

CASCO BAY FERRY PROPULSION **SYSTEM FEASIBILITY STUDY**

PROPULSION SYSTEM ANALYSIS AND SIMULATION FOR CASCO BAY LINES

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EXECUTIVE SUMMARY

The Shearer Group, Inc (TSGI) was tasked to provide an analysis and feasibility study on options for the power generation plant on a new ferry for Casco Bay Lines to consider.

The power generation systems that were considered and the abbreviations used in this report are:

1. MECH: Diesel mechanical with 2x C18 engines (500 bkW each) and 2x house generators (72 ekW each)
2. DE 2xC18s: Diesel electric with 2x C18 generators (430 ekW each) and 1x house generator (45 ekW)
3. DE 3xC18s: Diesel electric with 3x C18 generators (430 ekW each) and 1x house generator (45 ekW)
4. DEWB NMC: Diesel electric with NMC batteries: 2x C18 generators (430 ekW each) and 1,000 kWh of NMC batteries
5. DEWB LFP: Diesel electric with LFP batteries: 2x C18 generators (430 ekW each) and 1,000 kWh of LFP batteries

Two different lithium-ion battery chemistries, nickel manganese cobalt (NMC) and lithium iron phosphate (LFP), were analyzed in this report. This study took the schedule of MAQUOIT II, the vessel that the new ferry will be replacing, and formulated operational profiles using resistance data from a computational fluid dynamics (CFD) analysis of the replacement vessel hull form at different speeds and drafts. From the operational profiles the amount of fuel burned, engine/generator hours, emissions, and electricity usage were calculated for a replacement vessel with the different types of propulsion systems.

A feasibility study was then conducted on the possible propulsion systems. Criteria to evaluate the propulsion systems include operating expenses (OPEX), capital expenses (CAPEX), sustainability, serviceability, and reliability. OPEX was evaluated by the costs incurred due to frequent engine/generator maintenance, fuel consumption, and electricity usage. CAPEX was evaluated by vessel construction cost estimates and infrequent equipment maintenance costs including overhauls and replacements. Sustainability was evaluated by daily CO₂ emissions. Serviceability was evaluated using five subjective metrics. Reliability was evaluated by the relative availability of the propulsion systems to meet operational requirements. Each propulsion system received a raw score for each criterion. These criteria were assigned weightings to capture the level of importance to the client. The raw score for each criterion was multiplied by the criteria weightings to provide a weighted criteria score. These scores were summed together to calculate the total propulsion system score.

Table #1 – Assigned criteria weightings used for propulsion system feasibility study.

Evaluation Criteria	Weighting of Overall Score
OPEX	39%
CAPEX	19%
Sustainability	12%
Serviceability	10%
Reliability	20%

Each criterion is composed of sub-criteria. These sub-criteria are similarly assigned weightings to capture the importance of each sub-criteria to the overall criteria score. These evaluations are further described in the body of this report and the process is outlined in Appendix III. The following tables provide the “unweighted” and “weighted” scores for the various candidate propulsion systems.

Table #2 – Criteria scores for each propulsion system (out of ten).

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	7.90	8.41	8.41	10.00	10.00
CAPEX	9.95	9.26	9.18	8.14	8.63
Sustainability	8.77	8.54	8.54	9.98	10.00
Serviceability	7.00	5.80	5.80	4.60	4.60
Reliability	7.18	4.40	8.43	10.00	10.00

The criteria raw scores were first rescaled so that the highest scoring system for each criteria received a score of ten. Then the criteria weightings were used to calculate the propulsion systems’ cumulative scores shown below.

Table #3 – Weighted criteria scores and cumulative scores of propulsion systems.

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	3.08	3.28	3.28	3.90	3.90
CAPEX	1.90	1.77	1.75	1.56	1.65
Sustainability	1.05	1.02	1.02	1.20	1.20
Serviceability	1.00	0.83	0.83	0.66	0.66
Reliability	1.44	0.88	1.69	2.00	2.00
Sum:	8.47	7.78	8.57	9.31	9.40

Based on the assigned criteria weightings, the diesel electric systems with batteries outperformed the other candidate propulsion systems. Incorporating energy storage reduced operational costs, lowered emissions, and improved redundancy with additional and reliable power sources. These improvements are at significant initial (and periodic) expense. The next highest scoring system was the diesel electric system with three C18s. This system had an average score for most criterion considered. This system has improved reliability due to the additional power source but will not require the battery related costs that the diesel electric systems with batteries do. This system retains benefits of a diesel electric system while avoiding the added complexity of energy storage systems. The next highest score was the diesel mechanical system. The diesel mechanical system results in the highest operating costs but has the lowest capital costs and system complexity. The diesel electric system with two C18s ranked the lowest of all propulsion systems receiving the lowest score in reliability due to the lack of redundancy and lower component availability.

All the operational costs shown in this report are comparative costs between the different propulsion architectures. Operational costs only include maintenance and consumable costs for equipment that are different between the propulsion systems. Equipment that is independent of the chosen propulsion system is not considered in this analysis. The operational cost includes the fuel, engine/generator maintenance, electricity, motor replacement, and battery replacement costs if applicable. In the following figure, the annual operational costs of the various propulsion systems are plotted for transit speeds between 8 and 11.

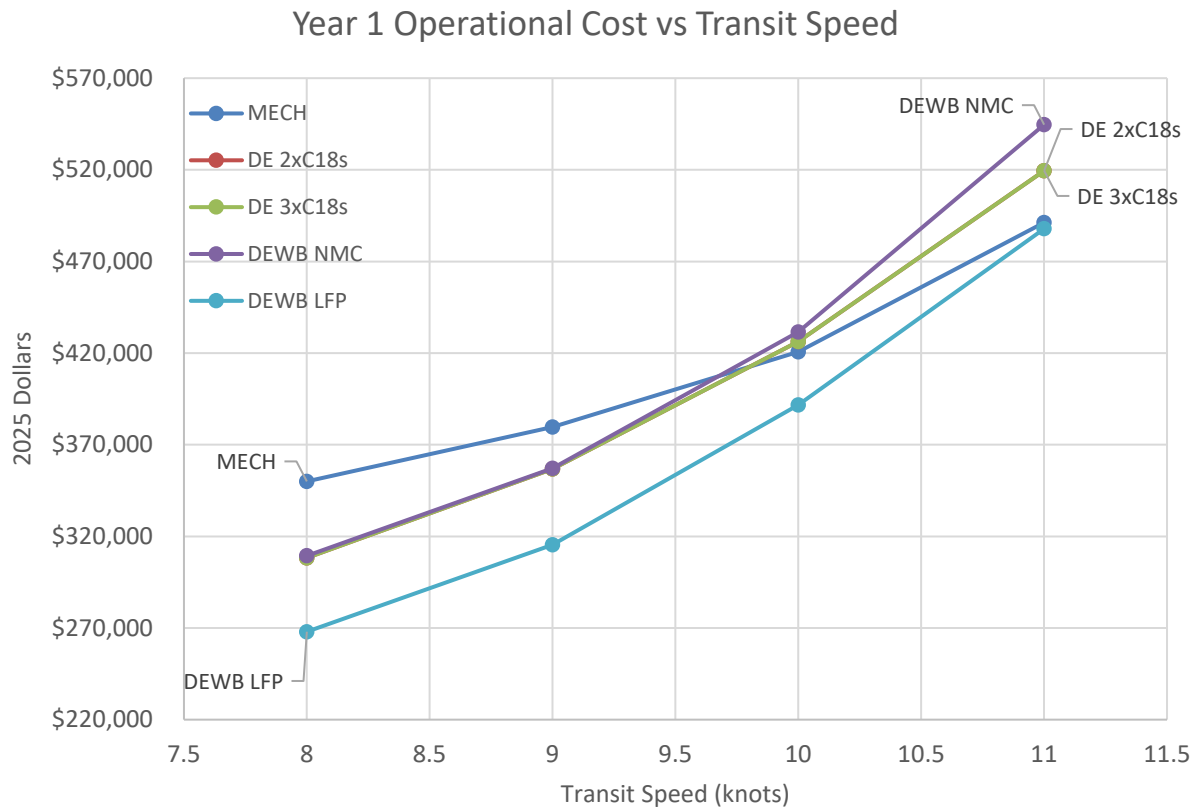


Figure #1 – Annual operational cost versus transit speed for different propulsion architectures.

INTRODUCTION

The goal of this report is to give the reader a general overview of the process of evaluating the possible propulsion systems on the new ferry. A feasibility study was undertaken to rank and provide a cost and relative benefit comparison of the new ferry utilizing different propulsion systems. The propulsion architectures studied are introduced first. The methodology behind the control logic used in the models of the propulsion systems are also described. Then, the process to create an operational profile and power requirements for the new vessel is summarized. The feasibility study metrics are then described, and system comparisons are discussed. Finally, the analysis is summarized and the results of the feasibility study are discussed.

CANDIDATE PROPULSION SYSTEMS

Five different types of propulsion architectures were considered in this analysis:

1. Diesel mechanical with 2x C18 engines (500 bkW each) and 2x house generators (72 ekW each)
2. Diesel electric with 2x C18 generators (430 ekW each) and a house generator (45 ekW)
3. Diesel electric with 3x C18 generators (430 ekW each) and a house generator (45 ekW)
4. Diesel electric with NMC batteries: 2x C18 generators (430 ekW each) and 1,000 kWh of NMC batteries
5. Diesel electric with LFP batteries: 2x C18 generators (430 ekW each) and 1,000 kWh of LFP batteries

The following sections discuss each system and briefly outline the control strategies that were used in the propulsion system analysis.

DIESEL MECHANICAL

A diesel mechanical system is what is currently on the existing ferry. In the diesel mechanical propulsion system modeled in this analysis, two Caterpillar C18 engines (500 bkW each) are each directly attached to the shaft and propeller through a reduction gear. During transit the house load is met by a single house generator. A second house generator is brought online when performing maneuvering operations to provide extra electrical power for a bow thruster. A single house generator is used while at port. In this type of system, the propulsion plant and electrical plant are separate. If a main engine goes down the ferry would lose 50% of its propulsion and maneuverability capability. This system also has worse throttle responsiveness (how quick the propulsion system can match an increase in power demand) compared to the other prospective propulsion systems, and maneuverability afforded by the bow thruster is not immediately available unless the second house generator set is brought online prior to reaching the dock. However, this option has the lowest capital cost and simplifies the propulsion and electrical systems. A 100% redundant with 50% reserve typical split propulsion plant and electrical plant is shown in the following figure.

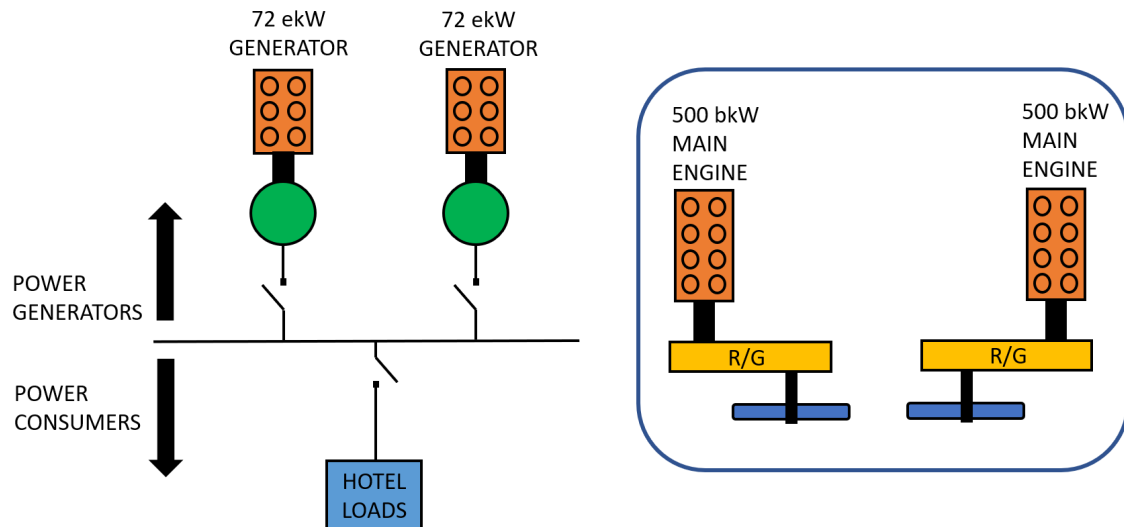


Figure #2 -Typical diesel mechanical system arrangement with segregated propulsion and electrical plants.

Control Strategy

The diesel mechanical propulsions system control was developed based upon the current vessel's typical operation as informed by client input. The engines start 20 minutes before each run if they are off. The main engines are turned off after runs "A", "B", "C" when the vessel is in Portland for extended periods of time. The power demand from the operational profile created from the MAQUOIT II schedule is directly used to determine the engine demand for the port and starboard engines.

DIESEL ELECTRIC (2X C18 GENERATORS)

The first diesel electric propulsion plant analyzed utilizes two Caterpillar C18 diesel generators (430 ekW each) that can provide the ferry propulsion power through electric motors. This architecture was studied at a request by the customer; it is TSGL's recommendation to have three main generators to provide improved redundancy. To reduce engine hours, fuel consumption, maintenance, emissions, and wear & tear on the main generators a house generator can be used for the house loads and the main generators can be turned off when no propulsion power is required. Redundancy is effectively increased in this system because if a prime mover goes down the system can maintain maneuverability and still operate both motors and shafts, albeit at a reduced power. Capital cost and complexity of the electrical system is increased when compared to the diesel mechanical system. The propulsion system's throttle response is improved compared to the diesel mechanical system but is still limited by the generator response. The bow thruster is immediately available so long as full propulsion power is not simultaneously required. Note that in this study it is assumed that for all diesel electric propulsion systems the electric propulsion motors will be used in conjunction with a reduction gear. The gear will provide proper shaft rpm required by the propeller as well as permit clutching, reversing, transmission of thrust, shaft fixity, and likely obviate the need for shaft brakes. This will reduce the motor costs, complexity, and maintenance and will improve replacement part/motor availability while permitting a simplified shaft arrangement.

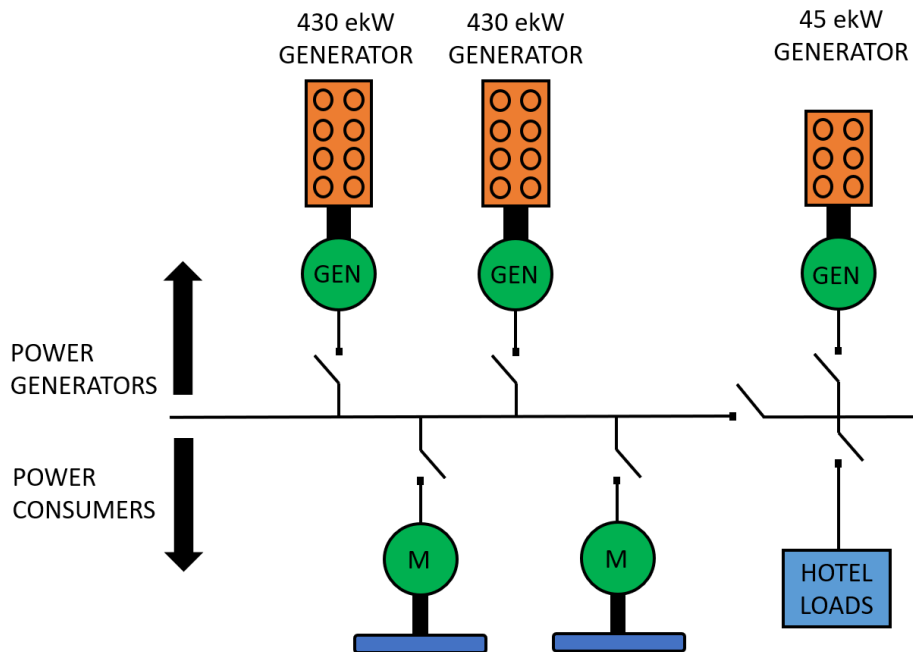


Figure #3 – Typical diesel electric system with a house generator arrangement.

Control Strategy

The diesel electric propulsion system with a house generator control strategy is like that of the mechanical system. The ferry is assumed to always have two main diesel generators always on while underway to be able to respond to any power demand at any point. This is an assumption that was made that may be required to prevent total loss of power in case of a generator failure and in some instances is a prescribed requirement of the local USCG office having jurisdiction. Like the mechanical system, the main generators were turned off after runs "A", "B", "C" when the vessel was in Portland for extended periods of time and the house generator was turned on to meet the house loads.

Alternative Operating Strategy

An alternative control strategy would use both C18 generators only during critical power periods that occur during maneuvering operations. Once the vessel gets up to speed, one C18 generator would be turned off and the house generator used to support hotel loads and act as the backup power source in case of a main generator failure to prevent total blackout. This strategy would put less engine hours on the main generators and result in lower maintenance costs. The implementation of this control strategy would be dependent on local Coast Guard requirements. This control strategy would not be possible for a 10 or 11-knot transit speed because both C18 generators are necessary to meet the propulsion power requirement. This alternative strategy is not further developed or assessed in this report because of the inherent speed limitations and unknown Coast Guard restrictions.

DIESEL ELECTRIC (3X C18 GENERATORS)

The next diesel electric propulsion plant that was analyzed utilizes three Caterpillar C18 diesel generators (430 ekW each) for propulsion power. The vessel operates with two main generators in operation, with the 3rd generator standing by as reserve power. As per the previous architecture, a house generator is used for the house loads while the main generators are turned off when no propulsion power is required for extended periods dockside. Redundancy is increased in this system because if a prime mover goes down, full propulsive and maneuvering capability can readily be restored by turning on the standby generator. Cost and complexity of the electrical system is increased somewhat when compared to the diesel electrical systems with two main generators.

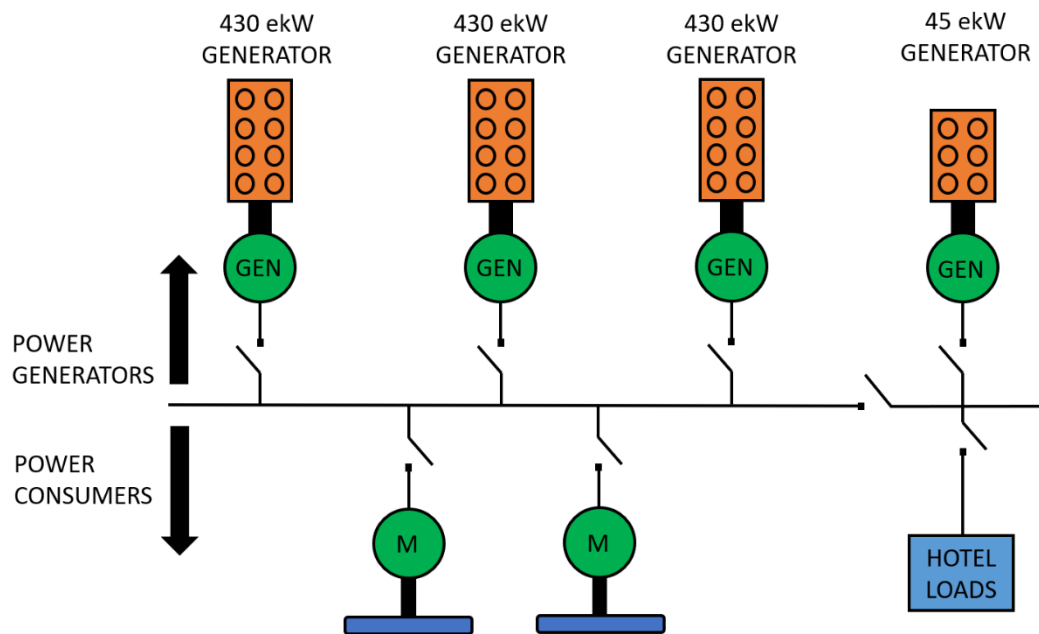


Figure #4 – Typical redundant diesel electric system with a house generator arrangement.

Control Strategy

The control strategy of this diesel electric propulsion plant is the same as the diesel electric propulsion plant with two C18 diesel generators. The plant operates with two main propulsion generators online, but also has one generator on standby.

DIESEL ELECTRIC WITH BATTERIES (NMC OR LFP)

The final two propulsion plants analyzed are diesel electric systems with nickel manganese cobalt (NMC) or lithium iron phosphate (LFP) batteries. The systems are designed to use diesel electric power generation integrated with an energy storage system in the form of battery modules. The energy storage system provides spinning reserve to the system, meaning it can be brought online quickly and provide power to meet sudden changes in demand. The energy storage system also performs peak shaving functions for the propulsion system. This is an energy management technique where the energy storage systems limits the power demand on the generators. Permitting the generators to be operated at their ideal cycle loading while the energy storage system is either discharged or charged respectively as required to match peaks and troughs in the power demand. This results in the generators being operated at an optimal load more often, reducing fuel consumption, emissions, wear & tear, and associated maintenance costs. This type of propulsion system increases redundancy by adding additional propulsion power sources. When utilizing energy storage, the ferry can operate with only one generator online and still meet operational requirements. The ferry could also operate with zero generators online and operate on batteries only (for a short duration). This can provide benefits such as zero emissions while in port and a quieter experience for passengers. It is important to note that there are additional losses when using energy storage systems due to the charging and discharging efficiencies and battery cooling requirements. There is also a larger initial cost for this system, and the batteries have a limited lifetime relative to other propulsion system components and require periodic replacement. A typical diesel electric system with batteries is shown in the figure below.

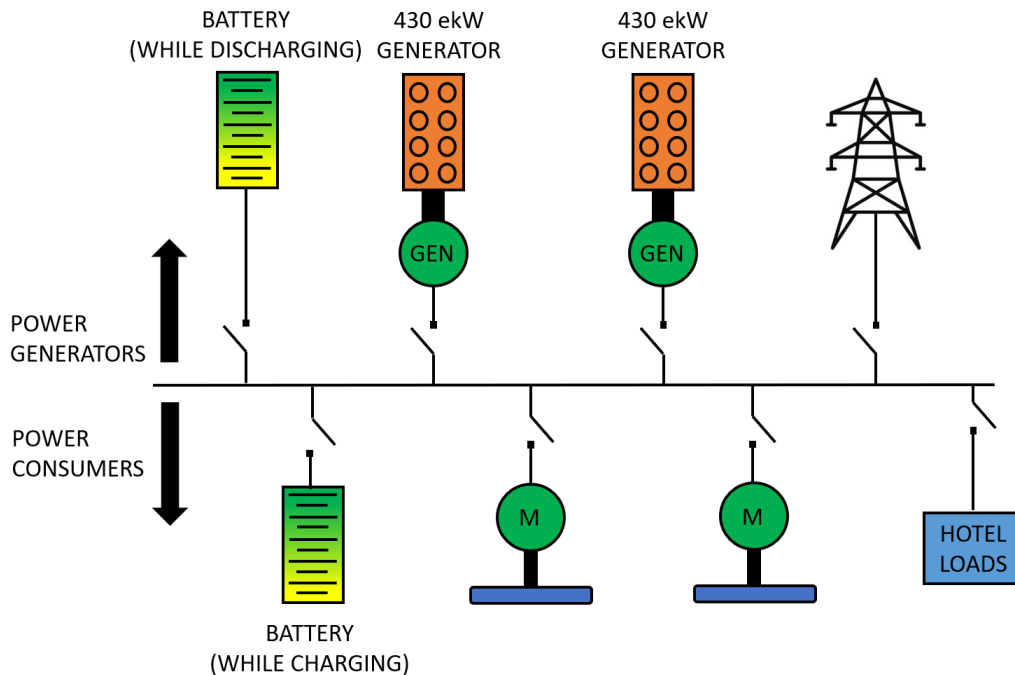


Figure #5 – Typical diesel electric system with batteries arrangement.

