Appendix D

Total Fuel Costs

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Fuel cost is an important element to consider for the entire operation and maintenance cost of a transit bus. Fuel cost is primarily affected by two factors: (1) fuel price per unit of fuel; and (2) fuel consumption. The latter consumption is determined by a combination of vehicle mileage (miles traveled) and vehicle fuel efficiency (fuel required per mile traveled). Because vehicle mileage is based on transit agencies' actual needs, vehicle fuel efficiency is an essential factor for fuel cost management. This appendix discusses both the fuel price and vehicle fuel efficiency amongst different fuels.

A. Introduction

Fuel cost is a major expense for transit operations. Vehicles with different fuel types and technologies have different fuel efficiencies. There is also a wide range of fuel efficiencies within vehicles that operate using the same technology. Fuel efficiency is affected by several factors such as driving cycle, weather, terrain, payload, driving pattern, etc. The first part of this appendix summarizes available fuel efficiency data from various sources. The second part of the document discusses various fuel prices, including for diesel, compressed natural gas (CNG), renewable diesel (RD), renewable natural gas (RNG), electricity, and hydrogen. Staff will also discuss here energy price projections from the U.S. Energy Information Administration (EIA), and the energy prices staff used in proposing the Innovative Clean Transit (ICT) cost analysis.

B. Fuel Efficiency

Vehicle fuel efficiency is affected by the different driving cycles and operating conditions in which bus fleets operate. Staff reviewed fuel efficiency data from three sources, including Altoona test reports, the National Renewable Energy Laboratory (NREL) transit bus evaluation reports, and the National Transit Database (NTD). All Altoona bus tests are conducted at the same facility in Pennsylvania under defined test cycles as described in the testing procedures. The NREL studies evaluated specific transit bus technologies for specific transit agencies. The NTD data reflects data reported by transit agencies. Based on the NTD data, staff calculated the fuel efficiency estimates for a specific transit fleet. The data from each of these sources are discussed in detail below.

1. Altoona Test

Pursuant to the Surface Transportation and Uniform Relocation Assistance Act (STURAA) of 1987, bus testing is required on all new model buses before they can be purchased with Federal Transit Administration (FTA) funds. The bus testing results are available in the form of Altoona testing reports. Starting October 31, 2016, the Altoona testing applies pass/fail requirements that previous testing did not have.[1]

The main purpose of the Altoona testing is to test the durability and reliability of a bus. Prior to October 31, 2016, the test also included both the fuel efficiency and the emissions testing (no emission testing for zero-emission buses). The fuel efficiency testing was performed on the bus testing lane at the Pennsylvania State University Testing Facility. The test was based on the Transit Coach Operating Duty Cycle (ADB Cycle), which included Central Business District (CBD), Arterial, and Commuter phases. Starting October 31, 2016, fuel economy testing is no longer performed separately; instead, the on-road fuel economy testing is performed as part of the emissions test.[2]

The emission testing, comprising three different testing cycles, is conducted in a laboratory on a chassis dynamometer. The emission testing includes the Manhattan Cycle, the Orange County Bus Driving Cycle, and the Heavy Duty Urban Dynamometer Driving Schedule (HD-UDDS).[3] Prior to October 31, 2016, the emission testing was only performed on non-zero emission buses. After October 31, 2016, these three testing cycles are performed on zero emission buses as an energy economy and range test.[4,5]

It is important to note that both the fuel efficiency and emission testing only provide a relative comparison among different buses under different driving cycles. Actual in-use driving cycles vary significantly among the transit agencies. The Altoona Bus Research and Test Center cautions the use of such data to predict in-use performance, and states that “the objective of this [fuel economy] test is to provide accurate comparable fuel consumption data on transit buses produced by different manufacturers. This test bears no relation to the calculations done by the Environmental Protection Agency. The results of this test will not represent actual "in service" fuel economy but will provide comparative data.” It further states that for emission testing “the objective of this test is to provide accurate, comparable gas and particulate emissions data for transit buses

[1] Federal Register (2016). 49 CFR Part 665. Bus Testing: Establishment of Performance Standards, a Bus Model Scoring System, a Pass/Fail Standard and Other Program Updates. Vol. 81, No. 147, August 1, 2016. Available: https://www.gpo.gov/fdsys/pkg/FR-2016-08-01/pdf/2016-17889.pdf.
[2] Federal Register (2016). 49 CFR Part 665. Bus Testing: Establishment of Performance Standards, a Bus Model Scoring System, a Pass/Fail Standard and Other Program Updates. Vol. 81, No. 147, August 1, 2016. Available: https://www.gpo.gov/fdsys/pkg/FR-2016-08-01/pdf/2016-17889.pdf.
[3] Fuel efficiency testing and emissions testing cycles are explained in the Altoona bus testing reports. The ADB cycle is structured as a set number of miles in a fixed time in the following order: CBD, Arterial, CBD, Arterial, CDB, and Commuter.
[4] As of May 31, 2018, the Manhattan Cycle, the Orange County Bus Driving Cycle, and the Heavy Duty Urban Dynamometer Driving Schedule (HD-UDDS) have been conducted on one battery electric bus, Proterra Catalyst E2.
[5] The Altoona Bus Research and Testing Center (2017). Altoona Test Report for Proterra Catalyst E2. September 2017. Available: http://altoonabustest.psu.edu/buses/reports/480.pdf?1521553696.

produced by different manufacturers while operating the vehicle over a simulated transit duty cycle on a dynamometer. The test will be performed on an engine after the bus has accumulated several thousand miles of operation, thus providing a more realistic indication of the level of emissions that can be expected in actual transit service. The results of this test may be used by transit operators for making relative comparisons between buses. This is not the same procedure that is used to meet the U.S. Environment [sic] Protection Agency (EPA) compliance testing."[6]

Twenty-five buses with a length between 35 and 42 feet have gone through Altoona Testing since 2010. Among these buses, six are battery electric buses (BEBs), one is a fuel cell electric bus (FCEB), seven are CNG buses, eight are diesel buses, and three are diesel hybrid buses. These buses are shown in Table 1. Data reviewed and presented here do not include cutaway buses.

Table 1: Altoona reports for bus (35 to 42 feet) tested since 2010

Manufacturer	Model	Test starting year	Vehicle length	Fuel type
Blue Bird Body Company	All American RE	2012	35'	Diesel
Blue Bird Body Company	All America FE	2012	36'	Diesel
BYD Motors, Inc.	BYD Electric Bus	2013	40'	BEB
Daimler Buses North America, Ltd.	ORION VII EPA10 Diesel	2012	41'	Diesel
Daimler Buses North America, Ltd.	Orion VII EPA10	2010	41'	Series Hybrid
Daimler Buses North America, Ltd.	Orion VII EPA 10 CNG	2011	41'	CNG
Eldorado National	Axess HD	2014	41'	CNG
Eldorado National	Axess	2013	41'	Diesel
Eldorado National	ARRIVO	2014	39'	Diesel
Eldorado National California, Inc.	Axess FC	2016	41'	FCEB
Gillig Corporation	Low Floor	2010	40'	CNG
Gillig, LLC	40' LOW FLOOR	2012	41'	Series Hybrid
Gillig, LLC	LOW FLOOR	2013	40'	CNG

[6] The Altoona Bus Research and Test Center. http://altoonabustest.psu.edu/bus-tests.htm. Accessed July 19, 2018.

Manufacturer	Model	Test starting year	Vehicle length	Fuel type
New Flyer	XDE40	2010	40'	Series Hybrid
New Flyer	XE40	2014	40'	BEB
New Flyer	C40LF	2011	41'	CNG
New Flyer	XN40	2014	41'	CNG
New Flyer	XD40	2012	40'	Diesel
North American Bus Industries	416.5	2010	40’	Diesel
North American Bus Industries	40-LFW	2013	41'	Diesel
Nova Bus, Division of Volvo Group Canada	CNG LFS 40	2013	40'	CNG
Proterra, Inc.	BE-35	2011	35'	BEB
Proterra, Inc.	BE35	2013	35'	BEB
Proterra, Inc.	BE40	2014	42’	BEB
Proterra, Inc.	Catalyst E2	2017	42’	BEB

The testing parameters of the testing cycles, including speed range, and the median, average, and standard deviation of the fuel efficiency (expressed as miles per diesel gallon equivalent) of buses (35 to 42 feet) tested from 2010 to 2016, are summarized in Table 2. As a point of comparison, although there are significant differences among transit agencies and even among routes for the same transit agency, the average speed for urban buses is commonly below 13 miles per hour.[7]

Table 2: Altoona testing cycles descriptions and fuel efficiency results for buses tested from 2010-2016

Testing type	Testing cycle	Max speed (mph)	Avg speed (mph)	Fuel Efficiency (mile/DGE)	BEB	CNG	Diesel	Diesel Hybrid
Emissions Testing*	Manhattan	25.4	6.8	Median	n/a	2.68	3.61	4.15
				Avg	n/a	2.74	3.58	4.29
				Stdev	n/a	0.27	0.46	0.38
	Orange County	41	12	Median	n/a	4.06	4.88	5.38
				Avg	n/a	4.07	5.02	5.68
				Stdev	n/a	0.25	0.67	0.67
	HD-UDDS	58	18.86	Median	n/a	5.37	6.49	6.08
				Avg	n/a	5.29	6.66	6.07

[7] American Public Transportation Association (2017). 2016 Public Transportation Fact Book. 67th Edition. February 2017. Available: http://www.apta.com/resources/statistics/Documents/FactBook/2016-APTA-Fact-Book.pdf.

