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# The Great Transition: A Cost-Benefit Analysis of Transitioning from Diesel Fuel Buses to Zero Emission Electric Buses for the NFTA in The Buffalo-Niagara Falls MSA

Jonathan C. Meyers
*State University of New York College at Buffalo - Buffalo State College*,
meyersjc01@mail.buffalostate.edu

Advisor
Nicole L Hunter
First Reader
Nicole L Hunter
Second Reader
Bruce L Fisher
Third Reader
Frederick Floss
Department Chair
Frederick Floss

**The Great Transition: A Cost-Benefit Analysis of Transitioning from Diesel-Fuel Buses to Zero Emission Electric Buses for the NFTA in the Buffalo-Niagara Falls MSA**

by

Jonathan Meyers

An Abstract of a Thesis In
Applied Economics

Submitted in Partial Fulfillment
Of the Requirements
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December 2020

State University of New York
College at Buffalo
Department of Economics and Finance

# Abstract

The scope of this report is intended to help shape the future operations of the Niagara Frontier Transportation Authority in a more economically and environmentally friendly way. In this report we analyze the Niagara Frontier Transportation Authority's (NFTA's) current diesel bus fleet, with respect to zero emission electric buses available in the marketplace. We compare the current diesel buses in use at the NFTA, with the costs and benefits associated with switching to zero emission electric buses. We examine the use of electric buses in other U.S. cities and their experiences with the new public transit bus technology in order to learn from and apply lessons to our local community. The results of our analysis conclude with offering suggestions on how the NFTA could improve efficiency within their own operations by reducing costs while also reducing their ecological footprint. The final recommendation of this study is that the NFTA should begin taking steps towards transitioning their bus fleet to all electric buses, phasing out the oldest diesel buses first.

Jonathan Meyers

Date

State University of New York
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A Thesis in Economics

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Approved by:

Nicole L Hunter, Ph.D.
Professor of Economics
Chairperson of the Committee/Thesis Advisor

Frederick Floss, Ph.D.
Professor of Economics
Chairperson of the Department of Economics and Finance

Bruce L Fisher, Ph.D.
Professor and Director of Economics and Finance Department
Committee member and reader

Kevin Miller, Ed.D
Dean of Graduate School

# Thesis Committee Signatory

Date of Approval:

Bruce L Fisher, Ph.D.
Professor and Director of Economics and Finance

Nicole L Hunter, Ph.D.
Professor of Economics and Finance

Frederick G Floss, Ph.D.
Chair of Economics and Finance Department

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## Acronyms

BAU…………………………………………………………………….….Business as Usual

BEB…………………………………………………………………...Battery Electric Bus

BEV…………………………………...……………...….Battery Electric Vehicle

CAPs…………………………………………………………...Criteria Air Pollutants

CBA…………………………………………………………....Cost Benefit Analysis

CLCPA……………………….……..Climate Leadership and Community Protection Act

EPA……………………………...…………......Environmental Protection Agency

EV……………………………………...……………...……..…. Electric Vehicle

FRED………………………………………………..Federal Reserve Bank of St. Louis

FTA……………………………………………......Federal Transit Administration

GHGs……………………………………………….…………...Greenhouse Gases

ICE………………………………….....…..……………. Internal Combustion Engine

LDV……………………………………………………………...….Light Duty Vehicle

MPGE…………………………………………………...Miles Per Gallon Equivalent

MTA……………………………………………….Metropolitan Transportation Authority

NFTA…………………………........……...Niagara Frontier Transportation Authority

NPV……………………………………………………………………...Net Present Value

ROI…………………………...……………………………......….Return On Investment

TCO…………………………………………………………....Total Cost of Ownership

# Chapter 1: Methodology

The motivation for this analysis was to address inefficiencies related to using fossil fuels as the means for public transportation. Research has mainly been extracted from secondary data sources, such as websites, journals and publications available through the Buffalo State college library online catalog. Knowledge acquired on fossil fuels, greenhouse gas emissions, and renewable energy has come from various accredited sources such as the EPA, and based on lessons learned in Energy and the Environment class taught at Buffalo State. Some information specific to the NFTA's diesel fleet was obtained through emails and phone calls with NFTA employees. The greenhouse gas and financial analysis were validated to some extent by comparing the results to similar publically available public transportation fleet electrification studies. Specifically some of the organizational features and calculations for our analysis were modelled after the *"Electric Bus Analysis for New York City Transit"* by Judah Aber from Columbia University.

## 1.1 Data Collection

Many different sources were referenced to gain a general understanding of the NFTA bus fleet. These sources can be found in the footnotes and work cited. There were gaps in the data for the average annual maintenance cost, therefore some assumptions had to be made in order to have complete data for this analysis. The data for the annual maintenance cost of a diesel bus was borrowed from the NYC Metro Transportation

Authority (MTA).[1] Based on the NYC MTA being 20 times larger than the NFTA, they have additional employees to keep more detailed records of their statistics.

One of the key data points used in this analysis is the number of diesel buses the NFTA has currently in their fleet. The exact number of buses changes throughout the year due to various reasons, but the data for the mix of buses is assumed to be the approximate fleet size at the year end of 2019. The primary source which was used to collect this data was the "2018-2019 NFTA Annual Performance Report" along with discussions with the NFTA maintenance manager. The NFTA annual performance report provides the number of buses in inventory, the annual miles traveled, and the average MPG.[2] The number of gallons consumed was simply derived by dividing the average annual miles driven by the average miles per gallon.

For the greenhouse gas emissions analysis, the source of the factors used to determine carbon dioxide (CO2), Methane (CH4), and Nitrous Oxide (N2O) emissions was the U.S. Environmental Protection Agency (EPA).[3] To convert the CH4 and N2O emissions to CO2 equivalents (CO2e), global warming potential (GWP) factors were obtained from the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report.[4] The data that was collected from the NFTA regarding diesel buses can be found in the following chart:

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[1] Barnitt, R., and K. Chandler. *New York City Transit Buses: Final Evaluation Results.* No. NREL/TP-540-40125. National Renewable Energy Laboratory, 2006, http://www.osti.gov/servlets/purl/894985-1XGnHq/. Accessed 11 Aug 2020.
[2] NFTA-Metro. *2018-2019 Annual Performance Report.* Buffalo, NY: NFTA-Metro, 2019. Web.
[3] United States Environmental Protection Agency. *eGRID Summary Tables 2018.* Washington, DC: Clean Air Markets Division, 2018. https://www.epa.gov/sites/production/files/2020-01/documents/egrid2018_summary_tables.pdf. Accessed 1 Aug 2020.
[4] "Direct Global Warming Potentials - 2.10.2." *IPCC Fourth Assessment Report: Climate Change 2007.*

**Figure 1: NFTA Diesel Bus Statistics**

| Bus Type | Qunatity | MPG | Ave. Age (yr) | Annual Miles per bus | Annual Gallons Consumed |
|---|---|---|---|---|---|
| 100% diesel | 126 | 4.5 | 10.1 | 32,058 | 7,124 |

## 1.2 Review of Literature/Introduction

Investing in the future of public transportation is worthwhile due to the role it plays in the communities it serves. For example, here in Buffalo and Niagara Falls, the NFTA is both a job creator and supporter. According to the American Public Transportation Association, every $1.25 billion dollars invested in public transit infrastructure supports an estimated 35,000 jobs.[5] Not only does it create jobs and an income source for families, it also saves them money. Families in large metropolitan areas that take public transit instead of owning a personal car save approximately $9,650 dollars per year.[6] Anyone who chooses to take public transit as opposed to owning a personal vehicle not only saves money, but also reduces their carbon footprint. Every year, public transit saves the United States millions of gallons of fuel and eliminates an estimated 41 million tons of carbon dioxide from the atmosphere that would have been emitted from personal vehicle use.[7] By investing in zero emission electric buses the NFTA would help further reduce their emissions.

Greenhouse gases trap heat in the Earth's atmosphere causing the planet's temperature to rise. Since around the start of the Industrial Revolution, human activities

[5] American Public Transportation Association. (2009) *"Public transportation gets our economy moving."*
[6] ibid
[7] ibid

have been responsible for almost all of the increases in greenhouse gases (GHGs) in the atmosphere beyond the natural cycle.[8] In Erie County, transportation accounts for the largest source of climate pollution.[9] The pollution is caused by the burning of fossil fuels, such as diesel, which creates serious health impacts for the people in the region. The most serious implication from the pollution directly corresponding to tailpipe exhaust are the thousands of premature deaths each year.[10] Generally, when you think of terrible pollution problems, what comes to mind is overpopulated cities with thick low lying smog. However, here in Buffalo, the air quality is also problematic and affects all of us.

A common goal of several related studies reviewed were to pinpoint specific actions that can be taken to limit rising global temperatures. In order to avoid runaway climate change, the atmospheric temperature must stay below 1.5 degrees Celsius above pre-industrial levels set by the Intergovernmental Panel on Climate Change (IPCC).[11] In order to do this we need to start taking actionable steps towards abating climate change. The best way to achieve this goal is to phase out the use of fossil fuels, and replace them with clean renewable energy. This report's contribution towards this goal will be an analysis focusing on how the NFTA can switch the mode of public transportation in our local economy from reliance on fossil fuels to one that relies on clean renewable energy.

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[8] IPCC (2007). Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[9] Steinberg, R. (2019, September 7). Another Voice: Zero-Emission Buses Would Bring about a cleaner Buffalo. *The Buffalo News*.

[10] Ibid

[11] Werani, Z. (2018, October 8). Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. Retrieved September 3, 2020, from https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

This will also better align the NFTA with New York State's Climate Leadership and Community Protection Act (CLCPA). Under the CLCPA, New York State has committed to responsible action against climate change by requiring carbon emission reductions of 40% and 85% by 2030 and 2050 respectively.[12] Since the transportation sector is responsible for the largest share of greenhouse gas contributions in Erie county, the NFTA plays an important role in helping to achieve the emission reduction goals.

