



**Economic and Operation Feasibility Study:
Conversion to Electric Bus for Gray Line's Airport Route**

Kimberly Ann Carpico

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Tough E. Questions

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date

Kimberly Ann Carpico
Master of Science

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Abstract

Widespread adoption of electric buses could take advantage of Iceland's low-carbon energy mix and simultaneously help Iceland reach its objective of reducing greenhouse gas emissions. The purpose of this project was to conduct an operational and economic feasibility study for the addition of an electric bus to Gray Line's Airport Express Route. This route provides transportation to and from Keflavik International Airport to Reykjavik. For the study we chose a BYD C9 electric bus as a candidate to replace the Volvo Sidreal 2000 diesel bus. The C9 electric bus performed nearly identical to the diesel bus in their current fleet, with no need for additional labor hours or changes in scheduled stops or frequency of stops. Minimal changes to the existing operational structure were necessary to utilize the electric bus for this route: (1) To ensure the battery of the electric bus was always sufficiently powered, it needed to be charged one hour at each end of the 51.6 kilometer trip to and from the airport by taking advantage of the already scheduled one-hour breaks in their current structure and (2) Arriving buses on each end of the trip need to form a horizontal row for access to the charging stations instead of the line formation currently used. An economic feasibility study examined the costs of three possible scenarios for the Airport Express Route in order to determine which scenario had the least inherent risk and therefore represented the best option. The three scenarios analyzed were the business as usual scenario in which the current 2013 Volvo Sidreal 2000 diesel bus is used, the scenario in which the BYD C9 electric bus is used accounting for half the cost of a charging station per bus, and the scenario in which the BYD C9 electric bus is used without the associated cost of charging stations. Accounting for the accumulated cost as a function of years, the cost of the electric bus without the needed charging stations broke-even with the NPV of the diesel bus in the 8th year. The project with the necessary installment of charging stations was the least feasible due to the higher costs associated with building the charging stations. Various sensitivity analyses were run to determine how different variables affected the NPV of the three investment options. Running the fluctuation of the cost of diesel to the NPV showed that the cost of fuel would only need to rise 7% before it was competitive with the investment in the BYD C9 electric bus without the cost of the fast-chargers included and 28% to be competitive with the EV bus plus 2 charging stations. The final sensitivity analysis showed that the cost of the charging stations would need to be supplemented in order for the project to be competitive with the 2013 Volvo Sidreal 2000 diesel bus. The results of this work illustrate the urgent need for both the political and economic will to support private companies and entrepreneurs with the start-up costs needed for the adoption of low-carbon alternatives, a competitive option that would also help meet the Icelandic government's stated objective to substantially reduce its GHG emissions.

Hagræn og rekstrarleg hagkvæmniathugun: Hraðleið Gray Line til og frá Keflavíkurflugvelli

Kimberly Ann Carpico
June 2016

Útdráttur

Víðtæk innleiðing rafknúinna hópferðabifreiða á Íslandi með því að nýta íslenska orkugjafa er vænlegur kostur og gæti samtímis styrkt Ísland í að ná markmiði sínu að minnka losun gróðurhúsalofttegunda. Tilgangur þessa verkefnis var að framkvæma hagræna og rekstrarlega hagkvæmni athugun á því að bæta við rafknúinni BYD C9 hópferðabifreið á hraðleið Gray Line til og frá Keflavíkurflugvelli. Afköst rafknúinnar C9 hópferða-bifreiðar voru nánast sambærilegar við díselknúnar hópferðabifreiðar fyrirtækisins og þurfti hvorki að fjölga vinnustundum né breyta tíðni eða lengd stoppa í áætlun Greay Line. Aðeins þurfti lágmarks breytingar á núverandi rekstri fyrirtækisins til að innleiða rafknúnu hópferðabifreiðina fyrir þessa áætlunarleið: (1) Til að tryggja að rafhlaða hópferðabifreiðarinnar væri ávallt nægilega hlaðin þurfti að hlaða hana í klukkutíma á hvorum enda hinnar 51,6 kílómetra leiðar til og frá flugvöllinum, sem féll beint inn í þáverandi klukkutíma hlé í áætluninni og (2) hópferðabifreiðarnar á hvorum enda leiðarinnar þurftu að standa hlið við hlið til að hafa aðgang að hleðslustöðvunum í stað þess að standa í röð eins og þær gera í dag. Gerð var rekstrarleg hagkvæmnisathugun á þremur mismunandi fjárfestingarvalkostum fyrir Keflavíkurflugvallarhraðleiðina til að komast að því hvaða fjárfesting fæli í sér minnsta áættu og væri þar af leiðandi hagkvæmasti fjárfestingarkosturinn. Fjárfestingarkostirnir þrír sem voru skoðaðir voru, kostnaður við að nýta núverandi 2013 árgerð Volvo Sidreal 2000 dísel hópferðabifreið, kostnaður við BYD C9 rafknúina hópferðabifreið ásamt tveimur hraðhleðslustöðvum, og við kaup á BYD C9 rafknúinni hópferðabifreið einni og sér. Þegar núvirtur heildar uppsafnaður kostnaður var skoðaður, sem fall af tíma kom í ljós að rafknúin hópferðabifreið án hleðslustöðva tekur rúmlega sjö ár að ná núllpunkti miðað við fjárfestingu í dísel hópferðabifreið. Fjárfestingarkosturinn sem inniheldur hleðslustöðvar var metinn óhagkvæmastur vegna hás kostnaðar við uppsetningu hleðslustöðvanna. Næmnigreining var gerð til að meta áhrif mismunandi þátta á núvirði fjárfestingarkostanna þriggja. Þegar skoðuð var breyting á verði á eldsneytis, kom í ljós að aðeins þurfti 7% hækkun upp í 61 kr/km til að kaup á BYD C9 rafknúinni hópferða-bifreið einni og sér væru jafn vænleg og kaup á dísel hópferðabifreið og 28% hækkun fyrir kaup á rafknúinni hópferðabifreið ásamt hleðslustöðvum. Næmnigreiningin sýndi einnig að nauðsynlegt er að fá kostnaðinn við hleðslustöðvarnar niðurgreiddann til að rafknúin hópferðabifreið ásamt hleðslustöðvum væri vænlegur kostur miðað við dísel hópferðabifreið. Niðurstaða verkefnisins sýnir fram á brýna þörf á pólitískum aðgerðum eða einkavæddu framtaki til að styðja fyrirtæki og frumkvöðla við fjármögnun upphafskostnaðar við innleiðingu lausna sem fela í sér lága kolvetnislosun, samkeppnishæfan kost sem hjálpar Íslandi að ná yfirlýstu markmiði sínu um stórlækkaðan útblástur gróðurhúsalofttegunda.

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List of Acronyms

UNFCCC	The United Nations Framework Convention on Climate Change
AER	Airport Express Route
IPCC	The Intergovernmental Panel on Climate Changes
EV	Electric Vehicle
NAS	National Academy of Science
EU-ETS	European Union – Emissions Trading Scheme
GHG	Greenhouse Gases
VAT	Value Added Tax
ICE	Internal Combustion Engine
TCO	Total Cost of Ownership
BYD	Build Your Dreams
LFP	Lithium Iron Phosphate
SOC	State of Charge
PV	Present Value
NPV	Net Present Value
PM	Particulate Matter
BMTC	Bangalore Metropolitan Corporation
EVEN	Electric Vehicle Environment
UTE	Uruguay’s National Utility Company
ROI	Return On Investment

1 Introduction

Iceland is often depicted as a land powered by clean energy, and open spaces. Iceland's near complete transition to a zero-emission carbon economy is widely recognized as a global world leader in transforming its space heating from predominantly coal to hydroelectric and geothermal. [1] Today the transportation and fishing vessels remain the largest sector still utilizing fossil fuels. [2] Iceland's Climate Strategy introduced in 2007 was created to serve as a framework for their stated objective of decreasing GHG emissions from their 1990 levels by as much as 50-75%. [3] This project explains how political and economic reform could help achieve the Icelandic government's ambitious goals. In light of Iceland's energy mix, Iceland has the opportunity to boost itself as self-sustaining global leader, and use its low-carbon energy mix to power electric buses and vehicles. This would save much needed currency to purchase diesel fuel. Private companies will need incentivized to adopt electric buses on wider scale.

The purpose of this project takes Gray Line, a touring company offering shuttle services to and from the airport to Reykjavik and first conducts an operational feasibility study comparing the differences in running an BYD C9 electric bus to a 2013 Volvo Sidreal diesel bus in their Airport Express Route (AER). The AER shuttles passengers to and from the airport. The two buses to be compared were picked because Gray Line stated the need to enlarge their current 7 bus AER fleet with the addition of two buses with a seating capacity of about 48 passengers each. Secondly, an economic feasibility study analyzed the costs of three investment alternatives to be compared, the 2013 Volvo Sidreal 2000 diesel bus, a BYD C9 electric bus with two fast-chargers and the cost of the C9 electric bus without the charging stations. Gray Line currently uses each bus in their AER for approximately 6 to 7 years. Therefore, the accumulated costs of each bus were accounted for over an 8-year lifecycle, to be sold at the beginning of the final year. The accumulated costs then account for the time-value of money, resulting in a NPV for each project. Because only costs were included, the lowest NPV was estimated to be the best investment. In addition, several sensitivity analyses were run to compare how individual variables would affect the competitiveness for the project. The results illustrated significant gaps in both political and economic incentives to lower carbon emissions as stated in Iceland's Climate Strategy. In order for the Icelandic government to reach their stated objective of reducing GHG emissions by 2050 significant reform will need to be implemented.

2 Background

2.1 Climate change

Climate change has become one of the most paramount issues of our time. By the year 2050, it is expected that nearly a quarter of the species on earth will become extinct due to rising environmental temperatures. [4] In February 2007 Iceland's Ministry of Environment put

forward a Climate Change Strategy as part of their effort to be a party member of both the UN Framework Convention on Climate Change and the Kyoto Protocol. Iceland's Climate Strategy was developed to serve as a structure to help create action and government backing for climate change issues. The Strategy seeks an ambitious goal of reducing greenhouse gases by 50-75% by the year 2050 relative to 1990 levels. [3]

In many respects Iceland's energy profile is unique. First, the majority of the electricity generated for space heating and electricity comes from geothermal, or hydropower, both of which are much cleaner energy sources than those used by most of the industrialized world. [5] Nearly 80% of greenhouse gas emissions is generated from transportation, including personal vehicles, fishing vessels and mobile machinery. [3] Given this criteria, it would be a missed opportunity not to act on building an electric car infrastructure that supports converting diesel buses to electric, and persuades personal vehicle owners to do the same. The construct of this alternative infrastructure is compelling in light of its proportional impact on the reduction of greenhouse gas emissions if it can also be proven to offer Iceland a model with an immediate and long term economic advantage. The figure below shows the breakdown of the Icelandic greenhouse gas emissions by sector. [6] The actions of the Icelandic government since 2008 has increasingly attracted the use of heavy industry because of its clean, abundant and stable supply of electricity.

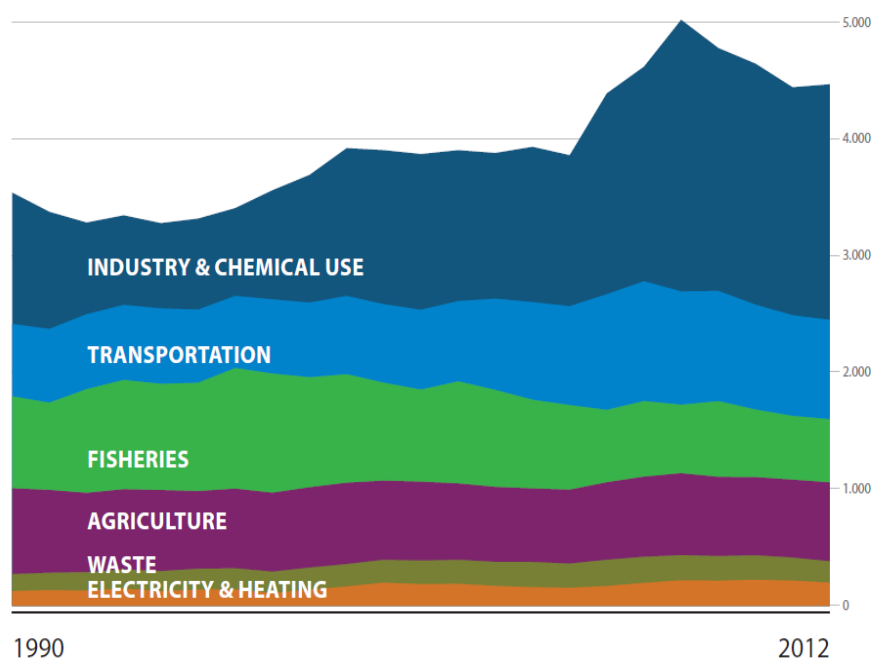


Figure 1: Icelandic greenhouse gas emissions by category (thousands of tons-CO2 equivalent) [6]

As part of The United Nations Framework Convention on Climate Change (UNFCCC) Iceland is required to submit a report annually of its inventory of anthropogenic emissions by category and removals, the purpose of which is to stay within limits set by the Kyoto Protocol. To comply with this agreement, Iceland prepared "The National Inventory Report 2015: Emissions of greenhouse gases in Iceland from 1990 to 2013." Despite these efforts, Iceland's carbon dioxide emissions have increased over 22% since 1990. [7] In the National

Inventory Report below the gases listed are CO₂ (carbon dioxide), methane (CH₄), nitrous oxide (N₂O) and fluorinated gases (f-gases). According to the Environmental Agency of Iceland the most significant increase of GHG emissions since 1990 has been the rapid expansion of metal production, specifically from aluminum plants, which also propelled the necessity for more power capacity. Since 1990, Decision 14/CP.7 allows Iceland to report certain industrial process emissions separately if it will make them exceed the agreed upon emissions in the reporting period. [8] The Icelandic legislature argued heavy, energy-intensive industries would best be exempted from taxes to discourage green-house emissions because Iceland's low-carbon energy mix would use less power than other country's production. It was argued that industry encouraged global business development and increased economic welfare within Iceland. It is for these reasons that it has become increasingly difficult to control how much the government is capable of regulating.

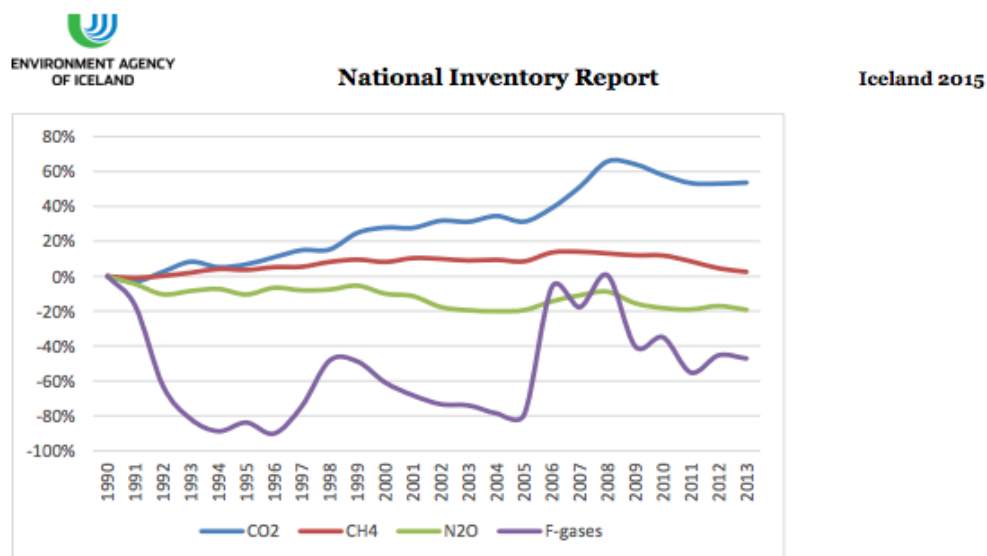


Figure 2 Percentage changes in emissions of GHG by gas 1990-2013, compared to 1990 levels [7]

The Intergovernmental Panel on Climate Change (IPCC) is a scientific panel which develops reports to assist the UNFCCC implement a framework to reduce greenhouse gas emissions. [9] The IPCC 3rd Working Group which focuses on the mitigation of climate change states in its Technical Summary that it is the lack of public policy and other supporting instruments that presents the largest barrier to deploying low-carbon technologies. [10] It goes without saying, that policy instruments which encourage carbon-intensive industries to utilize the tax exemptions for economic growth, preclude the use of other financial tools which would support a new economic growth model which capitalizes on Iceland's low-carbon energy mix. Incentives to strengthen the viability of implementing low-carbon technologies hold great promise to the extent that current economic and political incentives need reanalyzed and reformed to meet both goals of the reduction of carbon emissions and economic growth offerings unique to Iceland. Investing in electric vehicle infrastructure for commercial use will encourage the future growth of electric vehicles (EV's) in the commercial and private sectors. For this reason, a commercial electric bus route to and from Keflavik International Airport could showcase this technology if deemed operationally, and economically feasible and in consideration to the various environmental gains. The overarching goal of this paper is to

analyze the operational and economic feasibility of converting to an electric bus model, specifically the feasibility for the replacement of one diesel bus, which operates on a specific route from the Keflavik airport to Reykjavik for Gray Line, one of two bus companies that currently operate this route. The study provides an environmental overview comparing the two methods of transportation.

