A. INTRODUCTION

1. Regulatory History

Adopted in 2000, the Fleet Rule for Transit Agencies (Transit Fleet Rule) was designed to serve as a diesel airborne toxic control measure that requires public transit agencies to use the best available control technologies. Public transit agencies operating urban bus[1] fleets were required to select either the diesel bus path or the alternative-fuel bus path. The diesel bus path required retrofitting existing buses with diesel particulate filters, while agencies utilizing alternative-fuel path had to ensure that 85 percent of urban bus purchases were alternative fueled buses. All agencies within the jurisdiction of South Coast Air Quality Management District (SCAQMD) followed the alternative-fuel path because these agencies were required to purchase alternative fuel buses per SCAQMD Rule 1192.

The Transit Fleet Rule also included a requirement for larger transit agencies with more than 200 urban buses to purchase zero-emission buses (ZEB) starting in 2011 for transit agencies that utilized the diesel path and one year later for transit agencies that utilized the alternative fuel path. Ten transit agencies were subject to the ZEB purchase requirements and together accounted for about 60 percent of the statewide urban bus fleet.

To date, except for the ZEB purchase requirement, all other regulatory provisions have been met and are being implemented. The ZEB purchase requirement of the Transit Fleet Rule includes the following elements:

- Applies to transit agencies with more than 200 urban buses in active service based on 2007 reporting data.
- 15 percent of new bus purchases must be ZEB.
- The purchase requirement starts in 2011 for fleets that continue to operate diesel buses and 2012 for fleets that switch to alternative fuels.
- The ZEB purchase requirement sunsets in 2026.

A 2006 amendment to the Transit Fleet Rule[2] added an advanced demonstration of the ZEB requirement for larger fleets with more than 200 urban buses in active service prior to the ZEB purchase requirement being reinstated. The advanced demonstration required these larger transit agencies to operate a small number of ZEBs in actual transit service, to install maintenance and fueling/charging infrastructure, to train staff, to collect and report data, and to submit a final report. Several agencies worked together on the early demonstration of ZEBs to gain experience with the technology. Further, the 2006 amendments required CARB staff to evaluate the status of technology with the help of demonstration projects and report back to

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[1] Under the Transit Fleet Rule, urban bus means "a passenger-carrying vehicle powered by a heavy heavy-duty diesel engine, or of a type normally powered by a heavy heavy-duty diesel engine, with a load capacity of fifteen (15) or more passengers and intended primarily for intra-city operation, i.e., within the confines of a city or greater metropolitan area".

[2] California Air Resources Board, Rulemaking to consider proposed amendments to the exhaust emission standards for 2007-2009 model-year heavy duty urban bus engines and the Fleet Rule for transit agencies, OAL approved the final rulemaking and filed it with the Secretary of State on September 7, 2006. The regulation became effective on October 7, 2006 (web link: https://www.arb.ca.gov/regact/sctransit/sctransit.htm, last accessed December 2017).

including methane and nitrous oxide, and costs that cannot be included due to modeling and data limitations. The Intergovernmental Panel on Climate Change (IPCC) has stated that the IWG SC-CO_2 estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.

b. Criteria Pollutant Emissions Benefits

The NO_X and $PM_{2.5}$ emissions impact of the proposed ICT regulation, relative to the baseline and the "current conditions," are presented in Figures B2 and B3 and are shown in tons per day (tpd). Relative to the baseline, from 2020 to 2043 the proposed ICT regulation is estimated to result in a 4,159 ton reduction in NOx and a 25 ton reduction in $PM_{2.5}$. Relative to the "current conditions," the proposed ICT regulation is estimated to result in 4,477 ton reduction in NOx and a 27 ton reduction in $PM_{2.5}$ from 2020 through 2043.