The generators used in the diesel electric and battery systems are the same C18 generators used in option #2. In this study, an installed battery capacity of 1,000kWh was assumed. Additionally, both NMC and LFP battery chemistry types were studied.

Battery Cooling Power

To address the extra electric load onboard the vessels with batteries an estimate was made for the battery cooling needed for these propulsion systems, based on the cooling requirements of a sample of existing vessels. A cooling demand was calculated based upon the time averaged C-rate of the batteries and the installed capacity of the battery system. The batteries' C-rate is a measurement of the speed it is charging or discharging. A C-rate of 1C corresponds to a full charge/discharge of the batteries' nominal capacity in one hour. This battery cooling power demand must be considered because an apparent gain of efficiency using batteries could be effectively negated by the additional power requirement required for cooling purposes. Batteries also require "hardened", ventilated, conditioned, and fire protected storage spaces.

Control Strategy

The diesel electric propulsion system with batteries has a more involved control strategy because it must meet the power demand of the vessel and determine the most fuel-efficient split of the power generation options while staying within the constraints imposed by the components of the system. The constraints include maximum power output of components, C-rate discharge and charge limits, and minimum and maximum state of charge of the batteries. These values are dependent on the battery's chemistry.

The objective of the control strategy of this propulsion system was centered on loading the generators at an optimal loading point so that it is most fuel efficient and best for component health. Doing so will also lead to lower greenhouse gas emissions as well as a longer life of the generators.

Shore Charging

The options with NMC and LFP batteries utilize shore power to charge the batteries overnight. It is assumed that the shoreside infrastructure will be capable of providing the necessary output to charge the batteries to the maximum allowable state of charge overnight. The modest charging rate required to charge the batteries overnight should require minimal infrastructure costs. No provisions for rapid charging are contemplated in this study.

Battery Only Operations

The desire to potentially operate the ferry with battery power only was expressed by the client. To operate utilizing only the batteries, the batteries must be sized to store enough usable energy to make the entire transit at the desired speed. The maximum power that batteries can provide is dependent on the battery capacity and the allowable C-rate of the battery's chemistry. In addition, to protect the batteries' lifespan, only a percentage of the battery's nominal capacity is usable. The required nominal battery bank size will thus depend on the battery chemistry and the allowable range of the battery state of charge. In this study we assume that NMC batteries must be kept between 40-80% and LFP between 10-80% state of charge.

In Appendix II, the trips that the MAQUOIT II currently takes and possible design speeds of the vessel were analyzed. The installed nominal battery capacity needed to make the transit between each port was determined. Other considerations such as minimum reserve power may increase these requirements.

OPERATIONAL PROFILE

This study took the schedule of the MAQUOIT II, the vessel that the new ferry will be replacing, and formulated an operational profile using resistance data from a CFD analysis of the hull form of the replacement vessel. Operational profiles were created for transit speeds of 8, 9, 10, and 11 knots at vessel drafts of 6', 6.5', and 7', each representing a different propulsion power demand and duration of time spent in transit. A minimum speed of 8 knots is necessary to ensure the ferry can meet its existing departure times out of Portland and enforce 30-minute load and unload time in Portland. To create the ferry schedule at different speeds the departure times from Portland are held constant (matching the existing schedule) and the following stops are scheduled based on assumed maneuvering time, dock time, and transit times shown in Appendix II. The operational power demand profile is determined using delivered power requirements from a computational fluid dynamics (CFD) analysis.

MAQUOIT II SCHEDULE

The MAQUOIT II typical schedule has 4 distinct routes that it regularly transits with up to 7 runs a day [1]. In this analysis we labeled these runs as “Run A”, “Run B”, “Run C”, and “Runs D1, D2, D3, D4”.

- Run A is scheduled to depart Portland at 8am and goes to Chebeague Island, Cliff Island, Long Island, Great Diamond, Little Diamond, and back to Portland.
- Run B is scheduled to depart Portland at Noon and goes to Cliff Island, Chebeague Island, Long Island, and back to Portland.
- Run C is scheduled to depart Portland at 4:15pm and goes to Diamond Cove, Great Diamond, Little Diamond, and back to Portland.
- Runs D1, D2, D3, and D4 are runs from Portland to Peaks Island and back to Portland that depart Portland at 7:15, 8:15, 9:15, and 10:30 respectively.

Runs A, B, and C occur every day of the week and Runs D1, D2, D3, and D4 occur Sunday through Thursday.

CFD RESISTANCE DATA

Bristol Harbor Group, Inc. ran a CFD analysis on the hull form under consideration for the replacement vessel, at 6, 6.5 and a 7-foot draft. In this propulsion study the vessel is assumed to operate at a 6.5' draft 50% of the time and at a 7' draft 50% of the time. The following chart shows the effective power demand required for speeds between 6 and 11 knots.

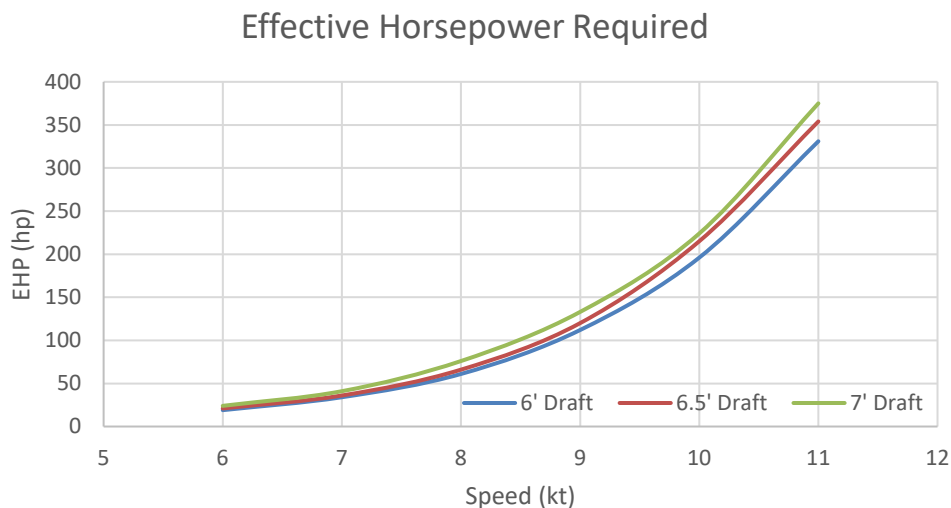


Figure #6 – Effective power demand calculated by CFD for different vessel speeds and drafts.

The effective horsepower requirement is the power required to move the hull at a given speed. To calculate the brake horsepower requirement (power from the engine/generator) the interaction between the propeller and hull as well as mechanical and electrical losses in the system need to be considered. Assumptions were made regarding added appendage resistance, propulsive efficiency, and losses in the propulsion system in order to estimate required brake horsepower. This process is outlined in further detail in Appendix II.

SIMULATION PROFILE

In Appendix II a schedule was determined for each transit speed. Assumptions were made regarding maneuvering/acceleration times and unload/loading times that could be refined further with client feedback. The following profiles were input into the propulsion system models to simulate a day on the Sunday–Thursday schedule. The profiles show the delivered power requirements (power to the propeller) at a 7’ draft. Profiles were also created according to the vessel’s Friday and Saturday schedule as well, which don’t include the evening trips to Peaks Island. Power profiles were also created for a 6’ and 6.5’ draft with the corresponding power demand requirements. The Friday & Saturday schedules and the 6’ & 6.5’ draft power profiles are included in Appendix II.

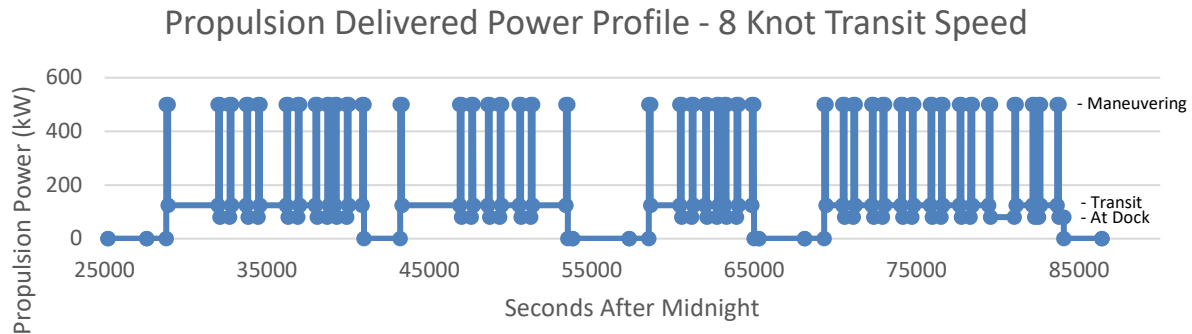


Figure #7 – 8 knot transit speed delivered propulsion power profile at a 7’ draft.

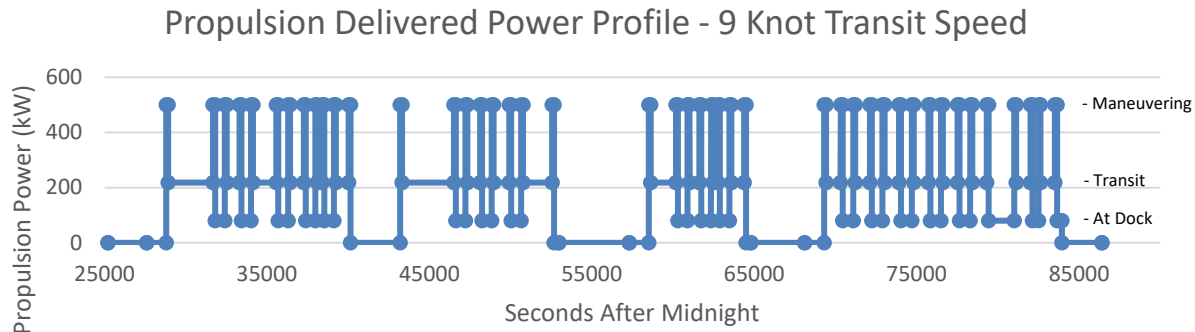


Figure #8 – 9 knot transit speed delivered propulsion power profile at a 7’ draft.

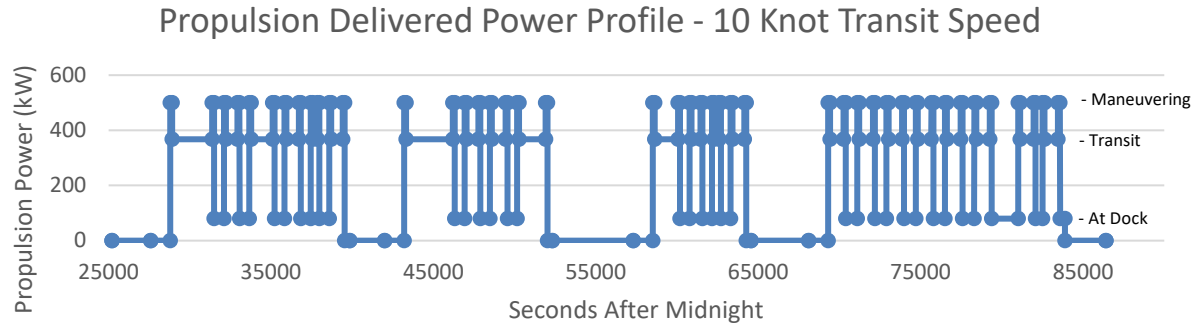


Figure #9 – 10 knot transit speed delivered propulsion power profile at a 7' draft.

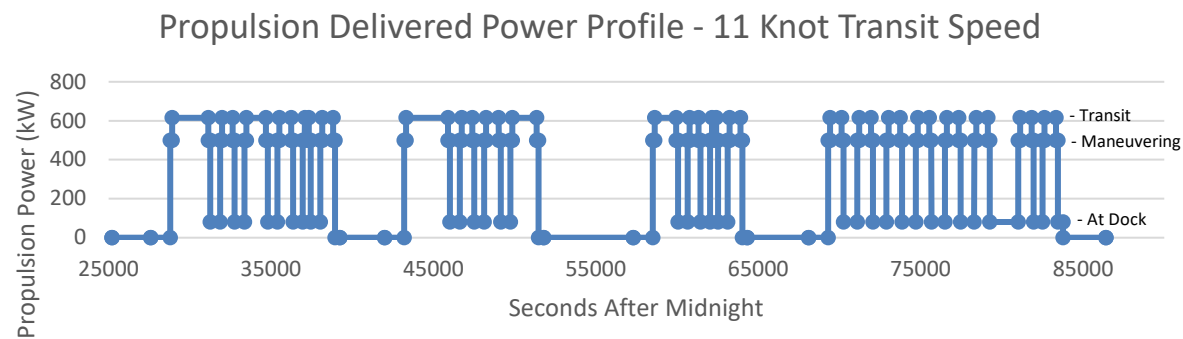


Figure #10 – 11 knot transit speed delivered propulsion power profile at a 7' draft.

Simulation Results

The logic and control sequencing for the different propulsion systems was developed using MATLAB and SIMULINK software to control the batteries, generators and/or propulsion engines as described by the control strategies in the propulsion system overviews outlined earlier in this report. Models of the propulsion systems including the engines, generators, and batteries were also created [2] [3] [4] [5]. After the control logic and propulsion system models were configured, the control logic was applied to the ferry's theoretical operational profiles. The models were used to calculate the engine/generator's power output, fuel consumption, engine hours, battery state of charge, charge and discharge state, et cetera. The time step of the simulations was one second. More information on the control strategy and governing equations can be found in Appendix I. The simulation results are included in Appendix V showing engine demand, generator demand, fuel burned, battery demand, battery state of charge and more for each speed, draft, and schedule over the course of the day. Note that simulation results for the diesel electric systems with 2x C18s and 3x C18s are not shown separately. These systems result in the same amount of engine hours and fuel consumption as the third C18 is used only as a standby generator in case a generator failure. The following figures show how the fuel consumption and engine hours vary with the transit speed.

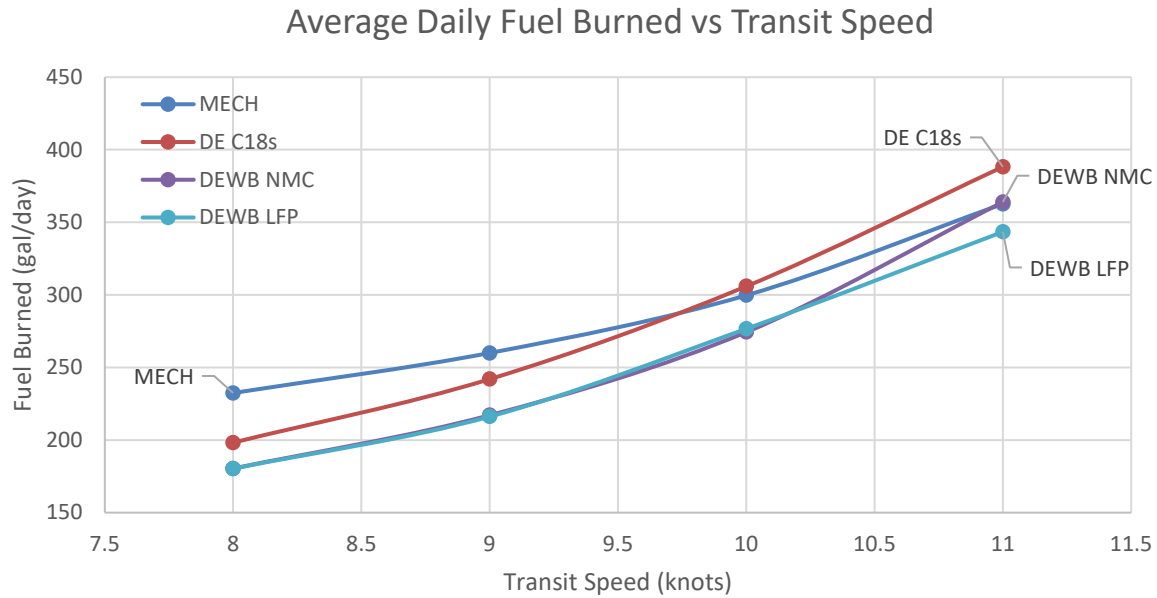


Figure #11 – Average fuel burned (gal/day) versus vessel transit speed

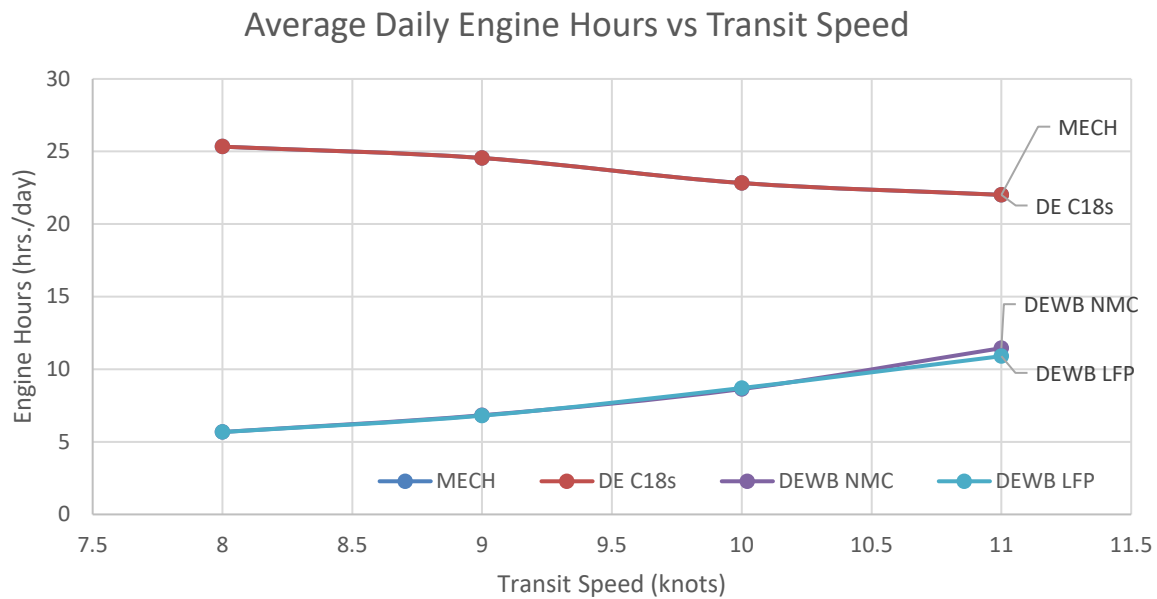


Figure #12 – Average total main propulsion engine/generator hours per day versus vessel transit speed

ONE YEAR AND VESSEL LIFETIME EXTRAPOLATION

The daily results were extrapolated to obtain estimated annual fuel consumption and engine hours for the different propulsion systems. The existing vessel was reported to be operated 365 days a year but undergoes a 6–8-week dry dock every other year. To calculate average annual values, 3.5 weeks of downtime were applied to each year equating to 340.5 days of operations per year. The data was also extrapolated into lifetime fuel consumption, electricity usage, engine hours, and maintenance costs. The financial analysis assumed the lifetime of the vessel will be 30 years.

Diesel and Biodiesel Blend Adjustment

It was reported that in the client's fleet a diesel-biodiesel fuel blend is used in an 80% diesel-to-20% B100 biodiesel ratio. The engine/generator manufacturer's fuel consumption curves are reported for #2 distillate diesel fuel, so the total fuel consumption numbers were adjusted to account for the blended fuel, based upon the BTU content of the blended fuel [6].

Table #4 – BTU content comparison of fuels in blend mixture.

Fuel	BTU/gal
Diesel	128,748
Bio-Diesel (B100)	119,550
80-20 Blend	126,908

This analysis reveals that due to the difference in BTU content of the fuels, at least a 1.62% volumetric increase in the fuel consumption would be incurred with the blended fuel compared to the diesel fuel curves provided by the engine/generator manufacturer.

EVALUATION CRITERIA

The following sections establish how the OPEX, CAPEX, sustainability, serviceability, and reliability metrics were defined and quantified.

OPERATIONAL COSTS

Operational expenses (OPEX) are costs that are incurred by the daily operation of the ferry. This includes costs due to the operation of equipment, consumables, and labor. These calculations are a comparative analysis, meaning only values that differ between the propulsion systems were considered. Labor and maintenance incurred on the new ferry independent of its chosen propulsion system are excluded from the operational cost estimate. TSGI used the simulation results and performed a cost projection for annual and lifetime operations.

The projection includes the following costs:

- 1) Engine maintenance
- 2) Generator maintenance
- 3) Motor maintenance/replacement
- 4) Battery replacement
- 5) Fuel costs
- 6) Electricity Costs

Engine and Generator Maintenance

Engine and generator maintenance costs are resolved into a cost per operating hour (\$/hr) figure based on the projected maintenance costs for each type of engine. The maintenance costs were further subdivided into "frequent maintenance" and "infrequent maintenance." This was done by request of the client to break out "daily" expenses from expenses that would likely occur at the shipyard at the vessel's dry-docking schedule. The \$/hr figure includes the cost of consumables used during periodic maintenance such as lube oil for lube oil changes.

Motor Maintenance

It is estimated that the electric motors may need to be replaced over the lifetime of the vessel. The annual operational cost includes the propulsion motors being replaced once in the vessel's lifetime broken down on an annual basis.

Battery Replacement

Battery replacement costs were considered when calculating the annual operational cost of the vessel. These costs assume that the NMC batteries would need to be replaced three times over the vessel's lifetime and LFP batteries would need to be replaced twice, based upon typical lifetimes of the batteries with the respective chemistries under standard C-rates and state of charge limits. If option 4 or 5 is chosen a more in-depth battery cycling analysis should be performed to optimize the battery size and control system to maximize efficiency and battery lifespan.

The following table shows the additional operational costs due to the replacement costs of motors and batteries, annualized.

Table #5 – Fixed annual operational costs.

	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Motor Replacement	\$0	\$5,000	\$5,000	\$5,000	\$5,000
Battery Replacement (1,000kWh)	\$0	\$0	\$0	\$75,000	\$33,333

Fuel Costs

In the last fiscal year, it was reported that Casco Bay Lines purchased diesel for \$3.50 per gallon and \$3 per gallon for biodiesel. Considering the fuel blend ratio, an average of \$3.40 per gallon is assumed for the blended fuel. This price was used for our year 1 baseline fuel costs.

Electricity Costs

The cost of the electricity used with options 4 & 5 to recharge the vessel's batteries overnight were accounted for. The energy rates currently being paid by Casco Bay Lines were used in the analysis which was reported to be \$0.11381 per kilowatt hour. The client had requested that a peak demand surcharge was not considered in terms of the electricity costs. If options 4 & 5 are chosen the intention is to only have the vessel shore charge during off peak hours. Additionally, a monthly base fee is also excluded from this analysis as this cost will be incurred regardless of the propulsion system chosen.

ANNUAL OPERATIONAL COST

Details of the calculation of the year 1 operational costs can be found in Appendix I. The figure below shows the sum of the operational costs considered in this analysis. This includes annualized costs due to engine/generator maintenance, motor maintenance/replacement, battery replacement, fuel consumption, and electricity usage.