Testing type	Testing cycle	Max speed (mph)	Avg speed (mph)	Fuel Efficiency (mile/DGE)	BEB	CNG	Diesel	Diesel Hybrid
				Stdev	n/a	0.49	1.08	1.30
Fuel Efficiency Testing (Eliminated after October 31, 2016)	CBD	20	12.7	Median	21.55	3.87	3.93	4.66
				Avg	21.45	4.07	3.97	4.92
				Stdev	1.93	0.56	0.41	0.47
	Arterial	40	27	Median	16.88	4.94	4.1	4.37
				Avg	16.87	4.99	4.35	4.45
				Stdev	1.34	0.83	0.44	0.62
	Commuter	40	38	Median	26.73	8.05	7.77	6.8
				Avg	26.71	7.92	7.93	6.78
				Stdev	1.08	1.25	0.94	1.02

* The emissions testing results do not include Proterra Catalyst E2 tested in 2017.

The characteristics of the three emissions testing cycles, including the Manhattan, the Orange County, and the HD-UDDS cycles, are shown in Figures 1 through 3 respectively.[8]

Figure 1 shows the characteristics of the Manhattan driving cycle. The test lasts for 1089 seconds (about 18 minutes), and the maximum and average speed of the test cycle are 25.4 and 6.8 mph respectively. There are frequent stops and the average speed is low in this cycle. The average speed is the lowest among all six testing cycles.

[8] The Altoona Bus Research and Testing Center (2017). Energy Economy Test – An Energy Consumption Test for Battery Electric Buses Using Appropriate Operating Cycles. October 2017. Available: http://www.larson.psu.edu/assets/docs/bus%20docs/6%200%20-%20Electric%20Energy%20Consumption_Nov%202017.pdf.

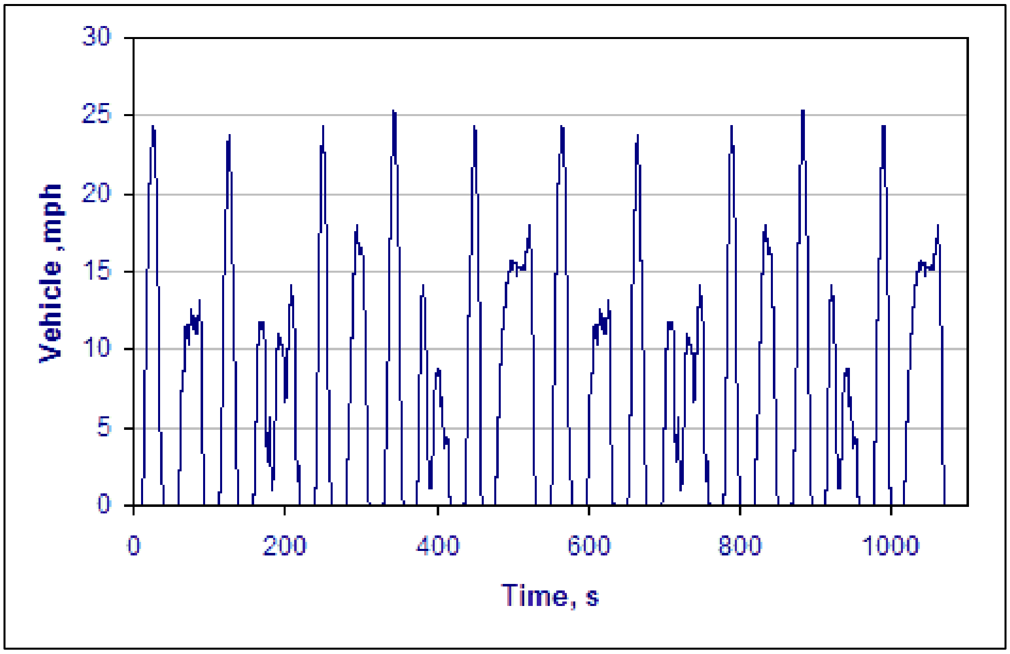

Figure 1: Manhattan driving cycle

Figure 2 shows the Orange County Bus Cycle. The Orange County cycle consists of urban and highway driving segments that lasts 1909 seconds (about 30 minutes). The maximum and the average speed are 41 mph and 12 mph respectively.

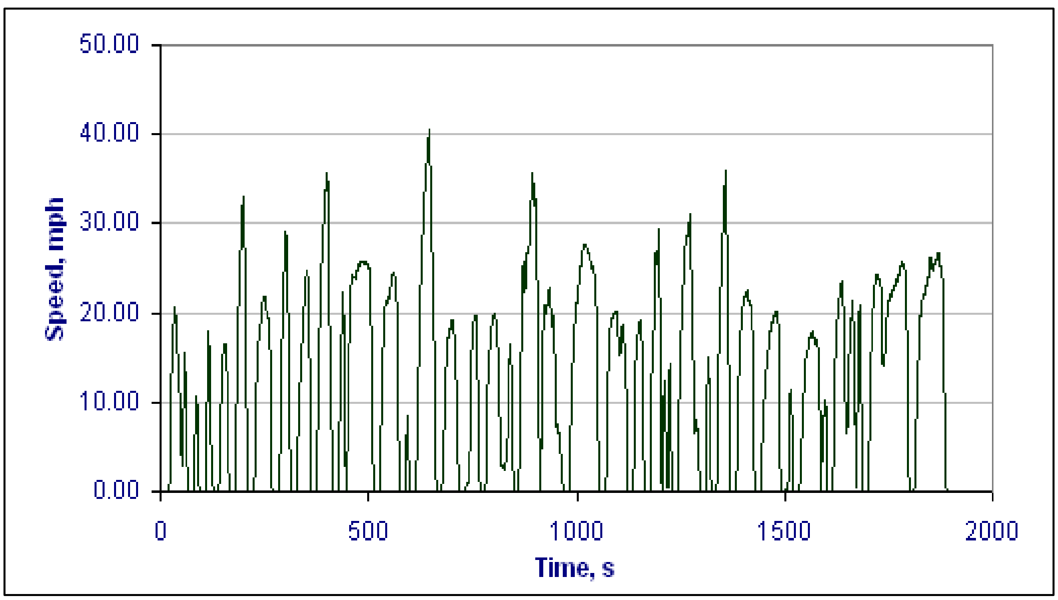

Figure 2: Orange County driving cycle

Figure 3 shows HD-UDDS cycle. The HD-UDDS cycle represents heavy duty vehicles driving in urban areas, which lasts 1060 seconds (almost 18 minutes). The maximum speed and the average speed are 58 mph and 18.86 mph respectively.

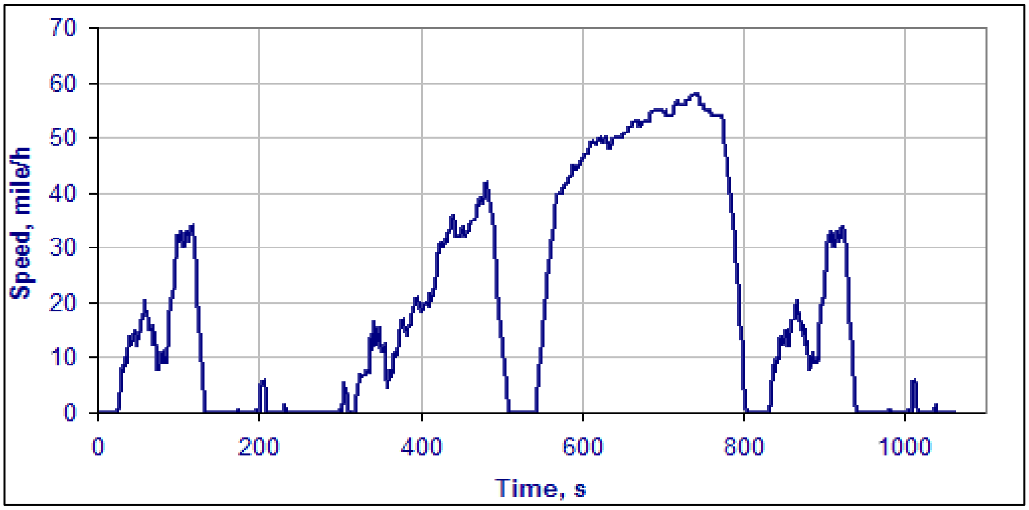

Figure 3: UDDS driving cycle

Figures 4 and 5 show the fuel efficiency profile of different propulsion technologies at different bus driving cycles. These can help us understand the effects of the different routes, speeds, and propulsion technologies that contribute to bus fuel efficiency.

Figure 4 contains information about the fuel efficiency of the diesel, CNG and diesel hybrid buses in HD-UDDS, Orange County and Manhattan cycles.[9] This shows:

- Diesel, CNG and diesel hybrid buses all have the highest fuel efficiencies in the HD-UDDS and Manhattan cycles.
- For diesel hybrid buses, their fuel efficiency is higher than that of diesel and CNG buses under the Manhattan and the Orange county cycles. This observation is also consistent with another study[10] performing Altoona Testing review. In addition, hybrid buses consistently have higher fuel efficiency than diesel and

[9] Prior to October 31, 2016, the HD-UDDS, the Orange County and the Manhattan cycles were only performed on non-zero emission buses.

[10] MJB & A (2013). Comparison of Modern CNG, Diesel and Diesel hybrid-Electric Transit Buses: Efficiency & Environmental. November 12, 2013. Available: http://mjbradley.com/sites/default/files/CNG%20Diesel%20Hybrid%20Comparison%20FINAL%2005nov13.pdf.

CNG buses, especially at lower speeds. Hybrid buses in general have a better fuel efficiency in a stop-and-go driving cycle due to regenerative braking.[11]

- When the average speed is higher, such as in the HD-UDDS cycle, diesel buses have the highest average fuel efficiency and CNG buses have the lowest fuel efficiency.