2.2 Tourism and Global Image

Transportation of a rapidly increasing amount of visitors to and from the airport by means of diesel buses would contribute to an increase in GHG (green-house gas) emissions. Adding, or converting diesel buses to electric buses has the potential to offset some of this increase. Tourism has become the largest sector of the Icelandic economy, overtaking fishing for the first time in history. [11] In 2013 an independent report undertaken by the Boston Consulting Group by a number of private companies concluded that for the next decade tourism in Iceland will likely continue to grow. [12] Of more significance to this project, this report sought to address the projected ten-year growth period of Icelandic tourism with a managed approach to a more sustainable growth. Based upon tourist spending patterns, they identified two target markets, “affluent adventurers and older relaxers” inherently drawn here for tourism. Both of these groups of tourists are drawn because of their perception of Iceland as a land of untouched nature. Given these two variables, defined as the most significant, marketing this image to the two segments will strengthen the appeal of Iceland and its economic growth by the most sustainable means. Transitioning, or creating an electric bus route to and from the airport would not only help market this image, but also bear truth as it helps to curb carbon emissions from the transportation sector referenced above as a major contributor. [3]

2.3 EV's in Iceland

The transportation and fishing fleets are the only two sectors that still rely on fossil fuels in Iceland. Some studies have been conducted on the optimum low-carbon transition for the vehicle fleet of Iceland. One such study examined alternative fuel vehicles based on fuel demand, GHG emissions, and their associated costs. [13] In consideration of these variables EV's were determined to be the overall winner. Moreover, the cost-analysis of this study determined that investment in alternative fuel infrastructure will mitigate GHG emissions, and save the government currency otherwise spent on fossil fuels. Other similar studies for Iceland consistently conclude that EV's are the most prominent solution for the transportation fleet in terms of cost effective way of reducing emissions and increasing energy security with the use of the domestic renewable energy sources. [14] [15] [16] [13] [17] [18]

The aforementioned studies do not consider the case of heavy duty vehicles like busses. This is partly due to lack of suitable electric heavy duty vehicles. That has however recently changed and now some very interesting heavy duty vehicles have been introduced in the market, in particular busses such as the BYD C9. The other part of the reason for why the aforementioned studies have not considered electric heavy duty vehicles is the fact that there is currently no VAT (Value Added Tax) for heavy duty vehicles regardless of whether it is diesel, electric, or hybrid. [19] Removing the VAT exemption for internal combustion engine (ICE) commercial vehicles would make EV's a more competitive technology. Of course, if EV's are to be widely adopted in Iceland it will be necessary to expand the charging

infrastructure to make the electrical model practical. For purposes of this project, the operational feasibility was conducted assuming the installment of the charging infrastructure. The economic feasibility was analyzed using two scenarios, one with fast-chargers and one without. More analysis needs conducted on which financial instruments would help offset the necessity of the extra infrastructure required.

Some studies have illustrated the possibility of EV's contributing to a larger market share in Iceland. [20] In order for this to be realized, it was determined that certain variables need to be met, including addressing vehicle taxes, fuel prices, future cost of EV's, and the need for additional infrastructure. [20] Similar investigative analysis has pointed to the need for push-pull schemes that drive the demand and competitiveness of low-carbon alternatives. [21] [22] An example of a push factor would be a subsidy offered to a business that may want to install charging infrastructure. In contrast, the pull factor would encourage businesses to invest in the development around electric vehicles. Both legislated incentives are designed to offset the total cost of ownership (TCO). In addition, Haddadian and colleagues emphasize that carbon reduction can only be achieved through EV's if the electricity being generated is from clean sources. The National Energy Authority states that Iceland generates 99% of its electricity from cleaner sources, such as hydroelectric and geothermal energy, therefore electrifying nonrenewable sourced transportation would have a significant impact on the reduction of GHG. [23] Iceland's strategic advantage of being powered by its low-carbon energy mix has the potential to reduce transportation-related emissions to a greater degree.

Because of the large abundance of under-utilized and stable energy sources, Iceland's electricity prices have not fluctuated [24] In addition, political stability aids in keeping the price stable. Electricity prices exclude the costs associated with the transmission and distribution of energy, so excluding this, energy prices in Iceland currently sit at 6.80kr. [25] It is for these reasons that some members of the Icelandic government have prioritized and capitalized on the development of its energy sources for economic growth. As it stands today, more than half of the power produced within the country is used for export-oriented energy-intensive industries. [24]

2.4 Fossil fuel importation to Iceland

Commercially converting, or adding electric buses to the frequented airport route would save currency otherwise spent on the importation of fossil fuels. This mirrors 20th Century Iceland as it transformed from one of the poorest countries in Europe, dependent on coal and fossil fuels, to a country that harnesses the majority of its energy production within the country through geothermal and hydroelectric power. [23] However, as the quality of life rose the number of vehicles on the road continued to increase. As a result, 1990 baseline GHG emissions from road transport steadily rose to nearly 39%. [13]Iceland, however remains dependent on the use of fossil fuels for transportation. Approximately 90% of the fuel imported is used for transportation, the burning of which represents one third of Iceland's total contribution to GHG emissions. [11]

Orkustofnun, a government agency under the administration of the Ministry of Industries and Innovation, calculated the cost of all imported fuels to be one-tenth of the country's annual average of total imports. [26]

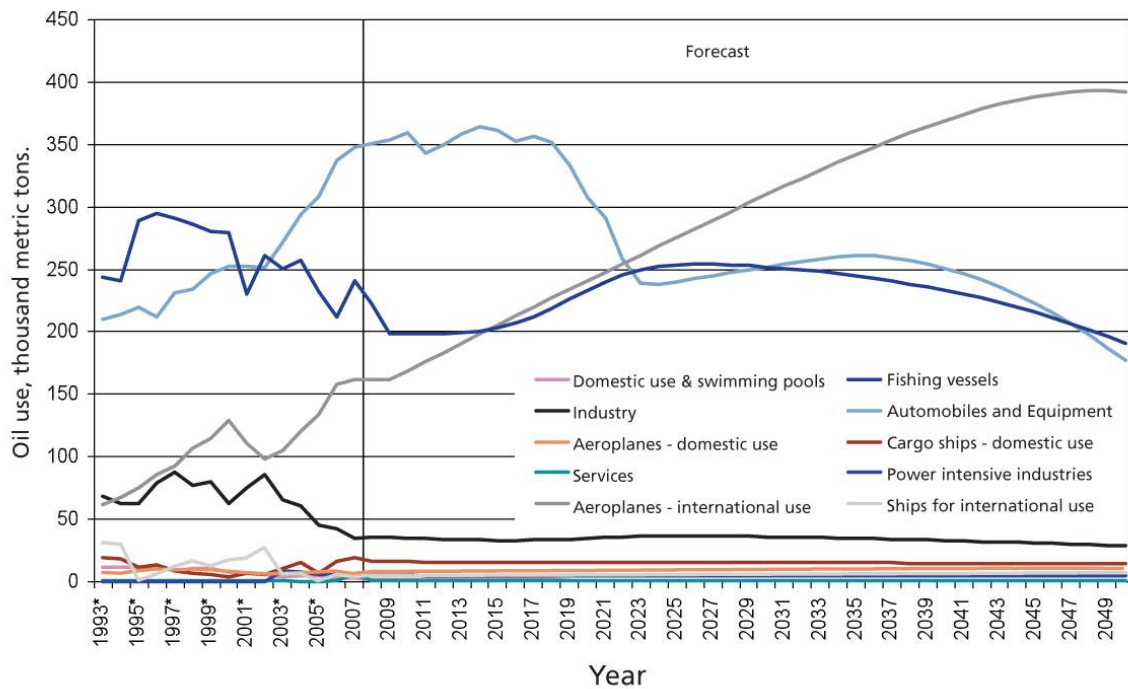


Figure 3: Fuel Use Forecast [27]

The above figure shows that in approximately the year 2020 vehicle use dramatically decreases, which indicates that Iceland will transition from fossil fuels to another source of energy. Orkustofnun collects data from private companies, institutions and energy organizations within Iceland, including the Ministry of Finance. Since the data indicates a clear decrease of oil use for automobiles and equipment, they may be analyzing methods of transitioning away from fossil fuels. Further analysis into the possible market mechanisms to push and pull wider adoption of electric vehicles and their required infrastructure is needed.

2.5 Electric Buses

Private companies need financial and political incentives to drive the competitiveness of electric buses, and dissuade further investment into diesel buses. A battery electric bus is 'fueled' by electricity that has been stored in on-board battery packs that power the motor. Even with the additional investment in charging stations, the overhead cost of a proposed railway from Keflavik to Reykjavik incurs much higher overhead costs. [28] Electric buses have the added advantage of being extremely quiet, and having zero direct emissions. Because electricity in Iceland is generated primarily from hydroelectric and geothermal sources, the amount of carbon emissions produced from both direct and indirect emissions is a significant proportion of its total.

An added benefit of electric buses is their capability of recovering some of the power loss dissipated through what is called regenerative braking. It is not included as part of the study analysis of this project because it is difficult to determine with certainty the amount of energy saved. A conventional bus braking system loses energy as heat, but in regenerative braking, kinetic energy is transformed into a form that can be used either immediately, or stored for later use. The main challenges in adopting electric buses include the initial investment cost of

the bus, the lack of economic and political incentives, and depending on circumstances, the driving range. Though the electric bus has been on the market for a number of years, Build Your Dreams (BYD) is currently the only manufacturer to offer the option of coming equipped with undercarriage storage for passenger's luggage. BYD's electric bus is designed with a wheel-hub motor which is installed in the rear drive axle together with regenerative braking technologies. The wheel-hub motor increases the transmission efficiency as the power from the motor goes directly to the wheels producing instant torque. An added benefit of the BYD wheel-hub system is that it reduces sound and vibrations felt in the interior and has lower floors making them elderly and disability friendly. [29]

2.6 Electrifying Bus Fleets in Other Countries

There are examples of cities in other countries which have already been successful in replacing their diesel buses with electric buses. Little data is available on the logistics of how they operate relative to the buses which were replaced, or the payback ratios. For example, at the Schiphol airport in Amsterdam, a fleet of 35 BYD electric buses moves the passenger's short distances from the aircraft to the gate. The BYD electric buses used were custom designed for the airport, providing under luggage storage space, and coach-styled seating. The electric fleet at Schiphol is the first of its kind actualized at an airport worldwide. This project has gained The Schiphol Group international recognition for its corporate responsibility in sustainability. [30] During 6 months of service, the buses have driven 338,000 kilometers, saving approximately 312,000 kilograms of carbon dioxide. [31]

Similar projects deploying electric buses have recently been commissioned by the Department of Transportation in Washington state when they successfully bid for 800 electric buses. [32] The political climate in Washington state advocates for greener technologies which supported the ease of implementing this project. Buses to be used will range in size from 9 to 18-meters depending on whether they will be used for highway, or inter-city. This project is well on its way to becoming the largest contract for buses in U.S. history.

As of 2014, comparable projects have advanced in China where a vast number of buses have already been converted; 80,000 of 500,000 buses are powered by electricity. [33] The success of the electric bus has been in part due to China's "863 Program", which is a program laid out by the government to make its own advances in technology that reduces their dependence on the fiscal obligations of foreign technologies. As of November 2015, through mandate, the Chinese Ministry of Transport, Ministry of Finance and the Ministry of Industry and Information Technology cooperatively released legislation that mandates both local governments and stakeholders to integrate electric buses into the country's transportation fleet. These policies have not only put a small dent in China's rapidly increasing GHG emission, and set a path for, even mandated further implementation of low-carbon electric buses. [33]

San Francisco is another pace-setting city for low-emission transport, leading the United States to having one of the largest clean air municipal fleets. As much as half of the city's buses and light rail are powered by zero-emission vehicles, a total of over 700 clean energy vehicles, including hybrid and electric. [34] Again, just as in the case of China, San Francisco's ambitious goal was chartered by a government initiative. The 700 clean energy vehicle conversion resulted in the removal of 1,014 carbon dioxide tons. [34]

An even more encompassing program materialized in Gothenburg, Sweden, an area with a history of heavy industry, which successfully transformed their industrial urban center to a green, innovative waterfront city. The Green Gothenburg Program is much more comprehensive than merely addressing their transportation fleet; it has become a green technology think tank hub, bringing together companies both foreign and local to help facilitate their vision. It includes things such as waste management, urban planning, green bonds, a recycling park, biogas technology, Ekocentrum (a large conference that provides knowledge-based learning for companies seeking to build on their vision), and ElectriCity, a sustainable public transport system. [35]

Gothenburg has become Scandinavia's largest and most sustainable transportation hub. District administrators and municipal companies in ElectriCity have 94% green cars. [35] The Gothenburg Green Bus Project, known as ElectriCity, won a European sustainability project award for using renewable energy to operate their public transportation using EV buses. They attribute the success of this program to the many private and public companies involved in sustaining their vision. Their long-term goals include the continuation of both building infrastructure and increasing their share of public transport, pedestrian and bicycle transport. They are on track to reach their goal of reducing carbon dioxide in the city by 80% by the year 2030 compared to the 2010 levels. Another aggressive goal is to double their share of public transportation from 24% to 55% by the year 2035. [35] The bus project's main goal is to electrify its bus route #55, a proposal which has gained a great deal of attention by setting a compelling example to follow within Europe. When the bus batteries need replaced, they will then be used to store energy for apartment buildings in the area. It is this combination of leading by example, and the advancement of innovative solutions which are tied to a green economy, which continues to attract global attention to The Gothenburg Project.

2.7 Electric Buses from Keflavik to Reykjavik

This project proposes that Gray Line would initiate the conversion by electrifying a segment of their scheduled routes utilizing electric buses. Replacing their diesel buses with electric buses would help mitigate carbon emissions, reduce pollution and its associated health effects, and bring other inherent benefits to human welfare. In order for private companies to take the initiative, it will be necessary to set policy initiatives which provide the right financial instruments to offset initial increased costs of low-carbon technologies requiring the extra charging infrastructure. This operational feasibility will assess whether the battery capacity in the electric bus is sufficient to complete the trip from Reykjavik to Keflavik.

To review, emissions from fossil fuel driven vehicles and fishing vessels remain the most important challenge to task in order to combat GHG emissions in Iceland. Since the majority of Iceland's primary energy production comes from renewable geothermal and hydroelectric energy sources, the transition of the mobile transportation sector to the use of renewable energy sources such as the electric bus would yield significant reductions in Iceland's total carbon emissions. The use of cleaner energy sources gives Iceland a strategic advantage for combatting carbon dioxide over a country such as the United States, which has a more diverse energy profile. In comparison to conventional buses, the battery-driven electric bus would emit zero direct emissions, and would not contribute carbon emissions from indirect sources as no

fuel transport is required. This represents a significant reduction to Iceland's overall GHG emissions since the majority of its energy production is already provided by renewable low carbon sources.

2.8 Competitive Pressure: Proposed Keflavik to Reykjavik Railway

Municipality workers who have long been proposing a high-speed railway connecting Reykjavik to the airport, have begun preparations to sign a contract for the initial work to begin. [36] The only commercial transportation available from the airport is provided by two companies, Gray Line and Reykjavik Excursions. Adding a railway that shuttles passengers would have a significant negative impact on the market share of both companies. An environmental impact study will be conducted this spring, and if all goes accordingly, construction would begin by as soon as the year 2018. [37] The plan for the train would leave the greater Reykjavik area from BSÍ, and proceed through an underground tunnel stopping once in Hafnarfjörður, where it would travel the rest of the journey to Keflavik International Airport above ground at a speed of approximately 175 kilometers per hour. [28] Under one of the proposed plans for the train it would only take 15 to 20 minutes to be shuttled from Keflavik International Airport to Reykjavik. [28] But under current estimations the railway will cost upwards of 102 billion kr. These estimates do not take into account the time value of money, or changes in labor costs in the future. Meaning this estimate could rise due to variations in its potential earnings capacity. The high initial investment cost of the project will take approximately 10 years to recover the cost of the project without consideration to additional maintenance costs. Although no available information could be found on how the proposed train will be powered, it is more likely to use diesel as its source of energy.

3 Methodology

Gray Line's Airport Express Route carries passengers to and from the airport to Reykjavik. A growing one-million tourists visit Iceland each year with the majority utilizing one of the two companies that offer transportation back to the city. In order to determine if an electric bus can replace or be added to Gray Line's Airport Express Route, this paper will compare the operation of a single BYD C9 electric bus to a similar sized diesel bus in their fleet. Ultimately the BYD C9 was chosen for comparison due to its features and ease of comparison. An operational feasibility study will determine if it is possible to use an electric bus in the same manner as a diesel bus accounting for the required re-charge rates. Provided in this section will be the description of the schedule of buses, how long the drivers stop at each end point, the average one-way distance from Keflavik to Reykjavik, and approximate location of the charging points.

Through an economic feasibility study, it will analyze the economic costs of running this bus in comparison to the 53 seat, 2013 Volvo Sidreal 2000 diesel bus because of its similarities in size, and seating capacity. In addition to the environmental considerations of replacing a diesel bus, it will examine the resultant reduction in carbon emissions, and other intrinsic factors. The methodology section will define the processes and detailed descriptions of all variables to

be compared for both a diesel and an electric bus, including how the charging station will be utilized.

3.1 Gray Line's Airport Express Route

Founded in 1910, Gray Line Worldwide has operated travel and sightseeing tours in more than 700 locations. [38] Its Iceland branch already provides trips 365 days a year to and from the airport to Reykjavik. Along with a growing list of sightseeing tours, including the Golden Circle, Gray Line's Iceland fleet currently has a total of 60 operating buses. The Airport Express Route shuttles incoming passengers from the airport back to their Main Bus Terminal in Reykjavik on large coaches. More details will be laid out in the following section.

3.1.1 Current Buses Utilized for Airport Express Route

Gray Line's airport shuttle utilizes only 7 coaches assigned to the fleet. Currently, if there is a need for more buses they are able to pull them from their main fleet in Reykjavik. During the busier summer months, sometimes up to 10 coaches are needed. A detailed list of their diesel buses are shown in the table below.

MODEL	YEAR	SEATS	Length [meters]
Volvo Sidreal 2000	2013	53	12.2
Volvo Sidreal 2000	2012	59	13
Volvo Sidreal 2000	2012	59	13
Volvo 9500	2014	59	13
Volvo SC7	2015	69	15
Volvo SC7	2015	69	15
MAN Sunstar	2014	39	10.3

Table 1: Make and Model of Diesel Buses Currently Used for Airport Express (provided by Rúnar at Gray Line)

Gray Line stated that the cost of these buses was on average 35,000,000 kr. each. Every bus in their fleet was paid in full at the time of purchase; none of the buses were financed. Buses in their fleet are used for an average life cycle of 6 to 7 years, then sold for approximately a quarter of their original purchase cost. Pay back in certain circumstances could not be guaranteed but this was the self-reported figure that Gray Line supplied. The average monthly cost of operating the Airport Express Route was based on the operational costs provided by Gray Line for the month of December 2015. Additional data provided by them included the number of kilometers driven, the amount of diesel consumed, and the average monthly maintenance costs.

Depending on the number of passengers, 38-45 one-way trips are taken from the airport daily. For purposes of this project, Gray Line defined the bus capacity as split into two equal portions, summer and winter. During the winter months the buses are at approximately 50% seating capacity, and during the summer months the buses are at 93-94% seating capacity. But surprisingly, the number of one-way journeys do not increase on a monthly basis in the summer. They accounted for this due to the tourists being more comfortable arranging their

own transportation such as a car rental during the warmer, sunnier summer months. By the same reasoning they assumed that more customers choose a bus for transportation to the city in the winter months because of the unpredictable weather, with the net number of trips working out to be approximately the same number each month of the year.