Climate change is often cited as the main reason to switch to clean renewable energy, however, there are many additional factors that may play key roles in this decision for individuals, firms and governments alike. Some of these factors include improving air quality, and reducing costs. Cost-benefit analysis (CBA) is a methodology which can be used to help determine if the switch to clean renewable energy makes economic sense. CBA is an approach to weigh the pros and cons of a decision, before having to expend the resources on that decision. Doing a CBA gives one the ability to anticipate what lies ahead if a particular decision or project were to be undertaken. CBA calculations can be useful when comparing monetary costs, as well as intangible costs, such as social costs. This is why we have chosen CBA as our methodology for this report.

There are many economic costs, including monetary and social, that are a direct result from climate change. In order to mitigate these costs, it is up to everyone worldwide to rethink their actions and start taking steps that would result in decreasing their ecological footprint. The main goal of our analysis will be to find a more

[12] Funke, D. (2020, January 1). Transit Will Be The Key for Meeting Governor Cuomo's CLCPA GHG Goals. *Citizens for Regional Transit*, Vol # *22*.

economical and sustainable way for the Buffalo and Niagara Falls public transportation system to move people around in the local community.

The NFTA's diesel buses are the oldest in the fleet. Some of the diesel buses are even past the 12 year useful age, recommended by the Federal Transit Administration (FTA).[13] Due to these buses being older, they are starting to break down more frequently causing them to be taken out of service, and incur costly repairs. On top of the mechanical issues related to the age of the vehicles, the older diesel buses are also retrofitted with emission control devices, which cause additional mechanical issues. The intention of the emissions control devices is to reduce the amount of pollutants in the exhaust, which to their credit they do partially, but not without causing separate mechanical issues. The devices restrict air flow that the engine needs in order to run properly. Since the diesel buses were not designed to have emission control devices equipped they cause the buses to run poorly and malfunction. These emission control devices are not a good permanent solution to the problem. Short and sweet, the diesel buses will need to be replaced in the near future, and should be replaced with zero emission electric buses.

Electrifying public transportation is already being implemented in several US cities, as well as cities across the globe. According to the Sierra Club's Clean Transportation for all Campaign, 13% of all U.S. transit agencies have electric buses in

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[13] US Department of Transportation. *Grant Management Requirements Circular.* FTA policy with respect to the useful life of equipment is set forth in FTA Grant Management Circular 5010.1D, pages IV - 16 /18.

their fleets, or have placed orders.[14] The number of transit agencies committing to purchasing electric buses is increasing. California has committed to having all electric buses statewide by 2040. Other countries around the world have already begun their transition of switching from diesel buses to electric buses. By the end of 2017 there were approximately 385,000 electric buses in operation worldwide, which made up about 13 percent of the global fleet, however 99% of these electric buses are located in China.[15] The U.S. has roughly 70,000 transit buses nationwide.[16] In 2017 there were approximately 360 electric buses on the roads in the U.S; One year later that number was up to 650.[17] This shows that the landscape is starting to shift. Cities are starting to make fleet electrification commitments because they are under pressure to find ways to cut C02 emissions and improve air quality. In October of 2017, 12 cities around the globe pledged to buy only electric buses from 2025 onwards as part of a declaration they all signed called C40 Fossil-Fuel-Free Streets.[18] Proterra, which is the largest electric bus manufacturer in the U.S., currently sells electric buses to municipalities, universities, airports, federal, and commercial transit agencies in 33 U.S. States and Canadian provinces, with orders continuing to grow.[19]

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[14] Coplon-Newfield, G., & Smith, C. (2019, February 21). For U.S. Transit Agencies, the Future for Buses Is Electric. Retrieved August 14, 2020, from https://www.sierraclub.org/articles/2019/02/for-us-transit-agencies-future-for-buses-electric

[15] Aleksandra O'Donovan, James Frith, and Colin Mckerracher, "Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2" (policy report, Bloomberg New Energy Finance, 2018), p. 3.

[16] Ibid., p. 5.

[17] Ibid., p. 5.

[18] Ibid., p. 6.

[19] Design, Razorfrog Web. "PROTERRA SELECTED IN ELECTRIC BUS CONTRACT BY GEORGIA DEPARTMENT OF ADMINISTRATIVE SERVICES." *Proterra*, Proterra, 25 June 2019, www.proterra.com/press-release/proterra-selected-in-electric-bus-contract-by-georgia-department-of-administrative-services/.

In New York City air pollution is a significant problem. The same can be said for many of the densely populated cities around the world. The Metropolitan Transportation Authority (MTA) in New York City is the largest bus network in the country and has around 5,700 buses in operation. According to the NYC.gov website, the air pollution problem in NYC is responsible for 6% of the deaths that happen within the city each year. One of the ways New York City plans to combat their air pollution problem is through their commitment to purchasing only electric buses after 2029 as well as having their entire fleet electric by 2040.

Looking specifically at the NFTA for the Buffalo-Niagara Falls Metropolitan Statistical Area (MSA) we find some key factors which may play a positive role in supporting the idea that the current fleet of diesel busses should be switched to electric. These factors include sprawl, percentage of the population which relies on public transit, and rising costs of diesel fuel. Reduced population densities caused by sprawl increases fuel and maintenance costs for the NFTA because riders are more spread out. Although the NFTA does not have the power to control the forces of sprawl, they do have the option to compensate for these increased costs by incorporating electric buses into their fleet. This will help to alleviate some of the financial burden incurred by the NFTA as a result of sprawl.

In the Buffalo and Niagara Falls region, a large portion of low income families rely heavily on the NFTA. Most of these families can not afford to own a personal car, who instead count on the NFTA services to get to work each day. If the NFTA ever had to cut routes due to financial shortcomings, it would worsen the effects of the areas spatial mismatch between where the jobs are and where the affordable housing is located. As a result low income families would be disproportionately affected the worst.

Long term diesel fuel prices are also projected to continue to increase. Diesel fuel is a derivative of oil, which is a finite fossil fuel. As oil becomes more difficult to extract, oil prices will continue to rise therefore diesel fuel prices will as well. The sooner we begin the transition to electric vehicles, with charging being sourced from clean renewable energy, the better off we will be. The technology is available, the need is urgent, and the opportunity is upon us to make this happen. All we need now is the political will. By anticipating the inevitable demise of fossil fuels we will be better able to prepare for a future less reliant on them. The NFTA is a perfect place to incorporate and demonstrate the benefits of electric vehicles since many residents, businesses and other government agencies might take notice and follow suit.

The considerations discussed above, and others, point to the importance of conducting a cost benefit analysis. The reasons also justify why conducting a cost benefit analysis would be worthwhile in order to demonstrate the health benefits, cost savings, and emission reductions from the transition. The last thing you want is for a state run public benefit corporation such as NFTA, which plays such a vital role in the local community, to be susceptible to budget cuts from the federal, state, or local government level. Anything this report can do to improve the NFTA financially and reduce their carbon footprint will be worthwhile to everyone living in the area based on the crucial role the NFTA plays here in Buffalo and Niagara Falls.

Erie County Executive Mark C. Poloncarz assembled a working group to produce a report to identify strategies the County could take in order to meet the goals set by the international Paris Climate Agreement. The report is called "*Erie County Commits to Paris: How Erie County Can Meet U.S. Target Reductions for Greenhouse Gas Emissions.*" The strategies developed in the report are based on keeping fossil fuels in the ground and striving for 100% clean renewable energy.[20] The working group outlined several projects that would reduce GHG emissions from Erie County government operations. One of the projects outlined is to reduce county fleet emissions by purchasing zero emission vehicles. This includes the NFTA buses because they are part of the county's fleet, and would align with the report's goal.

In the following sections, we will demonstrate the costs and benefits associated with a switch from diesel to electric buses for the NFTA. The main focus of our comparison will be on purchase price, fuel, maintenance, and environmental/healthcare costs. The public transportation system in Buffalo and Niagara county will be analyzed in order to examine the feasibility of switching public transportation to a more sustainable practice, one that fades out the use of the high polluting internal combustion engine, and replaces it with zero emission electric buses. The region that will be used in the following analysis will be the Buffalo-Niagara Falls metropolitan statistical area. If the NFTA electrifies their fleet, they will take a great stride towards a cleaner, more sustainable transportation future, and the community as a whole will benefit.

[20] Poloncarz, M. C. (2017, June 2). Climate Action and Sustainability: Environment & Planning. Retrieved November 17, 2020, from https://www2.erie.gov/environment/index.php?q=sustainability

## Chapter 2: Fuel Cost Diesel vs Electricity

The fuel cost savings of an electric bus are mainly dependent on local energy prices. For our fuel cost analysis we will be using the local electricity price per kilowatt-hour and the diesel price per gallon and then converting and comparing them on a fuel cost per mile basis. Through the ReCharge NY program from the New York Power Authority (NYPA) the NFTA qualifies to use specially allocated NYPA power which is set aside by the government and NYPA. The program was created so that qualifying local not-for-profit businesses have access to the inexpensive clean renewable energy that the Niagara Falls Hydro-Electric Power Project produces. The price of electricity from the Recharge power program and for our analysis will be 3.3 cents per Kilowatt-hour (Kwh) and the price of diesel fuel is $3.10 per gallon.[21] [22] The spot price for diesel fuel was taken from the New York State Energy Research and Development Authority website. The local electricity rate was taken from the New York Power Authority schedule of rates for sale of Recharge New York Power. An electric bus saves money on fuel cost because the miles per gallon equivalent (mpge) of an electric bus is 25.3 mpge compared to that of a diesel bus which gets only 4.5 mpg.[23] What this means is that an electric bus is more than 5 times more energy efficient than a diesel bus, which is a key factor of how they reduce costs. One of the reasons for this is because electric powertrains are much more efficient at converting energy into power than the internal combustion engine. Also,

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[21] *"Schedule of Rates for Sale of Recharge New York Power"* Issued by Keith T. Hayes, Vice President Power Authority. July 1,2017

[22] Foler, T. (2020, December 15). NYS Weekly Diesel Fuel Prices. Retrieved December 07, 2020, from https://www.nyserda.ny.gov/researchers-and-policymakers/energy-prices/on-highway-diesel/weekly-diesel-prices

[23] Holden, G. (2020, October 12). Fuel Economy Proterra Buses. Retrieved December 3, 2020, from https://www.proterra.com/vehicles/zx5-electric-bus/fuel-economy/

electric buses use almost no energy when idling at a bus stop or red light since there is no drain on the battery when the bus is stationary. On the other hand, a diesel bus burns fuel to keep the motor running even when the bus is stationary. This is another explanation of why there is such a large difference between the miles per gallon of an electric bus and a diesel bus.

