Alternative Fuel Cost Report

Executive Summary

This report documents the potential costs and benefits of employing one or more alternative fuel sources (electric-hybrid, compressed natural gas (CNG), or electric-battery) as a substitute for the diesel fuel RTS currently uses to power its fleet. Specifically, the paper uses localized data (when available), transit industry correspondence, and national publications to define for each fuel source capital costs associated with fleet expansion and replacement, vehicle operation and maintenance (O&M) costs, and upfront lump sum costs. The findings conclude that RTS should pivot from diesel to CNG as the dominant fuel source of the fleet. Main findings of this study include:

- Compared to the base diesel scenario, the energy costs of CNG are so low that even after accounting for its higher capital and O&M costs the average cost savings per bus per year is more than $13,000.
- The total cost per bus per year for hybrid and electric buses, is $10,560 and $4,944, respectively, higher than the base diesel scenario.
- Electric buses offer comparable energy saving as to CNG buses and offer much lower O&M costs than all other fuel sources, but their high capital cost makes them not cost effective.
- Initially two CNG implementation scenarios were considered. One explored a procurement scenario where RTS's maximum fleet age remained constant and the other explored a procurement scenario where capital expenditures remained constant.
- Under the fixed maximum age scenario, cumulative net savings[1] are over $43 million (Table 4-1) constant 2016 dollars by year 2045. At the end of year 2029, which is 13 years into the project, annual savings from employing CNG buses pay off anticipated financing (principal and interest) requirements.[2]
- Under the fixed capital scenario, cumulative net savings is approximately $30 million (Table 4-2) constant 2016 dollars by year 2045. When financing is accounted for it takes two additional years to fully pay off all costs under this scenario. Using the net savings to purchase additional CNG buses, any bus purchase difference will be rectified by 2034 with the total number of replaced buses the same between the CNG and the base diesel scenarios.
- Lastly, a modified fixed capital scenario was developed to rectify deficiencies in the two original scenarios by including an upfront bus loan and using future year savings to purchase additional CNG buses. If a $5 million bus loan is acquired and a fixed annual loan payment is set at $583,000, the internal rate of return (IRR) is 20% and the payback period is 7.9 years.

This report first proceeds with an overview of the study methodology, including a description of the fuel types examined and the framework within which the analysis was conducted (See Chapter 1 *Introduction*). Chapter 2 *Annual Cost Differential Analysis* provides a preliminary cost-effective analysis for alternative fuel sources. Next, the paper presents findings of the cost analysis with figures and tables

[1] Apart from financing costs.
[2] The fleet size in 2045 is assumed to be 150.

showing monetized items (See Chapter 3 *Cost Analysis*). *A Financial Investment Analysis* is then presented in Chapter 4 to help identify possible revenue sources to cover the costs identified in Chapter 3. Also in this chapter the modified fixed capital scenario is introduced. Finally, Chapter 5 provides a *Conclusion* and recommends areas for further study.

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1 Introduction

Transit agencies around the country are increasing their use of alternative fuels. According to the American Public Transportation Association (APTA), the use of alternative fuels in transit buses has increased over 300% in the last 15 years with over 40% of agencies now utilizing alternative fuels (Vock, 2014). However, the appeal of alternative fuels still varies by agency. While the new fuel sources purport long term savings and greater environmental benefits than traditional diesel buses, the upfront costs (both monetary- and education-based) can preclude agencies from making the switch.

RTS last considered the issue in 2011 through a contracted study with Tindale Oliver & Associates.[3] This report updates that study by further tailoring the analysis to local conditions, and incorporating changes in the fast evolving alternative fuels field to create a comprehensive evaluation framework. It focuses on a cost comparison of alternative fuel options for 40-ft heavy-duty buses. Support vehicles are not explored.[4] The study also excludes the paratransit fleet.[5]

There are a wide range of fuel options for transit agencies to choose from. Transit Cooperative Research Program (TCRP) Report 146 lists 13 fuel options, including four liquid fuels (diesel, biodiesel, gasoline, and ethanol), five gaseous fuels (compressed natural gas (CNG), liquefied natural gas (LNG), hydrogen, propane, and dimethyl ther), and four electric power types (trolleybus, battery electric, hybrid electric, and fuel Cell). Based on a combination of factors such as maturity and reliability of the technology, availability for the type of vehicles RTS operates, and extent of adoption by other agencies, RTS identified a short list of three alternative fuel options – CNG, hybrid electric, and battery electric – in this study.[6] The study consists of four fuel scenarios, which include the three alternative fuel options identified above, as well as a base scenario reflecting the current diesel-dominant fleet.

The cost analysis captures capital costs[7] (including costs associated with both vehicle expansion and replacement),[8] O&M costs (including vehicle operation and maintenance costs, facility costs, and fuel

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[3] The study concluded without any specific recommendations.

[4] RTS has 37 support vehicles. These include a range of vehicle types, such as heavy duty trucks, vans, and sedans. RTS typically only has a small number of each type of vehicle and it is not apparent whether each of the alternative fuel technologies being studied is available for each type of vehicle. Moreover, the fuel composition relative to the transit bus fleet is minimal; these vehicles combined consume under 14K gallons of fuel per year versus the over 1 million gallons of fuel consumed by the bus fleet. For these reasons, transitioning these vehicles to a new fuel source would be a secondary analysis after RTS has already identified a positive return on investment for transitioning the bus fleet to a new fuel source.

[5] RTS has contracted for paratransit service for over a decade. While the cost differential between RTS provision of the service and contractor provision of the service has shrunk, contractor provision is still projected to remain favorable in the foreseeable future. Under the contracted arrangement RTS only has partial control over the fleet. The contractor houses, fuels, and maintains all vehicles off-site. Introducing an alternative fuel source would likely force all these activities to occur on-site at RTS. The logistical challenges and inefficiencies this would introduce preclude their consideration from analysis. If RTS proceeds to a new fuel source this can be re-evaluated the next time the paratransit contract is rebid.

[6] Both CNG and LNG can be used as the fueling source for transit. In this study CNG fast fill option was selected in the short list based on multiple factors such as optimal vehicle type, duty cycle, and hours of service according to Westport (2013).

[7] For the battery electric scenario, battery replacement cost is included in the capital costs.

and fueling costs), and lump sum expenses associated with alternative fuel deployment (including staff training, external infrastructure, and facility conversion expenses).[9] Data used in this study comes from a variety of sources and is uniquely identified. The base diesel scenario relies heavily on recent RTS performance while information for the alternative fuel scenarios comes from sources such as TCRP reports and correspondence with transit agencies, bus manufacturers, and energy companies. Energy cost projections for both diesel and alternative fuels are obtained from the U.S. Energy Information Administration (EIA).[10]

In this study, the cost analysis proceeds with multiple steps. First, a preliminary analysis is conducted to calculate at the individual bus level the annual cost differential between a diesel-powered bus and the comparable alternative fuel-powered buses. The objective is to identify whether any of the alternative fuels offer annualized savings compared to diesel buses. Only the alternative fuel type(s) that satisfy this criterion are retained for further analysis.

Next, the retained alternative fuel sources are compared against the base scenario over a 30-year period under two replacement schedules:

- *Fixed maximum age*: procurement occurs in such a manner that buses are replaced automatically when they reach the average useful life of RTS buses. The fixed maximum age scenario has an aggressive replacement schedule which ensures a reasonable fleet age but is unlikely in the face of current funding streams.
- *Fixed capital scenario:* bus procurement quantity occurs commensurate with historic acquisition behavior (average number of buses purchased annually in the past five years). The fixed capital scenario is financially pragmatic but occurs at the expense of an aging fleet.

These two scenarios encapsulate the likely future potential range of procurement schedules which dictate the cost effectiveness of employing any alternative fuel source. An intermediate solution is then presented to rectify deficiencies in the two original scenarios by including an upfront bus loan and using

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[8] RTS reached out to various bus manufacturers and transit agencies to determine if portions of the existing fleet could be retrofitted to one of the fuel sources being considered. Companies/transit agencies that RTS has reached out include Omnitek Engineering Corp., Agility Fuel Systems, Greater Cleveland Regional Transit Authority, and Dallas Area Rapid Transit. All of them indicated that a bus's fuel source substantially dictates the design of the bus. Converting a bus from one fuel source to another (even if possible) would require modification of the bus's frame, engine compartment, etc. and would require federal certification that the structural modifications have not rendered the bus unsafe. Given the likely substantial effort to do this and the general uncertainty of the process this analysis only considers new vehicles.

[9] The study does not attempt to monetize the environmental benefits of each fuel source.

[10] See http://www.eia.gov/analysis/projection-data.cfm#annualproj. Note that all results throughout this paper are extremely sensitive to fuel projections, as the difference in fuel costs are the source of all proposed savings. However, even if all CNG energy costs are doubled, the general trends would stay the same.

future year savings to purchase additional CNG buses. Each replacement scenario includes a loan payment schedule that uses annual fuel source savings to pay off loan principal and interest.[11]

Given the potential effect of fleet expansion on the results, four expansion scenarios are considered under each procurement scenario to capture possible RTS growth during the study period: no growth (128 buses), or expansion to 150, 175, or 200 buses.[12,13]

[11] Another strategy observed when developing this paper is the incorporation of capital costs into fuel prices. This occurs when an agency buys fuel through a turn-key solution as opposed to a local utility. The full mechanics of transforming capital costs into operating costs is not known so this strategy is not presented here.

[12] The recent historical growth rate of the RTS fleet applied to a future 30 year period would result in over 300 vehicles. Given RTS's existing service area it's unlikely without some multi-County expansion this fleet size would ever be achieved.

[13] The overall conclusion of the study remains unchanged under the different expansion scenarios. Therefore, only the 150 bus expansion scenario is presented in the main body of this report. The other expansion scenarios are available upon request.

2 Annual Cost Differential Analysis

The annual cost differential analysis determines which of the alternative fuel scenario(s) should be retained for further examination by comparing the sum of annual O&M and annualized capital costs. An alternative fuel source is cost effective if this summation produces a smaller value than the summation for diesel buses.

2.1 Model Input

Table 2-1 lists the input parameters for this analysis.

Table 2-1. Parameters for Annual Cost Differential Analysis.[14]

Parameter	Fuel Type			
	Diesel	Hybrid	CNG	Electric
Capital Cost Parameters				
Bus Price ($)	447,613[15]	668,334[15]	498,114[16]	800,598[17]
Battery Price ($)	0	0	0	80,160[18]
Bus Service Life (years)	17	17	17	17
Battery Service Life (years)	0	0[19]	0	6[17]
O&M Cost Parameters				
Average Fuel Price ($ per diesel gallon equivalent (DGE))	3.31[20]	3.31[21]	1.01[22]	3.97[22]
Average Annual Miles Traveled[23] (miles)	30,200	30,200	30,200	30,200
Fuel Economy (miles per DGE)	3.66[23]	4.01[23]	4.40[24]	18.80[25]
Vehicle and Facility O&M Rate ($ per mile)	0.91[26]	0.91[27]	1.05[27]	0.77[27]
Fueling Staff Wage[28] ($)	12.50	12.50	12.50	12.50
Fueling Rate (DGE per minute)	40	40	15	0

[14] All dollar values unless otherwise noted in this report are in 2016 dollars. Inflation rates were obtained from http://www.usinflationcalculator.com/inflation/current-inflation-rates/.
[15] Based on recent RTS purchases.
[16] Gillg Limited Liability Company (LLC) correspondence 07/16/2015.
[17] Proterra correspondence 07/22/2015.
[18] Price for buses equipped with six-pack batteries (Proterra 07/22/2015).
[19] Hybrid vehicles have a battery replacement schedule similar to electric vehicles. It is, however, unclear if the battery cost is equivalent between the two vehicle types. Since hybrid vehicles are the least cost effective of all examined fuel types whether this cost is or is not included in the analysis does not change the paper's recommendations.
[20] Derived from EIA fuel projections and adjusted using RTS data.
[21] Hybrid bus uses a diesel-electric powertrain which is partially powered by diesel.
[22] Derived from EIA fuel projections and adjusted using Gainesville Regional Utility (GRU) data.
[23] Based on RTS 2014 data.
[24] Calculated based on Gillig LLC report and RTS 2014 data.
[25] Proterra correspondence 08/13/2015. This is equivalent to 0.50 miles per kWh (according to http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf, 1 DGE = 37.64 kWh).
[26] RTS 2015 maintenance cost data.
[27] RTS 2015 maintenance cost data and TCRP Reports 132 and 146.
[28] Based on RTS 2015 wage data.

2.1.1 Bus and Battery Service Life

The minimum service life of heavy-duty large buses (35-ft to 60-ft) established by the Federal Transit Administration (FTA) for transit vehicles purchased with federal funds is 12 years or 500,000 miles, whichever comes first. This policy has been misinterpreted by many agencies as the actual useful life and therefore 12 years is often adopted as the retirement policy for 40-ft buses (Federal Transit Administration, 2007). RTS buses annually travel fewer miles than most other transit agencies (and thereby reach 500,000 miles after 12 years).[29] This is reflected in inventory records for the last several decades, which show an average service life of 17 years. This study assumes that this service life duration would also be applicable to hybrid, CNG, and electric buses.[30]

According to Proterra, the battery life of electric buses is 6 to 8 years and has a replacement cost of $80,160 (six-pack battery).[31] This study conservatively assumes a battery replacement schedule of every six years (or twice over the life of the vehicle).[32]

2.1.2 Fuel Price

The average fuel price for each fuel type is calculated based on a 30-year projection of fuel prices. The EIA provides energy costs for 2013 to 2040 for diesel, natural gas, and electricity. The 2013 values are converted to 2016 dollars. Costs for the remaining years of the study (2041 to 2045) are calculated by assuming a fixed relative growth rate of 2.37% (the annual average relative growth rate between 2030 and 2040 according to EIA projections).[33] Finally, energy price projections are adjusted to local conditions by calculating the ratio of current local energy prices to EIA energy prices and applying this ratio to future year EIA projections. For example, the ratio of local diesel prices to prices provided by the EIA is 0.84. The same price ratio is applied to electricity and CNG.

The local natural gas price in 2015 was provided by Gainesville Regional Utilities (GRU), which offers a multi-tier rate structure. The two tiers applicable to this study are general service and large volume service; RTS will likely qualify for the latter when fleet size reaches 40 vehicles.[34] For general service, the

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[29] At RTS' average annual miles per bus rate, 500,000 miles is reached after 16.6 years. Nationally, most buses on average travel over 37,000 miles per year (http://www.fta.dot.gov/documents/WVU_FTA_LCC_Final_Report_07-23-2007.pdf). At this rate, 500,000 miles is reached after 13.5 years.

[30] There is a high level of uncertainty in this assumption. Manufacturers of non-diesel vehicles advocate that these vehicles (outside certain components) have equivalent service lives to diesel vehicles. Typically, this is within the 12-year paradigm stated above so it's unclear even with the reduced mileage of RTS vehicles if they can be in service for the 17 years assumed here. Since there is lack of definitive evidence against this assumption and not making it would strongly weigh against any of the alternative technologies, no difference in life span is assumed.

[31] Electric buses are a nascent technology which should improve over time. Since there is no way of knowing how performance will change, current conditions are assumed to remain constant. This assumption is likely to over-estimate the cost of electric buses.

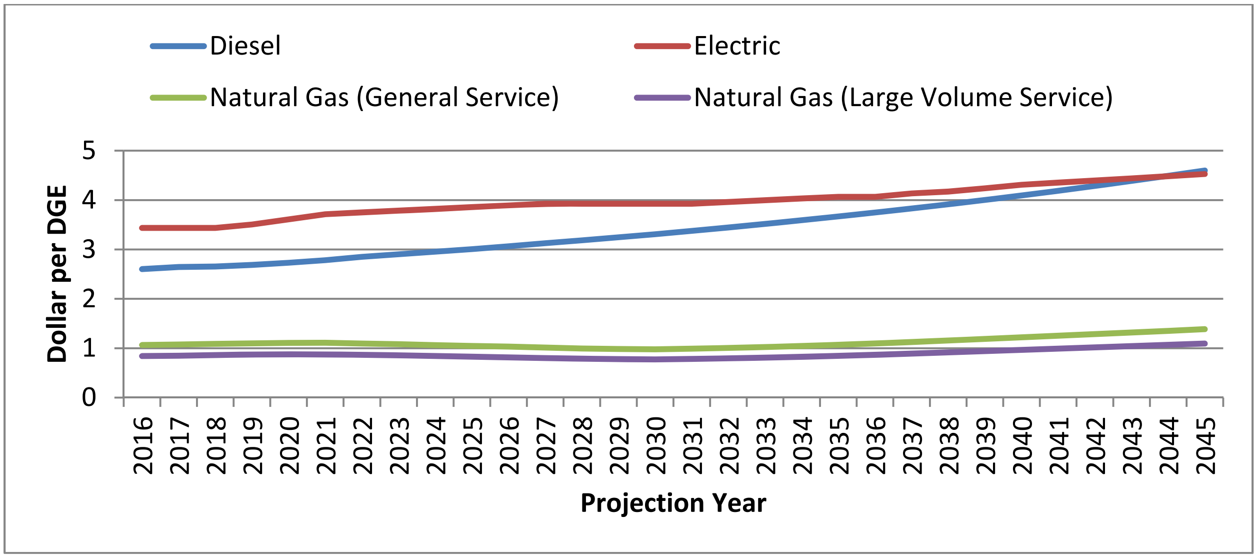
[32] While assuming an 8 year replacement schedule improves the cost competitiveness of electric vehicles it does not change the overall conclusions of this section.

[33] This growth rate does not take into account inflation. All calculated prices are in 2016 dollars and reflect actual projected shifts in energy costs.

[34] According to GRU, the cutoff amount between general service and large volume service is 30,000 therm per month, or 360,000 therm per year. A bus traveling 30,200 miles per year at 4.4 miles per gallon consumes 6,864 DGE or 9,400 therms. This amounts to about 40 vehicles (360,000/9,400).

rate is $0.76 per therm,[35] or $1.05 per DGE (one therm equals 0.73 DGE)[36], plus $45 per month customer charge. For large volume service, the rate is $0.60 per therm, or $0.83 per DGE, plus $400 per month customer charge. The ratio of 2015 natural gas price to EIA 2015 price was calculated and the same ratio was applied to future year EIA projections in order to get a local projection.[37] The average CNG price during the project's timespan, including both general service and large volume service, was calculated for this analysis ($1.01 per DGE).[38] Figure 2-1 shows the energy price projections per DGE between 2016 and 2045.

Figure 2-1. Fuel Price Projections.[39]



2.1.3 Average Annual Miles Traveled

The data used to calculate average miles traveled per year per vehicle is derived from RTS historical data. The average miles traveled is 30,200 miles per year per vehicle. It is calculated by dividing the total miles traveled in 2014 by the total number of buses operated in the same year. The same average miles traveled per year per vehicle is applied to all future years and all fuel scenarios.

2.1.4 Fuel Economy

For diesel buses, fuel economy is calculated by dividing annual fuel consumption (gallons) by total miles traveled.[40] The fuel economy for 40-ft CNG buses is derived from bus manufacturer Gillig LLLC and is

[35] This includes a non-fuel energy charge ($0.38 per therm), manufactured gas plant cost recovery factor ($0.0556 per therm), gross receipts tax index ($0.028 per therm), and purchased gas adjustment ($0.30 per therm).
[36] The conversion rate is obtained from http://energyalmanac.ca.gov/transportation/gge.html.
[37] The ratio for general service is 0.44; for large volume service the ratio is 0.35.
[38] This figure includes $0.02 for the per month customer charge converted to DGE. While it will vary by year, the maximum values will occur in the first year of each fuel volume type because that is when RTS will spread this cost over the minimum number of DGEs.
[39] The annually surcharges for both general service and large volume service of natural gas are not included in the figure but as noted above would not exceed more than $0.02 in any given year.

adjusted to local conditions. Specifically, the fuel economy is calculated as averaging the Altoona test results for Gillig LLC's Central Business District (CBD) and arterials fuel economies (0.81 M per pound (lb) and 1.04 M per lb, respectively), weighted by the total miles traveled in Gainesville on CBD versus arterials.[41] CBD routes are defined as routes 46, 300, and 117 through 127. The total revenue miles traveled on CBD and arterials in fiscal year 2014 were 391,842 and 3,004,656 miles, respectively. The weighted average fuel economy is 1.01 miles per lb, or 6.52 miles per diesel gallon equivalent (DGE) (1 DGE = 6.38 lb of natural gas according to Loves (2014)). This figure is then adjusted to account for a varied fleet age and fuel loss factor during fueling. First, the same method and data sources were used to get a weighted average diesel fuel economy which is 4.31 miles per gallon (MPG); the information from Gillig LLC included the same testing results for a comparable diesel bus manufactured by them. To adjust for the local fleet age, this figure was divided by the local fuel economy of 3.66 MPG to get a multiplier, which was then applied to CNG bus. Finally, the fuel economy is further adjusted to take into account fuel loss (20%) that occurs with gaseous fuels during fueling (see Westport 2013). The fuel economy for 40-ft electric buses is based on data provided by Proterra.[42] It is assumed that fuel economy holds constant in future years for all fuel types.[43]

2.1.5 Vehicle and Facility O&M Rate

Vehicle and facility O&M rates for diesel buses are derived from local data. Vehicle maintenance costs are derived from data that covers the first five months of 2015; linear projection is used to estimate 2015 annual costs. Facility maintenance costs came from 2014 budget expenditures. The rate is calculated by applying Equation (1):

$$MR = (VMC_{2015} \div M_{2015}) + (FOMC_{2014} \div M_{2014}) \qquad \text{Equation (1)}$$

Where:

- MR_i is the vehicle and facility O&M rate for diesel buses,
- VMC_{2015} in the projected 2015 vehicle maintenance cost adjusted to 2016 dollars, which includes labor, parts, overhead, and outside costs,[44]
- M_{2015} is the projected total miles traveled in 2015,
- $FOMC_{2014}$ is the facility O&M cost in 2014 adjusted to 2016 dollars,[45] and

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[40] Hybrid vehicles only make up four percent (five out of 128 vehicles) of the RTS fleet and are assigned to routes that optimize their performance. Because of this small share, they were not used to calculate hybrid fuel economy and were included in the global calculation of fuel economy for RTS diesel vehicles.

[41] Route mileage from September 2014 Ridership Report "FY14 Revenue Miles & Hours" tab.

[42] Sufficient information is not available to adjust the fuel economy of electric buses to local condition.

[43] It is likely that fuel economy will improve for each technology. However, since it is unclear how and if these economies will change relative to each other no change was assumed. There is also the issue of electric vehicles which are a new, evolving technology that has yet to be adopted by any agency on a system-wide scale and thus injects significant uncertainty into efficiency estimates.

[44] Information from bus manufacturers and transit agencies indicated that other energy costs, such as oil, lubricant, and coolant costs are comparable across fuel sources. Definitive information supporting or refuting this assumption could not be found so these costs were excluded from the analysis.

[45] Facility O&M cost includes expenses associated with pest control, janitorial services, building grounds maintenance, utilities, and trunked radio system.

- M_{2014} is total miles traveled in 2014.

The vehicle and facility O&M rate holds constant in future years. Applying equation (1) the vehicle maintenance rate for diesel bus is $0.83 per mile and the facility O&M rate is $0.08 per mile, totaling $0.91 per mile.

TCRP Report 132 gives vehicle maintenance rates for hybrid- and CNG-powered buses as $0.59 per mile and $0.68 per mile, respectively.[46] However, they note that hybrid maintenance costs are likely underestimated by as such as 50% since at the time of the report this was an emerging technology with attractive warranties that negated many expenses. As a result, the vehicle maintenance cost of hybrid buses is considered to be the same as diesel buses in this study.