For the month of December 2015, Gray Line's fleet of 7 coaches drove 63,085 kilometers. It cost the company 3,753,557 kr. For the total kilometers driven by the fleet of 7 busses or approximately 57 kr. per kilometer driven or approximately 9012 kilometers driven per month for one single diesel bus, since it was determined there is roughly no differentiation in the number of trips taken per month throughout the year. Gray Line stated that they received a discounted rate for their diesel fuel, but did not state the exact amount. During the month of December diesel cost an average of 175 kr. per liter which was used for the calculation. Although improbable, for simplicity it was assumed that this amount also stayed the same. Later a sensitivity analysis will examine the outcome as the cost of diesel fluctuates given the volatility of the oil market. The buses use an estimated 34 liters per 100 km. The actual cost for the fleet was 3,753,557 kr. for December 2015. The fleet of 7 coaches consumed 21,448 liters of diesel fuel which calculates to 3,064 liters per month for one bus, again remaining uniform throughout the year. Using the actual 63,085 kilometers distance and the actual total cost of 3,754,557 kr., it was determined that the diesel costs approximately 57 kr. per kilometer per bus after proprietary discounts.

The price of diesel is highly volatile, and it is not uncommon for the cost of fuel to vary substantially from one year to year. This will be discussed in the economic sensitivity analysis section. For example, Brent oil prices have gone from \$115 per barrel in June 2014 to just \$60 per barrel by May 2015. [39] Though diesel prices are typically 10-15% higher than the Brent oil price because of increased demand of diesel. [40] In addition, the size of the tanks varies by bus, ranging in size from 350 to 600 liters. Gray Line stated that they only have to fill the buses up once at the end of the evening.

The price of diesel is highly volatile, and it is not uncommon for the cost of fuel to vary substantially from year to year. This will be covered in the economic section in a sensitivity analysis. For example, Brent oil prices have gone from \$115 per barrel in June 2014 to just \$60 per barrel by May 2015. [39] Though diesel prices are typically 10-15% higher than the Brent oil price because of increased demand of diesel. [40] In addition, the size of the tanks varies by bus, and they range in size holding between 350 to 600 liters. Gray Line stated that they only have to fill the buses up once at the end of the evening.

Given 2015's near 20% average annual growth in tourism, the number of passengers who rode a bus on their Airport Express fleet increased from 1700 to 2050 seats. [11]Based on the projected growth rate, Gray Line intends to expand their Airport Express fleet with two 12-meter, 48 passenger buses by late 2016. However, for simplicity this project will analyze only one electric bus to one diesel bus to determine its operational feasibility. If the project goes forward it is possible for it to be sized with respect to projected growth rate. Because only two companies Gray Line and Reykjavik Excursions are in operation, the market share of both of these companies is quite large. Gray Line's current market share is nearly 30% (for both the Airport Express route and as a company as a whole). If the train is constructed, both companies would expect to reduce their relative market share.

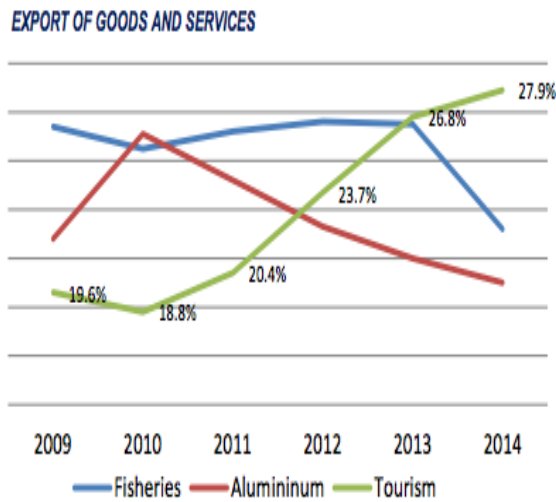


Figure 4: Export of Goods and Services, April 2015 [41]

3.1.2 Current Operations for Airport Express

This section examines the current operational details for the Gray Line Fleet, Airport Express Route to be used in determining if the current operational logistics will be achievable with an electric bus model of transportation for the airport route. From Keflavik, large coaches currently transport passengers from Keflavik to the Main Bus Terminal at Holtagarðar 10, just outside the main city center. Today, a one-way transfer cost 2700 kr., and if bought as a round trip ticket it costs 4900 kr., saving a passenger 500 kr. If the passengers need further transport to their hotels, they must board smaller coaches at their Main Bus Terminal since the city restricts larger vehicles that would block the small streets in the main city center. For uniformity, this part of the route will not be covered because in comparing the operational and economic factors of one diesel bus to an electric bus, it would be imprecise to compare two sets of coaches. For this section of the route, 8 small coaches known as sprinters are used. Electrifying the route will likely be more feasible if it is implemented as a multi-step process. Initially deploying electric buses at the airport, the first point of entry, would have a greater positive impact both financially and perceptually to encourage this mode of transport. Additional analysis should be conducted to determine the parameters for future expansion of this project if it is deemed operationally feasible.

Each of the 38 to 45 one-way trips per day from the Main Bus Terminal at Holtagarðar 10 to the airport takes about 45 minutes for the 51.6 kilometer trip. On the Keflavik side of the journey, the buses are scheduled to depart 30 to 45 minutes after a flight arrival, 24-hours a day, every day of the year. [42] After the arrival of the first bus, each succeeding bus pulls in behind the bus in front of it, where it sits for approximately one-hour in the line. During this time a driver often helps load the next bus in line for the trip to Reykjavik if needed; if not they take a break for the remainder of the hour. However, when they return back at Gray Line's Main Bus Terminal the drivers often again break for an hour. The one-hour breaks may prove beneficial for the required charging of the electric buses upon implementation. To be a compatible alternative, the electric bus route would need to be able to operate 24 hours per day, with charging breaks which are compatible with the current operational logistics of the

Airport route to minimize any delays and maintain the operational efficiencies of the current Gray Line routing system.

4 Operational Feasibility

In order to determine if BYD electric buses are both operationally and economically feasible for the Airport Express route, a thorough review of each type of diesel bus is compared in detail below. Comparing the capacities of each bus illustrates how an electric bus is adaptable for this route as-well-as the differences and systemization required to operate it within the routing schedule established.

4.1 Diesel Bus to be Compared: Year 2013 Volvo Sidreal 2000

Of the buses in use, the 2013 Volvo Sidreal is most similar in size and seating capacity to the 48 seat capacity bus that Gray Line will add to their fleet by the end of 2016, therefore this is the diesel bus that will be compared for this project. The table is listed again to show the sizes and seating capacities of available Gray Line buses.

MODEL	YEAR	SEATS	Length [METERS]
Volvo Sidreal 2000	2013	53	12.2
Volvo Sidreal 2000	2012	59	13
Volvo Sidreal 2000	2012	59	13
Volvo 9500	2014	59	13
Volvo SC7	2015	69	15
Volvo SC7	2015	69	15
MAN Sunstar	2014	39	10.3

Table 2: Make and Model of Diesel Buses used for Airport Express (data provided by Rúnar at Gray Line)

As of early 2016, Gray Line operates 7 diesel buses from the Main Bus Terminal to the airport, 365 days per year, 24 hours a day. 38-45 one-way trips are routed per day with each trip being a length of 51.6 kilometer. The number of trips per month is constant summer and winter but a 20% annual increase is predicted due to the tourist trade. Because of the steady growth, Gray Line has plans to add two 12 meter, 48 passenger buses by late 2016. Trips are scheduled to leave the airport 30 to 45 minutes after each flight arrival. [42] The buses continue departing until passengers have been accommodated, and at times it is necessary for additional buses to be pulled from the Main Bus Terminal. Once started, the transfer to Holtagarðar 10 takes an average of 45 minutes. At both Keflavik International Airport and Gray Line's Main Bus Terminal, newly arriving buses park at the end of the line of buses, and remain stopped for nearly an hour and then stops again when the bus returns to the Main terminal when the driver takes a one-hour break. Given electric buses will need charging times, the route's one-hour breaks may prove to be purposeful. In terms of costs, Gray Line's December 2015 monthly accounts were shared for this project, which delineated the actual number of kilometers driven, the amount of diesel consumed and the average monthly maintenance costs.

For the month of December 2015, the express fleet drove 63,085 kilometers and the 7 bus fleet consumed 21,448 liters of diesel fuel at an average 175 kr. Per liter, which cost the company 3,753,557 kr. for their Airport Express Route. As stated previously Diesel prices generally are 10-15% above the Brent oil price depending on the demand of the market and have a history of large fluctuations. The express route's current fleet varies in size anywhere from 350 to 600 liters but Gray Line stated they fill up their current fleet once, at the end of the day at their Main Bus Terminal.

4.2 Electric Bus to be Compared: BYD C9

The electric bus that will be compared to the 2013 Volvo Sidreal 2000 is a model by BYD known as the C9. There were a limited number of buses to choose from for shuttling passengers with luggage as BYD is currently the only electric bus manufacturer on the market that has under carriage storage for luggage, which is one of the requirements for a bus of this purpose. The C9 just hit the market in 2015. The C9 is a 12-meter coach-styled bus that has a seating capacity of 47 passengers, very similar to the 48 seat capacity model that Gray Line will be adding to their fleet in 2016. Given that all data is available for the C9, and that its seating capacity was nearly the same capacity, it was the most comparable model with the added benefit of being the model of choice which Gray Line intends to add to their fleet. The seating capacity of the C9 was also similar to the 53 seat capacity Volvo Sidreal 2000 which they are currently using for this route. It should be noted that it would be beneficial to conduct further analysis on electrifying the 8 smaller sprinters that passengers use to re-board at Gray Line's Main Bus Terminal. For this purpose, BYD has a 7-meter C6 model with a seating capacity of 21 passengers.

The stated driving range of the C9', 365 kWh lithium-ion iron-phosphate battery is 300 kilometers on one charge. [43] Depending on temperature and driving conditions, the maximum best case range was shown to be as far as 386 to 434 kilometers on a single charge. [44] The buses top speed of 101 kilometers per hour would not be a limiting factor since the speed limit between Reykjavik and Keflavik does not exceed 90 km/h. Recent projects such as the one at Amsterdam's Schiphol Airport have incorporated the 12-meter electric bus purchased from BYD's website. The 12-meter bus has 31 seats, and 4 folding seats before customization. There is no publicly available data on the prices paid for these buses, or the costs associated with customization but customization varies widely and is likely to be more expensive than purchasing the C9 model already equipped with under carriage luggage storage, when all costs are factored. [45] The C9 claims a significantly better charging time than the 12-meter electric bus listed on their site. [45] Relevant to this study, the C9 is reported to charge from empty to full in as little as 2 hours on a 200 kW charging infrastructure. The C9 continues to improve and BYD will soon be releasing a slightly larger model C10 with a larger 58 person seating capacity, a slightly larger 394 kWh battery than the C9 365 kWh battery yet will maintain the same 300 km range. [46] The manufacturer stated that the charging time for this bus is also slightly shorter, requiring only 1.3 hours to fully charge.

4.3 Lithium-ion Iron Phosphate Battery Life and Cycle Claims

The Lithium iron phosphate battery (LFP) battery is a type of rechargeable battery which has the advantage of longer cycle life and has a constant discharge voltage allowing it to deliver virtually full power until it is discharged. BYD claimed their 365 kW lithium-ion Iron Phosphate battery can be re-charged in less than 2 hours by way of a 200 kW charging source. They further state it can be re-charged for up to 6,000 cycles before it reaches 80% efficiency in ideal temperature conditions. [47] It is estimated to reach 80% efficiency in 12 years meaning it retains 80% of its efficiency after 12 years. Battery performance is dependent on environmental conditions which are not specified in market advertising, so there is no way to predict this accurately without having a battery to physically test. There are no publicly available battery performance discharging curves available for any models of BYD electric buses Powered by a 365 kWh lithium-ion iron phosphate battery. It is reported to charge in 2 hours under optimal conditions through a 200 kW fast charging system. It is common practice for manufacturers to overestimate their lifecycle rate with knowledge that many consumers will not spot-check their battery at different stages of its life. However, relative to other available battery technologies for electric vehicles lithium-ion iron phosphate batteries have a stable crystalline structure that allows them to have comparatively longer life cycles than other battery technologies available at this time. [48]

Li-ion batteries work by the movement of lithium ions across positive and negative electrodes when charging and discharging. When a battery has completely discharged it is called a cycle, with battery life measured in total number of cycles until it is incapable of recharging. Cycle life is subject to different temperature scenarios. Battery cycle counts have been shown to be inaccurate because a discharge can vary in depth such that there is no precise level of what constitutes a given discharge and there are no clearly defined scientific standards of what constitutes a cycle. In fact, there is no precise means to determine how long a battery will last; it depends on how heavy the battery is used, the way that it is used, and if it was used in unfavorable temperature conditions. In addition, the battery's capacity will drop as it is put through an increasing number of cycles. Discharging the Lithium-ion iron phosphate battery reduces some of the stress put on it which in turn affects its lifespan. Exposing a battery to elevated temperatures and dwelling in a full state-of-charge for an extended time can be more stressful than cycling and decrease the life of the battery. [49] The depth of discharge can also have an impact on the total number of discharges in the lifecycle of a battery. Smaller discharges and partial discharges on Li-ion battery causes less stress. Avoiding full discharges and charging the battery more often will increase the life of the battery. Since many factors cause variance in the life cycle of the battery, only an estimate of the C9 battery capacity can be made.

Iceland's temperatures are often slightly below or above the freezing mark. It has been shown that the driving range of EV's is significantly affected by temperatures under 0° C. [50] Xianzhi Gong and Chunting Chris Mi from the Department of Electrical and Computer Engineering at University of Michigan, conducted research on the driving range of electrical vehicles using an electrochemical impedance spectroscopy test, and a dynamic driving schedule test, under a series of constant temperatures from 25°C to -20°C. [50] Their analysis showed that both temperature and the use of heating or air conditioning can decrease

battery efficiency. Their results showed that at low temperatures, the Ohmic resistance increases, significantly affecting the ability for a charge to transfer below freezing temperatures due to the decreased conductivity of the electrolytes present in the battery at low temperatures – as resistance increases, electron conductivity decreases. Discharging was not as affected by cold temperatures. Through their research it was determined that the battery lost only 10% of its capacity at temperatures below the freezing point when discharging. [50] If this were applied to this project it would mean, instead of the electric bus allowing 300 kilometers capacity when full, it will instead provide 270 kilometers. For purposes of this project however, precautionary measures were taken, and a 25% reduction in BYD's stated battery capacity was assumed. Therefore, the study assumed that a fully charged battery would yield at least a 225 kilometers driving range on a single charge. If discharged to near empty, this would equate to 4 one-way journeys to and from the airport. Given that there is a one-hour break for the buses on each leg of the trip, there is time to charge the battery between one-way trips, keeping the battery at levels more than adequate for each trip with a large reserve. It was also assumed that the energy usage was consumed at a steady-state, meaning there was always the same amount of energy consumed by the battery regardless of different levels of acceleration, local topography changes or use of air-conditioning or heating. The energy usage data for the BYD C9 electric bus was provided by the manufacturer. Charging the battery below the freezing point is more sensitive than discharging at these temperatures. The C9 uses a Li-ion battery which charges under two-phases, the first is a slower constant current phase, the second is the faster constant voltage phase. During the first charging process, a set-point voltage provides a constant current at a fixed range as the battery current rapidly rises until it reaches the constant voltage charge threshold of the battery. It is during the constant current phase that nearly 65% of the battery will charge. [48] If a fast-charger is used only 63% of the battery capacity will charge due to the increased polarization of the electrodes. When the battery voltage rises towards the threshold value which is the upper limit of effective charging voltage (the actual voltage of the battery) the charge current is limited by what the battery will accept at that voltage, and the second phase begins, which is the constant voltage stage. In this second stage, the current acts a regulator through the influx of the steady-state charge. At the beginning of this phase the battery while the voltage remains constant, the current rapidly drops, tapering off asymptotically until it reaches the lower threshold determined by a certain percentage of the battery charge. Essentially this means as the battery approaches a full charge, the battery charge drops until it reaches capacity.

The battery takes 2 hours to charge fully through both phases providing a stated 300 kilometers driving range. After the 25% reduction from the stated driving range due to Iceland's below freezing temperatures effect, one charge will provide a total of 225 kilometers total capacity on a 2-hour charge - 146.25 kilometers drive range from the first phase and 78.75 kilometers range from the second phase. Phase one, the constant current phase, gains power at a slower rate but charges nearly 63-70% of the total capacity, providing an approximate 146.25 kilometers of driving range. Phase two, the constant voltage stage, charges more rapidly and provides the final 30-37% charge and sustains a 78.75 kilometers of driving range. The electric bus airport route will be recharging in the second phase. No information on the exact time frame of each phase of the battery could be found. To ensure an adequate driving range will be available for the Airport Express route utilizing the one-hour breaks for recharges, precautionary measures were applied in this study such that phase 2 will be overestimated to take one hour or half of the total 2-hour charging time. While we know that phase 2 is actually

faster than phase one, it is better to assume the longer time for phase 2 out of an air of precaution since the battery will be recharging in phase 2. Therefore, one of the main assumptions in this feasibility study was that the phase 2 charge time will be overestimated at one hour. Overestimating the time to charge will underestimate the drive range reserve. Therefore, if it is operationally feasible under these conditions, it would not be a challenge to operate the C9 electric bus route to and from the Reykjavik airport.

The one-hour bus breaks on each end of the trip to and from the airport can be used to fully charge the buses during the one-hour bus breaks on each end of the trip. The layout for the charging stations will be given later. Given the li-ion battery gains power quicker in the second phase, the constant voltage stage or “topping off phase,” it is best to charge on each end of the journey, once the battery has an initial full 2-hour charge. In a single one-way trip, driven 51.6 kilometers to the airport, a fully-charged battery will have an approximate remaining range of 174.4 kilometers left on its battery reserves. If allowed to sit on a dedicated charger for one-hour, the battery will return to its full capacity of 225 kilometers since we know that phase 2 charging is capable of adding an additional 78.75 kilometers of driving range and only 51.6 kilometers range is needed to be back to full capacity.

