RESEARCH & DEVELOPMENT

Vessel Electrification Investigation for the NCDOT Ferry Division Fleet

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Prepared by:

John Hildreth, PhD
Bora Karayaka, PhD
Western Carolina University

Grant Bennett
Geoff Morrison, PhD
Bridget Gilmore
The Cadmus Group LLC

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16. Abstract

Ferry electrification is a growing domestic and global trend, driven by an interest in reducing operational and maintenance costs, and mitigating emissions at ports. Ferries are particularly well suited for electrification due to their relatively short travel distances over fixed routes, predictable schedule, and their ample onboard space for battery packs and equipment. The purpose of this investigation was to evaluate the technical and economic feasibility of electrifying vessels in the NCDOT Ferry Division fleet as well as to provide a preliminary implementation plan for prioritizing which vessels should be electrified, if any. In this study, the research team conducted a literature review, lifecycle cost analysis (LCCA), and emissions analysis. Additionally, the research team conducted interviews with technology integrators, utilities, naval architects, battery system suppliers, and ferry charging system suppliers, as well as ferry crossing site visits. At the four ferry routes included in this study, replacement of the current vessels with plug-in hybrid vessels is advantageous with respect to lifecycle cost, emissions, and human health impacts. The most economical configuration at all four routes is a plug-in hybrid vessel charging on one side of the ferry crossing and utilizing a shoreside energy storage system to reduce overall power demand from the electrical grid. The research team recommend NCDOT Ferry Division implement ferry electrification in this order: Currituck Sound, followed by Pamlico River, Neuse River, and finally Cape Fear River. This prioritization is based on lifecycle cost, emissions, vessel age, potential grid infrastructure improvements, the number of vessels operated at each route, and the number of crossings per vessel per day.

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NCDOT Staff Lead: Catherine Peele, CPM

Research Lead: John Hildreth, PhD, Western Carolina University

Research Support:

- Bora Karayaka, PhD, Western Carolina University
- Grant Bennett, Cadmus
- Geoff Morrison, PhD, Cadmus
- Bridget Gilmore, Cadmus

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GLOSSARY

Conductor: Component of the electric distribution grid that transmits current.
Consumption charge: Utility fee for energy usage, typically charged per kilowatt-hour (kWh).
Demand charge: Utility fee for peak power demand, typically charged by kilowatt (kW).
Discount rate: Investment rate of return, representing the expected return on alternative investments.
Drivetrain: For marine vessels, the components between the gearbox and propeller.
Electric efficiency: For electrical equipment, the power output compared to power consumed.
Electric propulsion equipment: For marine vessels, the components delivering electric power to the drivetrain.
Emission factor: As defined by the EPA, a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.
Emissions & Generation Resource Integrated Database (eGRID): Comprehensive data source on the environmental characteristics of U.S. electric power generation.
Energy storage system (ESS): In this study, an ESS refers to battery banks installed shoreside or onboard a vessel.
Grid carbon intensity: The amount of carbon produced during electric power general.
Hybrid vessel: A marine vessel that uses multiple power sources for propulsion.
Junction box: A protective housing for electrical wiring connections.
Lifecycle cost analysis (LCCA): An economic evaluation of the total lifetime cost of a project, facility, or other investment.
Line loss: The energy lost during the transmission and distribution of electricity.
Meter: An electric component that measures the amount of energy consumption.
Net present value (NPV): The present-day value of all cash inflows and outflows over the life of a project or investment.
Plug-in vessel: A marine vessel equipped with an onboard energy storage system charged by the grid.
Rapid charging system: In this study, the power delivery system that supplies a large amount of power (2–5 megawatts (MW)) to the vessel through an electrical connection.
Roll-on/roll-off ferry vessel: A ferry equipped to transport vehicles in which vehicles are driven directly onto and off of the vessel.
Single phase power: AC power that is delivered through a single conductor, typically used in residential applications to supply smaller loads than three-phase power.
Substation: A component of the electrical distribution grid, typically transforming power from one voltage to another or acting as an interconnection between transmission lines, or both.
Three-phase power: AC power that is delivered through three conductors, typically used in industrial applications to supply higher loads and more consistent power than single phase power.
Transformer: A component of the electrical distribution grid that transfers AC power from one circuit to another, typically stepping up or stepping down the voltage between circuits.
Upstream emissions: In this study, emissions from power generation or fuel sourcing and transportation.
24-hour load shape: The time-of-day variations in energy consumption from the electric grid.

EXECUTIVE SUMMARY

Background

Today more than 15 ferry systems in the United States operate or plan to soon operate either fully electric or hybrid electric ferries. With the passage of the Bipartisan Infrastructure Law (BIL) in 2021, the U.S. federal government is dedicating $500 million toward alternative fuel ferries from 2022 to 2026. North Carolina's Clean Transportation Plan[1] and Clean Energy Plan,[2] written in accordance with Executive Order 80[3], outline strategies to reduce greenhouse gas emissions by 40% in 2025 compared to 2005 levels and to achieve a 60% to 70% reduction in emissions from the electric power sector by 2030 compared to 2005 levels—reaching zero emissions by 2050. With this context, the North Carolina Department of Transportation (NCDOT) is interested in exploring the feasibility of electrifying portions of its ferry system—a system that includes 22 ferries along eight routes, serving over 700,000 vehicles and 1.5 million passengers annually.

Purpose

This study examines the techno-economic feasibility of electrifying four ferry routes in NCDOT's Ferry System. Table 1 summarizes the four routes examined in the study.

Table 1. Summary of Routes Assessed in Report

	Pamlico River (Bayview – Aurora)	**Currituck Sound** (Currituck – Knotts Island)	**Cape Fear River** (Southport – Fort Fisher)	**Neuse River** (Cherry Branch – Minnesott Beach)
Distance (One-Way)	4 miles	5 Miles	4 miles	2 miles
Duration (One-Way)	30 minutes	40 minutes	35 minutes	20 minutes
No. of Vessels Typically Operating	1	1	2	2
Crossings per Day (One-Way)	14	10	28 or 32 (season dependent)	56
Time in Port between Crossings	15 minutes	20 minutes	10 minutes	10 minutes
Age of Vessel(s) (Vessel Name)	31 years (Governor Daniel Russell)	39 years (Governor James Baxter Hunt Jr)	27 & 23 years (Southport & Fort Fisher)	25 & 23 years (Neuse & Lupton)
Electric Utilities	Tideland EMC	Dominion	Duke Energy & Brunswick EMC	Carteret-Craven & Tideland EMC

For each of the four ferry routes, the lifecycle cost, emissions, and health impacts of plug-in electric hybrid ferry vessels (battery-electric with a diesel engine backup) were compared to diesel mechanical and diesel hybrid vessels. All-electric vessels were not considered due to

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[1] nc-clean-transportation-plan-final-report.pdf (ncdot.gov)

[2] Clean Energy Plan Report Cover Rev 7.15 UPDATE.ai (nc.gov)

[3] open (nc.gov)

requirements for vessels to periodically travel to Manns Harbor, North Carolina, for United States Coast Guard (USCG) required inspections, emergency repairs, and to support operation in times of emergency response. For the plug-in electric configuration, one-sided versus two-sided charging and vessels with and without shore energy storage systems (ESS) were examined.

Findings

For all analyzed routes, plug-in electric ferries have the lowest lifecycle costs,[4] greenhouse gas emissions, local air pollutant emissions, and human health impacts. These findings were robust across most reasonable cost and financing assumptions. Table 2 presents the net present value of costs during a 40-year lifecycle using a 2% discount rate for the various vessel and shore configurations analyzed. At every route evaluated in this study, the configuration with the lowest lifecycle cost is a plug-in hybrid vessel charging on one side and utilizing a shoreside energy storage system. Emissions and health impacts are presented in the full report below.

Table 2. Estimated Lifecycle Cost Per Vessel, By Configuration and Location

Configuration	Pamlico River[1]	Currituck Sound[1]	Cape Fear River[1]	Neuse River[1]
Plug-in Hybrid, no Shore ESS, One-Sided Charging	$57.5M	$50.0M	$80.8M	$62.9M
Plug-in Hybrid, Shore ESS, One-Sided Charging	$51.7M	**$49.5M**	**$60.8M**	**$57.7M**
Plug-in Hybrid, Shared Shore ESS, One-Sided Charging	**$50.4M**	NA	NA	NA
Plug-in Hybrid, no Shore ESS, Two-Sided Charging	$61.4M	NA	$101.8M	$65.7M
Plug-in Hybrid, Shore ESS, Two-Sided Charging	$57.4M	NA	$69.7M	$61.7M
Plug-in Hybrid, Shared Shore ESS, Two-Sided Charging	$56.1M	NA	NA	NA
Diesel Hybrid	$63.9M	$63.9M	$69.9M	$86.1M
Diesel Mechanical	$62.8M	$62.8M	$69.6M	$84.8M

[1]One-sided charging on the following: Pamlico River – Bayview; Currituck Sound – Currituck; Neuse River – Cherry Branch; Cape Fear – Fort Fisher.

Implementation Plan

Based on the potential for cost, emission, and health benefits, the recommendation is to pursue electrification on all four of the routes analyzed in this study, prioritizing electrification of the vessel(s) at Currituck Sound, followed by Pamlico River, Neuse River, and finally Cape Fear. The recommended configuration at all four routes is a plug-in hybrid vessel, charging on one side and utilizing a shoreside ESS that is accessible by the utility if applicable. This prioritization is based on lifecycle cost, emissions, vessel age, and potential grid infrastructure improvement requirements. Additionally, prioritization considered the number of vessels operated at each route and the number of crossings per vessel per day. Phasing these projects allows the NCDOT to gain experience in the funding, financing, and operations of the electric ferries prior to moving to the next project.

[4] Including upfront, maintenance, operating, and battery replacement costs.

INTRODUCTION

Motivation of Report

The NCDOT Ferry Division is the second largest state-operated ferry system in the United States and is a critical component of the state's economy and transportation infrastructure for coastal residents and tourists. In 2022, over 700,000 vehicles and 1.5 million passengers used the state's 22 ferries.[5] The NCDOT Ferry System also plays a role in coastal emergencies, able to evacuate people in advance of hurricanes and operate an emergency route in case of damage to NC Highway 12. This is critical to Ocracoke Island which is only accessible by ferry vessel, private boat, or private air transportation.

In 2021, the NCDOT Research and Development Unit commissioned this study to address the need for specific research on the feasibility of electrification of NCDOT ferry vessels operating short haul routes. This study comes after the recommendation to examine electrification options for vessels by the Ferry Division in "Ferry Forward 2050" and is aligned with North Carolina's commitment to a clean energy economy as outlined in Executive Order 80. The results will support the NCDOT Ferry Division leadership in integrating milestone goals for infrastructure improvements and vessel modification/acquisition into long-range budgetary and operations plans, pursuing funding external to the NCDOT in support of ferry electrification, and effectively communicating with stakeholders.

State of the Industry

Ferry electrification is expanding rapidly around the globe, driven by interest in reducing operational and maintenance costs, and mitigating greenhouse gas emissions. Most ferries are well suited for electrification due to their predictable fixed routes and their ample onboard space for battery packs. Early deployments of electric ferries suggest beneficial impacts. For example, the M/V Ampere in Norway, an all-electric ferry placed into operation in 2015, has a reported 80% reduction in operating costs from cheaper fuel and maintenance and 95% reduction in CO_2 emissions compared to similar fossil fuel-powered vessels.[6] After the launch of the M/V Ampere in 2015, Norway has continued to invest heavily in electrifying its ferry fleet, leading the world with around 80 electric commuter ferries in operation today.[7] In 2021 the world's largest electric ferry, the Bastø Electric, was put into service across the busiest ferry route in Norway. The 470-foot vessel draws up to 9 megawatts (MW) to charge its 4.3 megawatt-hour (MWh) battery bank and is estimated to cut emissions by 75% along its route.[7]

Outside of Norway, Portugal and New Zealand are already operating electrified ferries while Bangkok has ordered 30 electric ferries and Kochi, India, is slated to have the world's largest electric ferry fleet with plans to build 78 in the coming years.[8] Set to launch in 2025, a 2,100

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[5] North Carolina Department of transportation 2022 Annual Performance Report

[6] All-electric ferry cuts emission by 95% and costs by 80%, brings in 53 additional orders | Electrek

[7] Norway showcases award-winning electric ferry technology (businessnorway.com)

[8] You're About to See Electric Ferries Everywhere

passenger battery powered ferry is currently under construction operation between Argentina and Uruguay.[8]

U.S. Federal Funding for Electric Ferries

The Infrastructure Investment and Jobs Act, passed in 2021, includes more than $2B in funding for ferry projects. Of this, approximately $100M is available per year as a competitive grant from FY 2022–2026 for the Electric or Low-Emitting Ferry Pilot program (Low-No). The Low-No program is designed to provide funding for states, territories, and tribes to purchase alternative fuel ferry vessels and build supporting infrastructure. The definition of alternative fuel for this funding does include electrically powered vessels. Low-No program grants cannot be used for planning or operations and maintenance of ferry vessels.

Within the United States, electrification of ferry routes is also accelerating. Today, more than 15 ferry systems are either operating electrified vessels or have plans to do so in the future. This trend is driven by similar factors as the global shift toward ferry electrification. Recent policy efforts to propel the clean energy transition in the United States feature funding specifically for low- or zero-emission ferries.[9] Beyond the positive environmental and human health impacts of reduced transportation emissions, U.S. ferry operators are recognizing the economic benefit of lower fuel costs and reduced maintenance requirements. As an illustrative example, Table 3 provides an overview of a subset of North American electrified vessels. For additional information regarding the status, technology, costs, and other details on the electrification projects in Table 3, see Appendix B.

Table 3. North America Ferry Operator Electrification Overview

Operator	Summary	Timeline	Powertrain	Charging Configuration
Washington State Ferries	Converting 3 and replacing 5 out of 21 in the fleet	Near-term phase by 2030	Plug-in hybrid	Rapid charging system, planning to have charging arm on the vessel and connect to shoreside power
BC Ferries	Replace 6 out of 38 in the fleet	Delivery in January 2022	Diesel hybrid Designed to be plug-in hybrid in 10 years	Using low voltage AC shore charging (AC to DC power conversion on board). When electrified, aiming for 2.5–3 MW charging power (front runner is Zinus)
Maid of the Midst	Replaced 2 out of 2 in the fleet	In service in 2020	All-Electric	Cavotech fast-chargers
Skagit County Ferry	Replace 1 vessel out of 1 in the fleet	In service by 2025	All-Electric	One-sided charging (Anacortes side), selected Canal Marine as the electric system integrator delivering approximately 2.0 MW of charging power
Casco Bay Ferry	Replace 1 out of 5 in the fleet	In service by 2024	Plug-in hybrid	Using 1.4 MW, automated charger provided by ABB

[9] FTA Ferry Programs | FTA (dot.gov)

Description of Routes Included in Study

This section provides an overview of the crossings, vessels, and electric utilities of the four NCDOT ferry routes considered in this study.

Currituck Sound

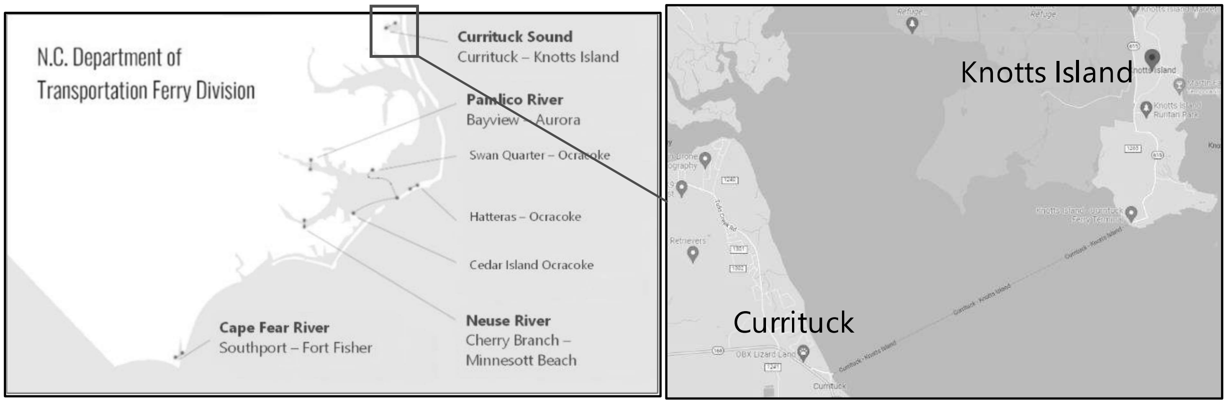

Figure 1. Location of Currituck Sound Crossing between Currituck and Knotts Island

Description of Crossing

The Currituck to Knotts Island route, crossing the Currituck Sound, is a year-round passenger and vehicle ferry route between the towns of Currituck and Knotts Island, North Carolina, operated by the NCDOT. The ferry departs each side five times daily (10 crossings total), between 6:15 a.m. and 5:15 p.m. The vessel serves a fixed, five-mile route, averaging 12 passengers and four vehicles per crossing[10]. There is no fee and ridership consists of 62% permanent residents, 33.8% visitors, and 4.2% seasonal residents[11]. The crossing takes approximately 40 minutes followed by a 20-minute embarkation/debarkation. The location of the crossing is shown in Figure 1.

Vessel Description

The M/V Governor James Baxter Hunt Jr is a 159' by 40' roll-on/roll-off ferry vessel, accommodating up to 150 passengers and 20 vehicles (Figure 4). The vessel was constructed in

Figure 2. The Governor James Baxter Hunt Jr

[10] Internal NCDOT data report

[11] 2018-11 Final Report.pdf (ncdot.gov)

1984 at a cost of $1.4M. The diesel-mechanical powertrain of the vessel includes two aft propellers, each powered through a gear reduction box by a 425 horsepower CAT 3412 main engine. The main engine room also houses two 105 kW CAT 3304 generator sets that alternate days in operation to provide electric power to the vessel systems.

Electric Infrastructure

Electrical power is provided by Dominion Energy on both the Currituck and Knotts Island side. To date, Dominion has shown interest in supporting ferry electrification.[12] There is limited infrastructure on the Knotts Island side, with only single-phase, 120V power available. Knotts Island is on the tail of a very long distribution side, whereas the Currituck side is located close to a substation.

At the Currituck ferry terminal, pole mounted transformers provide three-phase 120/208V power. Dominion Energy has indicated that a comprehensive engineering study would be needed to fully understand the grid improvements and cost of providing power necessary to support an electrified ferry. However, the results of an informal assessment conducted by Dominion Energy for providing up to 2 MW of charging power at the Currituck terminal was an estimated cost of $82,000.[12] Table 4 details the rate structure for Dominion Energy.

Pamlico River

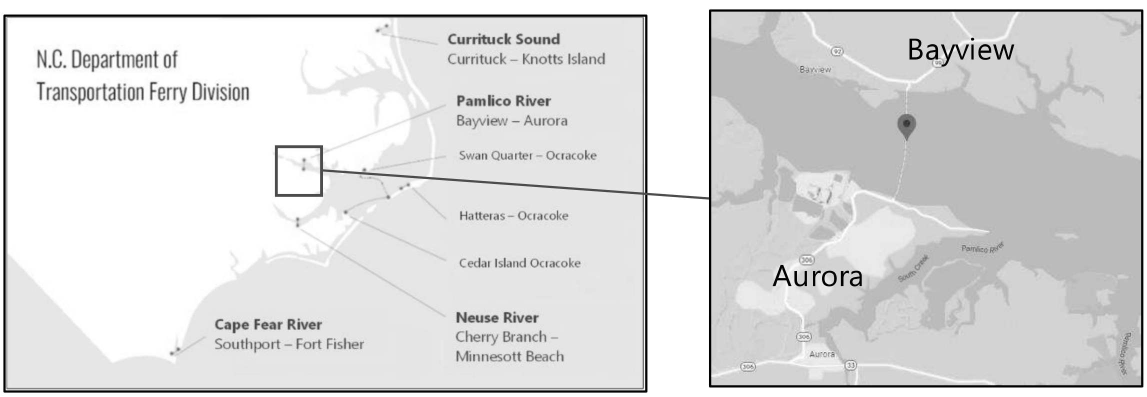

Figure 3. Location of Pamlico River Crossing between Bayview and Aurora

Description of Crossing

The Pamlico River crossing is a year-round passenger and vehicle ferry route between the towns of Bayview and Aurora, North Carolina, operated by the NCDOT. The ferry departs each side seven times daily (14 crossings total), between the hours of 5:45 a.m. and 6:15 p.m. The vessel serves a fixed, four-mile route, averaging 11 passengers and eight vehicles per crossing[13]. There is no fee and ridership consists of 91.7% permanent residents, 7.1% visitors, and 1.2% seasonal residents[14]. The crossing takes approximately 30 minutes followed by a 15-minute embarkation/debarkation. The location of the crossing is shown in Figure 3.

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[12] Email correspondence between Dominion and Dr. John Hildreth
[13] Internal NCDOT data report
[14] 2018-11 Final Report.pdf (ncdot.gov)

Vessel Description

The M/V Governor Daniel Russell is a 180′ by 44′ roll-on/roll-off ferry vessel, accommodating up to 300 passengers and 40 vehicles (Figure 4). The vessel was constructed in 1992 at a cost of $3.4M. The diesel-mechanical powertrain of the vessel includes fore and aft propellers each powered through a gear reduction box by a 575 horsepower CAT 3412 main engine. The main engine room also houses two 105 kW CAT 3304 generator sets that alternate days in operation to provide electric power to the vessel systems.

Electric Infrastructure

Figure 4. Governor Daniel Russell Underway (left) and Loading (right)

Electrical power is provided at both the Bayview and Aurora terminals by the electric co-op Tideland EMC. Conversation between the research team and Tideland EMC staff suggest the utility has great interest in supporting ferry electrification.[15]

A 150-kVA pad mounted transformer currently provides three-phase power at 7200 V to the Bayview terminal. Tideland EMC estimates up to 1 MW can be provided without grid infrastructure improvements. Additionally, Tideland EMC estimates a cost of $1M for grid improvements at the Bayview terminal to provide power above 1 MW for vessel charging. Such improvements would likely include a transformer upgrade at the substation and upgrading the conductor from the substation to the Bayview terminal.

The existing electric service at the Aurora terminal is single phase 120/208V. However, three-phase power at 14400 V is available immediately adjacent to the terminal with an estimated capability of providing up to 500 kW without grid infrastructure improvements. Table 4 details the rate structure for Tideland EMC.