Considering a long term perspective of what the future price of diesel fuel may be, the economic incentive of using diesel for fuel will most likely deteriorate as the price is projected to increase over time as seen in Figure 2 below. This is mainly due to diesel fuel being a derivative of oil and oil being a finite resource. As easily accessible oil becomes harder to extract, the energy return on investment (EROI) will most likely decrease for oil mining and refining operations. When the first oil fields were struck they originally yielded an EROI in excess of 100:1. In today's world where oil reserves are much more depleted, the EROI for oil is around 20:1, or if you are talking about tar sands or oil shale the EROI tends to be closer to 5:1 and 3:1.[24] What this means for the future is that the prices of oil and therefore diesel fuel will increase as it requires more capital and energy to get the oil out of the ground. However with that being said, in the short run there will still be temporary supply or demand side shocks that cause price volatility, but over the long run prices of diesel fuel should theoretically increase. There are many factors that contribute to the fluctuations of the price of oil, most of them tend to be geopolitical. The temporary decline in the price of oil could also be to stall the momentum of the electric vehicle revolution that is finally starting to gain traction in the

[24] Murphy, T. (2011, October 18). Do The Math: The Energy Trap. Retrieved August 25, 2020, from https://dothemath.ucsd.edu/2011/10/the-energy-trap/

marketplace. By driving down the price of diesel fuel it makes it harder for electric vehicle startups to be cost competitive. However, over the long run the benefits of using the finite resource oil will most likely eroad, causing price to increase. The conclusion that can be drawn from the recent decline in oil prices may be a last ditch effort by big oil companies, who will slowly start to lose market share as the electric vehicle industry takes off.

In Figures 2 and 3 below the percentage price increase of diesel fuel and electricity is depicted graphically from 1995 to 2020 to represent the historical price increases of both commodities. Using this data extracted from the Federal Reserve Bank of St. Louis (FRED) we established a trend line and then forecasted it out for five years for both commodities to show the difference in price increases.

**Figure 2: U.S. Diesel Fuel Percentage Increase In Price Per Gallon**

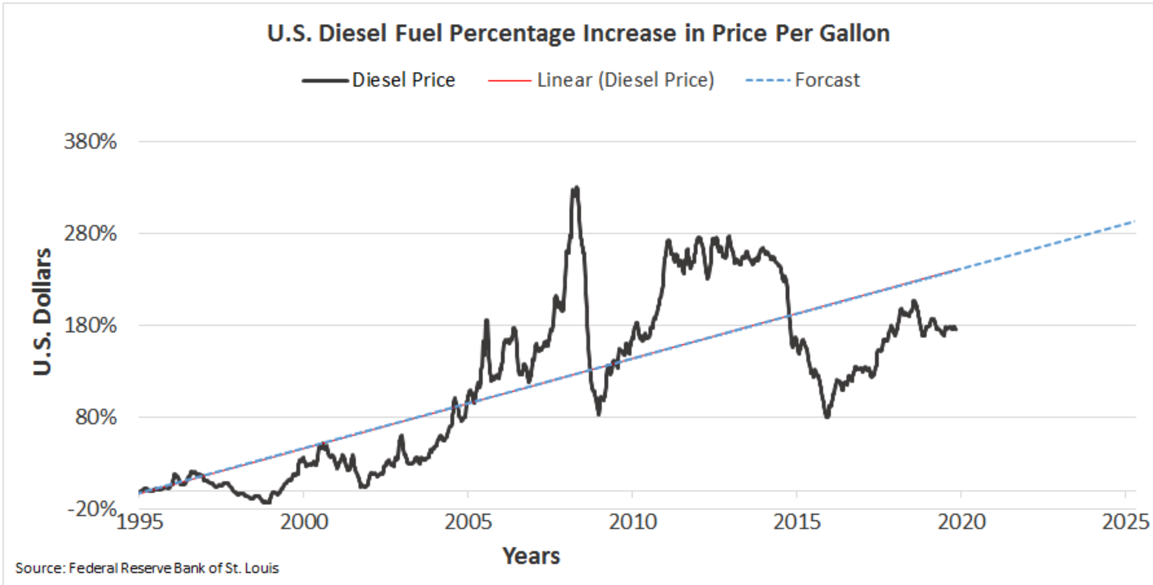
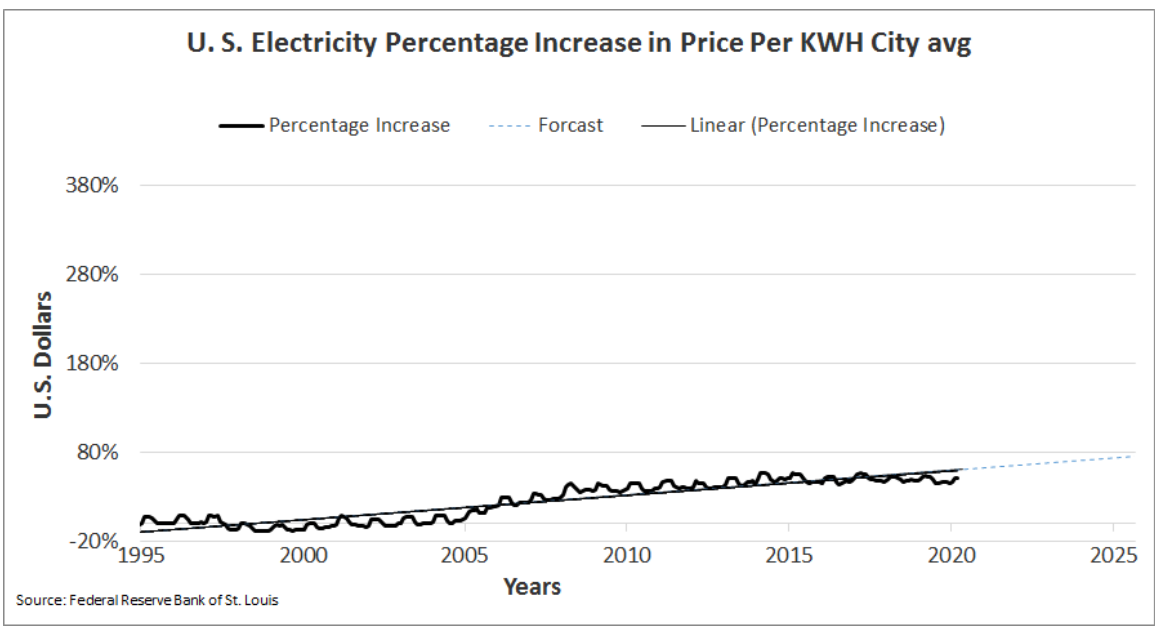



**Figure 3: U.S. Electricity Percentage Increase in Price Per KWH City avg.**




As you can see from the above graphs, the price of diesel fuel has increased by roughly 200% from 1995 to 2020 whereas electricity has only increased roughly 75%. Electricity over the same period has been far less volatile, which means that switching to electricity as the main source of fuel, would reduce costs and create greater predictability for the NFTA and allow them to better plan their budget accordingly.

In New York state Governor Andrew Cuomo mandated that 70% of electricity generated in the state must come from renewable energy sources by 2030. This likely will have the effect of further bringing down the cost of electricity and stabilizing prices. Once renewable energy sources such as wind, water, and solar become more prevalent and connected into our electricity grid in Erie County, we will see reduced energy prices as a result. The hydro power being generated from Niagara falls, the windmills on Lake Erie's shoreline, and the various solar farms popping up in the area are all for the same purpose, to decarbonize electricity generation and reduce costs. Thus cutting the current rate of 11.7 cents per Kwh in Buffalo to something closer to the 4.5 cents per Kwh, which is what Canadians are paying currently in Quebec. The reason Quebec's electricity prices are less expensive compared to Buffalo's is due to their achievement of reaching economies of scale in renewable energy power generation. In Quebec their electrical grid is sourced from 97% clean renewable energy projects.[25]

In the case of Erie county, as we start incorporating more renewable energy power projects into the electrical grid, the benefits of electric vehicles will increase further. At the present time it is already cheaper to operate an electric bus compared to a diesel bus on a cost per mile basis and the benefits are projected to continue to improve. The cost is

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[25] Fisher, B. (2019, November 24). Talking Energy and Climate. Retrieved December 11, 2020, from http://www.dailypublic.com/articles/11242019/talking-energy-and-climate

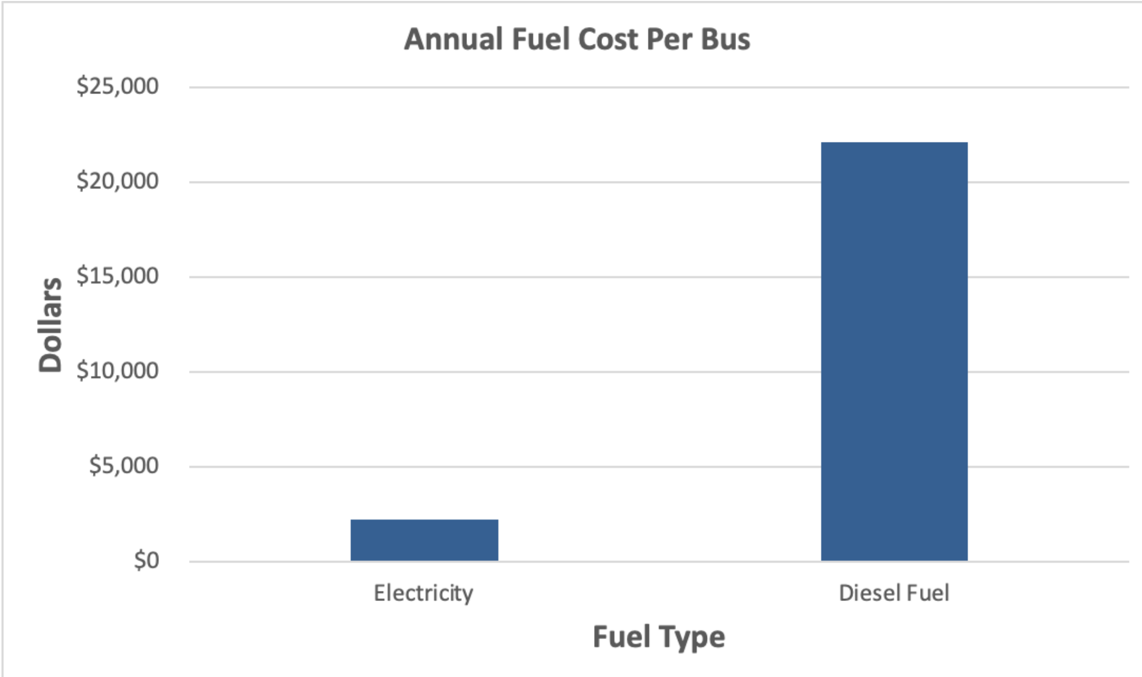
roughly about one-tenth to power an electric bus to travel one mile compared to a diesel bus. The arithmetic of the exact calculation will be demonstrated below.