Figure B2: Estimated NOx Emissions under the Baseline, Current Conditions, and the Proposed ICT Regulation

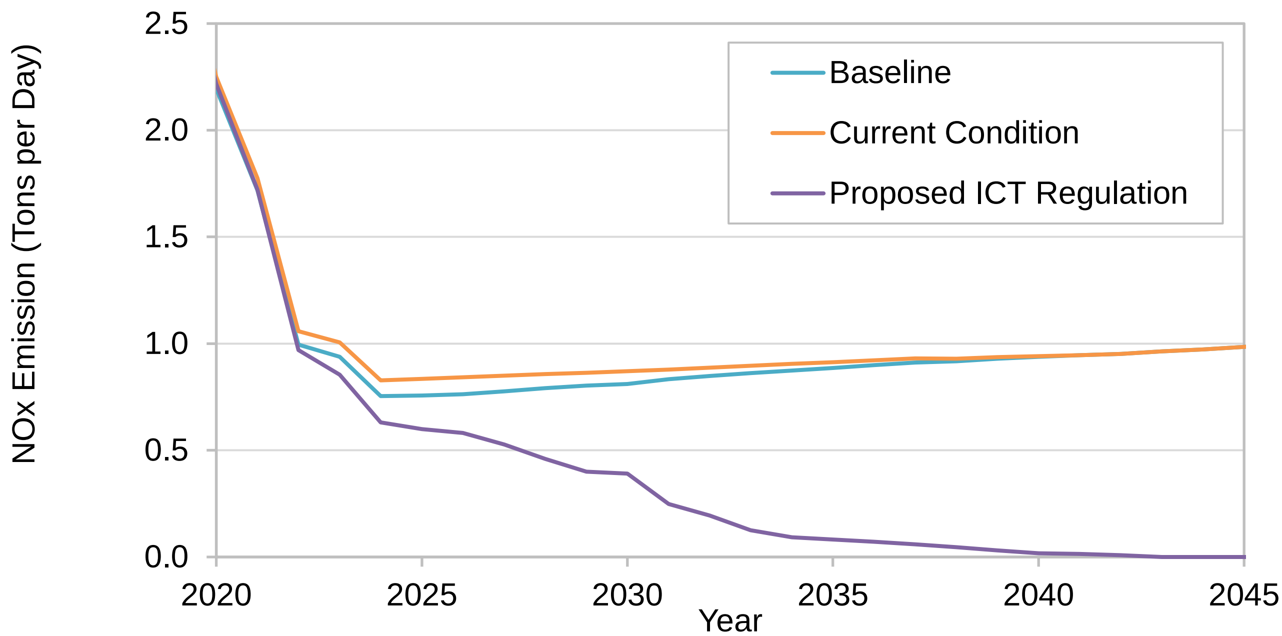
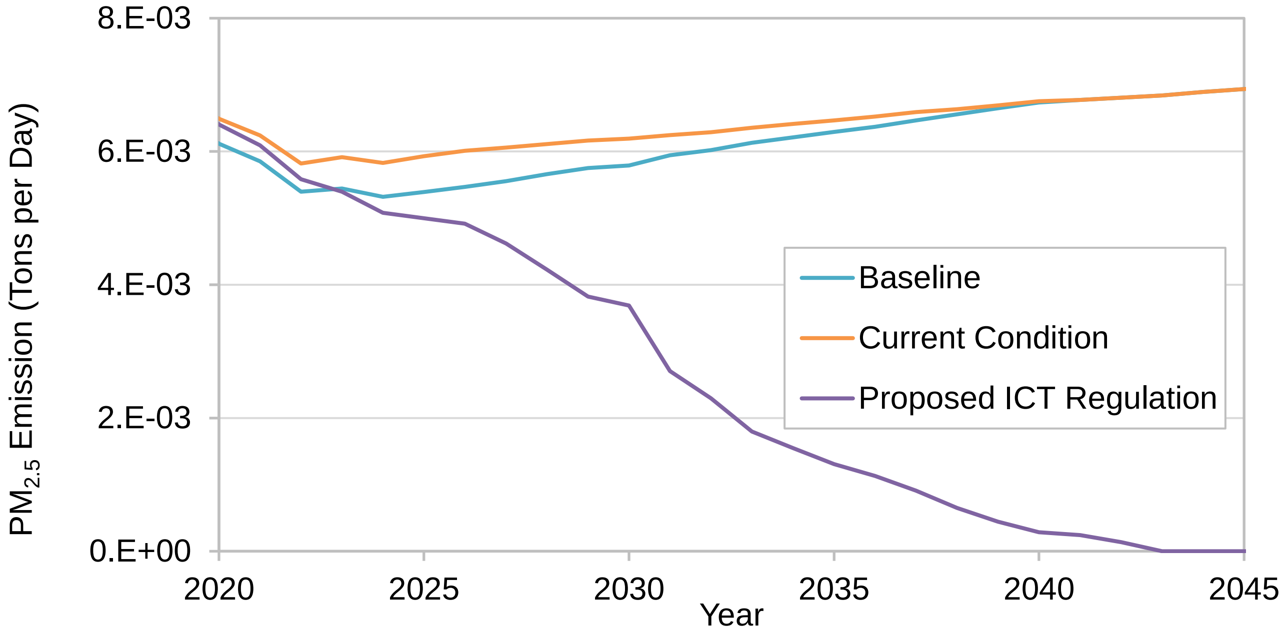