[15] Email correspondence between Tideland EMC and Dr. John Hildreth

Neuse River

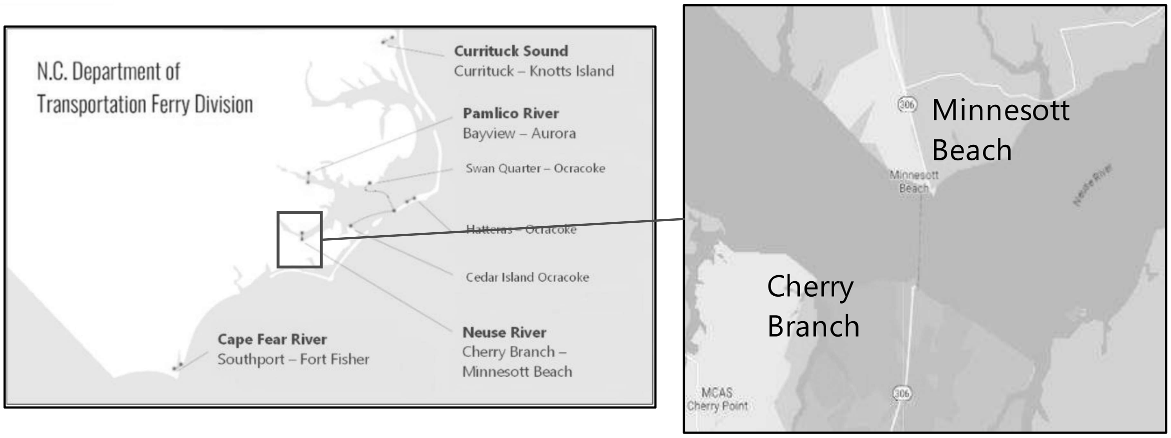

Figure 5. Location of Neuse River Crossing Between Cherry Branch and Minnesott Beach

Description of Crossing

The Neuse River crossing is a year-round passenger and vehicle ferry route between the Cherry Branch and Minnesott Beach, North Carolina, operated by the NCDOT. The ferry departs each side 28 times daily (56 crossings total), between the hours of 5:00 a.m. and 11:00 p.m. The vessel serves a fixed, 2-mile route, averaging 18 passengers and 11 vehicles per crossing[16]. There is no fee and ridership consists of 79.9% permanent residents, 10.8% visitors, and 9.3% seasonal residents[17]. The crossing takes approximately 20 minutes followed by a 10-minute embarkation/debarkation. The location of the crossing is shown in Figure 7.

Vessel Description

The M/V Neuse and M/V Lupton are both 180' by 44' roll-on/roll-off ferry vessels, accommodating up to 300 passengers and 40 vehicles (Figure 8). The vessels were constructed in 1998 and 2000, respectively, at a cost of approximately $5.4M each. The diesel-mechanical powertrain of the vessels includes fore and aft propellers each powered through a gear reduction box by a 475 horsepower CAT 3412 main engine. The main engine rooms also house

Figure 6. Neuse River Ferries Underway (left) and Loading (right)

[16] Internal NCDOT data report
[17] 2018-11 Final Report.pdf (ncdot.gov)

two 105 kW CAT 3304 generator sets that alternate days in operation to provide electric power to the vessels.

Electric Infrastructure

Electrical power is provided by Carteret-Craven at the Cherry Branch terminal and by Tideland EMC at the Minnesott Beach terminal. To date, both Carteret-Craven and Tideland EMC have shown interest in supporting ferry electrification.[18]

At both the Cherry Branch and Minnesott Beach terminals, the respective utilities have indicated that there is capacity to support the 3 MW required for single-sided charging without grid infrastructure upgrades. At both terminals, on-site electrical equipment such as transformers, meters, and junction boxes would require upgrades to support electrified ferries. Table 4 details the rate structure for Carteret-Craven and Tideland EMC.

Cape Fear River

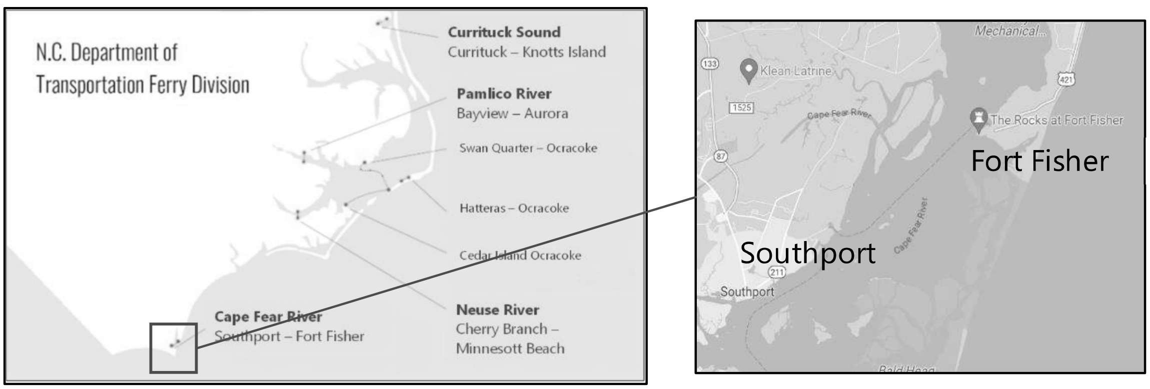

Figure 7. Location of Cape Fear River Crossing between Southport and Fort Fisher

Description of Crossing

The Cape Fear River crossing is a year-round passenger and vehicle ferry route between the towns of Southport and Fort Fisher, North Carolina, operated by the NCDOT. Depending on the season, the ferry departs each side fourteen to sixteen times daily (up to 32 crossings total), between the hours of 5:30 a.m. and 7:00 p.m. The vessels serve a fixed, four-mile route, averaging 40 passengers and 15 vehicles per crossing[19]. The vessels can accommodate vehicles up to 65 feet in length and fares range from $1 to $28, depending on vehicle type. Ridership consists of 50.4% permanent residents, 41.2% visitors, and 8.4% seasonal residents[20]. The crossing takes approximately 35 minutes followed by a 10-minute embarkation/debarkation. The location of the crossing is shown in Figure 7.

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[18] Meetings conducted between research team and Tideland EMC/ Carteret-Craven Utilities

[19] Internal NCDOT data report

[20] 2018-11 Final Report.pdf (ncdot.gov)

Vessel Description

The M/V Southport and M/V Forth Fisher are both 180' by 44' roll-on/roll-off ferry vessels, accommodating up to 300 passengers and 40 vehicles (the Fort Fisher shown in Figure 8). The vessels were constructed in 1996 and 2000, respectively, at a cost of $5M each. The diesel-mechanical powertrain of the vessels includes fore and aft propellers each powered through a gear reduction box by a 475 horsepower CAT 3412 main engine. The main engine rooms also house two 105 kW CAT 3304 generator sets that alternate days in operation to provide electric power to the vessels.

Figure 8. The Fort Fisher Underway (left) and at Southport Ferry Terminal (right)

Electric Infrastructure

Electrical power is provided by Duke Energy at the Fort Fisher terminal and by the City of Southport at the Southport terminal. To date, both Duke Energy and the City of Southport have shown interest in supporting ferry electrification.[21]

At the Fort Fisher terminal, Duke Energy indicated it has the capacity to support the 4 to 5 MW required for single-sided charging without grid infrastructure upgrades. On the Southport side, the City of Southport noted that grid improvements would be required to support an electric ferry charging for both one- and two-sided charging. Additionally, the City of Southport indicated that a comprehensive engineering study would be needed to fully understand the grid improvements and cost of providing power necessary to support an electrified ferry. Both terminals would require upgrades to on-site electric equipment to support electrified ferries. Table 4 details the rate structure for City of Southport and Duke Energy.

Electric Utility Rate Structure

Table 4 shows the electricity charges for an electric ferry operating in the service areas relevant to each route. Of note, demand charges typically account for the majority of electricity costs for sites with megawatt-plus loads. Additional fees or discounts could apply to the electric rates shown in **Error! Reference source not found.** depending on assessment of the 24-hour load shape from vessel charging by the utility.

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[21] Meetings conducted between the research team and Duke Energy/Brunswick EMC Utilities

Table 4. Power Provider Rates

Route	Utility (Terminal)	Consumption Charge	Demand Charge	Fixed Charge
		$/kWh for every kWh consumed during month	*$/kW for maximum power drawn during month*	*$/year*
Pamlico River	**Tideland EMC (Bayview/Aurora)**	$0.06232	$9.17	$2,220
Currituck Sound	**Dominion (Currituck/Knotts Island)**	$0.072 - $0.095	$3.46	$227.16
Cape Fear River	**Duke Energy (Fort Fisher)**	$0.0536	$15.02	$3082
	City of Southport (Southport)	$0.0578	$26.00 coincidental peak $4.00 non-coincidental peak	$900
Neuse River	**Carteret-Craven (Cherry Branch)**	$0.0411	$9.75 - $13.00	$6,000
	Tideland EMC (Minnesott Beach)	$0.06232	$9.17	$2,220

METHODOLOGY

This section details the methodologies utilized in the technical and economic analyses conducted during this study including the ESS sizing, lifecycle cost analysis (LCCA), and estimation of emissions and human health impacts. This study also included interviews with integrators, utilities, naval architects, battery system suppliers, and ferry charging system suppliers, as well as ferry crossing site visits and a literature review.

Vessel and Shore Configurations

The research team considered the following three vessel configuration options in its analysis of the four routes.

- **Plug-in hybrid.** Plug-in hybrid vessels are electrically powered vessels whose primary power source is an onboard battery system regularly charged by connection to a shoreside charging system. The hybrid vessels also have onboard diesel-powered generator sets as a secondary power source to be used for range extension and/or emergency operations.
- **Diesel hybrid (diesel electric hybrid with peak shaving).** Diesel hybrid vessels are electrically powered vessels that utilize onboard diesel-powered generator sets as the primary power source. Energy is stored in relatively small onboard battery systems and available to meet peak power requirements. Batteries may also be used in times of low power requirement.

- **Diesel mechanical.** Diesel mechanical vessels are propelled by a traditional mechanical powertrain configuration with diesel-powered main engines connected to shaft propellers through a gear reduction box. Onboard generator sets provide power to electrical equipment.

A 100% battery electric powertrain (without diesel backup) was considered but not evaluated due to the need for emergency operation and periodic travel to the NCDOT Manns Harbor Shipyard for maintenance and inspections.

For the plug-in hybrid configuration, the following shoreside options were considered for providing charging power to the vessel:

- **No shoreside battery (no shore ESS).** Plug-in hybrid vessel charges from the grid.
- **Battery used by ferry operator only (shore ESS).** Plug-in hybrid vessel rapid charges from a shoreside battery slow charged from the grid. Only ferry operator access to the battery.
- **Battery shared between utility company and the ferry operator (shore ESS (shared))**. Plug-in vessel rapid charges from a shoreside battery slow charged from the grid. The ferry operator and utility company share use of the battery as a grid asset.

Currituck Sound

At Currituck Sound, plug-in hybrid configurations were evaluated for charging on a single side (Currituck) only, which requires approximately 2 MW. Charging was only considered at the Currituck terminal because the Knotts Island terminal is located at the tail end of a distribution line with only 120V single phase power currently available. Table 5 below shows all the configurations included in the analysis of Currituck Sound.

Table 5. Configuration Included in Analysis of Currituck Sound

	No Shore ESS	Shore ESS	Shore ESS (Shared)
Plug-in Hybrid One-Sided Charging	√	√	
Diesel Hybrid	√		
Diesel Mechanical	√		

Pamlico River

At Pamlico River, plug-in hybrid configurations were evaluated for charging on a single side (Bayview) and both sides (Aurora and Bayview). The Bayview terminal was selected for one-sided charging because the M/V Governor Daniel Russell currently docks overnight at Bayview. One-sided charging requires approximately 2 MW and two-sided charging requires approximately 1 MW per side. Table 6 below shows all the configurations included in the analysis of Pamlico River.

Table 6. Configuration Included in Analysis of Pamlico River

	No Shore ESS	Shore ESS	Shore ESS (Shared)
Plug-in Hybrid One-Sided Charging	√	√	√
Plug-in Hybrid Two-Sided Charging	√	√	√
Diesel Hybrid	√		
Diesel Mechanical	√		

Neuse River

At Neuse River, plug-in hybrid configurations were evaluated for charging on a single side (Cherry Branch) and both sides (Cherry Branch and Minnesott Beach). The Cherry Branch terminal was selected for one-sided charging because the M/V Neuse and M/V Lupton currently dock overnight at Cherry Branch where the NCDOT Ferry Division has significant facilities. One-sided charging requires approximately 3 MW and two-sided charging requires approximately 1.5 MW per side. Table 7 below shows the configurations included in the analysis of Neuse River.

Table 7. Configuration Included in Analysis of Neuse River

	No Shore ESS	Shore ESS	Shore ESS (Shared)
Plug-in Hybrid One-Sided Charging	√	√	
Plug-in Hybrid Two-Sided Charging	√	√	
Diesel Hybrid	√		
Diesel Mechanical	√		

Cape Fear River

At Cape Fear River, plug-in hybrid configurations were evaluated for charging on a single side (Fort Fisher) and both sides (Southport and Fort Fisher). One-sided charging at Southport terminal was considered, but not included in the analysis because the energy costs were significantly higher and the utility's estimate for grid improvement cost would need additional study. One-sided charging requires approximately 4.6 MW and two-sided charging requires approximately 2.3 MW. Table 8 below shows the configurations included in the analysis of Cape Fear River.

Table 8. Configuration Included in Analysis of Cape Fear River

	No Shore ESS	Shore ESS	Shore ESS (Shared)
Plug-in Hybrid One-Sided Charging	√	√	
Plug-in Hybrid Two-Sided Charging	√	√	
Diesel Hybrid	√		
Diesel Mechanical	√		

Energy Storage System Sizing

Energy storage system (ESS) or battery size requirements were estimated based on the energy estimated for a single trip and by using the ESS sizing tool provided by Corvus Energy. The one-way trip was used to consider charging at both terminals and the round trip was used for single-side charging. The historic fuel consumption data used to calculate trip energy for each route is shown in Table 9. Trip energy was calculated assuming 40 kWh per gallon and accounting for efficiencies of a diesel engine (33%), electric motor (90%), AC/DC conversion (90%), and charging efficiency (90%).

Table 9. Historic Fuel Consumption Data

Route	Vessel	Fuel Consumption (gallons of diesel)	
		One-way	Round Trip
Pamlico River	M/V Governor Daniel Russell	14.1	28.2
Currituck Sound	M/V Governor James Baxter Hunt Jr	15.4	30.9
Cape Fear River	M/V Southport & MV Forth Fisher	17.0	33.9
Neuse River	M/V Neuse & MV Lupton	10.5	21.1

The Corvus Energy tool estimates the ESS size of the vessel and shore ESS based on the energy requirement, number of daily battery discharges, system voltages, charge time, and an assumed 10-year replacement cycle. Similarly, the shoreside ESS was sized for daily vessel charging and a 10-year replacement cycle. Table 10 shows the estimated battery sizing and charging demand for the plug-in vessel configurations at each route. The charge times correspond to the existing operational schedule of the vessel, and the analysis assumed 2–3 minutes are needed to engage/disengage the charging plug.

Table 10. Estimated Battery Capacity Needed, Charge Time, and Power Demand

(a) Currituck Sound

	One-Sided Charging	
	No Shore ESS	Shore ESS
Shore ESS Capacity (kWh)	0	1,360
Charge Time (min)	17	17
Avg Power in Charging Event (kW)	2,000	380
Vessel ESS Capacity (kWh)	1,250	1,250
Energy Usage from Grid (kWh/Charge)	569	632

(b) Pamlico River

	One-Sided Charging			Two-Sided Charging		
	No Shore ESS	Shore ESS	Shore ESS (Shared)	No Shore ESS	Shore ESS	Shore ESS (Shared)
Shore ESS Capacity (kWh)	0	1,500	1,700	0	800	1,700
Charge Time (min)	12	12	12	12	12	12
Avg Power in Charging Event (kW)	2,323	500	500	1,162	500	500
Vessel ESS Capacity (kWh)	1,356	1,356	1,356	904	904	904
Energy Usage from Grid (kWh/Charge)	517	574	574	258	286	286

(c) Neuse River

	One-Sided Charging		Two-Sided Charging	
	No Shore ESS	Shore ESS	No Shore ESS	Shore ESS
Shore ESS Capacity (kWh)	0	2,150	0	1,150
Charge Time (min)	8	8	8	8
Avg Power in Charging Event (kW)	3,000	1,200	1,500	600
Vessel ESS Capacity (kWh)	1,500	1,500	1,025	1,025
Energy Usage from Grid (kWh/Charge)	389	432	194	216

(d) Cape Fear River

	One-Sided Charging		Two-Sided Charging	
	No Shore ESS	Shore ESS	No Shore ESS	Shore ESS
Shore ESS Capacity (kWh)	0	2,600	0	1,400
Charge Time (min)	8	8	8	8
Avg Power in Charging Event (kW)	4,667	1,121	2,333	561
Vessel ESS Capacity (kWh)	1,700	1,700	1,250	1,250
Energy Usage from Grid (kWh/Charge)	622	691	311	346

Lifecycle Cost Analysis

The net present value (NPV) was calculated for each of the vessel-shore configurations over a 40-year lifetime of the vessel. The analysis included the following cost categories:

- **Vessel capital costs.** Vessel, electrical equipment, vessel ESS, vessel ESS replacement.
- **Vessel operational costs.** Fuel (electricity and diesel), generator engine maintenance, generator electrical maintenance, rapid charging maintenance, motor and drive maintenance.
- **Shoreside costs.** Electrical grid system upgrades, terminal improvement, rapid charging system, rapid charging system replacement, shoreside ESS, shoreside ESS replacement.
- **Revenue.** Sharing of shore ESS with utility (only in shore ESS (shared) configurations at the Pamlico River).

Key assumptions made by the research team are shown in Table 11.

Uncertainties in Lifecycle Cost Analysis

As with any long-term infrastructure planning assessment, there is inherent uncertainty to analyzing the lifetime costs of traditional and electric ferry vessels. Over the planned 40-year life of these vessels, fluctuations in fixed costs like construction and infrastructure improvements and dynamic costs like fuel, maintenance, and equipment replacement will impact the final lifecycle costs estimates. There are four notable areas of uncertainty:

- **Battery technology.** It is expected that as the market and manufacturing technology for large scale battery storage expand, costs will decrease. Expectations for future battery costs in this study, included in Table 11, have been determined through discussions with multiple marine battery manufacturers, but potential variability in the battery market introduces a degree of uncertainty for vessel lifecycle costs. Additionally, ESS batteries are estimated to have a 10-year life, both on the vessel and shoreside. Battery life is heavily dictated by charge and discharge cycle, meaning improper operation of an electrically-powered vessel could negatively impact the expected life of the batteries and increase lifecycle costs. These batteries will also have some residual value (or salvage value). However, no residual value was included in the LCCA because at this time there is little information to accurately estimate residual value. At the end of their service life, the batteries will be in a depleted state but may have a second life in an ESS. It is also expected that a market for second life batteries will mature in the coming years.
- **Charger technology.** Similar to the market for battery technology, the medium-duty-heavy-duty (MDHD) charger market is quickly evolving and expanding but as a whole, rapid charging technology for electrically powered ferries is relatively new. Costs and expected lifetime for a ferry rapid charging system, outlined in Table 11, are based on discussions with multiple ferry charging system manufacturers. Variation in the cost at the time of procurement, lifetime of rapid charging systems, or the required maintenance for the system are all sources for uncertainty in this analysis.
- **Diesel and electric fuel cost inflation.** Over the life of the vessel the increasing cost of fuel, both diesel and electric, will impact the NPV of the various vessel configurations. This analysis considered an annual increase of 10 cents per gallon for diesel fuel and 2% for electric fuel. These estimations are based on the linear cost trend of no. 2 diesel retail prices over the past 25 years and historical electric costs for industrial users in North Carolina respectively. Variation from historical diesel and electric fuel price trends is a source of uncertainty in this analysis and would impact the result of this lifecycle cost analysis and potentially change which vessel configuration is most economical.
- **Discount rate.** The NPV of a capital project represents the present-day value of all cash inflows and outflows over the life of the project. For this vessel electrification analysis, the inflows and outflows include vessel capital costs, vessel operation costs, shoreside costs, and utility revenue. The discount rate represents the time value of money and is used to convert (or discount) future costs to an equivalent present cost. Discount rates used in analyzing government projects are typically based on treasury bond rates, which are reflective of inflationary conditions. The discount rate utilized in this analysis was 2%. An explanation of assumptions made for this analysis can be found in Table 11.

Table 11. Key Assumptions in Lifecycle Cost Calculations

Category	Sub-Category	Detail
General Assumptions	Discount rate	The discount rate referenced in the NCDOT Pavement Design Procedure is "the 30-year Real Treasury Interest Rate as provided in the Office of Management and Budget (OMB) Circular A-94 Appendix C." Currently that rate is 2.0%.
	Battery costs	\$700/kWh as year 0 price \$570/kWh as year 10 price \$500/kWh as years 20 and 30 prices These estimated costs are based on discussions with multiple marine battery manufacturers.
	Grants	Assume no federal or state grants are used.
Vessel Capital Assumptions	Vessel capital cost	\$30 million for all configurations of vessels.
	Electrical equipment cost	\$4M for equipment and systems required for electrical propulsion (all configurations except diesel mechanical). These estimated costs are based on discussions with marine architects.
	Vessel lifetime	40 years
	Vessel ESS lifetime	10 years
Vessel Operational Assumptions	Energy charge	See Of note, demand charges typically account for the majority of electricity costs for sites with megawatt-plus loads. Additional fees or discounts could apply to the electric rates shown in **Error! Reference source not found.** depending on assessment of the 24-hour load shape from vessel charging by the utility. Table 4 for energy charge by utility. An annual increase of 2% was applied to electric costs based on an analysis of historical costs for industrial users in North Carolina.
	Demand charge	See Of note, demand charges typically account for the majority of electricity costs for sites with megawatt-plus loads. Additional fees or discounts could apply to the electric rates shown in **Error! Reference source not found.** depending on assessment of the 24-hour load shape from vessel charging by the utility. Table 4 for demand charge by utility.
	Fixed charge	See Of note, demand charges typically account for the majority of electricity costs for sites with megawatt-plus

		loads. Additional fees or discounts could apply to the electric rates shown in **Error! Reference source not found.** depending on assessment of the 24-hour load shape from vessel charging by the utility. Table 4 for fixed charge by utility.
	Diesel cost	$3.25 per gallon initially and increasing $0.10 per year. This initial cost is estimated based on current and recent historical costs. The annual increase is based on the linear cost trend in no. 2 diesel retail prices over the past 25 years.
	Run time of diesel backup for plug-in configuration	1 hr. per day / 365 hr. per year An additional approximately 6 hours per day is included for days on which Tidelands EMC accesses the shoreside ESS.
Shoreside Assumptions	Electrical system upgrades	**Pamlico River** – $1M at Bayview and $1.5M at Aurora to provide necessary charging power if shoreside ESS not used; $0 at both locations if shoreside ESS used.
		Currituck Sound – $82,000 at Currituck to provide necessary charging power if shoreside ESS not used; $0 if shoreside ESS used.
		Cape Fear River – $1M at Southport[22] and $0 at Fort Fisher to provide necessary power for vessel charging.
		Neuse River – $0 at both locations regardless of shoreside ESS.
	Terminal improvements	$1.25M per terminal to upgrade/install shoreside electrical system to support vessel charging.
	Rapid charging system	$1.5M per system with a 20-year life and assumed annual maintenance cost at 1% of capital cost. These estimated costs are based on discussions with ferry charging system manufacturers.
	ESS lifetime	10 years
Revenue Assumptions **(Pamlico River Only)**	Winter months shared usage	Up to 5 shoreside ESS discharges in each of 3 winter months.
	Summer months shared usage	Up to 5 shoreside ESS discharges in each of 4 summer months.
	EMC energy consumption per event (kWh)	1,250 kWh

[22] An estimation of $1M was used for the cost of grid improvements as the City of Southport indicated comprehensive engineering study would be needed to provide an approximation of costs.