In Buffalo the average price of diesel fuel is $3.10 per gallon. By taking the price of diesel fuel and dividing it by 4.5mpg, we come up with the cost of 69 cents per mile. This cost will be used as the diesel bus fuel price per mile. The average distance a typical NFTA bus travels in a year is 32,058 miles. If we multiply 69 cents by 32,058 miles per year, we come up with an annual cost of **$22,120** for diesel fuel for every diesel bus.

According to the National Renewable Energy Laboratory it takes 2.15 kilowatt-hours (kWh) of electricity in order to power an electric bus to travel one mile. [26] Considering the price of Recharge electricity in Buffalo, New York is approximately 3.3 cents per kWh, if we multiply 3.3 cents by 2.15kWh we come up with a cost per mile for using electricity as fuel to be 7 cents per mile. If we then multiply the cost of 7 cents per mile by the average distance a NFTA bus travels in a year which is 32,058 miles, we come up with the annual fuel cost of an electric bus to be **$2,244**. The annual fuel cost for an electric bus is approximately one-tenth of the annual fuel cost of a diesel bus. What this means for the NFTA is that they would save roughly $20,000 a year in fuel expense for every bus they switch over from diesel to electric.

[26] Ayre, J. (2016, February 22). Electric Buses Efficient As He**, NREL Finds. Retrieved July 2, 2020, from https://cleantechnica.com/2016/02/22/electric-buses-efficient-as-he-nrel-finds/

**Figure 3: Annual Fuel Cost Based On 32,058 Miles Traveled Per Bus**




Based on our cost per mile comparison of using electricity or diesel fuel as means to power transportation, we conclude that using electricity instead of oil is more sustainable and efficient. Whether it be a government agency or individual consumer, whoever chooses to drive an electric vehicle over a diesel powered vehicle will reduce their fuel expenditure. This fuel cost calculation will be used in the lifetime cost analysis section to see how long it takes the fuel and maintenance cost savings to recoup the additional upfront cost difference between a diesel and electric bus.

## 2.1 Purchase Price

The Federal Transit Administration (FTA), which is where the majority of funding for transit buses comes from, has recommended the useful life of a 40 foot transit bus to be 12 years and/or 500,000 miles.[27] According to the 2018-2019 NFTA Annual Performance Report the average age of the buses in the fleet were 10 years old with 350,000 miles. When the report came out in 2019 it stated that 32% of the NFTA buses or 100 out of the 302 buses in the fleet were already beyond the useful age according to the FTA guidelines.[28] Considering it has been over a year since the report came out in March of 2019, the number of buses beyond the useful age is most likely even higher now. One of the conclusions that can be drawn from this information is that the NFTA will soon need to retire some of the oldest buses in their fleet, and replace them with new buses in the near future.

In this section we will compare the purchase price of a 40' diesel bus to that of a 40' electric bus. Since the largest barrier that is holding back the rapid adoption of electric buses in the U.S. is the high upfront cost, this section will be about how we overcome this issue. The electric bus manufacturer Proterra sells their standard electric bus model the Catalyst XR for $750,000.[29] By comparison, the cost of a conventional 40' diesel bus of similar characteristics costs roughly $500,000.[30] The features and materials of the buses are assumed to be comparable except for the different powertrain technologies, electric vs. diesel, ceteris paribus.

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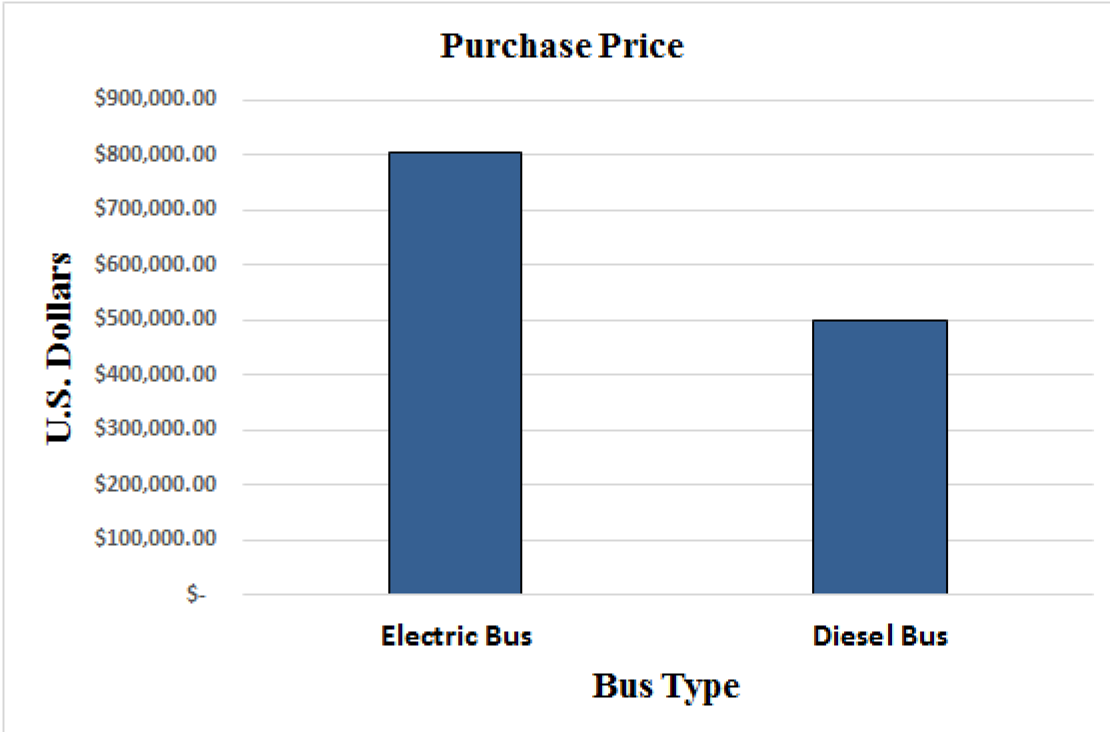
[27] NFTA-Metro. *2018-2019 Annual Performance Report.* Buffalo, NY: NFTA-Metro, 2019. Web

[28] Ibid,.p24

[29] Coren, M. "An Electric Bus Just Snagged A World Record by Driving 1,100 Miles on A Single Charge," Quartz, 19 September 2.

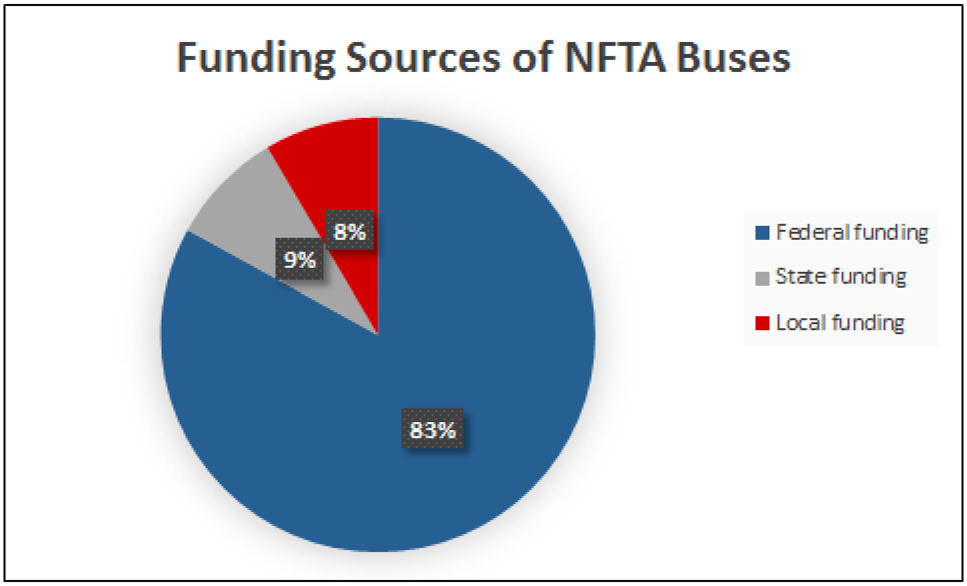
[30] MacKechnie, C. (2019, January 31). How Much Does It Cost to Purchase and Operate a Bus? Retrieved March 16, 2020, from https://www.liveabout.com/bus-cost-to-purchase-and-operate-2798845

For our infrastructure cost calculation, we used the *Charging Station Infrastructure Study* conducted by Trophy Point Construction Services & Consulting, along with C&S Engineers Inc. The study was requested by the NFTA for the purpose of examining which of the 3 NFTA bus garages would be most suitable to try an electric bus charging station. The results of the study recommended the Cold Spring bus garage with pantograph style charging configuration. The pantograph charging configuration is designed for overhead charging, and is the same style of charging that the NFTA rail car already uses. This style of charging is good for 30- 50 years with little or no maintenance. It has been utilized with the NFTA's rail car for several decades and, over time, has proven dependable. The estimated cost for the electric bus charging infrastructure determined by Trophy Point is $6,697,000. The infrastructure has the ability to charge 20 buses at a time and charging takes approximately 2.5 hours per bus and can be done overnight. Based on this information, we have chosen for our analysis to spread the cost of the charging infrastructure over 126 buses since this is the number of buses currently in inventory at the Cold Spring location. This gives us an approximate cost of $53,000 per bus in charging infrastructure related expenses. This was added to the initial purchase price of an electric bus which is $750,000 giving us a total of **$**803,000 for a new electric bus**. $303,000** will be used in the lifetime cost analysis section because this figure represents the additional cost of purchasing an electric bus plus related charging equipment as opposed to purchasing a diesel bus. In the lifetime costs analysis section we will also use this figure when calculating the payback period for the $303,000 price differential.