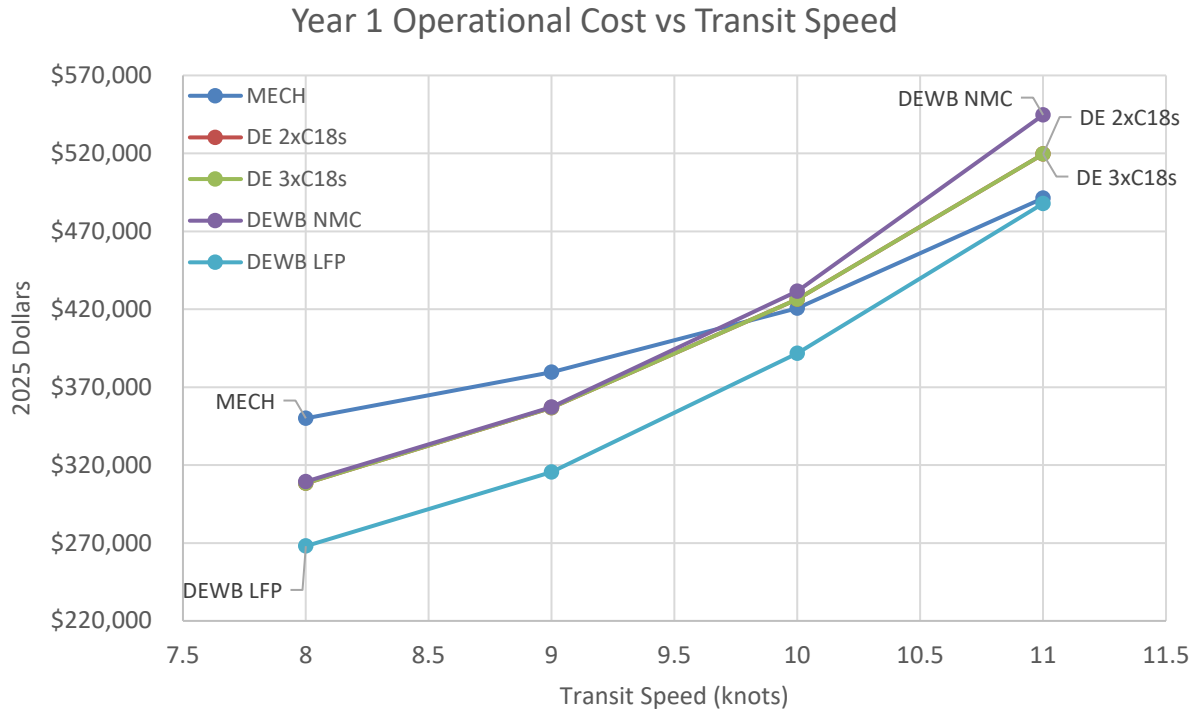


Figure #13 – Baseline 2025 annual comparative operational costs of propulsion systems

VESSEL LIFETIME OPERATIONAL COST

An average inflation of 2.57% every year was projected through the vessel’s lifetime, based on the average inflation over the last 40 years. Inflation was applied to the maintenance cost of engines and generators, motor replacements, and fuel costs. Inflation was not applied to battery replacement costs due to the trend of decreasing battery prices and the possibility of a more advanced battery technology being developed in the future. A conservative approach was taken to assume that the price of batteries per kWh would stay approximately the same throughout the vessel’s lifetime.

OPEX SCORING

To evaluate the operating expenses (OPEX) for the feasibility study the yearly fuel, electricity, and frequent main engine/generator maintenance costs were compared. Frequent engine/generator maintenance was defined as events occurring at less than 1000-hour intervals. These costs were evaluated at a 9-knot transit speed for the purpose of the feasibility study.

The costs were directly compared, and the scores were calculated. Details of these calculations are included in Appendix III.

Table #6 – OPEX criteria scores for propulsion systems (out of ten).

OPEX Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	7.90	8.41	8.41	10.00	10.00

CAPITAL EXPENSES

To evaluate capital expenses (CAPEX) TSGI has developed a construction cost estimate for a replacement vessel with the various propulsion systems considered. The construction cost estimates reflect the different engines, generators, motors, switchboards, and VFD drives that are required. For the systems with battery energy storage, the added HVAC equipment, sensors, monitors, insulation, and fire protection equipment are accounted for. More details of this analysis can be found in Appendix I. The installed battery capacity onboard the vessel will impact the initial cost of the system.

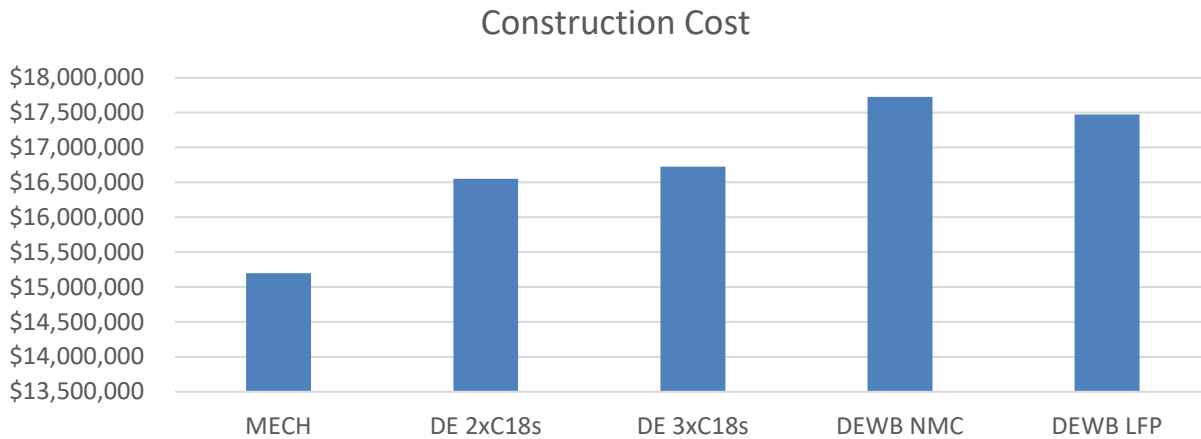


Figure #14 – Construction cost summary

CAPEX SCORING

CAPEX for the propulsion systems was evaluated by comparing construction cost estimates and infrequent equipment maintenance costs including overhauls and replacements. Infrequent engine/generator maintenance was defined as events occurring at greater than 1000-hour intervals. Replacement costs of equipment included the replacement of motors, batteries, and house generators. Equipment maintenance and replacement costs are broken down to a yearly cost and are evaluated for a 9-knot transit speed for the purpose of the feasibility study.

Table #7 - Sub-criteria weightings for CAPEX.

CAPEX Sub-Criteria:	Sub-Criteria Weighting
Construction Costs	90%
Equipment Overhaul and Replacement Costs	10%

The costs were directly compared, and the scores were calculated. Details of these calculations are included in Appendix III.

Table #8 - CAPEX sub-criteria scores for propulsion systems.

CAPEX Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Construction Costs	10.00	9.18	9.09	8.58	8.70
Equipment Overhaul and Replacement Costs	9.51	10.00	10.00	4.26	8.03

With a score assigned to each sub-criteria the sub-criteria weightings were used to obtain an overall CAPEX criteria score for each propulsion system.

Table #9 - CAPEX sub-criteria weighted scores and propulsion system cumulative scores (out of ten).

CAPEX Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Construction Costs	9.00	8.26	8.18	7.72	7.83
Equipment Overhaul and Replacement Costs	0.95	1.00	1.00	0.43	0.80
Sum:	9.95	9.26	9.18	8.14	8.63

TOTAL LIFETIME COST

To compare the different propulsion systems' performance over the lifetime (30 years) of the vessel, the vessels' comparative lifetime operational cost was summed with the vessel construction cost to net a total cost. These values are displayed in the figure below.

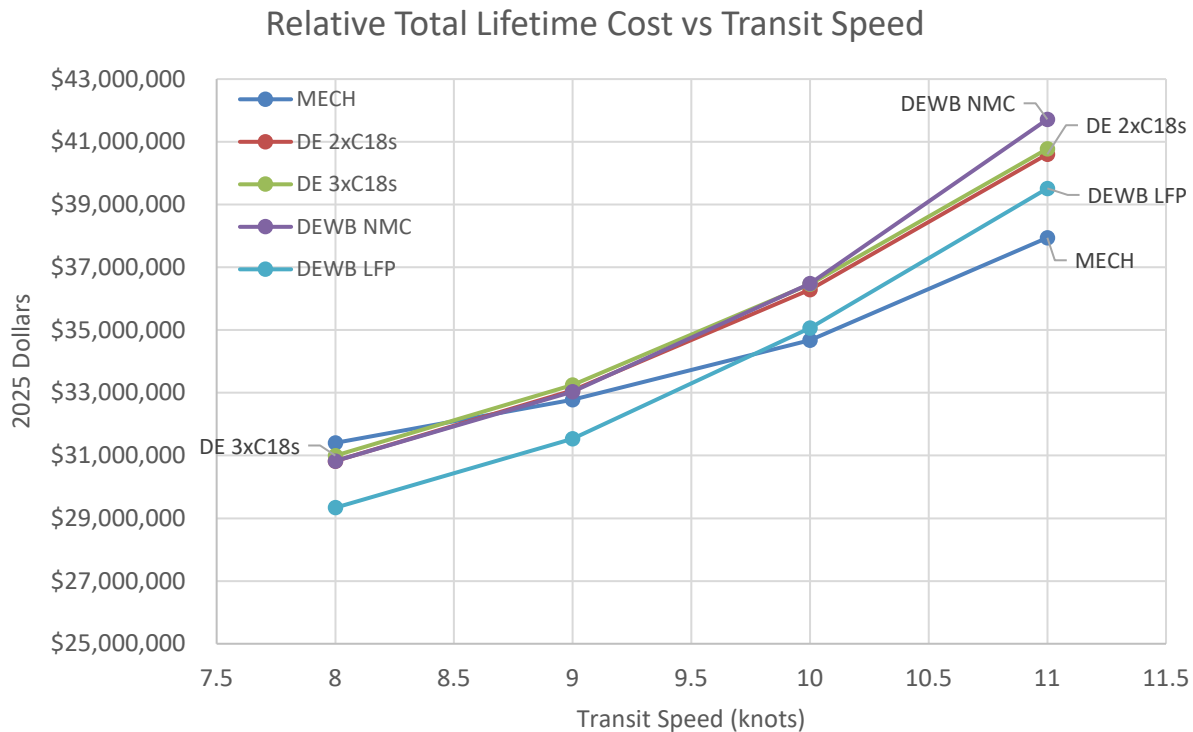


Figure #15 – Comparative lifetime cost of propulsion systems

SUSTAINABILITY

Sustainability of the ferry was defined in this feasibility study as the environmental impact of the propulsion systems. Sustainability of the propulsion systems was measured by daily CO₂ emissions. To capture the total ferry emissions the “well-to wake” emissions were calculated. This includes engine emissions, grid emissions, and fuel production emissions. The fuel and emission curves for the engine and generator sets were used to calculate the fuel burned and emissions based upon the power demand [2, 3, 4, 5, 7, 8]. The emissions to produce the energy consumed from the electrical grid in candidate propulsion system options 4 & 5 were estimated using available data for the regions electrical grid [9]. To account for the emissions due to the production of fuel the “well-to-tank” emissions were calculated using data from the U.S. Department of Energy's National Renewable Energy Lab (NREL) [10]. These calculations are described in detail in Appendix I.

The emission impacts of using the diesel-biodiesel blend are not specifically calculated. Any emission impacts from the fuel blend usage are assumed to be proportional across all systems and would result in no impact to the system scores. The production method of the biodiesel used will impact the environmental impact of the fuel blend usage but is independent of the propulsion system chosen and is not explored further. This study does not include transient effects such as engine start up. The following figures show how the CO₂ emissions vary with the transit speed.

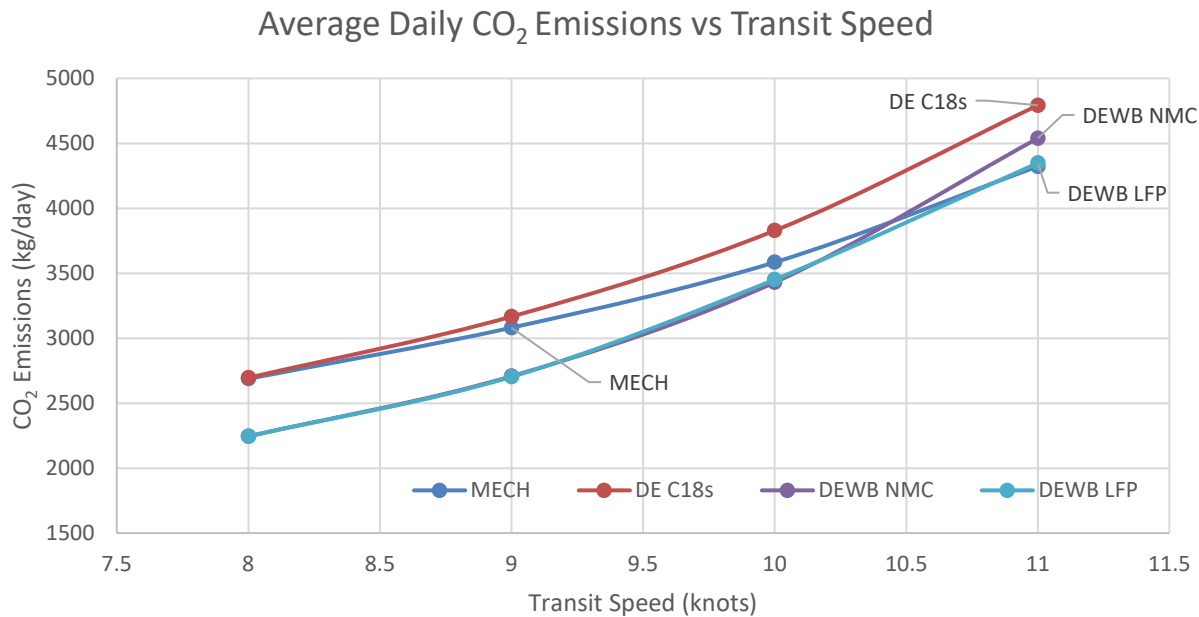


Figure #16 – Average carbon dioxide (CO₂) emissions per day in kilograms versus vessel transit speed

The vessel CO₂ emissions were evaluated at a 9-knot transit speed for the purpose of the feasibility study. The calculations performed to score the emissions are shown in Appendix III.

Table #10 - Sustainability criteria scores for propulsion systems (out of ten).

Sustainability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Carbon Dioxide (CO ₂) Emissions	8.77	8.54	8.54	9.98	10.00

SERVICEABILITY

Serviceability was defined as the ease of maintaining and repairing the propulsion systems. This was evaluated based on five subjective sub-criteria. These sub-criteria include spare parts requirements, replacement part availability, service technician availability, downtime for repairs, and fleet similarity. Weightings were evenly assigned to each sub-criteria as shown in the following table.

Table #11 - Sub-criteria weightings for Serviceability.

Serviceability Sub-Criteria:	Sub-Criteria Weighting
Spare Parts Requirements	20%
Replacement Part Availability	20%
Service Technician Availability	20%
Downtime for Repairs	20%
Fleet Similarity	20%

The sub-criteria were scored subjectively with a possible ranking from 1-10. In general, TSGI did not evaluate any sub-criteria as extremely low or high as the technology being proposed has been industry proven and Casco Bay Lines has an existing ferry or a new build ferry that utilizes all the technologies being proposed. If CBL uses the same vendors utilized on their recent new build on the proposed ferry then serviceability and fleet integration should not vary much across the candidate propulsion systems. The rationale behind the rankings of each sub-criteria are detailed in Appendix III.

Table #12 - Serviceability sub-criteria scores for propulsion systems (out of ten).

Serviceability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Spare Parts Requirements	7.00	5.00	5.00	4.00	4.00
Replacement Part Availability	7.00	5.00	5.00	4.00	4.00
Service Technician Availability	7.00	6.00	6.00	4.00	4.00
Downtime for Repairs	7.00	7.00	7.00	5.00	5.00
Fleet Similarity	7.00	6.00	6.00	6.00	6.00

The sub-criteria weightings are used to get an overall serviceability criteria score for each propulsion system.

Table #13 - Serviceability sub-criteria weighted scores and propulsion system cumulative scores (out of ten).

Serviceability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Spare Parts Requirements	1.40	1.00	1.00	0.80	0.80
Replacement Part Availability	1.40	1.00	1.00	0.80	0.80
Service Technician Availability	1.40	1.20	1.20	0.80	0.80
Downtime for Repairs	1.40	1.40	1.40	1.00	1.00
Fleet Similarity	1.40	1.20	1.20	1.20	1.20
Sum:	7.00	5.80	5.80	4.60	4.60

RELIABILITY

Reliability was defined as the ability of the propulsion system to function safely and consistently without failure or at reduced capacity in the event of a redundant component failure. Reliability was measured by the expected availability of the propulsion system to be at full operational capacity. Details of the calculations performed to arrive at this metric are shown in Appendix IV.

Only the components that differ between the candidate propulsion systems were considered in this analysis. To calculate the availability of the propulsion systems the individual components were evaluated based upon component level reliability metrics published by the Department of the Army for power generation components [11]. The data published in the referenced technical manual is the most comprehensive data set available. The reliability data is collected from land-based installations and may skew failure rates and repair time. It is also dated and component dependence on software and use of solid-state electronics may not be accounted for. However, these calculations are done as a comparison tool and should not be applied to any maintenance forecasting. Any data used will be dependent on the frequency of preventative maintenance. This analysis assumes that components fail independently of one another.

Availability is the instantaneous probability that the system will be functioning. The availability of a system considers the mean time between system failures and the mean time to repair the system after a failure occurs. The expected availability of the ferry was calculated for the situation where the ferry is operable with full power to both shafts in spite of a failure. This evaluates the probability that the ferry has sufficient power to both shafts to operate normally and can continue scheduled service. This scenario considers component redundancy and system robustness.

The calculations performed to score the availabilities are shown in Appendix III.

Table #14 - Reliability criteria scores for propulsion systems (out of ten).

Reliability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Availability	7.18	4.40	8.43	10.00	10.00

SUMMARY

TSGI has modeled five different candidate propulsion systems for Casco Bay Lines' new ferry. Operational profiles at transit speeds of 8-11 knots and 6', 6.5', and 7' drafts were developed for the new ferry based upon the current vessel's schedule, using a computational fluid dynamics analysis of the new ferry's hull. Control logic for the propulsion systems was defined, and the models were analyzed against the operational profiles to develop a preliminary estimate of fuel consumption, engine hours, electricity usage, and vessel emissions. These results were used to estimate comparative operating expenses of the propulsion systems. A capital cost estimate of the vessel with each propulsion system was also calculated. Using the major components of the propulsion system the availability of the propulsion systems was evaluated to assess reliability.

TSGI used these calculations to develop a comparative analysis of the propulsion systems. The feasibility study considered the categories OPEX, CAPEX, sustainability, serviceability, and reliability. The feasibility study considered a transit speed of 9-knots for all applicable calculations. The scores for each of the criteria were multiplied by the weighting assigned to each and summed together.

Table #15 – Weighted criteria scores and cumulative scores of propulsion systems (out of ten).

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	3.08	3.28	3.28	3.90	3.90
CAPEX	1.90	1.77	1.75	1.56	1.65
Sustainability	1.05	1.02	1.02	1.20	1.20
Serviceability	1.00	0.83	0.83	0.66	0.66
Reliability	1.44	0.88	1.69	2.00	2.00
Sum:	8.47	7.78	8.57	9.31	9.40

With the assigned criteria weightings the diesel electric systems with batteries outperformed the other candidate propulsion systems. Using energy storage decreased operational costs, lowered emissions, and increased redundancy with additional and reliable power sources, but at significant initial (and periodic) expense. Following the diesel electric systems with batteries was the diesel electric system with three C18s. This system was in the middle of the pack for most criterion considered. This system has improved reliability due to the additional power source but will not require the initial and periodic battery costs like the diesel electric systems with batteries do. This system will carry the benefits of a diesel electric system but will not add the complexity that comes with energy storage systems. Scoring the next highest score was the diesel mechanical system. The diesel mechanical system has the highest operating costs but has lower capital costs. The diesel mechanical system has the lowest system complexity and received a higher score for serviceability. The diesel electric system with two C18s scored the worst of all propulsion systems. This system received the lowest score in reliability due to the lack of redundancy and lower component availability.

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APPENDIX I

23494-199-1 Ferry Propulsion System Analysis Calculations

REVISION HISTORY					
REV	ZONE	DESCRIPTION	DATE	BY	CHECK
0	-	1. Initial Release	03NOV25	MDL	JSS

GENERAL NOTES

-

5	23494-199-5	Propulsion Systems Simulation Results
4	23494-199-4	Propulsion System Reliability Calculations
3	23494-199-3	Feasibility Study Calculations
2	23494-199-2	Ferry Operational Profile Calculations
1	23494-099-1	Ferry Propulsion System Feasibility Study
NO.	DRAWING	TITLE

REFERENCES

TITLE:			Ferry Propulsion System Analysis Calcs		
FOR:			Casco Bay Lines		
VESSEL:			MAQUOIT II Replacement	HULL NO:	
				-	
DATE			03NOV25	SCALE:	
				N.T.S.	
DWG. NO:			23494-199-1	REV:	
				0	
DRAWN BY:			MDL	CHECK BY:	
				JSS	



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PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Ferry Propulsion System Analysis Calcs: Overview		Date:	03NOV25	Checked:	JSS

Goal:

These calculations are for TSGL's feasibility analysis for Casco Bay Line's new ferry. The goal was to use the existing schedule of the MAQUOIT II and BHGI's CFD hull analysis to do an initial projection of operational and capital costs of the future vessel with different propulsion systems.

Propulsion Systems Considered

1. Diesel mechanical system with 2 C18 engines (500 bkW each) and 2 house generators (72 ekW each)
2. Diesel electric system with 2 C18 generators (430 ekW each) and 1 house generator (45 ekW)
3. Diesel electric system with 3 C18s generators (430 ekW each) and 1 house generator (45 ekW)
4. Diesel electric system with 2 C18 generators (430 ekW each) and 1,000 kWh of NMC batteries
5. Diesel electric system with 2 C18 generators (430 ekW each) and 1,000 kWh of LFP batteries

Simulation Operational Profile

The existing schedule for the Maquoit II was used to create operational profiles for the propulsion system analysis. This process is described in References 1 & 2.

Control Strategies

Diesel mechanical system with 2 C18s and 2 house generators

The control strategy for the mechanical system is governed by the operational profile power demand and the current vessel's operational practice as reported by the client. These practices include things like engine start-up time before departure, engine shut-down after arrival, and other necessary factors to determine fuel usage. During transit the house load is met by a single house generator. A second house generator is brought online when performing maneuvering operations to provide extra electrical power for a bow thruster. A single house generator is used while at port.

Diesel electric system with 2 C18 generators and a house generator

The diesel electric system with 2 C18s and a house generator has a very similar control strategy to that of the mechanical system. While underway this system has two generators turned on at all times to be able to respond to any power demand of the vessel. The main generators would be turned off at port like the mechanical system and the vessel house load would be met by the house generator.