	Energy value for demand response by utility ($/kWh)	$8.00/kWh at Bayview and $10/kWh at Aurora

Emissions and Human Health Impacts

The methodology for estimating emissions and human health impacts is described below.

Greenhouse gas impacts

Greenhouse gas emissions were estimated using diesel emission factors from ICCT (2021) for heavy fuel oil (HFO) in a slow speed diesel. For electricity emission factors, the analysis used the U.S. Environmental Protection Agency's (EPA) eGrid data for the SRVC region[23] and assumed 5.3% in line losses from the plant to the plug.[24] Emissions from CO_2, CH_4, and N_2O were summed to a CO_2e value using 100-year global warming potentials from the IPCC Fifth Assessment Report.[25] The analysis did not account for changes in the electricity grid carbon intensity in future years. Therefore, estimates of upstream emissions for electricity are only valid for the next few years. To estimate the annual emissions, the annual gallons of diesel and annual kWh of electricity were multiplied by their respective emission factor.

Local air pollutant impacts

Annual emissions of six local pollutants were estimated at the vessel: NO_x, PM_{10}, $PM_{2.5}$, VOC, CO, and SO_2. The analysis used emission factors from the EPA's Port Emissions Inventory Guidance (2022).[26] The diesel engines on the various vessel configurations were assumed to abide by Tier 2 standards. To estimate the annual emissions by pollutant, the annual gallons of diesel consumed were multiplied by the emission factor.

Human health impacts

To estimate the annual health impact costs, the analysis used the EPA COBRA online tool which links marginal increases in emissions to an epidemiological model that measures health impacts.[27] The tool captures the impact of an additional ton of pollutant of NO_x, $PM_{2.5}$, VOC, and SO_2 on adult and infant mortality, non-fatal heart attacks, respiratory hospital admissions, cardiovascular-related hospital admissions, acute bronchitis, upper and lower respiratory symptoms, asthma exacerbations, asthma emergency room visits, minor restricted activity days, and work loss days.[28]

[23] https://www.epa.gov/egrid/data-explorer
[24] https://www.epa.gov/egrid/frequent-questions-about-egrid
[25] https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf
[26] Table H.7 https://www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance
[27] https://cobra.epa.gov/
[28] Co-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool: How COBRA Works (epa.gov)

FINDINGS

This section summarizes the findings on costs and emissions for the four routes included in this analysis.

Lifecycle Cost Estimates

This section details the results for the lifecycle cost analyses conducted in this study. Assumptions and included costs for this analysis can be found in the Methodology section of this report and specifics about the estimated lifecycle costs for each route are discussed in the following sub sections. All cost estimations are presented per vessel and a complete summary of the lifecycle cost analyses are provided in Appendix A. For every vessel and shore configuration analyzed on all four routes, the lifecycle costs are dominated by upfront capital costs and fuel costs throughout the analysis period. Generally, across the four routes, the configurations with the least NPV are:

- **Plug-in hybrid.** These configurations include the substantial capital costs of electric propulsion equipment, the rapid charging system, and onboard ESS. However, the operating costs are lower than diesel powered configurations because of the significantly lower cost of electric fuel.
- **Plug-in hybrid charging on one side.** These configurations include the significant costs and savings of a plug-in hybrid vessel but are more economical than charging on two sides because of the high cost of duplicating shoreside infrastructure and incurring second demand charges for electricity.
- **Plug-in hybrid utilizing a shoreside ESS.** These configurations include the significant costs and savings of a plug-in hybrid vessel plus the additional capital costs of a shoreside ESS. However, configurations utilizing a shoreside ESS are the most economical because the shoreside ESS mitigates electric demand charges reducing overall operational costs.

In general, the configurations with the highest lifetime NPV are:

- **Diesel powered.** Configurations using diesel as the primary fuel source experience lower initial capital costs but are significantly less economical overall because of the high and increasing cost of diesel fuel.
- **Diesel hybrid.** In three of the four routes analyzed, the diesel hybrid configurations proved more expensive than traditional diesel mechanical configurations. Although traditionally diesel mechanical configurations require more fuel during operation, the increased efficiency of the hybrid system did not outweigh the additional capital cost of the diesel hybrid configurations.

Currituck Sound

The NPV of estimated lifecycle costs of the vessel and shore configuration analyzed at Currituck Sound are presented in Table 12 and the analysis details are provided in Appendix A. The most economical option at Currituck Sound is a plug-in hybrid vessel charging on one side at the Currituck terminal and utilizing a shoreside ESS. Compared to primarily diesel-powered configurations, a plug-in hybrid vessel is estimated to save more than $13M over the lifetime of the vessel. Unlike the three other routes analyzed for this study, a shoreside ESS provides less significant savings at Currituck Sound and is only slightly more economical than similar configurations without a shoreside ESS.

Table 12. Currituck Sound Lifecycle Cost Analysis Results for NPV at 2% Discount Rate

	No Shore ESS	Shore ESS
Plug-in Hybrid One-Sided Charging	$50.0M	$49.5M
Diesel Hybrid	$63.9M	
Diesel Mechanical	$62.8M	

A breakdown by component of the NPV lifecycle costs at a 2% discount is provided in Figure 9. The lifecycle costs for the plug-in hybrid configurations at Currituck Sound are primarily vessel and shoreside capital costs, which range from approximately 80%% to 85% of total costs depending on the use of a shore ESS. The remaining costs are largely electric fuel, with maintenance and diesel fuel accounting for the final 6% of total costs.

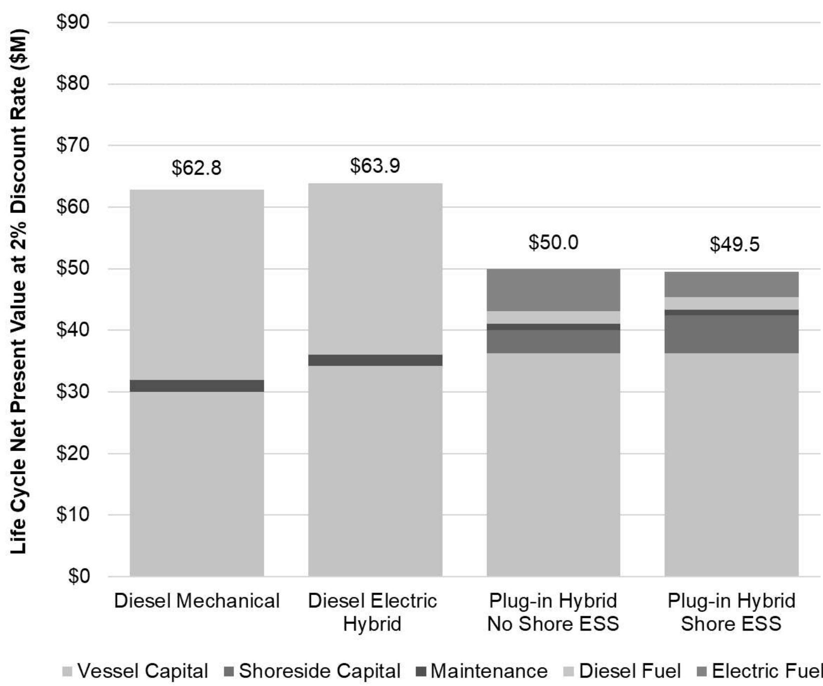

Figure 9. NPV of Lifecycle Costs by Component for Currituck Sound

The lifecycle costs for diesel powered configurations at Currituck Sound are balanced between capital and operational costs, with each comprising approximately half of total costs. Fuel is a significantly larger portion of operational cost for diesel powered configurations, with diesel fuel accounting for approximately 45% to 55% of the total costs. For these vessel configurations, maintenance costs make up approximately 3% of total costs.

Unique to the Currituck Sound route is that use of a shoreside ESS is not significantly more economical than charging directly from the grid. The capital cost of a shoreside ESS is typically offset by significantly reducing or eliminating the need for grid infrastructure improvements and by limiting demand charges. In this location, the cost of grid improvements required to charge without an ESS are very low, as are the demand charges. The initial capital cost for a shoreside ESS at the Currituck location is estimated to be approximately $1M and the annual energy costs are reduced by approximately $100k. The shoreside ESS is designed for a 10-year life and will effectively pay for itself over the life of the system.

Pamlico River

The NPV of estimated lifecycle costs of the vessel and shore configuration analyzed at Pamlico River are presented in Table 13 and the analysis details are provided in Appendix A. The most economical option at Pamlico River is a plug-in hybrid vessel charging on one side at the Bayview terminal and utilizing a shoreside ESS which can be accessed by Tideland EMC. Compared to primarily diesel-powered configurations, a plug-in hybrid vessel is estimated to save more than $12M over the lifetime of the vessel. Granting utility access to the shoreside ESS is unique to Pamlico River and further contributes to the economic viability of utilizing a plug-in hybrid vessel at this location.

Table 13. Pamlico River Lifecycle Cost Analysis Results for NPV at 2% Discount Rate

	No Shore ESS	Shore ESS	Shore ESS (Shared)
Plug-in Hybrid One-Sided Charging	$57.5M	$51.7M	$50.4M
Plug-in Hybrid Two-Sided Charging	$61.4M	$57.4M	$56.1M
Diesel Hybrid	$63.9M		
Diesel Mechanical	$62.8M		

A breakdown by component of the NPV lifecycle costs at a 2% discount is provided in Figure 10. The lifecycle costs for the plug-in hybrid configurations at Pamlico River are primarily vessel and shoreside capital costs which range from approximately 70% to 90% of total costs depending on vessel configuration. The remaining costs are largely electric fuel, with maintenance and diesel fuel accounting for the final 5% to 7% of total costs.

The lifecycle costs for diesel powered configurations at Pamlico River are balanced between capital and operational costs, with each comprising approximately half of total costs. Fuel is a significantly larger portion of operational cost for diesel powered configurations, with diesel fuel accounting for approximately 45% to 50% of the total costs. For these vessel configurations, maintenance costs make up approximately 3% of total costs.

The initial capital cost for a shoreside ESS at the Bayview location is estimated to be $1M which is approximately equal to the required grid infrastructure improvements if an ESS is not used. Also, the annual energy costs are reduced by approximately $200k because the shoreside ESS use significantly reduces the demand charges. The shoreside ESS is designed for a 10-year life and will effectively pay for itself in 5 years.

There is also an economical advantage to providing Tideland EMC access to a shoreside ESS for demand response which would result in revenue to the Ferry Division. Tideland EMC has been engaged with the research team throughout this project and has expressed an interest in a shoreside ESS as a demand response resource. In order to provide access to 1.25 MWh, the size of the ESS must be increased which is an increased capital cost. However, the increase is approximately 200 kWh for one side charging at Bayview with a shoreside ESS. At $700 per kWh, the cost increase is approximately $200k and revenue resulting is estimated to be $70k per year which provides an approximate 3-year pay-off period. While it cannot be considered within an economic analysis, there is likely value resulting from the goodwill that would accrue from sharing an asset for the benefit of a critical infrastructure system.

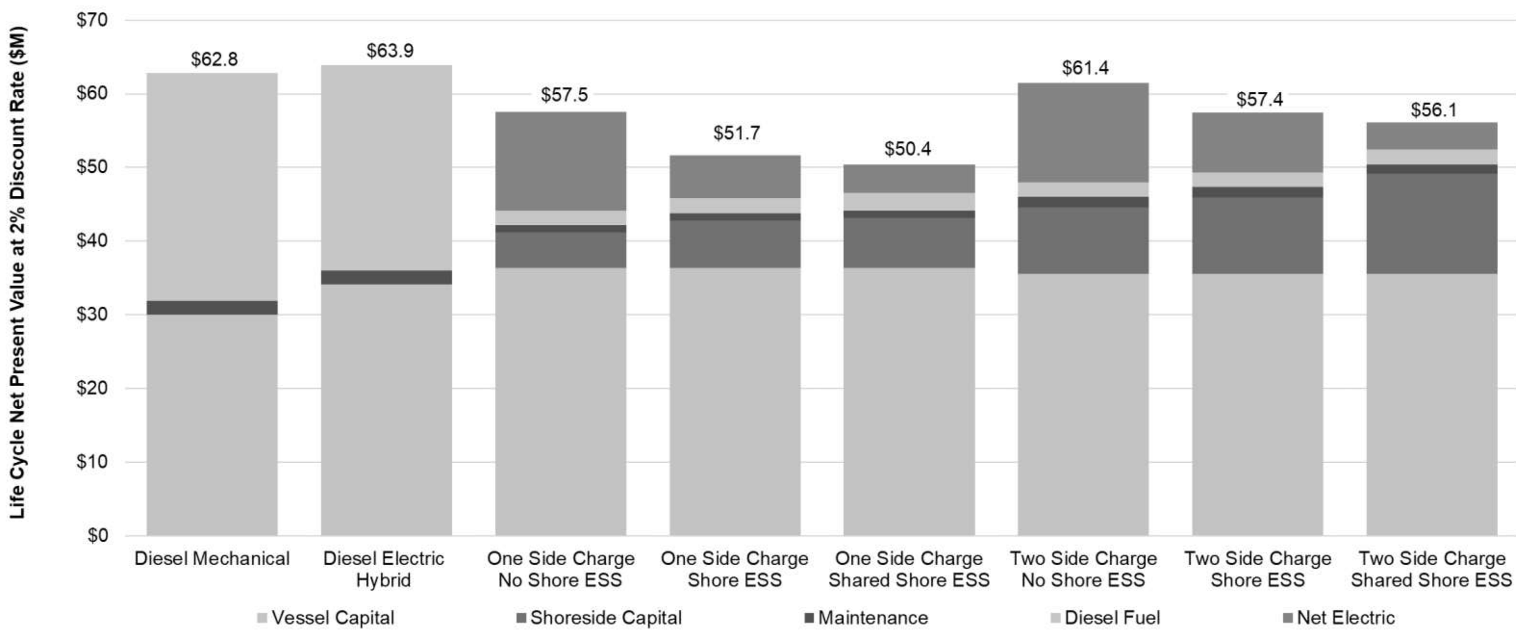

Figure 10. NPV of Lifecycle Costs by Component for Pamlico River

Neuse River

The NPV of estimated lifecycle costs of the vessel and shore configuration analyzed at Neuse River are presented in Table 14 and the analysis details are provided in Appendix A. The most economical option at Neuse River is a plug-in hybrid vessel charging on one side at the Cherry Branch terminal and utilizing a shoreside ESS. Compared to primarily diesel-powered configurations, a plug-in hybrid vessel is estimated to save more than $27M over the lifetime of the vessel. The relatively long period of daily operations at Neuse River means that plug-in hybrid vessels have the greatest lifetime savings at this location as compared to the other three routes. A longer operating window requires more fuel and maintenance, resulting in significant cost reductions when switching from diesel power to plug-in hybrid. Additionally, Neuse River was the only route where the diesel hybrid configuration was more economical than the diesel mechanical configuration.

Table 14. Neuse River Lifecycle Cost Analysis Results for NPV at 2% Discount Rate

	No Shore ESS	Shore ESS
Plug-in Hybrid One-Sided Charging	$62.9M	$57.7M
Plug-in Hybrid Two-Sided Charging	$65.7M	$61.7M
Diesel Hybrid	$84.8M	
Diesel Mechanical	$86.1M	

A breakdown by component of the NPV lifecycle costs at a 2% discount is provided in Figure 11. The lifecycle costs for the plug-in hybrid configurations at Neuse River are primarily vessel and shoreside capital costs, which range from approximately 65% to 80% of total costs depending on configuration. The remaining costs are largely electric fuel, with maintenance and diesel fuel accounting for approximately 6% of total costs.

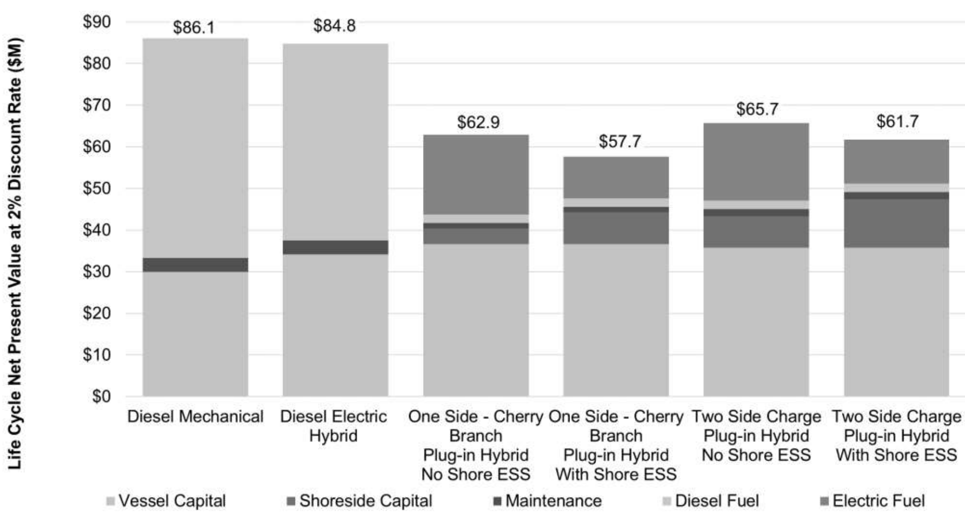

Figure 11. NPV of Lifecycle Costs by Component for Neuse River

The lifecycle costs for diesel powered configurations at Neuse River are dominated by operational costs, with diesel fuel accounting for approximately 55% to 60% of total costs. Capital costs account for the majority of remaining costs, making up approximately 35% to 40% of the total costs. For these vessel configurations, maintenance costs make up approximately 3% of total costs.

The initial capital cost for a shoreside ESS at the Cherry Branch location is estimated to be approximately $1.5M and the annual energy costs are reduced by approximately $250k because of significantly reduced demand charges. The shoreside ESS is designed for a 10-year life and will effectively pay for itself in 6 years.

Cape Fear River

The NPV of estimated lifecycle costs of the vessel and shore configuration analyzed at Cape Fear River are presented in Table 15 and the analysis details are provided in Appendix A. The most economical option at Cape Fear River is a plug-in hybrid vessel charging on one side at the Fort Fisher terminal and utilizing a shoreside ESS. Compared to primarily diesel-powered configurations, a plug-in hybrid vessel is estimated to save almost $9M over the lifetime of the vessel. Compared to the other routes, utilizing plug-in hybrid vessels at the Cape Fear River provides less significant savings over primarily diesel-powered vessels because of higher electric fuel costs as a result of more expensive demand charges.

Table 15. Cape Fear River Lifecycle Cost Analysis Results for NPV at 2% Discount Rate

	No Shore ESS	Shore ESS
Plug-in Hybrid One-Sided Charging	$80.8M	$60.8M
Plug-in Hybrid Two-Sided Charging	$101.8M	$69.7.1M
Diesel Hybrid	$69.9M	
Diesel Mechanical	$69.6M	

A breakdown by component of the NPV lifecycle costs at a 2% discount is provided in Figure 12. The lifecycle costs for the plug-in hybrid configurations at Cape Fear River are primarily vessel and shoreside capital costs which range from approximately 45% to 75% of total costs depending on vessel configuration. The remaining costs are largely electric fuel, with the maintenance and diesel fuel making up the final 3% to 5% of costs.

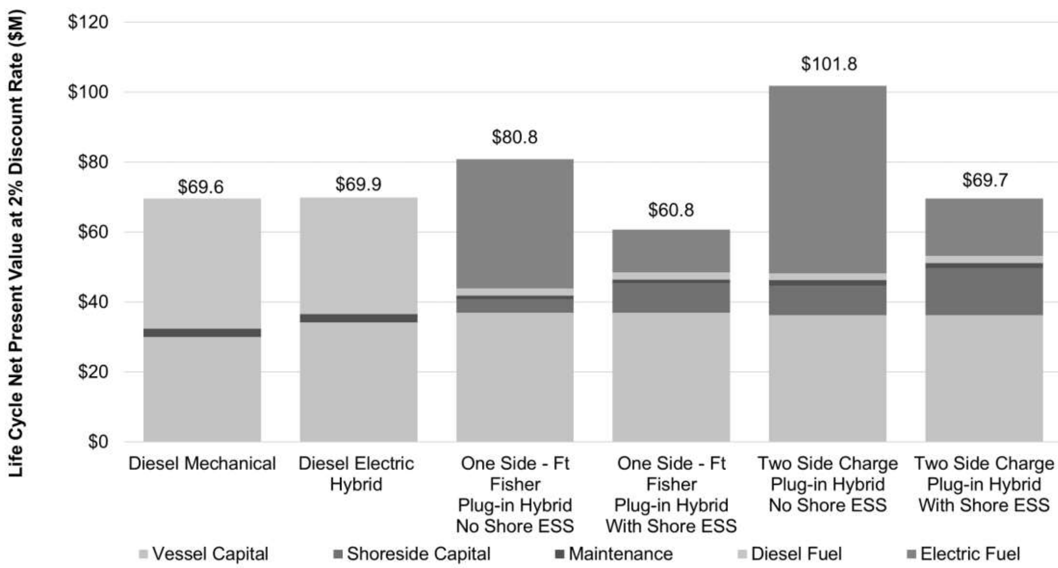

Figure 12. NPV of Lifecycle Costs by Component for Cape Fear River

The lifecycle costs for diesel powered configurations at Cape Fear River are more balanced between capital and operational costs, with each comprising approximately half of total costs. Fuel is a significantly larger portion of operational cost for diesel-powered configurations, with diesel fuel accounting for approximately 50% to 55% of the total costs. For these vessel configurations, maintenance costs make up approximately 3% of total costs.

The initial capital cost for a shoreside ESS at the Fort Fisher location is estimated to be $1.8M and would reduce annual energy costs by approximately 50%. This means the shoreside ESS, designed for a 10-year life, will effectively pay for itself in 3–4 years.

Emissions and Human Health Impact Estimates

Table 16 presents the estimated annual CO_2e and local pollutant emissions and the health impacts resulting from the local pollutants from one vessel at the four routes analyzed in this study.

As expected, CO_2e emissions per year are highest for the diesel mechanical configurations and lowest for the plug-in vessel configuration. When emissions from the electricity production are included (second row of each table), the CO_2e are still approximately five times lower in the plug-in vessel than the diesel mechanical vessel. This finding is driven by the relatively low emitting power supply in North Carolina, which has 13% coal, 39% natural gas, and 48% renewable and nuclear generation.