The majority of funding for public transit buses comes from federal, state, and local governments. The approximate percentage breakdown of how much each branch of the government contributes to new bus purchases can be found in the following pie chart.

**Figure 4: NFTA Funding Sources to Purchase New Buses**




Source: NFTA website: procurement percentage breakdown

There are several federal and state grant programs available that will help the NFTA cover a portion of the purchase price of new electric buses. Some of the programs include: Low or No Emission Grant Program, and the Clean Fuels Grant Program.

According to the Federal Transit Administration website under Grant Program: Low or No Emission Vehicle Program - (5339c), the main purpose of the program is to support the transition of the nation's transit fleet to the lowest polluting and the most energy efficient transit vehicles. As part of this grant program the NFTA was specifically awarded $2.5 million dollars in federal funding from the Department of Transportation (DOT).[31] The funds received from this Federal Government program are for the NFTA to

[31] Report, S. (2019, July 24). NFTA secures fed funding to upgrade the bus fleet. Retrieved April 9, 2020, from https://www.bizjournals.com/buffalo/news/2019/07/24/nfta-secures-fed-funding-to-upgrade-bus-fleet.html

purchase 10 new electric buses and related charging equipment. The program provides funding to support the wider deployment of advanced propulsion technologies within the nation's transit fleet. A spokesperson representing the program said, "In 2019 this program allocated just under $85 million in grants to 38 projects in 38 states. While other types of buses are eligible for funding through the program, all of the 2019 grants were for electric buses."[32] What this statistic represents is that 38 different state agencies who had the choice to buy either diesel, hybrid, compressed natural gas, or electric buses are all in consensus that the best way to appropriate funds from the federal government for new public transit buses is to purchase electric buses. This unanimous decision shows that individual states are willing to take initiative on fighting climate change by transitioning their public transit fleets from fossil fueled buses to electric buses.

The Clean Fuels Grant Program - (5308) provides funding for three eligible activities.[33] The three activities include, purchasing or leasing clean fuel buses, constructing or leasing electrical recharging equipment, and any other projects related to clean fuel or zero emission technology buses that exhibit equivalent or superior emissions reductions compared to existing bus technologies.[34] Based on these requirements the NFTA is eligible for this program and could potentially receive funding to help with the cost of new electric buses and related charging equipment.

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[32] Federal Transit Administration. (2019, December 8). Fiscal Year 2019 Low or No-Emission (Low-No) Bus Program Projects. Retrieved November 07, 2020, from https://www.transit.dot.gov/funding/grants/fiscal-year-2019-low-or-no-emission-low-no-program-projects

[33] Federal Transit Administration. (2005, January 1). Clean Fuels Grant Program (5308). Retrieved April 7, 2020, from https://www.transit.dot.gov/funding/grants/clean-fuels-grant-program-5308

[34] Ibid p.23

Lastly, a portion of funds from the Volkswagen scandal will also be awarded to the NFTA to purchase electric buses. Volkswagen was fined $4.3 billion as part of a national settlement plan for having installed deceptive software in their diesel vehicles. New york state will receive $127.7 million dollars from the settlement and Governor Andrew Cuomo has stated, “a portion of the funds will be appropriated for the purchase of new clean electric transit buses and charging infrastructure.”[35] This is another example of where the NFTA will be able to raise funds for purchasing new electric buses, in order to help offset the additional $303,000 initial price differential.

Electric bus manufacturer Proterra also offers a pay as you save program to help overcome high upfront costs. The benefit of using this financing structure is that the cost savings and emissions reductions from electric buses can be put into use today, while the financial savings can then be used to repay the purchase price over time, therefore having the new electric buses pay for themselves. This would allow the NFTA to introduce new zero emission electric buses into their fleet quicker, therefore reducing emissions and costs from their own operations. This would adhere to what climate scientists have been calling for, which is that humanity must reduce their CO2 emissions or face huge financial and societal costs as a result from climate change.

New York State’s Executive Budget is providing transit systems an additional $100 million in capital assistance over five-years from 2020-2024 to aid local transit agencies in the transition to electric buses.[36] Under the program, five of the largest

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[35] Felix, T. (2018, September 6). New York to use $127.7m from Volkswagen emissions scandal for electric vehicles. Retrieved October 16, 2020, from https://www.citationmachine.net/apa/cite-a-website

[36] Minkel, K. (2020, March 26). NFTA Budget & Financial Plan. Retrieved August 24, 2020, from https://www.nfta.com/media/cbafjih0/2021-fye_budget.pdf

upstate and suburban transit authorities will electrify 25% of their fleets by 2025 and 100% by 2035.[37] The funds from this program are for non-MTA transit systems, MTA being the transit system that covers NYC, Long Island, Lower Hudson Valley, and Coastal Connecticut. The goal of these funds are to help upstate and suburban communities with their transition to electric buses which encompasses the Buffalo-Niagara NFTA. This is another reason why it would be advantageous for the NFTA to acquire electric buses because the funds from this program are only available for electric buses.

Currently electric buses are more expensive than diesel buses because they are a relatively new technology. This will most likely only be the case temporarily. Once electric bus manufacturing production chains become more developed and reach economies of scale, prices will fall. Government agencies and businesses will respond to these lower prices, and the quantity demanded for electric buses will increase. This will incentivize suppliers to increase production. As a result, the purchase price differential between a diesel and electric bus will narrow because the cost savings achieved through scaling up production will be passed down to the consumer because of the nature of price competition. As more startups and existing companies bring electric buses to the marketplace they will have to compete for customers, as a result prices of the buses will come down which will benefit anyone buying them. Like many other newly adopted technologies that first come out, it is generally expensive at first but prices decrease overtime due to the fundamental nature of a free market system such as capitalism.

[37] ibid. p.122

Since the NFTA is not the only public transit agency in the state with plans to acquire new electric buses, there is also the option to purchase new buses in larger quantities with other public transit agencies in the state. Rochester, NY and New York, NY both have plans to purchase new electric buses. If Buffalo, along with these two municipalities, purchased their buses in a bulk order they may be able to purchase at a discounted price. San Francisco, CA and King County, CA both purchased their new electric buses together in order to receive a discounted price for buying in greater volume. Using these other county's as examples the same approach could be applied to counties within New York State.

## 2.2 Maintenance Costs

As mentioned previously the NFTA's diesel buses are the oldest in the fleet. Due to these buses being older, they are starting to break down more frequently causing them to be taken out of service, and incur costly repairs. On top of the mechanical issues related to the age of the vehicles, the diesel buses are also retrofitted with emission control devices, which cause additional mechanical issues. The intention of the emissions control devices is to reduce the amount of exhaust emitted, which to their credit they do partially, but not without causing separate mechanical issues. The devices restrict air flow that the engine needs in order to run properly. Since the diesel buses were not designed to have emission control devices equipped they cause the buses to run poorly and malfunction. Emission control devices may be a good temporary fix but they are not a good permanent solution to the problem. The diesel buses will need to be replaced in the near future, and should be replaced with zero emission electric buses.

Stated in the "2018-2019 NFTA Annual Performance Report" each month there are roughly 30 NFTA buses out of service due to maintenance issues.[38] The majority of the issues that arise are problems associated with the internal combustion engine. The internal combustion engine (ICE) is what a diesel bus relies on for propulsion. Switching from a diesel bus to an electric bus would help cut down on maintenance issues and costs, as well as reduce the number of buses out of service. One reason for this is due to the fact that the propulsion system in an electric bus relies on a much simpler mechanical design with fewer moving parts, thus making them more cost effective and reliable.

The electric powertrain system in an electric bus has one fifth of the moving parts compared to that of the internal combustion engine.[39] Due to there being fewer moving parts in an electric bus compared to a diesel bus there are less opportunities for something to malfunction. Electric buses save money on maintenance costs because by having less moving parts there are less chances of having costly mechanical problems.

Looking at the data from the "2018-2019 NFTA Annual Performance Report" we can see that the miles traveled without service interruptions for a diesel bus are 5,195 vs a hybrid bus 8,954.[40] What this data shows is that the hybrid buses travel further without service interruptions. The reasoning for this is because the battery is the only thing used for propulsion purposes until the bus exceeds eighteen miles per hour, then the engine kicks in and is used because that is when it is most efficient. This can mainly be

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[38] NFTA-Metro. *2018-2019 Annual Performance Report.* Buffalo, NY: NFTA-Metro, 2019. Web
[39] Evans, C. (2019, April 24). Here's Seven Reasons Why Electric Vehicles Will Kill The Gas Car. Retrieved April 21, 2020, from https://insideevs.com/news/340502/heres-seven-reasons-why-electric-vehicles-will-kill-the-gas-car/
[40] NFTA-Metro. *2018-2019 Annual Performance Report.* Buffalo, NY: NFTA-Metro, 2019. Web

attributed to the fact that when only the battery is being used to move the bus there is a lot less that can go wrong mechanically, which is why the buses travel further before needing repairs. The majority of maintenance repairs in 2019 were predominantly from engine related problems which were responsible for 475 defects in 2019.[41] If the NFTA were to replace their diesel powered buses at the end of their useful life with new electric buses, it would reduce the number of maintenance issues and therefore maintenance repair costs.