Figure B3: Estimated $PM_{2.5}$ Emissions under the Baseline, Current Conditions, and the Proposed ICT Regulation



Over time, the proposed ICT regulation results in lower GHG, NOx, and $PM_{2.5}$ emissions relative to the baseline and the "current conditions." Compared with the baseline, the proposed ICT regulation achieves slightly fewer emissions reductions from 2020 to 2023, but achieves substantially more emissions reductions after 2023 for WTW GHG and NOx, and $PM_{2.5}$. Relative to the "current conditions," the proposed ICT regulation is anticipated to result in greater emissions reductions every year, from 2020 through 2043.

c. Health Benefits

The proposed ICT regulation reduces NOx and $PM_{2.5}$ emissions, resulting in health benefits for individuals in California. The value of these health benefits are due to fewer instances of premature mortality, fewer hospital and emergency room visits, and fewer lost days of work. As part of setting the National Ambient Air Quality Standard for PM, the U.S. EPA quantifies the health risk from exposure to PM[25] and CARB relies on the same health studies for this evaluation. The evaluation method used in this analysis is the same as the one used for CARB proposed Low Carbon Fuel Standard 2018 Amendments, and Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program. A detailed summary of the health modeling methodology is included in Appendix A of the Proposed Regulatory

[25] U.S. EPA, Quantitative Health Risk Assessment for Particulate Matter (Final Report, released June 2010) (web link: https://www3.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf, last accessed February 2018)

Amendments to the Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program SRIA.[26]

The largest estimated health benefits correspond to regions in California with the most transit buses such as South Coast Air Basin and San Francisco Bay Air Basin, with minor health benefits distributed among other regions. Tables B2 and B3 show the estimated avoided mortality and morbidity incident because of the proposed ICT regulation for 2020 through 2043 by California air basin, relative to the baseline and the "current conditions," respectively. Only the regions with values of 1 or higher are shown, and regions with zero or insignificant impacts are not shown. Values in parenthesis represent the 95 percent confidence intervals of the central estimate. As detailed in the previous section, the proposed ICT regulation is estimated to reduce overall emissions of $PM_{2.5}$ and NOx in most years, and lead to net reduction in adverse health outcomes statewide, relative to the baseline and the "current conditions."

The proposed ICT regulation may decrease the occupational exposure to air pollution of California bus operators, passengers, and employees who work around bus traffic. CARB staff cannot quantify the potential effect on occupational exposure due to lack of data on the typical occupational exposure for these types of workers.

Table B2: Incremental Regional and Statewide Avoided Mortality and Morbidity Incidents from 2020 to 2043 under the Proposed ICT Regulation (Relative to the Baseline)*

Region	Avoided Premature Deaths	Avoided Hospitalizations	Avoided ER Visits
Sacramento Valley	2 (2-2)	0 (0-1)	1 (0-1)
San Diego County	2 (2-3)	0 (0-1)	1 (1-1)
San Francisco Bay	6 (4-7)	1 (0-2)	2 (2-3)
San Joaquin Valley	2 (1-2)	0 (0-1)	1 (0-1)
South Coast	22 (17-26)	3 (0-7)	9 (6-13)
Statewide	**35 (27-42)**	**5 (1-12)**	**15 (9-20)**

* Values in parenthesis represent the 95% confidence interval. Totals may not add due to rounding.