Similarly, the plug-in vessel configuration has lower emissions for other pollutants (e.g., NO_x) than the diesel hybrid and diesel mechanical configurations. The plug-in vessel emissions are non-zero because of the assumed occasional use of the onboard diesel backup.

The emissions of NO_x, PM_{10}, $PM_{2.5}$, VOC, CO, and SO_2 at the vessel contribute to the background emissions level in the vicinity of the ferry. These slightly higher emission levels (compared to no ferry) results in negative human health impacts, such as higher mortality, nonfatal heart attacks, infant mortality, etc. Output from the EPA's COBRA tool suggests the annual, monetized cost of the three electric ferry configurations are lowest in the plug-in vessel and highest in the diesel mechanical vessel.

Table 16. Annual Emissions and Human Health Impact Estimates per Vessel

a) Annual Impacts for Currituck Sound

Impact	Units	Plug-in Hybrid	Diesel Hybrid	Diesel Mechanical
CO_2e Vessel Only	Tons / year	166	2,241	2,490
CO_2e Vessel+Upstream	Tons / year	600	2,600	2,900
NO_x Vessel Only	Tons / year	3.4	45.3	50.3
PM_{10} Vessel Only	Tons / year	0.09	1.19	1.32
$PM_{2.5}$ Vessel Only	Tons / year	0.09	1.15	1.28
VOC Vessel Only	Tons / year	0.18	2.37	2.63
CO Vessel Only	Tons / year	0.55	7.37	8.19
SO_2 Vessel Only	Tons / year	0.0037	0.0501	0.0557
Health Impacts	$ per Year	$21,300 to $48,000	$280,000 to $630,000	$313,000 to $704,000

b) Annual Impacts for Pamlico River

Impact	Units	Plug-in Hybrid	Diesel Hybrid	Diesel Mechanical
CO_2e Vessel Only	Tons / year	166	2,241	2,490
CO_2e Vessel+Upstream	Tons / year	600	3,000	3,300
NO_x Vessel Only	Tons / year	3.4	45.3	50.3
PM_{10} Vessel Only	Tons / year	0.09	1.19	1.32
$PM_{2.5}$ Vessel Only	Tons / year	0.09	1.15	1.28
VOC Vessel Only	Tons / year	0.18	2.37	2.63
CO Vessel Only	Tons / year	0.55	7.37	8.19
SO_2 Vessel Only	Tons / year	0.0037	0.0501	0.0557
Health Impacts	$ per Year	$23,000 to $52,000	$300,000 to $700,000	$340,000 to $770,000

c) Annual Impacts for Neuse River

Impact	Units	Plug-in Hybrid	Diesel Hybrid	Diesel Mechanical
CO_2e Vessel Only	Tons / year	166	3,810	4,233
CO_2e Vessel+Upstream	Tons / year	800	4,500	5,000
NO_x Vessel Only	Tons / year	3.4	76.9	85.5
PM_{10} Vessel Only	Tons / year	0.09	2.02	2.24
$PM_{2.5}$ Vessel Only	Tons / year	0.09	1.96	2.18
VOC Vessel Only	Tons / year	0.18	4.03	4.48

CO Vessel Only	Tons / year	0.55	12.53	13.92
SO_2 Vessel Only	Tons / year	0.0037	0.0852	0.0946
Health Impacts	$ per Year	$24,500 to $55,300	$550,000 to $1,239,000	$612,000 to $1,378,000

d) Annual Impacts for Cape Fear River

Impact	Units	Plug-in Hybrid	Diesel Hybrid	Diesel Mechanical
CO_2e Vessel Only	Tons / year	166	2,689	2,988
CO_2e Vessel+Upstream	Tons / year	700	3,200	3,500
NO_x Vessel Only	Tons / year	3.4	54.31	60.35
PM_{10} Vessel Only	Tons / year	0.09	1.43	1.58
$PM_{2.5}$ Vessel Only	Tons / year	0.09	1.38	1.54
VOC Vessel Only	Tons / year	0.18	2.85	3.16
CO Vessel Only	Tons / year	0.55	8.84	9.83
SO_2 Vessel Only	Tons / year	0.0037	0.0601	0.0668
Health Impacts	$ per Year	$30,800 to $69,500	$485,000 to $1,094,000	$539,000 to $1,217,000

IMPLEMENTATION PLAN

This section summarizes the implementation strategy for the four routes analyzed in this study, including if electrification at each route is recommended and if so, in what configuration. Additionally, this section is organized to reflect the order in which electrifying the four routes is recommended based on the results of this study. The implementation strategy primarily considers the economic feasibility of electrification at the four routes, as ferry electrification has proven technological feasibility as detailed in the introduction of this report.

Electrification at any of the four routes detailed below would also require some modification and upgrades to the NCDOT State Shipyard in Manns Harbor. Costs for modifications to the shipyard facilities to accommodate electrified ferries are not included in this assessment. Any upgrades to infrastructure or modifications at Manns Harbor would not be as complex or costly as those required at the ferry terminals designated below because vessels do not need to charge rapidly resulting in significantly lower power demand.

Finally, the applicability of the recommendations in this section is subject to change as new information becomes available with respect to electric grid capacity, fuel price, and battery technology. Additional analyses may be required to verify or update the recommendations provided.

Currituck Sound

Deployment of a plug-in hybrid vessel charging at the Currituck Ferry Terminal utilizing a shoreside ESS is recommended along the Currituck Sound ferry route. This configuration is estimated to reduce total life cycle costs by more than $13M when compared to non-hybrid configurations and benefits from significant positive air quality and health impacts. While a shoreside ESS at this location is not significantly more economical, it is still recommended as it eliminates the need for any electric grid infrastructure improvements and mitigates some risk due to potential change in electricity rates. Charging at the Currituck terminal is recommended because of already existing infrastructure to overnight the ferry.

Currituck Sound is recommended to be the first electrified route because a single ferry vessel is operated at this location and the vessel is making relatively few crossings per day, reducing the initial capital investment required and overall operational impact of electrification. Additionally, Currituck Sound is recommended to be electrified before the Pamlico River, which also operates only one ferry, because life cycle costs are lower, potential grid infrastructure improvements are less expensive, and the vessel operated at Currituck Sound is significantly older.

Pamlico River

Deployment of a plug-in hybrid vessel charging at the Bayview Ferry Terminal utilizing a shared shoreside ESS is recommended along the Pamlico River ferry route. This configuration is estimated to reduce total life cycle costs by more than $12M when compared to non-hybrid configurations and benefits from significant positive air quality and health impacts. Charging at the Bayview terminal is recommended because of already existing infrastructure to overnight the ferry.

Pamlico River is recommended to be the second electrified route because only one ferry is operated at this location, reducing the initial capital investment required.

Neuse River

Deployment of a plug-in hybrid vessel charging at the Cherry Branch Ferry Terminal utilizing a shoreside ESS is recommended along the Neuse River ferry route. This configuration is estimated to reduce total lifetime costs by more than $27M per vessel when compared to non-hybrid configurations and benefits from significant positive air quality and health impacts. Charging at the Cherry Branch terminal is recommended because of already existing infrastructure to overnight the ferry.

While electrification at the Neuse River route benefits from significantly higher cost reduction over the lifetime of the vessel as compared to the Currituck Sound or Pamlico River routes, the need for two vessels at this location make initial capital investment significantly higher.

Cape Fear River

Deployment of a plug-in hybrid vessel charging at the Fort Fisher Ferry Terminal utilizing a shoreside ESS is recommended along the Cape Fear River ferry route. This configuration is estimated to reduce total lifetime costs by almost $9M per vessel when compared to non-hybrid configurations and benefits from significant positive air quality and health impacts. Charging at the Fort Fisher terminal is recommended because of reduced total lifetime costs due to lesser electricity demand charges.

Cape Fear River is recommended to be the last route electrified because of the high initial capital investment required for two vessels and significantly smaller reduction in lifetime costs.

WORKFORCE DEVELOPMENT

Deployment of plug-in hybrid ferry vessels brings with it opportunities and challenges related to economic development. Expansion of local energy generation, electrical system upgrades, and improvements to vessel terminals supporting electrified ferries will create job opportunities in already existing sectors. However, marine electrification for commercial scale vessels like those operated by the NCDOT will also present unique needs for workforce training and development. While some roles like installation and maintenance of proprietary vessel chargers will likely be staffed by equipment suppliers, regular operation, service, and monitoring of electrified vessels will require the appropriate education and training for new technologies. Additionally, vessel crew emergency responders must understand and be trained for the unique emergency response challenges introduced by alternative fuel vessels.

If the NCDOT pursues ferry electrification, it should plan workforce development efforts in conjunction with other implementation planning steps. This would mean identifying specific workforce development needs, identifying training programs, establishing training partners, and pursuing funding for workforce development. Examples of workforce education and training programs relevant to plug-in hybrid ferries are listed in Table 17.

Table 17. Example Training Programs Applicable to Plug-in Hybrid Vessels

Marine Electrical	
Marine Electrical Certification - American Boat and Yacht Council	• Designed as introduction to marine electrical systems offering education across a wide variety of basic concepts. • Organization also offers advanced marine electrical certification.
Training - National Marine Electronics Association	• Self-study certifications for marine electronics technicians. • Basic to advanced training course for marine electronics installation.
NC MARTEC - Carteret Community College	• Curriculum covering a variety of marine training and education subjects including marine electrical and electronics installation and service.
Emergency Response	
National Fire Protection Association (NFPA)	• Alternative Fuel Vehicles Training Program for Emergency Responders. • Introduction to alternative fuel vehicle concepts including, electric, hybrid, fuel cell, biodiesel, and gaseous fuels such as CNG (Compressed Natural Gas), LNG (Liquefied Natural Gas), and Propane. • The program also covers identification techniques, immobilization and power-down procedures, extrication challenges, recommended practices for dealing with hazards such as fires and submersion, incidents involving charging/refueling stations, and more.

APPENDIX A. SUMMARY OF LIFECYCLE COST ANALYSES

Diesel-Mechanical (Pamlico River)

Vessel ESS (kWh)	0	Shoreside ESS (MWh)	0	Current Cost	Annual Use (hr/yr)
				$ 3.25	3,650 / 1,825

Year	Vessel: Battery Cost ($/kWh)	Vessel: Capital Construction	Vessel: ESS	Shoreside: Capital Grid Improvement	Shoreside: Capital Terminal Improvement	Shoreside: ESS	Shoreside: Rapid Charging System	Operation: Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Prop Engine Maintenance	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Total
0	$ 700	$ 30,000,000	$ -	$ -	$ -	$ -	$ -		$ 3.25								$ 30,000,000
1								219,000	$ 3.35	$ 759,930		$ 20,000	$ 8,000	$ -			$ 787,930
2								219,000	$ 3.45	$ 781,830		$ 29,000	$ 12,000	$ -			$ 822,830
3								219,000	$ 3.55	$ 803,730		$ 76,000	$ 17,000	$ -			$ 896,730
4								219,000	$ 3.65	$ 825,630		$ 24,000	$ 12,000	$ -			$ 861,630
5								219,000	$ 3.75	$ 847,530		$ 29,000	$ 12,000	$ -			$ 888,530
6								219,000	$ 3.85	$ 869,430		$ 76,000	$ 64,000	$ -			$ 1,009,430
7								219,000	$ 3.95	$ 891,330		$ 31,000	$ 12,000	$ -			$ 934,330
8								219,000	$ 4.05	$ 913,230		$ 22,000	$ 12,000	$ -			$ 947,230
9								219,000	$ 4.15	$ 935,130		$ 76,000	$ 17,000	$ -			$ 1,028,130
10	$ 570		$ -			$ -		219,000	$ 4.25	$ 957,030		$ 31,000	$ 12,000	$ -			$ 1,000,030
11								219,000	$ 4.35	$ 978,930		$ 78,000	$ 68,000	$ -			$ 1,124,930
12								219,000	$ 4.45	$ 1,000,830		$ 20,000	$ 8,000	$ -			$ 1,028,830
13								219,000	$ 4.55	$ 1,022,730		$ 29,000	$ 12,000	$ -			$ 1,063,730
14								219,000	$ 4.65	$ 1,044,630		$ 80,000	$ 19,000	$ 70,000			$ 1,213,630
15								219,000	$ 4.75	$ 1,066,530		$ 20,000	$ 10,000	$ -			$ 1,096,530
16								219,000	$ 4.85	$ 1,088,430		$ 29,000	$ 12,000	$ -			$ 1,129,430
17								219,000	$ 4.95	$ 1,110,330		$ 80,000	$ 68,000	$ -			$ 1,258,330
18								219,000	$ 5.05	$ 1,132,230		$ 27,000	$ 8,000	$ -			$ 1,167,230
19								219,000	$ 5.15	$ 1,154,130		$ 22,000	$ 12,000	$ -			$ 1,188,130
20	$ 500		$ -			$ -		219,000	$ 5.25	$ 1,176,030		$ 80,000	$ 19,000	$ -			$ 1,275,030
21								219,000	$ 5.35	$ 1,197,930		$ 27,000	$ 10,000	$ -			$ 1,234,930
22								219,000	$ 5.45	$ 1,219,830		$ 78,000	$ 68,000	$ -			$ 1,365,830
23								219,000	$ 5.55	$ 1,241,730		$ 20,000	$ 8,000	$ -			$ 1,269,730
24								219,000	$ 5.65	$ 1,263,630		$ 31,000	$ 12,000	$ -			$ 1,306,630
25								219,000	$ 5.75	$ 1,285,530		$ 78,000	$ 19,000	$ -			$ 1,382,530
26								219,000	$ 5.85	$ 1,307,430		$ 20,000	$ 10,000	$ -			$ 1,337,430
27								219,000	$ 5.95	$ 1,329,330		$ 31,000	$ 12,000	$ 70,000			$ 1,442,330
28								219,000	$ 6.05	$ 1,351,230		$ 78,000	$ 68,000	$ -			$ 1,497,230
29								219,000	$ 6.15	$ 1,373,130		$ 27,000	$ 8,000	$ -			$ 1,408,130
30	$ 500		$ -			$ -		219,000	$ 6.25	$ 1,395,030		$ 24,000	$ 12,000	$ -			$ 1,431,030
31								219,000	$ 6.35	$ 1,416,930		$ 78,000	$ 19,000	$ -			$ 1,513,930
32								219,000	$ 6.45	$ 1,438,830		$ 27,000	$ 10,000	$ -			$ 1,475,830
33								219,000	$ 6.55	$ 1,460,730		$ 78,000	$ 68,000	$ -			$ 1,606,730
34								219,000	$ 6.65	$ 1,482,630		$ 24,000	$ 12,000	$ -			$ 1,518,630
35								219,000	$ 6.75	$ 1,504,530		$ 27,000	$ 8,000	$ -			$ 1,539,530
36								219,000	$ 6.85	$ 1,526,430		$ 78,000	$ 19,000	$ -			$ 1,623,430
37								219,000	$ 6.95	$ 1,548,330		$ 31,000	$ 12,000	$ -			$ 1,591,330
38								219,000	$ 7.05	$ 1,570,230		$ 20,000	$ 10,000	$ -			$ 1,600,230
39								219,000	$ 7.15	$ 1,592,130		$ 78,000	$ 68,000	$ -			$ 1,738,130
40								219,000	$ 7.25	$ 1,614,030		$ 31,000	$ 12,000	$ 70,000			$ 1,727,030
																NPV (2%)	$ 62,821,207

Diesel-Electric Hybrid with Battery for Peak Shave (Pamlico River)

									Current Cost				Annual Use (hr/yr)				
	Vessel ESS (kWh)		100	Shoreside ESS (MWh)		0			$ 3.25				3,650				
		Vessel			Shoreside						Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 70,000	$ -	$ -	$ -	$ -		$ 3.25								$ 34,070,000
1			$ -					197,100	$ 3.35	$ 683,937		$ 20,000	$ -	$ -	$ -	$ -	$ 703,937
2			$ -					197,100	$ 3.45	$ 703,647		$ 29,000	$ -	$ -	$ -	$ -	$ 732,647
3			$ -					197,100	$ 3.55	$ 723,357		$ 76,000	$ -	$ -	$ -	$ -	$ 799,357
4			$ -					197,100	$ 3.65	$ 743,067		$ 24,000	$ -	$ -	$ -	$ -	$ 767,067
5			$ -					197,100	$ 3.75	$ 762,777		$ 29,000	$ -	$ -	$ -	$ -	$ 791,777
6			$ -					197,100	$ 3.85	$ 782,487		$ 76,000	$ -	$ -	$ -	$ -	$ 858,487
7			$ -					197,100	$ 3.95	$ 802,197		$ 31,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 978,197
8			$ -					197,100	$ 4.05	$ 821,907		$ 22,000	$ -	$ -	$ -	$ -	$ 843,907
9			$ -					197,100	$ 4.15	$ 841,617		$ 76,000	$ -	$ -	$ -	$ -	$ 917,617
10	$ 570		$ 57,000			$ -		197,100	$ 4.25	$ 861,327		$ 31,000	$ -	$ -	$ -	$ -	$ 949,327
11			$ -					197,100	$ 4.35	$ 881,037		$ 78,000	$ -	$ -	$ -	$ -	$ 959,037
12			$ -					197,100	$ 4.45	$ 900,747		$ 20,000	$ -	$ -	$ -	$ -	$ 920,747
13			$ -					197,100	$ 4.55	$ 920,457		$ 29,000	$ -	$ -	$ -	$ -	$ 949,457
14			$ -					197,100	$ 4.65	$ 940,167		$ 80,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 1,165,167
15			$ -					197,100	$ 4.75	$ 959,877		$ 20,000	$ -	$ -	$ -	$ -	$ 979,877
16			$ -					197,100	$ 4.85	$ 979,587		$ 29,000	$ -	$ -	$ -	$ -	$ 1,008,587
17			$ -					197,100	$ 4.95	$ 999,297		$ 80,000	$ -	$ -	$ -	$ -	$ 1,079,297
18			$ -					197,100	$ 5.05	$ 1,019,007		$ 27,000	$ -	$ -	$ -	$ -	$ 1,046,007
19			$ -					197,100	$ 5.15	$ 1,038,717		$ 22,000	$ -	$ -	$ -	$ -	$ 1,060,717
20	$ 500		$ 50,000			$ -		197,100	$ 5.25	$ 1,058,427		$ 80,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 1,333,427
21			$ -					197,100	$ 5.35	$ 1,078,137		$ 27,000	$ -	$ -	$ -	$ -	$ 1,105,137
22			$ -					197,100	$ 5.45	$ 1,097,847		$ 78,000	$ 80,000	$ -	$ 80,000	$ 25,000	$ 1,360,847
23			$ -					197,100	$ 5.55	$ 1,117,557		$ 20,000	$ -	$ -	$ -	$ -	$ 1,137,557
24			$ -					197,100	$ 5.65	$ 1,137,267		$ 31,000	$ -	$ -	$ -	$ -	$ 1,168,267
25			$ -					197,100	$ 5.75	$ 1,156,977		$ 78,000	$ -	$ -	$ -	$ -	$ 1,234,977
26			$ -					197,100	$ 5.85	$ 1,176,687		$ 20,000	$ -	$ -	$ -	$ -	$ 1,196,687
27			$ -					197,100	$ 5.95	$ 1,196,397		$ 31,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 1,372,397
28			$ -					197,100	$ 6.05	$ 1,216,107		$ 78,000	$ -	$ -	$ -	$ -	$ 1,294,107
29			$ -					197,100	$ 6.15	$ 1,235,817		$ 27,000	$ -	$ -	$ -	$ -	$ 1,262,817
30	$ 500		$ 50,000			$ -		197,100	$ 6.25	$ 1,255,527		$ 24,000	$ -	$ -	$ -	$ -	$ 1,329,527
31			$ -					197,100	$ 6.35	$ 1,275,237		$ 78,000	$ -	$ -	$ -	$ -	$ 1,353,237
32			$ -					197,100	$ 6.45	$ 1,294,947		$ 27,000	$ -	$ -	$ -	$ -	$ 1,321,947
33			$ -					197,100	$ 6.55	$ 1,314,657		$ 78,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 1,537,657
34			$ -					197,100	$ 6.65	$ 1,334,367		$ 24,000	$ -	$ -	$ -	$ -	$ 1,358,367
35			$ -					197,100	$ 6.75	$ 1,354,077		$ 27,000	$ -	$ -	$ -	$ -	$ 1,381,077
36			$ -					197,100	$ 6.85	$ 1,373,787		$ 78,000	$ -	$ -	$ -	$ -	$ 1,451,787
37			$ -					197,100	$ 6.95	$ 1,393,497		$ 31,000	$ -	$ -	$ -	$ -	$ 1,424,497
38			$ -					197,100	$ 7.05	$ 1,413,207		$ 20,000	$ -	$ -	$ -	$ -	$ 1,433,207
39			$ -					197,100	$ 7.15	$ 1,432,917		$ 78,000	$ -	$ -	$ -	$ -	$ 1,510,917
40			$ -					197,100	$ 7.25	$ 1,452,627		$ 31,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 1,628,627
																NPV (2%)	$ 63,871,696

One side charging - No shoreside ESS Pamlico River

Vessel ESS (kWh)	1,356	Shoreside ESS (MWh)	0	Current Cost	Annual Increase	Annual Use (hr/yr)	Annual Maintenance
				$ 3.25	2%	500	1%

Year	Vessel: Battery Cost ($/kWh)	Vessel: Capital Construction	Vessel: ESS	Shoreside: Capital Grid Improvement	Shoreside: Capital Terminal Improvement	Shoreside: ESS	Shoreside: Rapid Charging System	Operation: Annual Fuel (gal)	Operation: Fuel Cost ($/gal)	Operation: Fuel	Operation: Elec Energy	Operation: Genset Engine Maintenance	Operation: Genset Elec Maintenance	Operation: Rapid Charging Maintenance	Operation: Propulsion Motor Maintenance	Operation: Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 949,200	$ 1,000,000	$ 1,250,000	$ -	$ 1,500,000		$ 3.25								$ 38,699,200
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 340,111	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 406,021
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 346,913	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 416,283
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 353,851	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 422,681
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 360,928	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 433,218
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 368,147	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 439,897
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 375,509	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 450,719
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 383,020	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 532,690
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 390,680	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 468,810
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 398,494	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 476,084
10	$ 570		$ 772,920			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 406,464	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,267,434
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 414,593	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 495,103
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 422,885	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 506,855
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 431,342	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 514,772
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 439,969	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 601,859
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 448,769	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 535,119
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 457,744	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 547,554
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 466,899	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 556,169
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 476,237	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 568,967
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 485,762	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 577,952
20	$ 500		$ 678,000			$ -	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 495,477	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 2,955,127
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 505,386	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 600,496
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 515,494	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 719,064
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 525,804	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 623,834
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 536,320	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 637,810
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 547,046	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 647,996
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 557,987	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 662,397
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 569,147	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 748,017
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 580,530	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 687,860
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 592,141	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 698,931
30	$ 500		$ 678,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 603,983	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,399,233
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 616,063	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 725,773
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 628,384	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 741,554
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 640,952	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 828,582
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 653,771	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 769,861
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 666,847	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 782,397
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 680,183	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 799,193
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 693,787	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 812,257
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 707,663	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 829,593
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 721,816	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 843,206
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 736,252	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 1,062,102
																NPV (2%)	$ 57,514,379