Proterra is the largest electric bus manufacturer in the U.S. and they estimate that switching from a diesel bus to an electric bus saves approximately $237,000 in maintenance costs over the life of the bus.[42] This breaks down to a savings of approximately $20,000 per year, which is on top of the savings from not having to purchase diesel fuel anymore. These cost savings come from parts that are completely taken out of the equation when switching from a diesel bus that relies on the internal combustion engine to an electric bus that relies on a battery and electric motor. For example there is no longer a need for the exhaust system, distributor, starter, clutch, drive belts, hoses, spark plugs, catalytic converter, or fuel tank full of fossil fuels.

Changing used motor oil and replacing used filters which usually qualifies as routine maintenance for diesel buses can be taken off the to do list entirely. Brake pad and rotor replacements will still need to be done but their useful life will be much longer thanks to the savings from the new regenerative braking systems that electric buses have.

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[41] ibid p.19

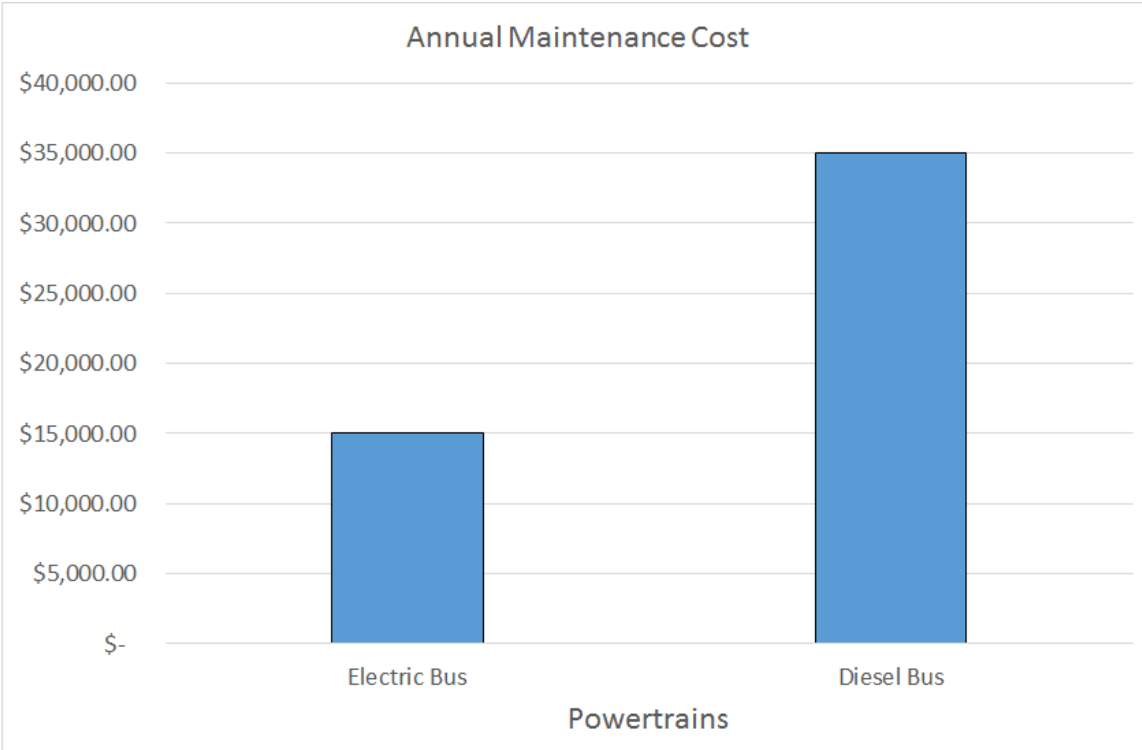
[42] Gilpin, Lyndsey, et al. "These City Bus Routes Are Going All-Electric — and Saving Money." *InsideClimate News*, 5 Nov. 2018, insideclimatenews.org/news/18102017/these-city-bus-routes-are-going-all-electric.

Regenerative braking systems in vehicles work by withholding electricity to electric motors when the vehicle is moving. As the vehicle rolls, its kinetic energy turns the motors’ rotors, causing the motor to function as a generator - applying a resistive force that slows the vehicle while generating electricity. This electricity is used to charge the vehicle’s batteries and is then used when the vehicle restarts or accelerates. This saves energy and also saves money because the brakes pads and rotors last longer. Extending the useful life of any product is both financially and environmentally responsible. By phasing out diesel buses and replacing them with electric buses the NFTA could eliminate a large portion of their maintenance expenses.

The Proterra electric bus body is made from carbon-fiber-reinforced composite materials, this minimizes repairs and maintenance while also extending the buses lifespan. The traditional steel frame body of an ordinary diesel bus that is currently in use within the NFTA fleet is more susceptible to rust and corrosion from the use of salt during harsh Buffalo winters. The salt eating away at the steel bus frames each winter is a contributing factor to the average 12 year life span of a bus. With the new Proterra electric buses being made from carbon-fiber-reinforced composite they are less susceptible to the corroding effects from salt, making the useful life of the Proterra electric bus last up to 18 years. This is a major cost reduction and significant benefit of electric buses over their steel framed diesel counterpart.

Unfortunately the data of the exact dollar amount for every repair that is needed to calculate the average diesel bus maintenance costs for the NFTA each year could not be obtained for this analysis. The reason for this is because the average maintenance costs depends on multiple variables that are specific to each bus. For example the older a bus is, generally the more maintenance costs that will be incurred. Also the topography of the routes like differences in elevation cause different stressors on each bus making maintenance costs different. The amount of sizable potholes on a route that initiate maintenance costs as well as many other specific factors related to each bus make it hard to quantify an average maintenance cost for the entire fleet. Instead we will fill this gap in the data by estimating the diesel bus maintenance cost to be $35,000 a year. This number is taken from the NYC MTA annual maintenance cost which has already been calculated. The NYC MTA has 5,700 buses in their fleet. They have a similar climate to Buffalo, meaning both buses are exposed to corrosive salt during winters. Both NYC and Buffalo have relatively flat terrain and the fact that their fleet has 5,700 buses gives us a good sample size to trust their $35,000 average annual maintenance cost which we will use as a benchmark for our maintenance cost analysis. Based on the manufacturer Proterra's expected maintenance cost savings of approximately $20,000 per year this is how we computed the electric bus maintenance cost per year of $15,000. The average annual maintenance cost for a diesel bus compared to an electric bus are represented in the figure below and will be referenced again in the lifetime cost section.

**Figure 5: Annual Maintenance Cost Electric vs. Diesel Bus**




## 2.3 Environmental Costs / Greenhouse Gas Analysis

In order to have a complete and in depth cost-benefit analysis between a diesel powered bus and an electric bus, externality costs must be included in the calculation. What is meant by externality cost are the negative effects imposed on third parties who did not choose to incur the cost. Examples of externality costs attributed to the internal combustion engine include, environmental pollution and exhaust induced health related issues.

In this section we will calculate the greenhouse gas emissions for both a diesel bus and an electric bus. The analysis in this section will be fully inclusive and will not only compare tailpipe emissions, but will also account for upstream emissions such as emissions associated from the power generation to charge an electric bus. The three greenhouse gases we will be focusing on in this section will be carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). The reason we will be focusing on these three greenhouse gases is because they make up 98% of the greenhouse gases in the atmosphere.[43]

In Table 2 below we calculated the emissions related to a typical NFTA diesel bus which travels the average annual miles and achieves the average fuel efficiency. The emissions were calculated for carbon dioxide, methane, and Nitrous Oxide, and then converted to carbon dioxide equivalents (CO2e) by multiplying by their individual global warming potential factor. The exact calculation can be seen delineated below.

**Table 2: Greenhouse Gas Emissions per Diesel Bus**

| **GHG Emissions per Diesel Bus** | | | | | | |
|---|---|---|---|---|---|---|
| **Carbon Dioxide (CO2) Emissions** | **Fuel (gallon)** | **Distance (mi)** | **lb CO2 / (gallon)** | **Annual CO2 Ton** | **GWP** | **CO2e** |
| Annual Gallons of Diesel Fuel | 7124 | NA | 22.51 | 80.2 | 1:1 | 80.2 |
| | | | | | | |
| **Methane (CH4) Emissions** | | | **CH4 (grams/mile)** | **Annual CH4 Ton** | | |
| Annual Miles Driven | NA | 32,058 | 0.0051 | 0.0002 | 25:1 | 0.0045 |
| | | | | | | |
| **Nitrous Oxide (N2O) Emissions** | | | **N2O (grams/mile)** | **Annual N2O Ton** | | |
| Annual Miles Driven | NA | 32,058 | 0.0048 | 0.0002 | 298:1 | 0.0505 |
| Total CO2e Emissions per diesel bus | | | | | | **80.2** |

The results conclude that a typical NFTA diesel bus emits roughly 80.2 tons of carbon dioxide equivalents into the atmosphere annually. The results for methane and nitrous oxide emissions were statistically insignificant for the purpose of this analysis.

[43] Weber, B. (2020, February 12). U.S. Greenhouse Gas Emissions and Sinks. Retrieved April 9, 2020.

Next we will conduct a similar analysis in order to find out the greenhouse gases associated with charging and operating an electric bus in table 3 below.

