over the next 30 years. Importantly, the results also show that while policy decisions on the timing of Euro VI-equivalent standards in Argentina will have only a temporary effect on HDV manufacturing costs, the positive effects on air quality and health outcomes for Argentines will persist in the long term. Compared with introducing Euro VI in 2023, doing so two years earlier would add $124 million, or 38%, to net benefits over the next 15 years. On the other hand, delaying Euro VI to 2025 would diminish the net benefits over the next 15 years by $108 million, or 33%, compared with the 2023 timeline and by $232 million, or 51%, compared with the 2021 timeline.

These findings underscore the societal benefits of implementing Euro VI standards in Argentina as soon as practicable. Considering the large fraction of new HDVs in Argentina that originate in Brazil, we recommend that Argentina consider aligning with Brazil's planned introduction of Euro VI-equivalent standards, which take effect for new type approvals on January 1, 2022, and for all new sales and registrations on January 1, 2023. Considering the greater net benefits of earlier introduction, Argentina should consider incentives for early adoption or accelerated fleet renewal in the case of replacement with Euro VI vehicles.

In addition to local benefits for public health, implementation of Euro VI-equivalent standards in Argentina would reduce BC emissions by an estimated 97% compared with the baseline scenario by 2050, delivering toward Argentina's commitments to take meaningful action on short-lived climate pollutants as a member of the CCAC and a participant in the HDV and SNAP initiatives.

Finally, as discussed earlier, there are several complementary actions that merit particular consideration in Argentina. These include reducing the risks of misfueling by adjusting fuel taxes to reduce or eliminate the price penalty of Grade 3 diesel; planning to transition the nationwide diesel supply to exclusively Grade 3 diesel; evaluating policy options to accelerate fleet renewal; and further considering local-level policies such as low-emission zones and fleet transitions to electric buses.

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