One side charging - Shoreside ESS (Pamlico River)

											Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
									Current Cost								
	Vessel ESS (kWh)		1,356	Shoreside ESS (MWh)		1,500			$ 3.25		2%	500		1%			
		Vessel			Shoreside						Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 949,200		$ 1,250,000	$ 1,050,000	$ 1,500,000		$ 3.25								$ 38,749,200
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 148,648	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 214,558
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 151,621	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 220,991
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 154,654	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 223,484
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 157,747	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 230,037
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 160,902	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 232,652
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 164,120	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 239,330
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 167,402	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 317,072
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 170,750	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 248,880
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 174,165	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 251,755
10	$ 570		$ 772,920			$ 855,000	$ -	14,600	$ 4.25	$ 62,050	$ 177,649	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,893,619
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 181,202	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 261,712
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 184,826	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 268,796
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 188,522	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 271,952
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 192,293	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 354,183
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 196,138	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 282,488
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 200,061	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 289,871
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 204,062	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 293,332
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 208,144	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 300,874
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 212,307	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 304,497
20	$ 500		$ 678,000			$ 750,000	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 216,553	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 3,426,203
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 220,884	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 315,994
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 225,301	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 428,871
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 229,807	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 327,837
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 234,404	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 335,894
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 239,092	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 340,042
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 243,874	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 348,284
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 248,751	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 427,621
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 253,726	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 361,056
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 258,801	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 365,591
30	$ 500		$ 678,000			$ 750,000	$ -	14,600	$ 6.25	$ 91,250	$ 263,977	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,809,227
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 269,256	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 378,966
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 274,641	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 387,811
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 280,134	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 467,764
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 285,737	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 401,827
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 291,451	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 407,001
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 297,280	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 416,290
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 303,226	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 421,696
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 309,291	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 431,221
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 315,476	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 436,866
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 321,786	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 647,636
																NPV (2%)	$ 51,676,242

One side charging - Shoreside ESS accessed by Tidelands EMC (Pamlico River)

Vessel ESS (kWh)	1,356	Shoreside ESS (MWh)	1,700	Current Cost	Annual Increase	Annual Use (hr/yr)	Annual Maintenance
				$ 3.25	2%	500	1%

Year	Vessel: Battery Cost ($/kWh)	Vessel: Capital Construction	Vessel: ESS	Shoreside: Capital Grid Improvement	Shoreside: Capital Terminal Improvement	Shoreside: ESS	Shoreside: Rapid Charging System	Operation: Annual Fuel (gal)	Operation: Fuel Cost ($/gal)	Operation: Fuel	Operation: Elec Energy	Operation: Genset Engine Maintenance	Operation: Genset Elec Maintenance	Operation: Rapid Charging Maintenance	Operation: Propulsion Motor Maintenance	Operation: Drive Maintenance	Revenue: EMC Revenue	Total
0	$ 700	$ 34,000,000	$ 949,200	$ -	$ 1,250,000	$ 1,190,000	$ 1,500,000		$ 3.25									$ 38,889,200
1			$ -			$ -	$ -	17,400	$ 3.35	$ 58,290	$ 146,144	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 151,434
2			$ -			$ -	$ -	17,400	$ 3.45	$ 60,030	$ 149,067	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 158,097
3			$ -			$ -	$ -	17,400	$ 3.55	$ 61,770	$ 152,048	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 160,818
4			$ -			$ -	$ -	17,400	$ 3.65	$ 63,510	$ 155,089	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 167,599
5			$ -			$ -	$ -	17,400	$ 3.75	$ 65,250	$ 158,191	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 170,441
6			$ -			$ -	$ -	17,400	$ 3.85	$ 66,990	$ 161,355	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 177,345
7			$ -			$ -	$ -	17,400	$ 3.95	$ 68,730	$ 164,582	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ (70,000)	$ 255,312
8			$ -			$ -	$ -	17,400	$ 4.05	$ 70,470	$ 167,874	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 187,344
9			$ -			$ -	$ -	17,400	$ 4.15	$ 72,210	$ 171,231	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 190,441
10	$ 570		$ 772,920			$ 969,000	$ -	17,400	$ 4.25	$ 73,950	$ 174,656	$ 11,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 1,946,526
11			$ -			$ -	$ -	17,400	$ 4.35	$ 75,690	$ 178,149	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 200,839
12			$ -			$ -	$ -	17,400	$ 4.45	$ 77,430	$ 181,712	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 208,142
13			$ -			$ -	$ -	17,400	$ 4.55	$ 79,170	$ 185,346	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 211,516
14			$ -			$ -	$ -	17,400	$ 4.65	$ 80,910	$ 189,053	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ (70,000)	$ 293,963
15			$ -			$ -	$ -	17,400	$ 4.75	$ 82,650	$ 192,834	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 222,484
16			$ -			$ -	$ -	17,400	$ 4.85	$ 84,390	$ 196,691	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 230,081
17			$ -			$ -	$ -	17,400	$ 4.95	$ 86,130	$ 200,625	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 233,755
18			$ -			$ -	$ -	17,400	$ 5.05	$ 87,870	$ 204,637	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 241,507
19			$ -			$ -	$ -	17,400	$ 5.15	$ 89,610	$ 208,730	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 245,340
20	$ 500		$ 678,000			$ 850,000	$ 1,500,000	17,400	$ 5.25	$ 91,350	$ 212,904	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ (70,000)	$ 3,467,254
21			$ -			$ -	$ -	17,400	$ 5.35	$ 93,090	$ 217,162	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 257,252
22			$ -			$ -	$ -	17,400	$ 5.45	$ 94,830	$ 221,506	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ (70,000)	$ 370,336
23			$ -			$ -	$ -	17,400	$ 5.55	$ 96,570	$ 225,936	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 269,506
24			$ -			$ -	$ -	17,400	$ 5.65	$ 98,310	$ 230,455	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 277,765
25			$ -			$ -	$ -	17,400	$ 5.75	$ 100,050	$ 235,064	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 282,114
26			$ -			$ -	$ -	17,400	$ 5.85	$ 101,790	$ 239,765	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 290,555
27			$ -			$ -	$ -	17,400	$ 5.95	$ 103,530	$ 244,560	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ (70,000)	$ 370,090
28			$ -			$ -	$ -	17,400	$ 6.05	$ 105,270	$ 249,451	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 303,721
29			$ -			$ -	$ -	17,400	$ 6.15	$ 107,010	$ 254,440	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 308,450
30	$ 500		$ 678,000			$ 850,000	$ -	17,400	$ 6.25	$ 108,750	$ 259,529	$ 11,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 1,852,279
31			$ -			$ -	$ -	17,400	$ 6.35	$ 110,490	$ 264,720	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 322,210
32			$ -			$ -	$ -	17,400	$ 6.45	$ 112,230	$ 270,014	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 331,244
33			$ -			$ -	$ -	17,400	$ 6.55	$ 113,970	$ 275,414	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ (70,000)	$ 411,384
34			$ -			$ -	$ -	17,400	$ 6.65	$ 115,710	$ 280,923	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 345,633
35			$ -			$ -	$ -	17,400	$ 6.75	$ 117,450	$ 286,541	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 350,991
36			$ -			$ -	$ -	17,400	$ 6.85	$ 119,190	$ 292,272	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 360,462
37			$ -			$ -	$ -	17,400	$ 6.95	$ 120,930	$ 298,117	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 366,047
38			$ -			$ -	$ -	17,400	$ 7.05	$ 122,670	$ 304,080	$ 4,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 375,750
39			$ -			$ -	$ -	17,400	$ 7.15	$ 124,410	$ 310,161	$ 2,000	$ -	$ 15,000	$ -	$ -	$ (70,000)	$ 381,571
40			$ -			$ -	$ -	17,400	$ 7.25	$ 126,150	$ 316,365	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ (70,000)	$ 592,515
																	NPV (2%)	**$ 50,405,125**

Two side charging - No shoreside ESS (Pamlico River)

									Current Cost		Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
	Vessel ESS (kWh)		904	Shoreside ESS (MWh)		0			$ 3.25		2%	500		1%			
		Vessel			Shoreside						Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 632,800	$ 1,500,000	$ 2,500,000	$ -	$ 3,000,000		$ 3.25								$ 41,632,800
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 342,154	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 423,064
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 348,997	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 433,367
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 355,977	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 439,807
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 363,096	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 450,386
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 370,358	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 457,108
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 377,765	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 467,975
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 385,321	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 549,991
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 393,027	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 486,157
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 400,887	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 493,477
10	$ 570		$ 515,280			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 408,905	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,027,235
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 417,083	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 512,593
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 425,425	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 524,395
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 433,933	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 532,363
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 442,612	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 619,502
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 451,464	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 552,814
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 460,494	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 565,304
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 469,704	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 573,974
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 479,098	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 586,828
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 488,680	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 595,870
20	$ 500		$ 452,000			$ -	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 498,453	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 4,232,103
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 508,422	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 618,532
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 518,591	$ 4,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 737,161
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 528,963	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 641,993
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 539,542	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 656,032
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 550,333	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 666,283
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 561,339	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 680,749
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 572,566	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 766,436
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 584,017	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 706,347
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 595,698	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 717,488
30	$ 500		$ 452,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 607,612	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,191,862
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 619,764	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 744,474
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 632,159	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 760,329
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 644,802	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 847,432
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 657,698	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 788,788
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 670,852	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 801,402
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 684,269	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 818,279
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 697,955	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 831,425
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 711,914	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 848,844
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 726,152	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 862,542
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 740,675	$ 60,000	$ 70,000	$ 30,000	$ 70,000	$ 5,000	$ 1,081,525
																NPV (2%)	$ 61,449,580

Two side charging - Shoreside ESS (Pamlico River)

									Current Cost		Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
	Vessel ESS (kWh)		900	Shoreside ESS (MWh)		800			$ 3.25		2%	500		1%			
		Vessel			Shoreside						Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 630,000		$ 2,500,000	$ 1,120,000	$ 3,000,000		$ 3.25								$ 41,250,000
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 205,692	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 286,602
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 209,806	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 294,176
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 214,002	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 297,832
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 218,282	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 305,572
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 222,647	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 309,397
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 227,100	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 317,310
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 231,642	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 396,312
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 236,275	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 329,405
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 241,001	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 333,591
10	$ 570		$ 513,000			$ 912,000	$ -	14,600	$ 4.25	$ 62,050	$ 245,821	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,773,871
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 250,737	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 346,247
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 255,752	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 354,722
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 260,867	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 359,297
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 266,084	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 442,974
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 271,406	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 372,756
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 276,834	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 381,644
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 282,371	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 386,641
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 288,018	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 395,748
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 293,779	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 400,969
20	$ 500		$ 450,000			$ 800,000	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 299,654	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 4,831,304
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 305,647	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 415,757
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 311,760	$ 4,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 530,330
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 317,995	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 431,025
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 324,355	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 440,845
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 330,842	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 446,792
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 337,459	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 456,869
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 344,208	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 538,078
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 351,093	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 473,423
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 358,115	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 479,905
30	$ 500		$ 450,000			$ 800,000	$ -	14,600	$ 6.25	$ 91,250	$ 365,277	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,747,527
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 372,582	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 497,292
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 380,034	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 508,204
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 387,635	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 590,265
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 395,387	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 526,477
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 403,295	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 533,845
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 411,361	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 545,371
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 419,588	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 553,058
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 427,980	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 564,910
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 436,540	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 572,930
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 445,270	$ 60,000	$ 70,000	$ 30,000	$ 70,000	$ 5,000	$ 786,120
																NPV (2%)	**$ 57,439,211**

Two side charging - Shoreside ESS accessed by Tidelands EMC (Pamlico River)

Vessel ESS (kWh)	904	Shoreside ESS (MWh)	1,700	Current Cost	Annual Increase	Annual Use (hr/yr)
				$ 3.25	2%	500

Annual Maintenance: 1%

	Vessel			Shoreside				Operation									Revenue	
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	EMC Revenue	Total
0	$ 700	$ 34,000,000	$ 632,800	$ -	$ 2,500,000	$ 2,380,000	$ 3,000,000		$ 3.25									$ 42,512,800
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 203,193	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 121,603
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 207,257	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 129,127
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 211,402	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 132,732
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 215,630	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 140,420
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 219,943	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 144,193
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 224,341	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 152,051
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 228,828	$ 2,000	$ -	$ 25,000	$ 70,000	$ 5,000	$ (157,500)	$ 230,998
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 233,405	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 164,035
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 238,073	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 168,163
10	$ 570		$ 515,280			$ 1,938,000	$ -	14,600	$ 4.25	$ 62,050	$ 242,834	$ 11,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 2,636,664
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 247,691	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 180,701
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 252,645	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 189,115
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 257,698	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 193,628
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 262,852	$ 4,000	$ -	$ 25,000	$ 70,000	$ 5,000	$ (157,500)	$ 277,242
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 268,109	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 206,959
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 273,471	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 215,781
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 278,940	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 220,710
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 284,519	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 229,749
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 290,210	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 234,900
20	$ 500		$ 452,000			$ 1,700,000	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 296,014	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ (157,500)	$ 5,572,164
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 301,934	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 249,544
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 307,973	$ 4,000	$ -	$ 25,000	$ 80,000	$ 25,000	$ (157,500)	$ 364,043
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 314,132	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 264,662
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 320,415	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 274,405
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 326,823	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 280,273
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 333,359	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 290,269
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 340,027	$ 2,000	$ -	$ 25,000	$ 70,000	$ 5,000	$ (157,500)	$ 371,397
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 346,827	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 306,657
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 353,764	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 313,054
30	$ 500		$ 452,000			$ 1,700,000	$ -	14,600	$ 6.25	$ 91,250	$ 360,839	$ 11,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 2,482,589
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 368,056	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 330,266
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 375,417	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 341,087
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 382,925	$ 2,000	$ -	$ 25,000	$ 70,000	$ 5,000	$ (157,500)	$ 423,055
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 390,584	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 359,174
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 398,395	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 366,445
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 406,363	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 377,873
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 414,491	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 385,461
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 422,780	$ 4,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 397,210
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 431,236	$ 2,000	$ -	$ 25,000	$ -	$ -	$ (157,500)	$ 405,126
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 439,861	$ 60,000	$ 70,000	$ 25,000	$ 70,000	$ 5,000	$ (157,500)	$ 618,211
																	NPV (2%)	**$ 56,110,648**

Diesel-Mechanical (Currituck Sound)

Vessel ESS (kWh) 0 Shoreside ESS (MWh) 0

Current Cost $ 3.25

Annual Use (hr/yr) 3,650 1,825

	Vessel			Shoreside				Operation								
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Prop Engine Maintenance	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Total
0	$ 700	$ 30,000,000	$ -	$ -	$ -	$ -	$ -		$ 3.25								$ 30,000,000
1								219,000	$ 3.35	$ 759,930		$ 20,000	$ 8,000	$ -			$ 787,930
2								219,000	$ 3.45	$ 781,830		$ 29,000	$ 12,000	$ -			$ 822,830
3								219,000	$ 3.55	$ 803,730		$ 76,000	$ 17,000	$ -			$ 896,730
4								219,000	$ 3.65	$ 825,630		$ 24,000	$ 12,000	$ -			$ 861,630
5								219,000	$ 3.75	$ 847,530		$ 29,000	$ 12,000	$ -			$ 888,530
6								219,000	$ 3.85	$ 869,430		$ 76,000	$ 64,000	$ -			$ 1,009,430
7								219,000	$ 3.95	$ 891,330		$ 31,000	$ 12,000	$ -			$ 934,330
8								219,000	$ 4.05	$ 913,230		$ 22,000	$ 12,000	$ -			$ 947,230
9								219,000	$ 4.15	$ 935,130		$ 76,000	$ 17,000	$ -			$ 1,028,130
10	$ 570		$ -			$ -		219,000	$ 4.25	$ 957,030		$ 31,000	$ 12,000	$ -			$ 1,000,030
11								219,000	$ 4.35	$ 978,930		$ 78,000	$ 68,000	$ -			$ 1,124,930
12								219,000	$ 4.45	$ 1,000,830		$ 20,000	$ 8,000	$ -			$ 1,028,830
13								219,000	$ 4.55	$ 1,022,730		$ 29,000	$ 12,000	$ -			$ 1,063,730
14								219,000	$ 4.65	$ 1,044,630		$ 80,000	$ 19,000	$ 70,000			$ 1,213,630
15								219,000	$ 4.75	$ 1,066,530		$ 20,000	$ 10,000	$ -			$ 1,096,530
16								219,000	$ 4.85	$ 1,088,430		$ 29,000	$ 12,000	$ -			$ 1,129,430
17								219,000	$ 4.95	$ 1,110,330		$ 80,000	$ 68,000	$ -			$ 1,258,330
18								219,000	$ 5.05	$ 1,132,230		$ 27,000	$ 8,000	$ -			$ 1,167,230
19								219,000	$ 5.15	$ 1,154,130		$ 22,000	$ 12,000	$ -			$ 1,188,130
20	$ 500		$ -			$ -		219,000	$ 5.25	$ 1,176,030		$ 80,000	$ 19,000	$ -			$ 1,275,030
21								219,000	$ 5.35	$ 1,197,930		$ 27,000	$ 10,000	$ -			$ 1,234,930
22								219,000	$ 5.45	$ 1,219,830		$ 78,000	$ 68,000	$ -			$ 1,365,830
23								219,000	$ 5.55	$ 1,241,730		$ 20,000	$ 8,000	$ -			$ 1,269,730
24								219,000	$ 5.65	$ 1,263,630		$ 31,000	$ 12,000	$ -			$ 1,306,630
25								219,000	$ 5.75	$ 1,285,530		$ 78,000	$ 19,000	$ -			$ 1,382,530
26								219,000	$ 5.85	$ 1,307,430		$ 20,000	$ 10,000	$ -			$ 1,337,430
27								219,000	$ 5.95	$ 1,329,330		$ 31,000	$ 12,000	$ 70,000			$ 1,442,330
28								219,000	$ 6.05	$ 1,351,230		$ 78,000	$ 68,000	$ -			$ 1,497,230
29								219,000	$ 6.15	$ 1,373,130		$ 27,000	$ 8,000	$ -			$ 1,408,130
30	$ 500		$ -			$ -		219,000	$ 6.25	$ 1,395,030		$ 24,000	$ 12,000	$ -			$ 1,431,030
31								219,000	$ 6.35	$ 1,416,930		$ 78,000	$ 19,000	$ -			$ 1,513,930
32								219,000	$ 6.45	$ 1,438,830		$ 27,000	$ 10,000	$ -			$ 1,475,830
33								219,000	$ 6.55	$ 1,460,730		$ 78,000	$ 68,000	$ -			$ 1,606,730
34								219,000	$ 6.65	$ 1,482,630		$ 24,000	$ 12,000	$ -			$ 1,518,630
35								219,000	$ 6.75	$ 1,504,530		$ 27,000	$ 8,000	$ -			$ 1,539,530
36								219,000	$ 6.85	$ 1,526,430		$ 78,000	$ 19,000	$ -			$ 1,623,430
37								219,000	$ 6.95	$ 1,548,330		$ 31,000	$ 12,000	$ -			$ 1,591,330
38								219,000	$ 7.05	$ 1,570,230		$ 20,000	$ 10,000	$ -			$ 1,600,230
39								219,000	$ 7.15	$ 1,592,130		$ 78,000	$ 68,000	$ -			$ 1,738,130
40								219,000	$ 7.25	$ 1,614,030		$ 31,000	$ 12,000	$ 70,000			$ 1,727,030
																NPV (2%)	$ 62,821,207

Diesel-Electric Hybrid with Battery for Peak Shave (Currituck Sound)

Vessel ESS (kWh)	100	Shoreside ESS (MWh)	0	Current Cost $ 3.25	Annual Use (hr/yr) 3,650	