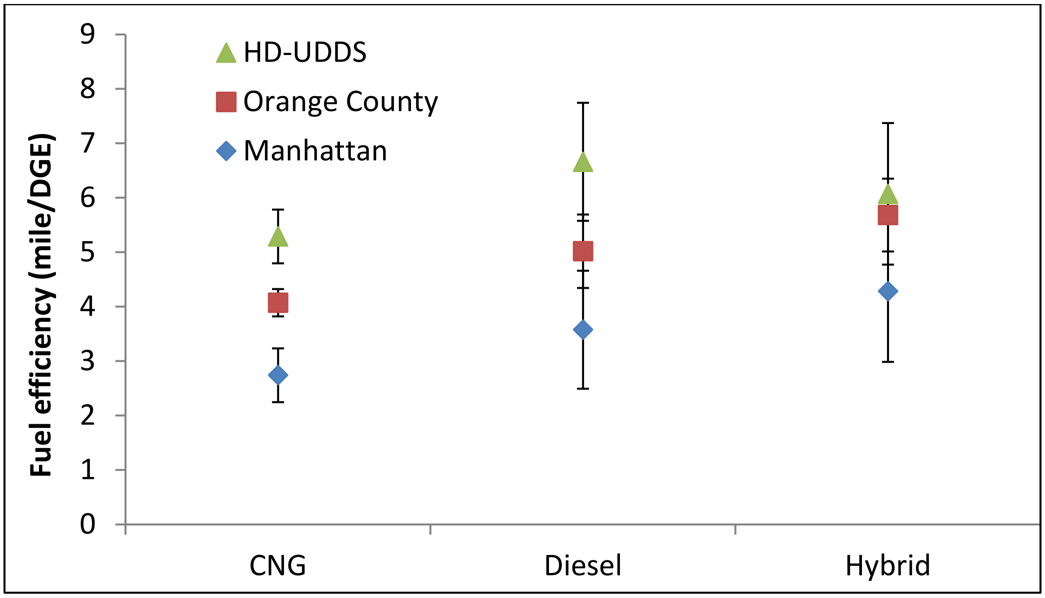

Figure 4: Conventional bus average fuel efficiency under the HD-UDDS, the Orange County and the Manhattan cycles

The fuel efficiency testing in previous Altoona testing is an on-the-road process that comprises central business district (CBD), arterial and commuter cycles. The driving traces for these three cycles are not illustrated here since the new testing does not include these cycles. The CBD cycle includes 2 miles with 7 stops per mile and a top speed of 20 mph; the arterial cycle includes 2 miles with 2 stops per mile and a top speed of 40 mph; and the commuter cycle includes 4 miles with 1 stop and a maximum speed of 40 mph. At each designated stop the bus will remain stationary for seven seconds. During this time, the passenger doors shall be opened and then closed to simulate the effect from dropping off and loading passengers. The average speed of CBD, arterial and commuter cycles is 12.7, 27 and 38 mph, respectively.

[11] Environmental and Energy Study Institute (2007). Hybrid Buses Costs and Benefits. March 20, 2007. Available: http://www.eesi.org/files/eesi_hybrid_bus_032007.pdf.

Figure 5 shows the bus fuel efficiency under these cycles. These fuel efficiency testing cycles have been eliminated since October 31, 2016. However, a few observations are made based on the results prior to October 31, 2016.

- BEBs have the highest fuel efficiency among all propulsion systems across all the testing cycles, which range from three to five times the conventional bus fuel efficiency.
    - In CBD urban cycle, which has a low average speed with a lot of stop-and-go driving, the average fuel efficiency of a BEB is about five times that of a diesel bus and a CNG bus.
    - In the arterial and the commuter routes where the average speed is higher and the stop-and-go activities are fewer, the fuel efficiency of a BEB is still about three times that of a diesel or CNG bus. The average fuel efficiency of BEBs in CBD, arterial and commuter cycles are 21.4, 16.9 and 26.7 miles/DGE, respectively.
- Arterial cycle data presents a few interesting characteristics that are not seen in other cycles:
    - It is the only test cycle that CNG buses have the highest fuel efficiency among all conventional combustion propulsion systems.
    - Diesel buses have the lowest fuel efficiency among all.
    - Hybrid, BEBs and FCEBs have the respective lowest fuel efficiency among all tested cycles.
- For the commuter test cycle:
    - Diesel buses and CNG buses have similar fuel efficiency.
    - Diesel hybrids have the lowest fuel efficiency among all combustion technologies. Hybrid buses do not have a fuel efficiency advantage at a higher cruising speed.

The results under the CBD cycle are comparable with the results of the Manhattan cycle, which comprises urban stop-and-go driving patterns. Technologies using regenerative braking have a much better fuel efficiency advantage under such cycles.

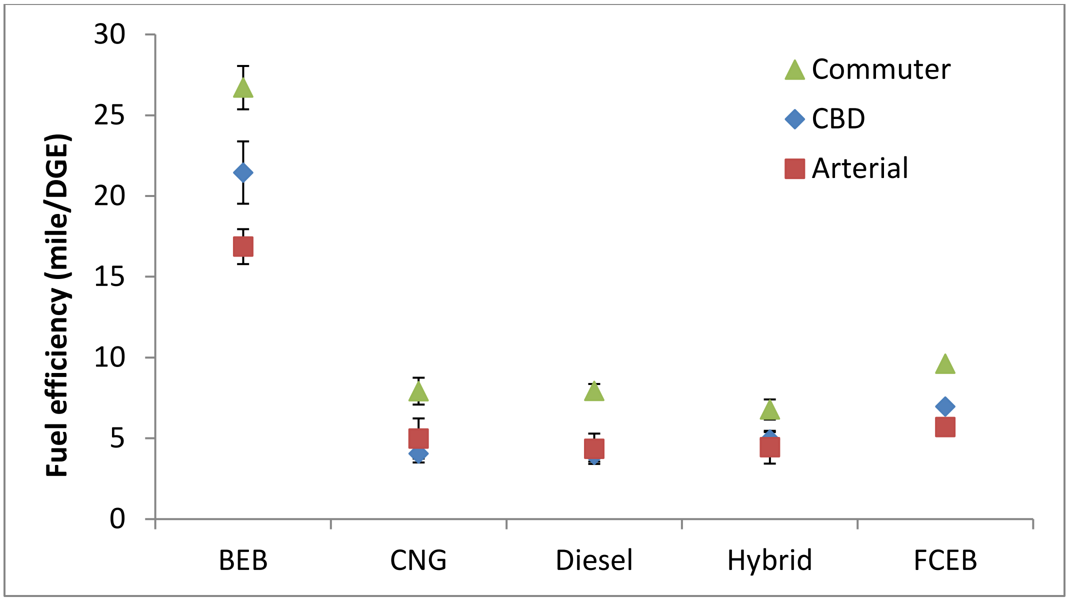

Figure 5: Average bus fuel efficiency under CBD, Arterial and Commuter cycles

Table 3 further summarizes the results from the fuel efficiency testing and energy efficiency ratio (EER) for different propulsion technologies when using diesel technology as the baseline. It is clear that both BEB and diesel hybrid buses have an advantage at lower speed with a lot of stop-and-go driving (CBD cycle).

Table 3: Summary of Altoona Fuel Efficiency Testing (mile/DGE) and Energy Efficiency Ratio (EER)

Testing Cycle	Testing Cycle Description	Max Speed (MPH)	Avg Speed (MPH)	Fuel Efficiency / **EER**				
				Diesel	Diesel Hybrid	CNG	BEB	FCEB
CBD	2 miles with 7 stops per mile	20	12.7	4.00 / **1**	4.92 / **1.23**	4.06 / **1.02**	21.45 / **5.36**	6.97 / **1.74**
Commuter	4 miles with 1 stop	40	38	7.93 / **1**	6.78 / **0.85**	7.92 / **1.00**	26.71 / **3.37**	9.61 / **1.21**
Arterial	2 miles with 2 stops per mile	40	27	4.35 / **1**	4.45 / **1.02**	4.99 / **1.13**	16.87 / **3.88**	5.70 / **1.31**

In general, BEB fuel efficiency stands out in all testing cycles, especially in low speed cycles. In urban cycles with lower speed and lots of stop-and-go driving, BEB's fuel efficiency is about five times that of diesel and CNG buses; while in commuter routes, BEB fuel efficiency is about three times that of diesel and CNG buses. Driving cycles need to be taken into consideration when comparing fuel efficiencies among different vehicle technologies. It is important to note that these observations are only made based on the three fuel efficiency testing cycles and do not represent the performance for the full speed range.

2. National Renewable Energy Laboratory (NREL)

NREL has conducted a number of studies that evaluate the operation and maintenance characteristics of different electric propulsion technologies compared to conventional buses in different transit fleets. The NREL studies include the following six transit agencies:

- Foothill Transit on-route charging BEBs compared to CNG buses[12,13,14]
- King County (KC) Metro Transit diesel hybrid buses compared to diesel buses[15]
- King County (KC) Metro Transit battery electric buses compared to diesel, diesel hybrid and trolley buses[16]
- New York City Transit (NYCT) diesel hybrid buses compared to CNG buses[17,18]
- Alameda-Contra Costa Transit (AC Transit) fuel cell electric buses compared to diesel buses[19,20,21]

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[12] NREL (2016). Foothill Transit Battery Electric Bus Demonstration Results. January 2016. Available: https://www.nrel.gov/docs/fy16osti/65274.pdf.
[13] NREL (2017). Foothill Transit Battery Electric Bus Demonstration Results: Second Report. June 2017. Available: https://www.nrel.gov/docs/fy17osti/67698.pdf.
[14] NREL (2018). Foothill Transit Agency Battery Electric Bus Progress Report. May 2018. Available: https://www.nrel.gov/docs/fy18osti/71292.pdf.
[15] NREL (2006). King County Metro Transit Hybrid Articulated Buses: Final Evaluation Results. December 2006. Available: https://www.nrel.gov/docs/fy07osti/40585.pdf.
[16] Federal Transit Administration (2018). Zero-Emission Bus Evaluation Results: King County Metro Battery Electric Buses. February 2018. Available: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/115086/zero-emission-bus-evaluation-results-king-county-metro-battery-electric-buses-fta-report-no-0118.pdf.
[17] NREL (2006). New York City Transit (NYCT) Hybrid (125 Order) and CNG Transit Buses. November 2006. Available: http://www.nrel.gov/docs/fy07osti/40125.pdf.
[18] NREL (2008). BAE/Orion Hybrid Electric Buses at New York City Transit. March 2008. Available: http://www.afdc.energy.gov/pdfs/42217.pdf.
[19] NREL (2015). Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Fourth Report. July 2015. Available: http://www.nrel.gov/docs/fy15osti/63719.pdf.
[20] NREL (2016). Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Fifth Report. June 2016. Available: https://www.nrel.gov/docs/fy16osti/66039.pdf.
[21] NREL (2017). Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Sixth Report. September 2017. Available: https://www.nrel.gov/docs/fy17osti/68413.pdf.