[26] California Air Resources Board, Proposed Regulatory Amendments to the Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program, Standardized Regulatory Impact Assessment (SRIA), released August 10, 2017 (web link: http://www.dof.ca.gov/Forecasting/Economics/Major_Regulations/documents/CARB%20HDVIP%20PSIP%20SRIA.pdf, last assessed February 2018)

Table B3: Incremental Regional and Statewide Avoided Mortality and Morbidity Incidents from 2020 to 2043 under the Proposed ICT Regulation (Relative to the Current Conditions)*

Region	Avoided Premature Deaths	Avoided Hospitalizations	Avoided ER Visits
Sacramento Valley	2 (2-2)	0 (0-1)	1 (0-1)
San Diego County	3 (2-3)	0 (0-1)	1 (1-1)
San Francisco Bay	6 (5-7)	1 (0-2)	3 (2-4)
San Joaquin Valley	2 (1-2)	0 (0-1)	1 (0-1)
South Coast*	24 (19-29)	3 (0-8)	10 (7-14)
Statewide	**37 (29-46)**	**6 (1-13)**	**16 (10-22)**

* Values in parenthesis represent the 95% confidence interval. Totals may not add due to rounding.

In accordance with U.S. EPA practice, health outcomes are monetized by multiplying each incident by a standard value derived from economic studies.[27] The value per incident is shown in Table B4. The value for avoided premature mortality is based on willingness to pay,[28] which is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year. While the cost-savings associated with premature mortality is important to account for in the analysis, the valuation of avoided premature mortality does not correspond to changes in expenditures, and is not included in the macroeconomic modeling (Section E). As avoided hospitalizations and ER visits correspond to reductions in household expenditures on health care, these values are included in the macroeconomic modeling.

Unlike mortality valuation, the cost-savings for avoided hospitalizations and ER visits are based on a combination of typical costs associated with hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, post-hospitalization medical care, out-of-pocket expenses, and lost earnings or both individuals and family members, lost recreation value, and lost household production (e.g., valuation of time-losses from inability to maintain the household or provide childcare).[29] These monetized benefits from avoided hospitalizations and ER visits are included in macroeconomic modeling (Section E).

[27] U.S. EPA, Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses (240-R-10-001, released December 2010) (web link: http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-22.pdf/$file/EE-0568-22.pdf, last accessed February 2018)

[28] U.S. EPA, An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction (EPA-SAB-EEAC-00-013, released July 27, 2000) (web link: https://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf, last accessed February 2018)

[29] Chestnut, L. G., Thayer, M. A., Lazo, J. K. and Van Den Eeden, S. K. (2006), The Economic Value Of Preventing Respiratory And Cardiovascular Hospitalizations, *Contemporary Economic Policy*, 24: 127– 143. doi: 10.1093/cep/byj007

Table B4: Valuation per Incident for Avoided Health Outcomes

Outcome	Units	2016$
Premature mortality	avoided death	$8,793,190
Hospitalizations for cardiovascular illness	avoided hospitalization	$52,826
Hospitalizations for respiratory illness	avoided hospitalization	$46,078
Emergency room visits for respiratory illness	avoided ER visit	$756
Emergency room visits for asthma	avoided ER visit	$756

The total statewide valuation because of avoided health outcomes for the proposed ICT regulation is summarized in Table B5. The spatial distribution of these cost-savings follows the distribution of emission reductions and avoided health outcomes, therefore most cost savings will occur in the South Coast and San Francisco Bay air basins.

Table B5: Estimated Incremental Valuation from Avoided Health Outcomes under the Proposed ICT Regulation from 2020 through 2043

Outcome	Relative to the Baseline		Relative to the Current Conditions	
	Avoided Incidents	Statewide Health Valuation (2016M$)	Avoided Incidents	Statewide Health Valuation (2016M$)
Avoided premature deaths	35	$303,365,048	37	$328,131,757
Avoided hospitalization	5	$256,159	6	$278,579
Avoided ER Visits	15	$11,101	16	$12,090
Total		**$303,632,308**		**$328,422,426**

d. Other Benefits to Individuals

In addition to benefits from emissions reductions, ZEBs can also provide a smoother and quieter ride when compared to conventional buses and offer a more pleasant, smoother and quieter ride to passengers than diesel and CNG and may reduce noise levels in communities.

C. DIRECT COSTS

1. Direct Cost Inputs

The estimated direct costs of the proposed ICT regulation, the baseline, and the "current conditions" in this analysis include upfront capital costs for bus purchases and cleaner engines, charging or fueling infrastructure, as well as maintenance bay upgrades. The direct cost also includes annual operational costs for bus and infrastructure maintenance and fuel consumption. Compared to conventional buses, ZEBs generally have higher upfront capital cost but lower operational cost that result in annual savings when compared to conventional buses. The assumptions underlying the direct costs are detailed in the following sections.

a. Upfront Capital Cost

Transit agencies make the initial investment in buses and charging or fueling infrastructure and pay upfront capital cost. The total capital cost of buses and infrastructure is based on the number of buses purchased and the unit cost per bus or infrastructure element. These two factors are discussed in details in the following sections.