Diesel electric system with 3 C18 generators and a house generator

The diesel electric system with 3 C18s and a house generator has the same control strategy to that of the diesel electric system with 2 C18s. The advantage of this system is that having a third main generators onboard will allow for more redundancy. The control of this system is similar to the diesel electric system with two C18s because there will only be two generators online while underway. The third generator does not impact the operation of the system and is just acting as a backup.

Diesel electric system with 2 C18 generators and 1,000 kWh of NMC or LFP batteries

The control strategy for the diesel electric system with 2 C18s and batteries utilizes a load leveling and peak shaving approach. The generators would ideally be run at the most efficient load and the batteries would handle the deflections around that point. The control of this system was determined by the battery state of charge (SoC), instantaneous C-rate, and average C-rate were considered when determining how many generators need to be online. An additional check was done to prevent over switching of the generators, meaning if a generator was switched on it would remain on for a minimum length of time.

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Modeling Assumptions

The following equations, variables, properties, etc. were used in the propulsion system modeling:

Engine/Generator Fuel Curves:

- Engine and generator fuel curves were estimated using manufacturer data at published percent loads and fit with quadratic approximations.
- At low power demand the fuel consumption rate was considered constant to represent fuel consumption while idling or lightly loaded.
- To allow a fair comparison across all architectures the fuel curves of each generator was extrapolated to the same % loading for the constant fuel consumption transition point.
- Exact manufacturer fuel curve data was not available for the C18 engine proposed. The fuel curve for the proposed engine is a 600 kW C18 engine fuel curve that has been scaled to the 500 kW C18 engine used in this study.
- The engine/generator manufacturer's fuel consumption curves are reported for #2 distillate diesel fuel. The fuel consumption numbers are adjusted based on BTU content to account for the diesel-biodiesel fuel blend that the client uses in an 80% diesel-to-20% B100 biodiesel ratio.

C4.4 Generator

Rated Power: 45 ekW

Fuel Consumption: 3.10 gal/hr at 30 ekW load

- Based upon information provided by the client a constant 30ekW was used as the base house load. The house load demand started every day at 7am and ended 30 minutes after the last run of the day.

C4.4 Generator

Rated Power: 72 ekW

Fuel Consumption: 3.00 gal/hr at 30 ekW load (Typical Operations)

Fuel Consumption: 4.33 gal/hr at 50 ekW load (Maneuvering Operations: 2 parallel generators providing 100 ekW total)

- For the mechanical architecture electrical power must be produced by the house generator for an electric bow thruster. This will upsize the house generators compared to the other architectures.

C18 Engine

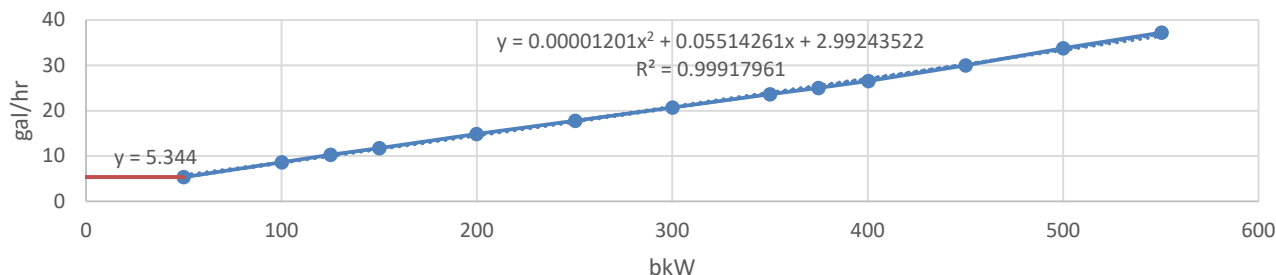
Rated Power: 500 bkW

Fuel Curve:

$$x < 50 \text{ bkW} \quad y = 5.344$$

$$x > 50 \text{ bkW} \quad y = 0.00001201x^2 + 0.05514261x + 2.99243522$$

C18 Engine



C18 Generator

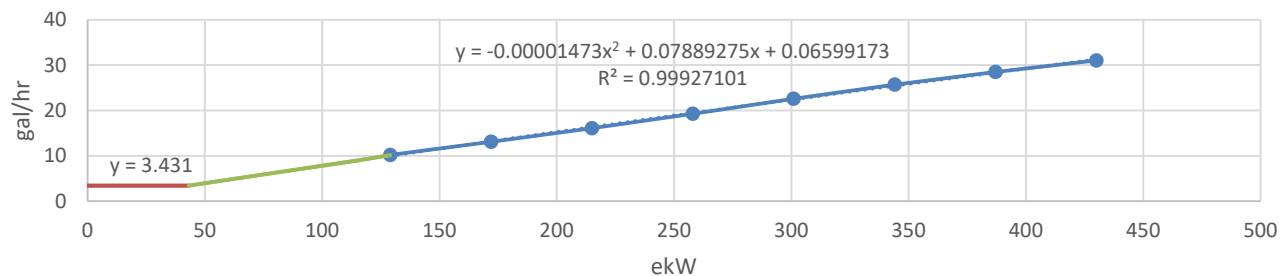
Rated Power: 430 ekW

Fuel Curve:

$$x < 43 \text{ ekW} \quad y = 3.431$$

$$x > 43 \text{ ekW} \quad y = -0.00001473x^2 + 0.07889275x + 0.06599173$$

C18 Genset



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System Properties

Variable	Units	Definition
t	sec	Current time step
T _s	sec	Time step length
L	sec	Length of simulation
η _{shaft}		Efficiency of shafting
η _{gear}		Efficiency of reduction gear
η _{elec}		Electrical transmission efficiency (distribution, transmission, power converters, etc.)
η _{motor}		Efficiency of motor
η _{batt}		Battery efficiency
P _{rated engine}	Watts	Power rating of engines
P _{rated gen}	Watts	Power rating of generators
P _d	Watts	Delivered Power
P _{mech demand}	Watts	Power demand at engine shaft on mechanical system
P _{engine}	Watts	Engine power delivered
P _{elec demand}	Watts	Electrical power demand from electric producers (generators and/or batteries)
P _{house}	Watts	Electrical house power demand
P _{per gen}	Watts	Power demanded per generator
N _{gen}		Number of generators online
P _{gen}	Watts	Total delivered electrical power by generators
P _{house gen}	Watts	House generator electrical power delivered
P _{batt}	Watts	Electrical power delivered by battery
P _{batt ave}	Watts	Average electrical power delivered by battery over chosen window size
P _{cooling}	Watts	Battery cooling power demand
SoC(t)		State of Charge (SoC) of battery at time step t
SoC(t-1)		State of Charge (SoC) of battery at previous time step
SoC _{min}		Minimum allowable SoC of battery dependent on battery chemistry
SoC _{max}		Minimum allowable SoC of battery dependent on battery chemistry
C-rate		Measurement of current that the battery is charging or discharging at
C-rate _{ave}		Average C-rate of battery over chosen window size
C-rate _{max}		Max allowable instantaneous C-rate of battery dependent on battery chemistry
C-rate _{ave max}		Max allowable sustained C-rate of battery dependent on battery chemistry
T _{window}	sec	Window size to determine sustained power/C-rate and in turn battery cooling demand
B _{capacity}	kWh	Battery capacity
T _{online}	sec	Time generator has been online
T _{min switch}	sec	Minimum time between switching generators on and off
ρ	kW/C-rate _{ave}	Cooling power per average C-rate scaled by amount of batteries installed
	/B _{capacity}	

Variable	Units	Equation
P _{mech demand}	Watts	$= P_d / \eta_{gear} / \eta_{shaft}$
P _{elec demand}	Watts	$= P_d / \eta_{gear} / \eta_{shaft} / \eta_{motor} / \eta_{elec} + P_{house} + P_{cooling}$
Fuel Rate	gal/s	$= f(P_{gen} \text{ or } P_{engine}) + \text{fuel rate of house gen if applicable}$
Total Fuel Consumption	gal	$= \sum_{t=0}^{t=L} Fuel\ Rate(t)$
C-rate		$= \frac{ P_{batt} }{B_{capacity}}$
C-rate _{ave}		$= \frac{\sum_{t=t-T_{window}}^{t=t} C-rate(t)}{T_{window}}$
P _{cooling}	Watts	$= \rho * C-rate_{ave} * B_{capacity} * 1000$
SoC(t)		$if\ P_{batt} > 0: SoC(t) = SoC(t-1) - \frac{1}{\eta_{batt}} * \frac{P_{batt}(kW)}{B_{capacity}(kWh)} * \frac{T_s(sec)}{3600}$ $if\ P_{batt} < 0: SoC(t) = SoC(t-1) - \eta_{batt} * \frac{P_{batt}(kW)}{B_{capacity}(kWh)} * \frac{T_s(sec)}{36000}$

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Governing Equations: Power balance and component limits

The controllers are governed by the following equations:

Diesel Mechanical System

$P_{\text{mech demand port}} = P_{\text{engine port}}$

$P_{\text{mech demand stbd}} = P_{\text{engine stbd}}$

$P_{\text{house}} = P_{\text{house gen}}$

$0 < P_{\text{engine}} < P_{\text{rated engine}}$

Diesel Electric System with House Generator

$P_{\text{elec demand}} + P_{\text{house}} = N_{\text{gen}} * P_{\text{gen}} + P_{\text{house gen}}$

$0 < P_{\text{gen}} < P_{\text{rated gen}}$

Diesel Electric With Batteries System

$P_{\text{elec demand}} = N_{\text{gen}} * P_{\text{gen}} + P_{\text{batt}}$

$0 < P_{\text{gen}} < P_{\text{rated gen}}$

$SoC_{\text{min}} < SoC(t) < SoC_{\text{max}}$

$C\text{-rate} < C\text{-rate}_{\text{max}}$

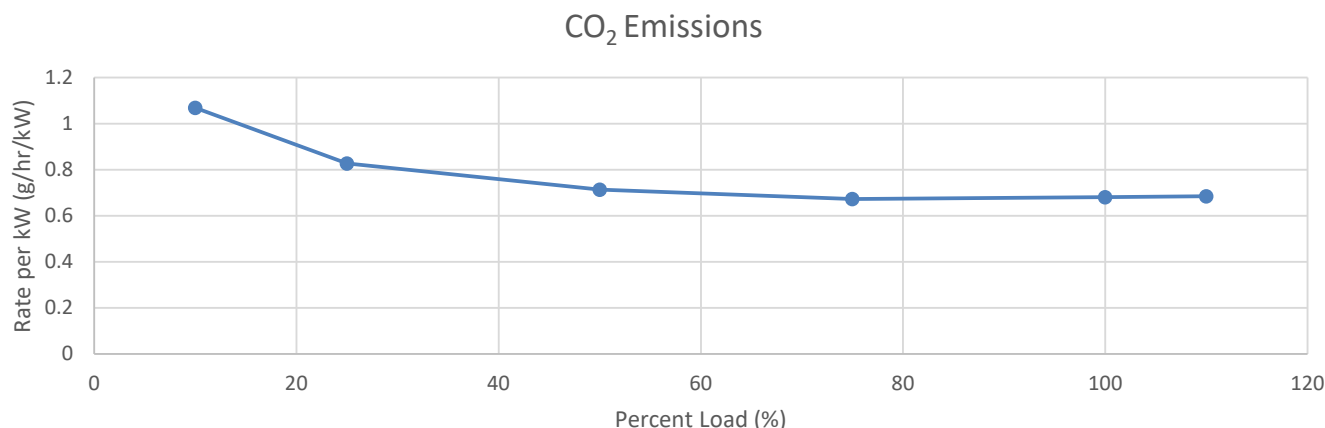
$C\text{-rate}_{\text{ave}} < C\text{-rate}_{\text{ave max}}$

$T_{\text{online @ switch}} > T_{\text{switch}}$

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Engine CO₂ Emissions

- To model the emissions of the different propulsion systems the engine and generator CO₂ emissions were calculated.
- Exhaust data was available for a 600kW C18 engine and a 550 ekW generator for loading percentages from 10% to 110%. These values were translated to a per/kW basis at each loading percentage and used to calculate emissions curves for the engines and generators used in this study.
- Power demands in between the percent loadings provided by the manufacturer were calculated by linear interpolation.
- The following curves show the emission data used to calculate the emission rate curves for each generator.



Electric Grid CO₂ Emissions:

- Emissions for shore charging was accounted for using emissions data for Maine's electrical grid.
- Emissions used data for the EPA subregion NEWE. Although Maine's electrical generation is cleaner than the subregion's, using the subregion data takes into account that Maine imports energy from other states and Canada during periods of high demand.

CO₂ Grid Emissions 539.30 lbs/MWh 0.2446 kg/kWh From EPA 2023 eGRID data

Fuel Production & Delivery ("Well-to-Tank") CO₂ Emissions

"Well-to-Tank" emissions are defined by the U.S. Department of Energy's National Renewable Energy Lab (NREL) as "emissions from fuel production at the primary source of energy (feedstock) to its delivery to the vehicle's energy storage system (e.g., fuel tank or battery)"

- Emissions are released during the production and transportation of the diesel fuel that is then consumed by the ferry. This is accounted for by including "Well-to-Tank" emissions.
- The CO₂ emissions for the fuel consumed is accounted for using data from NREL.
- Emissions data for diesel fuel were given on a g/mmBtu basis. This was converted to a kg/gal value for the fuel consumed for daily operations using the assumed energy content of the fuel used.

CO₂ Fuel Emissions 17700 g/mmBtu 2.25 kg/gal From NREL Annual Technology Baseline

Total Ferry Emissions

The total CO₂ emissions of the ferry or the "Well-to-Wake" emissions is calculated by the following equation:

Daily CO₂ Emissions (Well-to-Wake) = Engine Emissions + Grid Emissions + Fuel Production Emissions (Well-to-Tank)

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The following table is a list of assumptions that went into the controller design of the propulsion architectures.

Propulsion System	Value	Unit	Variable	Notes
<u>All Propulsion Systems</u>				
Base house power demand	30	ekW	P_{house}	From 7am to 30 minutes after last run returns to Portland.
Added Appendage resistance	1.1			
Shaft efficiency	0.98		η_{shaft}	
Prop efficiency	0.5		η_{prop}	
Fuel Blend Adjustment	1.0162			Due to lower BTU content of bio-diesel
<u>Diesel Mechanical System</u>				
Electrical power demand during maneuvering	100	ekW		Includes load from a bow thruster
House generator fuel rate at base load	3.00	gal/hr		C4.4 (72 ekW rated generator @ 30 ekW load)
House generator fuel rate during maneuvering	4.33	gal/hr per gen		C4.4 (72 ekW rated generator @ 50 ekW load)
Reduction gear efficiency	0.98		η_{gear}	
<u>Diesel Electric Systems</u>				
House generator fuel rate if applicable	3.1	gal/hr		C4.4 (45 ekW rated generator @ 30 ekW load)
Electrical efficiency	0.94		η_{elec}	Includes electrical distribution, transformers, power converters
Motor efficiency	0.98		η_{motor}	
Reduction gear efficiency	0.98		η_{gear}	
<u>Diesel Electric With Batteries System</u>				
Electrical efficiency	0.94		η_{elec}	Includes electrical distribution, transformers, power converters
Motor efficiency	0.98		η_{motor}	
Reduction gear efficiency	0.98		η_{gear}	
Battery cooling power per C-rate per installed kWh	0.0318	kW/C-rate/kWh	ρ	
"Sustained battery power" window size	5	min	T_{window}	
Minimum time b/w number of generators online can switch	10	min	$T_{min\ switch}$	
NMC battery efficiency	0.98		η_{batt}	
NMC maximum instantaneous C-rate	3		$C-rate_{max}$	
NMC maximum sustained C-rate	1.5		$C-rate_{ave\ max}$	
NMC maximum SoC	0.8		SoC_{max}	
NMC minimum SoC	0.4		SoC_{min}	
LFP battery efficiency	0.98		η_{batt}	
LFP maximum instantaneous C-rate	1		$C-rate_{max}$	
LFP maximum sustained C-rate	0.5		$C-rate_{ave\ max}$	
LFP maximum SoC	0.8		SoC_{max}	
LFP minimum SoC	0.1		SoC_{min}	
Initial SoC	0.8		$SoC(t=0)$	
Gen 1 On trigger	Min SoC + 0.3*DoD			DoD = depth of discharge
Gen 1 Off trigger	Min SoC + 1.0*DoD			DoD = depth of discharge
Gen 2 On trigger	Min SoC + 0.1*DoD			DoD = depth of discharge
Gen 2 Off trigger	Min SoC + 0.5*DoD			DoD = depth of discharge
Electricity Cost	0.11381	\$/kWh		Provided by client

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The following abbreviations are used:

1. MECH: Diesel mechanical system with 2 C18 engines (500 bkW each) and two house generators (72 ekW each)
2. DE C18s: This includes both the diesel electric system with 2 C18 generators (430 ekW each) and one house generator (45 ekW) and the diesel electric system with 3 C18s generators (430 ekW each) and one house generator (45 ekW)
3. DEWB NMC: Diesel electric system with 2 C18 generators (430 ekW each) and 1,000 kWh of NMC batteries
4. DEWB LFP: Diesel electric system with 2 C18 generators (430 ekW each) and 1,000 kWh of LFP batteries

The following tables are the test matrices used in the simulations of the propulsion systems

11 Knot Transit Speed & 7ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	406.08	24.50	17.73	0.00	4836.26
DE C18s	434.78	24.50	4.02	0.00	5380.56
DEWB NMC	413.28	13.01	0.00	242.04	5138.45
DEWB LFP	390.93	12.39	0.00	530.29	4931.12

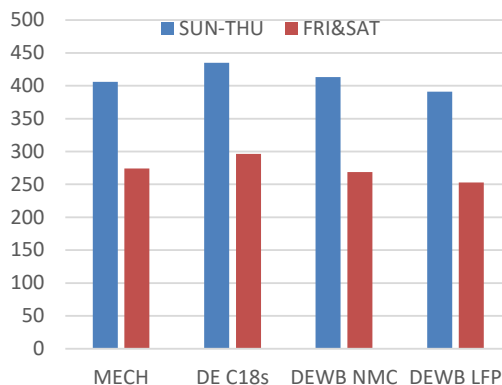
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	274.34	15.80	11.80	0.00	3268.27
DE C18s	296.39	15.80	2.97	0.00	3651.24
DEWB NMC	268.61	8.45	0.00	329.12	3381.73
DEWB LFP	252.72	8.04	0.00	534.29	3233.54

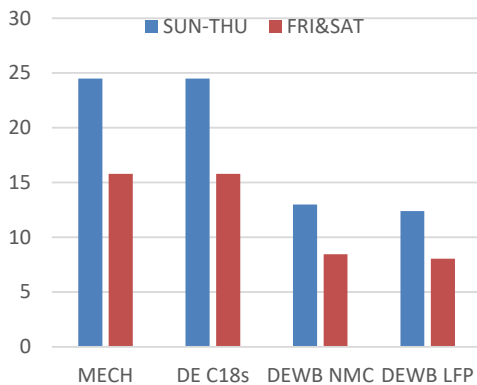
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	368.44	22.01	16.04	0.00	4388.26
DE C18s	395.24	22.01	3.72	0.00	4886.46
DEWB NMC	371.95	11.71	0.00	266.92	4636.53
DEWB LFP	351.44	11.15	0.00	531.44	4446.10

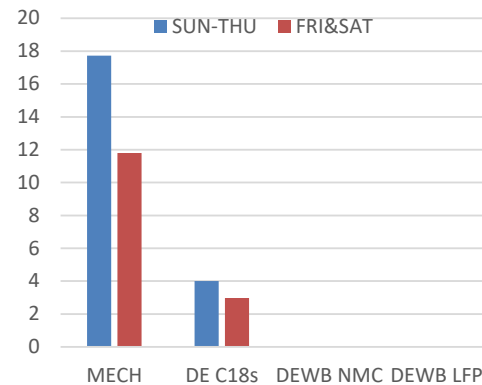
11 Knot - 7ft - Fuel Burned
(gal/day)



11 Knot - 7ft - Engine Hours
(hours/day)



11 Knot - 7ft - House Gen
Hours (hours/day)



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11 Knot Transit Speed & 6.5ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	393.56	24.50	17.73	0.00	4691.96
DE C18s	419.52	24.50	4.02	0.00	5176.46
DEWB NMC	395.53	12.45	0.00	248.47	4921.86
DEWB LFP	374.96	11.90	0.00	512.48	4730.20

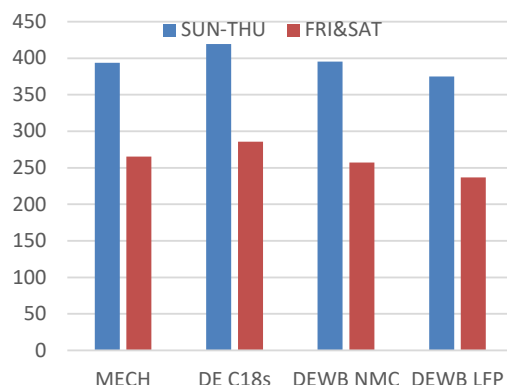
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	265.47	15.80	11.80	0.00	3166.08
DE C18s	285.58	15.80	2.97	0.00	3506.69
DEWB NMC	257.32	8.10	0.00	320.15	3240.83
DEWB LFP	236.75	7.55	0.00	584.17	3049.17

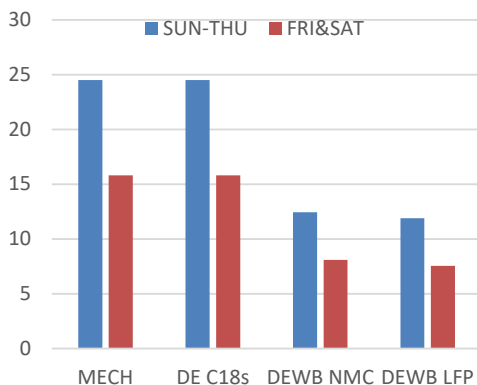
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	356.97	22.01	16.04	0.00	4256.00
DE C18s	381.25	22.01	3.72	0.00	4699.39
DEWB NMC	356.04	11.21	0.00	268.95	4441.57
DEWB LFP	335.47	10.65	0.00	532.96	4249.90

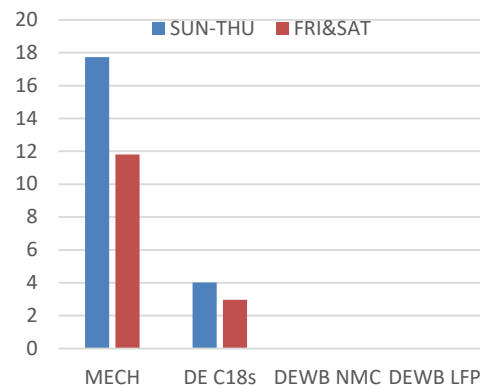
11 Knot - 6.5ft - Fuel Burned
(gal/day)



11 Knot - 6.5ft - Engine
Hours (hours/day)



11 Knot - 6.5ft - House Gen
Hours (hours/day)



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11 Knot Transit Speed & 6ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	379.95	24.50	17.73	0.00	4534.14
DE C18s	402.66	24.50	4.02	0.00	4952.59
DEWB NMC	384.81	12.11	0.00	134.76	4762.24
DEWB LFP	364.57	11.50	0.00	401.83	4578.58