- SunLine Transit fuel cell electric buses compared to CNG buses[22,23]
- British Columbia Electric Railway (BC Transit) fuel cell electric buses compared to diesel buses[24]

Figure 6 and Table 4 summarize fuel efficiency and average vehicle speed from the NREL studies. These studies show that diesel hybrid buses have higher fuel efficiency than their diesel or CNG counterparts within the same transit agency. The fuel efficiency of FCEBs is about two times that of the CNG buses at SunLine Transit. In the New York City Transit case, the fuel efficiency of a diesel hybrid bus is about fifty percent higher than that of a CNG bus when the average speed is low (about 6 mph).

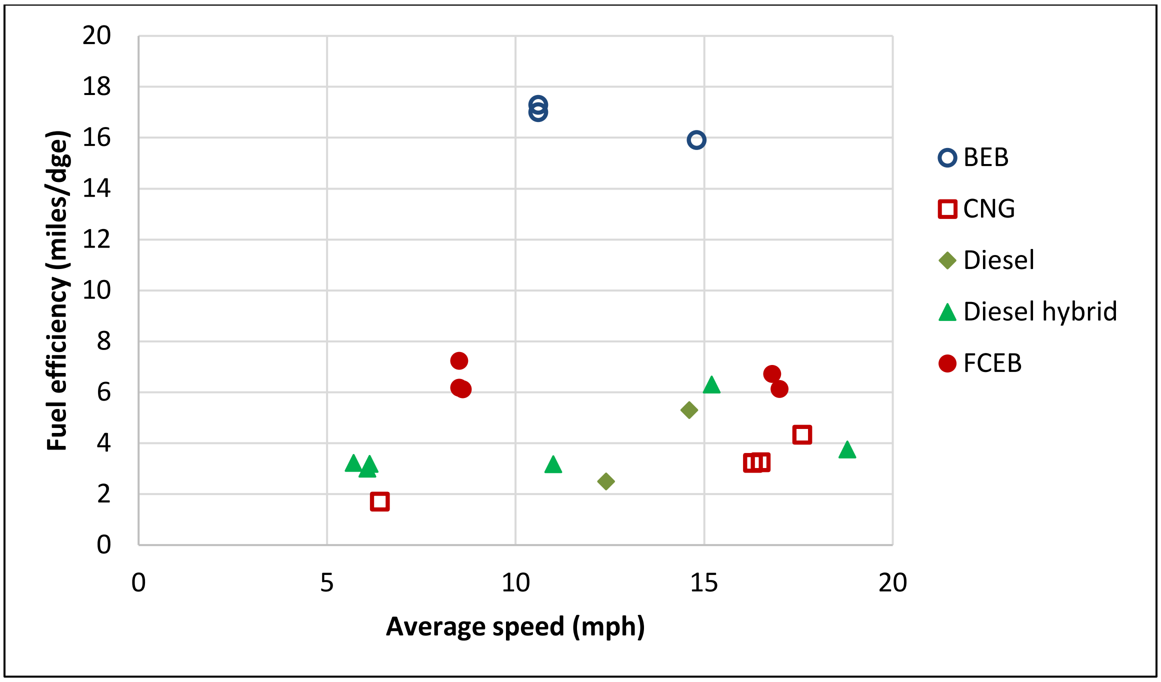

Figure 6: Fuel efficiency and speed from the NREL studies

[22] NREL (2015) American Fuel Cell Bus Project Evaluation: Second Report. September 2015. Available: http://www.nrel.gov/docs/fy15osti/64344.pdf.
[23] NREL (2017). American Fuel Cell Bus Project Evaluation: Third Report. May 2017. Available: https://www.nrel.gov/docs/fy17osti/67209.pdf.
[24] NREL (2014). BC Transit Fuel Cell Bus Project: Evaluation Results Report February 2014. Available: http://www.nrel.gov/docs/fy14osti/60603.pdf.

Table 4: Fuel efficiency and speed from the NREL studies

Transit Agency	Fuel Type	Model	Model Year	Average Speed (mph)	Fuel Efficiency (miles/DGE)	Evaluation Period
AC Transit	Diesel	Gillig Diesel	2013	N/A	4.36	11/2013-12/2014
AC Transit	Diesel	Van Hool Diesel A300L	2009	N/A	3.95	11/2013-12/2014
AC Transit	FCEB	Van Hool A300L FC	2010	8.5	7.23	11/2013-12/2014
AC Transit	Diesel	Gillig Diesel	2013	N/A	4.25	1/2015-12/2015
AC Transit	FCEB	Van Hool A300L FC	2010	8.5	6.18	1/2015-12/2015
AC Transit	Diesel	Gillig Diesel	2013	N/A	4.21	1/2016-12/2016
AC Transit	FCEB	Van Hool A300L FC	2010	8.6	6.12	1/2016-12/2016
AC Transit	FCEB	New Flyer	2009	N/A	4.53	4/2011-3/2013
Foothill Transit	BEB	Proterra BE35	2014	10.6	17.28[a]	4/2014-12/2017
Foothill Transit	BEB	Proterra Catalyst Fast Charge	2016	10.6	16.99[a]	1/2017-12/2017
Foothill Transit	CNG	NABI	2014	17.6	4.32[a]	10/2014-12/2017
King County Metro	Diesel	New Flyer articulated D60LF	2004	12.4	2.5[b]	4/2005-3/2006
King County Metro	Diesel Hybrid	New Flyer articulated DE60LF	2004	11	3.17[b]	4/2005-3/2006
King County Metro	Diesel Hybrid	New Flyer articulated DE60LF	2004	18.8	3.75	4/2005-3/2006
King County Metro	BEB	Proterra Catalyst	2015	14.8	15.9[a]	4/2016-3/2017
King County Metro	Diesel Hybrid	New Flyer Xcelsior hybrid	2015	15.2	6.3[a]	4/2016-3/2017
King County Metro	Diesel	Gillig G27D102N4	2015	14.6	5.3[a]	4/2016-3/2017
New York City Transit	CNG	Orion VII	2002	6.4	1.7	10/2004-9/2005
New York City Transit	Diesel Hybrid	Orion VII Gen I	2002	6.13	3.19	10/2004-9/2005
New York City Transit	Diesel Hybrid	Orion VII Gen I	2002	5.7	3.22	10/2005-9/2006
New York City Transit	Diesel Hybrid	Orion VII Gen II	2004	6.07	3	2/2006-1/2007
SunLine Transit	CNG	New Flyer	2008	16.3	3.22	3/2013-6/2015
SunLine Transit	FCEB	ElDorado National Axess	2011, 2014	16.8	6.72	3/2013-6/2015

Transit Agency	Fuel Type	Model	Model Year	Average Speed (mph)	Fuel Efficiency (miles/DGE)	Evaluation Period
SunLine Transit	CNG	New Flyer	2008	16.5	3.24	7/2015-12/2016
SunLine Transit	FCEB	ElDorado National Axess	2011, 2014	17	6.13	7/2015-12/2016

[a] ZEBs and conventional internal combustion engine buses operated along differing routes.
[b] Buses have similar services and duty cycles.

The buses evaluated in the NREL studies were in revenue services. Therefore, the reported fuel efficiencies are real-world data with buses operated in actual transit routes. However, the fuel efficiency data from the NREL studies are snapshots and represent a specific route or two. The driving and duty cycles are different among transit agencies, or even within a single transit agency. For example, in the Foothill Transit study, BEBs and CNG buses were operated on different routes with the BEBs operated in the conditions with lower speed and more stop-and-go driving. The average speed of the BEBs was 8.57 mph. The average speed of the CNG bus in the Foothill study was operated at a much higher speed of 17.6 mph. Even so, the fuel efficiency of BEBs is about four times as much as that of the CNG buses. The BEBs had an overall fuel efficiency of 17.35 miles per diesel gallon equivalent (mile/dge), and the CNG buses had an average fuel efficiency of 4.34 miles/dge. To make a more direct comparison, NREL has used data loggers to record two days of data from CNG buses operated on the same route as BEBs. The fuel efficiency of BEBs (with an average speed of 7 mph) is 8 times as much for that of a CNG bus (with an average speed of 9.5 mph) when comparing the logged data.[25] It is important to note that all these studies were conducted under one or two fixed routes and cannot represent a transit agency's entire operation. However, these studies do provide a good understanding of the technology characteristics.

3. National Transit Database

Transit agencies receiving grants from the Federal Transit Administration (FTA) Section 5307 or Section 5311 programs are required to submit data to the National Transit Database (NTD). NTD provides a good overview of transit operations. Based on the NTD data, staff calculated the fuel efficiency estimates for specific transit fleets. Average fuel efficiency is calculated by dividing the actual vehicle miles traveled by the total fuel consumption. Average speed of a fleet is calculated by dividing actual vehicle miles traveled by actual vehicle hours.