Vehicle maintenance costs are higher for CNG buses than diesel buses because two components exclusive to CNG buses, pressure sensors and ignition systems, are vulnerable to failure (Cape Fear Public Transportation Authority, 2012). In addition, other parts of CNG buses, like the fuel filter, are reported to be less forgiving of extended service intervals (Adams and Horne, 2010). Shorter service intervals result in more frequent inspection, maintenance and replacement, driving vehicle maintenance costs of CNG buses up.

TCRP Report 132 does not include the vehicle maintenance cost for electric-powered bus. The only available information is for the propulsion system, a subset of vehicle maintenance cost, which is identified as $0.09 per mile less than a diesel bus (TCRP Report 146).[47] According to TCRP Report 132, the median vehicle maintenance rate for diesel buses is $0.59 per mile. Therefore, vehicle maintenance is estimated for electric buses at $0.50 per mile.

The facility O&M rate[48] for diesel, hybrid, CNG, and electric buses, according to TCRP Report 146, are $0.18 per mile, $0.18 per mile, $0.23 per mile, and $0.13 per mile, respectively. CNG facility O&M rates are higher than the other fuel sources because of the large amount of electricity used to compress natural gas for vehicle use.[49,50] As a result, the total vehicle and facility O&M rates for these four fuel sources, according to TCRP Reports, are $0.77 per mile, $0.77 per mile, $0.91 per mile, and $0.63 per mile, respectively.

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[46] It is important to note that according to TCRP Report 132, vehicle maintenance rates vary dramatically because of the unique management and operational situations and the varying fleet age at different test sites. Total maintenance cost is very sensitive to vehicle maintenance cost. This study employs the median values reported in TCRP Report 132.

[47] According to TCRP Report 146, vehicle maintenance costs for electric buses are lower because of the minimal maintenance requirements for their drivetrains and transmissions. Electric motors have only one moving part as opposed to the hundreds found in internal combustion engines.

[48] According to Westport (2013), there is likely to be an electric demand charge from the energy company at peak fueling times (this citation was specifically addressing CNG costs but such surcharges would likely also apply to electric buses). Due to the lack of information on the demand charge curve it is not accounted for in this study.

[49] While generators are common components of transit maintenance facilities, agencies that use CNG often need to install generators larger than those required for diesel fueling to handle the significantly increased load that the CNG compressors demand. It is assumed that these costs are included in lump sum capital projections.

[50] As an aside, because of the safety risks associated with CNG, contract maintenance programs are widely employed by transit agencies nationwide (Adams and Horne, 2010).

Both TCRP reports do not explicitly state the methodology used to derive the stated rates. For this reason, to ensure the figures are comparable the maintenance rate differentials between diesel and alternative fuel buses reported in TCRP Reports 146 and 132 are added to the local diesel O&M rate ($0.91 per mile) to derive the localized O&M rates for alternative fuel type buses. For example, the equivalent localized vehicle and facility O&M rate for electric buses is calculated as (0.63 – 0.77) + 0.91 = $0.77 per mile.[51]

2.1.6 Fueling Rate

RTS can fuel at 40 gallons per minute for both diesel and electric-hybrid buses. For CNG buses, the fueling rate is 2,000 standard cubic feet (scf) per minute or 14.6 DGE per minute.[52]

Electric-powered buses will primarily employ on-route charging so there are no fueling costs associated with this fuel type.[53]

2.2 Cost Differential Analysis

The annual cost differential between an alternative fuel bus and a diesel bus consists of a summation of capital cost and O&M cost differentials (see Table 2-2).

[51] TCRP Report 146 does not specifically address whether battery replacement cost is included in capital or operating costs. It is assumed that it is not included in O&M costs since the reported O&M cost is much lower than that for diesel buses.

[52] According to Compressed Natural Gas (CNG) Transit Bus Experience Survey: April 2009 – April 2010, prepared for National Renewable Energy Laboratory (Adams and Horne, 2010).

[53] Electric buses are charged either on-route or on-site. On-route charging requires no staff intervention. The driver simply pulls the bus up to the charging station at the stop and waits several minutes for the bus to charge. This occurs at locations where the driver already has to wait between trips. On-site charging typically occurs overnight at the maintenance facility. While buses have to be jockeyed back and forth to access the charging station the functionality is understand to be plug and go and not require on-going supervision and may occur through the routine movement of buses at the end of the day due to probing, washing, etc. For this reason, fueling costs are not assigned to either of the charging processes.

Table 2-2. Average Annual Diesel Bus Cost Differential.

	Hybrid	CNG	Electric
Annualized Capital Cost Differential ($)	12,984	2,971	30,194
O&M Cost Differentials ($)			
Vehicle + Facility O&M Cost	0	4,236	-4,236
Fuel Cost	-2,420	-20,416	-20,971
Fueling Cost	-4	52	-43
Annual Cost Differential ($)	10,560	-13,156	4,944

The annualized capital cost for all bus types is calculated by dividing their cost by the assumed bus service life (17 years). For electric buses this also includes the annualized cost of battery replacements.[54]

The annual vehicle and facility O&M cost per bus is calculated by multiplying the O&M rate by the average annual miles traveled.

Fuel cost is computed by applying Equation 2.

$$C = M \div MPG \times FP \qquad \text{Equation (2)}$$

Where:

- C is the average fuel cost per bus,
- M is the average annual miles traveled per vehicle,
- MPG is the fuel economy (all fuel types are converted to miles per DGE), and
- FP is the average fuel price in dollars per DGE.

The fueling cost is computed by applying Equation 3:

$$FCC = FH \times WR \qquad \text{Equation (3)}$$

Where:

- FCC is the fuel charging cost,
- FH is the time (in hours) it takes to fuel one bus in one year. It is calculated as the average fuel consumed per year divided by the fueling rate; the earlier is computed by dividing the average miles driven by fuel economy which is assumed to remain constant in future years, and
- WR is the average hourly wage rate for fueling staff.

[54] Electric bus annual capital cost includes annualizing battery replacement cost. Over a 17 year lifespan, a battery with 6-year service life will be replaced twice, amounting to $9,400 per bus per year (2*80)/17.

As shown in Table 2-2, only CNG-powered buses are cost effective compared to diesel bus, with an annual savings of over $13,000 per bus.[55] The annualized capital and O&M costs for hybrid- and electric-powered buses are higher than diesel buses. Therefore, subsequent analyses only include CNG. Given the increasing attractiveness of electric buses nationwide, however, a more robust analysis of that vehicle type is included in *Appendix A*.

[55] In the absence of interest, lump sum capital costs divided by this value provides an indication of the number of vehicle years required to break even.

3 Cost Analysis

Building upon the prior section's analysis, this chapter explores the cost of implementing CNG across the entire fleet over a 30-year period under two different procurement scenarios. Costs associated with the CNG bus scenario are compared to those of the base diesel scenario.[56]

3.1 Fixed Maximum Age Scenario

3.1.1 Replacement Schedule

The fixed maximum age scenario follows an aggressive bus replacement schedule where buses are automatically replaced in the year they reach the end of their service life (17 years). The replacement schedule is based on the manufacture year for the RTS fleet (Table 3-1).[57] To date RTS has 128 buses in service, including 123 diesel buses with an average fleet age of nearly ten years and five hybrid electric buses purchased in 2012 and 2013. At the time of the analysis, nine refurbished buses were acquired from Lynx. During 2016 the nine refurbished buses will take the place of the nine 1997 buses currently in the RTS fleet in order to meet FTA spare ratio requirements. These changes will maintain the fleet size of 128 buses in 2016.

[56] Note that for the CNG scenarios, the costs shown in subsequent tables and figures reflect the total cost of a combined fleet of diesel and CNG buses. The latter corresponds to the replacement schedule dictated by the procurement scenario. No cost, however, was associated with operating a mixed fleet.

[57] For simplicity sake, it is assumed that buses are in service during their manufacture year. For example, a bus manufactured in 2000 will operate in the year 2000 and thus a 17 year service span for this bus ranges from 2000 (year 1) to 2016 (year 17). A new bus will take its place in 2017.

Table 3-1. Fleet Size by Manufacture Year.

Manufacture Year	Number of Buses	Fuel Type
2000	2	Diesel
2001	43	Diesel
2002	6	Diesel
2004	6	Diesel
2005	7	Diesel
2006	4	Diesel
2007	17	Diesel
2009	4	Diesel
2010	17	Diesel
2011	6	Diesel
2012	8	Diesel (6), Hybrid (2)
2013	3	Hybrid
2014	3	Diesel
2015	2	Diesel
Total	128	Diesel (123), Hybrid (5)

Since the 30-year projection period of the analysis exceeds all estimated vehicle service lives, a number of vehicle slots in the fleet will be replaced twice. For example, RTS's 2001 vehicles will be replaced in both 2018 and 2035. Figure 3-1 shows the annual bus acquisition schedule, which includes both bus expansion and replacement. In the 30-year period when the fleet size expands to 150 buses, this replacement schedule amounts to 250 bus acquisitions, at an average rate of 8.3 buses per year. Due to a large number of buses built in 2001, over 40 buses will need to be replaced in years 2018 and 2035. Figure 3-2 shows the average fleet age in each projection year. The oldest average fleet age occurs in year 2017 (11.9 years); with a plurality of buses replaced in the following year the average fleet age stays below nine years in most projection years.[58] Figure 3-3 shows the fleet composition with this replacement schedule. In year 2032 all diesel buses will be replaced with CNG buses; it should be noted that through 2031 the costs for the CNG scenario are inclusive of both diesel and CNG-fueled vehicles.

[58] Given the replacement strategy under this scenario it should be unsurprising that the average age of the fleet will remain similar to what it is today.

Figure 3-1. Annual Bus Acquisition – Fixed Maximum Age.

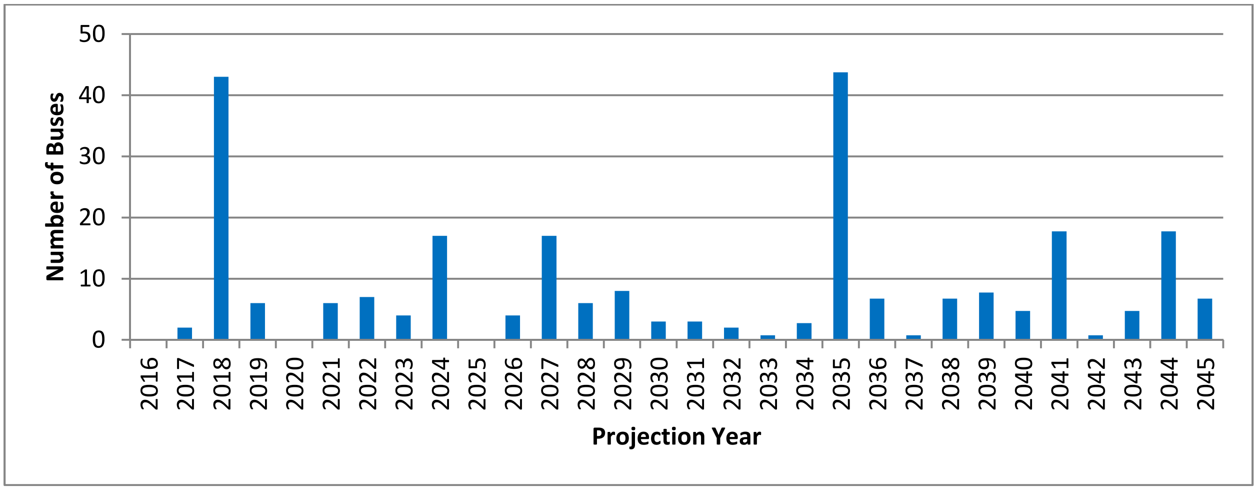


Figure 3-2. Average Fleet Age – Fixed Maximum Age.

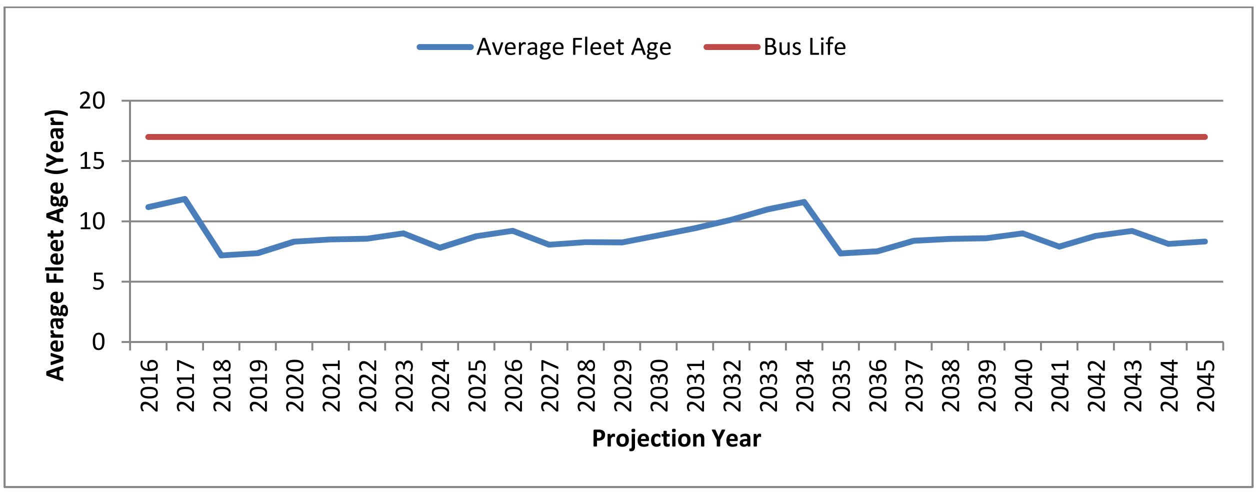
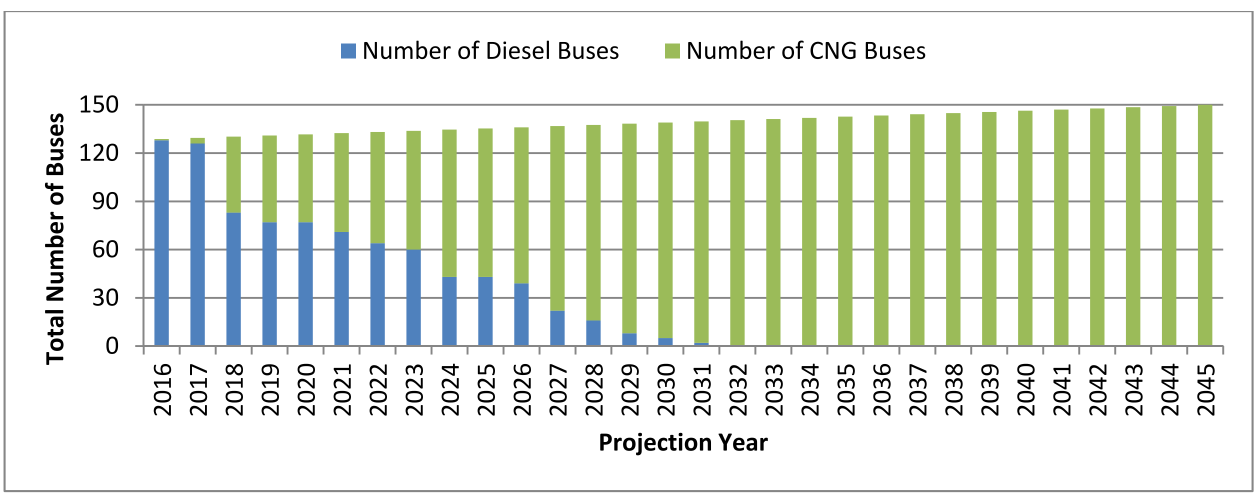


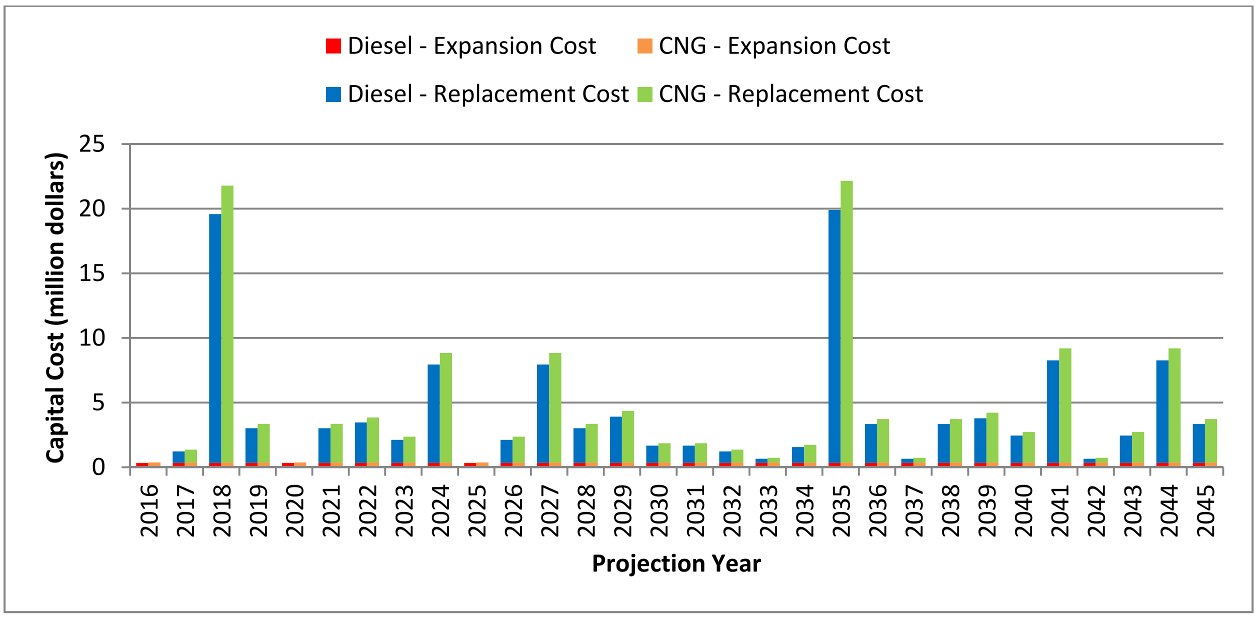
Figure 3-3. Fleet Composition by Year – Fixed Maximum Age.



3.1.2 Vehicle Capital Costs

Vehicle capital costs include both fleet expansion and replacement costs. Under the fixed maximum age scenario the expansion schedule is assumed to be linear and independent from projected revenue. For example, in the 150 fleet expansion scenario, the number of buses added annually will be calculated as (150-128)/30 = 0.73. All expansion buses will have the same fuel type as the underlying fuel scenario. Therefore, the annual expansion costs for the diesel bus and CNG bus scenarios are $328,250 and $365,284, respectively. Figure 3-4 shows the fleet expansion and replacement costs for both the diesel and CNG bus scenarios. In both scenarios, fleet expansion is only a small portion of the total annual bus acquisition cost: in the 150 vehicle expansion scenario, the average expansion to replacement cost ratio is 0.09.

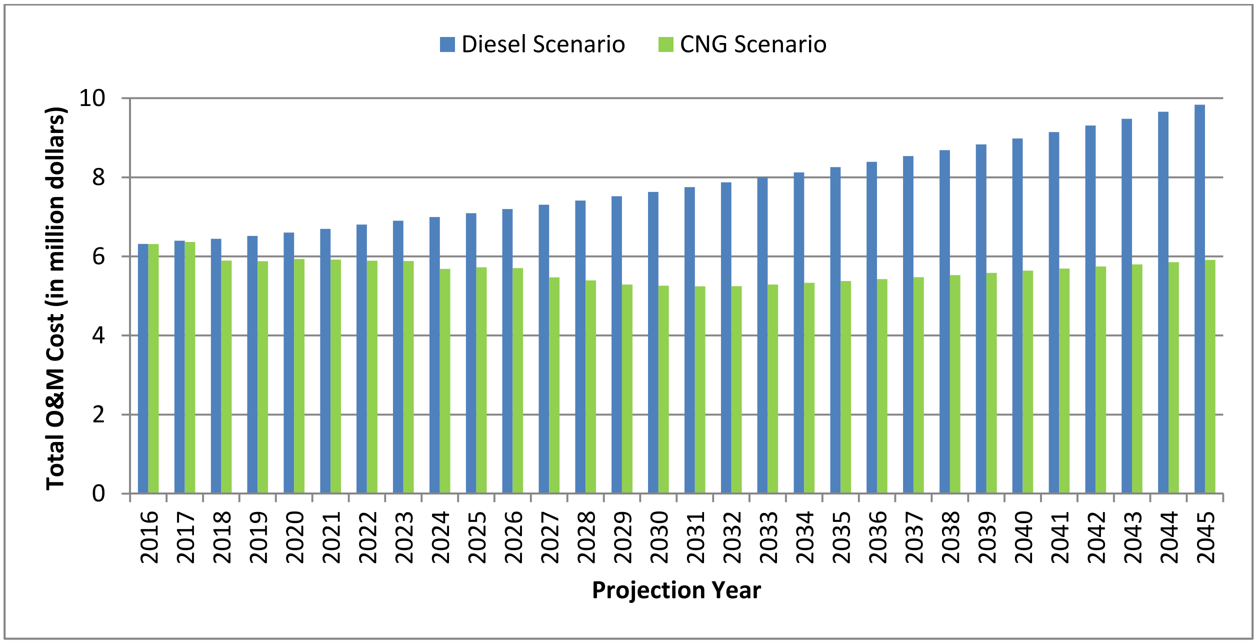
Figure 3-4. Capital Costs for Diesel and CNG Bus Scenarios – Fixed Maximum Age.



3.1.3 Total O&M Costs

Figure 3-5 shows the total vehicle and facility O&M costs in projection years. The following sub-sections break down the total O&M costs into vehicle maintenance, facility O&M, fuel, and fueling costs. As the fleet size expands, the total O&M cost for the diesel scenario increases steadily from less than $6.3 million in 2016 to $9.8 million in 2045. For the CNG scenario, total O&M costs generally decrease in early projection years as the number of CNG buses increase and due to a predicted annual decrease in fuel costs. Starting in 2031, however, the total O&M cost increases, albeit at a slower pace than diesel bus, and reaches $5.9 million by 2045.

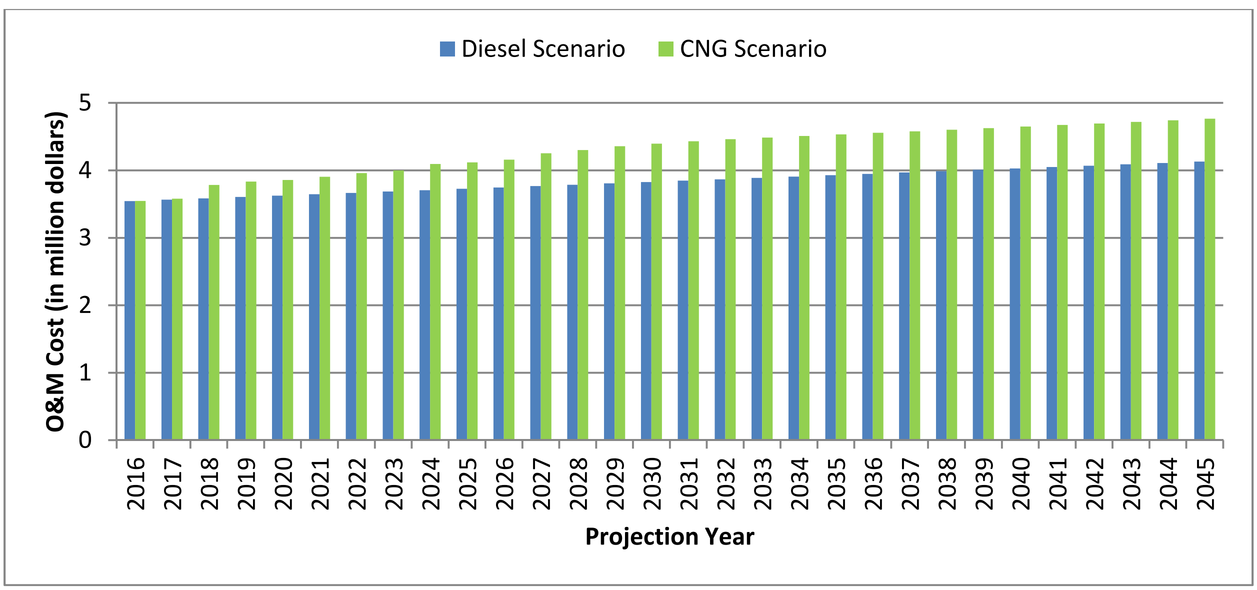
Figure 3-5. Total Vehicle and Facility O&M Costs – Fixed Maximum Age.