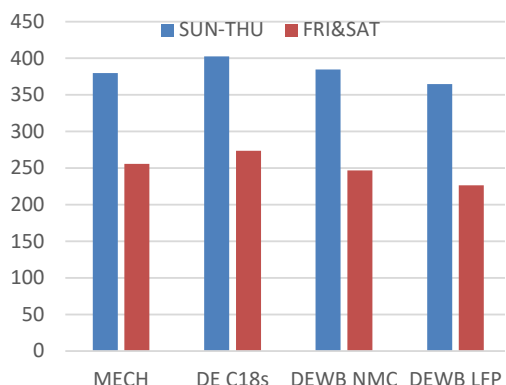
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	255.84	15.80	11.80	0.00	3054.31
DE C18s	273.63	15.80	2.97	0.00	3348.15
DEWB NMC	246.60	7.76	0.00	280.58	3099.35
DEWB LFP	226.37	7.15	0.00	547.65	2915.69

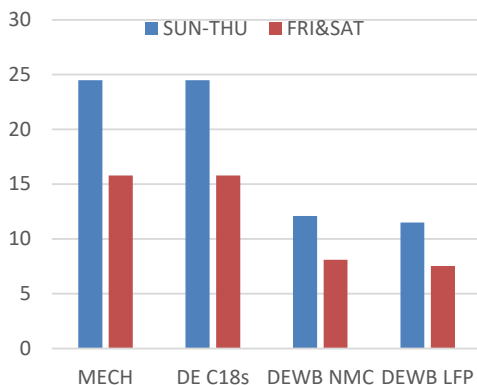
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	344.49	22.01	16.04	0.00	4111.33
DE C18s	365.79	22.01	3.72	0.00	4494.18
DEWB NMC	345.32	10.87	0.00	176.42	4287.13
DEWB LFP	325.09	10.25	0.00	443.49	4103.47

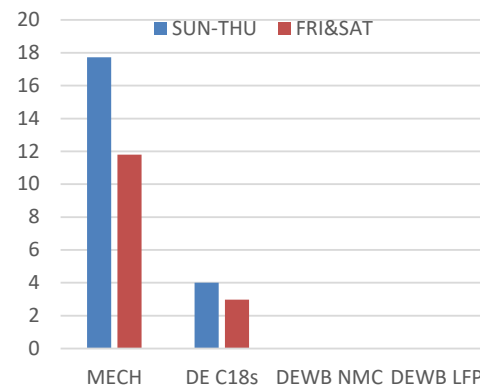
11 Knot - 6ft - Fuel Burned
(gal/day)



11 Knot - 6ft - Engine Hours
(hours/day)



11 Knot - 6ft - House Gen
Hours (hours/day)



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10 Knot Transit Speed & 7ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	334.03	25.33	17.77	0.00	3995.00
DE C18s	341.56	25.33	3.63	0.00	4271.65
DEWB NMC	306.95	9.66	0.00	265.86	3837.51
DEWB LFP	314.85	9.91	0.00	160.46	3908.75

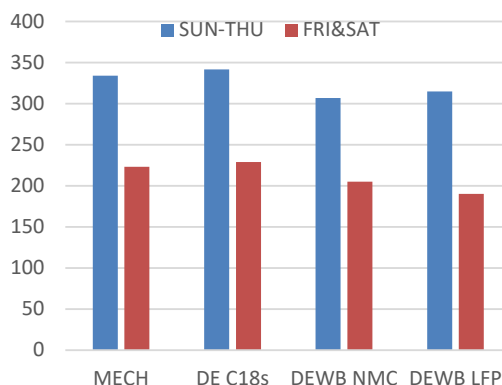
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	223.05	16.57	11.87	0.00	2668.54
DE C18s	229.14	16.57	2.65	0.00	2855.98
DEWB NMC	204.92	6.45	0.00	172.94	2560.73
DEWB LFP	190.21	5.99	0.00	382.62	2431.30

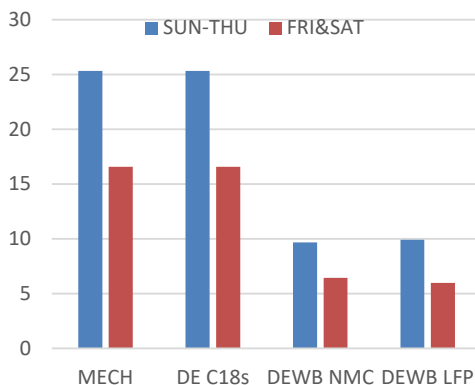
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	302.32	22.83	16.08	0.00	3616.01
DE C18s	309.44	22.83	3.35	0.00	3867.17
DEWB NMC	277.80	8.74	0.00	239.31	3472.72
DEWB LFP	279.24	8.79	0.00	223.93	3486.62

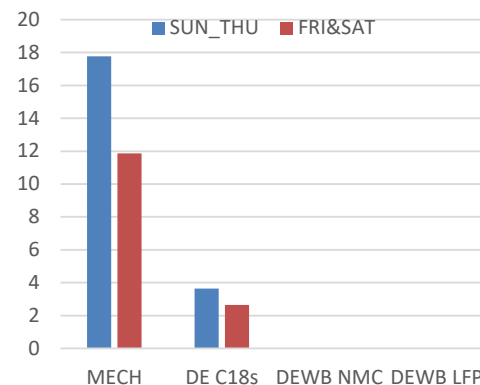
10 Knot - 7ft - Fuel Burned
(gal/day)



10 Knot - 7ft - Engine Hours
(hours/day)



10 Knot - 7ft - House Gen
Hours (hours/day)



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10 Knot Transit Speed & 6.5ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	328.32	25.33	17.77	0.00	3925.59
DE C18s	333.81	25.33	3.63	0.00	4186.66
DEWB NMC	299.07	9.41	0.00	264.46	3740.25
DEWB LFP	309.33	9.74	0.00	127.95	3832.94

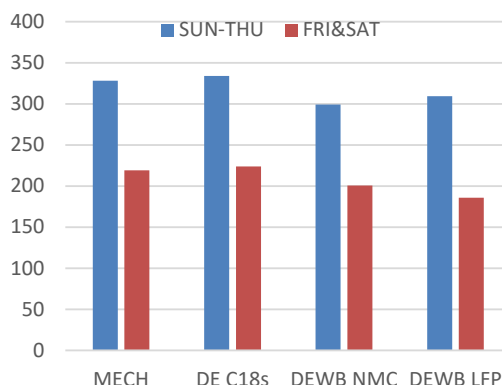
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	219.07	16.57	11.87	0.00	2620.26
DE C18s	223.75	16.57	2.65	0.00	2796.85
DEWB NMC	200.55	6.31	0.00	157.89	2503.35
DEWB LFP	185.82	5.85	0.00	367.81	2373.76

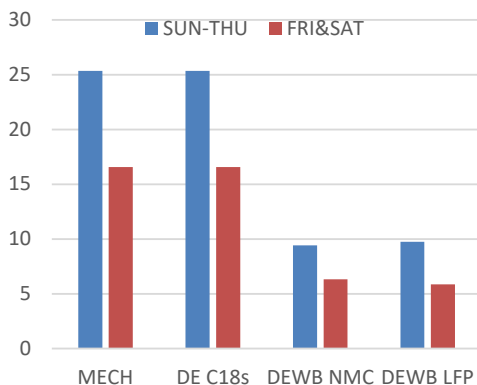
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	297.10	22.83	16.08	0.00	3552.64
DE C18s	302.36	22.83	3.35	0.00	3789.57
DEWB NMC	270.92	8.53	0.00	234.01	3386.85
DEWB LFP	274.04	8.63	0.00	196.48	3416.03

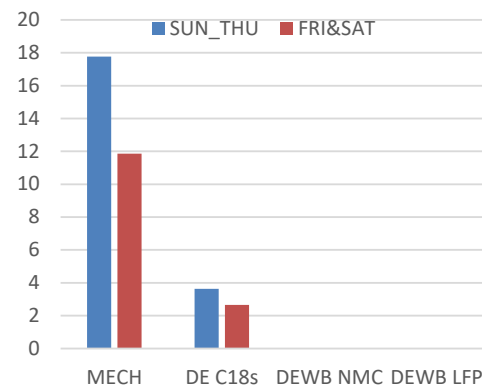
10 Knot - 6.5ft - Fuel Burned (gal/day)



10 Knot - 6.5ft - Engine Hours (hours/day)



10 Knot - 6.5ft - House Gen Hours (hours/day)



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10 Knot Transit Speed & 6ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	316.31	25.33	17.77	0.00	3779.19
DE C18s	317.35	25.33	3.63	0.00	4005.05
DEWB NMC	283.22	8.91	0.00	260.92	3544.61
DEWB LFP	297.49	9.36	0.00	67.10	3672.58

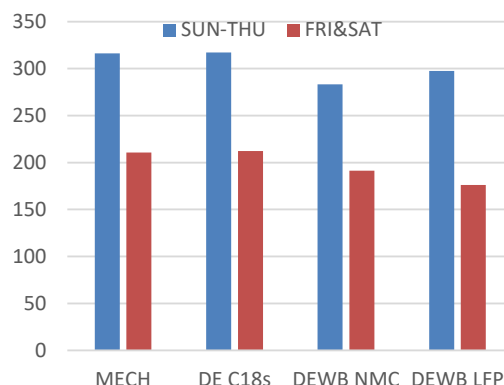
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	210.72	16.57	11.87	0.00	2518.42
DE C18s	212.30	16.57	2.65	0.00	2670.52
DEWB NMC	191.28	6.02	0.00	133.79	2383.60
DEWB LFP	176.13	5.54	0.00	343.95	2248.83

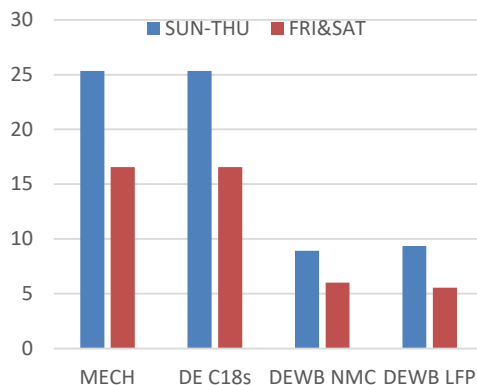
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	286.14	22.83	16.08	0.00	3418.97
DE C18s	287.33	22.83	3.35	0.00	3623.76
DEWB NMC	256.95	8.09	0.00	224.59	3212.89
DEWB LFP	262.82	8.27	0.00	146.20	3265.79

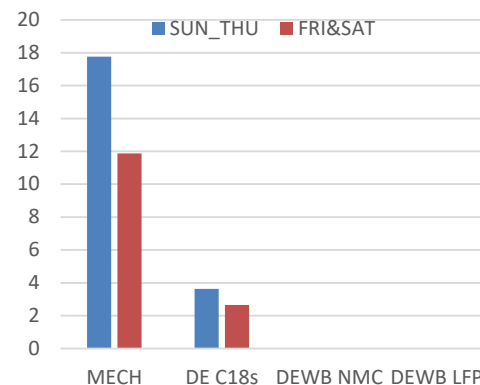
10 Knot - 6ft - Fuel Burned
(gal/day)



10 Knot - 6ft - Engine Hours
(hours/day)



10 Knot - 6ft - House Gen
Hours (hours/day)



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9 Knot Transit Speed & 7ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	291.07	27.07	17.78	0.00	3456.67
DE C18s	273.42	27.07	2.78	0.00	3563.16
DEWB NMC	243.53	7.67	0.00	211.24	3044.71
DEWB LFP	250.60	7.89	0.00	134.24	3112.69

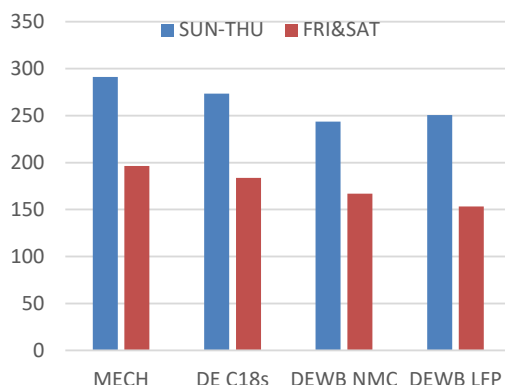
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	196.29	18.27	11.93	0.00	2331.71
DE C18s	183.63	18.27	1.87	0.00	2394.59
DEWB NMC	166.92	5.25	0.00	75.78	2070.05
DEWB LFP	153.30	4.82	0.00	277.83	1951.99

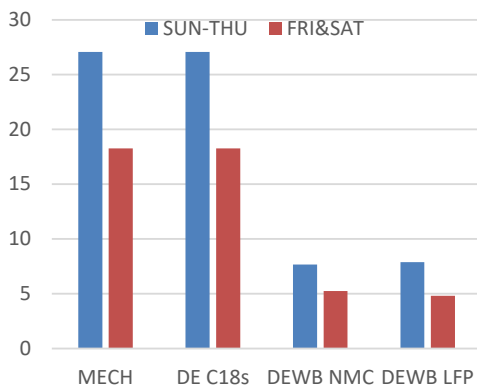
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	263.99	24.55	16.11	0.00	3135.26
DE C18s	247.76	24.55	2.52	0.00	3229.28
DEWB NMC	221.65	6.98	0.00	172.54	2766.23
DEWB LFP	222.80	7.01	0.00	175.27	2781.07

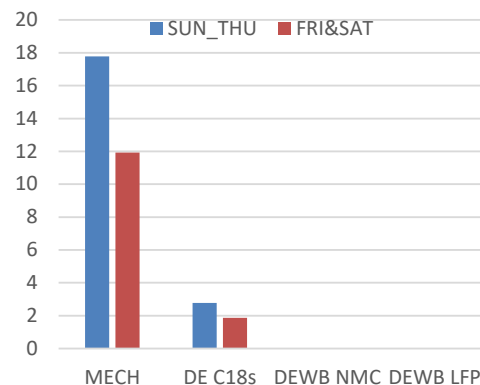
9 Knot - 7ft - Fuel Burned
(gal/day)



9 Knot - 7ft - Engine Hours
(hours/day)



9 Knot - 7ft - House Gen
Hours (hours/day)



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9 Knot Transit Speed & 6.5' Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	282.36	27.07	17.78	0.00	3338.27
DE C18s	260.77	27.07	2.78	0.00	3425.96
DEWB NMC	232.29	7.31	0.00	201.22	2904.09
DEWB LFP	235.18	7.40	0.00	179.45	2934.20

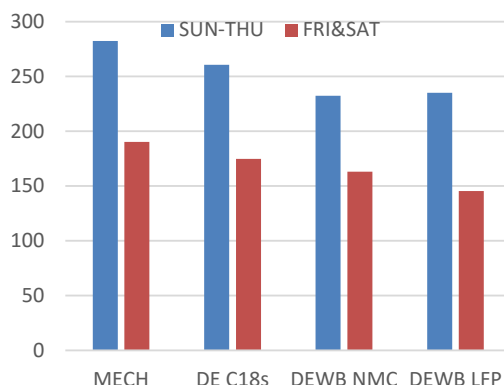
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	190.19	18.27	11.93	0.00	2248.74
DE C18s	174.76	18.27	1.87	0.00	2298.45
DEWB NMC	163.21	5.14	0.00	10.40	2008.44
DEWB LFP	145.36	4.58	0.00	269.42	1852.33

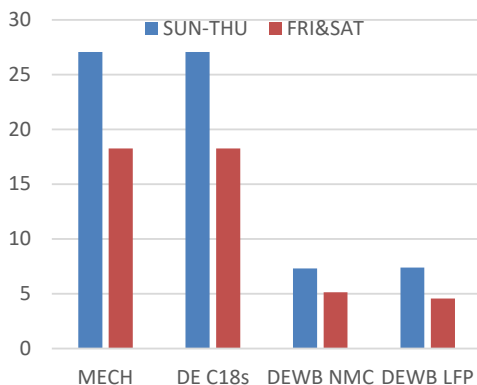
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	256.03	24.55	16.11	0.00	3026.97
DE C18s	236.20	24.55	2.52	0.00	3103.82
DEWB NMC	212.55	6.69	0.00	146.70	2648.19
DEWB LFP	209.51	6.59	0.00	205.15	2625.10

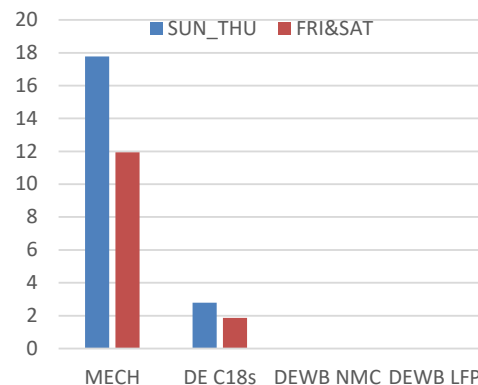
9 Knot - 6.5ft - Fuel Burned
(gal/day)



9 Knot - 6.5ft - Engine Hours
(hours/day)



9 Knot - 6.5ft - House Gen
Hours (hours/day)



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9 Knot Transit Speed & 6ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	277.02	27.07	17.78	0.00	3265.45
DE C18s	252.96	27.07	2.78	0.00	3341.46
DEWB NMC	225.09	7.08	0.00	196.69	2814.45
DEWB LFP	226.90	7.14	0.00	190.05	2835.08

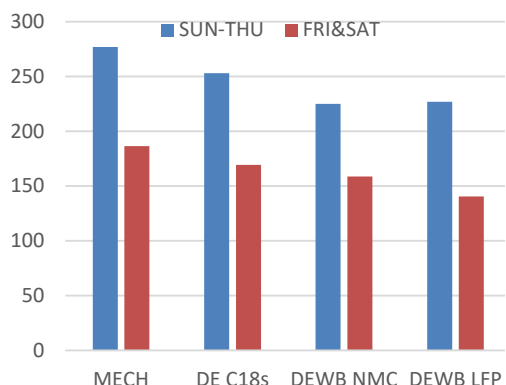
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	186.45	18.27	11.93	0.00	2197.71
DE C18s	169.29	18.27	1.87	0.00	2239.24
DEWB NMC	158.59	4.99	0.00	1.45	1949.40
DEWB LFP	140.57	4.42	0.00	262.42	1791.85

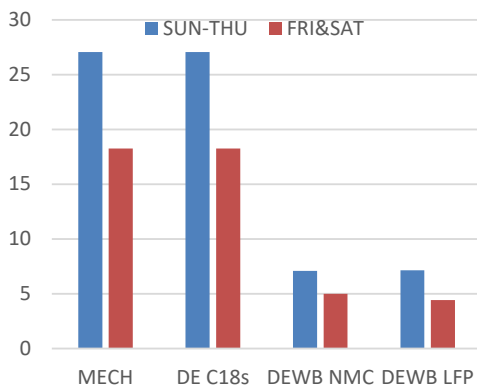
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	251.14	24.55	16.11	0.00	2960.38
DE C18s	229.05	24.55	2.52	0.00	3026.54
DEWB NMC	206.09	6.49	0.00	140.91	2567.29
DEWB LFP	202.23	6.37	0.00	210.73	2537.02

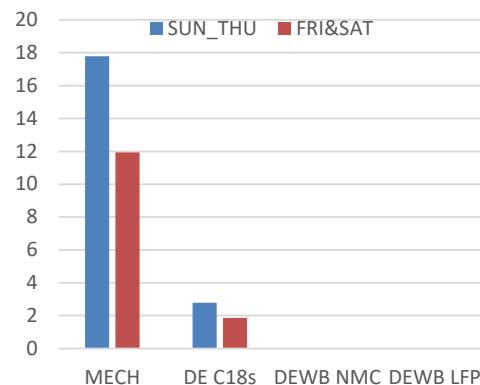
9 Knot - 6ft - Fuel Burned (gal/day)



9 Knot - 6ft - Engine Hours (hours/day)



9 Knot - 6ft - House Gen Hours (hours/day)



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8 Knot Transit Speed & 7ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	259.88	27.87	17.82	0.00	3013.99
DE C18s	224.53	27.87	2.42	0.00	3039.63
DEWB NMC	205.04	6.45	0.00	121.25	2549.64
DEWB LFP	201.97	6.36	0.00	172.40	2524.38

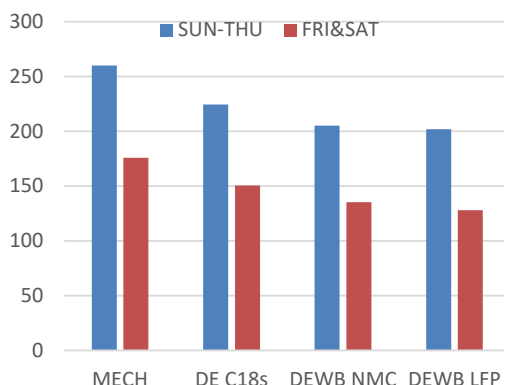
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	175.69	19.00	12.07	0.00	2036.07
DE C18s	150.47	19.00	1.63	0.00	2043.34
DEWB NMC	135.26	4.26	0.00	94.81	1685.52
DEWB LFP	127.86	4.02	0.00	202.34	1620.89

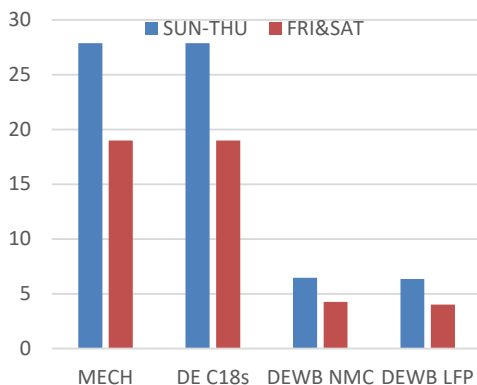
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	235.83	25.33	16.17	0.00	2734.58
DE C18s	203.37	25.33	2.19	0.00	2754.98
DEWB NMC	185.10	5.83	0.00	113.69	2302.75
DEWB LFP	180.80	5.69	0.00	180.95	2266.24

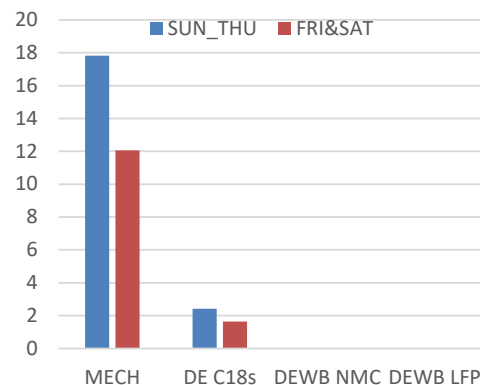
8 Knot - 7ft - Fuel Burned
(gal/day)



8 Knot - 7ft - Engine Hours
(hours/day)



8 Knot - 7ft - House Gen
Hours (hours/day)



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8 Knot Transit Speed & 6.5' Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	252.47	27.87	17.82	0.00	2911.43
DE C18s	213.31	27.87	2.42	0.00	2909.38
DEWB NMC	195.10	6.14	0.00	109.30	2424.52
DEWB LFP	200.21	6.30	0.00	49.11	2472.61

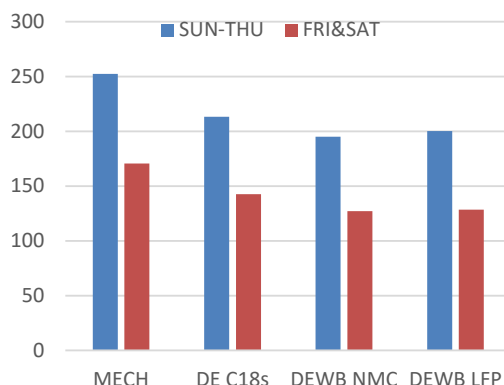
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	170.50	19.00	12.07	0.00	1964.30
DE C18s	142.62	19.00	1.63	0.00	1952.20
DEWB NMC	127.16	4.00	0.00	101.06	1587.57
DEWB LFP	128.50	4.04	0.00	90.54	1601.39