[25] NREL (2017). Foothill Transit Battery Electric Bus Demonstration Results: Second Report. June 2017. Available: https://www.nrel.gov/docs/fy17osti/67698.pdf.

NTD does not always have the needed data resolution for staff's cost analysis. For example, NTD lumps all mileage together under the same mode[26] within a transit agency. Therefore, if a transit agency has a diesel bus sub-fleet and a CNG bus sub-fleet, NTD presents a single mileage under the bus (MB) mode without differentiating diesel from CNG. With this limitation, it is hard to identify the fuel efficiencies for diesel and CNG fleets respectively. To overcome this limitation, staff first identified the fleets that predominantly operate buses with one fuel type (diesel or natural gas, NG). If diesel or NG accounts for more than 90 percent of the total fuel consumption within a mode under one type of service (TOS) (either directly operated (DO) or purchased transportation (PT)),[27] then the fleets were selected for analysis.

A transit agency can have multiple vehicle types[28] (e.g., buses, articulated buses, vans) under each fuel type. Our focus is to look at the fuel efficiency of buses. Since we are looking at the fleet average fuel efficiency, staff ignored the fuel efficiency difference among vehicle types if the majority of vehicles are buses. Using these assumptions, for a CNG fleet, the average fuel efficiency is 3.1 miles/DGE for the bus mode (MB), and 4.5 miles/DGE for the commuter bus mode (CB). The CB mode has a higher average speed than the MB mode (Table 5).

Table 5: Fuel efficiency and average speed for CNG fleets from the National Transit Database

Agency Name	Mode	TOS	Average Speed (mph)[29]	Fuel Efficiency (miles/ DGE)[30]	No. of Buses (BU)	Total no. of vehicles by mode and by TOS	% of Buses (BU)
Golden Empire Transit District	MB	DO	13.26	2.33	88	88	100%
Sacramento Regional Transit District	MB	DO	12.23	2.88	203	218	93%
San Diego Metropolitan Transit System	MB	DO	12.93	2.34	188	286	66%
Omnitrans	MB	DO	13.38	3.04	181	198	91%
Riverside Transit Agency	MB	DO	14.21	3.28	104	104	100%

[26] 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). See NTD Glossary "Non-rail modes" at https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary. Accessed July 9, 2018.
[27] NTD Glossary. "Type of Service (TOS): Describes how public transportation services are provided by the transit agency: directly operated (DO) or purchased transportation (PT) services." Available: https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary. Accessed: July 9, 2018.
[28] NTD Glossary. See "vehicle type" and "buses (BU)" at Available: https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary. Accessed: July 9, 2018.
[29] Average speed = Actual vehicles miles / Actual vehicles hours
[30] Fuel efficiency = Actual vehicles miles / Total fuel consumption

Agency Name	Mode	TOS	Average Speed (mph)[29]	Fuel Efficiency (miles/ DGE)[30]	No. of Buses (BU)	Total no. of vehicles by mode and by TOS	% of Buses (BU)
Gold Coast Transit	MB	DO	10.95	2.53	54	54	100%
Culver City Municipal Bus Lines	MB	DO	10.79	2.80	54	54	100%
City of Commerce Municipal Bus Lines	MB	DO	12.95	2.99	12	13	92%
SunLine Transit Agency	MB	DO	15.01	3.00	66	66	100%
Sonoma County Transit	MB	PT	17.51	4.28	45	49	92%
Yolo County Transportation District	MB	PT	20.85	3.73	48	55	87%
Unitrans - City of Davis/ASUCD	MB	DO	10.50	3.17	41	48	85%
Foothill Transit	MB	PT	14.98	2.91	285	315	90%
Victor Valley Transit Authority	MB	PT	17.93	3.47	31	47	66%
Los Angeles County Metropolitan Transportation Authority	MB	DO	11.62	2.15	1,842	2,151	86%
Santa Clarita Transit	MB	PT	15.57	3.10	61	64	95%
Chula Vista Transit	MB	PT	10.95	2.70	41	41	100%
Placer County Department of Public Works and Facilities	MB	DO	22.24	3.59	20	25	80%
Kings County Area Public Transit Agency	MB	PT	16.68	3.69	19	21	90%
City of Elk Grove	MB	PT	15.10	3.87	54	54	100%
City of Redondo Beach - Beach Cities Transit	MB	PT	12.01	3.17	12	14	86%
Santa Cruz Metropolitan Transit District	CB	DO	25.33	4.33	20	20	100%
Riverside Transit Agency	CB	DO	26.12	4.27	20	20	100%
Orange County Transportation Authority	CB	PT + DO	26.16	4.28	30	30	100%
Victor Valley Transit Authority	CB	PT	36.98	3.87	12	12	100%
City of Elk Grove	CB	PT	22.58	5.69	54	54	100%
Average fuel efficiency for CNG buses (MB mode)				**3.10**			
Average fuel efficiency for CNG buses (CB mode)				**4.49**			

For a diesel fleet, some transit agencies also operate diesel hybrid buses. Staff calculated the fuel efficiency for two groups of buses in the diesel fleets: (1) the group in which more than 20 percent of the buses (BU) are diesel hybrid buses within a mode and TOS, and (2) the group in which less than 20 percent of the buses (BU) are diesel hybrid buses within a mode and TOS.[31]

The average fuel efficiency for the bus mode (MB) is 4.57 miles/DGE for the fleets with both diesel and diesel hybrid buses, and 4.23 miles/DGE for the fleets with mainly diesel buses (Table 6).

[31] The analysis excluded the following transit agencies and/or mode (bus (MB) or commuter bus (CB)): (1) Santa Clara Valley Transportation Authority has a calculated fuel efficiency of 148 miles/DGE; (2) San Francisco MUNI MB mode and type of service (TOS) DO: over 30 percent of the buses are articulated buses, which have lower fuel efficiency than standard buses; (3) The commuter bus (CB) mode for the following agencies: San Joaquin Regional Transit District, Alameda-Contra Costa Transit District, Santa Barbara Metropolitan Transit District, San Diego Metropolitan Transit System, and Yuba-Sutter Transit Authority. A large proportion of the buses under the CB mode are not standard buses (BU).

Table 6: Fuel efficiency and average speed for diesel fleets from the National Transit Database

Agency Name	Mode	TOS	Average Speed (mph)	Fuel Efficiency (miles/ DGE)	No. of Buses (BU) - Diesel	No. of Buses (BU) - Diesel hybrid	Total no. of vehicles by mode and by TOS	% of Buses (BU) - Diesel	% of Buses (BU) - Diesel hybrid
San Joaquin Regional Transit District	MB	DO + PT	13.20	4.96	45	29	91	49%	32%
City of Santa Rosa	MB	DO	11.81	4.31	24	10	34	71%	29%
Santa Barbara Metropolitan Transit District	MB	DO	12.84	4.96	66	18	87	76%	21%
City of Fairfield - Fairfield and Suisun Transit	MB	PT	13.86	4.03	20	7	27	74%	26%
Antelope Valley Transit Authority	MB	PT	14.57	2.92	26	15	44	59%	34%
Livermore / Amador Valley Transit Authority	MB	PT	15.40	4.82	46	20	66	70%	30%
Solano County Transit	MB	PT	13.10	6.01	3	21	24	13%	88%
Average fuel efficiency for Diesel and Diesel Hybrid Buses (MB mode)				**4.57**					
Modesto Area Express	MB	PT	12.77	3.88	73	1	74	99%	1%
San Mateo County Transit District	MB	DO + PT	15.01	3.96	237	25	344	69%	7%
Alameda-Contra Costa Transit District	MB	DO + PT	11.43	4.06	396	0	483	82%	0%
Golden Gate Bridge, Highway and Transportation District	MB	DO	17.88	3.74	176	0	176	100%	0%
Yuba-Sutter Transit Authority	MB	PT	11.84	4.21	22	0	22	100%	0%
Monterey-Salinas Transit	MB	DO	15.29	4.33	77	0	77	100%	0%
Central Contra Costa Transit Authority	MB	DO	12.71	4.68	120	0	120	100%	0%
Santa Maria Area Transit	MB	PT	15.19	4.49	23	0	26	88%	0%
Redding Area Bus Authority	MB	PT	15.36	4.17	20	0	22	91%	0%
City of San Luis Obispo	MB	PT	12.18	3.64	14	0	17	82%	0%
Western Contra Costa Transit Authority	MB	PT	17.19	4.50	36	0	46	78%	0%
The Eastern Contra Costa Transit Authority	MB	PT	14.66	4.00	53	0	62	85%	0%

Agency Name	Mode	TOS	Average Speed (mph)	Fuel Efficiency (miles/ DGE)	No. of Buses (BU) - Diesel	No. of Buses (BU) - Diesel hybrid	Total no. of vehicles by mode and by TOS	% of Buses (BU) - Diesel	% of Buses (BU) - Diesel hybrid
San Luis Obispo Regional Transit Authority	MB	DO	24.71	5.19	40	0	50	80%	0%
City of Petaluma	MB	PT	13.08	4.41	11	0	11	100%	0%
Average fuel efficiency for diesel buses (MB mode)				**4.23**					

Figure 7 summarizes fuel efficiency and average speed for both diesel and CNG fleets from the NTD. Data presented in Figure 7 shows that diesel buses generally have higher fuel efficiencies than CNG buses.