Bus Population

In this analysis, the current estimates of bus population are based on the Natural Transit Database (NTD).[30] Most transit agencies report to NTD about their vehicle fleet by mode[31] and vehicle type.[32] Urban agencies report vehicles by fuel type, but rural agencies do not. Rural reporters usually own 100 or fewer buses, as shown in the NTD. The reported fuel types for buses in urban agencies include:

- Compressed natural gas (CNG),
- Liquefied natural gas (LNG),
- Liquefied petroleum gas (LPG),
- Diesel fuel,
- Hybrid diesel,
- Gasoline,
- Hybrid gasoline,
- Battery electric, and
- Hydrogen cell.

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[30] National Transit Database (NTD), NTD Data Reports (Annual Database Revenue Vehicle Inventory) (web link: https://www.transit.dot.gov/ntd/ntd-data, last accessed January 2018)

[31] According to NTD Glossary, "Mode" is defined as "a system for carrying transit passengers described by specific right-of-way (ROW), technology and operational features." NTD recognizes eight non-rail modes, including bus (MB) and commuter bus (CB) (web link: https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary, last accessed January 2018).

[32] According to NTD Glossary, "Vehicle Type" is defined as "The form of passenger conveyance used for revenue operations" (web link: https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary, last accessed January 2018).

For ease of calculation in this analysis, the fuel types with similar powertrains are regrouped into four categories:

- CNG (including CNG, LNG, and LPG),
- Diesel fuel (including diesel fuel and gasoline fuel),
- Hybrid diesel (including hybrid diesel and hybrid gasoline), and
- ZEBs (including battery electric and hydrogen cell).

Without fuel type data for rural agencies, the bus distributions among fuel types in this analysis are assumed to be the same for both rural and urban agencies. Table C1 shows the total bus population by agency size and fuel type based on NTD 2016.

Table C1: Statewide Bus Population by Agency Size and Fuel Type (NTD 2016)

Reporting Type	Agency Group	Diesel	Diesel Hybrid	CNG	ZEBs[a]	Total
Urban	Large (>=100)	4300	357	5640	62	10359
	Medium (>=30 & <100)	1392	149	749	5	2295
	Small (<30)	317	3	452	2	774
Subtotal		*6009*	*509*	*6841*	*69*	*13428*
Rural	Large (>=100)	0	0	0	0	0
	Medium (>=30 & <100)	219[b]	23[b]	118[b]	1[b]	361
	Small (<30)	165[b]	2[b]	235[b]	1[b]	403
Subtotal		384[b]	25[b]	353[b]	2[b]	*764*
Total		**6393[b]**	**534[b]**	**7194[b]**	**71[b]**	**14192**

[a] This ZEB population is based on NTD 2016; CARB's ZEB maps provides more up-to-date information (web link: https://arb.ca.gov/msprog/ict/zbusmap.pdf, last accessed January, 2018)

To analyze fuel cost, the bus population is further grouped and allocated to different utility areas. For this analysis, all the diesel and diesel hybrid buses are assumed to be operated in Pacific Gas and Electric Company (PG&E) area. For CNG buses, those operating in San Diego Metropolitan Transit System (SD MTS) and North County Transit District (NCTD) are assigned to San Diego Gas and Electric (SDG&E) territory, all CNG buses operating within the City of Los Angeles Department of Transportation (LADOT) and 67 percent of CNG buses within the Los Angeles County Metropolitan Transportation Authority (LA Metro) are assigned to the Los Angeles Department of Water and Power (LADWP) area (the LA Metro fleet is the largest in the State and spans two utility service areas). The remaining CNG buses are assumed to operate in the Southern California Edison (SCE) area.

Bus population projections and turnover are based on a 14-year average bus lifetime, which is consistent with the existing practices of most transit fleets. While it is possible that future bus population may vary with human population, the status of economy, regional transportation planning, and other factors, the cost analysis does not reflect growth in the bus population to simplify the analysis and the relative change in costs are proportionally the same.