4.4 Charging Infrastructure

The C9 would be charged best with a 200 kW charging station that enables it to reach a full charge in 2-hours maximum. This station purchased through BYD has an estimated cost of 100,000 Euros, including the cost of the installment: using the 144.556 exchange rate, the net cost would be approximately 14,455,600 kr. [51] This study will focus on the C9 model most comparable to the existing buses as it is sufficient for the needs of this route if proven feasible. After plugging in the C9, the AC Power-Interface Charging Station calculates the charging time, collects on-board vehicle information, and uploads it to the service center when needed. For purposes of this study one electric bus on the Airport Express Route will need 2 charging stations, one on each end of the journey, one at their Main Bus Terminal and one at the airport. If Gray Line were to add two electric 12-meter buses instead of diesel, no additional charging infrastructure would be needed as each charger can accommodate two buses with its dual plug. Keeping the buses at a charge that is close to, or full will both allow the bus or buses to take advantage of the faster, second charging phase and ensures they will have battery reserve capacity to make a single one-way trip either to or from the airport. Additional planning for the growth of their electric fleet will be necessary to give enough space for the addition of more charging stations, and the new layout suggested below.

4.5 Future Growth of Airport Express Fleet

Gray Line has expressed the need to add to its fleet of buses to meet the increasing tourist demand. Implementation of different types of charging stations have the ability to charge electric buses quicker than others. The C9 would be charged most efficiently for this purpose utilizing 200 kW charging solution which would allow a fully depleted battery to charge in 2 hours. The C10 electric bus claims a 1.3-hour charge using a 300 kW charger. Both of the stations purchased through BYD are estimated to cost around 100,000 Euros each, including the cost of installment. A plan is needed to guide the alternative use of electric buses toward a more viable long term solution. Listed below is the timetable listing the replacement year for

each bus in Gray Line's current Airport Express fleet. with no accounting for growth due to tourism. Keep in mind that the entire fleet is unfinanced as Gray line purchased each bus outright and Gray Line indicated that two new buses of 12-meter, 48 passenger seating capacity will be needed by the end of 2016.

MODEL	YEAR	ESTIMATED REPLACEMENT YEAR	SEATS	METERS
Volvo Sidreal 2000	2013	2019-2020	53	12.2
Volvo Sidreal 2000	2012	2018-2019	59	13
Volvo Sidreal 2000	2012	2018-2019	59	13
Volvo 9500	2014	2020-2021	59	13
Volvo SC7	2015	2021-2022	69	15
Volvo SC7	2015	2021-2022	69	15
MAN Sunstar	2014	2020-2021	39	10.3

Table 3: Estimated year of replacement (data provided by Rúnar at Gray Line)

Most likely by the time the next bus in the fleet needs replaced, which occurs in the year 2018, advanced models of coach-styled electric buses will be released to the market, but as long as the alternative electric bus is proven feasible to operate the Gray Lines Airport Express route, there would be no immediate need to keep upgrading to newer models. If the current business growth continues, as detailed in the results below for the time period 2010 through 2016 it should be expected that Gray Line's Airport Express fleet will continue to grow by at least 1 additional bus per year.

YEAR	NUMBER OF BUSES IN FLEET
2010	3
2011	3
2012	4
2013	5
2014	6
2015	7
2016	9

Table 4: Growth of Airport Express fleet from 2010 to 2016 (data provided by Rúnar at Gray Line)

Higher than predicted increases may occur in 2016 due to sooner than expected replacement of one of the buses or increases in market share may be increasing as the Iceland tourist industry grows. However, it will not be necessary to predict the proportional increase in the number of tourists using their current 30% market share as results would be scalable to the growth at that time. There was no information on the life cycle assessment for EV buses that could be found, therefore in this study it was assumed that the buses that will be compared will

be used for the same 6 to 7-year life cycle as the buses used in their current fleet. Additional information provided by Gray Line indicated that they currently run an average of 50% capacity during the winter which would allow for future growth; while near full capacity is already realized during peak tourist season in the summer (excluding 3 to 4 seats reserved for unforeseen circumstances.) They do have a bus reserve to pull from when necessary, tapping into their 60 bus fleet at the Main Bus Terminal in Reykjavik. As noted previously, sometimes they have been noted to run as many as ten buses to accommodate unexpected demand.

4.6 BYD C9 Buses for the Airport Express Route

One of the most important prerequisites of an electric bus alternative for Gray Line is their ability to operate their fleet in the same manner, with the same operating schedule as their current diesel fleet; buses are synchronized with arriving flights at the airport and bus passenger capacity. Gray Line's current schedule of stops at each end of the trip from Reykjavik to Keflavik International Airport easily facilitates a similar operational schedule for an electric bus, given there was a charging infrastructure at both ends of the trip. Although this operational feasibility study only compares one diesel bus to one electric bus, it would be easy to apply this study to a two electric bus pilot program because each single charging station has a dual plug which can accommodate two buses. Although one fully charged eBus (electric bus) battery has at least the assumed 225 kilometers battery capacity capable of making approximately 4 one-way journeys to or from the airport, it is advisable for the battery to be charged after each one-way journey to ensure there is always a large reserve and to take advantage of the quicker battery charge of the second phase of the battery charging system.

Gray Line would be responsible for the installment and cost of the charging stations, unless the government helps to fund or subsidize some of the cost of the charging infrastructure. Charging stations must eventually be incorporated into the plan to operate the electric bus and is included in this operational feasibility study. The economic feasibility study analyzed the costs of the project once with the charging stations as part of the cost, and once without them for comparison.

4.7 Analysis: Operational Feasibility

This analysis was prepared from a non-engineering perspective but could be investigated further from an engineering perspective to build a physical model to simulate energy use of the EV bus for this route, including input for all scheduled breaks and the specifics technological details for charging and discharging times for the C9 under real life conditions. This would provide more exact measurements and explain in depth the energy uses and efficiencies of the BYD C9 bus. Given that the available data on the C9 is compatible with the logistics of running the current Gray Line Airport Express route, it is highly probable that the C9 electric bus would easily navigate the same route and with the same time frames utilizing the already set one hour breaks at each end of the trip as recharge points without disrupting the established operation. Gray Line can add the 2 additional buses planned without additional charging stations as each can accommodate 2 buses with its dual plug. Therefore, additional charging stations would be needed for the expansion of every two buses. When the new layout model is adopted the buses will be able to charge for about one-hour on each end of the journey to or from the Keflavik airport. One easily adaptable change would need to be incorporated

into the parking system of arriving buses wherein the next arriving bus would need to form a row instead of forming a line behind the preceding bus in order to facilitate the charging station (illustrated in the diagram below).

Research from Xianzhi Gong and Chunting Chris Mi's was used which estimated the effects of extreme weather conditions on the Li-ion battery. Their study analyzed the state-of-charge (SOC) variations, in extreme weather conditions like that encountered in Iceland. [50] SOC is similar to a fuel gauge for the battery in an electric vehicle. While their research indicated a 10% reduction for the effects of extreme weather effects on charging and discharging, this project assumed the more aggressive 25% reduction in battery capacity of the BYD C9 which then predicts a 225 kilometers driving range on a single complete charge.

Charging a battery in below freezing temperatures is more sensitive than the discharging process. As noted previously, the battery charging process has two-phases and it is during the second phase that the battery is able to acquire charge at a quicker rate. This study assumed that during the slower first phase 65% of the battery is charged and 35% in the more rapid constant voltage, phase 2. Applying the 25% reduction in battery capacity due to extreme weather conditions, the battery would still be more than adequate to power the one-way trips and still provide a safety-net for error due to unforeseen circumstances. Charging in between the one-way trips will top off in the phase 2 charging portion since one trip is only 51.6 kilometers and will charge to near capacity during the hour breaks allowing a considerable reserve even in the most inclement weather that would reduce capacity by the study's assumed 25%.

4.8 Results: Operational Feasibility

4.9 Layout of Charging Infrastructure

The Gray Line Airport Express route would remain the same with the addition of an electric bus, with no changes needed for the arrival of the bus on either end of the trip from the Keflavik airport to Reykjavik. In the electric bus model, since the bus would be stopped one hour uninterrupted for charging at each end of the trip, a land area would need to be set aside and dedicated for charging purposes and to allow for further growth of an electric fleet. Currently, when an arriving bus gets to the airport it pulls to the back of the line, and the buses all pull forward in order to board the next incoming group of passengers, whereas a row formation would be conducive to the charging of the electric bus fleet. However, modifications to charging cables may be an alternative solution to making a dedicated electric bus row as the electric bus fleet grows, enabling no changes to the existing layout at least initially. For simplicity, arranging any growth in electric buses in an arrangement similar to a repeated row pattern as in the following diagram would help expedite the loading, and ensure each bus would get the maximum charge time during each break. In one possible arrangement, and accounting for future growth of Gray Line's electric bus fleet, two buses could be assigned per charging station and the buses could be laid out as illustrated in the diagram. Another possible setup is to place charging station 2 behind charging station 1, and instead have the busses form two lines. Since this project is only comparing one BYD C9 electric bus to the average bus in Gray Line's current fleet, minimal changes to the layout is necessary immediately but having an understanding of how future buses will park to utilize maximum recharge times is far reaching.

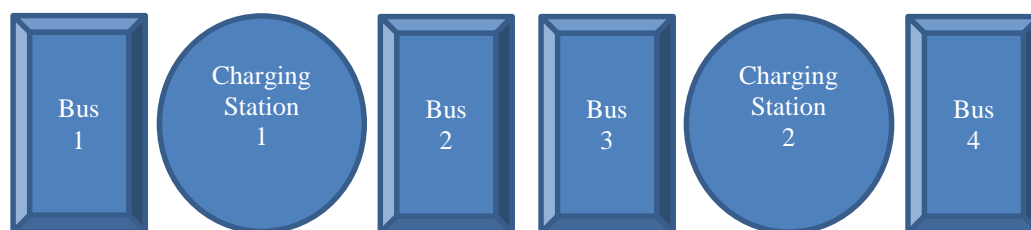


Figure 5: Potential layout of future growth of charging stations and electric buses

There is no need for additional labor hours, or other major operational changes in the way an electric bus navigates in comparison to the Volvo Sidreal 2000, a bus representative of Gray Line's Airport Express fleet. There are only two required changes in operations. First, rather than the buses forming a linear line as they arrive, they would park in a row formation to facilitate the charging process at the charging stations. Second, rather than the once per end-of-day refueling of the 2013 Volvo Sidreal 2000 diesel bus, the C9 Electric bus would be charged at the end of each one-way journey. The additional refueling stops via the charging station would not require additional labor or major alterations in process to accomplish as the buses already stop one hour at each end of the journey. Converting to an electric bus would require a minor mindset change with minimal disruption to the overall operational structure and current schedule of Gray Line's airport route. The next phase of this project evaluated the economic feasibility of replacing the 2013 Volvo Sidreal 2000 diesel bus with the 2016 BYD C9 electric bus.

5 Economic Feasibility

This section of the thesis compares an economic assessment for the operation of the 2013 Volvo Sidreal 2000 to that of a new 2016 BYD C9 electric bus. Profits were determined on a per seat basis for both the diesel bus and the electric bus. First operational costs with variables not shared by each type of bus were determined. Next, all relevant data was collected from Gray Line in order to procure both the revenue and running costs associated with the Airport Express fleet today, including initial investment costs in the bus to compare. For the same information on the BYD C9 electric bus to be compared, information was collected on its initial investment costs as well as the amount of revenue that would be obtained from operating a C9 electric bus. Though revenues show part of the picture, they were excluded in the NPV analysis because the number of seats filled were nearly identical.

After all relevant data was collected, a cash flow sheet was created under three scenarios: 1) costs to purchase and operate the average diesel bus of similar size as the C9; 2) costs to operate BYD's C9 electric bus including the purchase of half of one charging station BYD 200 kW dual-plugged chargers; and 3) costs to operate BYD's C9 electric bus excluding the purchase of the charging stations. Only the costs of the project were analyzed as the revenues of a bus of the same seating capacity would be equal. Included in the cash-flow charts were the initial investments of each, operating cash-flow for each projects lifetime, as well as the inclusion of the resale value of each bus, and charging station. Excluded in these costs were line items that would incur the same costs on both buses. More will be detailed later, but for example, since both buses will require insurance at the same cost, this was not included. Part of the economic analysis also included calculating the accumulated PV (Present Value) cost for each, in order to complete the calculations for NPV (Net Present Value) for the three scenarios. The comparison of the three NPV's was then used to explain which investment was the least risky. To further evaluate each scenario, multiple sensitivity analysis was run to assess the impact that various parameters had on the overall economic feasibility of the project to show which variables had the greatest impact.

5.1 Barriers to Converting to an Electric Bus

The main challenges in converting to an electric bus remains the high initial investment cost, the limitations of battery driving range, and the need for additional charging infrastructure. As was shown in the operational feasibility operating an electric bus requires a shift of mind for the operational logistics with only slight augmentations in how they are run. With an increasing number of buses in the area, there would also be a causal increase in the rancid smell of diesel in the air with its associated increased ill health effects linked to high concentrations of diesel air pollution. However, no quantitative data could yet be found for the current effects of diesel in the greater Reykjavik area. Research conducted by Zuurbier, Gerard, Oldenwening, Lenters, Meliefste, Hazel and Brunekreef found that the highest concentration of PM (Particulate Matter) emitted was by diesel buses (at 38,500 particles/cm³), while electric buses had the lowest concentrations (at 29,200 particles/cm³). [52] Iceland's low-carbon energy mix could have a more significant impact on reducing the amount of PM in the air. However, as important as they are to the community, the health impacts of pollution are not typically included factors in an economic feasibility study. Other studies have shown that as the costs of batteries for

electric vehicles goes down by 10-30%, it would allow them to be more competitive. [53] Gray Line's Airport Express Route is a first point of perception for the increasing number of tourists and serves to market Iceland as a unique green destination. Various other factors will be raised in the discussion section, including ways to incentivize low-carbon technologies.

5.2 Comparison of Operating Costs of 2016 BYD C9 Bus to 2013 Volvo Sidreal 2000

There are considerable cost differences in the initial investment, and operating expenses of both buses. Table 5 below displays a break-down of the capital costs, and many of the operation expenses. Each will be discussed in the following chapter before going through a detailed economic analysis.

	2013 Volvo Sidreal 2000	2016 BYD C9
Cost of New Bus (ISK)	35,000,000	70,000,000
Number of Seats	53	47
Insurance (ISK/km.)	4	4
Maintenance (ISK/km.)	20	12
Depreciation (ISK/km.)	81	81
Diesel/Electricity (ISK/km.)	57	10.2
Tires (ISK/km.)	10	10
Lubrication (ISK/km.)	4	
Resale Value Bus (ISK)	8,750,000	17,500,000
Resale Value Charging Station (ISK)	-	3,613,900

Table 5: Comparison Volvo Sidreal 2000 (2013) to BYD C9 (2016) (data provided by Rúnar at Gray Line)

6 Methods

The economic feasibility section of the thesis analyzes a 2016 BYD C9 electric bus compared to a diesel 2013 Volvo Sidreal 2000 bus with data for the diesel bus which was provided by Rúnar Garðarsson, the Operating Manager at Gray Line's Main Bus Terminal. Information for the BYD bus was provided by Gisli Gislison, through his contact at BYD. First, the operational costs and revenues were calculated. In deciding which variables to include for the operational costs, only costs were included that differed between the diesel and electric bus. The exclusions will be detailed in the Exclusions section below.

Next, a cash-flow for the three scenarios was prepared to calculate the accumulated Present Value (PV) cost for each of the three-scenarios: 1) a diesel bus, 2) electric bus + charging station and 3) the electric bus alone. Then the NPV formula was applied to these three options. The profits were not included in this part of the calculation for reasons discussed below. Finally, the significance of different variables was assessed by analysis of several in-depth sensitivity parameters.

6.1 Assumptions for Operation Costs 2013 Volvo Sidreal 2000

6.1.1 Assumptions for diesel bus

Operational costs for the 2013 Volvo Sidreal 2000, did not include variables that would be identically applied to both buses. For example, cost of insurance, depreciation and tires were not used for this project. These individual factors would result in a net-zero gain for either bus because they would both require the same cost factor. Financing, according to Rúnar Garðarsson refers to the mortality of the bus on a kilometer basis. However distinctive variables for each bus were included. For example, the diesel bus included lubrication, fuel cost and maintenance cost on a kilometer basis for the diesel bus. These variables were provided by Gray Line, and included the items listed in the table below.

Lubrication (ISK per kilometer)	4
Fuel cost (ISK per kilometer)	57
Maintenance (ISK per kilometer)	20

Table 6: Operationally included variables for diesel bus

The cost of diesel, monthly number of kilometers driven, and monthly diesel costs were provided by Gray Line for the month of December 2015. For the entire duration of this project, these numbers were assumed to not fluctuate. Diesel prices were an included operational value, however they tend to be volatile and can change rapidly as a result of unforeseen consequences. For simplicity this project did not take into consideration any inflation rate.

6.1.2 Operating cost of diesel bus

The operating cost of the 2013 Volvo Sidreal bus was calculated by the summation of the above included variables for the diesel bus multiplied by the 9,012.14 kilometers driven per

month, times the number of months in a year. This yielded the total costs of the diesel bus at 8,759,802.86 ISK per year. Given the slight difference in the number of seats available a calculated cost of 165,279.30 ISK per seat per year was calculated by dividing the total costs per year by the 53 passenger seating capacity of the diesel bus. The operating costs on a per seat per year basis was 165,279.30 ISK.

6.2 Revenue of diesel bus

6.2.1 Assumptions for revenues of diesel bus

The number of kilometers an average individual bus currently drives on the Airport Express route was determined by dividing 63,085 (kilometers driven over the month of December 2015) by 7 coaches in the fleet. This resulted in the determination that a bus in their current diesel fleet drives approximately 9,012.14 kilometers per month. This amount was then assumed to be uniform for all 12-months of the year. In addition, the 51.6 kilometer distance to and from Keflavik was projected via the use of Google Maps. It was also assumed that there were only two seasons, winter and summer. Therefore, the seasons were split into 6 months to calculate the seasonal revenue for the two seasons.