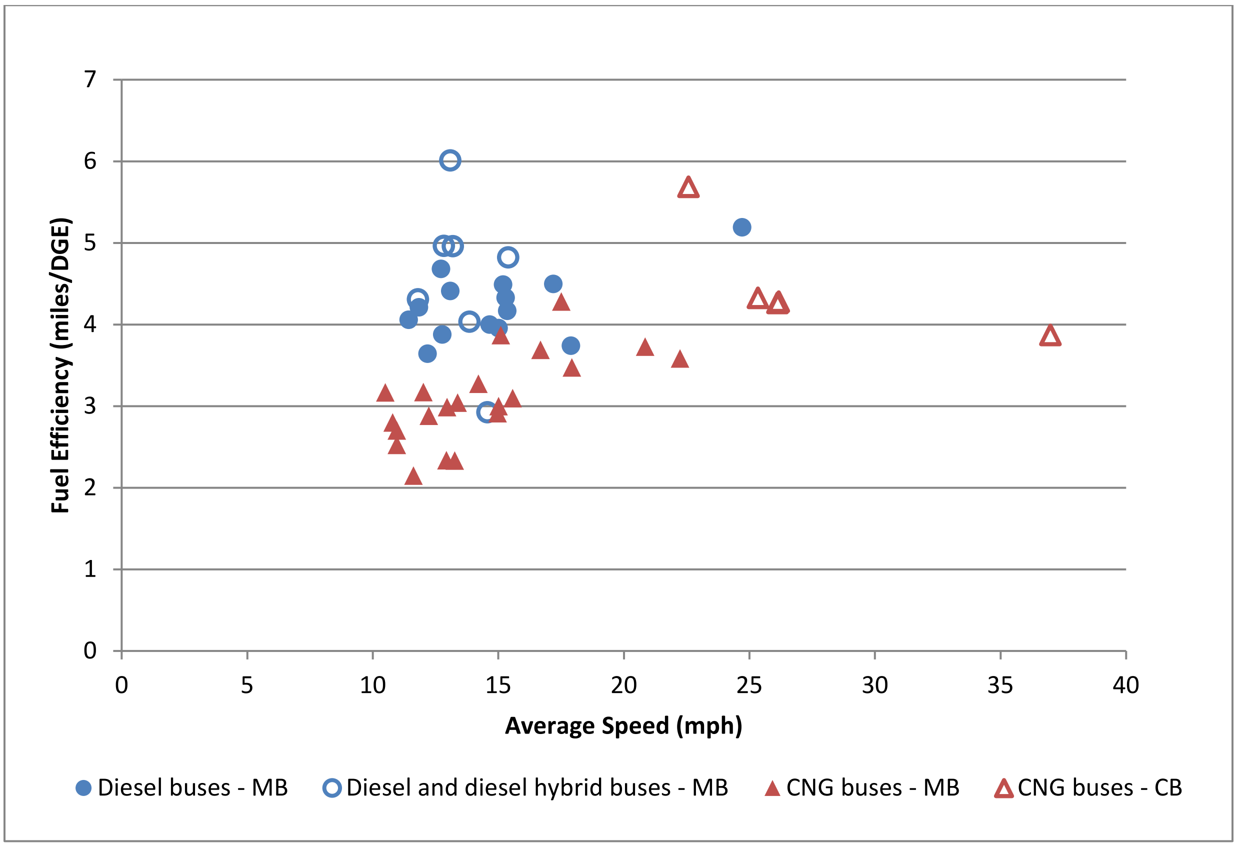

Figure 7: Fuel efficiency and average speed from the National Transit Database

Source: Staff's calculation based on NTD database.

4. Summary of Fuel Efficiency

In summary, in the Altoona test, the fuel efficiency provides a relative comparison among different buses under different driving cycles. The results cannot be used to represent in-use situations, but provide clear comparisons that show fuel efficiency is heavily impacted by driving cycle and that BEBs outperform other fuel types across all driving cycles. In the NREL studies, the reported fuel efficiencies are real-world data with buses operated in actual transit routes. Hence, the fuel efficiency data are snapshots of a fleet. The test cycles are different among transit agencies, or even within a single transit agency. The fuel efficiency calculated based on the NTD database is a fleet average. The NTD database does not have the resolution that would allow staff to calculate the fuel efficiency for a bus with a specific fuel type. Fuel efficiency varies with driving cycles, speed, and other factors.

C. Fuel Cost

We will now discuss the first factor that primarily affects transit agency fuel costs: the price per unit of fuel. For combustion fuels diesel and natural gas, transit agencies use different fuel purchasing strategies, including short-term and long-term contracts. For example, in purchasing natural gas, transit agencies may utilize monthly purchases from a local utility (no contract); six- to 12-month contracts for half or all of expected consumption and additional fuel purchased monthly at spot prices; or all commodity gas purchased through contracts.[32] The prices on the fuel contracts can be different than that of the retail market, where prices can fluctuate daily. Transit agencies often pay lower diesel and natural gas prices than the pump prices at the retail markets, partly due to the volume they purchase and the fuel contracts.

1. Diesel

Diesel price has fluctuated widely in the past. Figure 8 shows the no. 2 diesel retail prices from 1995 to 2017 in the U.S. and in California published by the EIA. The retail prices of diesel surged to $4/gallon in 2008, and again during the 2011-2014 period (Figure 8).[33] The average retail price in California in 2016 was around $2.65/gallon. Diesel price in California has been higher than the U.S. average. The average price

[32] R. Adams and D.B. Horne (2010). Compressed Natural Gas (CNG) Transit Bus Experience Survey, NREL/SR-7A2-48814, September 2010. Available: http://www.nrel.gov/docs/fy10osti/48814.pdf.
[33] Energy Information Administration (EIA) (2018). California Annual Retail Gasoline and Diesel Prices. Released on July 16, 2018. Available: https://www.eia.gov/dnav/pet/xls/PET_PRI_GND_DCUS_SCA_A.xls.

difference between California and the U.S. average in 2016 was around 35 cents per gallon.[34]

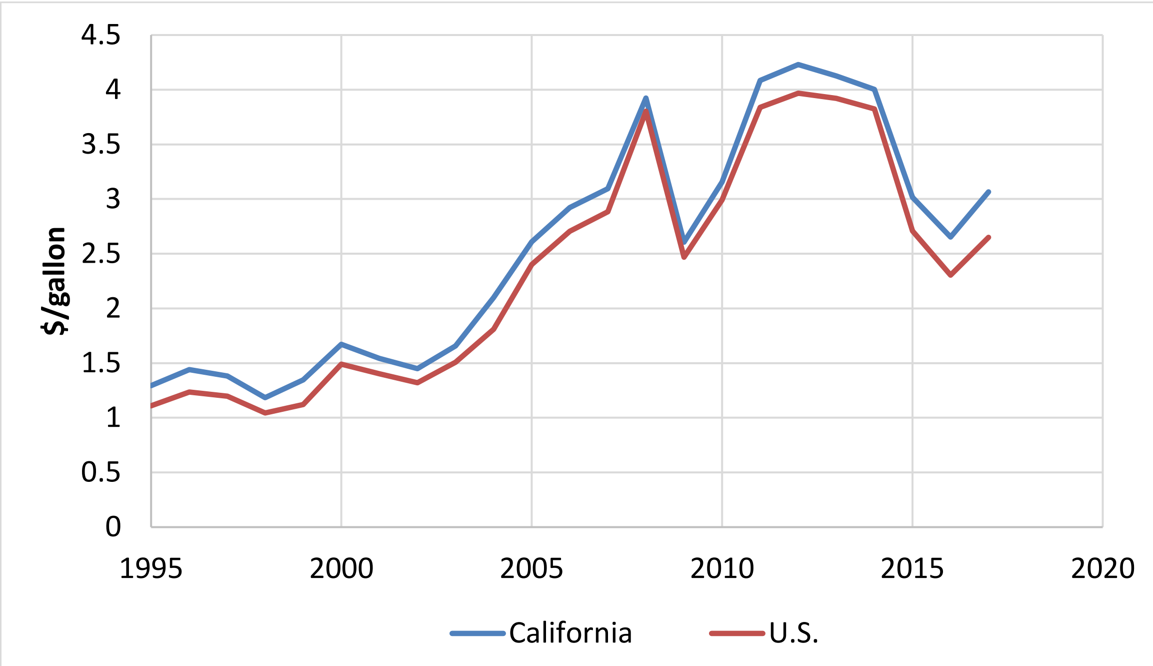

Figure 8: EIA No. 2 diesel retail prices (1995-2017)

2. Natural Gas

Natural gas prices fluctuate as in the case for diesel fuel. Figure 9 shows the annual natural gas prices sold to commercial consumers from 1995 to 2017 for California and the U.S.[35,36,37]

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[34] Energy Information Administration (EIA) (2018). U.S. Annual Retail Gasoline and Diesel Prices. Released on July 16, 2018. Available: https://www.eia.gov/dnav/pet/xls/PET_PRI_GND_DCUS_NUS_A.xls.

[35] Energy Information Administration (EIA) (2018). California Natural Gas Prices. Released on June 29, 2018. Available: https://www.eia.gov/dnav/ng/xls/NG_PRI_SUM_DCU_SCA_A.xls.

[36] Energy Information Administration (EIA) (2018). U.S. Natural Gas Prices. Released on June 29, 2018. https://www.eia.gov/dnav/ng/xls/NG_PRI_SUM_DCU_NUS_A.xls.

[37] Energy Information Administration (EIA) (2018). Natural Gas Definitions, Sources and Explanatory Notes. Available: http://www.eia.gov/dnav/ng/TblDefs/ng_pri_sum_tbldef2.asp. Accessed July 9, 2018.