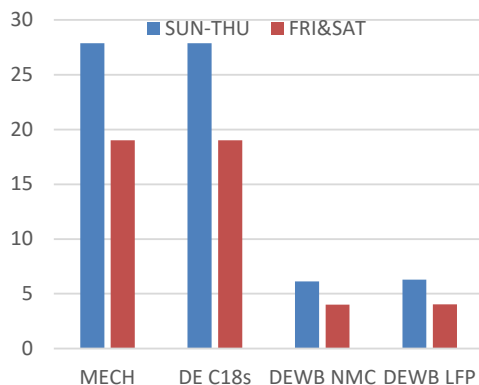
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	229.05	25.33	16.17	0.00	2640.82
DE C18s	193.12	25.33	2.19	0.00	2635.90
DEWB NMC	175.69	5.53	0.00	106.95	2185.39
DEWB LFP	179.72	5.66	0.00	60.95	2223.69

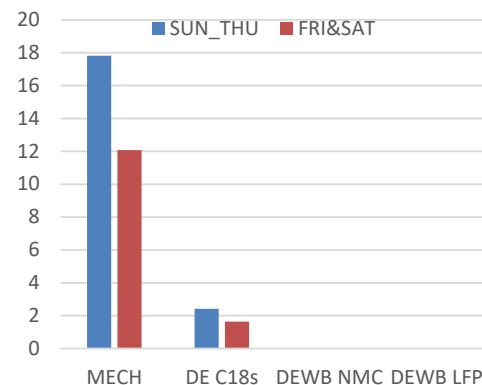
8 Knot - 6.5ft - Fuel Burned
(gal/day)



8 Knot - 6.5ft - Engine Hours
(hours/day)



8 Knot - 6.5ft - House Gen
Hours (hours/day)



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8 Knot Transit Speed & 6ft Draft: Daily Consumption and Emissions

Sunday - Thursday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	248.77	27.87	17.82	0.00	2860.18
DE C18s	207.69	27.87	2.42	0.00	2844.22
DEWB NMC	183.81	5.79	0.00	199.40	2307.83
DEWB LFP	195.83	6.16	0.00	37.90	2415.98

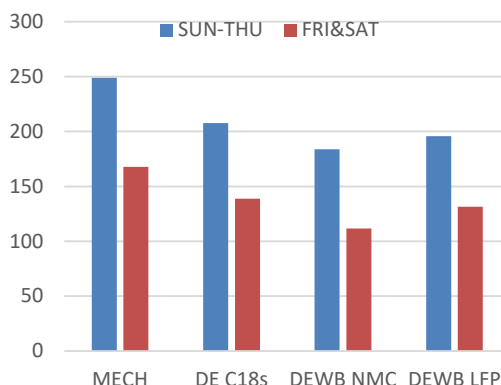
Friday & Saturday

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	167.91	19.00	12.07	0.00	1928.43
DE C18s	138.69	19.00	1.63	0.00	1906.60
DEWB NMC	111.59	3.51	0.00	263.66	1435.91
DEWB LFP	131.47	4.14	0.00	2.11	1616.23

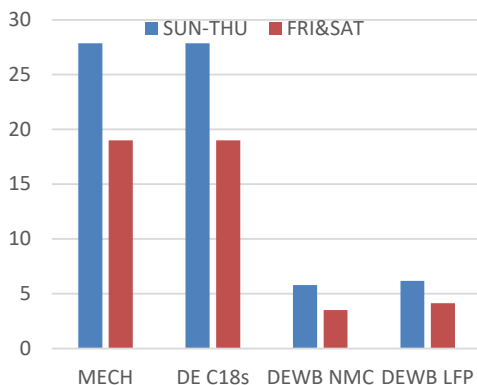
Daily Average

Propulsion System	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
MECH	225.67	25.33	16.17	0.00	2593.96
DE C18s	187.97	25.33	2.19	0.00	2576.33
DEWB NMC	163.18	5.14	0.00	217.76	2058.71
DEWB LFP	177.44	5.58	0.00	27.68	2187.48

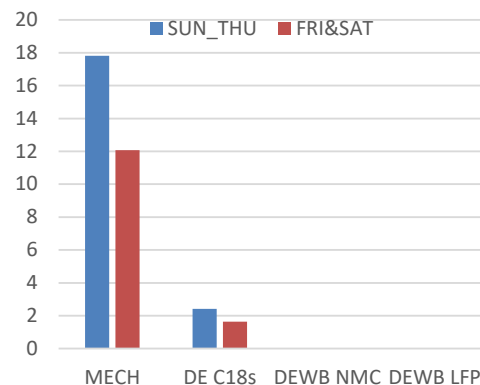
8 Knot - 6ft - Fuel Burned
(gal/day)



8 Knot - 6ft - Engine Hours
(hours/day)



8 Knot - 6ft - House Gen
Hours (hours/day)



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Summary of Results By Type of Propulsion System

Mechanical Propulsion System: Daily Consumption and Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
<u>7 ft Draft</u>					
11	368.44	22.01	16.04	0.00	4388.26
10	302.32	22.83	16.08	0.00	3616.01
9	263.99	24.55	16.11	0.00	3135.26
8	235.83	25.33	16.17	0.00	2734.58
<u>6.5 ft Draft</u>					
11	356.97	22.01	16.04	0.00	4256.00
10	297.10	22.83	16.08	0.00	3552.64
9	256.03	24.55	16.11	0.00	3026.97
8	229.05	25.33	16.17	0.00	2640.82
<u>6 ft Draft</u>					
11	344.49	22.01	16.04	0.00	4111.33
10	286.14	22.83	16.08	0.00	3418.97
9	251.14	24.55	16.11	0.00	2960.38
8	225.67	25.33	16.17	0.00	2593.96

Diesel Electric with 2 C18s Propulsion System: Daily Consumption and Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
<u>7 ft Draft</u>					
11	395.24	22.01	3.72	0.00	4886.46
10	309.44	22.83	3.35	0.00	3867.17
9	247.76	24.55	2.52	0.00	3229.28
8	203.37	25.33	2.19	0.00	2754.98
<u>6.5 ft Draft</u>					
11	381.25	22.01	3.72	0.00	4699.39
10	302.36	22.83	3.35	0.00	3789.57
9	236.20	24.55	2.52	0.00	3103.82
8	193.12	25.33	2.19	0.00	2635.90
<u>6 ft Draft</u>					
11	365.79	22.01	3.72	0.00	4494.18
10	287.33	22.83	3.35	0.00	3623.76
9	229.05	24.55	2.52	0.00	3026.54
8	187.97	25.33	2.19	0.00	2576.33

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Summary of Results By Type of Propulsion System, Continued

Diesel Electric with NMC Batteries Propulsion System: Daily Consumption and Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
<u>7 ft Draft</u>					
11	371.95	11.71	0.00	266.92	4636.53
10	277.80	8.74	0.00	239.31	3472.72
9	221.65	6.98	0.00	172.54	2766.23
8	185.10	5.83	0.00	113.69	2302.75
<u>6.5 ft Draft</u>					
11	356.04	11.21	0.00	268.95	4441.57
10	270.92	8.53	0.00	234.01	3386.85
9	212.55	6.69	0.00	146.70	2648.19
8	175.69	5.53	0.00	106.95	2185.39
<u>6 ft Draft</u>					
11	345.32	10.87	0.00	176.42	4287.13
10	256.95	8.09	0.00	224.59	3212.89
9	206.09	6.49	0.00	140.91	2567.29
8	163.18	5.14	0.00	217.76	2058.71

Diesel Electric with LFP Batteries Propulsion System: Daily Consumption and Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
<u>7 ft Draft</u>					
11	351.44	11.15	0.00	531.44	4446.10
10	279.24	8.79	0.00	223.93	3486.62
9	222.80	7.01	0.00	175.27	2781.07
8	180.80	5.69	0.00	180.95	2266.24
<u>6.5 ft Draft</u>					
11	335.47	10.65	0.00	532.96	4249.90
10	274.04	8.63	0.00	196.48	3416.03
9	209.51	6.59	0.00	205.15	2625.10
8	179.72	5.66	0.00	60.95	2223.69
<u>6 ft Draft</u>					
11	325.09	10.25	0.00	443.49	4103.47
10	262.82	8.27	0.00	146.20	3265.79
9	202.23	6.37	0.00	210.73	2537.02
8	177.44	5.58	0.00	27.68	2187.48

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Daily Consumption and Emissions Adjusted for Variable Vessel Drafts

Percentage of Time at Respective Draft:

7 ft Draft	50%
6.5 ft Draft	50%
6 ft Draft	0%

Mechanical Propulsion System: Average Daily Consumption and Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
11	362.70	22.01	16.04	0.00	4322.13
10	299.71	22.83	16.08	0.00	3584.32
9	260.01	24.55	16.11	0.00	3081.12
8	232.44	25.33	16.17	0.00	2687.70

Diesel Electric with 2 C18s Propulsion System: Average Daily Consumption and Engine Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
11	388.25	22.01	3.72	0.00	4792.92
10	305.90	22.83	3.35	0.00	3828.37
9	241.98	24.55	2.52	0.00	3166.55
8	198.24	25.33	2.19	0.00	2695.44

Diesel Electric with NMC Batteries Propulsion System: Average Daily Consumption and Engine Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
11	364.00	11.46	0.00	267.93	4539.05
10	274.36	8.64	0.00	236.66	3429.79
9	217.10	6.83	0.00	159.62	2707.21
8	180.40	5.68	0.00	110.32	2244.07

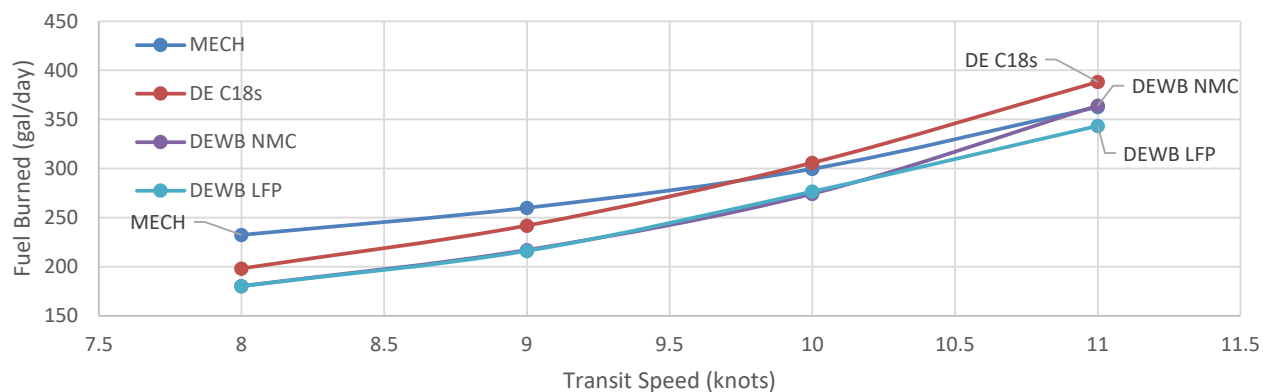
Diesel Electric with LFP Batteries Propulsion System: Average Daily Consumption and Engine Emissions

Speed (knots)	Simulated Fuel Burn (gal)	Simulated Engine Hours (hrs)	House Gen Engine Hours (hrs)	Grid Electricity Usage (kWh)	CO ₂ Emissions (kg)
11	343.46	10.90	0.00	532.20	4348.00
10	276.64	8.71	0.00	210.21	3451.33
9	216.16	6.80	0.00	190.21	2703.08
8	180.26	5.67	0.00	120.95	2244.97

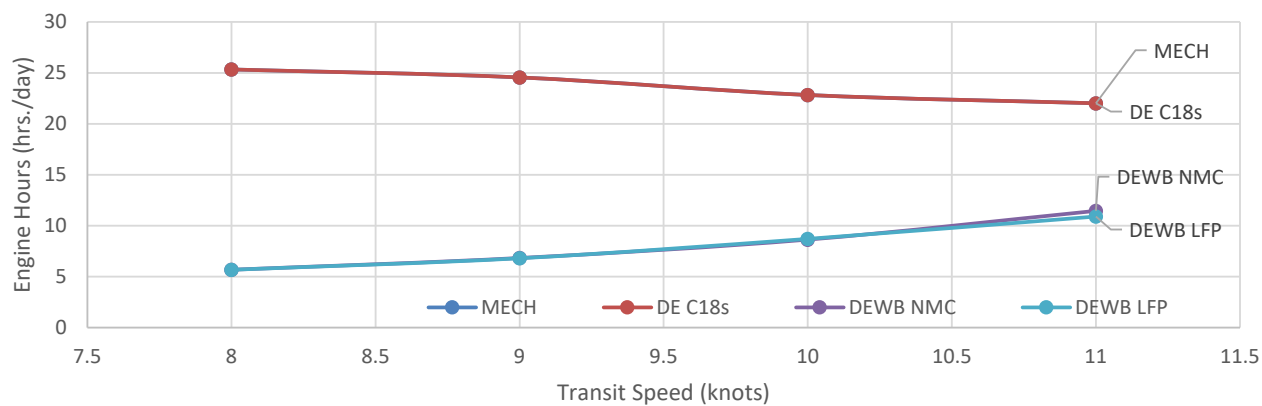
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Results versus Speed

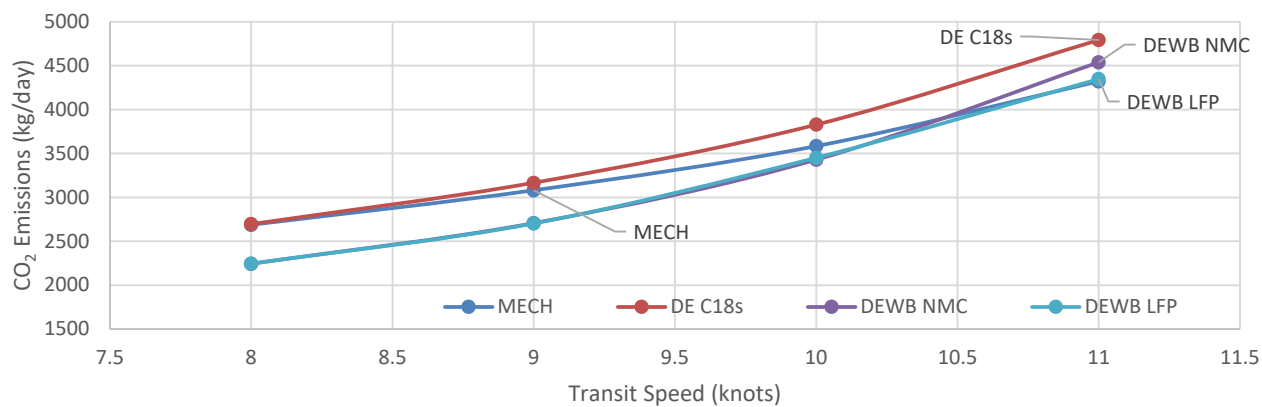
Average Daily Fuel Burned vs Transit Speed



Average Daily Engine Hours vs Transit Speed



Average Daily CO₂ Emissions vs Transit Speed



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Cost Inputs:

Fuel Costs	\$	3.40	
OPEX cost increase per year		2.57%	
Days Operational/year		340.5	
Simulation Length		1	days
Lifetime of Vessel		30	years
Cost per Main Engine Hour (Daily)	\$	4.65	\$/engine hour
Cost per Main Engine Hour (Infrequent)	\$	3.77	\$/engine hour
Cost per House Gen Hour	\$	1.50	\$/engine hour
NMC Battery Replacement (3x over lifetime of vessel)		\$750	\$/kWh
LFP Battery Replacement (2x over lifetime of vessel)		\$500	\$/kWh
Mechanical Construction Costs		\$15,200,000	
DE (2 C18s) w/ HG Construction Costs		\$16,554,000	
DE (3 C18s) w/ HG Construction Costs		\$16,726,000	
DEWB Construction Costs (1MWh NMC)		\$17,724,000	
DEWB Construction Costs (1MWh LFP)		\$17,474,000	
Electric Motors Replacement Costs		\$5,000	\$/year
Electricity delivery rate		0.11381	\$/kWh

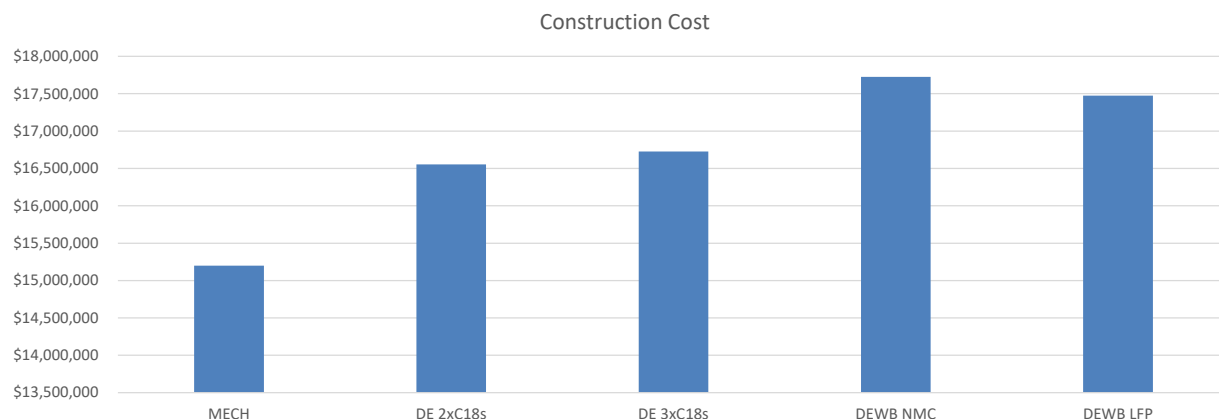
80% diesel at \$3.50/gal. 20% bio-diesel at \$3/gal
OPEX inflation adjustment over lifetime of vessel (average inflation over last 40 years)
365-3.5 weeks (Reported 6-8 week drydock every other year)

\$30k / 20,000 hrs

\$75.00 \$/year/kWh \$75,000 \$/year

\$33.33	\$/year/kWh	\$33,333	\$/year
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Replace 2x motors at \$75k each once over lifetime



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11 Knot Transit Speed

Average Daily/Yearly Values

Propulsion System	Avg. Daily Engine Hours (hrs)	Yearly Engine Hours (hrs)	Avg. Daily House Gen Hours (hrs)	Yearly House Gen Hours (hrs)	Avg. Daily Fuel Burned (gal)	Yearly Fuel Burn (gal)	Daily Electricity Usage (kWh)	Daily Cost of Electricity
MECH	22.01	7495.86	16.04	5461.00	362.70	123499.91	0.00	\$ -
DE C18s	22.01	7495.86	3.72	1265.55	388.25	132197.93	0.00	\$ -
DEWB NMC	11.46	3900.97	0.00	0.00	364.00	123940.38	267.93	\$ 30.49
DEWB LFP	10.90	3712.02	0.00	0.00	343.46	116947.21	532.20	\$ 60.57

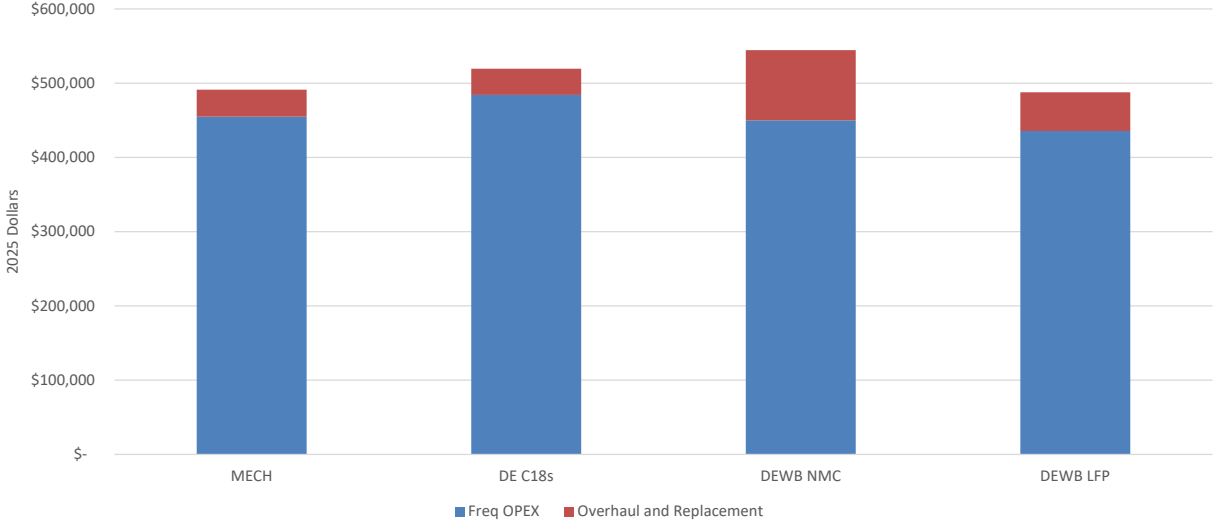
Year 1 Cost Calculations

Propulsion System	Frequent OPEX				Equipment Overhaul and Replacement Costs						Year 1 Total OPEX
	Year 1 Freq. Main Eng/Gen Maint. Costs	Year 1 Fuel Costs	Year 1 Electricity Cost	Year 1 Freq. OPEX	Year 1 Infreq. Main Eng/Gen Maint. Costs	Year 1 House Gen Maint. Costs	Year 1 Motor Cost	Year 1 Battery Cost	Year 1 Infreq. OPEX		
MECH	\$ 34,856	\$419,900	\$0	\$ 454,755	\$ 28,272	\$ 8,191.50	\$0	\$0	\$ 36,463	\$ 491,219	
DE C18s	\$ 34,856	\$449,473	\$0	\$ 484,329	\$ 28,272	\$ 1,898.33	\$5,000	\$0	\$ 35,170	\$ 519,499	
DEWB NMC	\$ 18,140	\$421,397	\$10,383	\$ 449,920	\$ 14,713	-	\$5,000	\$75,000	\$ 94,713	\$ 544,633	
DEWB LFP	\$ 17,261	\$397,620	\$20,624	\$ 435,505	\$ 14,000	-	\$5,000	\$33,333	\$ 52,334	\$ 487,839	

Lifetime Cost Calculations

Propulsion System	Capital Costs	Year 1 OPEX Cost (ex. Batteries)	Lifetime Maint. Cost (inc inflation)	Lifetime Battery Replacement Cost (no inflation)	Total Costs
MECH	\$ 15,200,000	\$ 491,219	\$ 22,741,771	\$ -	\$ 37,941,771
DE 2xC18s	\$ 16,554,000	\$ 519,499	\$ 24,051,044	\$ -	\$ 40,605,044
DE 3xC18s	\$ 16,726,000	\$ 519,499	\$ 24,051,044	\$ -	\$ 40,777,044
DEWB NMC	\$ 17,724,000	\$ 469,633	\$ 21,742,417	\$ 2,250,000	\$ 41,716,417
DEWB LFP	\$ 17,474,000	\$ 454,506	\$ 21,042,081	\$ 1,000,000	\$ 39,516,081