6.2.2 Total revenues of diesel bus

First, the number of one-way journeys to and from the airport was determined by dividing the average number of kilometers driven a month by the 51.6 kilometers for a single one-way journey. This yielded in an average of about 175 single trips either to or from the airport each month. Approximate revenues were then calculated for the diesel bus by accounting for the average percentage of seat utilization given by Gray Line. They stated that during winter months the seats are roughly 50% full, and during summer months the buses are 93-94% full in addition to the 3 to 4 empty seats left empty for any unforeseen circumstances. Accounting for this, during the winter the average seat utilization was determined by dividing the 25 seats assumed to be filled with passengers by the total number of 53 available seats, yielding a 47% seat utilization. The total winter revenue was calculated by multiplying by 6 winter months, by the 47% seat utilization, by the average 174.99 journeys a month, by the 2700 ISK one-way fare price, by the number of seats. This resulted in a total winter revenue of 70,872,191.40 ISK. Similarly, in the summer months the average seat utilization was calculated by taking 50 seats, a nearly full Volvo Sidreal 2000 minus the 3 seats for unforeseen circumstances divided by the 53 seating capacity. This resulted in a 94% seat utilization for the summer months. The total summer months' revenue was calculated by multiplying the 6 summer months, by the 94% seat utilization, by the average 174.99 journeys a month, by the 2700 ISK fare, by the 53 available seats on the bus. This yielded a 141,744,382.80 ISK total revenue for the summer months. Finally, the summer and winter revenues were added together to calculate the total revenue per year per bus. This ended with a net total revenue per bus per year of 212,616,574.20 ISK, and a 4,011,633.48 ISK per seat per year revenue.

6.3 Assumptions for Operation Costs 2016 BYD C9 Electric Bus

6.3.1 Assumptions for 2016 BYD C9

Similar assumptions are applied for the exclusions to the electric bus. For clarification, the cost of insurance, depreciation and tires are also not included in the operational costs for C9 for the same reason. The operational costs for the BYD C9 electric bus will however include the following:

Electricity (ISK per kilometer)	10.2
Maintenance (ISK per kilometer)	13

Table 7: Included Variables for BYD C9 Electric Bus

There were no specific case studies on the average cost of maintenance of the C9 model. There are however several testaments that give credence to the claim that BYD has made, stating that electric buses require only a third of the maintenance required by that of the average diesel bus. [31] Research by Adheesh, Vasisht and Ramasesha compared the air pollution and economics of a diesel bus versus an electric bus. [54] Their research data was collected from the Bangalore Metropolitan Transport Corporation (BMTC) for the operating and maintenance costs of running a BYD electric bus within the city limits. A similar analysis then compared the same variables for an existing bus operating on the same route as the BYD bus. Their research concluded that introducing a BYD bus would provide both economic and environmental benefits. According to this research, the additional maintenance costs of the diesel bus are attributed to the increased breakdowns of the diesel bus. In this study the BYD bus was said to break down less often due to the decrease in the number of moving parts which make its operation simpler. Therefore, this study worked with the assumption that the maintenance costs of a BYD electric bus are a third less than that of the diesel bus. Other studies led by Proterra, another electric bus company, calculated the maintenance costs to be approximately 3 cents per mile, instead of the average diesel costs of 19 cents per mile. [55] They again attribute this to having 30% less moving parts, and lack of the fuel regulator systems that ICE (Internal Combustion Engines) require. [56] Proterra's calculated maintenance cost of 19 cents per mile was similar to the maintenance cost provided by Gray Line of 20 ISK per kilometer. ICE often require the removal of large mechanical parts to gain access to the part that needs repaired. Electric vehicles may not be prone to less mechanical failures, however, studies indicate that due to their inherent simplicity they are often much simpler and cheaper to maintain.

In addition, electric vehicles do not have the extra expense of oil changes, belts, and other mechanical failures that would happen in an ICE. The most expensive component in an electric vehicle is the battery. BYD claims that their installed li-ion battery comes equipped with a battery guarantee for a 12-year lifecycle. However, for this project there is no accurate research on the projected battery life of the lithium-ion iron phosphate battery used in the C9. Therefore, given there is no access to such a battery and it is imprudent to wait 12-years for results, plus that a batteries capacity is affected by different temperature scenarios and driving conditions, for this study calculations worked with the assumption that the C9 battery will last

12 years as the manufacturer states. The electric buses are also assumed to last as long as the same 7-year time frame that Gray Line keeps their average diesel bus, there is a big enough cushion for this assumption to be a workable number. Lance Noel and Regina McCormack stated in their research that the point when a battery will need replaced can range from 70% to 90% of the capacity it comes equipped with. [57] Given the BYD C9 bus's 12-year stated battery life, the battery would be efficient the entire current 6-7-year life cycle of one of Gray Line's diesel buses. Therefore, the replacement of the battery in a C9 will not be considered for this project.

Instead of diesel costs, electric bus fuel efficiency is measured in kilowatt-hours per kilometers. The assumed cost per kilometer for the C9 was determined by multiplying the cost of electricity (in ISK per kWh) by the efficiency of a similar, but older model of a BYD electric 12-meter, 324 kWh battery pack because the C9 is too new to have available data. The efficiency that was provided by Uruguay's National Utility Company's (UTE) using a 2014 version of this similar BYD electric bus consumed 1.26 kWh per kilometer. [58] While another Canadian BYD electric bus test resulted in an energy utilization of 1.5 kWh per kilometer. [59] Because no other data could be found, and for precautionary measures this project assumed the greater 1.5 kWh energy usage to calculate the electricity cost per kilometer for the C9 electric bus.

6.4 Operating cost of electric bus

In order to determine the operating cost of the BYD C9 electric bus, it was first necessary to calculate the cost of electricity per kilometer. The cost of electricity in Iceland was given by ON Power, a power subsidiary of Orkuveitu Reykjavíkur (Reykjavik Energy) owned by the city of Reykjavik, and the municipalities of Akranes and Borgarbyggð. The cost of electricity to local businesses as of January 2016 was 6.80 ISK per kWh. [25] To determine the electricity cost per kilometer, the 6.80 ISK per kWh was multiplied by the energy usage of 1.5 kWh per kilometer. This resulted in the average kWh/Km cost of electricity for the C9 of 10.2 ISK per kilometer. The 9,012.14 kilometers driven for the e-bus are the same amount driven for the diesel bus monthly or 108,145.71 kilometers per year. Because the maintenance cost of an electric bus was approximated to be 35% less than a conventional diesel bus, the cost per kilometer was calculated to be 35% less, or 13 ISK per kilometer. The total operating costs per year were calculated by the summation of the operating costs multiplied by the 108,145.71 kilometers driven per year.

6.4.1 Assumption for revenues of electric bus

The general assumptions for the C9 electric bus were calculated using the same ones as the 2013 Volvo Sidreal 2000. That is, the same 63,085 kilometers driven over December 2015 were divided by the average 7 coaches used in the fleet. From this it was calculated that the fleet drove 9,012.14 kilometers per month uniformly applied to all 12-months of the year. Driven the exact same route to and from Gray Line's Main Bus Terminal, a one-way trip is still assumed to be 51.6 kilometers projected from Google Maps. It was assumed to be two cost analysis seasons, winter and summer, with each seasons composed of 6 months which was used to calculate the seasonal revenue for each of the two seasons.

6.4.2 Total revenue of electric bus

Similar to the diesel bus, it was assumed to be an average of 175 one-way trips of 51.6 kilometers each. An estimated revenue was calculated for the BYD C9 electric bus utilizing the average per cent seasonal seat utilization provided by Gray Line. As given, during winter months the seating capacity was approximately 50%, while during the summer months the seating capacity was 93-94% full, leaving 3 to 4 seats unoccupied for any emergencies that may arise. Using this information, winter seat utilization was found by taking roughly half plus 3 seats, assuming 22 seats were used divided by the 47 seats. These numbers yielded a result of 47% seat utilization in the winter months. Next, total winter revenue was calculated by multiplying the 6 months, by the 47% seat utilization, by the 174.99 average one-way trips per month, by the 2700 ISK bus fare, by the 47 seats. From this, the total winter months' revenue was 62,367,528.43 ISK. For summer months' seat utilization was found by dividing the 45 seats used by the 47 seating capacity of the bus. Yielding an average seat utilization of about 96%. Finally, total revenue per bus per year was calculated by the summation of both the winter and summer months, resulting in a 189,937,472.52 ISK total revenue per bus per year. And, an average total revenue of 4,041,222.83 ISK per seat per year.

6.5 Cash-flow and Net Present Value Calculations

6.5.1 Assumptions for Cash-flow + Net Present Value

The study used cash flow calculations over an 8-year period to adhere to the existing life cycle of the buses used in the Gray Line fleet. It was assumed that the electric bus would be sold after the same 8-year period and net the same one quarter resale price. This study postulated the charging stations would also be turned in the 8th year for resale and realize one quarter return on the purchase cost. Maintenance costs for the electric bus were predicted to cost roughly a third less than that of an internal combustion engine due as it has less moving parts to operate. [60] In addition, the costs to run the electric bus would differ significantly because of the added expense of the fuel needed for the diesel bus in comparison to the cheap cost of Iceland's electricity to power the electric bus. In time, further analysis may prove the electric bus to last longer than the diesel as would be predicted from the reduced maintenance requirements. However, the revenues of a diesel bus and an electric bus would be the same. It is for this reason that the revenues were not included as part of the calculation for determining the NPV of the three scenarios. A similar bus by BYD, model C10 can seat 58 passengers and holds 5 more passengers than the 2013 Volvo Sidreal 2000 currently used, while the C9 seats 6 less. Because the buses are not filled to capacity the difference of several passengers on either bus will not change the number of routes, or other factors relevant to the operational costs of the project. Additionally, as negotiated by Gray Line on the purchase of each bus, a discount rate of 10% was applied. The discount rate serves as the required rate of return to make the investment a worthwhile pursuit.

6.5.2 Bus Costs

The BYD C9 electric bus costs upwards of 70,278,165.39 kr. depending on the detail of the customized configurations available. This value was determined by the price of comparable model of BYD electric bus. Gisli at EVEN estimated that there may be a price increase for the

coach-styled seating that the C9 comes configured with and therefore estimated the cost of BYD C9's bus to be roughly €500,000 using the conversion rate of 1 EUR = 140,556 ISK. This bus is fitted with a 365 kW battery pack. The estimated cost of a similar sized diesel bus from Airport Express' current route was based on the only bus in their fleet that is of 12-meters, an equal size that Gray Line would like to add to their fleet in the coming year. This bus is a Volvo Sidreal 2000 (2013) that has a seating capacity of 53 passengers when filled to capacity. These buses were bought new for 35,000,000 kr. Gray Line's objective of buying two additional buses of 12-meters each was to accommodate for their increasing market share. The C9 can only accommodate 48 passengers, but given all the variables, this should not pose any unforeseen challenges. In addition, the diesel bus average fuel economy gets 34 liters per 100 kilometers. The usage of battery power is expected to discharge at a steady-state. No non-linear factors of discharge were included for this project. The adoption of a BYD C9 electric bus will require additional costs due to the need for the installation of two charging stations at each end to and from the airport.

6.5.3 Exclusions

Similar to estimations on the operational costs, no variables were included that were shared between the three scenarios. This simplified the cash-flow to include only the initial investment cost of the bus, fuel/electricity cost, maintenance costs, resale of either bus, as well as the resale value of the charging infrastructure.

6.6 Cash-flow & NPV of Diesel Bus: 2013 Volvo Sidreal 2000

The cash-flow of the diesel bus required an initial investment of 35,000,000 ISK. Costs for the other variables were calculated over an 8-year period. Although an average bus is used 6 to 7 years, an 8-year period was assumed because the bus would be sold at the beginning of the final period listed. The average fuel cost for the year was estimated to cost roughly 6,164,306 ISK uniformly spread over the 12-months. The Sensitivity Analysis section will then demonstrate how a variable such as fuel price will affect the NPV. Gray Line provided the cost of maintenance as a cost per kilometer based on the bus driving 100,000 kilometers. This was given as 20 ISK per kilometer. The yearly cash flow rate for the maintenance costs was determined by multiplying the 20 ISK per kilometer by the 108,145.71 kilometers driven a year, which resulted in an annual rate of 2,162,914 ISK per year. As per Gray Line's claim that at the end of a buses 6 to 7-year life span it is sold for roughly a quarter of its initial price, the diesel bus's resale income was assessed to be 8,750,000 ISK. The total costs for the 8-year period summed together both the yearly fuel cost of 6,164,306 ISK, and the yearly maintenance costs of 2,162,914 ISK for each year over the 8-year period, which totaled 8,327,220 ISK per year. Next, to account for the time-value of money, the cash-flow sheet then calculated the annual Accumulated PV cost, including the fuel and maintenance costs for each year, plus the 35,000,000 ISK cost of the bus, and minus the 8,750,000 ISK resale value of the bus at the beginning of the year 2024 which offsets the total expenses. This resulted in a NPV of 71,458,454.97 ISK for the comparable diesel bus.

6.7 Cash-flow and NPV of Electric Bus: 2016 BYD C9 + fast-charging stations

Only one fast-charging station will be required for every two electric buses purchased, therefore the cash-flow with inclusion of the fast-chargers only took into account half the cost of a charging station per bus. Scaling the project with the purchase of two electric buses may be the best alternative. With this considered, the initial investment costs of the 2016 BYD C9 electric bus and the two fast-chargers proportionate to each bus will cost a total of 77,227,800 ISK. The charging infrastructure is assumed to have the same lifespan as the electric buses. The price for electricity in Iceland significantly drops the costs related to powering the bus in comparison to the cost of diesel fuel. The cost of electricity was estimated to cost annually 1,103,086 ISK, again including the value in each of the annual 8-year time periods. Unlike the high-volatility of the fuel prices, electricity prices in Iceland are relatively stable, and there is not the same likelihood of any significant fluctuations in production that would affect the price. Additionally, because there are less moving parts in the electric bus, it was assumed that electric vehicle's cost of maintenance is roughly a third less expensive than that of an internal combustion engine. [60] Therefore, 65% of the given maintenance costs provided by Gray Line were used for the electric bus. This resulted in a 12 ISK per kilometer cost associated with maintenance costs, and a yearly maintenance cost of 1,297,749 ISK for each year again over the 8-year period. In addition to the resale value of the electric bus at the beginning of the 8-year time period, the two fast-chargers were assumed to have the same lifecycle, as well as be worth an estimated quarter of its cost as was the C9 bus. The resale values combined, both the electric bus and the two fast-chargers had a resale value of 19,306,950 ISK at the end of its lifecycle. The calculated total costs for each annum of the 8-years was a summation of both the 1,103,086 ISK per year electricity cost, and the 1,297,749 ISK per year maintenance costs. Finally, the Accumulated PV costs were calculated, including the initial investment costs for both the C9 and the charging stations over the 8-year period. Accumulated PV costs considered the time-value of money, which yielded a NPV of 79,909,234.93 ISK.

6.8 Cash-flow and NPV of Electric Bus: 2016 BYD C9 (without fast-charging stations)

The initial investment cost of the 2016 BYD C9 without fast-chargers will cost approximately 70,000,000 ISK. The yearly cost of electricity is the same as that with the charging infrastructure, 1,103,086 ISK per year over the 8-year time period. The maintenance costs remain identical at 1,297,749 ISK per annum. Additionally, the resale income of 17,500,000 ISK was applied at the end of the anticipated life cycle. Total costs were then calculated by summing the 1,103,086 ISK electricity costs with the 1,297,749 ISK maintenance costs to attain the annual total cost of 2,400,835 ISK for each year of the 8-year period. Just like the previous two cash-flows, the time-value of money was accounted for by calculating the Accumulated PV cost of the project over 8-years, including the investment cost of 70,000,000 ISK BYD C9 electric bus. The resulting NPV of all of the Accumulate PV costs yielded a NPV of 73,524,390.44 ISK.

6.9 Results and Discussion

A central question for analysis of the NPV's of the three scenarios is whether the short-term, high initial investment costs of the electric bus with or without the charging infrastructure, with consideration to the discounted cash-flow, could be recovered in the 6 to 7-year lifespan that Gray Line will utilize the bus. Since the NPV was calculated based on the differing costs of each investment, the lowest valued NPV had the least inherent risk. Therefore, the better investment is the one with the lowest calculated NPV. Of the three investment decisions, Diesel had the lowest risk with a calculated NPV of 71,458,454.97. However, the electric bus without the two fast-chargers was only 14,291 Euros more than diesel with a NPV of 73,524,390. To this end, the renewable EV choice would be more easily implemented if the government could help off-set the slightly higher initial costs, which in this project represents the slight additional cost of the BYD C9 electric bus and the charging infrastructure. This will be discussed in the ending discussion of this thesis.

The second-lowest calculated NPV of the EV without charging stations was 73,524,390, which could be offset by small government subsidies or over a period of years, slight increases in the market fuel cost of diesel could offset the higher initial cost and this will be explored.

There will be a sensitivity analysis that will show how a variable such as fuel cost will affect the NPV for each of the three-scenarios, and a discussion that follows. As can be expected from the addition of the two fast-chargers to the EV option, both the resulting initial cost, and the NPV were the largest of the three options, and therefore has the most inherent risk. Of the three-options given, without governmental economic or political financial instruments to off-set the costs of the initial implementation of lower-carbon technologies, which in this study is represented by the small difference in EV price and the installation of charging infrastructure, it would not be the best investment. Only with proper incentives, would it be possible to offset these costs and make replacing or adding electric buses more competitive with diesel buses.

6.9.1 Accumulated cost as a function of years for all three-scenarios

Accounting for the time-value of money, the accumulated cost as a function of years, was plotted to show when the break-even point would be reached for the three-scenarios.