3.1.3.1 O&M Costs[59]

Vehicle and Facility O&M costs in year i are calculated as the O&M rate (derived from Equation 1) multiplied by the average miles traveled per vehicle and by the number of buses in that year for that fuel source. Figure 3-6 shows vehicle and facility O&M costs for both the diesel and CNG bus scenarios. The O&M cost differential after 2031 when all buses become CNG powered is about $0.6 million.

Figure 3-6. Vehicle and Facility O&M Costs – Fixed Maximum Age.

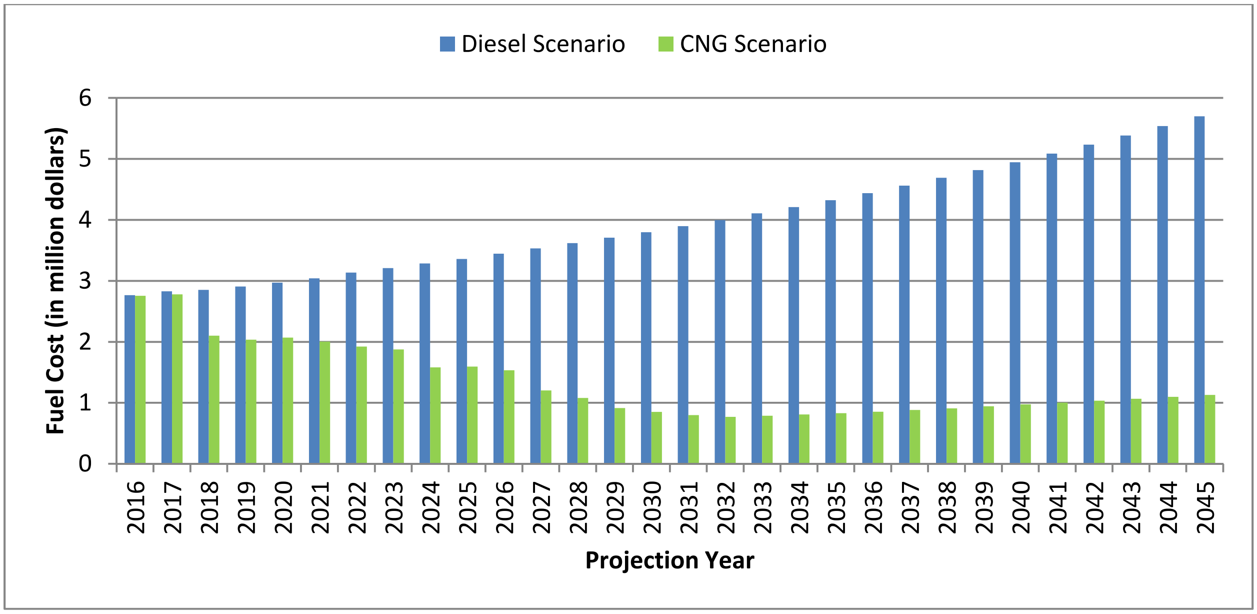


[59] O&M costs include both vehicle and facility O&M costs.

3.1.3.2 Fuel Costs

Annual fuel costs are derived from Equation 2 and multiplied by the number of buses per fuel type in year i; note that instead of using the average fuel price in Equation 2, the projected fuel price in year i is applied. Figure 3-7 shows annual fuel costs for both the diesel and CNG bus scenarios. In year 2045, fuel costs are over $4 million less in the CNG scenario.

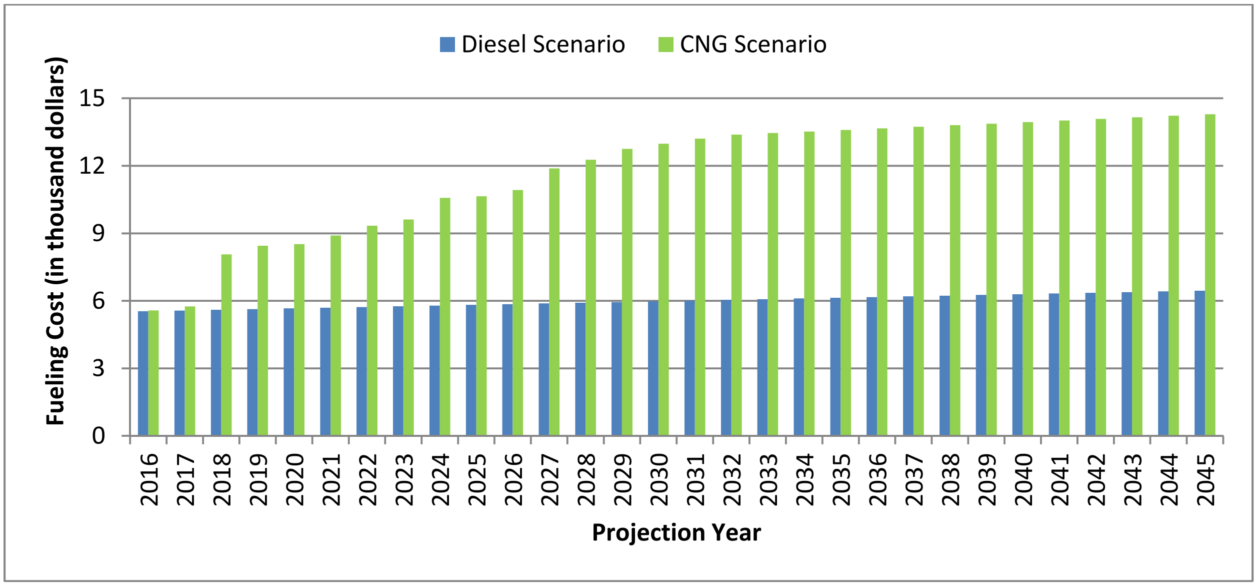
Figure 3-7. Fuel Costs – Fixed Maximum Age.



3.1.3.3 Fueling Costs

Annual fueling costs are the fuel charging cost in Equation 3 multiplied by the number of buses per fuel type in year i. Figure 3-8 shows annual fueling costs for both the diesel and CNG bus scenarios. Following the bus replacement schedule, the fueling cost differential between the diesel and CNG scenarios increases over the 30-year period but the rate of increase remains almost constant after all diesel buses are converted to CNG.

Figure 3-8. Fueling Costs – Fixed Maximum Age.



3.1.4 Upfront Lump Sum Costs

The conversion from a diesel- to CNG-powered fleet requires an upfront investment on infrastructure and staff training. The total lump sum cost for the 150-vehicle fleet CNG scenario is $4.54 million. Parameters for calculating the lump sum cost are shown in Table 3-2.

Table 3-2. Parameters for Lump Sum Costs.

Parameters	Values
Staff Training Cost ($)	**5,767**
Mechanic I Count[60]	11
Mechanic II Count[60]	10
Mechanic I Average Hourly Wage[60] ($)	21.94
Mechanic II Average Hourly Wage[60] ($)	23.92
Training Time[61] (hours)	12
External Cost ($)	**169,538**
Pipe to Facility for CNG[62] ($)	141,282
Contingency[63] (%)	20
Facility Conversion Cost ($)	**4,364,355**
Base Cost[63] ($)	1,119,062
Incremental Cost[63] ($)	16,786
Contingency[61] (%)	20
Total Lump Sum Cost	**4,539,660**

[60] RTS 2015 wage data.
[61] TCRP Report 132 adjusted to 2015 dollars.
[62] Based on GRU input.
[63] TCRP Report 146.

3.1.4.1 Staff Training

The training cost for mechanics is based on training needed above and beyond what would be required for a traditional diesel bus (i.e., no additional training costs are assumed for diesel buses). It is based on the number of trainees and their labor rates. Currently RTS has 11 mechanics I at an average labor rate of $21.94 per hour and 10 mechanics II at an average rate of $23.92 per hour. According to TCRP Report 132, it is assumed that each of these individuals would receive 12 hours of training (252 total hours of training). Operationally, CNG buses should represent a seamless transition for operators so no costs are included for their training. To this end, the additional staff training cost for CNG is $5,767.

3.1.4.2 External Costs

Currently, there is not a natural gas pipeline immediately adjacent to the RTS maintenance facility. Mike Brown, GRU-Gas Sales and Marketing, indicated that the cost to bring a 4" pipe providing 60 pounds per square inch of pressure (psi) from the closet head point downtown to the RTS facility would be about $101,000 (the yellow line on Figure 3-9 represents the proposed path of the pipeline).[64] This cost does not include extending the pipe on-site to the location of the fuel station which RTS estimates as another $40,000.[65] A 20% contingency is applied to these external costs to reflect risk and uncertainty, bringing the total external cost to $169,538.

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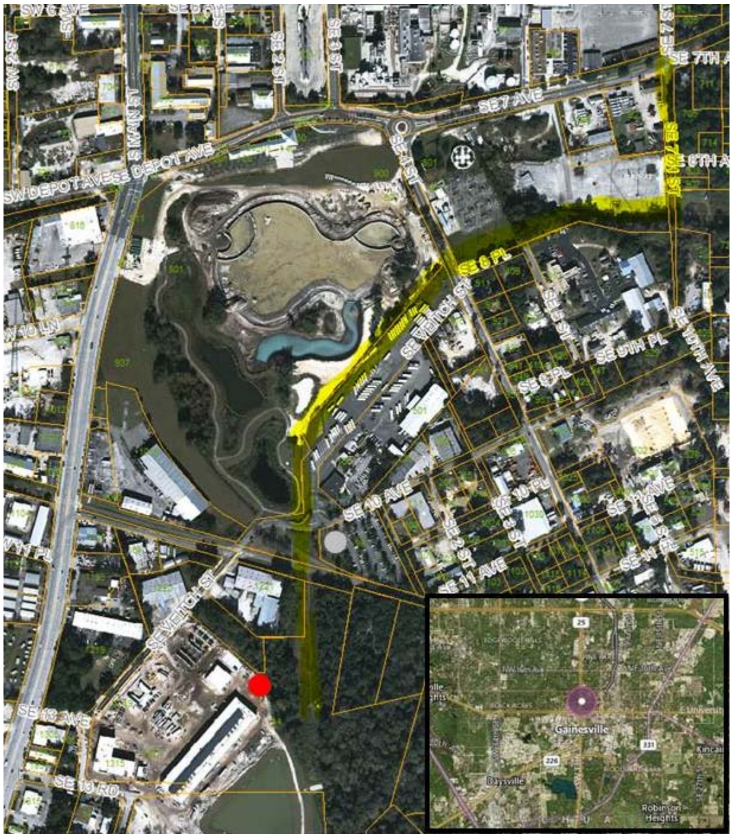
[64] It should be noted that GRU provided some indication that this price was contingent on anticipated consumption levels. At certain volumes, the project would be profitable enough where they would not pass this cost along to RTS. A specific amount, however, was not identified.

[65] There is not a strong basis for this estimate. The per foot cost for the proposed pipeline from downtown to the RTS maintenance facility would result in a cost that is only a quarter of what is estimated here. However, extending the pipeline from the proposed off-site terminus to an appropriate location in the yard is not directly comparable. For this reason, a much higher value was assumed to hopefully provide a conservative estimate.

Figure 3-9. Proposed Natural Gas Pipeline and Facility Location.



3.1.4.3 Facility Conversion Costs

Facility conversion cost includes things like installing fueling equipment and fuel-specific safety modifications to the existing facility. Based on a national survey, TCRP Report 132 developed the following formula to determine CNG facility costs:

$$FC = BC + Fleet\ Size \times UC \qquad \text{Equation (4)}$$

Where:

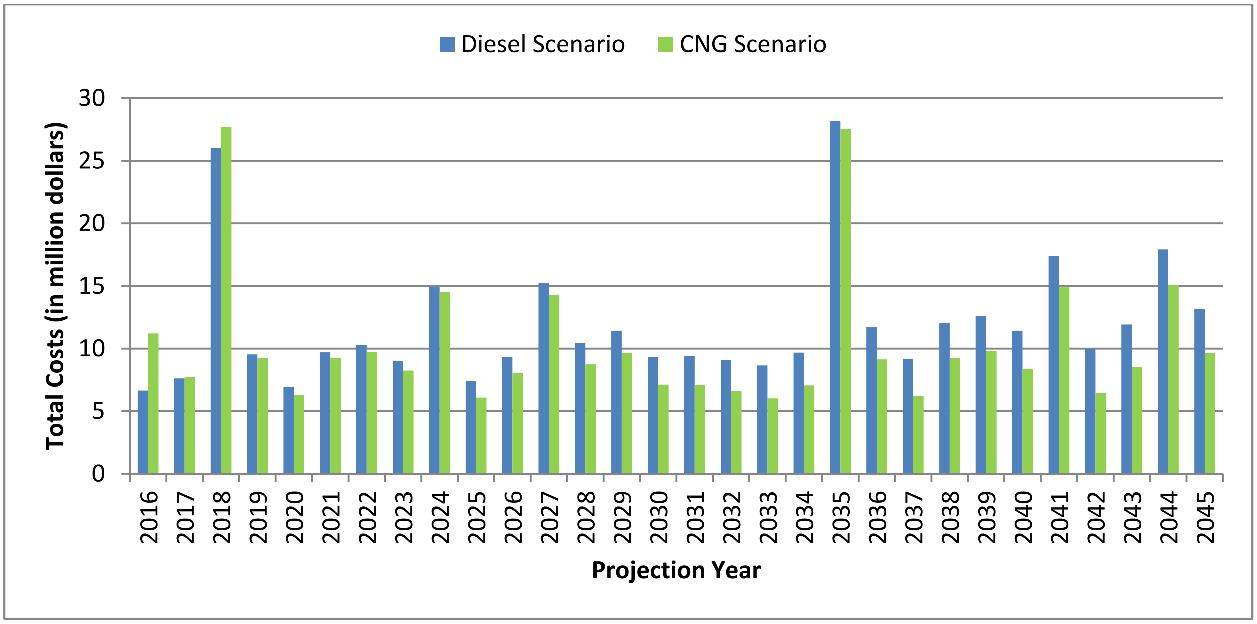
- FC is facility conversion cost,
- BC is the base cost. TCRP Report 132 (2009) reported $1 million, or $1.12 million in 2016 dollars,
- Fleet size is the number of CNG buses in the fleet, and
- UC is per bus cost, estimated at $15,000 (TCRP Report 132, 2009), or $16,786 in 2016 dollars.

Included in these costs are the costs associated with constructing a fueling facility and modifications needed for maintenance and storage facilities such as methane detection sensors and expanded ventilation systems. A 20% contingency is added to the external cost to reflect risk and uncertainty, bringing the total facility conversion cost to $4.54 million for a 150-vehicle fleet.

3.1.5 Total Costs

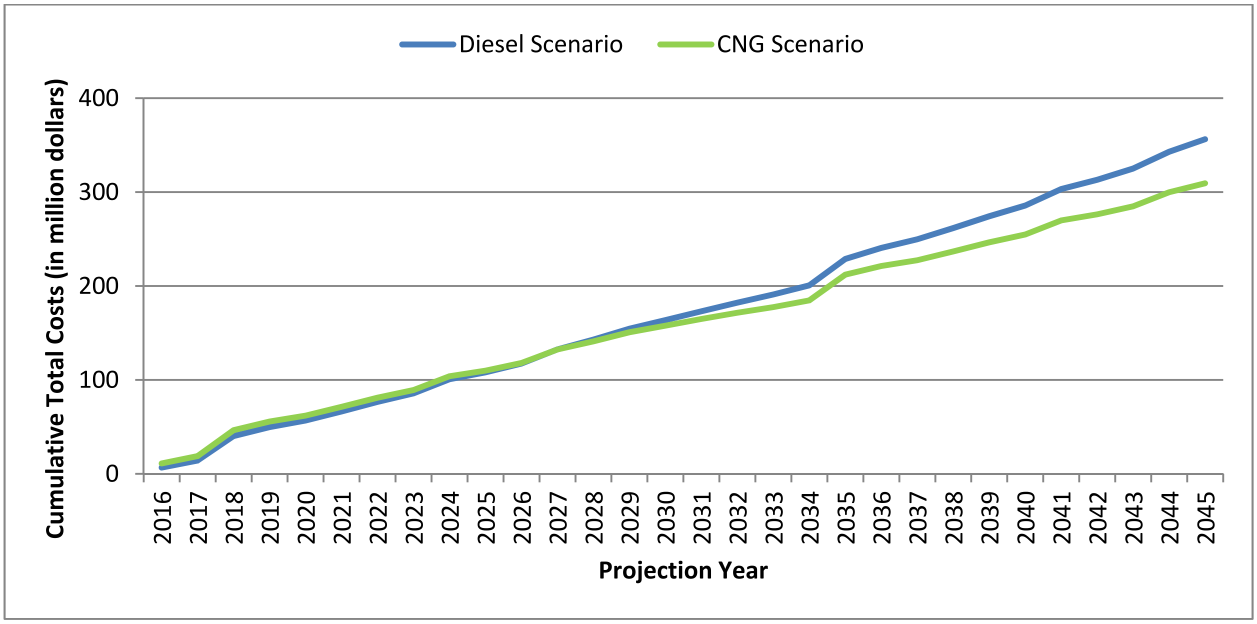
Figure 3-10 shows the total costs – including capital costs, O&M costs, and lump sum costs, for both the diesel and CNG scenarios. In most of the projection years (except for year 2016 and 2019), the CNG scenario is more cost-effective than the diesel scenario. Cumulatively, in 30 years the cost difference between diesel and CNG scenarios is about $47 million (see Figure 3-11).

Figure 3-10. Total Costs – Fixed Maximum Age.[66]



[66] Lump sum cost is included in 2016 for CNG scenario.

Figure 3-11. Cumulative Total Costs – Fixed Maximum Age.



3.2 Fixed Capital Scenario

3.2.1 Replacement Schedule

The fixed capital scenario assumes that RTS's average bus capital expenditure for the last five years will remain unchanged in the future. Specifically, RTS will use approximately $1.95 million for bus acquisitions per year.[67] This equates to 4.4 diesel buses or an equivalency of 4.0 CNG buses per year. Assuming that bus acquisitions remain constant throughout the projection period, each year the newly-added buses will first meet the fleet expansion need and then go towards replacing the oldest buses in the fleet. Based on this replacement schedule, Figure 3-12 compares the annual average fleet age between the diesel and CNG scenarios. With the limited number of buses being replaced each year, an aging fleet is inevitable. Under the diesel scenario, the average fleet age increases from ten years in 2016 to 17 years in 2045 while the CNG scenario produces a higher average because less buses are being purchased each year. At an individual level, the maximum bus age increases from 15 years in 2016 to 35 years in 2045 (see Figure 3-13).[68] Figure 3-14 shows the fleet composition for the CNG scenario with this replacement schedule. At this replacement rate, over 30 (one fifth of) buses in the fleet will still be diesel-powered after 30 years.

[67] As elsewhere in this section, this assumes constant purchasing power so the amount of buses that can be purchased with this amount is the same in 2016 as it is in 2045.

[68] Presumably vehicle maintenance costs per mile will increase as the average fleet age increases. Documentation detailing or providing possible cost curves were not readily identified. Therefore, this cost is not factored into the paradigm presented here. Moreover, globally, cost differentials produced by evolving vehicle age distributions are not directly handled. Rather an older fleet is acknowledged as a non-desirable state and recommendations are made later in the paper to control it to the greatest extent feasible.

Figure 3-12. Average Fleet Age – Fixed Capital.

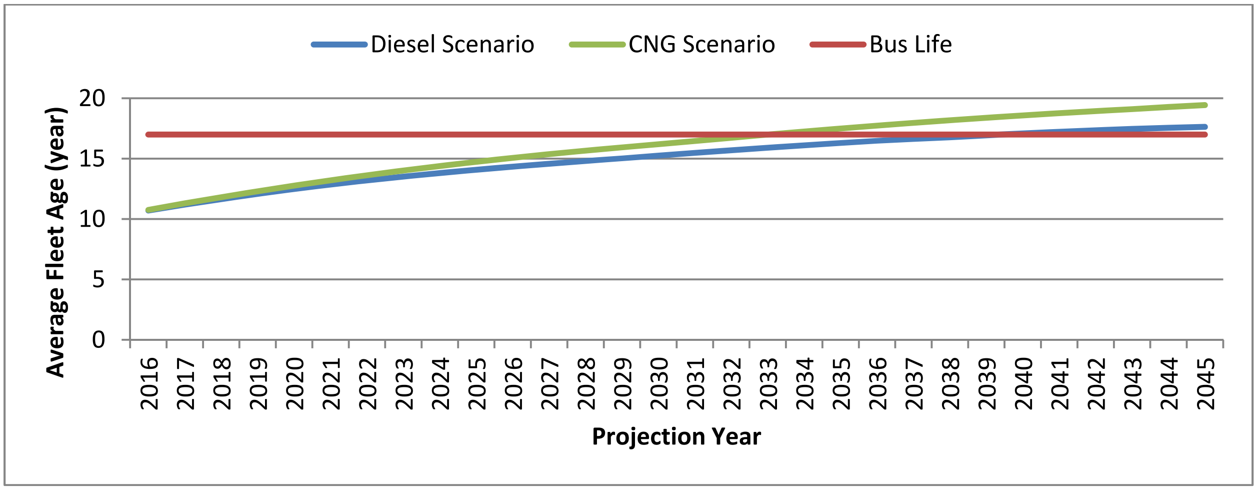


Figure 3-13. Maximum Bus Age – Fixed Capital.