11 Knot: Year 1 Operational Cost



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10 Knot Transit Speed

Average Daily/Yearly Values

Propulsion System	Avg. Daily Engine Hours (hrs)	Yearly Engine Hours (hrs)	Avg. Daily House Gen Hours (hrs)	Yearly House Gen Hours (hrs)	Avg. Daily Fuel Burned (gal)	Yearly Fuel Burn (gal)	Daily Electricity Usage (kWh)	Daily Cost of Electricity
MECH	22.83	7773.13	16.08	5475.59	299.71	102052.15	0.00	\$ -
DE C18s	22.83	7773.13	3.35	1141.51	305.90	104159.00	0.00	\$ -
DEWB NMC	8.64	2940.34	0.00	0.00	274.36	93419.68	236.66	\$ 26.93
DEWB LFP	8.71	2964.83	0.00	0.00	276.64	94195.71	210.21	\$ 23.92

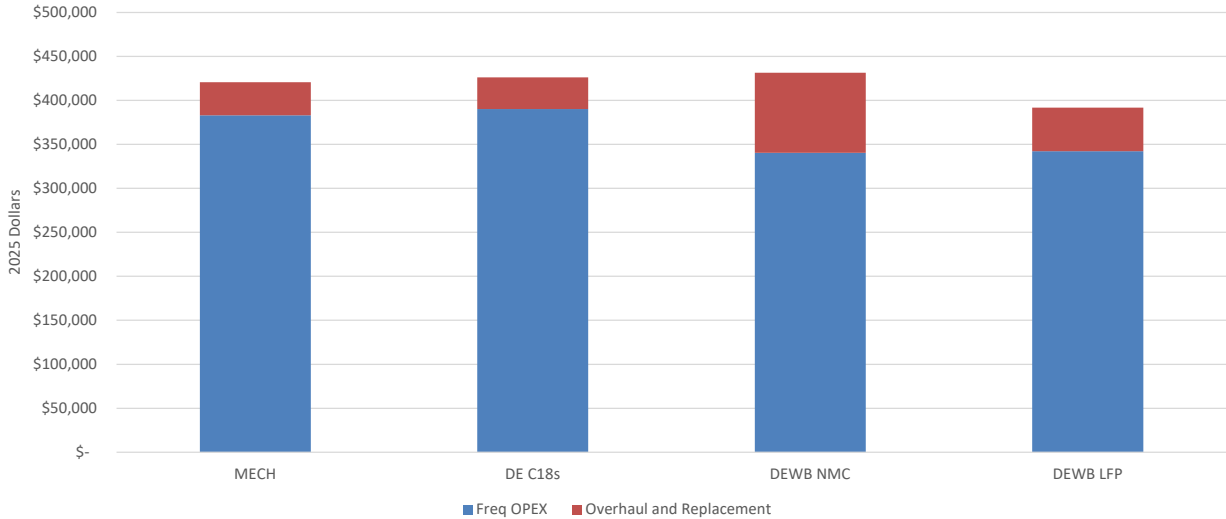
Year 1 Cost Calculations

Propulsion System	Frequent OPEX				Equipment Overhaul and Replacement Costs						Year 1 Total OPEX
	Year 1 Freq. Main Eng/Gen Maint. Costs	Year 1 Fuel Costs	Year 1 Electricity Cost	Year 1 Freq. OPEX	Year 1 Infreq. Main Eng/Gen Maint. Costs	Year 1 House Gen Maint. Costs	Year 1 Motor Cost	Year 1 Battery Cost	Year 1 Infreq. OPEX		
MECH	\$ 36,145	\$346,977	\$0	\$ 383,122	\$ 29,318	\$ 8,213.39	\$0	\$0	\$ 37,531	\$ 420,653	
DE C18s	\$ 36,145	\$354,141	\$0	\$ 390,286	\$ 29,318	\$ 1,712.27	\$5,000	\$0	\$ 36,030	\$ 426,316	
DEWB NMC	\$ 13,673	\$317,627	\$9,171	\$ 340,471	\$ 11,090	-	\$5,000	\$75,000	\$ 91,090	\$ 431,561	
DEWB LFP	\$ 13,786	\$320,265	\$8,146	\$ 342,198	\$ 11,182	-	\$5,000	\$33,333	\$ 49,516	\$ 391,714	

Lifetime Cost Calculations

Propulsion System	Capital Costs	Year 1 OPEX Cost (ex. Batteries)	Lifetime Maint. Cost (inc inflation)	Lifetime Battery Replacement Cost (no inflation)	Total Costs
MECH	\$ 15,200,000	\$ 420,653	\$ 19,474,828	\$ -	\$ 34,674,828
DE 2xC18s	\$ 16,554,000	\$ 426,316	\$ 19,736,968	\$ -	\$ 36,290,968
DE 3xC18s	\$ 16,726,000	\$ 426,316	\$ 19,736,968	\$ -	\$ 36,462,968
DEWB NMC	\$ 17,724,000	\$ 356,561	\$ 16,507,554	\$ 2,250,000	\$ 36,481,554
DEWB LFP	\$ 17,474,000	\$ 358,380	\$ 16,591,792	\$ 1,000,000	\$ 35,065,792

10 Knot: Year 1 Operational Cost



PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Ferry Propulsion System Analysis Calcs: Cost Calculations		Date:	03NOV25	Checked:	JSS

9 Knot Transit Speed

Average Daily/Yearly Values

Propulsion System	Avg. Daily Engine Hours (hrs)	Yearly Engine Hours (hrs)	Avg. Daily House Gen Hours (hrs)	Yearly House Gen Hours (hrs)	Avg. Daily Fuel Burned (gal)	Yearly Fuel Burn (gal)	Daily Electricity Usage (kWh)	Daily Cost of Electricity
MECH	24.55	8360.09	16.11	5486.13	260.01	88532.80	0.00	\$ -
DE C18s	24.55	8360.09	2.52	858.57	241.98	82394.04	0.00	\$ -
DEWB NMC	6.83	2326.68	0.00	0.00	217.10	73922.60	159.62	\$ 18.17
DEWB LFP	6.80	2316.55	0.00	0.00	216.16	73600.84	190.21	\$ 21.65

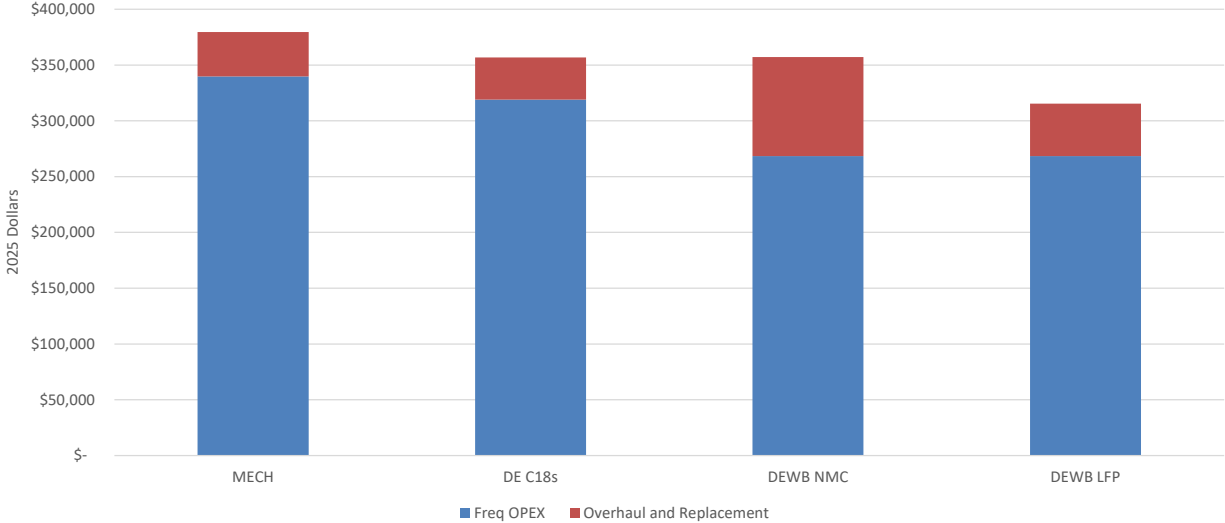
Year 1 Cost Calculations

Propulsion System	Frequent OPEX				Equipment Overhaul and Replacement Costs						Year 1 Total OPEX
	Year 1 Freq. Main Eng/Gen Maint. Costs	Year 1 Fuel Costs	Year 1 Electricity Cost	Year 1 Freq. OPEX	Year 1 Infreq. Main Eng/Gen Maint. Costs	Year 1 House Gen Maint. Costs	Year 1 Motor Cost	Year 1 Battery Cost	Year 1 Infreq. OPEX		
MECH	\$ 38,874	\$301,012	\$0	\$ 339,886	\$ 31,531	\$ 8,229.20	\$0	\$0	\$ 39,761	\$ 379,647	
DE C18s	\$ 38,874	\$280,140	\$0	\$ 319,014	\$ 31,531	\$ 1,287.86	\$5,000	\$0	\$ 37,819	\$ 356,833	
DEWB NMC	\$ 10,819	\$251,337	\$6,186	\$ 268,342	\$ 8,775	-	\$5,000	\$75,000	\$ 88,775	\$ 357,117	
DEWB LFP	\$ 10,772	\$250,243	\$7,371	\$ 268,386	\$ 8,737	-	\$5,000	\$33,333	\$ 47,071	\$ 315,457	

Lifetime Cost Calculations

Propulsion System	Capital Costs	Year 1 OPEX Cost (ex. Batteries)	Lifetime Maint. Cost (inc inflation)	Lifetime Battery Replacement Cost (no inflation)	Total Costs
MECH	\$ 15,200,000	\$ 379,647	\$ 17,576,351	\$ -	\$ 32,776,351
DE 2xC18s	\$ 16,554,000	\$ 356,833	\$ 16,520,182	\$ -	\$ 33,074,182
DE 3xC18s	\$ 16,726,000	\$ 356,833	\$ 16,520,182	\$ -	\$ 33,246,182
DEWB NMC	\$ 17,724,000	\$ 282,117	\$ 13,061,062	\$ 2,250,000	\$ 33,035,062
DEWB LFP	\$ 17,474,000	\$ 282,123	\$ 13,061,350	\$ 1,000,000	\$ 31,535,350

9 Knot: Year 1 Operational Cost



PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL	
CALC:	Ferry Propulsion System Analysis Calcs: Cost Calculations			Date:	03NOV25	Checked:	JSS

8 Knot Transit Speed

Average Daily/Yearly Values

Propulsion System	Avg. Daily Engine Hours (hrs)	Yearly Engine Hours (hrs)	Avg. Daily House Gen Hours (hrs)	Yearly House Gen Hours (hrs)	Avg. Daily Fuel Burned (gal)	Yearly Fuel Burn (gal)	Daily Electricity Usage (kWh)	Daily Cost of Electricity
MECH	25.33	8626.00	16.17	5507.21	232.44	79144.85	0.00	\$ -
DE C18s	25.33	8626.00	2.19	746.69	198.24	67502.11	0.00	\$ -
DEWB NMC	5.68	1933.33	0.00	0.00	180.40	61425.20	110.32	\$ 12.56
DEWB LFP	5.67	1931.85	0.00	0.00	180.26	61377.98	120.95	\$ 13.77

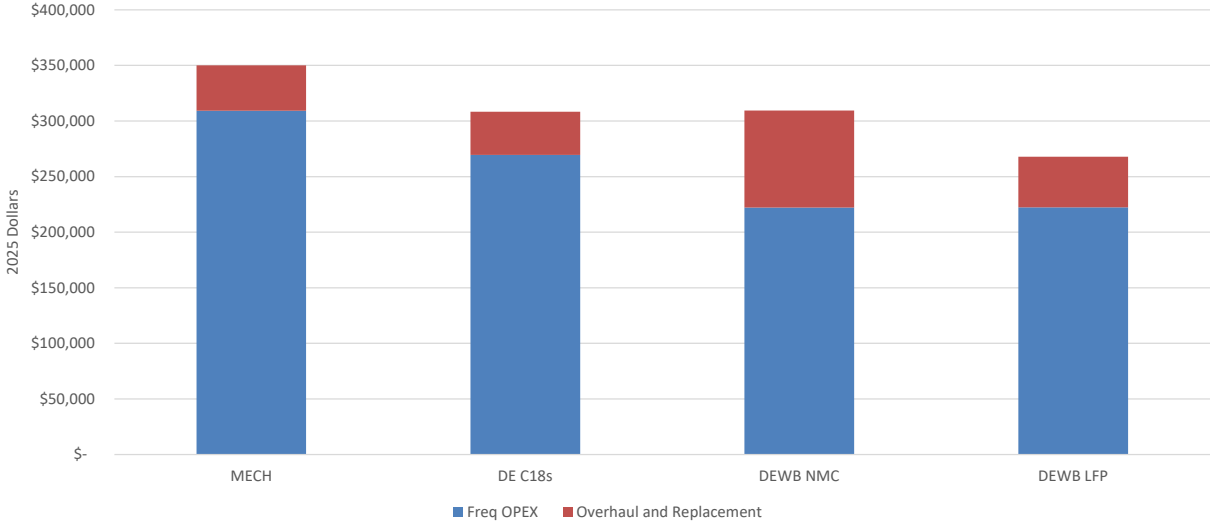
Year 1 Cost Calculations

Propulsion System	Frequent OPEX				Equipment Overhaul and Replacement Costs						Year 1 Total OPEX	
	Year 1 Freq. Main		Year 1 Electricity		Year 1 Infreq. Main	Year 1 House Gen	Year 1 Battery	Year 1 Infreq.				
	Eng/Gen Maint.	Costs	Year 1 Fuel Costs	Cost	Year 1 Freq. OPEX	Eng/Gen Maint. Costs	Maint. Costs	Year 1 Motor Cost	Cost	OPEX		
MECH	\$	40,111	\$269,092	\$0	\$ 309,203	\$	32,534	\$ 8,260.81	\$0	\$0	\$ 40,795	\$ 349,999
DE C18s	\$	40,111	\$229,507	\$0	\$ 269,618	\$	32,534	\$ 1,120.04	\$5,000	\$0	\$ 38,654	\$ 308,273
DEWB NMC	\$	8,990	\$208,846	\$4,275	\$ 222,111	\$	7,292	\$ -	\$5,000	\$75,000	\$ 87,292	\$ 309,403
DEWB LFP	\$	8,983	\$208,685	\$4,687	\$ 222,355	\$	7,286	\$ -	\$5,000	\$33,333	\$ 45,620	\$ 267,975

Lifetime Cost Calculations

Propulsion System	Capital Costs	Year 1 OPEX Cost (ex. Batteries)	Lifetime Maint. Cost (inc inflation)	Lifetime Battery Replacement Cost (no inflation)	Total Costs
MECH	\$ 15,200,000	\$ 349,999	\$ 16,203,751	\$ -	\$ 31,403,751
DE 2xC18s	\$ 16,554,000	\$ 308,273	\$ 14,271,975	\$ -	\$ 30,825,975
DE 3xC18s	\$ 16,726,000	\$ 308,273	\$ 14,271,975	\$ -	\$ 30,997,975
DEWB NMC	\$ 17,724,000	\$ 234,403	\$ 10,852,052	\$ 2,250,000	\$ 30,826,052
DEWB LFP	\$ 17,474,000	\$ 234,642	\$ 10,863,113	\$ 1,000,000	\$ 29,337,113

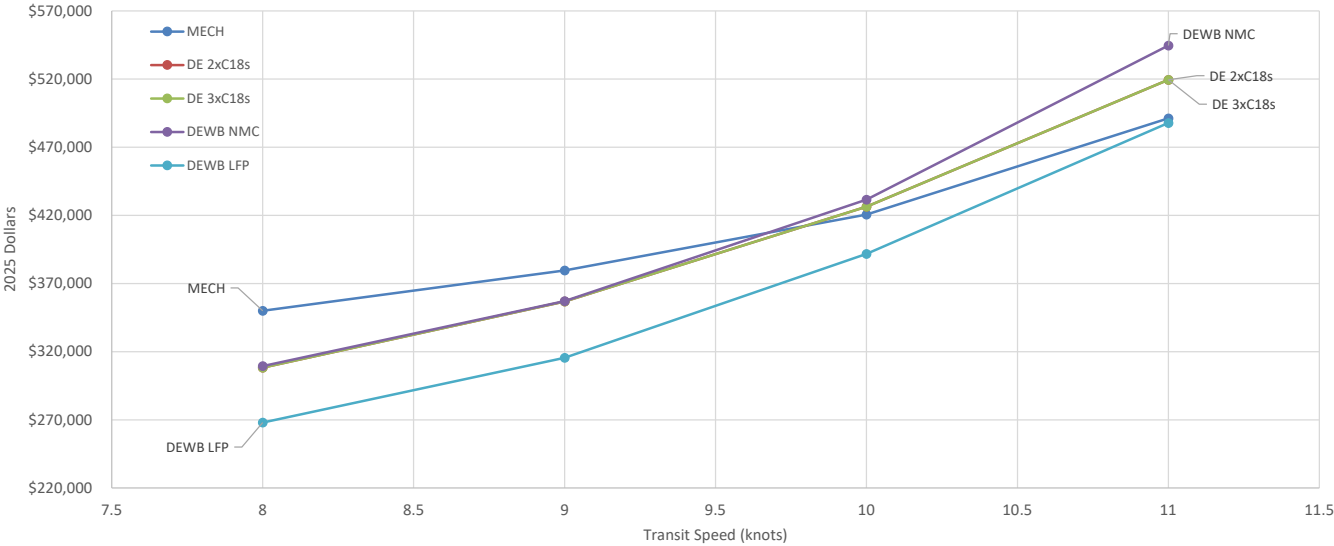
8 Knot: Year 1 Operational Cost



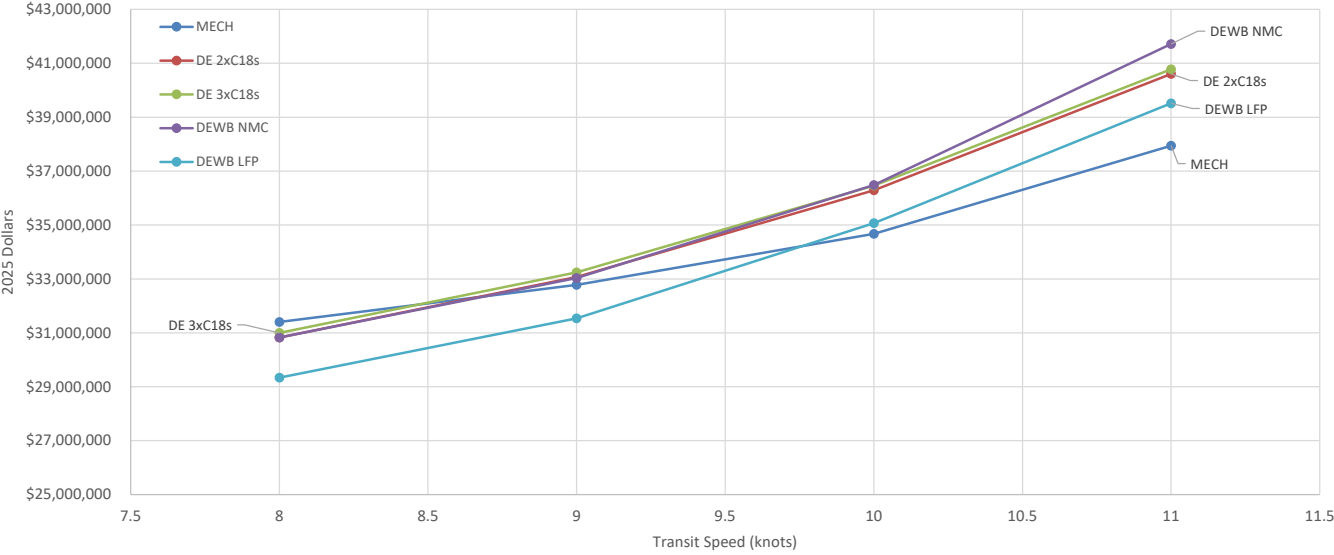
PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL	
CALC:	Ferry Propulsion System Analysis Calcs: Cost Calculations			Date:	03NOV25	Checked:	JSS

Results versus Speed

Year 1 Operational Cost vs Transit Speed



Relative Total Lifetime Cost vs Transit Speed



PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Ferry Propulsion System Analysis Calcs: Supporting Calculations		Date:	03NOV25	Checked:	JSS

Supporting Calculations:

MECH	Cost/unit	Qty	Total
Baseline Vessel Cost	\$ 14,930,000	1	\$ 14,930,000
Prime Mover	\$ 105,000	2	\$ 210,000
Ship Service Generators	\$ 30,000	2	\$ 60,000
Total:			\$ 15,200,000

DE 2 C18s	Cost/unit	Qty	Total
Baseline Vessel Cost	\$ 14,930,000	1	\$ 14,930,000
Generators:	\$ 172,000	2	\$ 344,000
AC Motor:	\$ 50,000	2	\$ 100,000
Propulsion Switchboard	\$ 750,000	1	\$ 750,000
VFD Drives	\$ 100,000	4	\$ 400,000
Ship Service Generators	\$ 30,000	1	\$ 30,000
Total:			\$ 16,554,000

DE 3 C18s	Cost/unit	Qty	Total
Baseline Vessel Cost	\$ 14,930,000	1	\$ 14,930,000
Generators:	\$ 172,000	3	\$ 516,000
AC Motor:	\$ 50,000	2	\$ 100,000
Propulsion Switchboard	\$ 750,000	1	\$ 750,000
VFD Drives	\$ 100,000	4	\$ 400,000
Ship Service Generators	\$ 30,000	1	\$ 30,000
Total:			\$ 16,726,000

DEWB	Cost/unit	Qty	Total
Baseline Vessel Cost	\$ 14,930,000	1	\$ 14,930,000
Generators:	\$ 172,000	2	\$ 344,000
AC Motor:	\$ 50,000	2	\$ 100,000
Propulsion Switchboard	\$ 750,000	1	\$ 750,000
Battery Room Equipment (HVAC, Monitors, Sensors, Insulation)	\$ 300,000	1	\$ 300,000
Additional Fire Protection	\$ 150,000	1	\$ 150,000
VFD Drives	\$ 100,000	4	\$ 400,000
Batteries	\$500-750/kWh	1000 kWh	Varies
Total:			\$ 16,974,000

+ Battery cost

Engine Maintenance Cost Calculation:			
This calculation is based on a 300kW engine. This is assumed the same for all options, whether its powering a generator or directly to the shaft			
Items	Hours	Cost	\$/hr
Frequent Engine Maintenance			
250 Hour Service	250	\$650	\$2.60
500 Hours	500	\$650	\$1.30
1000 Hour Service	1000	\$750	\$0.75
Total:		\$/hr	\$4.65
Infrequent Engine Maintenance			
Zero Hour Overhaul	25000	\$43,500	\$1.74
Coolant System Change	12000	\$1,900	\$0.16
3000 Hour	3000	\$1,900	\$0.63
Top End Overhaul	5000	\$6,200	\$1.24
Total:		\$/hr	\$3.77
Total Cost per Hour			
Total:		\$/hr	\$8.42

Fuel	BTU/gal
Diesel	128,748.00
Bio-Diesel (B100)	119,550.00
80-20 Blend	126,908.40

APPENDIX II

23494-199-2 Ferry Operational Profile Calculations

REVISION HISTORY					
REV	ZONE	DESCRIPTION	DATE	BY	CHECK
0	-	1. INTIAL RELEASE	03NOV25	MDL	JSS

GENERAL NOTES

-

5	23494-199-5	Propulsion Systems Simulation Results
4	23494-199-4	Propulsion System Reliability Calculations
3	23494-199-3	Feasibility Study Calculations
2	23494-199-1	Ferry Propulsion System Analysis Calcs
1	23494-099-1	Ferry Propulsion System Feasibility Study
NO.	DRAWING	TITLE

REFERENCES

TITLE: FERRY OPERATIONAL PROFILE CALCS		
FOR: CASCO BAY LINES		
VESSEL:	MAQUOIT II REPLACEMENT	HULL NO: -
DATE	03NOV25	SCALE: N.T.S.
DWG. NO:	23494-199-2	REV: 0
DRAWN BY:	MDL	CHECK BY: JSS



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THE SHEARER GROUP

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PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: Overview & Provided Info		Date:	03NOV25	Checked:	JSS

Overview

This study took the schedule of the MAQUOIT II, the vessel that the new ferry will be replacing, and formulated an operational profile using resistance data from a CFD analysis of the hull form of the replacement vessel. From the operational profile the amount of fuel burned, electricity used, emissions, and the resulting engine and generators hours were calculated for a replacement vessel with different propulsion systems. Operational profiles were created for transit speeds of 8, 9, 10, and 11 knots at vessel drafts of 6', 6.5', and 7', each representing a different propulsion power demand and duration of time spent in transit. A minimum speed of 8 knots is necessary to ensure the ferry can meet its existing schedule. The operational power demand profile is determined using delivered power requirements from a computational fluid dynamics (CFD) analysis. Assumptions were made regarding maneuvering/acceleration times and unload/loading times that could be refined further with client feedback.