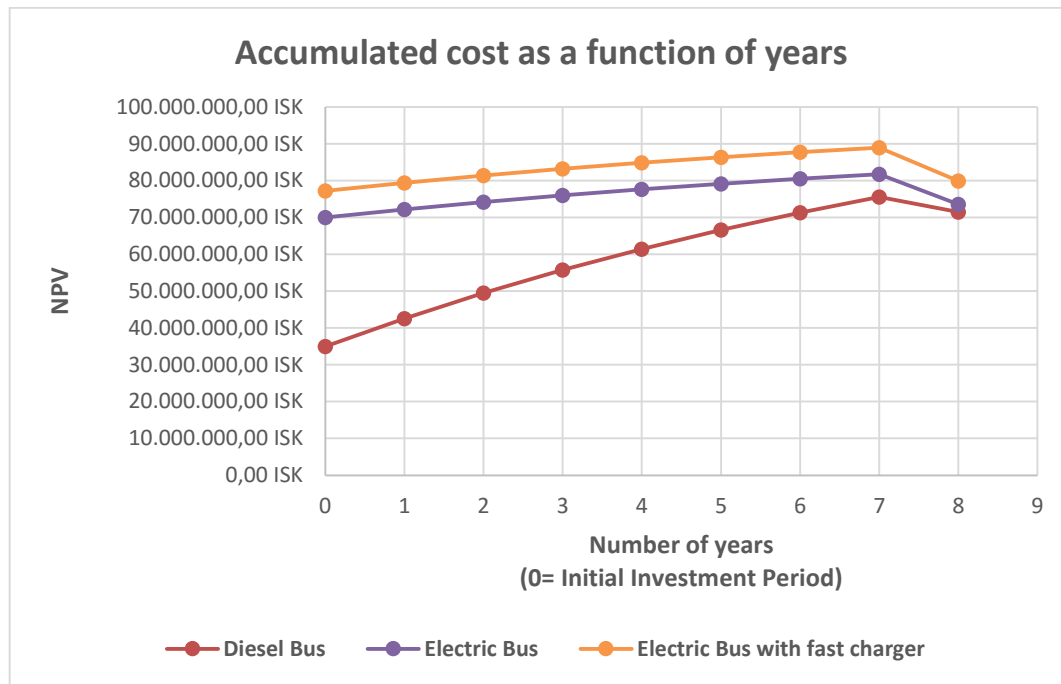


Figure 6: Accumulate cost as a function of years

Despite the high initial investment of the electric bus, the accumulated cost as a function of years looks like they would nearly break-even towards the end of the 8th year, or beginning of the 9th year. On the other hand, the higher cost of an electric bus with two fast-chargers was not able to break-even if the buses were traded in at the beginning or any time in the eighth-year. The cost of two fast-chargers brought the initial cost of the investment up 7,277,800 ISK. The costs of the EV and charging infrastructure would not break even within the planned life cycle of 8 years that Gray Line typically keeps their buses due to the high initial investment cost. It is reasonable to expect the EV to last longer than diesel due to its lower maintenance costs, but there is no data available. The Icelandic government could help encourage low-carbon buses by creating political and economic incentives to make them more competitive with more established technologies, such as the diesel bus in this comparison. For example, implementing a carbon-tax and subsidizing the charging stations are 2 methods that would help off-set the higher initial investment costs.

6.10 Sensitivity Analysis

In order to determine how changes in individual parameters will affect the outcome of the NPV, several sensitivity analyses were run on variables that were predicted to affect the overall projection of the study.

6.10.1 Volatility of diesel prices

The volatility of oil and diesel prices would have a significant impact on the economic parameters in comparing the NPV's. The instability of diesel prices are a result of supply and demand in the world market. Diesel prices generally follow the same economic trends as crude oil prices. Europe relies more heavily on diesel fuel than the U.S. Much currency is used for the importation of oil. Domestic consumption of oil neared 601 thousand tons in the year 2007. [51] According to the oil forecast on this site, new energy sources will increase their market share significantly by the year 2020. [51] Although, there were no stated projections of why, or what source this would be.

The figure below shows a sampling of how prices have significantly fluctuated over the last 19-years.

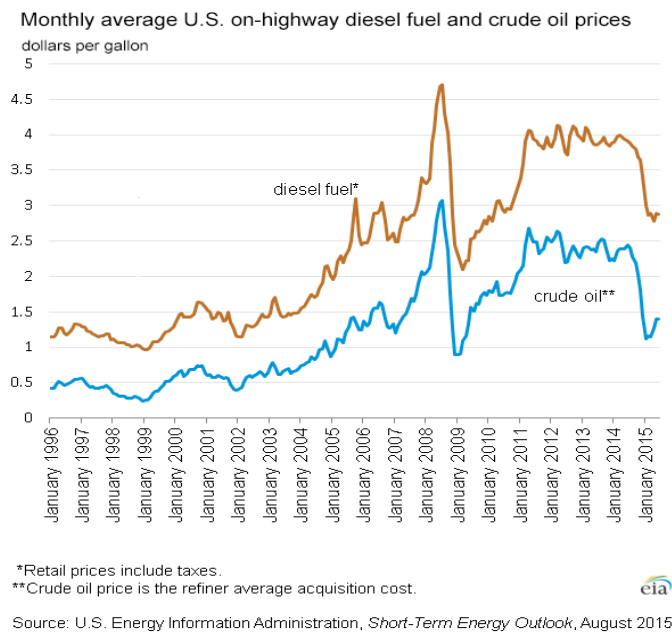


Figure 7: U.S. Energy Information Administration, Short-Term Energy Outlook, August 2015 [61]

The price of diesel looked even more volatile when viewed from a dollar per barrel basis from 2014 to projections in the year 2017. The cost of diesel per barrel over these 4-year years are shown below.

	2014	2015	2016	2017
Diesel (dollars per barrel)	3.83	2.71	2.11	2.33

Table 8: Price Summary of Diesel from the year 2014 to 2017 [62]

The cost of diesel has fluctuated nearly 65% over just four-years. So, it would not be unforeseeable for the price of diesel to change substantially over the coming years.

6.10.2 Sensitivity Analysis: NPV, Diesel price

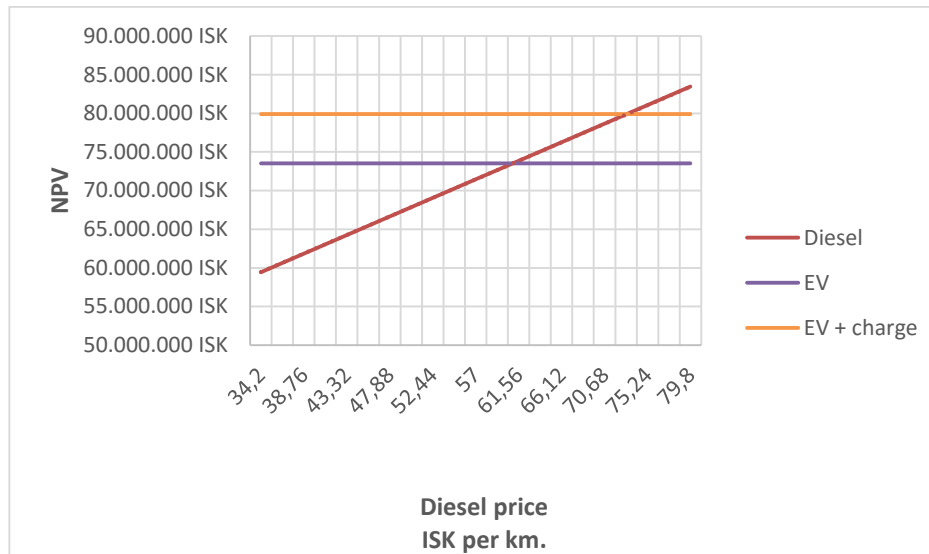


Figure 8: Sensitivity Analysis: NPV, Diesel Price

In performing a sensitivity analysis with NPV on the Y-axis, and the cost of diesel in ISK per kilometer on the X-axis, it was shown that the cost of diesel needed to increase only 4 ISK/km from today's cost of 57 ISK per km today to about 61 ISK per km before the EV alone had a lower NPV and would represent the best investment. However, the diesel price would need to rise to approximately 73 ISK per kilometer before the NPV of the EV plus charging stations would have a lower NPV than the diesel model. This would only require a fluctuation of 7% in diesel price before the EV alone would reach a break-even point with diesel. If the diesel price of 57 ISK per kilometer today were to rise to about 73 ISK per kilometer, the break-even point of the diesel bus would be met with respect to the cost of the electric buses with the two fast-chargers which represents a 28% increase in fuel. This may be somewhat less likely in the near future, but the cost of fuel has been subject to market factors and political climates in which large fluctuations have occurred. In Figure 7 above, diesel prices have shown great fluctuations in the last 4 to 5 years, fluctuations much greater than 28%.

6.10.3 Sensitivity Analysis: NPV, EV Resale Value in ISK

There was no available data on the resale cost of electric buses. For this project it was assumed that the C9 electric bus would generate the same one-fourth of its original cost while due to the reduced maintenance costs it may prove to have a higher value but data was not available. Another sensitivity analysis was run to see what impact a different resale value for the C9 electric bus had when comparing NPV's for the given projects. As can be seen from the sensitivity analysis below, as the resale income from the electric bus goes up, its NPV goes down. The break-even point between the two projects is reached when the resale of the C9 electric bus is approximately 21,600,000 ISK, which is 4,100,000 ISK or 23% higher than the projected one quarter resale price of 17,500,000 ISK. As electric buses accumulate more years of use there will be more research available for more accurate resale values for the EV which may be projected higher than the one fourth used in the study, but no data is currently available.

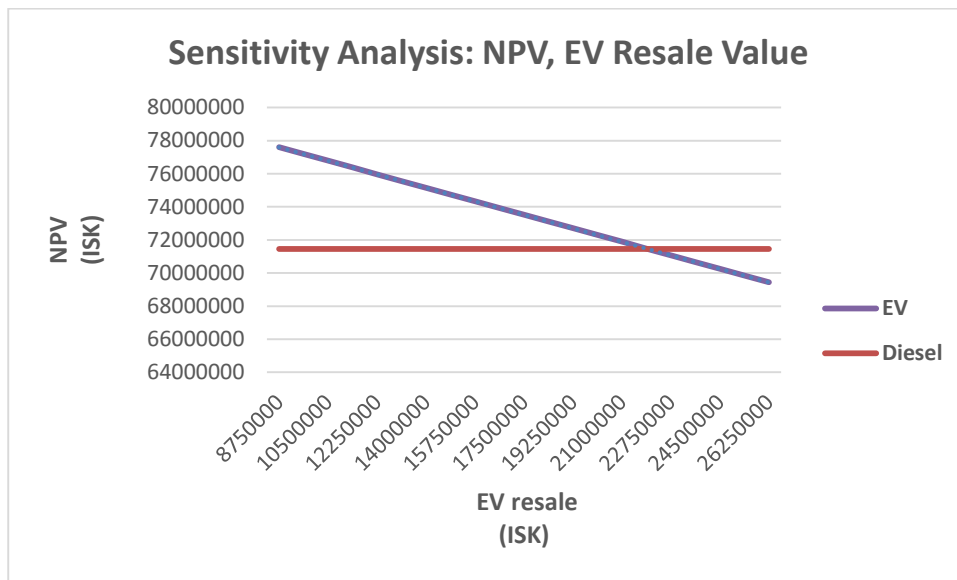


Figure 9: Sensitivity Analysis: NPV, EV Resale Value

6.10.4 Sensitivity Analysis: NPV, 2013 Volvo Sidreal 2000 Resale

Another sensitivity analysis was run accounting for how the diesel bus resale value would affect the NPV of the other projects. The estimated resale value of the diesel bus is 8,750,000 ISK, which makes it the best choice for investment if there is no government assistance to offset the higher start-up cost of the EV and necessary charging stations. The diesel bus would need a resale value of 5,000,000 ISK, considerably under the projected 8,750,000 kr, for the EV bus to be at the break-even point. There is no value for the diesel bus in which the EV with two 200 KW fast-charging stations represents the best value; the diesel bus represents the best option of all 3 models unless the resale value of the electric bus is considerably higher than the estimated one quarter used for this study.

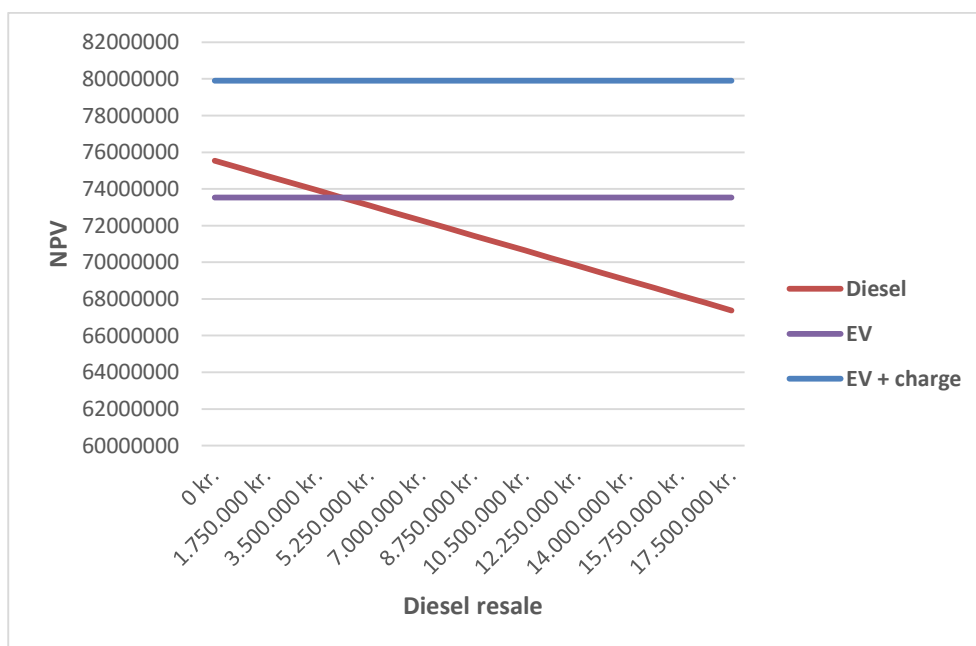


Figure 10: Sensitivity Analysis: NPV, Diesel Resale

6.10.5 Sensitivity Analysis: NPV, Fast-charging Station

A fourth sensitivity analysis was run accommodating for the cost of the charging stations relative to the NPV of the diesel bus. As the cost of the charging infrastructure goes up significantly, the NPV for the project goes up rapidly, making it the least feasible option without a means to off-set the additional investment required for the charging infrastructure. In the previous cash-flow and NPV calculation given for the electric bus with the charging stations, half of the charging stations costs were accounted for since two buses can utilize one charging station. This is because two new fast-chargers-one on each end of the trip, will be required for every two buses purchased. If the entire cost of the charging infrastructure were subsidized the break-even point would not be reached without any subsidization from the Icelandic government. However, if the total cost of the charging stations were subsidized it would make the ability for Gray Line and other private enterprises to convert to low-carbon transportation alternatives more feasible.

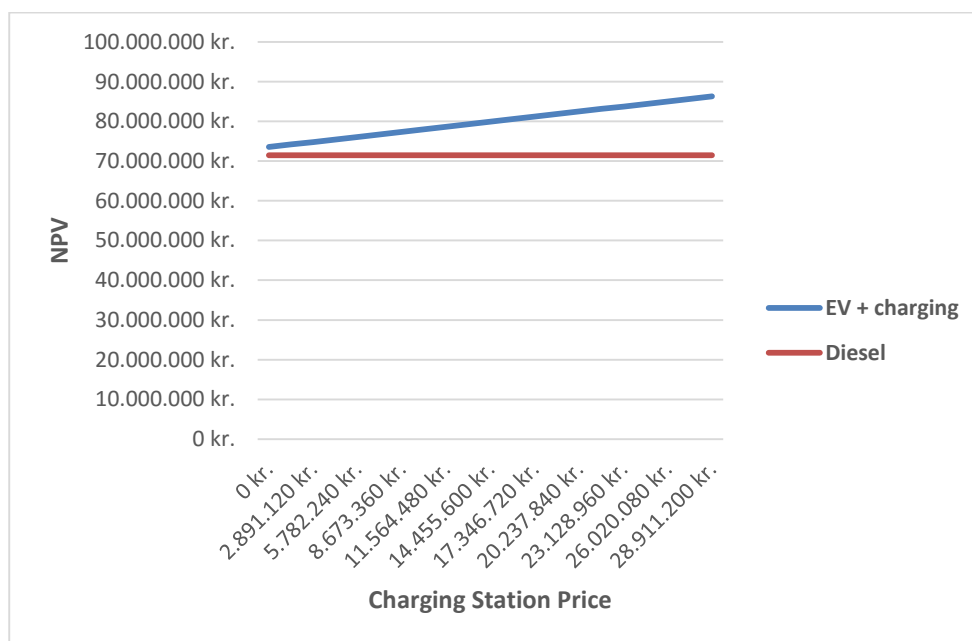


Figure 11: NPV, Charging Station Price

6.11 Results of Sensitivity Analyses

As can be seen from running the above sensitivity analyses, there is significant need for both political and economic incentives to off-set the higher initial investment of low-carbon technologies infrastructure. To be discussed are the several factors that showed a significant influence in the running the above NPV analyses for each project. The first sensitivity analysis chose to see how the cost of diesel would affect the NPV given its high likelihood that it would exhibit volatility over any period of time. The results yielded that diesel prices would only have to increase 4 ISK per kilometer from today's price of 57 ISK, before the EV bus alone would be the best investment. This only represented a 7% increase in diesel prices which is highly likely given the large fluctuations of diesel in the last 5 years. Diesel prices would have to increase 28% to 73 ISK per kilometer for the EV plus charging stations to represent a break even value. The additional need for charging infrastructure presents a barrier to private

companies, such as Gray Line who would like to make use of Iceland's low-carbon energy mix. Given that diesel prices have fluctuated over 65% in the last 5 to 6 years, it is not so unlikely for either the EV bus or EV bus plus infrastructure to become competitive with diesel. Clearly, external support for the additional infrastructure is needed to represent a break even option for renewables with the added advantage of being independent from the crude oil market.

Since there was no data available, the second sensitivity analysis showed the extent the NPV would change with respect to resale income generated from the C9. This test was run because of the lack of available data on how much resale value an electric bus could truly generate after a period of time. Not surprisingly, when the resale value for the electric bus went up, the NPV went down, making it the better investment. The NPV of the diesel bus remains lower and does not reach a break even NPV with the EV alone until its resale value was 21,600,000 ISK which was 23% greater or 4,100,000 ISK than its projected resale value of 17,500,000. A to offset the operating cost. This again illustrated the feasibility of adding an electric bus to the fleet only when proper incentives to off-set the initial start-up cost is given although more accurate resale prices for the EV bus will most likely offset some of the costs.

Similar to the second sensitivity analysis, it showed how the effect of the diesel bus resale income value moved the NPV relative to the electric bus, both with and without the charging infrastructure. Gray Line estimated the current resale income generated from an average bus in their Airport Express Route to be roughly 8,750,000 ISK. There was no resale value in which the electric bus with two fast-chargers represents the best investment option in regards to the resale price. The resale cost of the diesel bus would only need to be 5,000,000 kr., well below the usual 8,750,000 kr. realized, in order for it to be the best option in regards to the resale price. It is possible that the resale price for the EV was underestimated but no data is available to support this. As the resale income of the diesel bus rose, the electric bus lost its advantage of being more competitive when needing a full installation of two fast-chargers for the C9 electric bus, but remains competitive if added without the charging stations. Again, this illustrates the effects of the absence of market incentives which could help off-set the larger upfront initial investment costs associated with the deployment of low-carbon technologies.