Year	Battery Cost ($/kWh)	Vessel: Capital Construction	Vessel: ESS	Shoreside: Capital Grid Improvement	Shoreside: Capital Terminal Improvement	Shoreside: ESS	Shoreside: Rapid Charging System	Operation: Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 70,000	$ -	$ -	$ -	$ -		$ 3.25								$ 34,070,000
1			$ -					197,100	$ 3.35	$ 683,937		$ 20,000	$ -		$ -	$ -	$ 703,937
2			$ -					197,100	$ 3.45	$ 703,647		$ 29,000	$ -		$ -	$ -	$ 732,647
3			$ -					197,100	$ 3.55	$ 723,357		$ 76,000	$ -		$ -	$ -	$ 799,357
4			$ -					197,100	$ 3.65	$ 743,067		$ 24,000	$ -		$ -	$ -	$ 767,067
5			$ -					197,100	$ 3.75	$ 762,777		$ 29,000	$ -		$ -	$ -	$ 791,777
6			$ -					197,100	$ 3.85	$ 782,487		$ 76,000	$ -		$ -	$ -	$ 858,487
7			$ -					197,100	$ 3.95	$ 802,197		$ 31,000	$ 70,000		$ 70,000	$ 5,000	$ 978,197
8			$ -					197,100	$ 4.05	$ 821,907		$ 22,000	$ -		$ -	$ -	$ 843,907
9			$ -					197,100	$ 4.15	$ 841,617		$ 76,000	$ -		$ -	$ -	$ 917,617
10	$ 570		$ 57,000			$ -		197,100	$ 4.25	$ 861,327		$ 31,000	$ -		$ -	$ -	$ 949,327
11			$ -					197,100	$ 4.35	$ 881,037		$ 78,000	$ -		$ -	$ -	$ 959,037
12			$ -					197,100	$ 4.45	$ 900,747		$ 20,000	$ -		$ -	$ -	$ 920,747
13			$ -					197,100	$ 4.55	$ 920,457		$ 29,000	$ -		$ -	$ -	$ 949,457
14			$ -					197,100	$ 4.65	$ 940,167		$ 80,000	$ 70,000		$ 70,000	$ 5,000	$ 1,165,167
15			$ -					197,100	$ 4.75	$ 959,877		$ 20,000	$ -		$ -	$ -	$ 979,877
16			$ -					197,100	$ 4.85	$ 979,587		$ 29,000	$ -		$ -	$ -	$ 1,008,587
17			$ -					197,100	$ 4.95	$ 999,297		$ 80,000	$ -		$ -	$ -	$ 1,079,297
18			$ -					197,100	$ 5.05	$ 1,019,007		$ 27,000	$ -		$ -	$ -	$ 1,046,007
19			$ -					197,100	$ 5.15	$ 1,038,717		$ 22,000	$ -		$ -	$ -	$ 1,060,717
20	$ 500		$ 50,000			$ -		197,100	$ 5.25	$ 1,058,427		$ 80,000	$ 70,000		$ 70,000	$ 5,000	$ 1,333,427
21			$ -					197,100	$ 5.35	$ 1,078,137		$ 27,000	$ -		$ -	$ -	$ 1,105,137
22			$ -					197,100	$ 5.45	$ 1,097,847		$ 78,000	$ 80,000		$ 80,000	$ 25,000	$ 1,360,847
23			$ -					197,100	$ 5.55	$ 1,117,557		$ 20,000	$ -		$ -	$ -	$ 1,137,557
24			$ -					197,100	$ 5.65	$ 1,137,267		$ 31,000	$ -		$ -	$ -	$ 1,168,267
25			$ -					197,100	$ 5.75	$ 1,156,977		$ 78,000	$ -		$ -	$ -	$ 1,234,977
26			$ -					197,100	$ 5.85	$ 1,176,687		$ 20,000	$ -		$ -	$ -	$ 1,196,687
27			$ -					197,100	$ 5.95	$ 1,196,397		$ 31,000	$ 70,000		$ 70,000	$ 5,000	$ 1,372,397
28			$ -					197,100	$ 6.05	$ 1,216,107		$ 78,000	$ -		$ -	$ -	$ 1,294,107
29			$ -					197,100	$ 6.15	$ 1,235,817		$ 27,000	$ -		$ -	$ -	$ 1,262,817
30	$ 500		$ 50,000			$ -		197,100	$ 6.25	$ 1,255,527		$ 24,000	$ -		$ -	$ -	$ 1,329,527
31			$ -					197,100	$ 6.35	$ 1,275,237		$ 78,000	$ -		$ -	$ -	$ 1,353,237
32			$ -					197,100	$ 6.45	$ 1,294,947		$ 27,000	$ -		$ -	$ -	$ 1,321,947
33			$ -					197,100	$ 6.55	$ 1,314,657		$ 78,000	$ 70,000		$ 70,000	$ 5,000	$ 1,537,657
34			$ -					197,100	$ 6.65	$ 1,334,367		$ 24,000	$ -		$ -	$ -	$ 1,358,367
35			$ -					197,100	$ 6.75	$ 1,354,077		$ 27,000	$ -		$ -	$ -	$ 1,381,077
36			$ -					197,100	$ 6.85	$ 1,373,787		$ 78,000	$ -		$ -	$ -	$ 1,451,787
37			$ -					197,100	$ 6.95	$ 1,393,497		$ 31,000	$ -		$ -	$ -	$ 1,424,497
38			$ -					197,100	$ 7.05	$ 1,413,207		$ 20,000	$ -		$ -	$ -	$ 1,433,207
39			$ -					197,100	$ 7.15	$ 1,432,917		$ 78,000	$ -		$ -	$ -	$ 1,510,917
40			$ -					197,100	$ 7.25	$ 1,452,627		$ 31,000	$ 70,000		$ 70,000	$ 5,000	$ 1,628,627
																NPV (2%)	**$ 63,871,696**

One side charging - No shoreside ESS (Currituck Sound)

											Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
									Current Cost								
	Vessel ESS (kWh)		1,250	Shoreside ESS (MWh)		0			$ 3.25		2%	500		1%			
	Vessel			Shoreside							Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 875,000	$ 82,000	$ 1,250,000	$ -	$ 1,500,000		$ 3.25								$ 37,707,000
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 175,502	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 241,412
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 179,013	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 248,383
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 182,593	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 251,423
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 186,245	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 258,535
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 189,969	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 261,719
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 193,769	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 268,979
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 197,644	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 347,314
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 201,597	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 279,727
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 205,629	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 283,219
10	$ 570		$ 712,500			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 209,742	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,010,292
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 213,937	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 294,447
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 218,215	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 302,185
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 222,580	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 306,010
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 227,031	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 388,921
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 231,572	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 317,922
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 236,203	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 326,013
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 240,927	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 330,197
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 245,746	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 338,476
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 250,661	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 342,851
20	$ 500		$ 625,000			$ -	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 255,674	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 2,662,324
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 260,787	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 355,897
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 266,003	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 469,573
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 271,323	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 369,353
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 276,750	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 378,240
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 282,285	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 383,235
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 287,930	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 392,340
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 293,689	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 472,559
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 299,563	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 406,893
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 305,554	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 412,344
30	$ 500		$ 625,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 311,665	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,053,915
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 317,898	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 427,608
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 324,256	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 437,426
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 330,741	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 518,371
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 337,356	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 453,446
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 344,103	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 459,653
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 350,986	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 469,996
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 358,005	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 476,475
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 365,165	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 487,095
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 372,469	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 493,859
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 379,918	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 705,768
																NPV (2%)	$ 49,952,468

One side charging - Shoreside ESS (Currituck Sound)

Vessel ESS (kWh)	1,250	Shoreside ESS (MWh)	1,360	Current Cost	$ 3.25	Annual Increase	2%	Annual Use (hr/yr)	500
Annual Maintenance	1%								

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 875,000		$ 1,250,000	$ 952,000	$ 1,500,000		$ 3.25								$ 38,577,000
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 105,146	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 171,056
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 107,249	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 176,619
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 109,394	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 178,224
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 111,582	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 183,872
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 113,814	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 185,564
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 116,090	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 191,300
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 118,412	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 268,082
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 120,780	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 198,910
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 123,196	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 200,786
10	$ 570		$ 712,500			$ 775,200	$ -	14,600	$ 4.25	$ 62,050	$ 125,660	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,701,410
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 128,173	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 208,683
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 130,736	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 214,706
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 133,351	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 216,781
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 136,018	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 297,908
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 138,738	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 225,088
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 141,513	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 231,323
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 144,343	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 233,613
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 147,230	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 239,960
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 150,175	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 242,365
20	$ 500		$ 625,000			$ 680,000	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 153,178	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 3,239,828
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 156,242	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 251,352
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 159,367	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 362,937
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 162,554	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 260,584
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 165,805	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 267,295
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 169,121	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 270,071
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 172,504	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 276,914
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 175,954	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 354,824
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 179,473	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 286,803
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 183,062	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 289,852
30	$ 500		$ 625,000			$ 680,000	$ -	14,600	$ 6.25	$ 91,250	$ 186,723	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,608,973
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 190,458	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 300,168
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 194,267	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 307,437
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 198,152	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 385,782
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 202,115	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 318,205
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 206,158	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 321,708
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 210,281	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 329,291
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 214,487	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 332,957
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 218,776	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 340,706
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 223,152	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 344,542
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 227,615	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 553,465
																NPV (2%)	$ 49,532,365

Diesel-Mechanical (Cape Fear River)

Vessel ESS (kWh) 0 Shoreside ESS (MWh) 0

Current Cost $ 3.25

Annual Use (hr/yr) 4,380 2,190

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Prop Engine Maintenance	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Total
0	$ 700	$ 30,000,000	$ -	$ -	$ -	$ -	$ -		$ 3.25								$ 30,000,000
1								262,800	$ 3.35	$ 917,172		$ 24,000	$ 12,000	$ -			$ 953,172
2								262,800	$ 3.45	$ 943,452		$ 33,000	$ 12,000	$ -			$ 988,452
3								262,800	$ 3.55	$ 969,732		$ 84,000	$ 21,000	$ -			$ 1,074,732
4								262,800	$ 3.65	$ 996,012		$ 33,000	$ 12,000	$ -			$ 1,041,012
5								262,800	$ 3.75	$ 1,022,292		$ 80,000	$ 68,000	$ -			$ 1,170,292
6								262,800	$ 3.85	$ 1,048,572		$ 35,000	$ 16,000	$ -			$ 1,099,572
7								262,800	$ 3.95	$ 1,074,852		$ 82,000	$ 19,000	$ -			$ 1,175,852
8								262,800	$ 4.05	$ 1,101,132		$ 35,000	$ 14,000	$ -			$ 1,150,132
9								262,800	$ 4.15	$ 1,127,412		$ 24,000	$ 12,000	$ -			$ 1,163,412
10	$ 570		$ -			$ -		262,800	$ 4.25	$ 1,153,692		$ 82,000	$ 68,000	$ -			$ 1,303,692
11								262,800	$ 4.35	$ 1,179,972		$ 35,000	$ 16,000	$ 70,000			$ 1,300,972
12								262,800	$ 4.45	$ 1,206,252		$ 82,000	$ 19,000	$ -			$ 1,307,252
13								262,800	$ 4.55	$ 1,232,532		$ 31,000	$ 12,000	$ -			$ 1,275,532
14								262,800	$ 4.65	$ 1,258,812		$ 84,000	$ 70,000	$ -			$ 1,412,812
15								262,800	$ 4.75	$ 1,285,092		$ 33,000	$ 12,000	$ -			$ 1,330,092
16								262,800	$ 4.85	$ 1,311,372		$ 84,000	$ 23,000	$ -			$ 1,418,372
17								262,800	$ 4.95	$ 1,337,652		$ 24,000	$ 12,000	$ -			$ 1,373,652
18								262,800	$ 5.05	$ 1,363,932		$ 33,000	$ 12,000	$ -			$ 1,408,932
19								262,800	$ 5.15	$ 1,390,212		$ 84,000	$ 70,000	$ -			$ 1,544,212
20	$ 500		$ -			$ -		262,800	$ 5.25	$ 1,416,492		$ 33,000	$ 12,000	$ -			$ 1,461,492
21								262,800	$ 5.35	$ 1,442,772		$ 80,000	$ 19,000	$ -			$ 1,541,772
22								262,800	$ 5.45	$ 1,469,052		$ 35,000	$ 16,000	$ 70,000			$ 1,590,052
23								262,800	$ 5.55	$ 1,495,332		$ 82,000	$ 68,000	$ -			$ 1,645,332
24								262,800	$ 5.65	$ 1,521,612		$ 35,000	$ 14,000	$ -			$ 1,570,612
25								262,800	$ 5.75	$ 1,547,892		$ 26,000	$ 12,000	$ -			$ 1,585,892
26								262,800	$ 5.85	$ 1,574,172		$ 80,000	$ 19,000	$ -			$ 1,673,172
27								262,800	$ 5.95	$ 1,600,452		$ 35,000	$ 16,000	$ -			$ 1,651,452
28								262,800	$ 6.05	$ 1,626,732		$ 82,000	$ 68,000	$ -			$ 1,776,732
29								262,800	$ 6.15	$ 1,653,012		$ 35,000	$ 14,000	$ -			$ 1,702,012
30	$ 500		$ -			$ -		262,800	$ 6.25	$ 1,679,292		$ 80,000	$ 19,000	$ -			$ 1,778,292
31								262,800	$ 6.35	$ 1,705,572		$ 33,000	$ 12,000	$ -			$ 1,750,572
32								262,800	$ 6.45	$ 1,731,852		$ 84,000	$ 72,000	$ -			$ 1,887,852
33								262,800	$ 6.55	$ 1,758,132		$ 26,000	$ 12,000	$ 70,000			$ 1,866,132
34								262,800	$ 6.65	$ 1,784,412		$ 31,000	$ 12,000	$ -			$ 1,827,412
35								262,800	$ 6.75	$ 1,810,692		$ 84,000	$ 21,000	$ -			$ 1,915,692
36								262,800	$ 6.85	$ 1,836,972		$ 33,000	$ 12,000	$ -			$ 1,881,972
37								262,800	$ 6.95	$ 1,863,252		$ 84,000	$ 72,000	$ 80,000			$ 2,099,252
38								262,800	$ 7.05	$ 1,889,532		$ 31,000	$ 12,000	$ -			$ 1,932,532
39								262,800	$ 7.15	$ 1,915,812		$ 82,000	$ 19,000	$ -			$ 2,016,812
40								262,800	$ 7.25	$ 1,942,092		$ 35,000	$ 14,000	$ -			$ 1,991,092
																NPV (2%)	$ 69,555,803

Diesel-Electric Hybrid with Battery for Peak Shave (Cape Fear River)

Vessel ESS (kWh)	100	Shoreside ESS (MWh)	0
Current Cost	$ 3.25	Annual Use (hr/yr)	4,380

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 70,000	$ -	$ -	$ -	$ -		$ 3.25								$ 34,070,000
1			$ -					236,520	$ 3.35	$ 820,724		$ 24,000	$ -		$ -	$ -	$ 844,724
2			$ -					236,520	$ 3.45	$ 844,376		$ 33,000	$ -		$ -	$ -	$ 877,376
3			$ -					236,520	$ 3.55	$ 868,028		$ 84,000	$ -		$ -	$ -	$ 952,028
4			$ -					236,520	$ 3.65	$ 891,680		$ 33,000	$ -		$ -	$ -	$ 924,680
5			$ -					236,520	$ 3.75	$ 915,332		$ 80,000	$ -		$ -	$ -	$ 995,332
6			$ -					236,520	$ 3.85	$ 938,984		$ 35,000	$ 70,000		$ 70,000	$ 5,000	$ 1,118,984
7			$ -					236,520	$ 3.95	$ 962,636		$ 82,000	$ -		$ -	$ -	$ 1,044,636
8			$ -					236,520	$ 4.05	$ 986,288		$ 35,000	$ -		$ -	$ -	$ 1,021,288
9			$ -					236,520	$ 4.15	$ 1,009,940		$ 24,000	$ -		$ -	$ -	$ 1,033,940
10	$ 570		$ 57,000			$ -		236,520	$ 4.25	$ 1,033,592		$ 82,000	$ -		$ -	$ -	$ 1,172,592
11			$ -					236,520	$ 4.35	$ 1,057,244		$ 35,000	$ 70,000		$ 70,000	$ 5,000	$ 1,237,244
12			$ -					236,520	$ 4.45	$ 1,080,896		$ 82,000	$ -		$ -	$ -	$ 1,162,896
13			$ -					236,520	$ 4.55	$ 1,104,548		$ 31,000	$ -		$ -	$ -	$ 1,135,548
14			$ -					236,520	$ 4.65	$ 1,128,200		$ 84,000	$ -		$ -	$ -	$ 1,212,200
15			$ -					236,520	$ 4.75	$ 1,151,852		$ 33,000	$ -		$ -	$ -	$ 1,184,852
16			$ -					236,520	$ 4.85	$ 1,175,504		$ 84,000	$ -		$ -	$ -	$ 1,259,504
17			$ -					236,520	$ 4.95	$ 1,199,156		$ 24,000	$ 70,000		$ 70,000	$ 5,000	$ 1,368,156
18			$ -					236,520	$ 5.05	$ 1,222,808		$ 33,000	$ -		$ -	$ -	$ 1,255,808
19			$ -					236,520	$ 5.15	$ 1,246,460		$ 84,000	$ 80,000		$ 80,000	$ 25,000	$ 1,515,460
20	$ 500		$ 50,000			$ -		236,520	$ 5.25	$ 1,270,112		$ 33,000	$ -		$ -	$ -	$ 1,353,112
21			$ -					236,520	$ 5.35	$ 1,293,764		$ 80,000	$ -		$ -	$ -	$ 1,373,764
22			$ -					236,520	$ 5.45	$ 1,317,416		$ 35,000	$ 70,000		$ 70,000	$ 5,000	$ 1,497,416
23			$ -					236,520	$ 5.55	$ 1,341,068		$ 82,000	$ -		$ -	$ -	$ 1,423,068
24			$ -					236,520	$ 5.65	$ 1,364,720		$ 35,000	$ -		$ -	$ -	$ 1,399,720
25			$ -					236,520	$ 5.75	$ 1,388,372		$ 26,000	$ -		$ -	$ -	$ 1,414,372
26			$ -					236,520	$ 5.85	$ 1,412,024		$ 80,000	$ -		$ -	$ -	$ 1,492,024
27			$ -					236,520	$ 5.95	$ 1,435,676		$ 35,000	$ -		$ -	$ -	$ 1,470,676
28			$ -					236,520	$ 6.05	$ 1,459,328		$ 82,000	$ 70,000		$ 70,000	$ 5,000	$ 1,686,328
29			$ -					236,520	$ 6.15	$ 1,482,980		$ 35,000	$ -		$ -	$ -	$ 1,517,980
30	$ 500		$ 50,000			$ -		236,520	$ 6.25	$ 1,506,632		$ 80,000	$ -		$ -	$ -	$ 1,636,632
31			$ -					236,520	$ 6.35	$ 1,530,284		$ 33,000	$ -		$ -	$ -	$ 1,563,284
32			$ -					236,520	$ 6.45	$ 1,553,936		$ 84,000	$ -		$ -	$ -	$ 1,637,936
33			$ -					236,520	$ 6.55	$ 1,577,588		$ 26,000	$ 70,000		$ 70,000	$ 5,000	$ 1,748,588
34			$ -					236,520	$ 6.65	$ 1,601,240		$ 31,000	$ -		$ -	$ -	$ 1,632,240
35			$ -					236,520	$ 6.75	$ 1,624,892		$ 84,000	$ -		$ -	$ -	$ 1,708,892
36			$ -					236,520	$ 6.85	$ 1,648,544		$ 33,000	$ -		$ -	$ -	$ 1,681,544
37			$ -					236,520	$ 6.95	$ 1,672,196		$ 84,000	$ 80,000		$ 80,000	$ 25,000	$ 1,941,196
38			$ -					236,520	$ 7.05	$ 1,695,848		$ 31,000	$ -		$ -	$ -	$ 1,726,848
39			$ -					236,520	$ 7.15	$ 1,719,500		$ 82,000	$ 70,000		$ 70,000	$ 5,000	$ 1,946,500
40			$ -					236,520	$ 7.25	$ 1,743,152		$ 35,000	$ -		$ -	$ -	$ 1,778,152
																NPV (2%)	$ 69,886,969

One side charging - Ft Fisher - No shoreside ESS (Cape Fear River)

Vessel ESS (kWh)	1,700	Shoreside ESS (MWh)	0	
Current Cost	$ 3.25			
Annual Increase	2%			
Annual Use (hr/yr)	500			
Annual Maintenance	1%			

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 1,190,000		$ 1,250,000	$ -	$ 1,500,000		$ 3.25								$ 37,940,000
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 941,647	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,007,557
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 960,480	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,029,850
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 979,690	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,048,520
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 999,284	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,071,574
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 1,019,269	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,091,019
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 1,039,655	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,189,865
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 1,060,448	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,135,118
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 1,081,657	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,159,787
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 1,103,290	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,180,880
10	$ 570		$ 969,000			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 1,125,356	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,182,406
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 1,147,863	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,303,373
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 1,170,820	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,254,790
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 1,194,236	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,277,666
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 1,218,121	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,305,011
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 1,242,483	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,328,833
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 1,267,333	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,357,143
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 1,292,680	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,456,950
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 1,318,533	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,411,263
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 1,344,904	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 1,542,094
20	$ 500		$ 850,000			$ -	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 1,371,802	$ 60,000	$ 70,000	$ -	$ -	$ -	$ 3,928,452
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 1,399,238	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,494,348
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 1,427,223	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,600,793
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 1,455,767	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,553,797
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 1,484,883	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,586,373
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 1,514,580	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,615,530
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 1,544,872	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,649,282
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 1,575,769	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,679,639
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 1,607,285	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,789,615
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 1,639,431	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,746,221
30	$ 500		$ 850,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 1,672,219	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,639,469
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 1,705,663	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,815,373
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 1,739,777	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,852,947
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 1,774,572	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,887,202
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 1,810,064	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,926,154
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 1,846,265	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,961,815
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 1,883,190	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 2,002,200
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 1,920,854	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 2,144,324
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 1,959,271	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 2,081,201
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 1,998,457	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 2,194,847
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 2,038,426	$ 60,000	$ 70,000	$ 15,000	$ -	$ -	$ 2,289,276
																NPV (2%)	**$ 80,788,222**

One side charging - Ft Fisher - Shoreside ESS (Cape Fear River)

									Current Cost		Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
		Vessel ESS (kWh)	1,700		Shoreside ESS (MWh)	2,600			$ 3.25		2%	500		1%			
		Vessel			Shoreside						Operation						
Year	**Battery Cost ($/kWh)**	**Capital Construction**	**ESS**	**Capital Grid Improvement**	**Capital Terminal Improvement**	**ESS**	**Rapid Charging System**	**Annual Fuel (gal)**	**Fuel Cost ($/gal)**	**Fuel**	**Elec Energy**	**Genset Engine Maintenance**	**Genset Elec Maintenance**	**Rapid Charging Maintenance**	**Propulsion Motor Maintenance**	**Drive Maintenance**	**Total**
0	$ 700	$ 34,000,000	$ 1,190,000		$ 1,250,000	$ 1,820,000	$ 1,500,000		$ 3.25							$ -	$ 39,760,000
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 313,337	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 379,247
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 319,603	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 388,973
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 325,996	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 394,826
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 332,515	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 404,805
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 339,166	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 410,916
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 345,949	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 496,159
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 352,868	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 427,538
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 359,925	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 438,055
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 367,124	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 444,714
10	$ 570		$ 969,000			$ 1,482,000	$ -	14,600	$ 4.25	$ 62,050	$ 374,466	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,913,516
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 381,956	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 537,466
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 389,595	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 473,565
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 397,387	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 480,817
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 405,334	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 492,224
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 413,441	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 499,791
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 421,710	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 511,520
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 430,144	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 594,414
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 438,747	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 531,477
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 447,522	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 644,712
20	$ 500		$ 850,000			$ 1,300,000	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 456,472	$ 60,000	$ 70,000	$ -	$ -	$ -	$ 4,313,122
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 465,602	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 560,712
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 474,914	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 648,484
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 484,412	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 582,442
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 494,100	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 595,590
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 503,982	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 604,932
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 514,062	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 618,472
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 524,343	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 628,213
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 534,830	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 717,160
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 545,527	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 652,317
30	$ 500		$ 850,000			$ 1,300,000	$ -	14,600	$ 6.25	$ 91,250	$ 556,437	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,823,687
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 567,566	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 677,276
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 578,917	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 692,087
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 590,496	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 703,126
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 602,306	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 718,396
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 614,352	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 729,902
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 626,639	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 745,649
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 639,172	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 862,642
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 651,955	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 773,885
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 664,994	$ 2,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 861,384
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 678,294	$ 60,000	$ 70,000	$ 15,000	$ -	$ -	$ 929,144
																NPV (2%)	**$ 60,776,907**

Two side charging - No shoreside ESS (Cape Fear River)

Vessel ESS (kWh)	1,250	Shoreside ESS (MWh)	0	Current Cost	Annual Increase	Annual Use (hr/yr)	Annual Maintenance
				$ 3.25	2%	500	1%