**Table 3: Greenhouse Gas Emissions Per Electric Bus Including Charging**

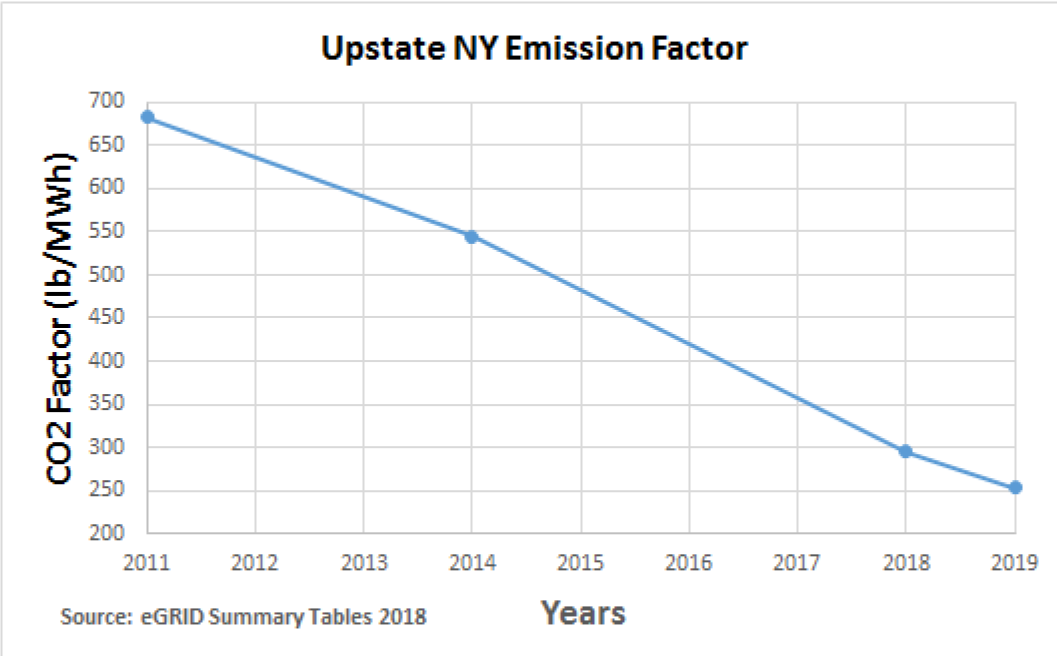
| GHG Emissions from Electric Bus Power Supply | Annual Distance (mi) | MWh / Mile | Annual MWh usage | Emission Factor (lb/MWh) | Annual Tons | GWP | CO2 e |
|---|---|---|---|---|---|---|---|
| Carbon Dioxide (CO2) Emissions | 32,058 | 0.00215 | 68.9 | 253.1 | 8.7 | 1:1 | 8.7 |
| Methane (CH4) Emissions | 32,058 | 0.00215 | 68.9 | 0.018 | 0.0006 | 25:1 | 0.02 |
| Nitrous Oxide (N2O) Emissions | 32,058 | 0.00215 | 68.9 | 0.002 | 0.00006 | 298:1 | 0.02 |
| **Total CO2e Emissions per Electric Bus** | | | | | | | **8.8** |

As you can see from the analysis in table 2 a typical NFTA diesel bus emits roughly 80.2 tons of CO2e annually. On the other hand, an electric bus traveling the same distance would only emit roughly 8.8 tons of CO2e annually, this can be seen in table 3. What this means is that switching from a diesel bus to an electric would reduce emissions by approximately 90%. One of the reasons for this incredible GHG emissions reduction comes from the fact that upstate New York has the cleanest electrical grid in the country, meaning that no other grid generates more of its power from clean renewable energy sources than upstate NY.[44] As you can see in the figure 6 below, the emissions from electricity generation in Upstate NY are becoming less carbon intensive each year. What this means is that the incentive for using electricity as fuel is improving every year, unlike the case for using a depleting resource such as diesel fuel. As time goes on it will become ever more costly in terms of social costs and financial costs if we keep relying on fossil fuels for our transportation needs. Whereas if we switch to using electricity as fuel for our transportation needs the greenhouse gas emissions and therefore social costs will

[44] United States Environmental Protection Agency. *eGRID Summary Tables 2018.* Washington, DC: Clean Air Markets Division, 2018.

continue to decrease going forward as more of our energy gets sourced from clean renewable energy projects.

**Figure 6: Upstate NY CO2 Emission Factor**




Finally we will convert our calculated GHG emissions into quantifiable financial costs, in order to represent the social cost of an electric vs. diesel bus. Costs associated with the release of greenhouse gas are monetized using the social cost of carbon method. This method is used to measure in dollars the long term damage done by a ton of carbon dioxide emissions released in the atmosphere. The dollar figure can also be used to represent the value of damages avoided from emission reductions. The cost of carbon can vary significantly based on the underlying assumptions that go into its calculation. For the purpose of this analysis we will use the EPA's estimated social cost of carbon which is $57 per ton of carbon dioxide, assuming a 3% discount rate.[45] Given that each diesel bus emits approximately 80.2 tons of carbon dioxide equivalent gases per year, the annual social cost from the emissions directly related to each diesel bus the NFTA has is **$4,571**. Repeating this calculation for an electric bus, which emits roughly 8.8 tons of carbon dioxide equivalents, we come up with an annual social cost of **$501** per electric bus. Not only does using electric buses lower maintenance and fuel costs for the NFTA, but as this section has demonstrated it also drastically lowers the social cost from GHG pollution which is shared by everyone, and will especially affect future generations. Everyone would benefit if emissions were reduced.

If the NFTA were to swap a diesel bus out for a new zero emission electric bus the NFTA would be eliminating approximately 857 tons of CO2e from the atmosphere over the 12 year lifetime of every bus that is replaced. The NFTA currently operates 126 diesel buses in their fleet as of 2019. If all of the diesel buses were swapped out with zero emission buses this would save 107,982 tons of CO2e from being emitted into the atmosphere. This would adhere to the Intended Nationally Determined Contribution that the U.S. submitted in support of the Paris COP21, which commits the U.S. to reduce GHGs by a billion metric tons per year by 2025, from 2015 actuals.[46] Emissions could even further be reduced if the NFTA replaced the compressed natural gas and hybrid buses with electric buses as well. However this is simply outside the scope of this paper because the NFTA just recently installed a compressed natural gas fueling station at one

[45] EPA Fact Sheet: Social Cost of Carbon pdf

[46] "Intended Nationally Determined Contribution." *United States of America.* UNFCCC, 2015.

of their bus garages so this bus garage will not be retiring any of the compressed natural gas buses in the near future.

The current approach by the NFTA to reduce greenhouse gas emissions from fleet buses is not working. This can be seen in the data when looking at the NFTA's system vehicles carbon footprint. Excluding the gasoline vans, the total fleet emissions in 2018 and 2019 were both the same. From 2018 to 2019 the CO2 emissions from the diesel buses were reduced but the CO2 emissions from the compressed natural gas buses increased by the same amount, equating to zero percentage change or no actual CO2 emission reductions. What this shows is that even though the NFTA is replacing some of their diesel buses for compressed natural gas buses, it is not achieving any emission reductions. This is mainly due to the fact that the compressed natural gas buses emit almost two hundred times more methane compared to a diesel bus. The greenhouse gas global warming potential of methane is 25 times more harmful than CO2. When the total emissions of a diesel bus and a compressed natural gas bus are converted to CO2e there is very little difference in terms of emissions. An entire compressed natural gas (CNG) analysis is outside of the scope of this report. However, due to CNG buses' lack of CO2e emission reductions compared to diesel buses, we suggest the NFTA no longer purchase CNG or diesel buses and instead only purchase electric buses.

## 2.4 Healthcare Costs from Diesel Emissions

Improving air quality and public health should be at the forefront of any decision when determining which fuel powered transit bus to purchase. The implications of business as usual of continuing to burn fossil fuels for our transportation needs would not only negatively affect our lives, but would also impose negative externality costs on third parties, including future generations. Since we all breathe the same air, the costs incurred as a result from pollution gets shifted to everyone, this is where the phrase social costs comes from. The good news is that there is now a better alternative for transit buses than continuing to burn fossil fuels, which release harmful greenhouse gases. The better alternative is zero emission electric buses which can be powered by clean renewable energy. Zero emission electric buses improve air quality and public health while also lowering operational costs as well as public health care costs.

According to the Union of Concerned Scientist, diesel powered vehicles account for two-thirds of all the particulate matter emitted from the U.S. transportation sector.[47] The pollution from diesel exhaust has been linked to increased rates of several diseases, including chronic heart and lung disease, lung cancer, asthma, and emphysema as well as many others. According to a study conducted by the Massachusetts Institute of Technology, emissions from tail pipe exhaust cause 53,000 premature deaths each year in the United States.[48]

Diesel exhaust is a mixture of thousands of gases and fine particles that contain more than 40 toxic air contaminants. Some are known cancer causing toxins such as benzene, arsenic and formaldehyde. The exhaust also includes nitrogen oxides which is one of the components of smog which can be visible to the naked eye in several major cities across the globe. When smog is inhaled, the risks of serious heart and lung disease

[47] Lyndsey Gilpin, "These City Bus Routes are Going All Electric." Inside Climate News. October 25, 2017, https://insideclimatenews.org/new/18102017/these-city-bus-routes-are-going-all-electric

[48] Chu, Jennifer (2013). "Study: Air pollution causes 200,000 ealry deaths each year in the U.S." MIT News Office.

increases. Long term exposure to diesel exhaust poses the highest cancer risk out of any of the air contaminants according to the Office of Environmental Health Hazard Assessment.