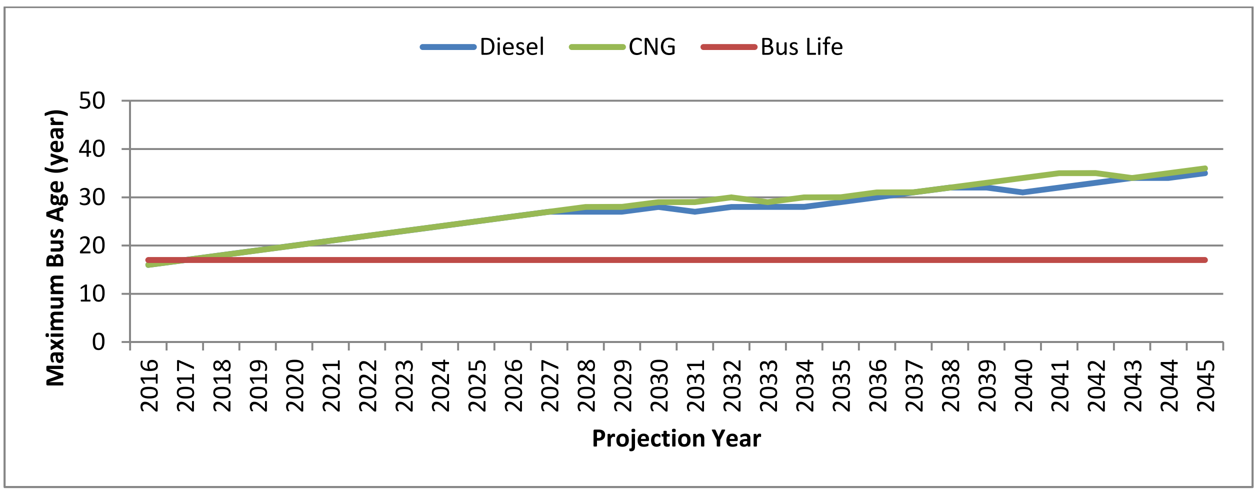
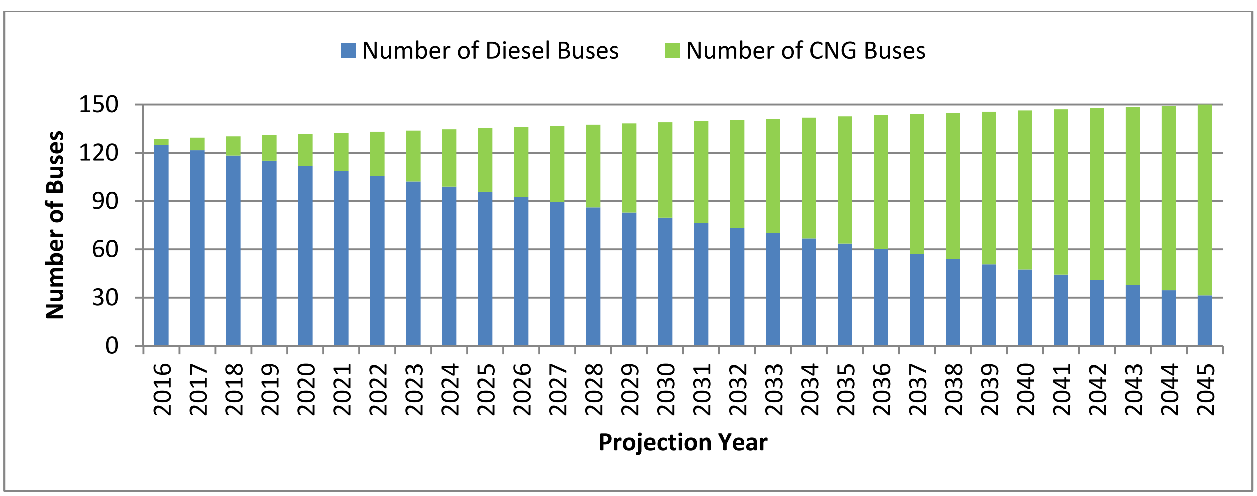


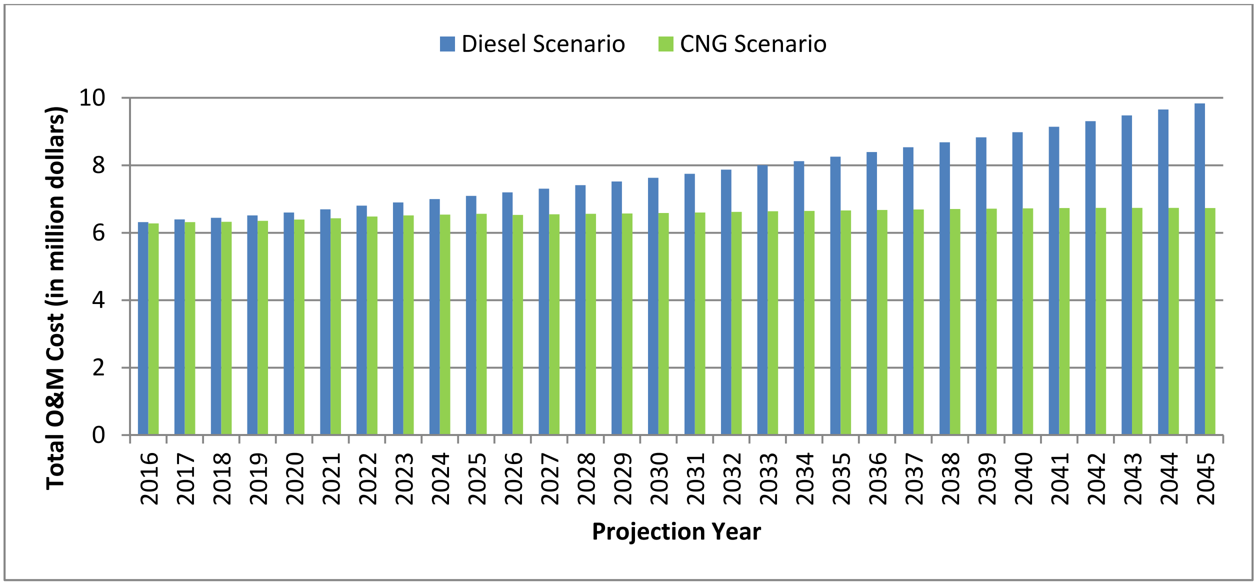
Figure 3-14. Fleet Composition – Fixed Capital.



3.2.2 Total O&M Costs

Figure 3-15 shows the total O&M costs through 2045. As above, total O&M costs include vehicle and facility O&M, fuel, and fueling cost. The total O&M cost (and all sub-O&M costs) is the same for diesel buses under both the fixed capital and max age scenarios but is higher for CNG under the fixed capital scenario since RTS would still be operating a mixed fleet by 2045.

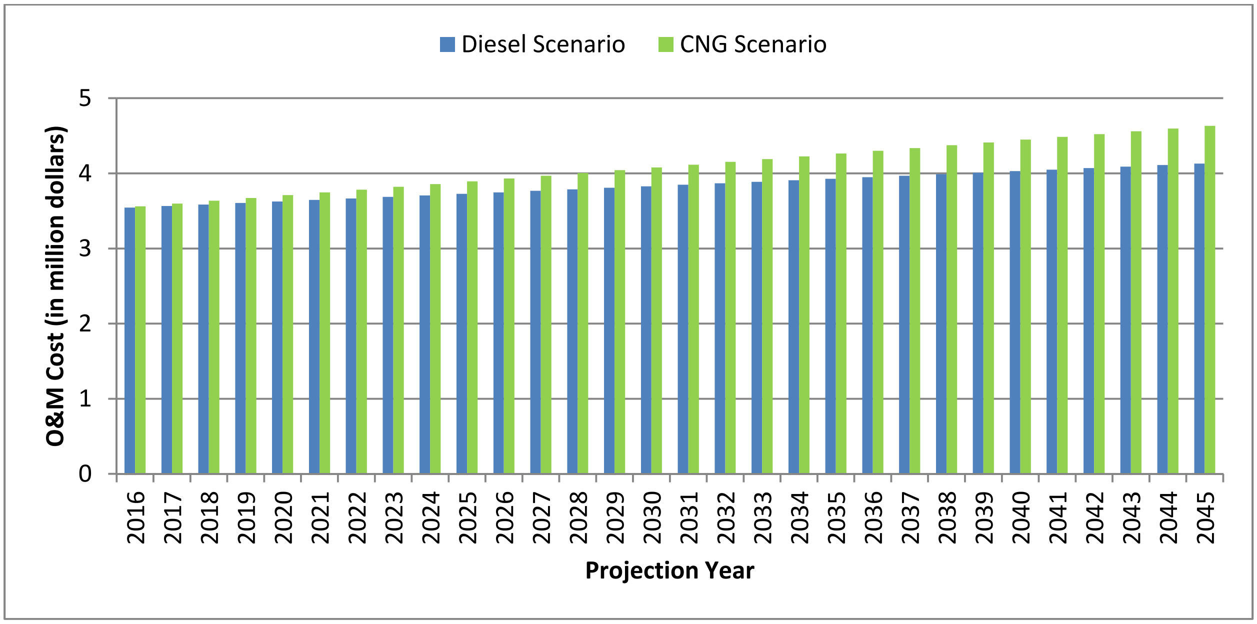
Figure 3-15. Total Vehicle and Facility O&M Costs – Fixed Capital.



3.2.2.1 O&M Costs

Figure 3-16 shows vehicle and maintenance facility O&M costs for both the diesel and CNG bus scenarios. The vehicle and maintenance facility O&M cost for the CNG scenario increases at a faster rate than for the diesel scenario. Relative to the base year, the O&M cost for the CNG scenario increases by $1.1 million while for the diesel scenario it only increases by $0.6 million.

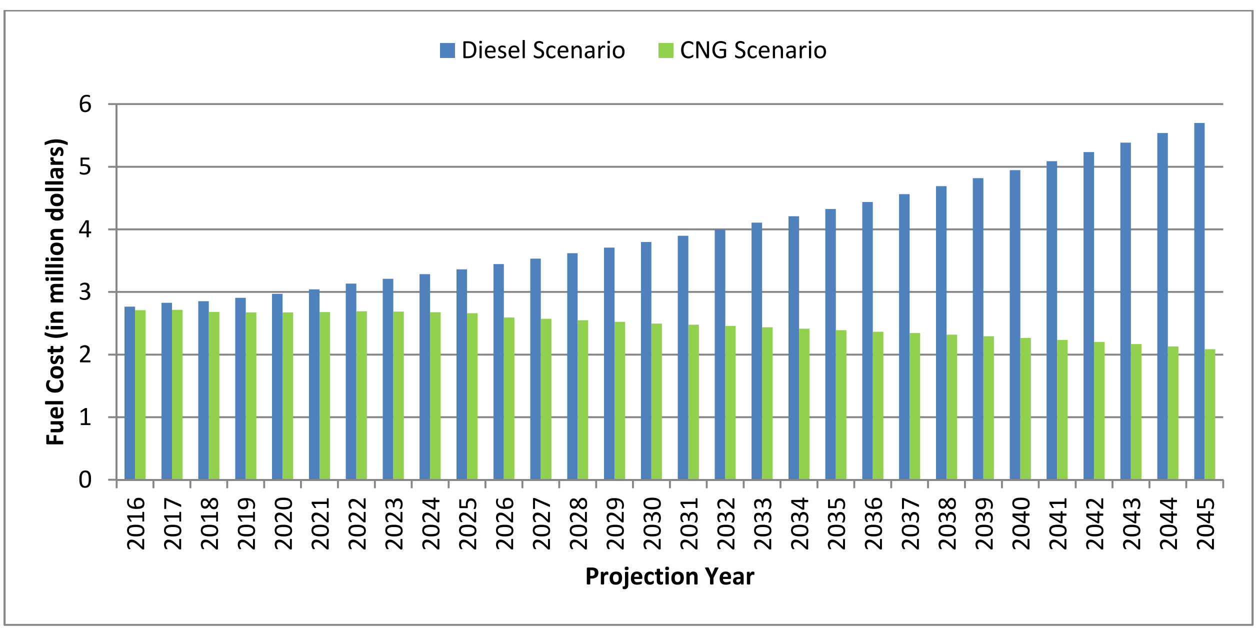
Figure 3-16. Vehicle and Facility O&M Costs – Fixed Capital.



3.2.2.2 Fuel Costs

Figure 4-17 shows annual fuel costs for both the diesel and CNG bus scenarios. In 30 years, fuel costs under the diesel scenario increase by almost $3 million to $5.7 million, whereas fuel costs for the CNG scenario decrease approximately $0.6 million to about $2.1 million.

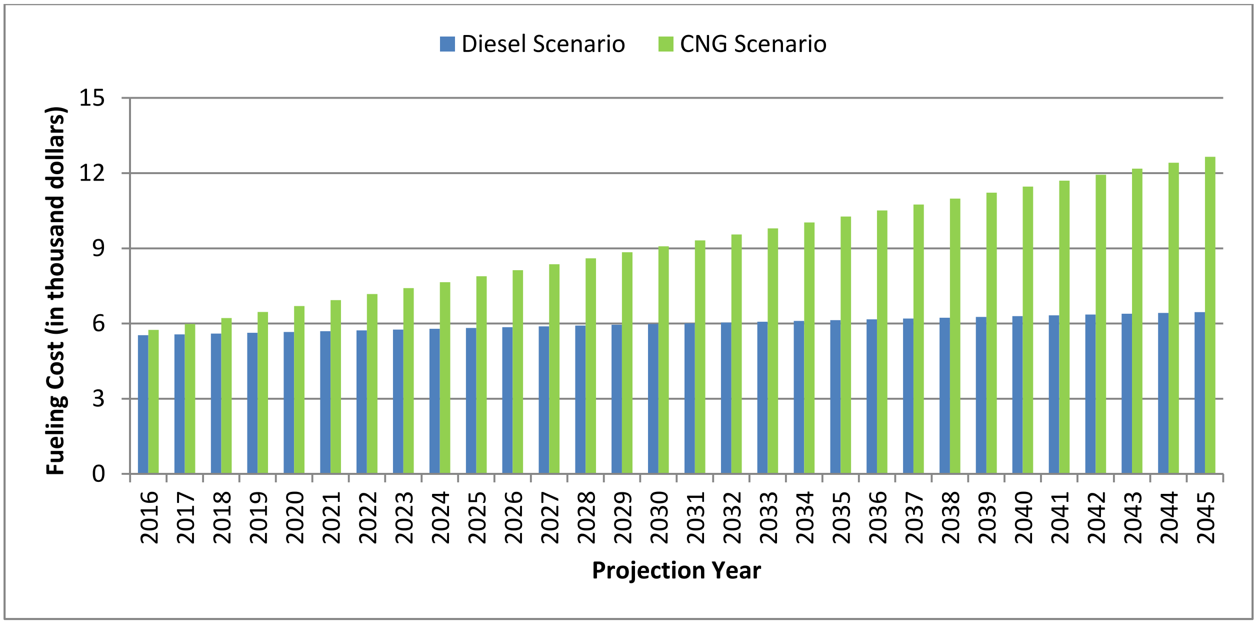
Figure 3-17. Fuel Costs – Fixed Capital.



3.2.2.3 Fueling Costs

Figure 3-18 shows the fueling costs for both the diesel and CNG bus scenarios. Following the bus replacement schedule, fueling costs for the CNG scenario increase at a faster rate than the diesel scenario. In 2045, the annual fueling costs for the CNG scenario approach $13,000, while the costs in the diesel scenario stay below $7,000.

Figure 3-18. Fueling Costs – Fixed Capital.



3.2.3 Upfront Lump Sum Costs

The upfront lump sum costs in the fixed capital scenario are the same as those in the fixed maximum age scenario, which amounts to $4.54 million.[69]

3.2.4 Total Costs

Figure 3-19 shows the total costs – including capital costs, O&M costs, and lump sum costs, for both diesel and CNG scenarios. Unlike the diesel scenario where total annual costs increase from $8.3 million in 2016 to $11.8 million in 2045, under the CNG scenario total annual costs remain fairly constant. Cumulatively, in 2045 the cost difference between the diesel and CNG scenarios is $33 million.

[69] Although the replacement schedule in this scenario does not allow full fleet-wide conversion in 30 years, the conversion would still continue outside of the window until RTS operated on a single fuel source. For this reason, the study assumes staff training costs, external costs, and facility conversion costs remain the same between the two scenarios.

Figure 3-19. Total Costs – Fixed Capital.[70]

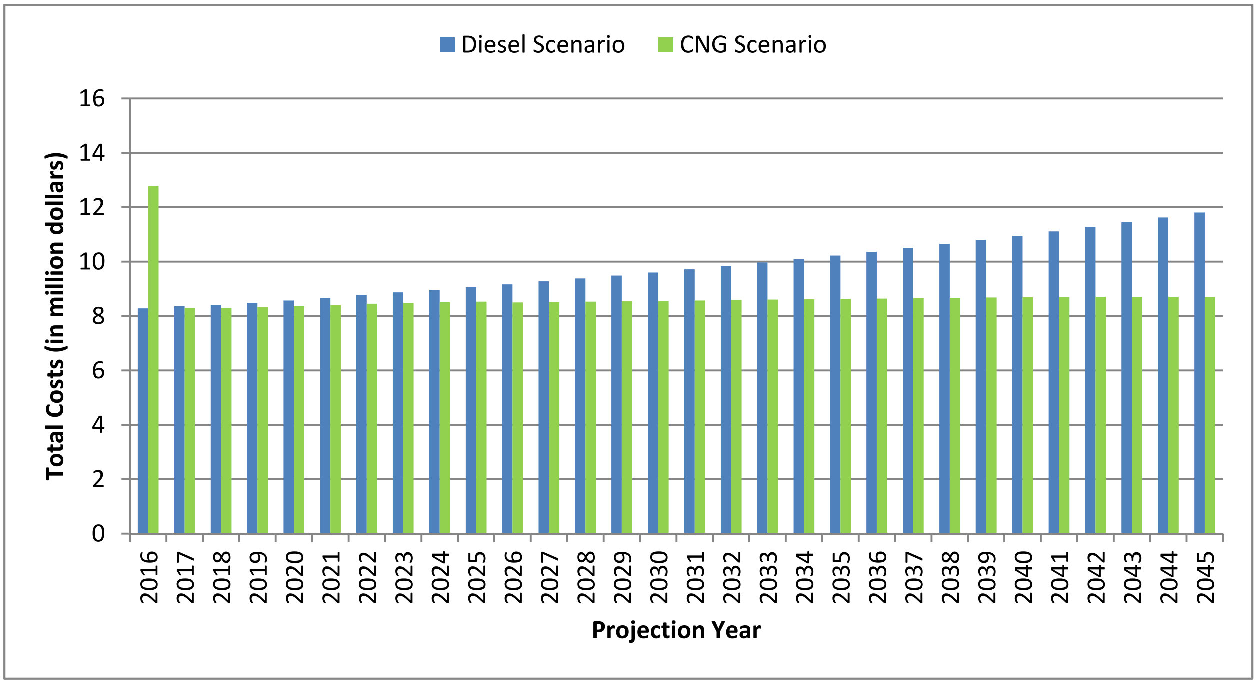
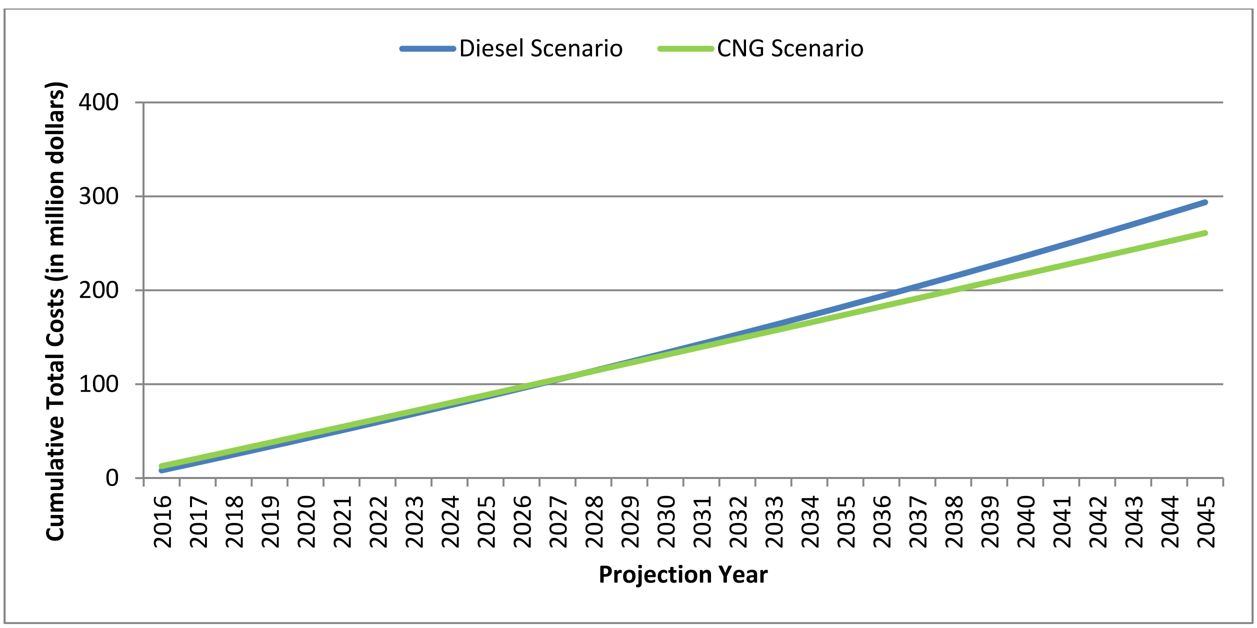


Figure 3-20. Cumulative Total Costs – Fixed Capital.[71]



3.3 Summary

In summary, the fixed maximum age scenario effectively keeps the average fleet age well below ten years in most of the projection years, sees the whole fleet converted to CNG, and results in a cumulative

[70] Lump sum cost is included in 2016 for CNG scenario.

[71] Lump sum cost is included in 2016 for CNG scenario.

savings of $47M. Conversely, under the fixed capital scenario the average fleet age exceeds 17 years by 2045, 31 buses remain diesel-powered at the end of the study period, and cumulative savings are $33 million. Critically, though, the benefits of the fixed maximum age scenario result from what is likely an unrealistic capital procurement schedule which would require $49 million more in funding.

4 Financial Investment Analysis

This chapter focuses on potential financing options to implement CNG and whether this financing could occur in such a manner that potential savings identified above would be maintained. Grants were not directly explored since they are discretionary, highly competitive, and therefore not a guaranteed funding source.

4.1 Loan Payment Schedules[72]

Based on the itemized costs in Chapter 3, this section develops loan payment schedules for both of the scenarios outlined above.[73] Principal and interest are paid using the savings generated from employing CNG buses. In subsequent years if the annual total cost of the CNG scenario is higher than the cost of the diesel scenario, the differential is treated as an additional loan needed in that year. For example, in 2017 per the assumptions stated in the prior section under the fixed maximum age scenario, the CNG framework will cost approximately $112,000 more to operate than the base diesel framework. This is reflected in Table 4-1 as a $112,000 loan in that year. The interest rate is set as 4.5% with annual compounding at the end of year.[74]

4.1.1 Fixed Maximum Age Scenario

Table 4-1 shows the loan payment schedule for the fixed maximum age scenario. A loan of $4.57 million is needed in year 2016[75] followed by additional loans of $103,237 and $1.66 million in years 2017 and 2018, respectively. At the end of year 2029, which is 15 years after the project starts, annual savings from employing CNG buses pay off both the principal and interest of these loans. Under this scenario, the cumulative net savings of transitioning to a CNG fleet are $43 million by year 2045.

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[72] Research did not reveal any universal or standard financing terms for related projects implemented by transit agencies. Interest rates, deferment options, disbursement and repayment schedules, and funding strategies based upon correspondence with entities like Clean Energy Fuels (CEF), which have provided turn-key CNG solutions at Hillsborough Area Rapid Transit (HART) and Jacksonville Transportation Authority (JTA), as well as experience with government-issued infrastructure loans. In 2013, the Florida Department of Transportation (FDOT) awarded RTS a State Infrastructure Bank (SIB) loan of $3.8 million to assist in completing the new maintenance facility. This loan compounded annually at 2%.

[73] For simplicity, only results for the 150 bus expansion scenario are presented here. While other expansion scenarios have been calculated, the 150 bus scenario is believed to be the most reasonable. Calculations on other scenarios have been performed but are omitted for brevity.

[74] RTS considers this a conservative interest rate based on dialogue with CEF and experience with a SIB loan.

[75] The majority of this amount is lump sum costs with the remainder being O&M differential costs.

Table 4-1. Loan Payment Schedule – Fixed Maximum Age (in thousand dollars).