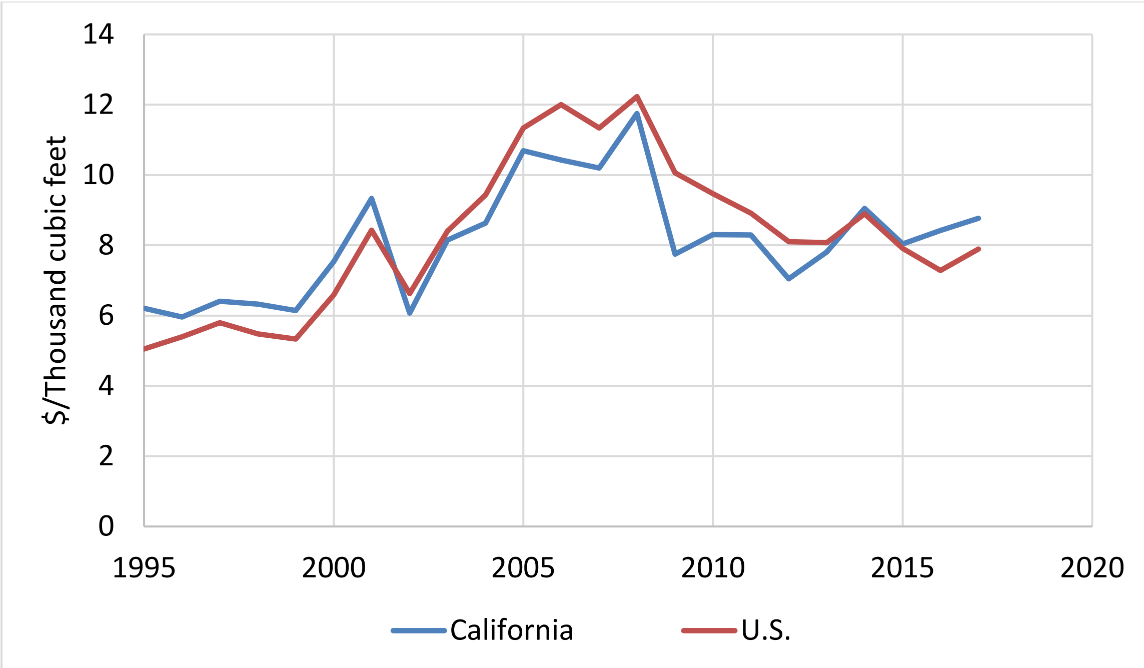

Figure 9: EIA Price of Natural Gas Sold to Commercial Consumers (1995-2017)

3. Renewable Diesel and Renewable Natural Gas

Renewable diesel (RD) and renewable natural gas (RNG) are available for transit agencies to procure and the cost of these renewable fuels are essentially the same as the conventional fuels because the value of credits from the federal Renewable Fuel Standard (RFS) program and California's Low Carbon Fuel Standard (LCFS) offset the higher costs of producing renewable fuels. For example, for RNG with a carbon intensity (CI) of 25 gCO2e/MJ, the LCFS credit revenue would be $0.87/DGE in 2016 at a credit price of $100/MT; for RD with a CI of 50 gCO2e/MJ, the LCFS credit revenue would be $0.67/DGE.[38] The credit revenue impacts fuels differently due to their carbon intensity scores. The LCFS is modeled as a fuel subsidy in CARB's Biofuel Supply Module analysis.[39] RFS and LCFS together make it possible for transit agencies to budget their fuel cost without having to take these renewable fuels' production into consideration.

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[38] CARB (2016). Draft Discussion Document: How Earned Low Carbon Fuel Standard Credits Change From Year To Year. August 17, 2016. Available: https://www.arb.ca.gov/msprog/bus/lcfs.pdf.
[39] CARB (2016). Biofuel Supply Module. Technical Documentation for Version 0.83 Beta. Released September 8, 2016. Available: https://www.arb.ca.gov/cc/scopingplan/meetings/090716/bfsmv83b.zip.

4. Electricity

Standard electricity rates vary by utility, schedule of demand, total customer demand, and season. Commercial customer electricity rates commonly have a demand charge on top of the electricity usage rate. The demand charge is based on the maximum power in kilowatts (kW) used during an interval, for example, a 15-minute interval. Electricity rates are a combination of demand charges, usage charges and meter fees. Usage charges are based on total electricity consumed and also vary by time of use. For detailed discussion, please refer to the draft discussion document, "Electricity Costs for Battery Electric Bus Operation,"[40] and the battery electric bus charging cost calculator.[41]

Figure 10 shows California annual electricity prices from 1995 to 2017 for the commercial sector.[42,43]

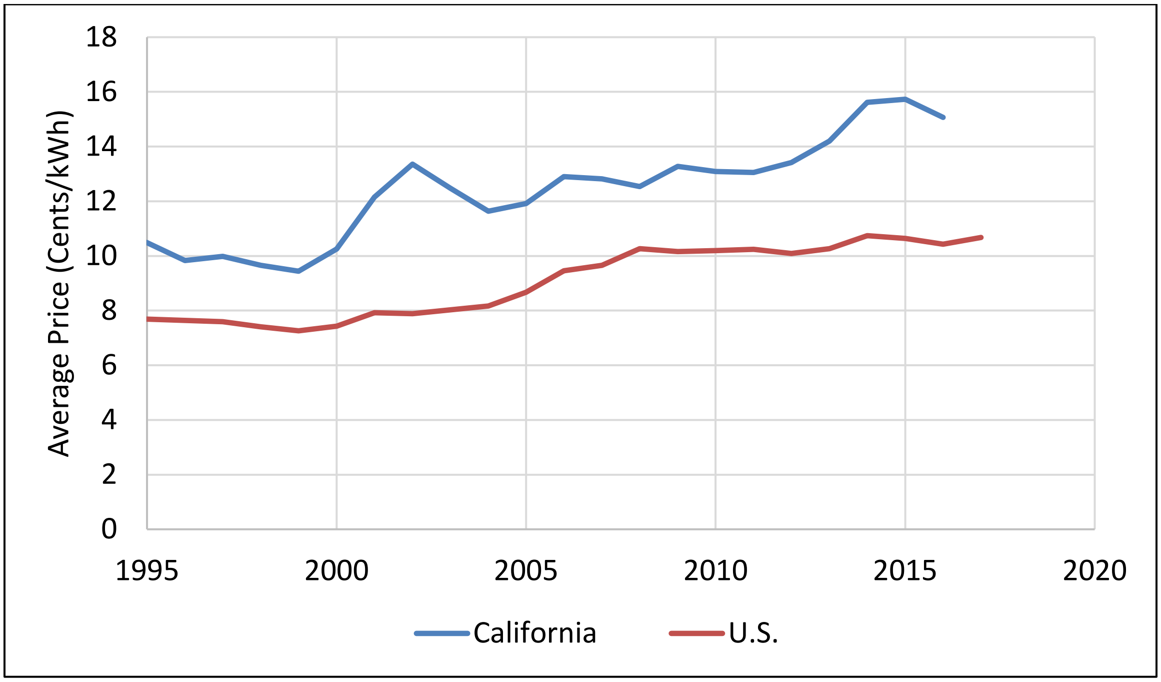

Figure 10: EIA Average electricity price for the commercial sector (1995-2017)

[40] CARB (2016). CARB Draft Discussion Document: Electricity Costs for Battery Electric Bus Operation. April 2016. Available: https://www.arb.ca.gov/msprog/bus/ratesanddemand.pdf.
[41] CARB (2017). CARB Battery Electric Truck and Bus Charging Cost Calculator. Version 3.0 – Updated 6/20/2017. Available: https://arb.ca.gov/msprog/ict/meeting/mt170626/170626chargecostcalcv3.xlsm.
[42] Energy Information Administration (EIA). Electricity - Average Price by State by Provider (EIA-861). November 3, 2017.Available: https://www.eia.gov/electricity/data/state/avgprice_annual.xlsx.
[43] Energy Information Administration (EIA). Monthly Energy Review. Table 9.8 Average retail price of electricity. Released on June 26, 2018. Available: https://www.eia.gov/totalenergy/data/browser/xls.php?tbl=T09.08&freq=m.

5. Hydrogen

Hydrogen price is affected by various factors, including station throughput, production and delivery methods, energy sources, and production rates.

Unlike crude oil, there is no international price standard for hydrogen. Hydrogen price is highly dependent on station throughput.

SunLine Transit's hydrogen station in Thousand Palms has been in operation for 15 years. Sunline Transit produces its own hydrogen from steam methane reformation. Its price consists of the cost of natural gas for the reformer, the maintenance cost for the station equipment, and the capital cost amortization. SunLine Transit maintains the station equipment, and provides parts and labor. Hydrogen cost is highly correlated with station throughput. The station produces up to 212 kg of hydrogen on-site each day. The four fuel cell electric buses currently in revenue service are filled each day with around 34.6 kg of 350 bar hydrogen. Fueling takes about 25 minutes per bus at an average cost of around $12.50 per kg.

At AC Transit, liquid hydrogen is delivered to its fueling stations and hydrogen is supplemented by on-site production via electrolysis using renewable electricity. The hydrogen price at AC Transit is about $9.10 per kg dispensed. It is challenging to use hydrogen price from AC Transit to assess the degree of deployment of this technology and project future hydrogen prices due to its multiple delivery and production means. Staff believes that SunLine Transit's data provide more relevant information about economies of scale and is more informative for hydrogen price projection.

The U.S. Department of Energy (DOE) has a target hydrogen price of $4 or less per gasoline gallon equivalent (GGE) by 2020.[44,45] The target price does not represent DOE's price projection. Rather, it is a price that DOE is aiming to meet to make hydrogen comparable to other fuels used in conventional technologies. SunLine Transit's data show a promising trend for hydrogen between price and throughput. While both SunLine Transit and AC Transit are expanding their fuel cell electric bus fleets, an even lower hydrogen price in the foreseeable near future is feasible.

[44] Department of Energy. Hydrogen and Fuel Cells Program. 2016 Annual Merit Review. June 6, 2016. Available: https://www.hydrogen.energy.gov/pdfs/review16/02_satyapal_plenary_2016_amr.pdf.
[45] Department of Energy. Fuel Conversion Factors to Gasoline Gallon Equivalents. Available: https://epact.energy.gov/fuel-conversion-factors. Accessed July 9, 2018.