The final sensitivity analysis factored in how the cost of the charging infrastructure affected the NPV. As was expected, as the cost of the charging stations rose, it became considerably less competitive than the diesel bus. The assumptions and values used in the study, indicate that the cost of the charging stations would need to be supplemented to make the EV bus competitive with the diesel initially. Specifically, if political and economic incentives subsidized the cost of the infrastructure, the project would not only be the better investment for Gray Line, but would encourage other commercial companies to adopt cleaner transportation methods, with the potential of market forces driving their prices down.

7 Environmental Considerations

As more electric buses and vehicles are adopted, Iceland has the opportunity to significantly reduce its percent carbon-based GHG emissions. As stated previously, Iceland's Climate Strategy sets an aggressive goal for reaching a significant 50-75% reduction in GHG emissions by the year 2050. [3] Private companies will most likely not make the higher initial investment costs of implementing lower-carbon technologies such as electric buses.

Iceland's energy mix is unique in that it is already primarily derived from lower-carbon energy sources with the exception of the fossil fuels used for vehicles and shipping fleets. In descending order of installed capacity hydro, geothermal, wind and fossil fuels make up the energy mix in Iceland. [63] Since the 1940's, Iceland's energy profile has transformed from only a 12.4% renewable mix, to an 85.3% in the year 2015. It is within Iceland's grasp to further this conversion by capitalizing on the strategic advantage of a large renewable energy source.

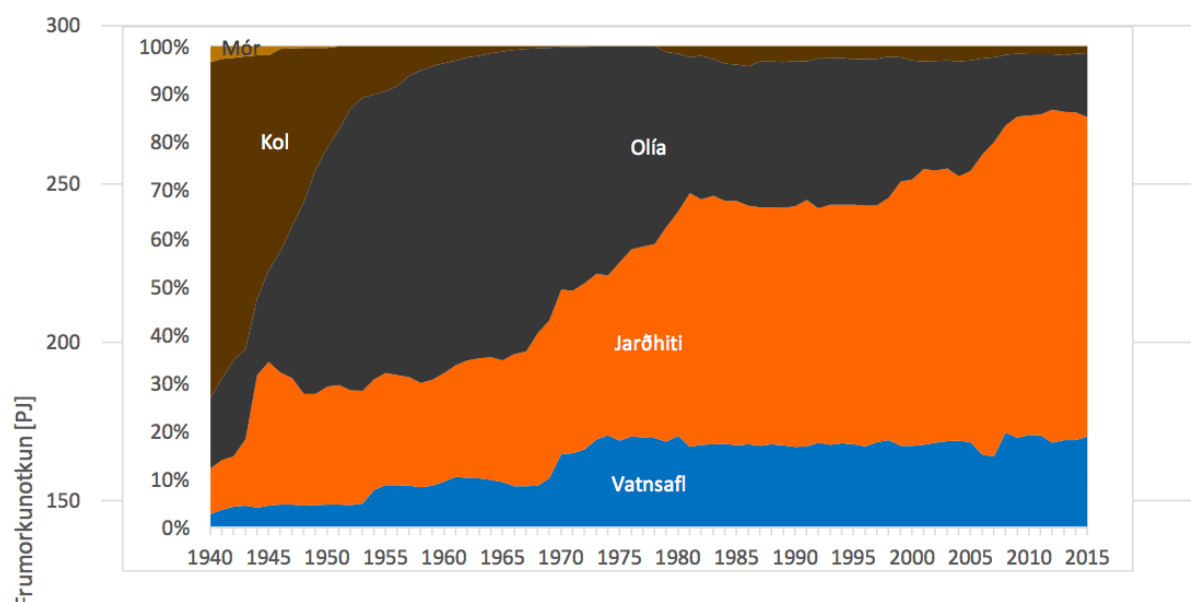


Figure 12: Primary Energy Uses in Iceland 1940-2015 [63]

Per translation:

Kol	Coal
Olía	Oil
Jarðhiti	Geothermal
Vatnsafl	Hydropower

Table 9: Translation of terms for the primary energy use in Iceland

If the government were to supplement start-up costs by providing financial incentives for the required infrastructure, it would become more economically feasible and electric vehicles and buses would be competitive with ICE buses, such as the diesel buses currently being utilized by Gray Line.

7.1 Environmental Externalities of Buses

There are equally important differences to consider including the major differences in the externalities produced when comparing a diesel bus, such as the 2013 Volvo Sidreal 2000 with the new C9 electric bus. The externalities of the two types of buses are discussed below.

7.1.1 Diesel Bus Externalities

The combustion of fossil fuels emits carbon and other pollutants, including PM from the incomplete combustion of diesel that cause both pollution and global warming. It has been estimated that just one liter of diesel emits 2.68 kilograms of carbon dioxide. [64] Considering an average diesel bus in the Airport Express Route gets approximately 34 liters of diesel per 100 kilometers, every one-way trip emits roughly 45 kilograms of carbon dioxide per bus. It is common practice to not include the social costs of carbon in operational and economic feasibility studies, and this study also did not. Private companies are not required to, and it should not be up to them to finance a particular project because it has less of an impact on the global environment. Much like the current gas and oil subsidies are offsetting the economic and environmental risks associated with the development of oil and gas, subsidies would also be used to make lower-carbon technologies more viable by creating incentives to make them more competitive transportation based on high-carbon technologies, such as diesel buses. Another option to explore would be the introduction of a carbon tax that would make alternative fuels more attractive by not including exemptions for heavy-industry.

It remains inherently politicized, and contentious to quantify the harms that carbon cost society, which are referred to as the social costs of carbon. The National Academy of Science (NAS) points to uncertainty, speculation and lack of sufficient data to quantify the economic losses incurred from carbon dioxide emissions as the reasoning. In addition, private companies and individuals are not incentivized for their purchase of lower-carbon transportation. The initial investment of electric buses is more expensive so private companies have not yet widely adopted electric buses in their fleets. For simplicity, uncertainties and ethical debates were not included as part of the economic feasibility study.

7.1.2 BYD C9 Electric Bus Externalities

However, the electric bus, such as the BYD C9 utilized for this project, has no direct emissions and is quieter than a diesel bus. Iceland has the advantage of utilizing their low-carbon energy mix composed of hydroelectric and geothermal to fuel an electric vehicle fleet, thus avoiding the so-called problem shifting of contributing to GHG emissions indirectly as would be the case with the higher carbon-sourced energy production of most countries. There are some negative environmental impacts associated with supply of copper and aluminum that are needed to manufacture the anode and cathode within a li-ion battery. [65] Notter and his colleagues, however determined that if the energy mix utilizes lower-carbon sources such as hydroelectric the environmental impact from electric vehicles is far less than the impact of an ICE vehicle. [65] Incentives to make electric buses more competitive and defray initial start-up costs would encourage private companies more likely to invest in cleaner technologies which eventually drives down costs further. Given an electric bus without the charging infrastructure is a more economically viable solution than a diesel bus over the analyzed 8-

year life cycle, companies would not base their investment decision on the initial investment, but on the cost to operate the bus over a period of time for maximum profitability. A unified support from companies with similar interests as Gray Line could cooperatively petition the Icelandic government to balance the cost of a diesel bus with an electric bus by providing compelling financial instruments to do so. This will be discussed in the Discussion section.

7.1.3 Iceland's market for eco-tourism

Tourism now makes up the largest segment of the Icelandic economy. It is the nature, and the large open spaces that has increasingly drawn people to this pristine and unique ecosystem. Despite the recent increase in tourism to this country, its development is in its infancy. Up until this point there has been little if any structure or organization to its process. As of 2013, the Icelandic government has had a number of private companies conduct a report through the Boston Consulting Group underlining the segment market. Their conclusion was that the future growth of tourism should target both “affluent adventurers and older relaxers,” drawn to Iceland to experience the unspoiled nature. [66] With this in mind, the Icelandic government and its people would benefit from taking steps to enhance and preserve this image. Adding electric buses at a highly perceptive point of contact, such as the Keflavik International Airport, would help promote and enhance this image of Iceland as an example of a successful green energy technology. It would also have the advantage of saving a significant amount of Icelandic currency which could be reinvested in other desired projects, otherwise used to import polluting fossil fuels. As cleaner sources of energy become more profitable, current gas and oil companies will be incentivized to invest in alternative fuel technologies and less likely to oppose its widespread implementation which would decrease revenues from existing investments.

7.2 Summary of Results: Operational, Economic & Environmental Feasibility Study

7.2.1 Summary of Results: Operational Feasibility

The operational feasibility of using a C9 electric bus instead of a bus similar to the 2013 Volvo Sidreal 2000 has promise. There are no required changes to the operating schedule, the number of stops or the need for extra labor hours. The electric bus can utilize already established one-hour breaks on each end of the 51.6 kilometer journey to let the buses charge for the full-hour. If multiple electric buses are purchased, a row formation should be established for arriving buses (as was illustrated above), instead of the linear arrangement in current practice, as each bus parks behind the previous bus upon arrival. Iceland's average temperature range often remains at or slightly below the freezing point, therefore this study assumed a 25% reduction in the expected battery capacity due to temperature effects. The expected distance range for a full battery cycle of the C9 bus, according to BYD's manufacturer claim was 300 kilometers, which in this study was reduced by 25% to account for temperature effects on the battery and assumed only a 225 kilometer range per full battery cycle. The electric bus used a lithium-ion iron phosphate battery. Li-ion batteries charge in two-phases that were explained in detail. During the first slower phase, 65% of the battery will charge, and during the second rapid phase, only 35% of the battery will charge. The constant charge of phase one and the rapid constant voltage of stage two were considered when planning the logistics of the charging

schedule as it was only known that the battery takes 2 total hours to charge fully. To ensure that the bus battery would always have a sufficient power charge for the 51.6 kilometer trips to and from the airport, a charge schedule was devised such that the bus would be charged at the beginning and ending of each trip, utilizing the rapid phase 2 phase to top off the battery. For purposes of this study, it was assumed that phase 2 would take one hour, or half the total 2-hour required battery charge time, even though this charge was known to progress at a more rapid rate. This allowed for plenty of battery reserve at all times, allowing the same schedule for Gray Line as that with the diesel buses. During the first hour 146.25 kilometers of battery capacity were expected, and in the second hour 35% of the expected 225 kilometer range, or 78.75 kilometers. Since each trip is just 51.6 kilometers, and the battery will recharge for one hour which provides 78.75 kilometers from phase two charging, the bus will have more than enough range to make each one-way trip. Essentially, the battery is kept nearly full, topping off the 51.6 kilometers range that was used at each end of the trip. Recharging was facilitated by taking advantage of the already scheduled one-hour breaks on each end of the trip that were built into the existing Gray Line Schedule. BYD also claimed that the battery can be recharged up to 6,000 cycles before it reaches its 80% efficiency, generally this would take about 12-years. Given that the buses compared for this project were assumed to be sold at the beginning of the 8th year of use, battery replacement would be adequate for the life cycle of the bus for Gray Line, and battery replacement was not considered. With the expectations delineated above, the C9 electric bus was found to be capable of meeting all of the requirements of running on Gray Line's Airport Express Route with almost identical operational parameter.

7.2.2 Summary of Results: Economic Feasibility

All data for the economic feasibility of the diesel bus being used in Gray Line's Airport Express fleet was provided by Rúnar Garðarsson, the Operating Manager at the Icelandic office at the Main Bus Terminal. The only variables used in the calculation for basic cash-flow and NPV analysis were those which differed for each of the following three projects: 1) diesel bus, 2) BYD C9 electric bus with the cost of fast-chargers, and 3) BYD C9 electric bus without a charging infrastructure. Same cost items incurred for both the diesel or electric bus, were left out because they would require the same amount of capital to run either. This included things such as same-cost insurance, depreciation costs and tires. Following this, the accumulated PV costs were determined for each project in order to account for the time-value of money. This resulted in the NPV of the three-projects.

The profits were not included because the buses seating capacity were assumed to be approximately the same. The C9 bus compared in this project has a 47 seating capacity, and the 2013 Volvo Sidreal 2000 had 53 seats. Gray Line stated that they wanted to increase the number of buses in their current fleet with a bus seating about 48 passengers. Therefore, the C9 was the most comparable to this seating capacity and used in the study. Given these two options, the number of profits derived from the two buses compared were assumed to be identical. Only the differing operational costs were assumed for points of comparison. After calculating the differential operational factors, the resulting lowest NPV was determined the least risky option and the better investment choice.

The end result of these calculations found the diesel bus to be a minimally better investment than the C9 electric bus without the charging stations, having only about a 14,000 Euros

advantage cost of NPV over the EV bus alone. The diesel bus NPV was found to be 71,458,454 ISK and the EV without charging stations was 73,524,390 ISK. Only the small difference would need to be supplemented to make this investment option equal to the diesel bus. The EV plus 2 charging stations produced the highest NPV of 79,909,234.93 ISK and would not equal the diesel option unless the total cost of the charging stations is supplemented. It represents the riskiest option of the three given scenarios without additional means to offset costs incurred from the high initial investment in startup costs for the installation of charging infrastructure. Showing the accumulated costs as a function of years, it was determined that the C9 electric bus without the charging stations, would reach the break-even point relative to the NPV during the 8th year of use. Gray line currently resells its fleet at the beginning of the 8th year, so to capitalize on this model given supplemental help for the infrastructure, there may need to be slight adjustments on the month of the resale to fit this model. However, the electric bus with the fast-charger's does not meet a break-even point that would fit the 8-year life cycle that Gray line currently utilizes and therefore would not be a competitive option without support for the cost of the 2 charger infrastructure and EV NPV differential of 14,000 Euro.

In order to determine how individual variables affected the outcome of the NPV, a variety of sensitivity analyses were run. The first analysis showed how change in diesel prices would affect the NPV. It was determined that the cost of diesel would need to increase 4 ISK/KM from today's price of 57 ISK per kilometer in order for the EV Bus alone to be the best investment option. This is only a 7 % increase in the cost of diesel which is very likely given the fluctuating price history of diesel. The Diesel price would need to be at 73 ISK per kilometer, or a 28% increase for the EV bus plus infrastructure to be an equal option. 28% is not hard to imagine either, given that diesel has fluctuated 2 fold in the last 5 to 6 years. Because of the limited data available for the resale cost of electric buses, it was assumed to generated the same one-fourth of its original cost. The next sensitivity analysis illustrated how the higher the resale value of the EV bus, the greater the effect on the NPV. This study determined that the higher the resale cost achieved, the more the risk went down for the electric bus, making it more economically feasible. The results showed that the resale value for the diesel bus would only need to be 5,000,000 for it to represent the best option with respect to resale. If the electric bus actual resale value proves higher than the one fourth used in the study, these results may trend closer but no data was available to support this. The final sensitivity analysis evaluated how the cost of the charging stations would affect the NPV. As was expected, as the cost of the infrastructure rose, so did the NPV of the project. The results of this analysis showed the costs of the required fast-chargers would need to be fully supplemented for the EV bus or EV plus chargers to be the most feasible of the three projects.

As has been shown from the following four sensitivity analyses, there was a lack of economic incentives to offset the higher initial investment costs of the project with both the charging infrastructure and the BYD C9 electric bus with the two fast-chargers, making this investment the weaker option. However, with only small fluctuations of fuel costs, there is a significant effect on NPV. The results of the diesel cost sensitivity analysis showed that fuel costs would only need to rise 7% to make the EV bus alone feasible, and 28% for the total unit to be feasible all possible in a volatile crude oil market so interdependent on external factors. Additionally, the sensitivity analysis run on the EV bus resale value highlighted that it was the lack of charging infrastructure that most significantly prevented private companies and entrepreneurs from investing in electric buses. This highlights that the biggest barrier to widespread

deployment of the electric bus is the lack of available charging infrastructure and this is probably a limiting factor in personal electric vehicle ownership as well.

The results of the sensitivity analyses show there is great opportunity for investors to support electric bus production and utilization in Iceland if there is at least a shared cost for the infrastructure. What has been missing in the past in order to implement Iceland's strategy for a green economy was a more specific cost-benefit analysis of each objective such as is found in this feasibility study of the addition of electric buses for public transportation and in this case for a limited route and use. A clear political strategy with well researched financial analyses gives Iceland's government the informed basis for incentivizing low-carbon technologies such as the addition of an electric bus and charging stations put forth in this project. In order to encourage Gray Line, and other private companies to electrify their fleets, it is necessary to set clear attainable goals and take actions which will offset the higher costs of investing in low-carbon technologies; relatively easy solutions are within reach to make the electric bus a sound investment option. Possible methods to address this will be discussed in the final Discussion section following the results of the environmental section.

7.2.3 Summary of Results: Assessment of Environmental Factors

There are major differences in the environmental externalities generated from an electric bus relative to a diesel bus. The combustion of diesel through its incomplete combustion releases carbon, PM and other pollutants that contribute to global warming. Given Iceland's low-carbon energy mix, adding, or replacing diesel with an electric bus would reduce these emissions into the atmosphere, an investment which also would help Iceland achieve its Climate Strategies goal of a 50-75% reduction in GHG emissions by 2050. It was calculated that a single journey to or from Keflavik International Airport by transport of a diesel bus emits roughly 45 kilograms of carbon dioxide per trip. However, it is not common practice for investment decisions to include the social costs of carbon, it is a driver for political support due the overall damage inflicted by the emissions of carbon. The 'social costs of carbon' remains an innately debated subject due to the uncertainty of the amount of damage to both public health and the environment which directly occurs as a result of carbon emissions. Frances Moore, a PhD student at Stanford University in the School of Earth Sciences, took issue with a recently released government study that put the 'social cost of carbon' at only \$37 per ton. [67] He then published a type of rebuttal article in Nature Climate Change that placed the cost of carbon at the substantially higher \$220 per ton. [67] This demonstrates the considerable range of uncertainty as to how much damage is caused from carbon emissions. As it currently stands, private companies pay no VAT for either a diesel bus, or an electric bus. Therefore, they are more likely to invest in the option with the lowest operating cost over the lifespan of that bus, excluding the costs incurred from the installation of charging stations. The BYD C9 electric bus emits no direct emissions, and exhibits very low road noise and has the Iceland advantage of no indirect emissions given its low-carbon energy mix of hydroelectric and geothermal sourcing used for the charging stations. Incentives to encourage low-carbon investments will be examined more thoroughly in the discussion section below.