Year	Loan Amount	Balance	Interest at 4.5%	Savings	Payment	Net Savings
2016	4,570	4,570	206	-	-	-
2017	103	4,879	220	-	-	-
2018	1,659	6,758	304	-	-	-
2019	-	7,062	318	300	300	-
2020	-	7,079	319	628	628	-
2021	-	6,770	305	434	434	-
2022	-	6,640	299	526	526	-
2023	-	6,413	289	778	778	-
2024	-	5,924	267	416	416	-
2025	-	5,774	260	1,332	1,332	-
2026	-	4,702	212	1,256	1,256	-
2027	-	3,658	165	942	942	-
2028	-	2,880	130	1,679	1,679	-
2029	-	1,330	60	1,795	1,390	405
2030	-	-	-	2,183	-	2,183
2031	-	-	-	2,319	-	2,319
2032	-	-	-	2,486	-	2,486
2033	-	-	-	2,641	-	2,641
2034	-	-	-	2,619	-	2,619
2035	-	-	-	636	-	636
2036	-	-	-	2,592	-	2,592
2037	-	-	-	2,989	-	2,989
2038	-	-	-	2,781	-	2,781
2039	-	-	-	2,822	-	2,822
2040	-	-	-	3,066	-	3,066
2041	-	-	-	2,520	-	2,520
2042	-	-	-	3,492	-	3,492
2043	-	-	-	3,406	-	3,406
2044	-	-	-	2,869	-	2,869
2045	-	-	-	3,548	-	3,548
Total	**6,334**		**3,350**	**53,055**	**9,682**	**43,373**

4.1.2 Fixed Capital Scenario

Table 4-2 shows the loan payment schedule for the fixed capital scenario. Under this scenario, a single loan of $4.54 million is needed in the base year. At the end of year 2031, which is 17 years after the project starts, annual savings from employing CNG buses will pay off the loan amount altogether. Additionally, by 2034 net O&M savings can eliminate[76] the bus acquisition deficit that results in earlier

[76] The fixed annual capital amount to purchase buses combined with the higher price of each CNG bus creates a bus acquisition deficit of 0.45 buses per year.

years from the higher cost of CNG vehicles. Even though 20% of the current diesel fleet will be retained under the fixed capital scenario the profit realized over the 30-year period is nearly $30 million. It is worth re-emphasizing here that this is not an endorsement for this fixed capital scenario, but rather an indication of how much could be saved by moving to CNG *assuming* the capital funds available for bus acquisitions is fixed at this relatively low level.

Table 4-2. Loan Payment Schedule – Fixed Capital (in thousand dollars).

Year	Loan Amount	Balance	Interest (@4.5%)	Savings	Payment	Net Savings	Bus Deficiency (Cumulative)	Additional Buses from Savings (Cumulative)
2016	4,540	4,540	204	39	39	-	-0.45	0.00
2017	-	4,705	212	80	80	-	-0.89	0.00
2018	-	4,837	218	120	120	-	-1.34	0.00
2019	-	4,934	222	164	164	-	-1.78	0.00
2020	-	4,993	225	210	210	-	-2.23	0.00
2021	-	5,007	225	263	263	-	-2.68	0.00
2022	-	4,970	224	325	325	-	-3.12	0.00
2023	-	4,869	219	388	388	-	-3.57	0.00
2024	-	4,700	211	456	456	-	-4.01	0.00
2025	-	4,455	200	528	528	-	-4.46	0.00
2026	-	4,127	186	667	667	-	-4.91	0.00
2027	-	3,645	164	757	757	-	-5.35	0.00
2028	-	3,052	137	851	851	-	-5.80	0.00
2029	-	2,339	105	947	947	-	-6.25	0.00
2030	-	1,496	67	1,047	1,047	-	-6.69	0.00
2031	-	517	23	1,149	540	609	-7.14	1.22
2032	-	-	-	1,253	-	1,253	-7.58	3.74
2033	-	-	-	1,366	-	1,366	-8.03	6.48
2034	-	-	-	1,476	-	1,476	-8.48	9.45
2035	-	-	-	1,595	-	1,595		
2036	-	-	-	1,717	-	1,717		
2037	-	-	-	1,847	-	1,847		
2038	-	-	-	1,981	-	1,981		
2039	-	-	-	2,116	-	2,116		
2040	-	-	-	2,256	-	2,256		
2041	-	-	-	2,412	-	2,412		
2042	-	-	-	2,574	-	2,574		
2043	-	-	-	2,743	-	2,743		
2044	-	-	-	2,919	-	2,919		
2045	-	-	-	3,103	-	3,103		
Total	**4,540**		**2,843**	**37,351**	**7,383**	**29,968**		

4.2 Modified Fixed Capital Scenario

Section 4.1 shows that converting the RTS fleet to CNG could lead to substantial profits. However, both scenarios operate from extreme premises that are potentially infeasible.[77] This section explores a more plausible financing scenario that balances fleet age (the fixed maximum age scenario) and pragmatic capital funding (the fixed capital scenario). In this intermediate scenario, short-term fleet age issues are controlled by assuming an additional up front loan for buses and longer term aging issues are addressed by assuming reinvestment of the project's long-term profits into new buses. Both are done without the vast investment of capital assumed in the fixed maximum age scenario. This strategy obviously substantially lowers the project's total profits, as will be shown, but it still leaves attractive the conversion to CNG and also critically addresses much of the aging bus issue inherent in RTS' existing replacement schedule.

This new scenario follows the calculation process of the fixed capital scenario with three major modifications that affect the fleet age composition as well as costs associated with it:

- an additional loan is placed at the beginning of the project to purchase CNG buses,
- in the years following loan pay off, savings are used to purchase new CNG buses,[78] and
- inflation is factored into calculations so that several financial metrics are more meaningful.[79]

4.2.1 Additional Financial Parameters

In addition to the model input parameters in the fixed capital scenario discussed above, estimates of the discount rate and the inflation rate are employed. The City Of Gainesville's Finance Department recommended a discount rate of 3.75% which is the City's weighted average cost of capital.[80] The inflation rate chosen was done to be intentionally conservative while still being reasonable over the length of this project. While recent (2014 and 2015) annual inflation estimates have been extremely low (or even perhaps negative by some calculations), it does not seem prudent to assume this trend is sustainable. Thus, the rate chosen was the average rate of inflation over the last 10 years, 1.80%.[81] Based on historical trends, this rate may still be on the low side. However, loans would only become more attractive as this estimate increases.

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[77] Specifically, RTS will not have the necessary capital to implement the fixed maximum age scenario (almost $65 million of additional capital beyond what can be reasonably anticipated is required to implement this scenario) and the resultant fleet age under the fixed capital scenario will presumably result in burdensome maintenance costs that are difficult to fully account for.

[78] At some undefined future point, RTS policy would dictate that an ideal, sustainable fleet age distribution will have been reached and re-investment in new buses would cease. As presented here, all savings are re-invested in new vehicle acquisitions.

[79] Since figures are adjusted for inflation, one important distinction to make is that unless otherwise noted all values presented in this section are in terms of nominal dollars while all previous sections refer to real, constant 2016 dollars. This is done so that discounting and loan repayments can be handled in a more realistic way. Over the course of a 30-year project the difference between real and nominal dollars can be dramatic.

[80] Future analysis may consider testing the sensitivity of the results to variations in this figure that more robustly take into account risk.

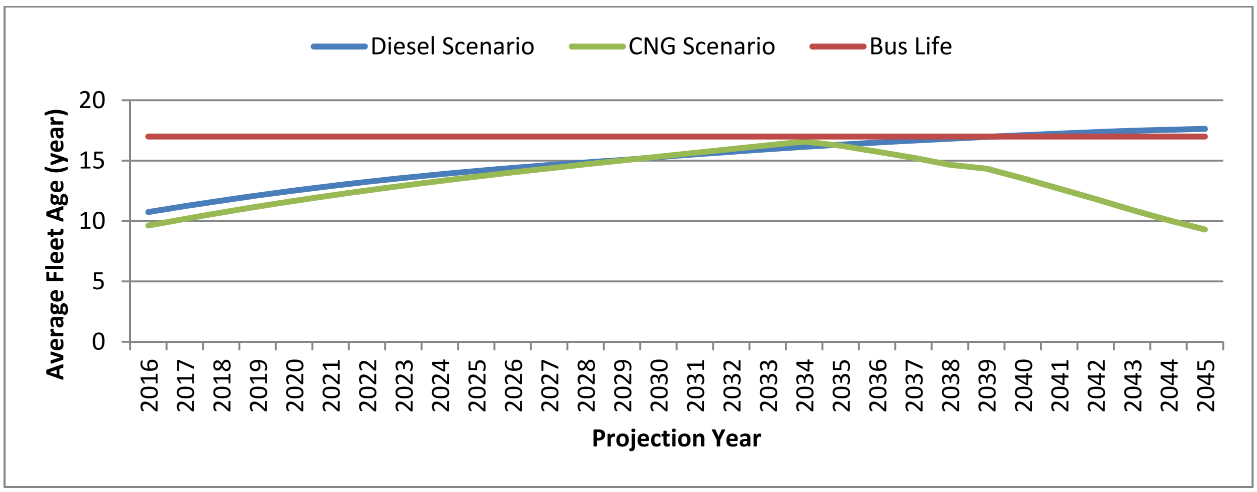
[81] http://www.usinflationcalculator.com/inflation/current-inflation-rates/ accessed on December 7th, 2015. This figure uses an approximation for the final 2015 inflation rate by taking the inflation rate over the 12 months ending in October 2015 (the most recent month for which inflation data was available).

4.2.2 Five Million Dollar Bus Loan

4.2.2.1 Overview

This section shows the consequences on the fixed capital scenario if a $5 million bus loan is acquired in year one.[82] Figure 4-1 compares the annual average fleet age between the diesel and CNG scenarios. The average fleet age of the CNG scenario starts to decrease in 2034 when profit begins to be used to purchase additional CNG buses. At the individual bus level, a somewhat similar trend is followed with the maximum bus age comparable between the diesel and CNG scenarios. The maximum age increases until 2035, at which point the CNG maximum age plateaus for several years while the CNG fleet increases in size and finally decreases to be 12 years less than in the diesel scenario (see Figure 4-2). Figure 4-3 shows the fleet composition for the CNG scenario with the new replacement schedule, and Figure 4-4 shows the difference in the vehicle age distribution in 2045. Importantly, this loan allows full transition of the fleet to CNG within the 30-year timeframe, lowers the maximum bus age in 2045 by 11 years, lowers the maximum average fleet age by 1.8 years, and decreases the average annual fleet age from 15.0 to 13.4 years.

Figure 4-1. Average Fleet Age – $5 Million Bus Loan.



[82] Later sections show the consequences of a wider range of bus loans. The value explored here attempts to balance the total debt the City would initially incur with perceptions on the feasibility of acquiring such debt at the stated terms and the City's appetite to generally acquire debt. Further, this section assumes loan repayment occurs from CNG savings as quickly as possible in order to minimize interest paid on the loan. Later sections explore the implications of moving to fixed annual payments over a 30 year period.

Figure 4-2. Maximum Bus Age – $5 Million Bus Loan.

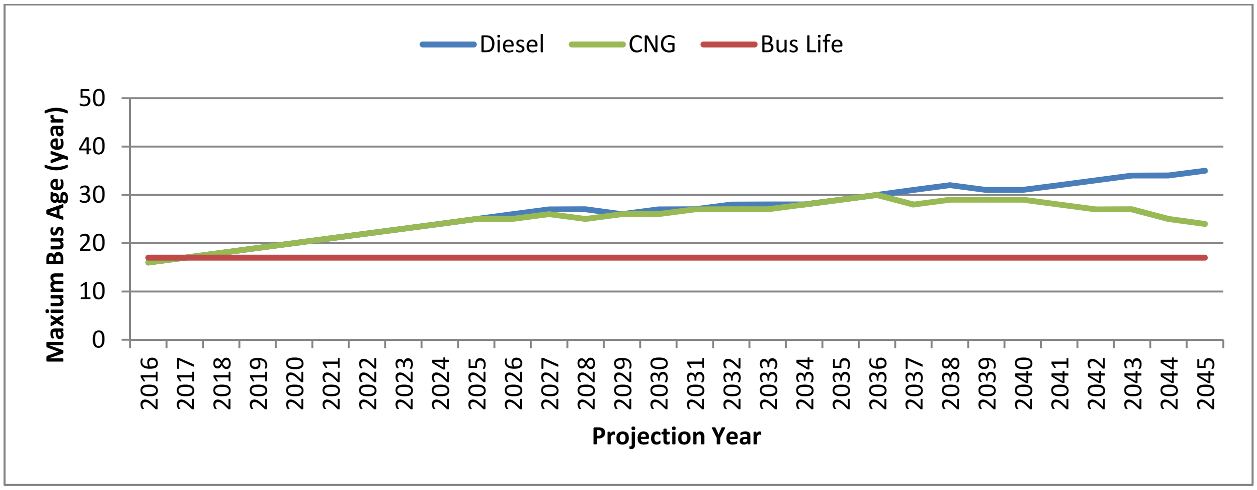


Figure 4-3. Fleet Composition – $5 Million Bus Loan.

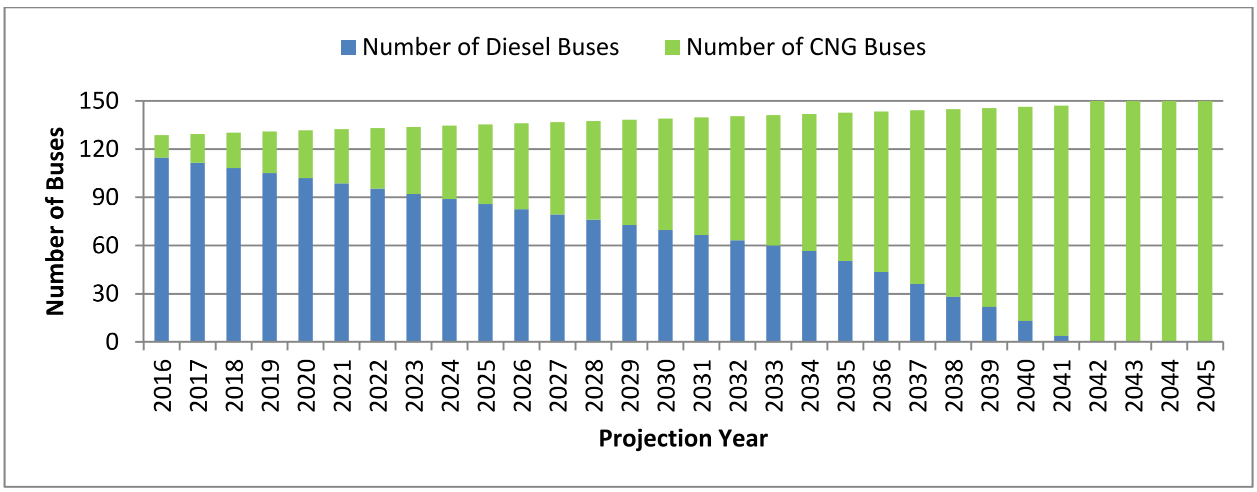
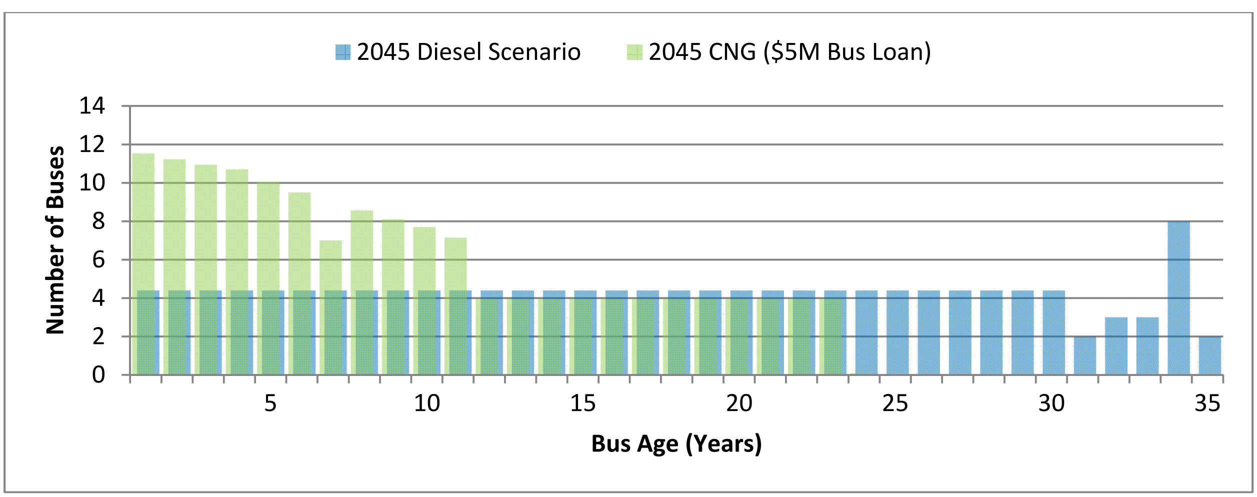
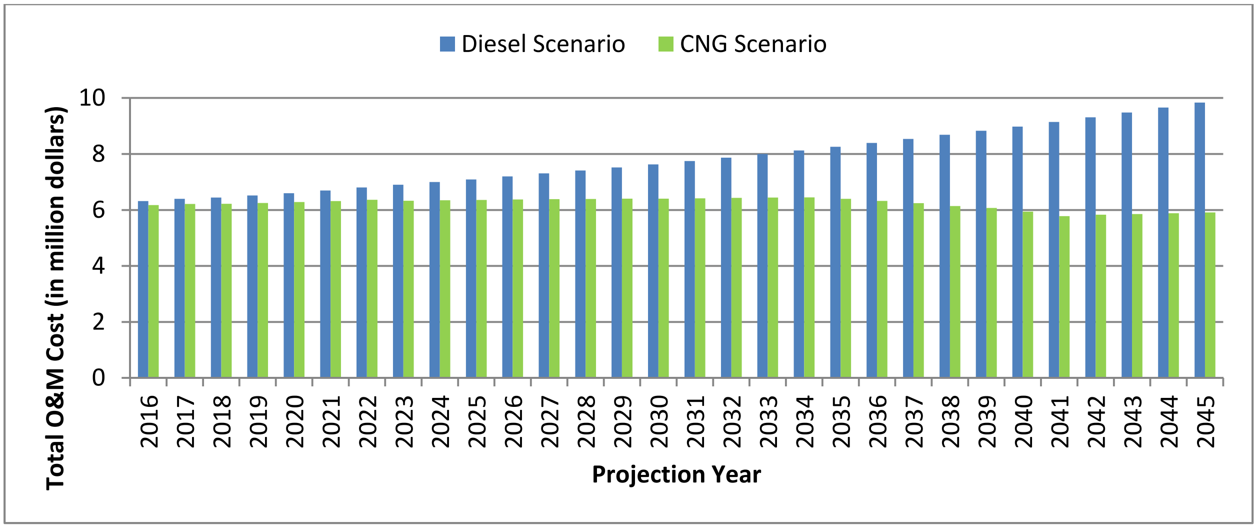


Figure 4-4. Fleet Composition in 2045 – $5 Million Bus Loan.



Total O&M costs through 2045 are shown in Figure 4-5. As above, total O&M costs include vehicle and facility O&M, fuel, and fueling costs. In the CNG scenario the total O&M costs are below $6 million after 2040 while projected costs in the base diesel scenario grow to nearly $10 million.

Figure 4-5. Total Vehicle and Facility O&M Costs – $5 Million Bus Loan.



The portion of the upfront lump sum costs tied to CNG facility conversion remain unchanged but overall upfront lump sum costs increase to $9.54 million due to the $5 million bus loan. Figure 4-6 shows the total costs – including capital costs, O&M costs, and lump sum costs, for both the diesel and CNG scenarios. Figure 4-7 shows the cumulative costs. In 2045 the cumulative cost differential is $38 million between the diesel and CNG scenarios. Critically, this is over $5 million (real 2016 dollars) more than the savings in the fixed capital scenario despite the additional $5 million loan and associated interest. This highlights the impact that timing of bus conversion and reinvestment of savings into buses have on overall project profitability.

Figure 4-6. Total Costs for Diesel and CNG Bus Scenarios – $5 Million Bus Loan.[83]

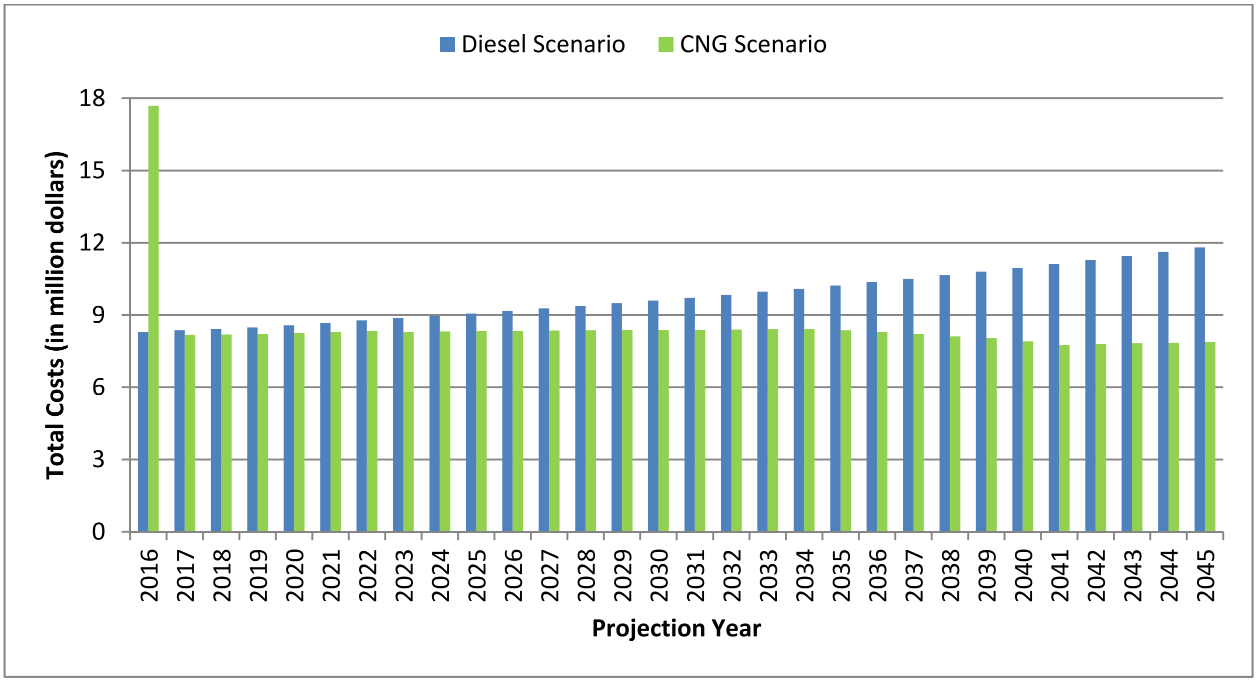
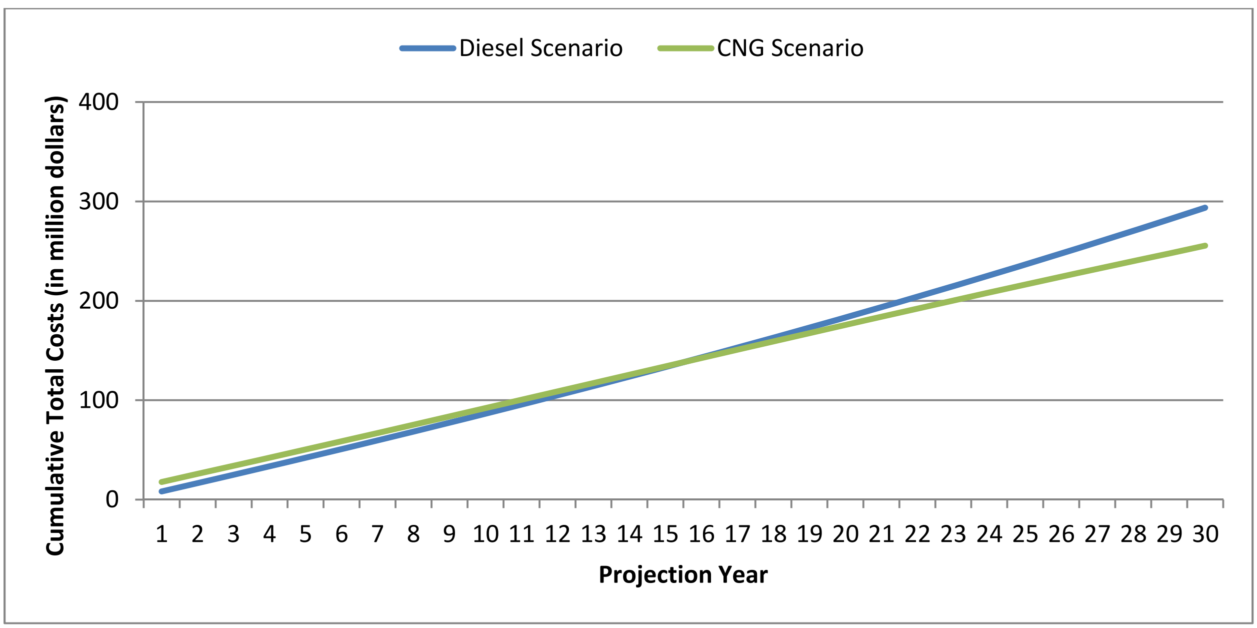


Figure 4-7. Cumulative Costs – $5 Million Bus Loan.