D. EIA Energy Price Projection

EIA provides energy price projections for various fuels. EIA's projections are based on results from EIA's National Energy Modeling System (NEMS).[46] The NEMS used for AEO2018 generally represent current legislation and environmental regulations, including recent government actions for which implementing regulations were available as of the end of September 2017.[47] The reference case for energy prices in the Pacific region from EIA's Annual Energy Outlook 2018 (AEO2018) are shown in Figure 11.[48,49,50] The Pacific region includes California, Oregon, Washington and Alaska. Figure 11 includes the energy price projection for diesel used in the transportation sector, and energy price projections for natural gas and electricity used in the commercial sector. Staff used the commercial sector price projections for natural gas and electricity in the cost analysis because transit agencies' natural gas prices are in line with the commercial price. Regarding electricity prices, transit agencies' electricity consumption typically falls into the rate schedule for the commercial sector. Therefore, staff used the electricity price growth rates for the commercial sector in the analysis (see discussion in section E below).

In Figure 11, electricity price decreases slightly till 2021. It starts to increase through 2034, and decreases slightly afterwards. The increase trend until 2034 could be due to states' requirements to increase the renewable portfolio in electricity, which requires infrastructure investments. For diesel fuel, the current price remains low. It is expected the price will increase over time. For natural gas, the fuel price change is relatively small compared with diesel fuel. This could be due to fracking, which increases the domestic natural gas supply and reduces production costs from avoidance of complying with major federal environmental regulations. Staff converted the EIA projected prices from 2017$/MMBtu to 2016$/DGE and 2016$/kWh (Table 7).

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[46] Energy Information Administration (EIA) (2018). Assumptions to AEO2018. Released on April 5, 2018. Available: https://www.eia.gov/outlooks/aeo/assumptions/#2.

[47] Energy Information Administration (EIA) (2018). Assumptions to AEO2018. Released on April 5, 2018. Available: https://www.eia.gov/outlooks/aeo/assumptions/#2.

[48] Energy Information Administration (EIA) (2018). Annual Energy Outlook 2018. Table 3. Energy Prices by Sector and Source (Pacific Region, Reference Case).

[49] The unit EIA reported is in 2017$/MMBtu. Staff converted 2017$/MMBtu to 2016$/DGE by using the following conversion factors: 1 MMBtu = 1055.06 MJ. Energy density for diesel is 134.47 MJ/gal, energy density for natural gas is 1.04 MJ/cubic feet, and energy density for electricity is 3.6 MJ/kWh. These energy densities are used in the LCFS regulation. Staff converted 2017 Dollar into 2016 dollar by using Consumer Price Index (CPI).

[50] Bureau of Labor Statistic (2018). Historical Consumer Price Index for All Urban Consumers (CPI-U). Archived Consumer Price Index Supplemental Files. June 2018. Available: https://www.bls.gov/cpi/tables/supplemental-files/historical-cpi-u-201805.pdf.

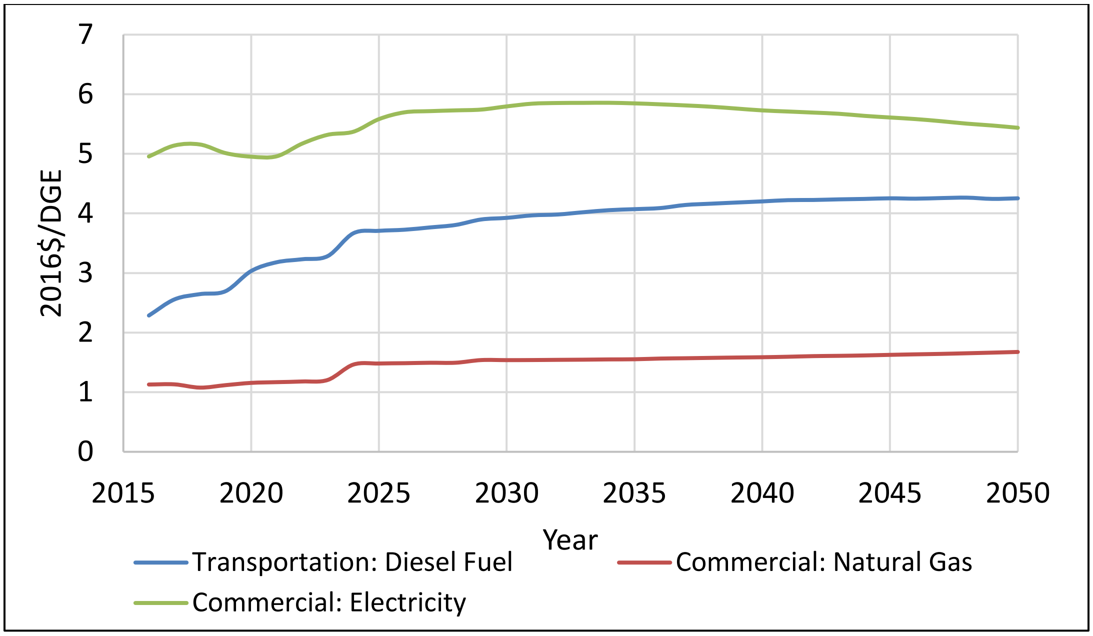

Figure 11: EIA Energy price projections for the Pacific region – Reference case (2016-2050)

Table 7: EIA energy price projections for the Pacific region (reference case prices in 2018)

Pacific Region - Reference case prices in 2018	2017 $/MMBtu	2016 $/DGE	2016 $/kWh
Diesel (distillate fuel oil) - transportation	21.20	2.65	
Natural gas - commercial	8.63	1.08	
Electricity - commercial	41.32	5.16	0.14

Although electricity has the highest price in terms of diesel gallon equivalent (DGE), this is not a reflection of total fuel cost. As discussed earlier, BEB has a fuel efficiency of 3 to 8 times as much as the CNG and diesel buses, depending on the driving cycle. Therefore, in terms of fuel cost per mile, electricity could be more favorable when other incentives are not included.

E. Energy Prices used in the ICT Analysis

California average diesel fuel retail price was $2.65/gallon in 2016.[51] According to the ICT Transit Agency Subcommittee Cost Subgroup, the diesel fuel price which transit agencies currently pay is close to the EIA AEO2018 diesel price for the transportation sector, which is around $2.29/gallon in 2016. This value is also consistent with the median diesel fuel cost from transit fleets' response to the ARB transit fleet operations survey for diesel fuel purchased in 2015. Thus, staff proposes to use the EIA projected diesel price for the transportation sector for the Pacific Region as the default in the cost analysis.

Natural gas fuel cost includes natural gas commodity cost, transmission cost, compression cost, and CNG station operating and maintenance (O&M) cost. Staff has examined the natural gas fuel cost breakdown from some transit agencies. Examples of CNG costs paid by transit agencies are presented in Table 8.

Table 8: Examples of CNG Costs paid by Transit Agencies

	San Diego MTS (Dec. 2016) (2016$/DGE)	OCTA* (Jul-Oct 2016) (2016$/DGE)	LA Metro (2015$/DGE)
Commodity	0.37	0.37	
Transmission	0.20	0.31	
Station maintenance	0.20	0.35	
Station utility	0.28	0.13	
Total	**1.05**	**1.16**	**0.99**

* Average of four depots

The total natural gas fuel cost for a transit agency, including commodity, transmission, compression, and station O&M is about $1/DGE before the LCFS, the RFS, and the federal alternative fuel tax credits. This is close to the EIA AEO2018 natural gas price for the commercial sector for the Pacific Region, which is about $1.13/DGE in 2016. Staff used the EIA projected price as the default value for future CNG fuel cost.

As discussed in Section C.4, electricity rates vary by utility, schedule, total customer demand, and season. Electricity cost also depends on charging strategies. Staff used CARB's Battery Electric Bus Charging Cost Calculator to estimate the electricity cost for

[51] Energy Information Administration (EIA). California retail gasoline and diesel prices. Released on July 16, 2018. Available: https://www.eia.gov/dnav/pet/xls/PET_PRI_GND_DCUS_SCA_A.xls.

a transit agency.[52] Staff also calculated the annual growth rate based on EIA's electricity price projection for the commercial sector for the Pacific Region, and applied the annual growth rate to the estimated electricity price.

For hydrogen price, staff assumed hydrogen price decreases gradually from $8/kg in 2016 to DOE's target at $4/kg in 2020 (see discussion in Section C. 5) due to station throughput increase. The hydrogen price used in the ICT analysis is shown in Table 9. The analysis is based on a statewide average with the assumption of a complete fleet deployment and DOE targets. For the rulemaking purpose, $4/kg is used for the cost for 2020 and on.

Table 9: Hydrogen price used in the ICT analysis

Year	Hydrogen (2016$/kg)
2016	$8.00
2017	$7.00
2018	$6.00
2019	$5.00
2020 onward	$4.00

[52] California Air Resources Board (CARB) (2017). Draft Battery Electric Truck and Bus Charging Cost Calculator (Version 3.0 – Updated: 6/20/2017). Available: https://arb.ca.gov/msprog/ict/meeting/mt170626/170626chargecostcalcv3.xlsm.

Reference List D

The following documents are the technical, theoretical, or empirical studies, reports, or similar documents relied upon in proposing these regulatory amendments, identified as required by Government Code, section 11346.2, subdivision (b)(3). Additionally, each appendix references the documents upon which it relies, as required by Government Code, section 11346.2, subdivision (b)(3).

Note: Each "Explanatory Footnote" is a footnote containing explanatory discussion rather than referencing specific documents relied upon.

1. Federal Register (2016). 49 CFR Part 665. Bus Testing: Establishment of Performance Standards, a Bus Model Scoring System, a Pass/Fail Standard and Other Program Updates. Vol. 81, No. 147, August 1, 2016. Available: https://www.gpo.gov/fdsys/pkg/FR-2016-08-01/pdf/2016-17889.pdf.

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