	Vessel			Shoreside				Operation									
Year	**Battery Cost ($/kWh)**	**Capital Construction**	**ESS**	**Capital Grid Improvement**	**Capital Terminal Improvement**	**ESS**	**Rapid Charging System**	**Annual Fuel (gal)**	**Fuel Cost ($/gal)**	**Fuel**	**Elec Energy**	**Genset Engine Maintenance**	**Genset Elec Maintenance**	**Rapid Charging Maintenance**	**Propulsion Motor Maintenance**	**Drive Maintenance**	**Total**
0	$ 700	$ 34,000,000	$ 875,000	$ 1,000,000	$ 2,500,000	$ -	$ 3,000,000		$ 3.25								$ 41,375,000
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 1,365,562	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,446,472
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 1,392,874	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,477,244
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 1,420,731	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,504,561
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 1,449,146	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,536,436
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 1,478,129	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,564,879
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 1,507,691	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,672,901
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 1,537,845	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,627,515
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 1,568,602	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,661,732
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 1,599,974	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,692,564
10	$ 570		$ 712,500			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 1,631,974	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 2,447,524
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 1,664,613	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,835,123
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 1,697,905	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,796,875
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 1,731,863	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,830,293
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 1,766,501	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,868,391
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 1,801,831	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,903,181
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 1,837,867	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,942,677
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 1,874,625	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 2,053,895
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 1,912,117	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,019,847
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 1,950,359	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 2,162,549
20	$ 500		$ 625,000			$ -	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 1,989,367	$ 60,000	$ 70,000	$ -	$ -	$ -	$ 5,821,017
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 2,029,154	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,139,264
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 2,069,737	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 2,258,307
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 2,111,132	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,224,162
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 2,153,354	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,269,844
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 2,196,422	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,312,372
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 2,240,350	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,359,760
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 2,285,157	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,404,027
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 2,330,860	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 2,528,190
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 2,377,477	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,499,267
30	$ 500		$ 625,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 2,425,027	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 3,182,277
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 2,473,527	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,598,237
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 2,522,998	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,651,168
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 2,573,458	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,701,088
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 2,624,927	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,756,017
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 2,677,426	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 2,807,976
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 2,730,974	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,864,984
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 2,785,594	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 3,024,064
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 2,841,305	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 2,978,235
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 2,898,132	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 3,109,522
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 2,956,094	$ 60,000	$ 70,000	$ 30,000	$ -	$ -	$ 3,221,944
																NPV (2%)	**$ 101,770,992**

Two side charging - Shoreside ESS (Cape Fear River)

Vessel ESS (kWh)	1,250	Shoreside ESS (MWh)	1,400	Current Cost	Annual Increase	Annual Use (hr/yr)	Annual Maintenance
				$ 3.25	2%	500	1%

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 875,000	$ 1,000,000	$ 2,500,000	$ 1,960,000	$ 3,000,000		$ 3.25							$ -	$ 43,335,000
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 419,502	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 500,412
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 427,892	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 512,262
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 436,450	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 520,280
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 445,179	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 532,469
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 454,082	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 540,832
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 463,164	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 628,374
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 472,427	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 562,097
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 481,876	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 575,006
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 491,513	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 584,103
10	$ 570		$ 712,500			$ 1,596,000	$ -	14,600	$ 4.25	$ 62,050	$ 501,343	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 2,912,893
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 511,370	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 681,880
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 521,598	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 620,568
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 532,030	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 630,460
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 542,670	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 644,560
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 553,524	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 654,874
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 564,594	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 669,404
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 575,886	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 755,156
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 587,404	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 695,134
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 599,152	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 811,342
20	$ 500		$ 625,000			$ 1,400,000	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 611,135	$ 60,000	$ 70,000	$ -	$ -	$ -	$ 5,842,785
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 623,357	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 733,467
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 635,825	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 824,395
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 648,541	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 761,571
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 661,512	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 778,002
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 674,742	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 790,692
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 688,237	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 807,647
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 702,002	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 820,872
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 716,042	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 913,372
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 730,363	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 852,153
30	$ 500		$ 625,000			$ 1,400,000	$ -	14,600	$ 6.25	$ 91,250	$ 744,970	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 2,902,220
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 759,869	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 884,579
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 775,067	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 903,237
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 790,568	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 918,198
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 806,379	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 937,469
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 822,507	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 953,057
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 838,957	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 972,967
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 855,736	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 1,094,206
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 872,851	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,009,781
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 890,308	$ 2,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,101,698
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 908,114	$ 60,000	$ 70,000	$ 30,000	$ -	$ -	$ 1,173,964
																NPV (2%)	**$ 69,654,905**

Diesel-Mechanical (Neuse)

Vessel ESS (kWh) 0 Shoreside ESS (MWh) 0

Current Cost $ 3.25

Annual Use (hr/yr) 6,205 3,102

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Prop Engine Maintenance	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Total
0	$ 700	$ 30,000,000	$ -	$ -	$ -	$ -	$ -		$ 3.25								$ 30,000,000
1								372,300	$ 3.35	$ 1,299,327		$ 43,000	$ 18,000	$ -			$ 1,360,327
2								372,300	$ 3.45	$ 1,336,557		$ 92,000	$ 25,000	$ -			$ 1,453,557
3								372,300	$ 3.55	$ 1,373,787		$ 45,000	$ 18,000	$ -			$ 1,436,787
4								372,300	$ 3.65	$ 1,411,017		$ 92,000	$ 74,000	$ -			$ 1,577,017
5								372,300	$ 3.75	$ 1,448,247		$ 103,000	$ 27,000	$ -			$ 1,578,247
6								372,300	$ 3.85	$ 1,485,477		$ 43,000	$ 18,000	$ -			$ 1,546,477
7								372,300	$ 3.95	$ 1,522,707		$ 92,000	$ 74,000	$ -			$ 1,688,707
8								372,300	$ 4.05	$ 1,559,937		$ 45,000	$ 18,000	$ 70,000			$ 1,692,937
9								372,300	$ 4.15	$ 1,597,167		$ 99,000	$ 25,000	$ -			$ 1,721,167
10	$ 570		$ -			$ -		372,300	$ 4.25	$ 1,634,397		$ 96,000	$ 78,000	$ -			$ 1,808,397
11								372,300	$ 4.35	$ 1,671,627		$ 43,000	$ 18,000	$ -			$ 1,732,627
12								372,300	$ 4.45	$ 1,708,857		$ 92,000	$ 25,000	$ -			$ 1,825,857
13								372,300	$ 4.55	$ 1,746,087		$ 101,000	$ 74,000	$ -			$ 1,921,087
14								372,300	$ 4.65	$ 1,783,317		$ 43,000	$ 18,000	$ -			$ 1,844,317
15								372,300	$ 4.75	$ 1,820,547		$ 96,000	$ 27,000	$ -			$ 1,943,547
16								372,300	$ 4.85	$ 1,857,777		$ 43,000	$ 18,000	$ 70,000			$ 1,988,777
17								372,300	$ 4.95	$ 1,895,007		$ 99,000	$ 74,000	$ -			$ 2,068,007
18								372,300	$ 5.05	$ 1,932,237		$ 94,000	$ 25,000	$ -			$ 2,051,237
19								372,300	$ 5.15	$ 1,969,467		$ 43,000	$ 18,000	$ -			$ 2,030,467
20	$ 500		$ -			$ -		372,300	$ 5.25	$ 2,006,697		$ 96,000	$ 78,000	$ -			$ 2,180,697
21								372,300	$ 5.35	$ 2,043,927		$ 99,000	$ 25,000	$ -			$ 2,167,927
22								372,300	$ 5.45	$ 2,081,157		$ 45,000	$ 18,000	$ -			$ 2,144,157
23								372,300	$ 5.55	$ 2,118,387		$ 92,000	$ 74,000	$ -			$ 2,284,387
24								372,300	$ 5.65	$ 2,155,617		$ 43,000	$ 18,000	$ 70,000			$ 2,286,617
25								372,300	$ 5.75	$ 2,192,847		$ 103,000	$ 27,000	$ -			$ 2,322,847
26								372,300	$ 5.85	$ 2,230,077		$ 92,000	$ 74,000	$ 80,000			$ 2,476,077
27								372,300	$ 5.95	$ 2,267,307		$ 45,000	$ 18,000	$ -			$ 2,330,307
28								372,300	$ 6.05	$ 2,304,537		$ 92,000	$ 25,000	$ -			$ 2,421,537
29								372,300	$ 6.15	$ 2,341,767		$ 43,000	$ 18,000	$ -			$ 2,402,767
30	$ 500		$ -			$ -		372,300	$ 6.25	$ 2,378,997		$ 103,000	$ 78,000	$ -			$ 2,559,997
31								372,300	$ 6.35	$ 2,416,227		$ 92,000	$ 25,000	$ 70,000			$ 2,603,227
32								372,300	$ 6.45	$ 2,453,457		$ 45,000	$ 18,000	$ -			$ 2,516,457
33								372,300	$ 6.55	$ 2,490,687		$ 92,000	$ 74,000	$ -			$ 2,656,687
34								372,300	$ 6.65	$ 2,527,917		$ 99,000	$ 25,000	$ -			$ 2,651,917
35								372,300	$ 6.75	$ 2,565,147		$ 47,000	$ 20,000	$ -			$ 2,632,147
36								372,300	$ 6.85	$ 2,602,377		$ 92,000	$ 74,000	$ -			$ 2,768,377
37								372,300	$ 6.95	$ 2,639,607		$ 45,000	$ 18,000	$ -			$ 2,702,607
38								372,300	$ 7.05	$ 2,676,837		$ 99,000	$ 25,000	$ -			$ 2,800,837
39								372,300	$ 7.15	$ 2,714,067		$ 92,000	$ 74,000	$ 70,000			$ 2,950,067
40								372,300	$ 7.25	$ 2,751,297		$ 47,000	$ 22,000	$ -			$ 2,820,297
																NPV (2%)	$ 86,082,625

Diesel-Electric Hybrid with Battery for Peak Shave (Neuse)

Vessel ESS (kWh) 100 Shoreside ESS (MWh) 0

Current Cost $ 3.25

Annual Use (hr/yr) 6,205

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 70,000	$ -	$ -	$ -	$ -		$ 3.25								$ 34,070,000
1			$ -					335,070	$ 3.35	$ 1,162,693		$ 43,000	$ -		$ -	$ -	$ 1,205,693
2			$ -					335,070	$ 3.45	$ 1,196,200		$ 92,000	$ -		$ -	$ -	$ 1,288,200
3			$ -					335,070	$ 3.55	$ 1,229,707		$ 45,000	$ -		$ -	$ -	$ 1,274,707
4			$ -					335,070	$ 3.65	$ 1,263,214		$ 92,000	$ 70,000		$ 70,000	$ 5,000	$ 1,500,214
5			$ -					335,070	$ 3.75	$ 1,296,721		$ 103,000	$ -		$ -	$ -	$ 1,399,721
6			$ -					335,070	$ 3.85	$ 1,330,228		$ 43,000	$ -		$ -	$ -	$ 1,373,228
7			$ -					335,070	$ 3.95	$ 1,363,735		$ 92,000	$ -		$ -	$ -	$ 1,455,735
8			$ -					335,070	$ 4.05	$ 1,397,242		$ 45,000	$ 70,000		$ 70,000	$ 5,000	$ 1,587,242
9			$ -					335,070	$ 4.15	$ 1,430,749		$ 99,000	$ -		$ -	$ -	$ 1,529,749
10	$ 570		$ 57,000			$ -		335,070	$ 4.25	$ 1,464,256		$ 96,000	$ -		$ -	$ -	$ 1,617,256
11			$ -					335,070	$ 4.35	$ 1,497,763		$ 43,000	$ -		$ -	$ -	$ 1,540,763
12			$ -					335,070	$ 4.45	$ 1,531,270		$ 92,000	$ 70,000		$ 70,000	$ 5,000	$ 1,768,270
13			$ -					335,070	$ 4.55	$ 1,564,777		$ 101,000	$ 80,000		$ 80,000	$ 25,000	$ 1,850,777
14			$ -					335,070	$ 4.65	$ 1,598,284		$ 43,000	$ -		$ -	$ -	$ 1,641,284
15			$ -					335,070	$ 4.75	$ 1,631,791		$ 96,000	$ -		$ -	$ -	$ 1,727,791
16			$ -					335,070	$ 4.85	$ 1,665,298		$ 43,000	$ 70,000		$ 70,000	$ 5,000	$ 1,853,298
17			$ -					335,070	$ 4.95	$ 1,698,805		$ 99,000	$ -		$ -	$ -	$ 1,797,805
18			$ -					335,070	$ 5.05	$ 1,732,312		$ 94,000	$ -		$ -	$ -	$ 1,826,312
19			$ -					335,070	$ 5.15	$ 1,765,819		$ 43,000	$ -		$ -	$ -	$ 1,808,819
20	$ 500		$ 50,000			$ -		335,070	$ 5.25	$ 1,799,326		$ 96,000	$ 70,000		$ 70,000	$ 5,000	$ 2,090,326
21			$ -					335,070	$ 5.35	$ 1,832,833		$ 99,000	$ -		$ -	$ -	$ 1,931,833
22			$ -					335,070	$ 5.45	$ 1,866,340		$ 45,000	$ -		$ -	$ -	$ 1,911,340
23			$ -					335,070	$ 5.55	$ 1,899,847		$ 92,000	$ -		$ -	$ -	$ 1,991,847
24			$ -					335,070	$ 5.65	$ 1,933,354		$ 43,000	$ 70,000		$ 70,000	$ 5,000	$ 2,121,354
25			$ -					335,070	$ 5.75	$ 1,966,861		$ 103,000	$ -		$ -	$ -	$ 2,069,861
26			$ -					335,070	$ 5.85	$ 2,000,368		$ 92,000	$ 80,000		$ 80,000	$ 25,000	$ 2,277,368
27			$ -					335,070	$ 5.95	$ 2,033,875		$ 45,000	$ -		$ -	$ -	$ 2,078,875
28			$ -					335,070	$ 6.05	$ 2,067,382		$ 92,000	$ 70,000		$ 70,000	$ 5,000	$ 2,304,382
29			$ -					335,070	$ 6.15	$ 2,100,889		$ 43,000	$ -		$ -	$ -	$ 2,143,889
30	$ 500		$ 50,000			$ -		335,070	$ 6.25	$ 2,134,396		$ 103,000	$ -		$ -	$ -	$ 2,287,396
31			$ -					335,070	$ 6.35	$ 2,167,903		$ 92,000	$ -		$ -	$ -	$ 2,259,903
32			$ -					335,070	$ 6.45	$ 2,201,410		$ 45,000	$ 70,000		$ 70,000	$ 5,000	$ 2,391,410
33			$ -					335,070	$ 6.55	$ 2,234,917		$ 92,000	$ -		$ -	$ -	$ 2,326,917
34			$ -					335,070	$ 6.65	$ 2,268,424		$ 99,000	$ -		$ -	$ -	$ 2,367,424
35			$ -					335,070	$ 6.75	$ 2,301,931		$ 47,000	$ -		$ -	$ -	$ 2,348,931
36			$ -					335,070	$ 6.85	$ 2,335,438		$ 92,000	$ 70,000		$ 70,000	$ 5,000	$ 2,572,438
37			$ -					335,070	$ 6.95	$ 2,368,945		$ 45,000	$ -		$ -	$ -	$ 2,413,945
38			$ -					335,070	$ 7.05	$ 2,402,452		$ 99,000	$ -		$ -	$ -	$ 2,501,452
39			$ -					335,070	$ 7.15	$ 2,435,959		$ 92,000	$ 80,000		$ 80,000	$ 25,000	$ 2,712,959
40			$ -					335,070	$ 7.25	$ 2,469,466		$ 47,000	$ 70,000		$ 70,000	$ 5,000	$ 2,661,466
																NPV (2%)	$ 84,816,300

One side charging - Cherry Branch - No shoreside ESS (Neuse)

		Vessel ESS (kWh)	1,500		Shoreside ESS (MWh)		0		Current Cost		Annual Increase	Annual Use (hr/yr)		Annual Maintenance			
									$ 3.25		2%	500		1%			
		Vessel			Shoreside							Operation					
Year	**Battery Cost ($/kWh)**	**Capital Construction**	**ESS**	**Capital Grid Improvement**	**Capital Terminal Improvement**	**ESS**	**Rapid Charging System**	**Annual Fuel (gal)**	**Fuel Cost ($/gal)**	**Fuel**	**Elec Energy**	**Genset Engine Maintenance**	**Genset Elec Maintenance**	**Rapid Charging Maintenance**	**Propulsion Motor Maintenance**	**Drive Maintenance**	**Total**
0	$ 700	$ 34,000,000	$ 1,050,000		$ 1,250,000	$ -	$ 1,500,000		$ 3.25								$ 37,800,000
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 487,425	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 553,335
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 497,173	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 566,543
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 507,117	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 575,947
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 517,259	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 664,549
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 527,604	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 599,354
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 538,156	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 613,366
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 548,920	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 623,590
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 559,898	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 713,028
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 571,096	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 648,686
10	$ 570		$ 855,000			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 582,518	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,525,568
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 594,168	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 674,678
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 606,052	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 765,022
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 618,173	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 806,603
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 630,536	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 717,426
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 643,147	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 729,497
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 656,010	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 820,820
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 669,130	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 758,400
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 682,512	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 775,242
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 696,163	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 788,353
20	$ 500		$ 750,000			$ -	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 710,086	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 3,241,736
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 724,288	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 819,398
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 738,773	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 837,343
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 753,549	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 851,579
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 768,620	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 945,110
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 783,992	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 884,942
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 799,672	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 1,009,082
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 815,666	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 919,536
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 831,979	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,014,309
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 848,618	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 955,408
30	$ 500		$ 750,000			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 865,591	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 1,732,841
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 882,903	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 992,613
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 900,561	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,088,731
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 918,572	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,031,202
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 936,943	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,053,033
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 955,682	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,071,232
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 974,796	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 1,168,806
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 994,292	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 1,112,762
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 1,014,178	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 1,136,108
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 1,034,461	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 1,260,851
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 1,055,150	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 1,381,000
																NPV (2%)	**$ 62,880,501**

One side charging - Cherry Branch - Shoreside ESS (Neuse)

Vessel ESS (kWh) 1,500 | Shoreside ESS (MWh) 2,150 | Current Cost $ 3.25 | Annual Increase 2% | Annual Use (hr/yr) 500 | Annual Maintenance 1%

	Vessel			Shoreside				Operation									
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 1,050,000		$ 1,250,000	$ 1,505,000	$ 1,500,000		$ 3.25								$ 39,305,000
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 256,650	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 322,560
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 261,783	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 331,153
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 267,018	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 335,848
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 272,359	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 419,649
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 277,806	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 349,556
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 283,362	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 358,572
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 289,029	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 363,699
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 294,810	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 447,940
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 300,706	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 378,296
10	$ 570		$ 855,000			$ 1,225,500	$ -	14,600	$ 4.25	$ 62,050	$ 306,720	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,475,270
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 312,855	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 393,365
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 319,112	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 478,082
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 325,494	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 513,924
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 332,004	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 418,894
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 338,644	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 424,994
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 345,417	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 510,227
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 352,325	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 441,595
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 359,372	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 452,102
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 366,559	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 458,749
20	$ 500		$ 750,000			$ 1,075,000	$ 1,500,000	14,600	$ 5.25	$ 76,650	$ 373,890	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 3,980,540
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 381,368	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 476,478
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 388,995	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 487,565
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 396,775	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 494,805
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 404,711	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 581,201
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 412,805	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 513,755
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 421,061	$ 4,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 630,471
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 429,482	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 533,352
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 438,072	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 620,402
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 446,834	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 553,624
30	$ 500		$ 750,000			$ 1,075,000	$ -	14,600	$ 6.25	$ 91,250	$ 455,770	$ 11,000	$ -	$ 15,000	$ -	$ -	$ 2,398,020
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 464,886	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 574,596
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 474,183	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 662,353
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 483,667	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 596,297
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 493,340	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 609,430
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 503,207	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 618,757
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 513,271	$ 4,000	$ -	$ 15,000	$ 70,000	$ 5,000	$ 707,281
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 523,537	$ 2,000	$ -	$ 15,000	$ -	$ -	$ 642,007
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 534,007	$ 4,000	$ -	$ 15,000	$ -	$ -	$ 655,937
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 544,688	$ 2,000	$ -	$ 15,000	$ 80,000	$ 25,000	$ 771,078
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 555,581	$ 60,000	$ 70,000	$ 15,000	$ 70,000	$ 5,000	$ 881,431
																NPV (2%)	$ 57,657,758

Two side charging - No shoreside ESS (Neuse)

	Current Cost	Annual Increase	Annual Use (hr/yr)	Annual Maintenance
Vessel ESS (kWh) 1,025 · Shoreside ESS (MWh) 0	$ 3.25	2%	500	1%

	Vessel			Shoreside							Operation						
Year	Battery Cost ($/kWh)	Capital Construction	ESS	Capital Grid Improvement	Capital Terminal Improvement	ESS	Rapid Charging System	Annual Fuel (gal)	Fuel Cost ($/gal)	Fuel	Elec Energy	Genset Engine Maintenance	Genset Elec Maintenance	Rapid Charging Maintenance	Propulsion Motor Maintenance	Drive Maintenance	Total
0	$ 700	$ 34,000,000	$ 717,500	$ -	$ 2,500,000	$ -	$ 3,000,000		$ 3.25								$ 40,217,500
1			$ -				$ -	14,600	$ 3.35	$ 48,910	$ 475,914	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 556,824
2			$ -				$ -	14,600	$ 3.45	$ 50,370	$ 485,433	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 569,803
3			$ -				$ -	14,600	$ 3.55	$ 51,830	$ 495,141	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 578,971
4			$ -				$ -	14,600	$ 3.65	$ 53,290	$ 505,044	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 667,334
5			$ -				$ -	14,600	$ 3.75	$ 54,750	$ 515,145	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 601,895
6			$ -				$ -	14,600	$ 3.85	$ 56,210	$ 525,448	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 615,658
7			$ -				$ -	14,600	$ 3.95	$ 57,670	$ 535,957	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 625,627
8			$ -				$ -	14,600	$ 4.05	$ 59,130	$ 546,676	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 714,806
9			$ -				$ -	14,600	$ 4.15	$ 60,590	$ 557,609	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 650,199
10	$ 570		$ 584,250			$ -	$ -	14,600	$ 4.25	$ 62,050	$ 568,762	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,256,062
11			$ -				$ -	14,600	$ 4.35	$ 63,510	$ 580,137	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 675,647
12			$ -				$ -	14,600	$ 4.45	$ 64,970	$ 591,740	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 765,710
13			$ -				$ -	14,600	$ 4.55	$ 66,430	$ 603,574	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 807,004
14			$ -				$ -	14,600	$ 4.65	$ 67,890	$ 615,646	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 717,536
15			$ -				$ -	14,600	$ 4.75	$ 69,350	$ 627,959	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 729,309
16			$ -				$ -	14,600	$ 4.85	$ 70,810	$ 640,518	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 820,328
17			$ -				$ -	14,600	$ 4.95	$ 72,270	$ 653,328	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 757,598
18			$ -				$ -	14,600	$ 5.05	$ 73,730	$ 666,395	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 774,125
19			$ -				$ -	14,600	$ 5.15	$ 75,190	$ 679,723	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 786,913
20	$ 500		$ 512,500			$ -	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 693,317	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 4,487,467
21			$ -				$ -	14,600	$ 5.35	$ 78,110	$ 707,184	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 817,294
22			$ -				$ -	14,600	$ 5.45	$ 79,570	$ 721,327	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 834,897
23			$ -				$ -	14,600	$ 5.55	$ 81,030	$ 735,754	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 848,784
24			$ -				$ -	14,600	$ 5.65	$ 82,490	$ 750,469	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 941,959
25			$ -				$ -	14,600	$ 5.75	$ 83,950	$ 765,478	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 881,428
26			$ -				$ -	14,600	$ 5.85	$ 85,410	$ 780,788	$ 4,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 1,005,198
27			$ -				$ -	14,600	$ 5.95	$ 86,870	$ 796,404	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 915,274
28			$ -				$ -	14,600	$ 6.05	$ 88,330	$ 812,332	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,009,662
29			$ -				$ -	14,600	$ 6.15	$ 89,790	$ 828,578	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 950,368
30	$ 500		$ 512,500			$ -	$ -	14,600	$ 6.25	$ 91,250	$ 845,150	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 1,489,900
31			$ -				$ -	14,600	$ 6.35	$ 92,710	$ 862,053	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 986,763
32			$ -				$ -	14,600	$ 6.45	$ 94,170	$ 879,294	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,082,464
33			$ -				$ -	14,600	$ 6.55	$ 95,630	$ 896,880	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,024,510
34			$ -				$ -	14,600	$ 6.65	$ 97,090	$ 914,817	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,045,907
35			$ -				$ -	14,600	$ 6.75	$ 98,550	$ 933,114	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,063,664
36			$ -				$ -	14,600	$ 6.85	$ 100,010	$ 951,776	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 1,160,786
37			$ -				$ -	14,600	$ 6.95	$ 101,470	$ 970,811	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 1,104,281
38			$ -				$ -	14,600	$ 7.05	$ 102,930	$ 990,228	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 1,127,158
39			$ -				$ -	14,600	$ 7.15	$ 104,390	$ 1,010,032	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 1,251,422
40			$ -				$ -	14,600	$ 7.25	$ 105,850	$ 1,030,233	$ 60,000	$ 70,000	$ 30,000	$ 70,000	$ 5,000	$ 1,371,083
																NPV (2%)	$ 65,743,244