[83] Lump sum cost is included in 2016 for CNG scenario. Also note that In Figures 4-6 and 4-7, as stated elsewhere, the costs presented are an indication of the annual savings differential between scenarios. In reality, these cost differences are initially paid for by a loan; in years 2017 and on, the differential goes to first pay off the loan and then the profits are rolled into bus acquisitions. Thus, in any given year, the total O&M plus capital costs are engineered to be equal to the value presented in the diesel scenario. It is worth re-emphasizing here, these savings critically depend on the reinvestment of savings into more CNG buses. If profits are not spent in this way, these savings will not occur.

4.2.2.2 Payment Schedule

4.2.2.2.1 Variable Payment Schedule

Another major decision that has a strong effect on all results is the choice of repayment schedule for the loan. The repayment method by which loans are paid off as quickly as possible in order to minimize total loan cost was carried out in the previous analysis and its schedule of payments is presented in Table 4-3. Under this scenario, a single loan of $9.54 million is needed in the base year. In year 2034, which is 18 years after the project starts, annual savings from employing CNG buses pay off the loan amount altogether. Under this scenario, the cumulative net savings are $53 million by year 2045.[84] While there is still an annual bus deficit resulting from the higher cost of CNG vehicles and fixed capital allotment, a combination of an initial loan plus reinvestment of profits into vehicles results in a larger cumulative total number of vehicles purchased in each year. By year 2045, profits from CNG will be able to pay off the initial loan and purchase a total of 65.6 more vehicles than in the diesel scenario.

[84]This is a nominal amount, as are all values in Table 4-3. The real 2016 dollar amount is $34 million.

Table 4-3. Loan Payment Schedule – Variable Loan Repayment Plan (in thousand dollars).

Year	Loan Amount	Balance	Interest (@4.5%)	Savings (Nominal $)	Payment	Net Saving	Bus Deficiency (Cumulative)	Additional Buses from Savings and Initial Loan (Annual)	Additional Buses from Savings and Initial Loan (Cumulative)
2016	9,540	9,540	429	138	138	-	-0.45	10.04	10.04
2017	-	9,830	442	186	186	-	-0.89	-	10.04
2018	-	10,087	454	231	231	-	-1.34	-	10.04
2019	-	10,309	464	284	284	-	-1.78	-	10.04
2020	-	10,490	472	342	342	-	-2.23	-	10.04
2021	-	10,620	478	410	410	-	-2.68	-	10.04
2022	-	10,687	481	494	494	-	-3.12	-	10.04
2023	-	10,674	480	648	648	-	-3.57	-	10.04
2024	-	10,506	473	751	751	-	-4.01	-	10.04
2025	-	10,229	460	861	861	-	-4.46	-	10.04
2026	-	9,828	442	983	983	-	-4.91	-	10.04
2027	-	9,287	418	1,117	1,117	-	-5.35	-	10.04
2028	-	8,588	386	1,262	1,262	-	-5.80	-	10.04
2029	-	7,712	347	1,413	1,413	-	-6.25	-	10.04
2030	-	6,646	299	1,573	1,573	-	-6.69	-	10.04
2031	-	5,373	242	1,742	1,742	-	-7.14	-	10.04
2032	-	3,872	174	1,918	1,918	-	-7.58	-	10.04
2033	-	2,129	96	2,113	2,113	-	-8.03	-	10.04
2034	-	112	5	2,309	117	2,193	-8.48	3.19	13.23
2035	-	-	-	2,616	-	2,616	-8.92	3.74	16.97
2036	-	-	-	2,958	-	2,958	-9.37	4.15	21.12
2037	-	-	-	3,342	-	3,342	-9.81	4.61	25.73
2038	-	-	-	3,767	-	3,767	-10.26	5.10	30.84
2039	-	-	-	4,162	-	4,162	-10.71	5.54	36.38
2040	-	-	-	4,669	-	4,669	-11.15	6.11	42.48
2041	-	-	-	5,255	-	5,255	-11.60	6.75	49.23
2042	-	-	-	5,538	-	5,538	-12.04	6.99	56.22
2043	-	-	-	5,872	-	5,872	-12.49	7.28	63.50
2044	-	-	-	6,222	-	6,222	-12.94	7.57	71.07
2045	-	-	-	6,589	-	6,589	-13.38	7.88	78.95
Total	**9,540**		**7,043**	**69,766**	**16,583**	**53,183**		**78.95**	

4.2.2.2.2 Fixed Payment Schedule

In line with refinements to financial terms, a secondary repayment method is also considered where the payments are fixed over a 30-year period. The payment structure is presented in Table 4-4. This allows savings from CNG to be put towards bus acquisitions as early as 2023 (i.e., 11 years earlier than the alternate repayment strategy) and the standard phrasing and loan terms are more likely to be accepted by financial institutions. However, this payment strategy is not revenue neutral each year. Over the first 7 years of the project, $1.9 million (in constant 2016 dollars) would need to be secured to make these fixed loan payments before yearly fuel savings would be sufficient to cover them.[85]

[85] This assumes that this deficit will be addressed either by additional revenue from the City or the use of existing formula grants. Further, this scenario assumes that part of the cost of the loan is assumed to be found external to the project, but *all* future year profits (defined here as (CNG Savings) – (Loan Payment)) are rolled into bus acquisitions. The net profits (in nominal dollars) will exceed the amount required in the first 7 years of the loan by 2028 (13 years into the loan). This is only a first order estimate though, as that profit is currently assumed to be invested in new buses which generate part of the profit in subsequent years. Diverting savings to pay back these costs would impact all aspects of fleet composition and would be detrimental to all fleet age estimates shown in this section.

Table 4-4. Loan Payment Schedule – Fixed Loan Repayment Plan (in thousand dollars).

Year	Loan Amount	Balance	Interest (@4.5%)	Savings (Nominal $)	Payment	Net Saving	Bus Deficiency (Cumulative)	Additional Buses from Savings and Initial Loan (Annual)	Additional Buses from Savings and Initial Loan (Cumulative)
2016	9,540	9,540	429	138	586	-	-0.45	10.04	10.04
2017	-	9,383	422	186	586	-	-0.89	-	10.04
2018	-	9,220	415	231	586	-	-1.34	-	10.04
2019	-	9,049	407	284	586	-	-1.78	-	10.04
2020	-	8,871	399	342	586	-	-2.23	-	10.04
2021	-	8,684	391	410	586	-	-2.68	-	10.04
2022	-	8,489	382	494	586	-	-3.12	-	10.04
2023	-	8,286	373	648	586	62	-3.57	0.11	10.15
2024	-	8,073	363	752	586	167	-4.01	0.29	10.44
2025	-	7,851	353	868	586	282	-4.46	0.48	10.92
2026	-	7,618	343	1,000	586	414	-4.91	0.69	11.62
2027	-	7,375	332	1,148	586	562	-5.35	0.93	12.54
2028	-	7,122	320	1,314	586	728	-5.80	1.18	13.72
2029	-	6,856	309	1,493	586	907	-6.25	1.44	15.17
2030	-	6,579	296	1,690	586	1,104	-6.69	1.73	16.89
2031	-	6,290	283	1,905	586	1,320	-7.14	2.03	18.92
2032	-	5,987	269	2,139	586	1,554	-7.58	2.34	21.26
2033	-	5,671	255	2,406	586	1,820	-8.03	2.70	23.96
2034	-	5,340	240	2,688	586	2,102	-8.48	3.06	27.02
2035	-	4,995	225	3,008	586	2,422	-8.92	3.46	30.48
2036	-	4,634	209	3,358	586	2,773	-9.37	3.89	34.38
2037	-	4,257	192	3,753	586	3,167	-9.81	4.37	38.75
2038	-	3,863	174	4,188	586	3,602	-10.26	4.88	43.63
2039	-	3,451	155	4,662	586	4,076	-10.71	5.43	49.05
2040	-	3,021	136	5,039	586	4,454	-11.15	5.82	54.88
2041	-	2,571	116	5,219	586	4,634	-11.60	5.95	60.83
2042	-	2,101	95	5,538	586	4,952	-12.04	6.25	67.07
2043	-	1,610	72	5,872	586	5,286	-12.49	6.55	73.63
2044	-	1,097	49	6,222	586	5,637	-12.94	6.86	80.49
2045	-	560	25	6,589	586	6,004	-13.38	7.18	87.67
Total	**9,540**		**8,030**	**73,585**	**17,570**	**56,016**		**87.67**	

4.2.3 Other Bus Loan Simulations

To provide a more robust analysis, additional bus loan simulations were run up to $15 million. In general, as the initial bus loan increases, the short term age of buses significantly decreases. However, this occurs at the cost of long term benefits. Namely, fewer buses can be purchased later due to realized savings and overall profit decreases because of the increased time required to pay off the loan amount. Note that the total number of buses that can be purchased over the 30-year period is greater under the $15 million loan than the $5 million loan, but fewer buses can be purchased using cost differential savings.

Several financial metrics are calculated for each loan simulation.[86] For clarity, a brief description of their definition and calculation methodology is provided. Net Present Value (NPV) is defined as the sum of Present Values (both inflows and outflows) in all future years for a given scenario, including initial loan amount and repayment schedule:[87,88]

$$NPV = \sum_{i=1}^{30}(S - L) \div (1 + r)^{i-1} \quad \text{Equation (4)}$$

Where:

- S is the savings that RTS would observe over the base diesel scenario in year i by going to CNG,
- L is the loan payment in year i, and
- r is the discount rate.

Note that all values other than the loan (and its associated payments) are expected to increase at approximately the rate of inflation. Thus, savings are estimated to be the constant year 2015 savings adjusted for inflation by multiplying by $(1 + \text{inflation rate})^i$ and the estimated cost to purchase a bus each year is multiplied by the same factor. The Internal Rate of Return (IRR) is then calculated as the

[86] All of the metrics presented have their limitations. For example, Net Present Value obscures relative scale (i.e., did you earn $1 million on a $5 million investment or a $10 million investment) while Internal Rate of Return (IRR) obscures absolute scale (i.e., an IRR of 100% resulting from a $1 investment increasing to $2 versus an IRR of 10% from a $100,000 investment increasing to $110,000).

[87] The appropriate framework to define NPV in this study is nebulous. Under the variable repayment loan schedule the only revenue utilized by RTS is already contained within its existing budgetary allotment. Therefore, in the years in which the loan is being paid the present value of savings less loan payment is zero. After the loan is paid off, "profit" is unobligated budget funds; however, in the analysis these "unobligated" funds are used to purchase buses. Under the fixed payment loan schedule the construct is somewhat different. As stated above, outside funds will be required to meet budget obligations. While these may be met through an expansion of RTS's budget allotment they are nonetheless obligations RTS must satisfy beyond its currently available resources. For this reason, in the years the loan is being paid if the payment is great than the savings, the present value of savings less loans is negative in that year. Like the variable repayment loan schedule, "profit" is unobligated budget funds.

[88] As stated throughout the paper, savings are re-invested to purchase buses rather than be held as cash or used for some other purpose. Through depreciation, salvage value, etc. this undoubtedly influences the NPV calculation. The authors acknowledge this as an effect that is not fully accounted for. The use of positive cash flows to purchase buses may also aggravate the already problematic reinvestment assumption associated with these financial metrics. The proposed strategy precludes the use of a modified internal rate of return to get a more accurate figure.

discount rate that makes the NPV equal to zero.[89] Return on Investment (ROI) is calculated as the total gain (savings obtained by converting to CNG) minus the total cost (sum of loan payments) divided by the total cost. As projects increase in duration, it becomes increasingly important to adjust these values for inflation, so inflation adjusted figures are presented here. Inflation adjusted ROI was calculated by converting all nominal values into real values each year and then taking the appropriate sums over years. The Rate of Return (ROR) was calculated as the geometric mean of the ROI over the project duration (30 years). Payback period is then calculated as the number of years until CNG savings exceed costs (i.e., years until annual profit is positive).[90]

4.2.3.1 Variable Loan Repayment Plan

Figure 4-8 compares the average fleet age between the diesel scenario and CNG scenarios with $0, $5, $10, and $15 million of additional bus loans respectively. Figure 4-9 compares the percentage of fleet with 17 years or older buses between diesel scenarios and CNG scenarios under the same loan scenarios. As shown in both figures, although this modified fixed capital scenario does not eliminate the aging fleet issue, it does substantially mitigate it.[91] Table 4-5 lists the key financial metrics of each loan size scenario from $0 to $15 million.

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[89] Note that by this definition of NPV, the variable repayment schedule has no IRR: All years before the loan is paid off are calculated as zero present value and all years after the loan is paid off are positive. If this situation holds, the NPV is strictly positive for all values of the discount rate. (Though in this situation NPV is monotonically decreasing as a function of the discount rate and $\lim_{Discount\ Rate \to +\infty} NPV = 0$.)

[90] This may represent a slight deviation from the standard definition. Usually cumulative profit would be considered here. However, the presence of loans obfuscates the situation. Thus, this term here instead represents something contextually useful; the number of years until profits can be used to purchase CNG buses.

[91] The most problematic years for fleet age occur before the breakeven point (between 2030 and 2040, depending on the initial loan size). This issue may be able to be addressed by a second bus loan some time before the breakeven point, but determining the size and year of the second loan is non-trivial and highly subjective. Further, securing a contract for a loan at a future date might present logistical challenges that do not have clear solutions. However, if a second loan were secured, the qualitative assessment of the situation is clear based on the understanding of the effects of an initial loan. A second loan somewhere around year 2030 would shift the fleet age down for the years immediately following 2030, but this would occur at the cost of a slightly higher average fleet age in the end-term (i.e., at year 2045) for two primary reasons. First, some profits are shifted from bus acquisitions to loan costs and fees. Also, the buses that an agency would purchase at a later date (in, e.g., 2045) are instead purchased earlier (in, e.g., 2030) and thus the same capital investment would result in older buses in 2045. While the bus acquisition price is partially paid off by the savings by going to CNG, one bus will not produce sufficient savings over its expected lifetime to cover its entire cost. If this were otherwise, the qualitative assessment of the situation would be substantially different.

Figure 4-8. Average Fleet Age by Year and Loan Size – Variable Loan Repayment Plan.

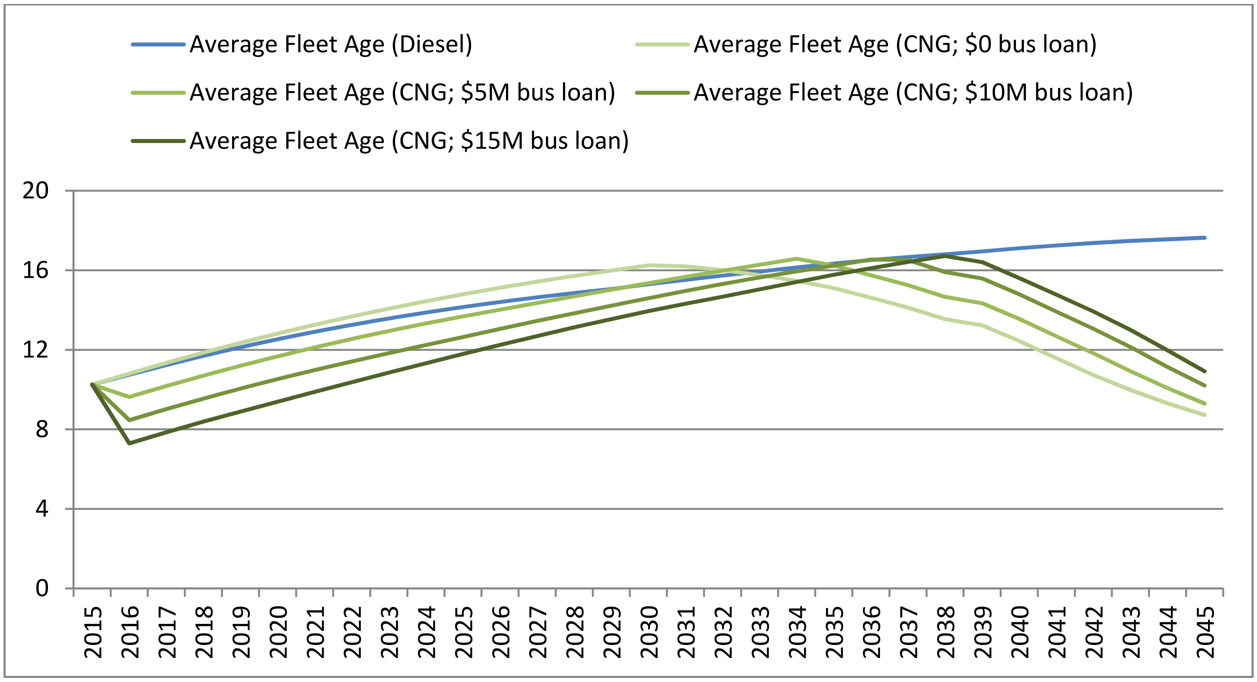

Figure 4-9. Percent of Fleet over 17 Years by Year and Loan Size – Variable Loan Repayment Plan.

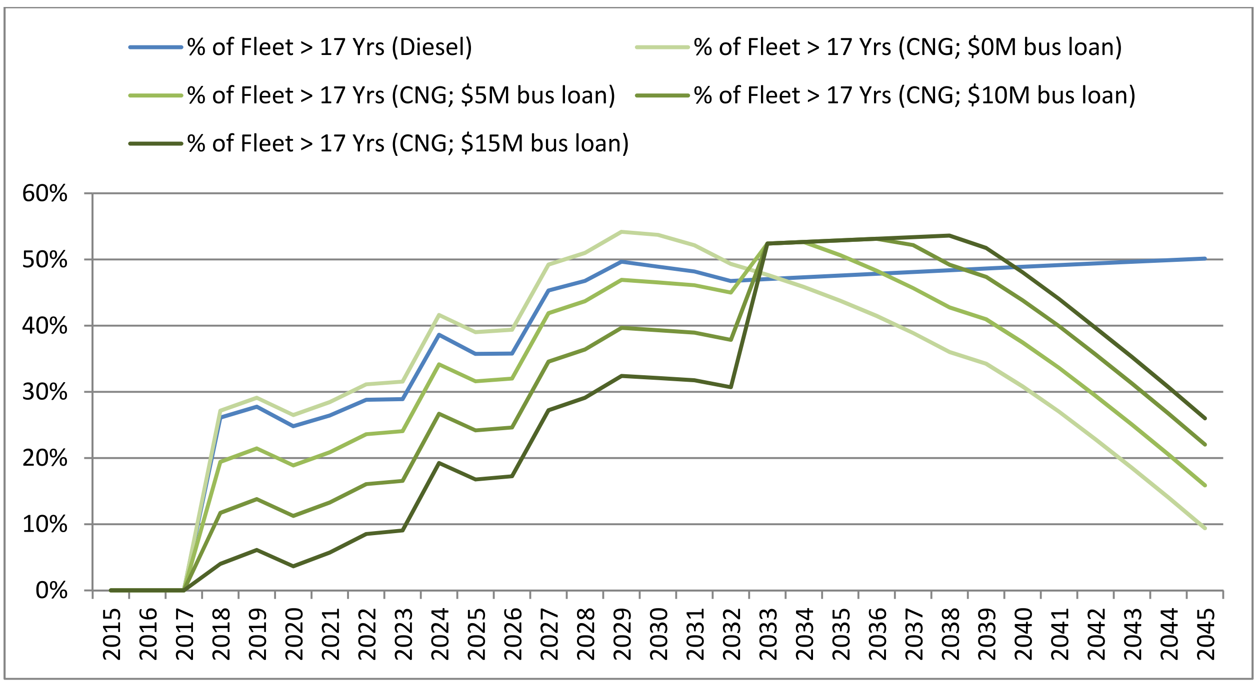

Table 4-5. Financial Metrics by Loan Size – Variable Loan Repayment Plan.

Loan Size (million $)	Average Change in Average Age (years)	NPV (million $)	Inflation Adjusted ROI (%)	Inflation Adjusted ROR (%)	Payback Period (years)
0	-1.6	25.25	647.6	6.9	14.2
1	-1.6	24.51	510.7	6.2	15.2
2	-1.6	23.73	415.5	5.6	16.0
3	-1.6	23.05	347.7	5.1	16.7
4	-1.7	22.31	295.3	4.7	17.4
5	-1.7	21.66	255.6	4.3	18.1
6	-1.7	20.96	222.8	4.0	18.6
7	-1.8	20.35	196.9	3.7	19.2
8	-1.8	19.68	174.5	3.4	19.7
9	-1.9	19.09	156.4	3.2	20.1
10	-1.9	18.45	140.3	3.0	20.6
11	-2.0	17.89	127.1	2.8	21.0
12	-2.0	17.28	114.9	2.6	21.4
13	-2.1	16.74	104.9	2.4	21.8
14	-2.2	16.17	95.6	2.3	22.1
15	-2.3	15.70	88.0	2.1	22.5

4.2.3.2 Fixed Loan Repayment Plan (30-year term)

The same loan simulation was conducted using a fixed loan repayment plan. Most results are very similar to the above.[92] Note that the fleet ages in a much smoother manner under this repayment structure because additional buses can be purchased sooner. The total amount of external funding that would be needed is calculated in Table 4-6.[93]

[92] It should be noted that NPV and ROI do not move in the same direction across the loan strategies. For example, a $1 million loan produces a higher NPV under a fixed payment schedule than under a variable payment schedule but it produces a lower ROI. This results from the nature of the terms and how they treat the time value of money, as well as the definition of profit used in this study for each repayment strategy.

[93] Depending on the contract, there may be some amount of freedom in the precise way that profits are distributed between bus acquisitions and loan payments. For instance, if it is determined that not as many buses are needed in a given year, that money may be able to be diverted to paying off the loan earlier which in turn would lead to less money going to interest and a lower overall cost of the loan. Alternatively, some agencies have secured financing by entering into contracts that pay the "loan" provider back by promising to pay the provider a fixed fee per DGE of CNG dispensed for a pre-defined period of time. This sort of phrasing might limit the flexibility of payoff methods, but it may translate to reduced risk for the transit agency.