For the first time in Icelandic history tourism made up the largest segment of the Icelandic economy, overtaking fishing as the most profitable segment of their economy. However, it was not until 2013 that the Icelandic government contracted the Boston Consulting Group to determine which market segments should be targeted. The largest markets were shown to be

made up of the “affluent adventurers” and “older relaxers” who came to experience the pristine beauty of Iceland’s nature. Therefore, seeking ways to capitalize on the financial economy driven from this image as well as the protection of the unique ecosystem would promote Iceland’s economic stability in the long run. Utilizing Iceland’s domestic energy supply to power buses would help preserve Iceland’s rugged wilderness. Vast sums of money would be saved and reinvested when there is not a need to import large quantities of fossil fuels into the country, especially when Iceland has viable alternatives that give it an economic edge. It might be expected that if the electric car infrastructure were encouraged through economic incentives there would be a backlash from gas and oil, it is also a possibility that the same companies would diversify into alternative energy technologies.

If the high initial investment costs are offset by political or economic incentives, private companies would be more likely to invest in lower-carbon technologies and charging stations when they become a profitable option. The political climate is changing favorably in both governments throughout the world and within the oil-driven industries, yet incentives are clearly needed to drive clean energy alternatives and redirect investments into alternatives such as the electric bus as they become more competitive in the market. It is primarily the ROI (return on investment) that drives investment in alternative energy, not any particular attachment to one form of energy over another. The Gray Line’s interest in the conversion of its fleet to an electric alternative is an example of this change.

7.3 Discussion

The results of the cash-flows and NPV for the three projects of 1) diesel bus, 2) BYD C9 electric bus with two fast-chargers and 3) BYD C9 electric bus without any charging stations, illustrate the need for both political and economic incentives to offset the higher initial investment costs required for private companies adding electric buses to their fleets. Gisli Gislison recently provided the Pirate Party with some recommendations on how to promote electric vehicles, and provide the required infrastructure. It was recently submitted and approved in 2016 by vote.

Up until this point, the Icelandic government has not made any long-term plans for electric vehicles, or the required infrastructure. With no specific plans or forward looking statements by the government to support the installation of charging stations, investors have expressed a hesitancy to invest in this industry and it was also cited as one of the major reasons that individuals do not purchase electric vehicles. With this information the Pirate Party recently submitted a proposal that would help balance the competition between ICE and the increased cost of electric vehicles.

Other barriers sighted are the limited one-year concessions. More specifically, as it currently stands there is no VAT on the first 6,000,000 ISK of importation value. Because this concession only applies to one-year at a time, and is often only approved several months before it expires it creates a sense of uncertainty in the future application of this process. For instance, last year this was not approved until just a few days before the Christmas holiday season began. This creates a hesitation for private companies to invest in charging infrastructures, and therefore does not encourage ownership in electric vehicles.

The Icelandic government continues to express the desire to increase energy use from renewables as demonstrated by its policies and agreements, yet a concise plan has not yet materialized. Iceland's government prepared a policy report entitled "Welfare for the Future: Iceland's National Strategy for Sustainable Policy Development 2002-2020" which was approved by the government prior to the UN Climate Summit. [68] It defined their priorities for the protection of the environment but also for the expanding use of renewable resources for the next 20 years until 2020. It is periodically reviewed to analyze new trends and determine objectives to accomplish their goals. As part of their commitment at the UN Climate Summit, the Icelandic government set the ambitious goal of attaining 10% of its total vehicle fleet as alternative fuel cars. However, this goal will not be achieved at the current rate because today there only about 600 electric vehicles on the road. In 2014, at the UN Climate Summit the Prime Minister of Iceland, Sigmundur Davíð Gunnlaugsson gave a speech stating that "Iceland is aiming to become a fossil fuel free economy, with almost all of our stationary energy coming from renewables, and our efforts towards reaching this goal are underway". [69] His concluding statement also reflected the need to participate in creating this vision by additionally stating that "we need participation and leadership of all members of society". [69] However, unless legislation can divert from its current path, and set a sound framework of compelling incentives, it is unlikely they would be able to reach 24,000 electric vehicles on the road by 2020.

Norway has taken some positive steps toward promoting the growing market for an electric vehicle fleet and infrastructure in their country, by not levying any VAT on electric vehicles, permitting free parking, free fare through bridges and tunnels, allowing EV's to pass through tunnels and ferries free of charge, and receiving a discount on personal income tax if the person is using the vehicle for company purposes. With its rising popularity, Iceland's Pirate Party proposed getting private companies, malls, and other parties to cooperate to set up charging stations around the country. They also proposed extending concessions for a number of years, or until EV use within Iceland reaches approximately 10%, in line with the 10% alternative fuel vehicle proposal issued at the 2014 UN Climate Summit. The Pirate Party would like to see a carbon tax issued on the importation of fossil fuels relative to the amount of emissions released per vehicle. Though they do not make mention of applying this tax to heavy duty vehicles that use diesel as fuel, and are currently exempt. They believe that the results of such an implementation would save currency exchange, achieve stated global goals of GHG emissions, foster its image as one of the cleanest countries in the world, and would increase the household income by roughly 30,000 ISK per month. The Pirate Party considers these changes a historic opportunity to transform society, and become the first country in the world to have a zero-market for fossil fuels.

Another funding model being deployed is a financed model to build the infrastructure such as the ChargePoint project called Net+Purchase Plan which allows municipalities and companies to install EV chargers with no upfront costs to allay the hesitancy companies have toward investing in the electrification of transport. [70] Essentially this moves the costs of financing an electric infrastructure to the driver, but it is still incentivized with tax rebates and other government initiatives even though the government is not directly part of the start-up company. Reed Hundt, CEO of the Coalition for Green Capital and former FCC Chairman in the Clinton Administration, stated that "The magic of the Net+Purchase program is that with very little capital, the electric vehicle industry will see rapid adoption. This is absolutely

critical for expansion of the EV market.” [71] ChargePoint’s program also covers installation and service, although they only sell level 2, 240-volt charging stations. [70] However, a consortium of finance companies, private backing, and government incentives could make the building of the infrastructure a viable option for charging stations for public transport. More analysis is needed on the time-frame for a return on the investment and the logistics for such a project. Most successful transitions to electro mobility have involved government incentives directly or indirectly but the addition of a financing option to the multi-pronged approach would help to eventually wean the costs away from the government with the infrastructure in the future. [70]

7.4 Case Studies: The Effect of Carbon Tax on Per Capita Carbon Dioxide Emissions

Case studies have been conducted on the impact of implementing a carbon tax, such as that proposed by the Pirate Party. They have met with varying degrees of success. The reasons for the weak success gives clues as to how Iceland could more effectively reduce their own carbon emissions, and encourage companies to adopt low-carbon alternatives, such as electric buses. There is scientific consensus that fossil fuels are a substantial contributor to the global emissions of carbon dioxide. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), of the 76% GHG emissions, approximately 57% were the result of the combustion of fossil fuels. [72]

Boqiang Lin and Xuehue Li explained why early adopters of taxing carbon have generated varying results on per capita carbon dioxide emissions. [73] Denmark, Sweden and the Netherlands have decreased their emissions only slightly, however Finland has been able to most effectively reduce its share of carbon through taxation. Norway’s emissions of carbon have actually increased. Carbon tax objectives have repeatedly shown to be undermined by the creation of tax exemptions for energy-intensive industries. In order for a carbon tax to be most effective, a flat-tax would need to be levied that holds no exemptions. Tax exemptions for high-carbon, heavy industry are created to increase their competitiveness in the market, therefore little consideration is given to alternative technologies. This negates the effect of a carbon tax and undermines the overall legislative objective of imposing a carbon tax. As in the case of Norway, a carbon tax did not yield lower levels of carbon emissions because of divergent exemptions that were applied to developing oil and natural gas. Boqiang Lin and Xuehue Li attribute the overall effectiveness of a country’s carbon tax to the amount levied on it, how many exemptions are applied, and how the revenue generated from the tax is then utilized. Finland’s carbon-tax works the most effectively of all the cases studied because they have been able to maintain competitiveness by imposing a flat rate tax which is notably lower than the other countries mentioned. This research has also shown that utilizing the revenue created by a carbon tax can spur growth for the development of renewable technologies.

It has become inevitable that the challenges of global warming are far reaching and must be addressed and cannot be ignored any longer. Investment in cleaner energy solutions of low-carbon technologies are paramount to lowering the emissions of carbon, and other GHG gases. Immediate committed action is needed by governments to set the direction to enable renewable-based technologies to offer a competitive option. Conversion to an electrically charged fleet for Iceland would be a huge step forward in attaining its goal to reduce GHG

emissions. It has the ability to capitalize on a technology in which it has a unique competitive advantage due to its sources of energy from geothermal and hydroelectric methods which generate no indirect emissions of GHG due to the transport of fossil fuels. In order to meet this challenge where the market has failed, it is necessary to create the necessary political and economic incentives to make lower-carbon technologies more feasible. A flat-tax implementation similar to Finland's carbon tax without industrial exemptions has proven a successful model with the best results thus far toward reducing the amount of carbon dioxide from high-carbon technologies such as diesel buses.

7.5 Carbon Tax in Iceland

In the last 10 years Iceland has introduced a diesel tax, a carbon tax, and a carbon-based tax on diesel. [74] Iceland's Ministry for the Environment and Natural Resources (Umhverfis og auðlindaráðuneytið) contributes the weak results to gaps and inconsistencies in data, an issue related to the data being scattered across various institutions and not being centralized. According to Umhverfis og auðlindaráðuneytið (Iceland's Ministry for the Environment and Natural Resources) these inconsistencies have yielded limited impact in reducing carbon emissions since Iceland joined the European Union's Emission Trading Scheme in 2007. While the data may be able to be centralized, changing this factor alone would not change the limited effectiveness.

Central to the weak results is that the Icelandic carbon tax was set too low. It was set in 2010 at only €14 per tonne of carbon dioxide. [75] OECD (Organization for Economic Cooperation and Development) is an international organization that helps governments tackle social and economic problems and promotes those policies that improve economic and social good. It is a 34 country membership that provides a forum where countries can work together with government, business and finance organizations represented. In their report "Environmental Performance Review: Iceland 2014", it states that the limited success of reducing carbon emissions through the EU-ETS (European Union – Emission Trading Scheme) in Iceland is in part because the carbon tax levied in Iceland is well below that of other Scandinavian countries. [75] There will be parties opposed, but increasing the tax rate would create a more competitive market for lower-carbon emission technologies such as electric buses.

Iceland's Ministry of the Environment and Natural Resources suggests that raising the tax rate for carbon would drive up the costs for diesel buses because the increased carbon they emit would be counted as an operating expense. Similarly, there are currently tax exemptions allowed for vehicles used for the transportation of passengers. Thus, a diesel bus and an electric bus are both exempt from paying the 24.5% VAT tax that is levied on other vehicles. [76] Policy makers could also take steps to encourage the creation of a consortium of financial support to fund the development of the electrical infrastructure which builds value in the infrastructure in and of itself. Both methods would help make the electrical model equally competitive with existing models with less immediate impact on existing oil-based economies until further development is realized. Future venture capital into an infrastructure market with such huge growth potential around the world becomes increasingly more likely, and profitable. Iceland and an Iceland based company is in an ideal position to succeed in this market. In an equally competitive market, political will and incentives would still drive these technologies positively without disrupting entire economies. For purposes of this study, government

support for the limited infrastructure needed to operate electric buses on the Gray Line Airport Express route, would make this option very competitive with a relatively small investment. The electric bus implementation would further drive the development of other low-carbon based modes of public transportation and electric commercial vehicles. If exemptions remain for both diesel and electric, then alternative ways of funding bear further analysis.

7.5.1 How to Make a Carbon Tax Work in Iceland

Finland was the first country to excise a carbon tax. [77] Their tax rate is €18.05 per ton of CO₂. [77] This is not significantly different than Iceland's 2010 carbon tax rate of €14 per tonne of carbon dioxide. [74] Despite similar carbon tax rates, Finland's success in reducing its carbon emissions is in large part due to its relatively few exemptions for energy intensive industries. Iceland has underutilized its competitive advantage of clean energy for energy intensive industry without carbon emissions, which if developed could be utilized as a revenue source to offset the costs of developing its electric infrastructure. There is a fine balance between protecting its environment that also drives its number one tourism market, and promoting heavy industry for additional revenue. Until this is analyzed and developed, an effective carbon tax with reduced exemptions is needed in order to progress. Currently, both private and commercial users have the same tax rate. According to Boqian Lin and Xuehue Li, the ability for a carbon tax to have the greatest effect comes from the number of exemptions applied to it, the way in which the revenue is used from the tax, and the rate of the tax itself. [72] Through these variables they analyzed the effectiveness of the carbon tax on Finland, Sweden, Norway, Denmark and Netherlands and determined that Finland's carbon tax reduced carbon emissions the most effectively. Furthermore, they also found that utilizing the carbon tax for the development of renewable energies is able to offset some of the increased costs that deploying lower-carbon technologies such as an electric bus program would initially require. In 1970, Iceland's energy consumption was dominated by fossil fuels. To encourage wider development of geothermal energy the government created a fund that distributed money to cover the costly process of borehole exploration, and cover some of the costs associated with the risk inherently associated with geothermal development. [1] Driven by the cost factors of the 1970's, including the massive spike in oil prices as a result of the oil embargo, the government and public pulled together to create greater energy security. Government incentives offset the costs of developing affordable and cleaner energy.

7.5.2 Implement Subsidies

When running the sensitivity analysis for the cost of the charging station, the break-even point of the NPV for the diesel bus met the costs of the C9 electric bus with the two fast-chargers, when the cost of both charging stations is supplemented. In other words, in relation to this project it would be feasible only if the charging stations and slight NPV differential were fully subsidize until market prices drive the costs of EV buses and infrastructure down. Consortiums of finance groups and private business have created funding models to offset the start up costs, and in fact have given the infrastructure itself increasing value. If the Icelandic government is to meet their pledged goal from the 2014 UN Climate Summit of having 10% of their vehicles come from alternative-fuels incentives for private company investments in electric buses would be accomplished by providing some form of subsidy for the charging stations and to be most effective, a VAT should be collected for any ICE buses, such as diesel buses. Equally important is that the annual concessions on electric buses should be extended for a period of

time. The Pirate Party suggested either employing no VAT on electric buses until 10% of transportation in Iceland is made up of alternative-fuel vehicles, or establishing a set number of years until it can be reassessed. Lessons can be learned from the Finland model who has had greater success by, providing a mix of subsidies and taxes to increase the share of lower-carbon technologies and promote private companies and entrepreneurs by providing incentives to invest in the required charging stations. This will help private companies and entrepreneurs invest in clean energy and the necessity for charging infrastructure.

8 Conclusions

Economic and operational differences were compared between the C9 Electric bus and the 2013 Volvo Sidreal 2000 diesel bus to determine the feasibility of adding the electric bus to the Gray Line Airport Express route. The economic feasibility study evaluated the costs and logistical differences and predicted which of the 3 models represented the best investment: 1) the diesel bus, 2) the electric bus with no charging infrastructure expense or 3) the electric bus with its apportioned cost of the 2 needed charging stations included.

Logistically, the electric bus parameters were compatible with the existing 24 hour operating schedule currently in place with no need to change the timing or number of trips to accommodate its use as an alternative to diesel. This was accomplished by utilizing existing one-hour breaks on each end of the trip and minor differences in the parking formation of arriving buses to allow access to the charging stations. The economic study demonstrated that the best investment and least risk was represented by the NPV of the diesel bus but only by a marginal 14,000 Euros (2,065,936 ISK) over the electric bus alone model. When the costs of the electric bus included its apportioned cost per bus of the charging infrastructure, it produced the highest NPV and represented the highest risk. Resale value was considered the same for both the diesel and electric bus with the break-even point for the C9 electric being reached in the 8th year, whereas no break-even point was reached for the EV bus plus infrastructure in the 8-year time frame used in the study. Without funding for the infrastructure, this model would not be economically feasible, but the investment of the bus alone was very comparable. However, it was shown that only small changes would make either option a competitive alternative. It was calculated that the cost of diesel only needs to rise 7% from today's 57 ISK/km to be competitive with the electric bus alone model, and only 28% to be competitive with the electric bus plus infrastructure model. Considering the history of fluctuating diesel prices over even the last 5 years, this is a significant possibility. The electric bus represents a more stable and predictable model as diesel has had 2 fold differences in cost from one year to the next.

The results clearly illustrated the need for political and economic incentives to fund the required charging station infrastructure and to encourage investments in low-carbon technologies for public transport. With funding support for the cost of the 2 charging stations, the addition of the C9 electric bus should proceed for the Gray Line Airport Express fleet as the competitive but low-carbon alternative. Given Iceland's low-carbon energy mix, incentivizing the electric bus for Grayline's busy airport route would help Iceland achieve the 50-75% reduction in greenhouse gases, an important step toward the commitment to their Climate Strategy

Creative methods to incentivize funding of the infrastructure are essential to implement the electric bus and electro mobility in general. Various methods have been tried around the world with the most successful ones utilizing government incentives to defray the additional cost. A carbon tax has proven successful when it is not set too low, when its effect is not negated by a number of exemptions and how the revenue generated is reinvested. Removal of VAT on diesel or extending the annual concession of no VAT on the first 6,000,000 ISK of import value for a longer period of time or until its 10% goal of renewable mobile transportation is achieved, has been suggested. At this point, competitive forces may have acted to drive prices down.

Never-the-less, results in general from these efforts have been weak. Organizing a financial consortium of government, private business, financial institutions and entrepreneurs holds promise but requires a clear plan and time-bound actions to succeed. In this regard, the government can help support the endeavor with a political and economic commitment.

Iceland has a clear advantage due to its large supply of renewable energies of hydroelectric and geothermal sources with no indirect emissions generated from the transport of diesel. It is in an ideal situation to support the electrification of its transportation sector, making it totally independent from the market impacts of fluctuating diesel prices while making a huge impact on its net total carbon emissions. In the current study, a small government commitment would make the electric bus an immediate renewable option as the private company Gray Line is already committed to providing the buses if the minimal infrastructure needed for its Gray Line Express route is supported. Furthermore, addition of the electric bus at the key perception point - the point of entry at the Keflavik airport, promotes Iceland's green image to arriving guests with pride that it is fulfilling its global commitment to reduce GHG emissions. The success of this project will spur further investment in green technologies in the transport sector of Iceland.

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