Two side charging - Shoreside ESS (Neuse)

Vessel ESS (kWh)	1,025	Shoreside ESS (MWh)	1,150	Current Cost	$ 3.25	Annual Increase	2%	Annual Use (hr/yr)	500
						Annual Maintenance	1%		

	Vessel			Shoreside				Operation									
Year	**Battery Cost ($/kWh)**	**Capital Construction**	**ESS**	**Capital Grid Improvement**	**Capital Terminal Improvement**	**ESS**	**Rapid Charging System**	**Annual Fuel (gal)**	**Fuel Cost ($/gal)**	**Fuel**	**Elec Energy**	**Genset Engine Maintenance**	**Genset Elec Maintenance**	**Rapid Charging Maintenance**	**Propulsion Motor Maintenance**	**Drive Maintenance**	**Total**
0	$ 700	$ 34,000,000	$ 717,500		$ 2,500,000	$ 1,610,000	$ 3,000,000		$ 3.25								$ 41,827,500
1			$ -			$ -	$ -	14,600	$ 3.35	$ 48,910	$ 268,371	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 349,281
2			$ -			$ -	$ -	14,600	$ 3.45	$ 50,370	$ 273,738	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 358,108
3			$ -			$ -	$ -	14,600	$ 3.55	$ 51,830	$ 279,213	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 363,043
4			$ -			$ -	$ -	14,600	$ 3.65	$ 53,290	$ 284,797	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 447,087
5			$ -			$ -	$ -	14,600	$ 3.75	$ 54,750	$ 290,493	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 377,243
6			$ -			$ -	$ -	14,600	$ 3.85	$ 56,210	$ 296,303	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 386,513
7			$ -			$ -	$ -	14,600	$ 3.95	$ 57,670	$ 302,229	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 391,899
8			$ -			$ -	$ -	14,600	$ 4.05	$ 59,130	$ 308,274	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 476,404
9			$ -			$ -	$ -	14,600	$ 4.15	$ 60,590	$ 314,439	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 407,029
10	$ 570		$ 584,250			$ 1,311,000	$ -	14,600	$ 4.25	$ 62,050	$ 320,728	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 2,319,028
11			$ -			$ -	$ -	14,600	$ 4.35	$ 63,510	$ 327,143	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 422,653
12			$ -			$ -	$ -	14,600	$ 4.45	$ 64,970	$ 333,686	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 507,656
13			$ -			$ -	$ -	14,600	$ 4.55	$ 66,430	$ 340,359	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 543,789
14			$ -			$ -	$ -	14,600	$ 4.65	$ 67,890	$ 347,166	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 449,056
15			$ -			$ -	$ -	14,600	$ 4.75	$ 69,350	$ 354,110	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 455,460
16			$ -			$ -	$ -	14,600	$ 4.85	$ 70,810	$ 361,192	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 541,002
17			$ -			$ -	$ -	14,600	$ 4.95	$ 72,270	$ 368,416	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 472,686
18			$ -			$ -	$ -	14,600	$ 5.05	$ 73,730	$ 375,784	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 483,514
19			$ -			$ -	$ -	14,600	$ 5.15	$ 75,190	$ 383,300	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 490,490
20	$ 500		$ 512,500			$ 1,150,000	$ 3,000,000	14,600	$ 5.25	$ 76,650	$ 390,966	$ 60,000	$ 70,000	$ -	$ 70,000	$ 5,000	$ 5,335,116
21			$ -			$ -	$ -	14,600	$ 5.35	$ 78,110	$ 398,785	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 508,895
22			$ -			$ -	$ -	14,600	$ 5.45	$ 79,570	$ 406,761	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 520,331
23			$ -			$ -	$ -	14,600	$ 5.55	$ 81,030	$ 414,896	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 527,926
24			$ -			$ -	$ -	14,600	$ 5.65	$ 82,490	$ 423,194	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 614,684
25			$ -			$ -	$ -	14,600	$ 5.75	$ 83,950	$ 431,658	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 547,608
26			$ -			$ -	$ -	14,600	$ 5.85	$ 85,410	$ 440,291	$ 4,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 664,701
27			$ -			$ -	$ -	14,600	$ 5.95	$ 86,870	$ 449,097	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 567,967
28			$ -			$ -	$ -	14,600	$ 6.05	$ 88,330	$ 458,079	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 655,409
29			$ -			$ -	$ -	14,600	$ 6.15	$ 89,790	$ 467,240	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 589,030
30	$ 500		$ 512,500			$ 1,150,000	$ -	14,600	$ 6.25	$ 91,250	$ 476,585	$ 11,000	$ -	$ 30,000	$ -	$ -	$ 2,271,335
31			$ -			$ -	$ -	14,600	$ 6.35	$ 92,710	$ 486,117	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 610,827
32			$ -			$ -	$ -	14,600	$ 6.45	$ 94,170	$ 495,839	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 699,009
33			$ -			$ -	$ -	14,600	$ 6.55	$ 95,630	$ 505,756	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 633,386
34			$ -			$ -	$ -	14,600	$ 6.65	$ 97,090	$ 515,871	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 646,961
35			$ -			$ -	$ -	14,600	$ 6.75	$ 98,550	$ 526,189	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 656,739
36			$ -			$ -	$ -	14,600	$ 6.85	$ 100,010	$ 536,712	$ 4,000	$ -	$ 30,000	$ 70,000	$ 5,000	$ 745,722
37			$ -			$ -	$ -	14,600	$ 6.95	$ 101,470	$ 547,447	$ 2,000	$ -	$ 30,000	$ -	$ -	$ 680,917
38			$ -			$ -	$ -	14,600	$ 7.05	$ 102,930	$ 558,395	$ 4,000	$ -	$ 30,000	$ -	$ -	$ 695,325
39			$ -			$ -	$ -	14,600	$ 7.15	$ 104,390	$ 569,563	$ 2,000	$ -	$ 30,000	$ 80,000	$ 25,000	$ 810,953
40			$ -			$ -	$ -	14,600	$ 7.25	$ 105,850	$ 580,955	$ 60,000	$ 70,000	$ 30,000	$ 70,000	$ 5,000	$ 921,805
																NPV (2%)	**$ 61,698,566**

APPENDIX B. U.S. FERRY ELECTRIFICATION PROJECTS

Washington State Ferries

Washington State Ferries (WSF) has a 2040 Long Range Plan to convert its fleet of 21 vessels to hybrid electric configurations. The program will deliver 16 new vessels, convert six diesel vessels to electric and complete 17 terminal electrification projects at 16 terminal locations. The plan estimates converting the fleet will yield a 53% reduction in carbon emissions by 2030 and a 76% reduction by 2040. WSF has received grant funding to support the project from the nationwide federal Volkswagen settlement ($35M), a Congestion Mitigation and Air Quality Improvement grant ($6.5M), and a Marine Highway Project Designation and grant award of $1.5M.[29] Three utility providers (Seattle City Light, Puget Sound Energy, and Snohomish Co. PUD) are involved in the project.[30]

In the near-term, engineering efforts are underway to convert three Jumbo Mark II Class to hybrid-electric propulsion and prepare for the acquisition of five new Hybrid-Electric Olympic (HEO) Class vessels. The Jumbo Mark II vessels are the largest vessels in the fleet, accounting for five million gallons of fuel usage annually or 26% of total fuel consumption for the fleet. The vessels are at their mid-life. The two diesel propulsion generators will be removed and replaced with lithium-ion batteries. Siemens is conducting propulsion control system replacement and hybrid conversion studies for the three Jumbo Mark II Class vessels.[31]

The initial Olympic Class vessel build contract in 2007 added four vessels to the fleet. This contract was extended to build hybrid-electric configurations. The first vessel is estimated to be delivered in 2023 and four others to be delivered between 2025-2030. Between 2028-2031, WSF is scheduled to replace four 124-car class vessels with new vessels. In the longer term, WSF will convert three diesel vessels and procure seven new 144-Car class vessels.[32]

BC Ferries

BC Ferry Systems, operating in British Columbia, Canada, consists of 38 vessels carrying 9 million vehicles and 22 million passengers annually. As a part of the Island Class Project, BC Ferries is operating six diesel-electric hybrid vessels with two already in service and four vessels just arriving. The vessels are planned to be in operation 40–50 years. The vessels are powered by 800 kWh Corvus Orca lithium-ion batteries with a nickel manganese cobalt cathode, air-cooled, with an 8–10-year battery life. With the current hybrid configuration, AC to DC power conversion takes place on the ship and allows for low voltage AC charging from the shore (690 V), eliminating the costs and equipment required from onshore power conversion. The operator is

[29] Ferry system electrification | WSDOT (wa.gov)

[30] PowerPoint Presentation (psrc.org)

[31] Siemens to help Washington State Ferries with hybrid conversion (cruiseandferry.net)

[32] Washington State Ferries - System Electrification Plan - December 2020

building all new vessels and considering a few potential retrofits for some hybridization projects for vessels.

The hybrid configuration is designed to be electrified in the next ten years. Once fully electric, BC Ferries is moving to 1000 kWh batteries with a life expectancy of 7–8 years. The batteries cycle between 50% to 90% depth of discharge with a 10-minute window to charge between trips. BC Ferries has not made a final decision on a charging system for future electrification. The front runner is the Norwegian company Zinus. The chargers utilize a tower and drop-down connector to compensate for tidal shifts and are aiming for 2.5–3 MW charging power with a high current of 2,000–3,000 amps. Currently operators are working with the utility to get a sense of the distribution needs and any current conversion requirements for rapid charging. The total cost of the project is estimated to be $160M and $1M for shoreside infrastructure (transformer, circuit breakers, etc.). The operator is budgeting that half of the cost of upgrading the fleet will be paid from its own capital program and the other half will be provided through government support.[33]

Maid of the Mist – Niagara Falls

In October 2020, Maid of the Mist Corporation placed two newly built, all-electric ferries into service for tourists at Niagara Falls. Taking tours of the falls, the ferries have repeating 20-minute crossings. The vessels are made of aluminum and powered by lithium-ion battery packs with a combined output of 316 kWh. The batteries have a 10-year life. Using ABB's Power and Energy Management System and Cavotec fast chargers, the all-electric ferries charge for seven minutes at each end of their crossing to ensure the batteries begin each trip with 80% of total charge, discharging 10% to 16% of the battery power. The boats live and are maintained in a facility next to the water. The Maid of the Mist also falls under Coast Guard regulations and removes the vessels from the water at the end of the season. Leadership expressed interest in converting to all-electric power specifically and did not consider other power options.[34]

Skagit County Ferry Replacement Project

Skagit County operates a 21-vehicle, 99-passenger diesel-powered ferry between Anacortes and Guemes Island, Washington, which was built and placed in service in 1979. The ferry provides the only access to Guemes Island. Recently, costs of maintenance and upkeep of the ferry have increased substantially in which the Ferry Division is spending half of its $2.5M annual budget on the vessel's upkeep. In 2013, the Ferry Division began researching vessel replacement. In 2016, a study concluded that an all-electric propulsion system would be highly feasible for this route.

The new 160-ft Guemes ferry will carry 28 vehicles and 150 passengers. The total cost is estimated to be $19M for the design, terminal construction, shoreside charging infrastructure,

[33] Interview with BC Ferries

[34] Interview with Maid of the Midst

and vessel construction. The current designs consist of a Lithium Nickle-Manganese-Cobalt battery chemistry with two battery banks, each 340–400kWh of capacity.

The preliminary report is sizing battery capacity based on a 10-year lifetime.[35] The Ferry Division put out an RFI for Automatic Shore Connection Systems in April 2020 and an RFP in July 2021. The electric ferry will have one-sided charging at the Anacortes Terminal as no shore charging connection is possible on the Guemes Island side. The connection requirements were determined to be 280 kWh for energy transfer, 2.0 MW for power transfer, 30 seconds for ramping, 30 seconds for connection/disconnection, and 10 minutes for charging.[36] After receiving nine proposals, in November 2021, the project team selected Canal Marine to be the Electrical System Integrator (ESI) and will be going out for bid next year for charging infrastructure. Canal Marine is the ESI for the Toronto Airport Ferry.

Casco Bay Electric Ferry

The Casco Bay Island Transit District uses five vessels to provide ferry service from Portland, Maine, to six islands in Casco Bay, carrying over 1 million passengers a year, plus freight and cars. Using a federal grant, the ferry operator is planning to replace the car ferry serving Peaks Island with a new electric ferry with diesel generator backup. This vessel is 34 years old and operates on a 2-mile route, 17 times daily and is in port for between 12 to 13 minutes at a time.

When examining the configuration of the battery size and charging speed, the ferry operator considered six criteria: capital cost, operating costs (20%), survivability, reliability, GHG emission reductions, and experience of customers. The ferry operator examined three potential battery sizes. The smallest size considered (400 kWh) would only assist in maneuvering the vessel while near the pier. A 900 kWh battery would provide the vessel with sufficient capacity to operate on battery in all operations while near the pier. The largest battery size would enable the ferry to complete all routes throughout the day on battery but would also require the fastest charging at the pier. The ferry operator chose the mid-sized (900 kWh) which balances system costs with the need to reduce emissions and noise while shoreside. The hybrid electric ferry will be charged using a 1.4 MW charger at the pier in Portland.[37] They are hoping to put the ferry into service in of 2024.[38]

[35] 17097.02-053-02 Preliminary Design Report Rev(-) (skagitcounty.net)

[36] GIFR Automatic Shore Connection System.pdf (skagitcounty.net) see Table 3 (pg. 7)

[37] Fleet Evaluation Project - Casco Bay Lines

[38] Casco Bay hybrid-electric ferry enters construction phase - Offshore Energy (offshore-energy.biz)

APPENDIX C. FUEL INFLATION ANALYSIS

Both electric and diesel fuel costs have increased over time and are expected to continue to increase over the 40-year life cycle period analyzed. Current base costs for both electric and diesel fuels are known. Utility providers at each ferry terminal location shared the current rate schedule applicable given the expected usage and demand. Similarly, the unit price of diesel fuel purchased for ferry vessel use is well documented and available. Thus, the need was to estimate an annual unit cost increase for both electric and diesel fuels.

Data maintained and published by the U.S. Energy Information Administration (USEIA) was used to estimate the annual unit cost increases.

The cost per kWh of electricity for industrial consumers in North Carolina over the period from 2001 to 2022 was collected from the USEIA and is provided in Figure 13. The unit price of electricity for these users increased from 4.61 cents/kWh to 6.89 cents/kWh over the period, which reflects a 2% annual increase.

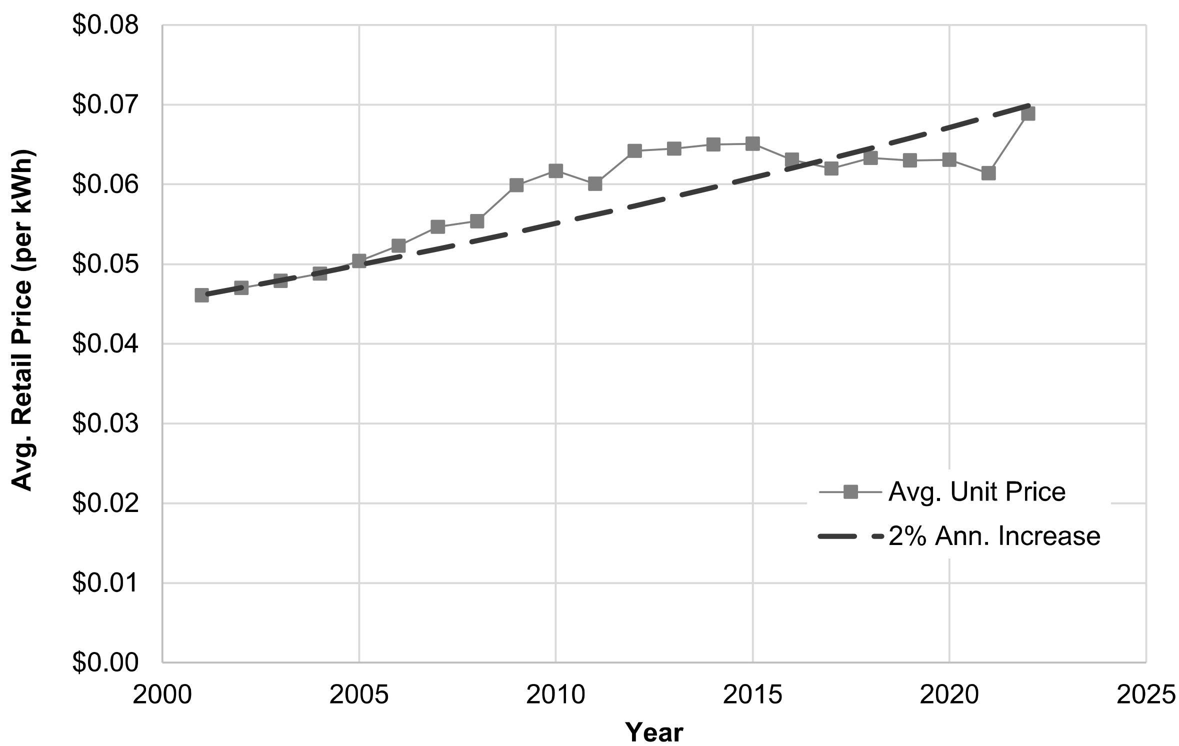

Figure 13. Average Unit Price of Electricity for NC Industrial Consumers

The average retail unit cost ($/gal) of No. 2 diesel fuel in the United States over the period from 1994 to 2022 was collected from the USEIA and is provided in Figure 14. The NCDOT does not purchase diesel fuel at a retail price. However, a comparison of historical NCDOT unit price and retail price indicates that price variations are similar. While diesel fuel prices fluctuate greatly, on average the unit price increases approximately $0.10 annually.

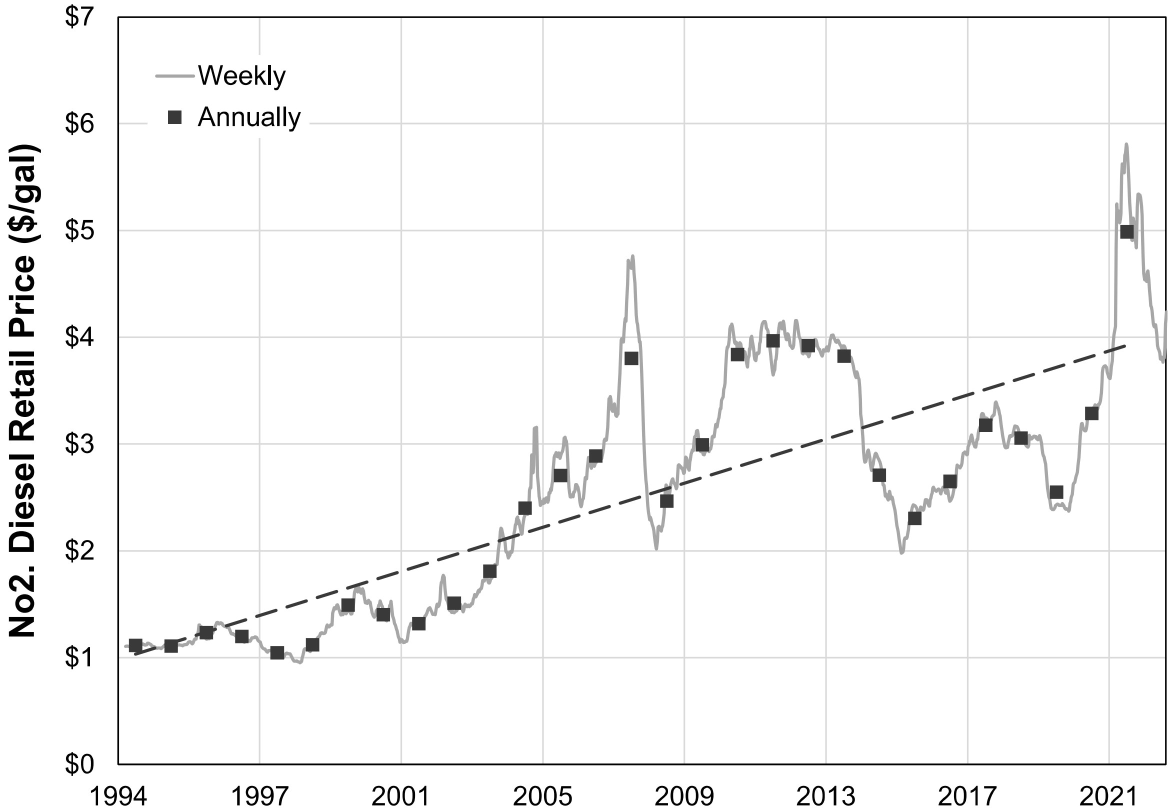

Figure 14. Average Retail Unit Price of Diesel Fuel in the U.S.