Figure 4-10. Average Fleet Age by Year and Loan Size – Fixed Loan Repayment Plan.

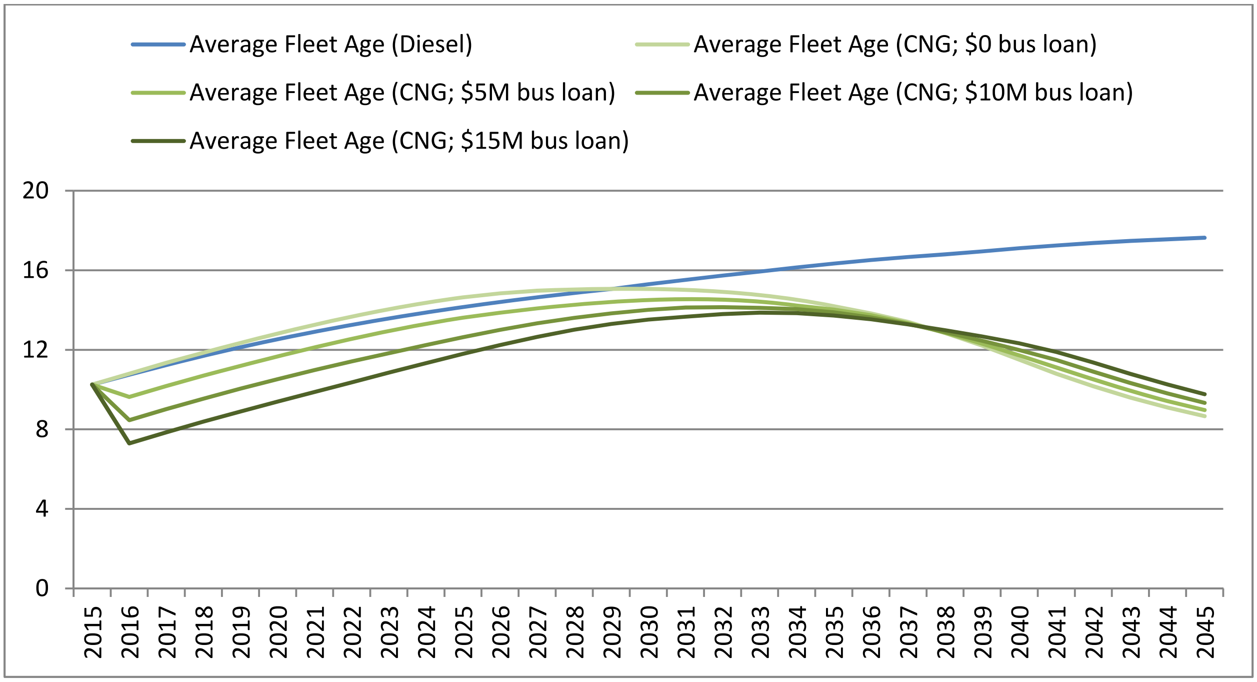

Figure 4-11. Percent of Fleet over 17 Years by Year and Loan Size – Fixed Loan Repayment Plan.

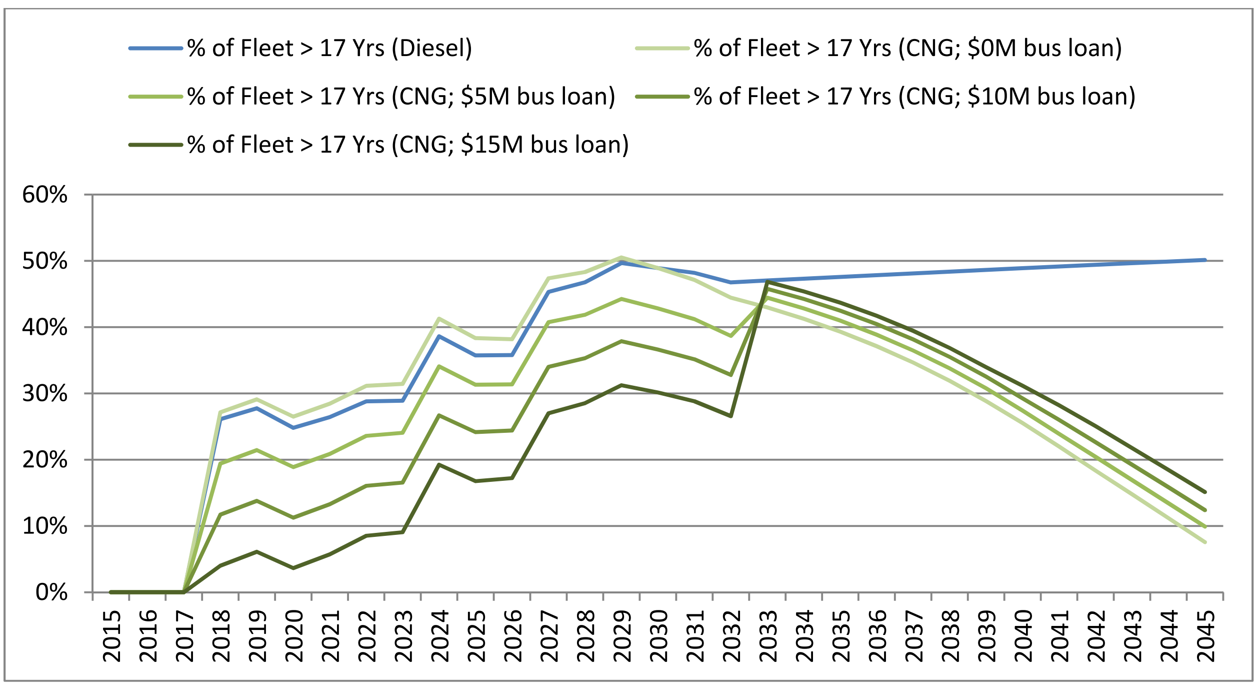

Table 4-6. Financial Metrics by Loan Size –Fixed Loan Repayment Plan.

Loan Size (million $)	Average Change in Average Age (years)	NPV (million $)	IRR (%)	Adjusted ROI (%)	Adjusted ROR (%)	Payback Period[94] (years)	Cost Before Savings Cover Payments (Real 2016 million $)
0	-2.1	26.43	28.9	619.6	6.8	6.0	0.73
1	-2.1	25.81	26.2	497.8	6.1	6.9	0.95
2	-2.2	25.19	24.2	413.3	5.6	7.0	1.17
3	-2.4	24.67	22.6	352.4	5.2	7.9	1.42
4	-2.4	24.07	21.2	305.0	4.8	7.9	1.68
5	-2.6	23.51	20.0	267.7	4.4	7.9	1.94
6	-2.6	22.86	19.0	236.8	4.1	8.0	2.20
7	-2.7	22.29	18.1	211.8	3.9	8.0	2.39
8	-2.8	21.70	17.2	190.7	3.6	8.9	2.67
9	-2.9	21.16	16.5	173.0	3.4	8.9	2.89
10	-3.0	20.55	15.8	157.4	3.2	9.0	3.17
11	-3.1	19.96	15.2	143.8	3.0	9.9	3.39
12	-3.2	19.33	14.6	131.6	2.8	9.9	3.69
13	-3.3	18.76	14.1	121.2	2.7	9.9	3.93
14	-3.3	18.17	13.6	111.8	2.5	10.0	4.23
15	-3.4	17.62	13.1	103.5	2.4	10.0	4.46

[94] Note that the slightly nonstandard definition of payback period results in a slightly different meaning in the fixed and variable loan repayment schemes. For variable loan repayments, payback period represents the time until the entire loan is paid, and thus is the same as the time until cumulative profits are positive. However, in the case of the fixed payment plan, the loan is always paid off at the end of the 30 year project timeline. Instead, the payback period here is defined as the number of years until CNG savings can be put towards the purchase of new buses, i.e., the number of years until annual savings surpasses the fixed annual payments.

5 Conclusion

In response to the momentum of using alternative fuel sources nationwide, this study evaluates the cost effectiveness of implementing some of the most popular alternatives locally. Of the three alternative fuel types evaluated, only CNG offers per bus savings relative to diesel with a cost differential of more than $13,000 per bus per year. The hybrid and electric bus scenarios found per bus differences of $10,600 thousand and $4,900 thousand more than the base diesel scenario, respectively. Notably, electric buses offer comparable energy savings to that of CNG buses, but their high capital cost makes them less cost effective.

A fleet-wide analysis of the CNG bus scenario that included the upfront costs of implementing CNG ($4.5 million along with associated financings costs) reaffirms the preliminary findings. The fleet-wide analysis consisted of a 30-year horizon with four expansion scenarios (status quo, 150 vehicles, 175 vehicles, and 200 vehicles) and two procurement schedules (fixed maximum bus age and fixed capital). With an assumed linear fleet size expansion to 150 buses by year 2045, total net cumulative savings under a fixed maximum bus age scenario are over $43 million. Under this scenario, the conversion of the entire fleet to CNG will be complete in year 2032 and the average fleet age over the period will range from 7 to 12 years. The loans required to cover startup costs and other cost differentials will be fully paid in year 2029.

The second replacement scenario has a total net cumulative savings of $30 million. With only four buses acquired each year under this scenario, about 20% of the fleet will remain as diesel-powered at the end of year 30 and the average fleet age will reach 20 years. The single loan required under this scenario is fully paid in year 2031. If the net savings in later years are then used to purchase additional CNG buses, in 2034 the total number of replaced buses will be the same between the CNG scenario and the base diesel scenario.

Both scenarios, however, are potentially infeasible since they either assume unrealistic capital funding levels or require the fleet to severely age. To address both these deficiencies an intermediate strategy was provided that includes a modest $5 million bus loan at the start of the project. Not only should the project still be pursued according to the results of calculated financial metrics, it also leaves the fleet age in a better state than the diesel status quo. Specifically the initial bus loan on a 30-year fixed repayment schedule would allow for the average fleet age to be strictly less than in the base diesel scenario in all years and would result in a total of $74 million in savings or $56 million in profits and an NPV of $23.5 million.[95]

If the City elects to pursue CNG there are several items that will require further consideration. The first is the potential to sell CNG to the public as a revenue source. CEF provided a planning level estimate of approximately $1 million as the typical cost to provide a pump station that offers fueling to the general public. GRU thought it would be another $90,000 for required pipeline infrastructure to serve the site. CEF was relatively skeptical of the potential profitability of such a move in the absence of fuel contracts

[95] These are in nominal dollars. The real 2016 dollar values are $50 million and $37 million, respectively.

with large entities like the Alachua County School System given the size of the community and the existing fueling option provided by WCA Waste Corporation near Interstate 75.

Another point of consideration is the degree to which a turn-key solution would be pursued. The WCA Waste Corporation fueling station, and as mentioned above, those built for large transit agencies in the state like HART were all done through varying degrees of a turn-key solution. Given typical organizational technical capacities most agencies at a minimum contract out design and construction but many also elect to contract out maintenance and supervision of fueling equipment, fuel purchases (hedging), and marketing and pursuit of fueling contracts if a public component is offered. Since this occurs so frequently it is assumed that it is accounted for to some degree in the base costs offered by TCRP 146, but its full impact on cost/revenue forecasts is unknown. While more specific details of rates, contract clauses, etc. were pursued for the RTS-context, vendors provided general information but viewed most details as proprietary that they would only provide under an official contract opportunity.

These findings conclude that CNG buses are the cost-effective alternative to the current diesel-dominant RTS fleet. Moreover, this study reveals that transitioning to this fuel source will also help to mitigate and eventually solve the aging fleet issue that will likely grow more severe as federal funding diminishes. In particular, a $9.5 million loan for buses and facility improvements that is paid back over 30 years may generate enough profits through CNG savings to allow the fleet to maintain a manageable age, even if the amount of capital available for bus purchases remains at the relatively low level that has persisted in the recent past.

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Appendix A Electric-Bus Scenario Analysis

Appendix A repeats the analytical process of Chapter 3 of this report for the electric bus scenario. Even though electric buses are currently not cost effective as illustrated in the preliminary cost analysis section (Chapter 2), as a fast-evolving, increasingly popular technology this may change in the near future and therefore a further cost analysis is conducted in this study. Unlike the CNG scenario in which the complete fleet conversion to CNG buses is pursued, the current battery storage capacity is not sufficient for a number of RTS routes. Specifically, while possible, it seems operationally problematic to apply the technology to any route that would require mandatory recharging after two rounds. Therefore, if more than 60% of the bus's battery capacity is consumed after two consecutive loops all buses on this route would not be eligible for electric buses. The average fuel efficiency (percent of battery power consumed per mile) is obtained from an analysis done by Proterra for RTS routes and found to be 3.65% per mile. Based on this threshold 38 buses running on 15 routes or approximately 36% of the RTS peak vehicle fleet can operate with electric buses (see Table A-1).[96,97] This conversion rate accrues to 54 electric buses by 2045 for the 150-vehicle expansion scenario.

[96] This ratio is then applied to all subsequent analyses for the electric scenario.

[97] Since the start of the analysis there have been minor changes in bus route distribution. While it affects the count of eligible buses for conversion the overall impact is minor and does not meaningfully change the results.

Table A-1. Electric Bus Scenario Conversion Rate.

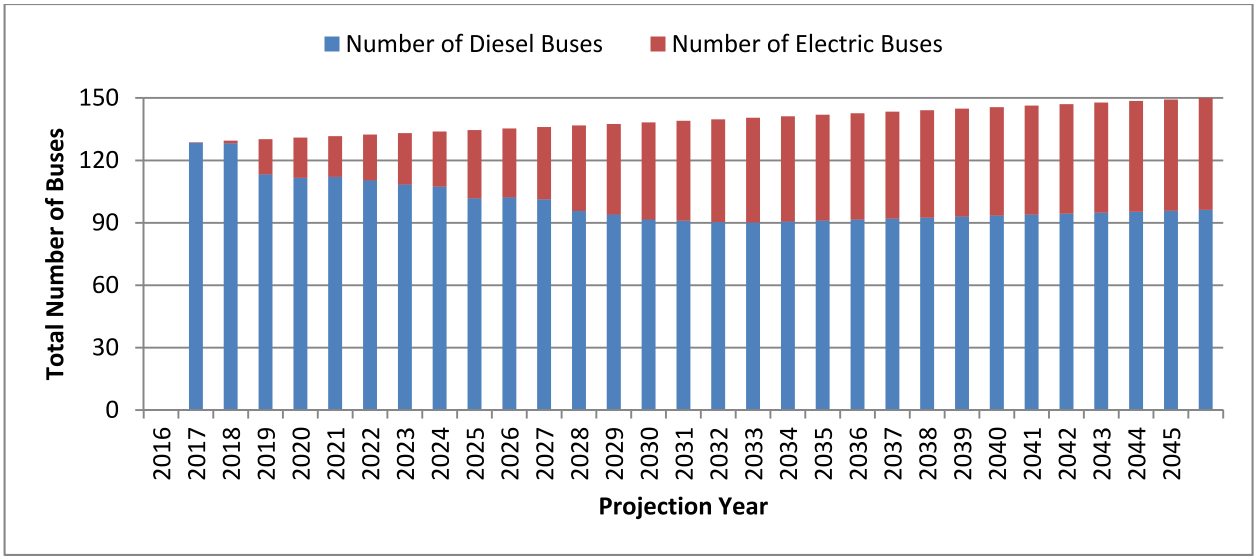
Route Number	Route Length (miles)	SOC[98] after two consecutive loops (%)	Electric Convertible Route (Yes/No)
1	10.0	27	NO
2	15.3	0	NO
5	12.6	7	NO
6	10.5	23	NO
7	12.1	11	NO
8	18.1	0	NO
9	7.6	44	YES
10	16.8	0	NO
11	12.7	7	NO
12	8.7	36	NO
13	5.8	57	YES
15	14.3	0	NO
16	6.0	56	YES
17	5.5	60	YES
20	11.0	19	NO
21	8.9	35	NO
23	8.4	39	NO
24	19.4	0	NO
25	15.9	0	NO
27	12.4	9	NO
28	9.3	32	NO
34	10.4	24	NO
35	9.6	29	NO
36	11.4	16	NO
38	7.4	46	YES
39	24.0	0	NO
41	16.4	0	NO
43	23.9	0	NO
46	3.6	73	YES
62	12.6	8	NO
75	29.5	0	NO
76	16.5	0	NO
77	15.3	0	NO
117	7.4	46	YES
118	5	63	YES
119	4.8	65	YES
120	2.2	84	YES
121	3.4	75	YES
122	7.5	45	YES
125	4.6	66	YES
126	7.2	47	YES
127	2.2	84	YES

[98] SOC = State of Charge

A.1 Fixed Maximum Age Scenario

Figure A-1 shows the fleet composition for the electric bus scenario with this replacement schedule under the assumption of fixed maximum age. Note that the annual average fleet age is the same as CNG scenario (Figure 3-2) because the number of new buses acquired each year is the same between CNG and electric scenarios.

Figure A-1. Fleet Composition – Electric Bus Scenario.



The total capital costs include fleet expansion and replacement costs. For the electric bus scenario battery replacement is also included in the capital cost. The annual expansion costs for the diesel bus and electric bus scenarios are $328,250 and $421,047, respectively. Figure A-2 shows the total capital cost for both scenarios.

Figure A-2. Capital Costs for Diesel and Electric Bus Scenarios.

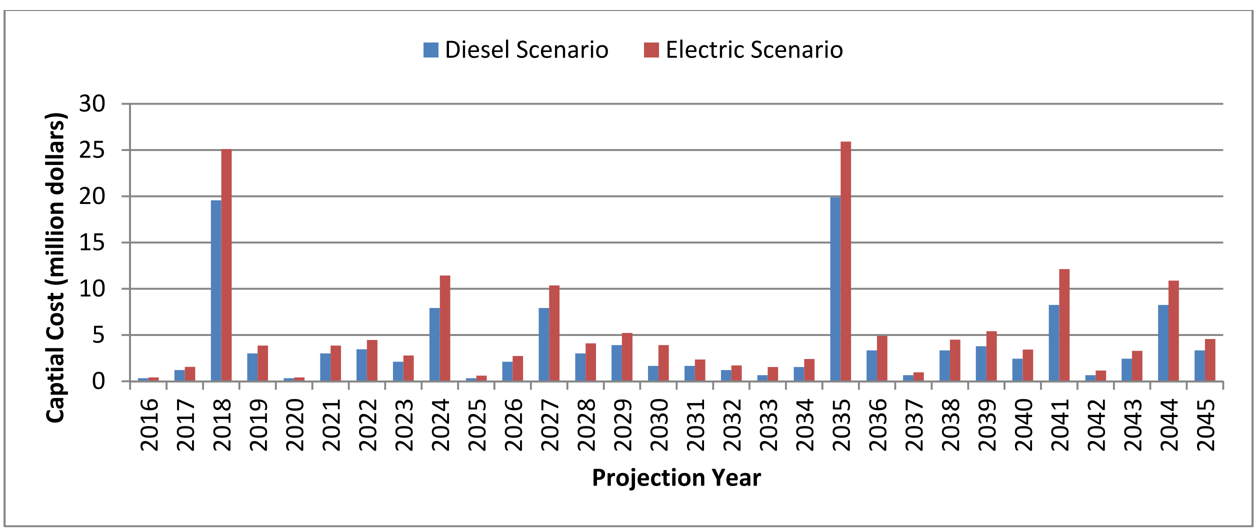
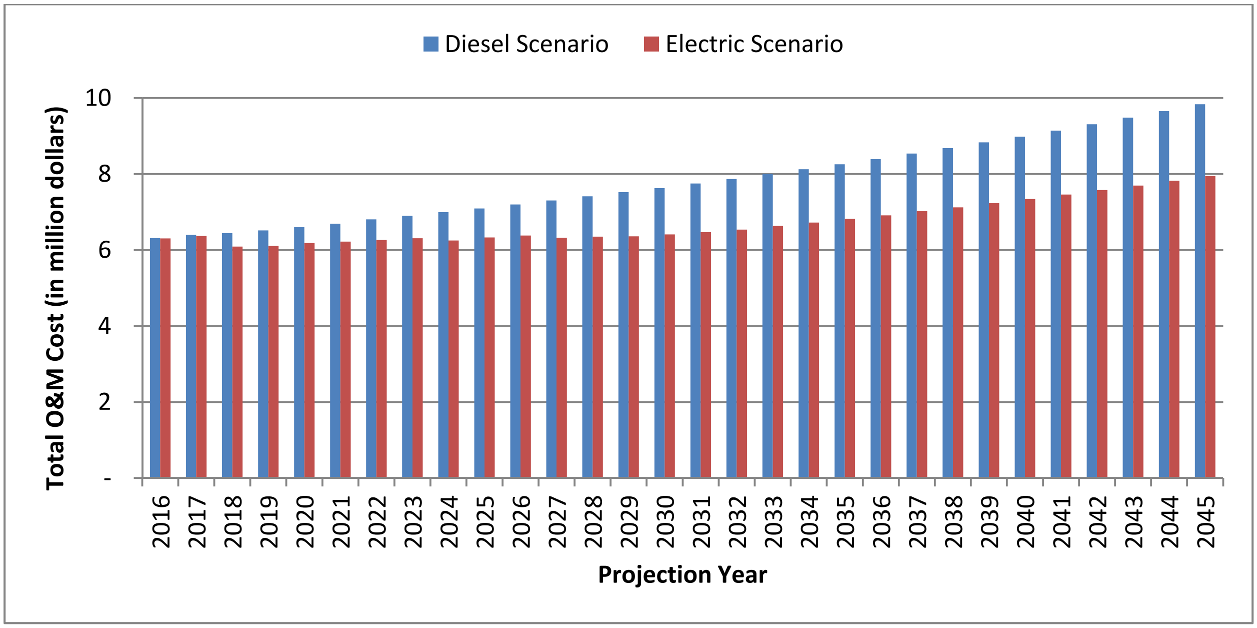


Figure A-3 shows the total fleet-wide vehicle and facility O&M costs, which includes vehicle maintenance and facility O&M costs and fuel costs. For the base diesel scenario the total O&M costs also includes fueling cost.

Figure A-3. Total O&M Costs for Diesel and Electric Bus Scenarios.



The conversion from a diesel-powered to electric-powered fleet requires an upfront investment on staff training, off-site infrastructure, and existing facility modifications. The total lump sum cost for electric buses is $6.77 million under the fixed maximum age scenario. Parameters for calculating the lump sum cost are shown in Table A-2.

Table A-2. Parameters for Lump Sum Costs – Electric Bus Scenario.

Parameters	Values
Staff Training Cost ($)	**39,579**
Mechanic I Count[99]	11
Mechanic II Count[99]	10
Operator Count[99]	205
Mechanic I Average Hourly Wage[99] ($)	21.94
Mechanic II Average Hourly Wage[99] ($)	23.92
Operator Average Hourly Wage[99] ($)	13.74
Training Time[100] (hours)	12
External Cost ($)[101]	**877,752**
Infrastructure Cost	
Shop Charger ($)	25,050 * 2
On-Route Charger ($)	35,070 * 9
Construction Cost	
Shop Charger ($)	25,050 * 2
On-Route Charger ($)	35,070 * 9
Contingency[102] (%)	20
Facility Conversion Cost ($)[102]	**5,856,890**
Shop Charger Price ($)	40,080 * 2
On-Route Charger Price ($)	349,698 * 9
Shop Charger Construction Cost ($)	150,300 * 2
On-Route Charger Construction Cost ($)	150,300 * 9
Contingency[100] (%)	20
Total Lump Sum Cost ($)	**6,774,221**

According to TCRP Report 132, electric bus training involves both maintenance staff and operators. The current average hourly wage for an operator is $13.74. To this end, staff training cost is $39,579.