The Federal Transit Administration's (FTA's) service-life policy for transit buses and vans establishes the minimum number of years (or miles) that transit vehicles purchased with federal funds must be in service before they can be retired without financial penalty. The minimum service-life requirements differ by vehicle size and range from 4 to 12 years.[33] Typically transit agencies keep buses for additional 2 years beyond the minimum requirements. Most industry experts commonly refer to a standard, 40-foot bus as a “12-year” bus reflecting its minimum useful life, and many transit authorities have adopted 12 years as their retirement policy for this vehicle type. While the statewide bus fleet is comprised of a variety of bus types and sizes, with diverse minimum service-lives, in this analysis, all buses are treated as standard buses with a 12-year minimum requirement, plus two additional years, which results in a 14-year lifetime. This is the consensus approach proposed by transit agencies.

Since each transit agency has different purchase patterns and cycles, it is difficult to estimate the number of buses to be replaced and purchased each year by a specific agency. However, on a statewide basis, CARB staff assume a uniform bus age distribution where on average 7.1 percent (=1/14) of bus population will be replaced by new ones in each year.

The ZEB phase-in schedule, or the percentage of ZEBs in each new purchase, determines the number of ZEBs that enter bus fleets annually. Table C2 shows ZEB phase-in schedules for the baseline, the “current conditions,” and proposed ICT regulation. The corresponding projections of ZEBs within the fleet are presented in Figure C1. Under the baseline, ZEBs would enter the fleet with the 15 percent ZEB purchase requirement for large transit agency beginning in 2011 or 2012 until 2026 when the existing rule sunset and no ZEBs would be purchased. The number of ZEBs peak at around 920 in 2026. Afterwards, ZEBs gradually phase-out because of the sunset of the existing rule. Under the proposed ICT regulation, 25 percent of ZEBs start to be purchased by large transit agencies beginning in 2020 and the ZEB fleet exceeds the baseline by 2023. Under the proposed ICT regulation, the number of ZEBs in the fleet will be around 2,000 (14 percent) in 2025, 6,200 (44 percent) in 2030, 10,900 (77 percent) in 2035, and eventually 100 percent of the bus fleet after 2042.

[33] Federal Transit Administration, Useful Life of Transit Buses and Vans (Report No. FTA VA-26-7229-07.1), released in April 2007 (web link: https://www.transitwiki.org/TransitWiki/images/6/64/Useful_Life_of_Buses.pdf, last accessed January 2017)

Table C2: ZEB Phase-In Schedules for the Baseline, the Current Condition, and the Proposed ICT Regulation

Year[c]	Baseline		Current Conditions	Proposed ICT		
	Large Diesel[a]	Large CNG[a]	All agencies	Large[b]	Medium[b]	Small[b]
2011	15%	0%	0%	0%	0%	0%
2012	15%	15%	0%	0%	0%	0%
2013	15%	15%	0%	0%	0%	0%
2014	15%	15%	0%	0%	0%	0%
2015	15%	15%	0%	0%	0%	0%
2016	15%	15%	0%	0%	0%	0%
2017	15%	15%	0%	0%	0%	0%
2018	15%	15%	0%	0%	0%	0%
2019	15%	15%	0%	0%	0%	0%
2020	15%	15%	0%	25%	0%	0%
2021	15%	15%	0%	25%	0%	0%
2022	15%	15%	0%	25%	0%	0%
2023	15%	15%	0%	50%	50%	0%
2024	15%	15%	0%	50%	50%	0%
2025	15%	15%	0%	50%	50%	0%
2026	15%	15%	0%	75%	75%	75%
2027	0%	0%	0%	75%	75%	75%
2028	0%	0%	0%	75%	75%	75%
2029	0%	0%	0%	100%	100%	100%

[a] The transit agencies with more than 200 urban buses are required to purchase 15% of ZEBs in the new purchase. The requirement for agencies following diesel-path starts from 2011 and for agencies following alternative fuel-path starts from 2012 and it sunsets after 2026.

[b] The definitions of large, medium, and small agencies in the proposed ICT regulation are different from the existing Transit Fleet Rule. The fleet sizes are defined based the number of buses within modes and vehicles types mentioned in this section

[c] The ZEB phase-in schedules are shown from 2011 to 2029. Before 2011, there is 0% of ZEBs in new purchases under all scenarios; after 2029, ZEB purchase percentages are the same as the ones in 2029.