The U.S. Environmental Protection Agency (EPA) has developed a tool called the Diesel Emissions Quantifier to help understand the impacts from diesel emissions.[49] The tool quantifies diesel emissions for the purpose of monetizing the social costs related to the emissions. The tool calculates improvements for particulate matter, greenhouse gases and nitrous oxides, however the health benefit analysis part of the tool is based on improvements in particulate matter only. Particulate matter from diesel exhaust is responsible for a number of lung and heart diseases such as heart attacks, irregular heartbeat, and decreased lung function which causes difficulty breathing.[50] The tool considers the cost from hospitalizations, emergency rooms visits, and the absence from work as a result from the above mentioned health issues. Switching from diesel to electric buses reduces the amount of particulate matter in the air, which improves public health and reduces healthcare costs. The tool was run assuming the buses travel 32,058 miles annually and use approximately 7,124 gallons of fuel annually per bus. The particulate matter reduction associated with the elimination of diesel fuel usage was calculated at 100% for the area in which the buses operate. It was assumed that 80% of the bus miles are driven in Erie county, and 20% of the miles were driven in Niagara county. The decision to use the 80%, 20% mileage breakdown is based on the population of Erie to Niagara county. Using this mix of bus miles, the health care cost which could be avoided

[49] "Diesel Emission Quantifier (DEQ)," U.S. Environmental Protection Agency, July 21,2020
[50] ibid

as a result of switching from a diesel bus to a zero emission electric bus is calculated to be approximately $**12,000** annually.[51]

**Table 3: EPA Diesel Emission Quantifier Tool Health Benefit Results**

| County and State | Annual Diesel PM2.5 Reduction (tons) | Annual Benefits |
|---|---|---|
| Erie, New York | 0.0113 | $9,700 |
| Niagara, New York | 0.0028 | $2,200 |
| **Total** | 0.0141 | **$12,000** |

Source: EPA Diesel Emission Quantifier Tool

Reduced emissions, leads to reduced spending on healthcare costs related to exhaust. According to the EPA's Diesel Emission Quantifier Health Benefits Methodology, the monetary value of the cost savings from reduced incidents of illnesses and respiratory diseases is $**12,000** annually per bus in Buffalo. Switching from a diesel bus to a zero emission electric bus saves money from reduced healthcare costs as well as improves public health.

In 2003 there was a study conducted by J. S. Mukasa-Lwebuga, who concluded that there is a statistically significant spatial correlation between high concentration areas of diesel exhaust and increased rates of Asthma.[52] The diesel trucks that sit in line on the Peace Bridge idling while waiting to get into Canada is the major reason why the densely populated west side of Buffalo neighborhood downwind from the Peace Bridge has some of the worst asthma rates in the country. This is mentioned because the diesel semi trucks

[51] ibid

[52] Lwebuga-Mukasa, J. S. (2003). "Traffic Volumes and Respiratory Health Care Utilization among Residents in Close Proximity to the Peace Bridge Before and After September 11, 2001." Journal of Asthma 40(8): 855-864.

that cross the peace bridge are burning the same fuel and emitting the same exhaust as the NFTA diesel buses. This is a local example of how diesel emissions are negatively impacting the health of our residents, and all the more reason to transition away from using diesel fuel.

# Chapter 3: Batteries

The two most important characteristics of an electric vehicles battery are the range and time it takes to recharge the battery. In a study that involved interviewing eight different transit authorities working on electric bus adoption programs the main concerns were found to be how well the batteries would perform in cold temperatures. Since this seems to be a common concern of transit authorities I wanted to address it and shed some light on it.

The company BYD which is the largest electric bus manufacturer, offers their electric bus model with 177 mile range. Proterra, the second largest manufacturer of electric buses offers their middle of the line model the zx5max with a 250 mile range. The average daily distance of a typical NFTA bus is 87 miles which is well within the range of a single charge of either option. Based on the fact that these electric buses offer twice as much range as the average NFTA bus needs, this should provide enough of a margin of error in terms of range when the batteries are exposed to freezing temperatures during winter. However, until the real world performance of the batteries are tested in cold weather and better understood the electric buses could be introduced into the fleet starting with replacing the diesel buses on the shortest routes. This would help compensate for any potential range reductions as a result of cold temperatures.

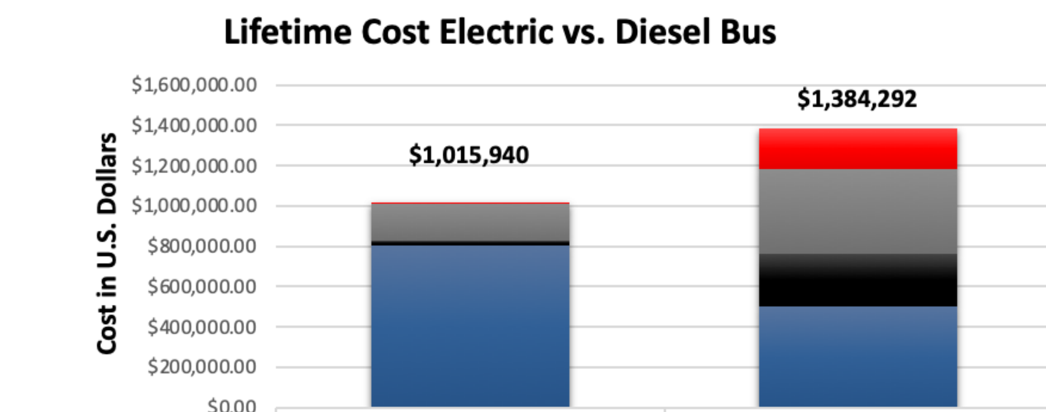
Charging times for these buses vary depending on the amount of power supplied to the charger but the average charge time is 2.5 hours and can be done overnight in the garages. Cell phones and laptops both demonstrate existing real world application of lithium-ion batteries. Since Lithium-ion batteries are successfully used in both of these applications there is solid evidence that they would work to power buses as well. Battery technology is also evolving and improving as more money pours into research as humanity looks for alternatives to fossil fuel use. As a result, battery costs which are the most expensive part of an electric bus, have fallen by 79% since 2010 at the same time battery density is increasing, and both of these factors will continue to do so as the market for electric bus batteries matures[53]

[53] Aleksandra O'Donovan, James Frith, and Colin Mckerracher," "Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2" (policy report, Bloomberg New Energy Finance, 2018).

# Chapter 4: Lifetime Costs Electric vs. Diesel Bus

This section aggregates all the financial costs which we have calculated throughout our analysis. Figure 7 below, visually represents the lifetime financial cost difference between a diesel and electric bus. When comparing the total lifetime costs of a typical NFTA diesel bus vs a zero emission electric bus traveling the same distance, the overall 12 year lifetime cost of an electric bus is about $368,352 or (27%) less than the cost of a diesel bus.

**Figure: 7 Total Lifetime Cost of an Electric Bus Compared to a Diesel Bus**




| | Electric Bus | Diesel Bus |
|---|---|---|
| Healthcare / Cost of Carbon | $6,012.00 | $198,852.00 |
| Maintenance Cost | $180,000.00 | $420,000.00 |
| Fuel/Electricity Cost | $26,928.00 | $265,440.00 |
| Purchase Price | $803,000.00 | $500,000.00 |

## 4.1 Payback Period & NPV

From the perspective of the NFTA, an upfront investment for a diesel bus or an electric bus requires careful consideration of the payback period and the net present value (NPV) of the series of cash flows which takes into account the time value of money. For the payback period and NPV calculations in (Table 4) below we did one calculation excluding the healthcare benefits and social cost of carbon and the other calculation including both these social costs. The results of the payback period calculation excluding the healthcare benefits and the social cost of carbon was 7.6 years. By including the healthcare benefits and social cost of carbon the payback period shortens to 5.4 years.

For the NPV calculation the initial cash outlay was $303,000 and the discount rate used was 3%. The $303,000 represents the additional cost of purchasing an electric bus over a diesel bus. The $303,000 also will be recovered by the payback period through the benefits of lower operational costs as discussed previously. The NPV excluding healthcare benefits and the social cost of carbon is a positive $93,925 whereas the NPV including the healthcare benefits and social cost of carbon is a positive $253,886. Based on these results the investment in new electric buses for the NFTA is worthwhile. The $253,886 represents the net present value of switching one diesel bus out for a one electric bus. If we then multiply this figure by 126 which is the amount of diesel buses in the NFTA fleet we come up with a net present value of just over 32 million dollars. What this means is that the transition away from diesel buses to electric buses for the NFTA is financially, socially and environmentally beneficial and the investment in new electric buses is worth undertaking.

**Table 4: NPV & Payback Period for the cost difference between diesel & electric bus**

| | |
|---|---|
| **Purchase Price Difference** | **$303,000** |
| Fuel Cost Savings | $19,876 |
| Maintenance Cost Savings | $20,000 |
| **Subtotal Savings / Year** | **$39,876** |
| Payback at Subtotal | 7.6 yrs |
| NPV | **$93,925** |
| Social Cost of Carbon Savings | $4,070 |
| Healthcare Cost Savings | $12,000 |
| **Total Savings / Year** | **$55,946** |
| Total Payback | 5.4 yrs |
| NPV | **$253,886.00** |

The case for the NFTA to transition to electric buses is financially sound before the funds from federal grant programs are even taken into consideration. However, the $2.5 million awarded to the NFTA for the purchase of new electric buses and related charging equipment would help cover the additional $303,000. Bloomberg New Energy Finance also estimates that electric buses will reach unsubsidised purchase price parity with diesel buses by 2030.[54] This will further improve the case for electric buses over diesel buses.

[54] Bloomberg NEF, *Electric Buses in Cities: Driving Towards Cleaner Air and lower CO2* March 29, 2018, archived at https://web.archive.org/web/20190920210558/https://data.bloomberglp.com/professional/sites/24/2018/05/Electric-Buses-in-Cities-Report-BNEF-C40-Citi.pdf.

## Conclusion

Based on the results of our analysis it can be concluded that a diesel to electric bus conversion for the NFTA would reduce bus costs to the city, as well as greenhouse gas and particulate matter emissions. This would improve the NFTA budget and health of our residents, while also lowering their healthcare costs. The initial cost of an electric bus compared to a diesel bus is higher, however the fuel and maintenance savings alone of an electric bus more than offsets the additional upfront cost over the life of the bus. When including the federal grants available for electric buses and the costs avoided from greenhouse gas emissions and related healthcare issues, electric buses are the clear choice over diesel buses for our transportation needs.

The most environmentally conscious, and fiscally responsible way to incorporate new electric buses into the NFTA fleet would be to start with replacing the oldest diesel buses first. By gradually introducing the electric buses into the fleet this would allow the NFTA time to gain experience and understanding with respect to the operations of an electric bus with a small number of them, before deciding on the best way to expand the rollout to the rest of the fleet. By taking part in the transition to electric buses the NFTA will be making a great stride towards a cleaner, more sustainable transportation future, and the NFTA along with the community as a whole will benefit.

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