External and facility conversion costs are determined by the number of chargers needed. Fast charge technology is considered in this study as that is what is most commonly adopted by transit agencies. Two shop chargers are needed at the maintenance site.[102] More on-route chargers, however, are needed. Their number is driven by their charging rate, the number of electric buses in the fleet, and the configuration of route alignments. Given the 36% conversion rate, there are 54 electric buses under the 150-vehicle expansion scenario. Assuming that the routes with electric buses have an average cycle of 30 minutes, in one peak hour the maximum number of charges is 108. Also, given that the average on-route fueling time is five minutes, in one peak hour the maximum number of buses that can be charged is 12. This calculation leads to a need for nine on-route chargers by 2045 (108/12).

[99] RTS 2015 wage data.
[100] TCRP Report 132.
[101] Based on GRU input.
[102] Based on Proterra input.

GRU provided price quotes for the necessary infrastructure to install a shop charger at RTS's maintenance facility and on-route chargers at Rosa Parks Downtown Station (700 SE 3rd Street).[103] The cost of labor and materials for transformer and conductor wire at each site ranges from $20,040 to $25,050[104] and $30,060 to $35,070[105], respectively. The higher end of the spectrum is assumed in both cases to reflect a conservative estimate. RTS would be responsible for items like required engineering work, transformer pad installation, and borings which GRU indicated could be equivalent to or more than the prices they quoted. For this reason, the total for two shop chargers is $100,200 and the total for nine on-route chargers is $631,260.

According to Proterra, a 500 kW on-route charging station costs $349,698, totaling $3.15 million for nine chargers. The price of one shop charger is $40,080. The estimated installation cost of each charger, including both shop chargers and on-route chargers is $150,300.[106] This leads to a total facility conversion cost of $5.86 million. It is assumed that equipment costs do not reoccur over the 30-year period.[107,108]

Figure A-4 shows the total costs – including capital costs, O&M costs, and lump sum costs, for both scenarios. In the majority of the projection years, the electric scenario is more costly than the base scenario. Figure A-5 shows the cumulative costs for diesel, CNG and electric scenarios.

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[103] It is important to note that based on existing route operating characteristics an ideal location for a charging facility would be the University of Florida (UF). Electric utilities on UF's campus are governed, however, by Duke Energy rather than GRU. RTS has not entered into a dialogue yet with Duke Energy to discuss possible charging station costs and feasibility. It is assumed that the costs provided by GRU will be similar to any provided by Duke Energy.

[104] This is inclusive of GRU installing a 75kVA/208V transformer connected radially from an existing transformer that feeds the RTS building (device #4577R1/6510k) and ~100' of #2 underground (UG) primary conductor between the two transformers.

[105] This is inclusive of GRU installing underground termination on a pole somewhere along the pole line that runs on SE 2nd Street and ~100' of #2 UG primary conductor between the two transformers.

[106] Based on input from Proterra.

[107] Over the 30-year period equipment will certainly have to be replaced. The extent and magnitude of this replacement is unclear given this is a new technology. This should just be acknowledged when reviewing fuel source differentials.

[108] RTS is not aware at this time of any transit agency that operates 54 electric vehicles. King County Metro Transit is currently testing several electric buses to determine whether they want to enter into a long-term contract to procure 200 additional vehicles. Because there are not clear case studies to look to for guidance a number of assumptions are made regarding charging needs that both simultaneously underestimate and overestimate the potential start-up costs for electric buses. For example, the charging rate provided represents an ideal situation where buses are not required to charge at the same time. In reality, most routes are designed so they will meet with a large number of routes at the same time to enable transfers. If this is the case, then the number of on-route chargers is severely underestimated here. Conversely, for simplicity sake, the paper assumes all on-route chargers will be implemented in year 1. In reality, there installation will be staggered to correspond to bus acquisition rate and the number of buses per charger.

Figure A-4. Total Costs for Diesel and Electric Bus Scenarios.[109]

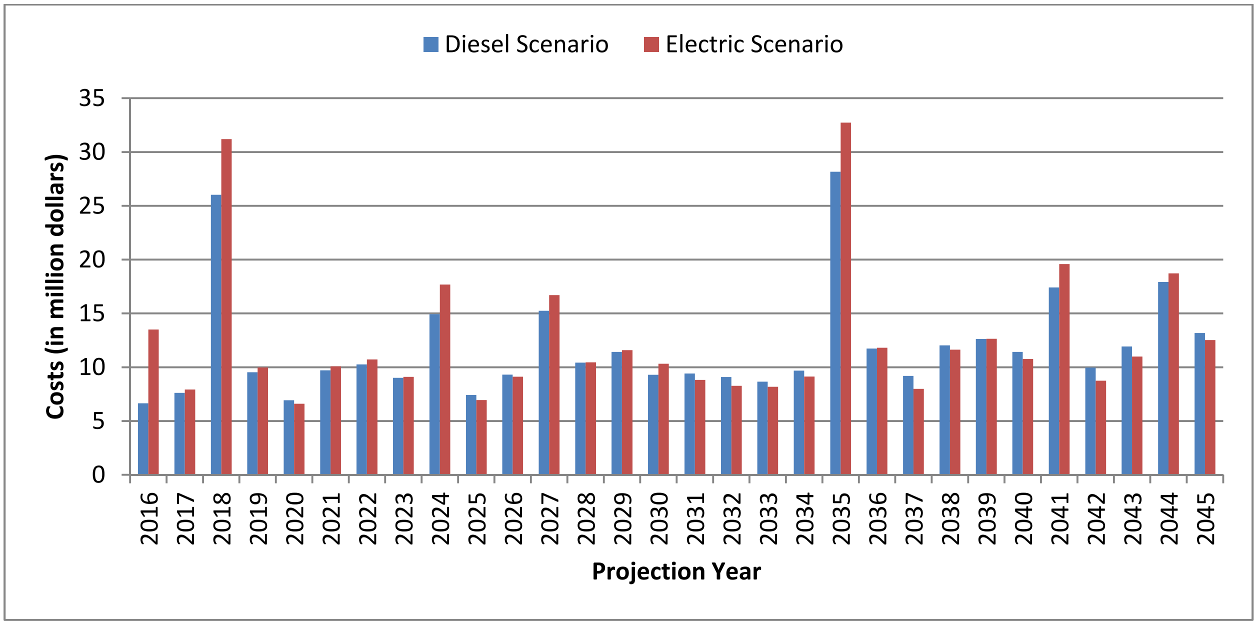
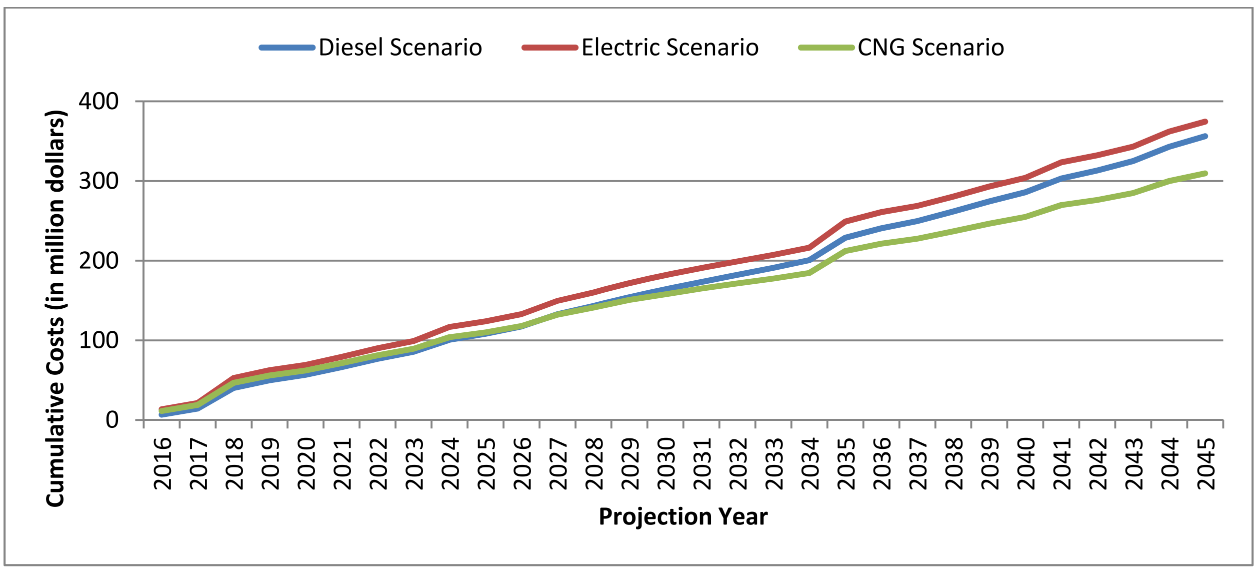


Figure A-5. Cumulative Costs for Diesel, CNG and Electric Bus Scenarios.



A.2 Fixed Capital Scenario

The fixed capital scenario sets the annual capital revenue unchanged across the fuel scenarios. Based on RTS's average annual bus acquisition (4.4 buses) in the past five years, the annual capital revenue is $1.97 million. This results in an equivalency of 1.9 electric buses per year. Assuming that bus acquisition remains constant, each year the newly-added buses will first meet the fleet expansion need and then go towards replacing the oldest buses in the fleet. Based on this replacement schedule, Figure A-6 compares the annual average fleet age between the scenarios. Figure A-7 shows the maximum bus age

[109] Lump sum cost is included in 2016 for electric scenario.

between the scenarios. Figure A-8 shows the fleet composition for the electric scenario with this replacement schedule. At this replacement rate, over 90 buses in the fleet will remain diesel-powered after 30 years.

Figure A-6. Average Fleet Age for Diesel and Electric Bus Scenarios.

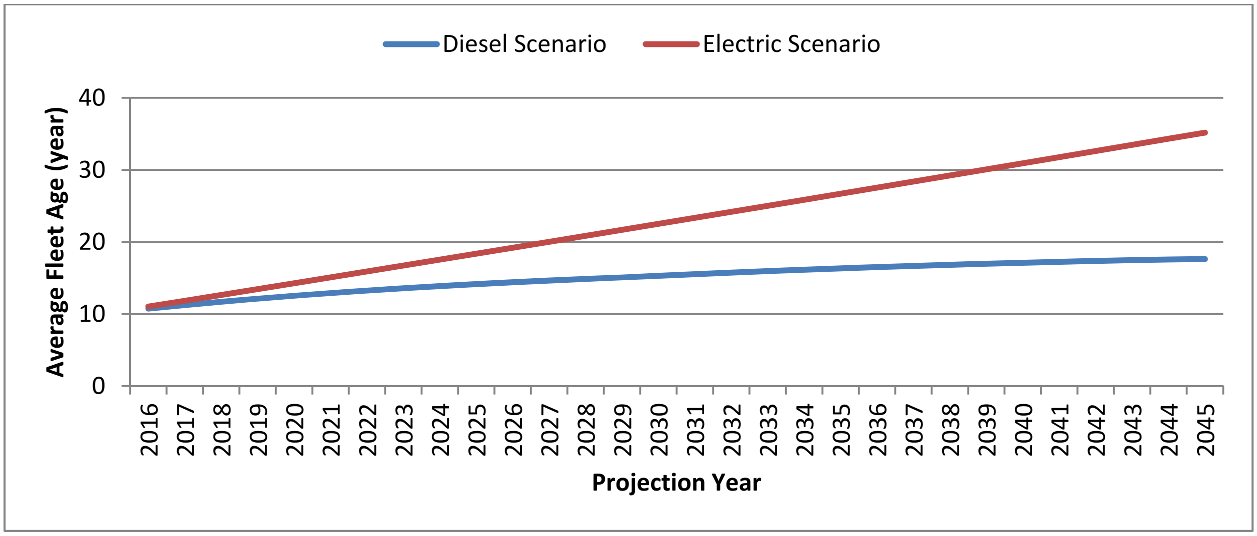


Figure A-7. Maximum Bus Age for Diesel and Electric Bus Scenarios.

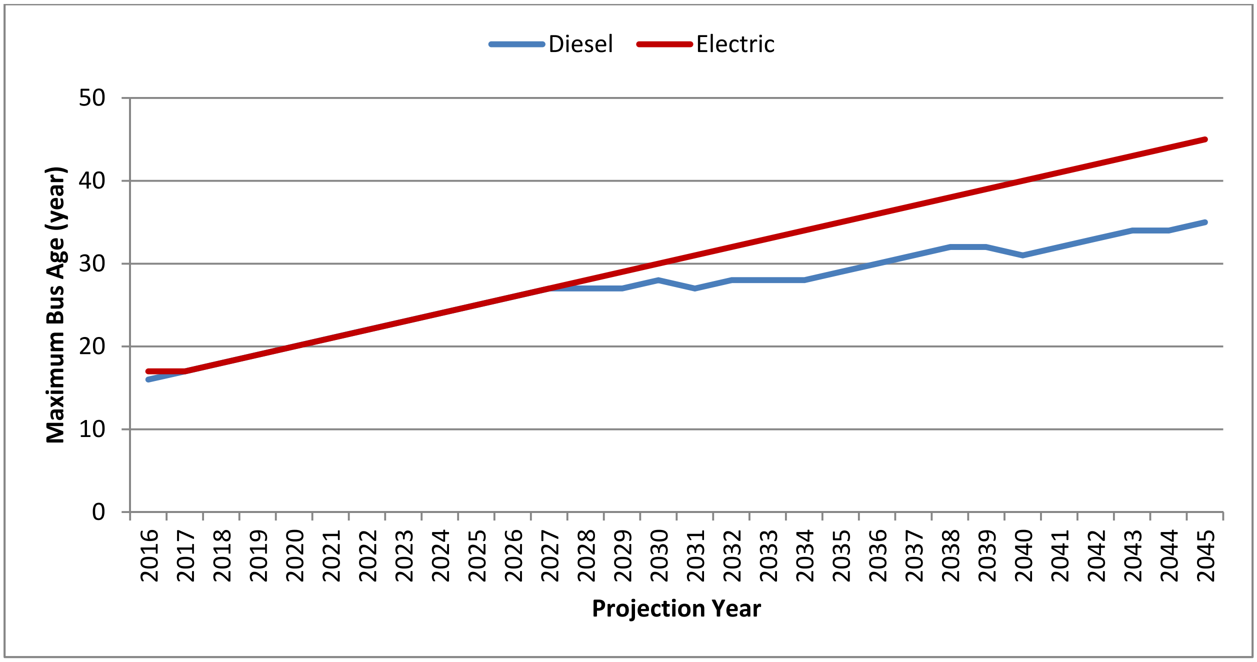


Figure A-8. Fleet Composition – Electric Bus Scenario.

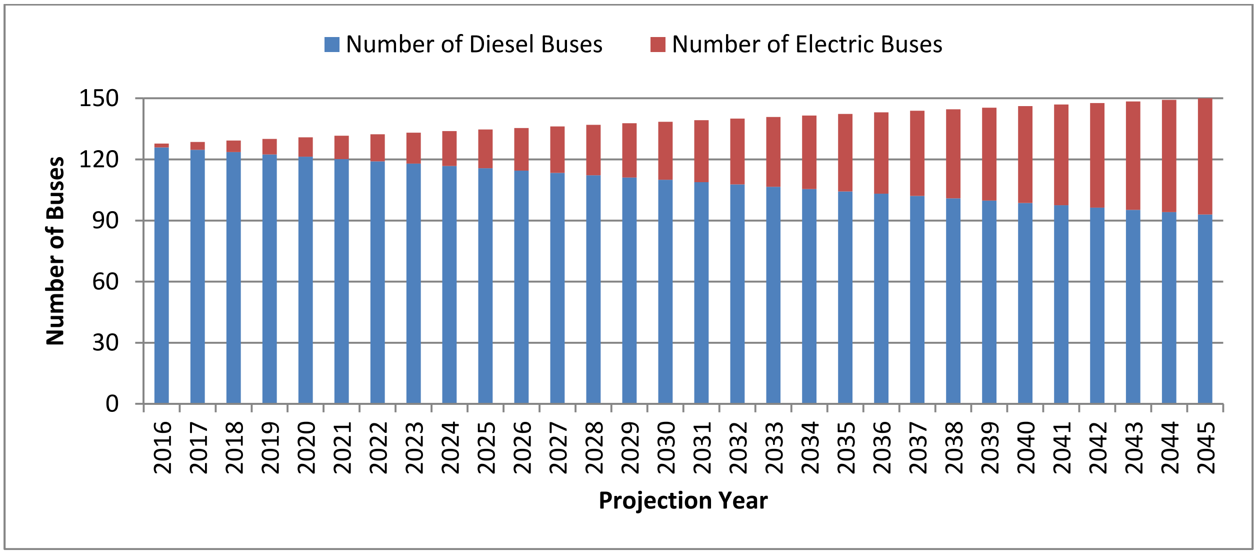
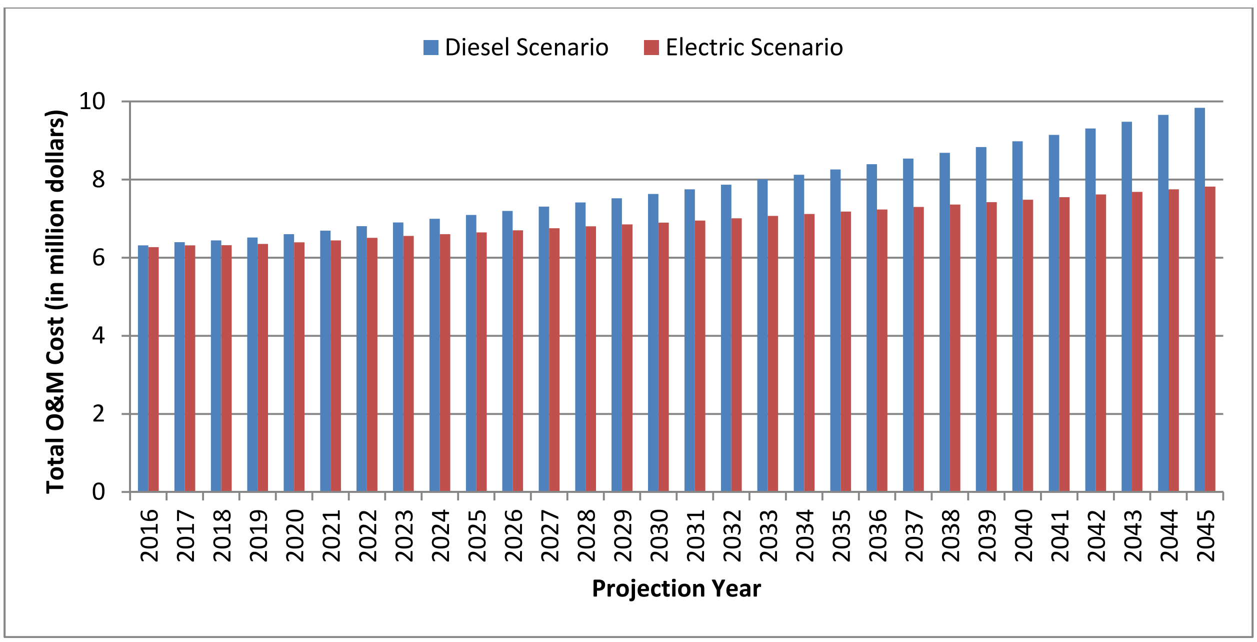


Figure A-9 shows the total O&M costs. Again, the total O&M costs in this scenario consist of vehicle and facility O&M costs and fuel cost.[110]

Figure A-9. Total Vehicle and Facility O&M Costs for Diesel and Electric Bus Scenarios.



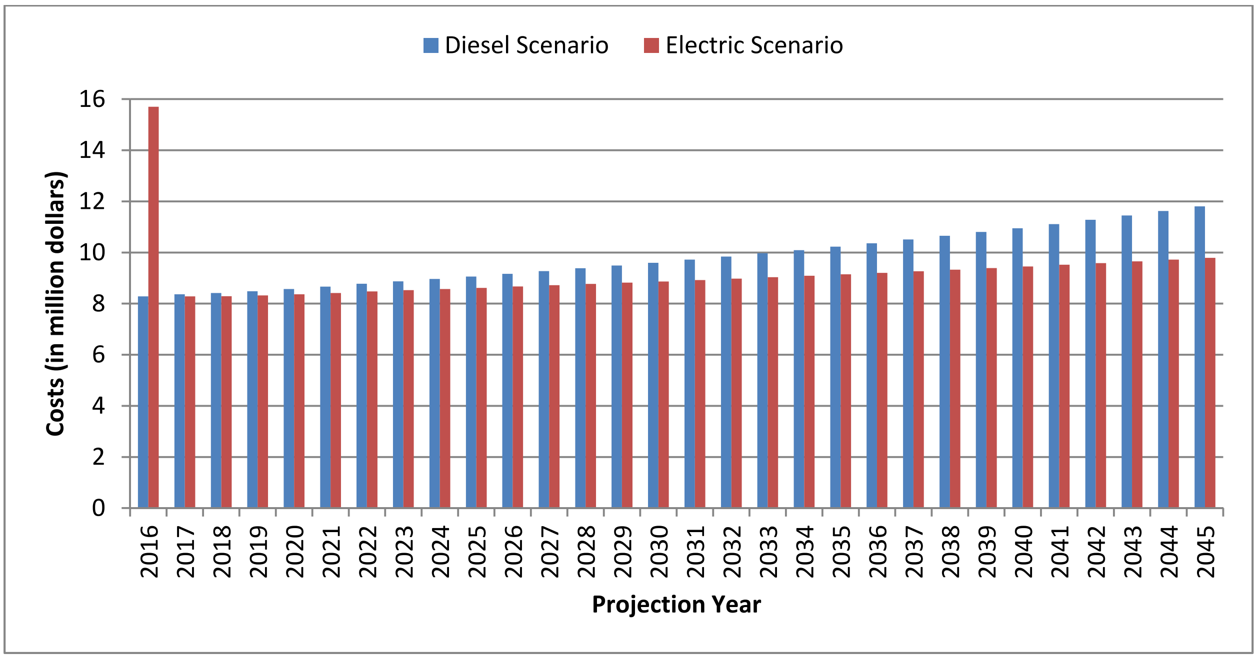
Under the fixed capital scenario, the upfront lump sum cost is higher than the fixed maximum age scenario. This is because one additional on-route charger is needed under this scenario due to more

[110] The diesel scenario also includes fueling costs.

buses in the fleet being converted into electric buses by 2045.[111] As a result, the total lump sum cost is about $7.46 million.

Figure A-10 shows the total costs – including capital costs, O&M costs, and lump sum costs, for both scenarios. Unlike the diesel scenario where total annual cost increases from $8.3 million in 2016 to $11.8 million in 2045, for the CNG scenario the total annual costs increase at a slower pace and reach $9.8 million in 2045. It is important to note that although it seems like the electric scenario is more cost-effective than diesel scenario, Figure A-10 must be weighed against earlier graphs that show that pursuing electric vehicles severely impacts fleet age. Figure A-11 shows the cumulative costs for diesel, CNG and electric bus scenarios.

Figure A-10. Total Costs for Diesel and Electric Bus Scenarios.[112]



[111] Under this scenario, assuming 1.9 electric buses are procured every year results in a total of 57 buses in year 2045. This slightly exceeds the maximum conversion rate (54 buses in the 150 expansion scenario) and was left in this state for calculation simplicity.
[112] Lump sum cost is included in 2016 for electric scenario.

Figure A-11. Cumulative Costs for Diesel, CNG and Electric Bus Scenarios.