Provided Schedule

The following schedule was provided to TSGL. This sequences of events determined the operating profile of the ferry.

Trip	Prescribed Event
Trip A	Leaves Portland 0800
	Leaves Chebeague Island 0910
	Leaves Cliff Island 0940
	Leaves Long Island 1005
	Leaves Great Diamond 1020
	Leaves Little Diamond 1025
	Arrives Back in Portland 1040
Trip B	Leaves Portland 1200
	Leaves Cliff Island 1335
	Leaves Chebeague Island 1400
	Leaves Long Island 1420
	Arrives Back in Portland 1450
Trip C	Leaves Portland 1615
	Leaves Diamond Cove 1705
	Leaves Great Diamond 1715
	Leaves Little Diamond 1720
	Arrives Back in Portland 1735
Trip D1	Leaves Portland 1915
	Leaves Peaks Island 1945
Trip D2	Leaves Portland 2015
	Leaves Peaks Island 2045
Trip D3	Leaves Portland 2115
	Leaves Peaks Island 2145
Trip D4	Leaves Portland 2230
	Leaves Peaks Island 2255

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: Overview & Provided Info		Date:	03NOV25	Checked:	JSS

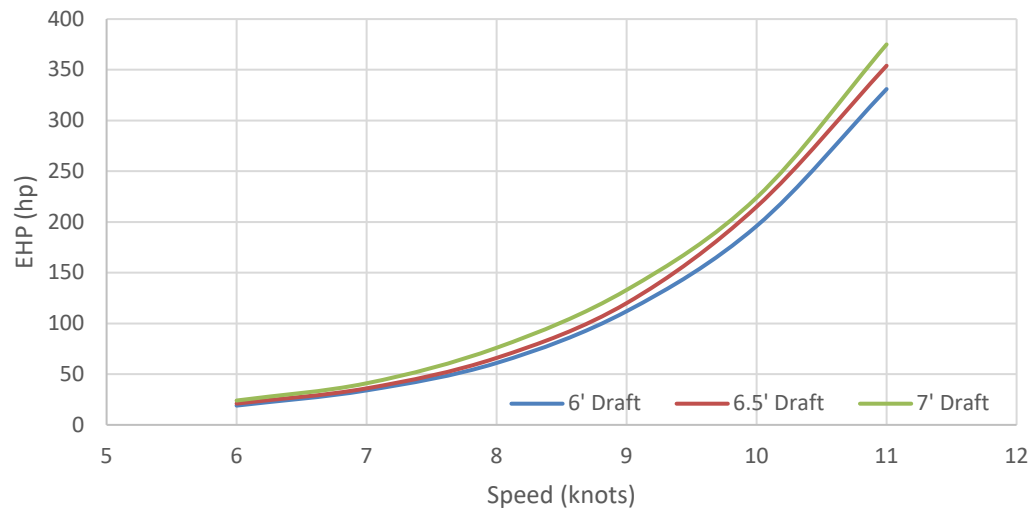
CFD Runs

	108' Dbl Chine	108' Dbl Chine	108' Dbl Chine
CFD Run:	6' Draft	6.5' Draft	7' Draft
Length (ft)	108	108	108
Beam (ft)	33	33	33
Draft (ft)	6	6.5	7
Disp (LT)	294	334	374

CFD Results

Speed (kt)	EHP	EHP	EHP
6	19	21	24
7	34	36	41
8	61	66	76
9	112	120	133
10	196	215	224
11	331	354	375

Effective Horsepower Required



PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: 8kt 6ft Profile		Date:	03NOV25	Checked:	JSS

8 Knot Transit Speed at a 6' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 61 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 134.20 HP 100.07 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

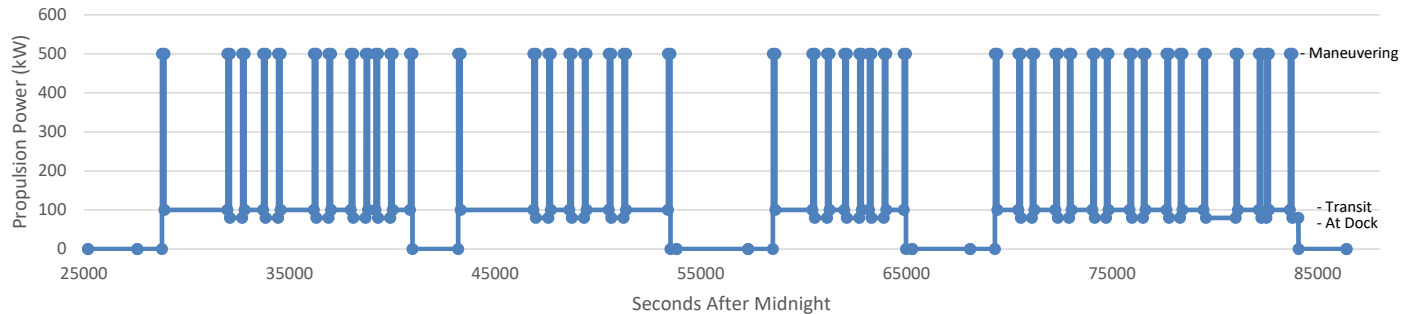
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



8 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:55	8:55	0:10	1:05	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:05	0:19	9:24	0:10	0:29	9:10	5
	A3	Cliff Island	Long Island	3.52	9:34	0:31	10:05	0:10	0:41	9:40	6
	A4	Long Island	Great Diamond	2.09	10:15	0:20	10:35	0:10	0:30	10:05	-10
	A5	Great Diamond	Little Diamond	0.71	10:45	0:10	10:55	0:10	0:20	10:20	-25
	A6	Little Diamond	Portland	1.85	11:05	0:18	11:23	0:37	0:55	10:25	-40
Trip B	B1	Portland	Cliff Island	7.84	12:00	1:03	13:03	0:10	1:13	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:13	0:19	13:32	0:10	0:29	13:35	22
	B3	Chebeague Island	Long Island	2.32	13:42	0:22	14:04	0:10	0:32	14:00	18
	B4	Long Island	Portland	4.45	14:14	0:38	14:52	1:23	2:01	14:20	6
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:34	16:49	0:10	0:44	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:59	0:16	17:15	0:10	0:26	17:05	6
	C3	Great Diamond	Little Diamond	0.71	17:25	0:10	17:35	0:10	0:20	17:15	-10
	C4	Little Diamond	Portland	1.85	17:45	0:18	18:03	1:12	1:30	17:20	-25
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:21	19:36	0:09	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:21	20:06	0:09	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:21	20:36	0:09	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:21	21:06	0:09	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:21	21:36	0:09	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:21	22:06	0:24	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:21	22:51	0:04	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:21	23:16		0:21	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 8kt 6.5ft Profile			Date:	03NOV25	Checked:	JSS

8 Knot Transit Speed at a 6.5' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 66 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 145.20 HP 108.28 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

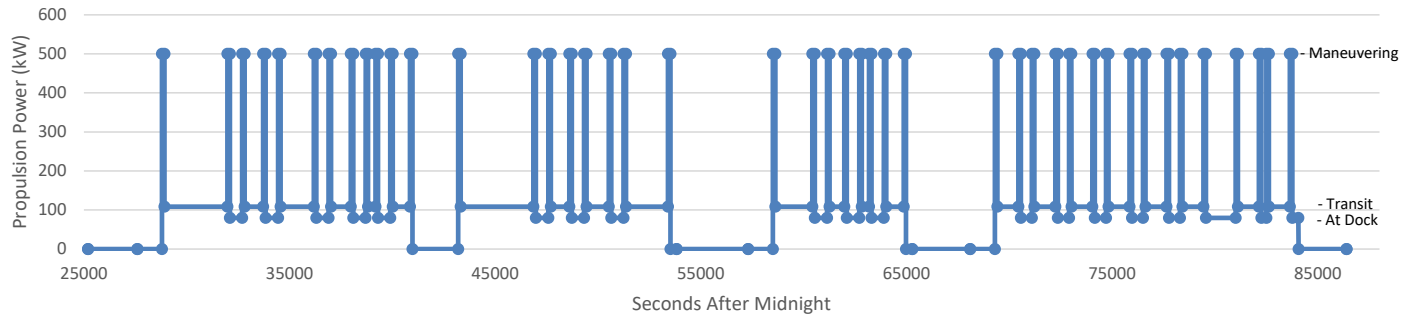
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



8 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:55	8:55	0:10	1:05	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:05	0:19	9:24	0:10	0:29	9:10	5
	A3	Cliff Island	Long Island	3.52	9:34	0:31	10:05	0:10	0:41	9:40	6
	A4	Long Island	Great Diamond	2.09	10:15	0:20	10:35	0:10	0:30	10:05	-10
	A5	Great Diamond	Little Diamond	0.71	10:45	0:10	10:55	0:10	0:20	10:20	-25
	A6	Little Diamond	Portland	1.85	11:05	0:18	11:23	0:37	0:55	10:25	-40
Trip B	B1	Portland	Cliff Island	7.84	12:00	1:03	13:03	0:10	1:13	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:13	0:19	13:32	0:10	0:29	13:35	22
	B3	Chebeague Island	Long Island	2.32	13:42	0:22	14:04	0:10	0:32	14:00	18
	B4	Long Island	Portland	4.45	14:14	0:38	14:52	1:23	2:01	14:20	6
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:34	16:49	0:10	0:44	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:59	0:16	17:15	0:10	0:26	17:05	6
	C3	Great Diamond	Little Diamond	0.71	17:25	0:10	17:35	0:10	0:20	17:15	-10
	C4	Little Diamond	Portland	1.85	17:45	0:18	18:03	1:12	1:30	17:20	-25
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:21	19:36	0:09	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:21	20:06	0:09	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:21	20:36	0:09	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:21	21:06	0:09	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:21	21:36	0:09	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:21	22:06	0:24	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:21	22:51	0:04	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:21	23:16		0:21	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: 8kt 7ft Profile		Date:	03NOV25	Checked:	JSS

8 Knot Transit Speed at a 7' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 76 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 167.20 HP 124.68 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

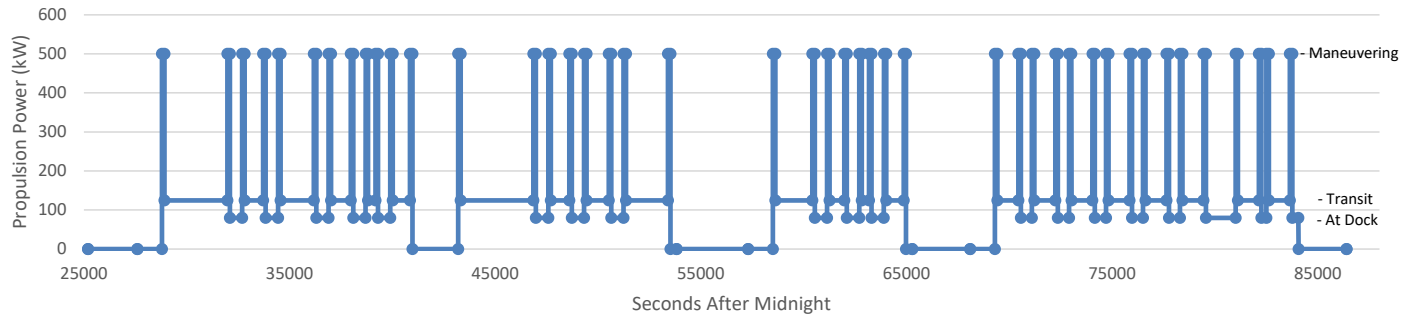
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



8 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:55	8:55	0:10	1:05	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:05	0:19	9:24	0:10	0:29	9:10	5
	A3	Cliff Island	Long Island	3.52	9:34	0:31	10:05	0:10	0:41	9:40	6
	A4	Long Island	Great Diamond	2.09	10:15	0:20	10:35	0:10	0:30	10:05	-10
	A5	Great Diamond	Little Diamond	0.71	10:45	0:10	10:55	0:10	0:20	10:20	-25
	A6	Little Diamond	Portland	1.85	11:05	0:18	11:23	0:37	0:55	10:25	-40
Trip B	B1	Portland	Cliff Island	7.84	12:00	1:03	13:03	0:10	1:13	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:13	0:19	13:32	0:10	0:29	13:35	22
	B3	Chebeague Island	Long Island	2.32	13:42	0:22	14:04	0:10	0:32	14:00	18
	B4	Long Island	Portland	4.45	14:14	0:38	14:52	1:23	2:01	14:20	6
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:34	16:49	0:10	0:44	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:59	0:16	17:15	0:10	0:26	17:05	6
	C3	Great Diamond	Little Diamond	0.71	17:25	0:10	17:35	0:10	0:20	17:15	-10
	C4	Little Diamond	Portland	1.85	17:45	0:18	18:03	1:12	1:30	17:20	-25
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:21	19:36	0:09	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:21	20:06	0:09	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:21	20:36	0:09	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:21	21:06	0:09	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:21	21:36	0:09	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:21	22:06	0:24	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:21	22:51	0:04	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:21	23:16		0:21	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 9kt 6ft Profile			Date:	03NOV25	Checked:	JSS

9 Knot Transit Speed at a 6' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = HP kW

Maneuvering Power = HP kW

At dock propulsion power = HP kW

Maneuvering/Acceleration Time minutes

Transit time = minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts =

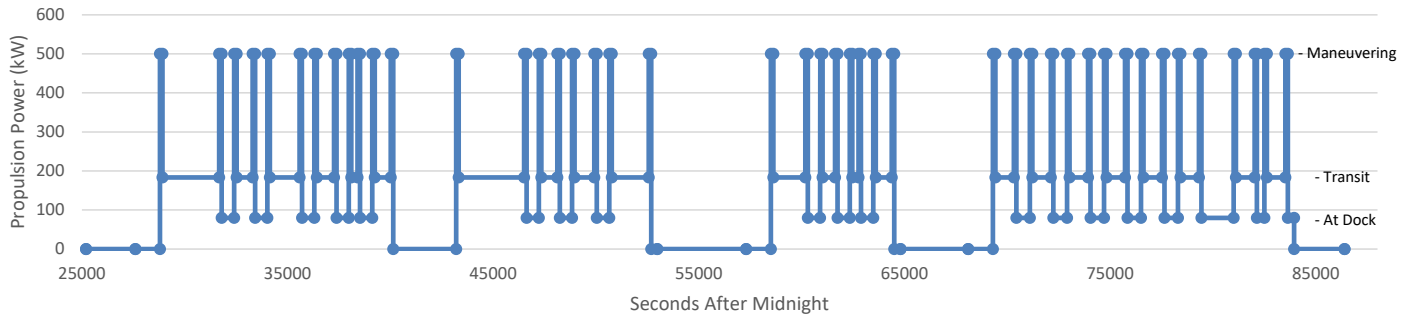
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



9 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:50	8:50	0:10	1:00	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:00	0:17	9:17	0:10	0:27	9:10	10
	A3	Cliff Island	Long Island	3.52	9:27	0:28	9:55	0:10	0:38	9:40	13
	A4	Long Island	Great Diamond	2.09	10:05	0:18	10:23	0:10	0:28	10:05	0
	A5	Great Diamond	Little Diamond	0.71	10:33	0:09	10:42	0:10	0:19	10:20	-13
	A6	Little Diamond	Portland	1.85	10:52	0:17	11:09	0:51	1:08	10:25	-27
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:57	12:57	0:10	1:07	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:07	0:17	13:24	0:10	0:27	13:35	28
	B3	Chebeague Island	Long Island	2.32	13:34	0:20	13:54	0:10	0:30	14:00	26
	B4	Long Island	Portland	4.45	14:04	0:34	14:38	1:37	2:11	14:20	16
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:30	16:45	0:10	0:40	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:55	0:14	17:09	0:10	0:24	17:05	10
	C3	Great Diamond	Little Diamond	0.71	17:19	0:09	17:28	0:10	0:19	17:15	-4
	C4	Little Diamond	Portland	1.85	17:38	0:17	17:55	1:20	1:37	17:20	-18
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:19	19:34	0:11	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:19	20:04	0:11	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:19	20:34	0:11	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:19	21:04	0:11	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:19	21:34	0:11	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:19	22:04	0:26	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:19	22:49	0:06	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:19	23:14		0:19	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 9kt 6.5ft Profile			Date:	03NOV25	Checked:	JSS

9 Knot Transit Speed at a 6.5' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = HP kW

Maneuvering Power = HP kW

At dock propulsion power = HP kW

Maneuvering/Acceleration Time = minutes

Transit time = minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts =

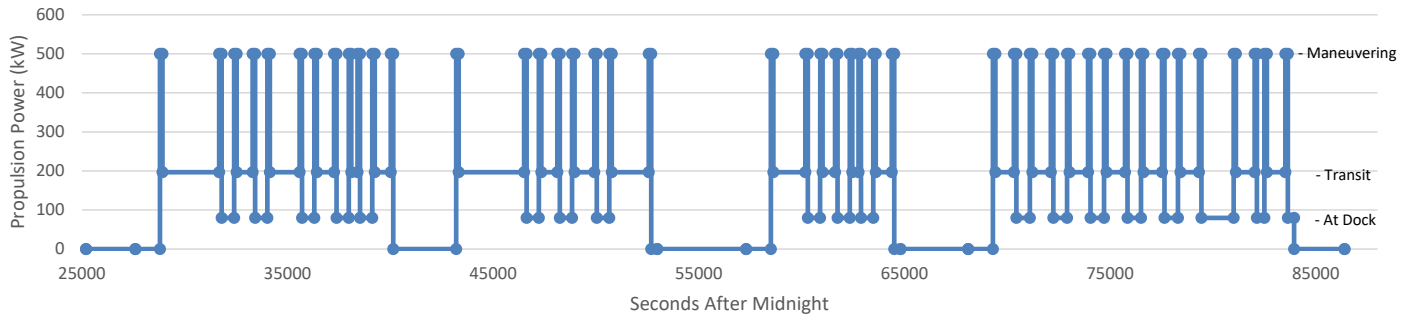
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



9 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:50	8:50	0:10	1:00	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:00	0:17	9:17	0:10	0:27	9:10	10
	A3	Cliff Island	Long Island	3.52	9:27	0:28	9:55	0:10	0:38	9:40	13
	A4	Long Island	Great Diamond	2.09	10:05	0:18	10:23	0:10	0:28	10:05	0
	A5	Great Diamond	Little Diamond	0.71	10:33	0:09	10:42	0:10	0:19	10:20	-13
	A6	Little Diamond	Portland	1.85	10:52	0:17	11:09	0:51	1:08	10:25	-27
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:57	12:57	0:10	1:07	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:07	0:17	13:24	0:10	0:27	13:35	28
	B3	Chebeague Island	Long Island	2.32	13:34	0:20	13:54	0:10	0:30	14:00	26
	B4	Long Island	Portland	4.45	14:04	0:34	14:38	1:37	2:11	14:20	16
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:30	16:45	0:10	0:40	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:55	0:14	17:09	0:10	0:24	17:05	10
	C3	Great Diamond	Little Diamond	0.71	17:19	0:09	17:28	0:10	0:19	17:15	-4
	C4	Little Diamond	Portland	1.85	17:38	0:17	17:55	1:20	1:37	17:20	-18
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:19	19:34	0:11	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:19	20:04	0:11	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:19	20:34	0:11	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:19	21:04	0:11	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:19	21:34	0:11	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:19	22:04	0:26	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:19	22:49	0:06	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:19	23:14		0:19	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: 9kt 7ft Profile		Date:	03NOV25	Checked:	JSS

9 Knot Transit Speed at a 7' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = HP kW

Maneuvering Power = HP kW

At dock propulsion power = HP kW

Maneuvering/Acceleration Time minutes

Transit time = minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts =

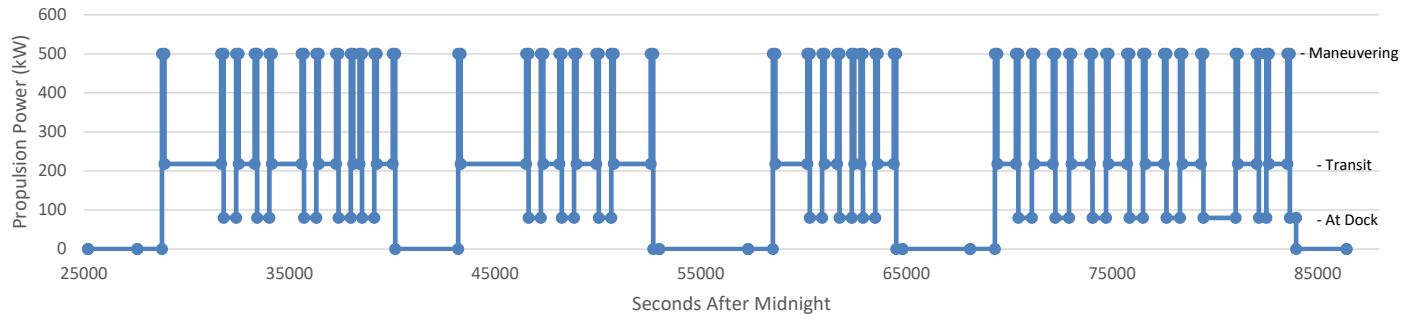
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



9 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:50	8:50	0:10	1:00	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	9:00	0:17	9:17	0:10	0:27	9:10	10
	A3	Cliff Island	Long Island	3.52	9:27	0:28	9:55	0:10	0:38	9:40	13
	A4	Long Island	Great Diamond	2.09	10:05	0:18	10:23	0:10	0:28	10:05	0
	A5	Great Diamond	Little Diamond	0.71	10:33	0:09	10:42	0:10	0:19	10:20	-13
	A6	Little Diamond	Portland	1.85	10:52	0:17	11:09	0:51	1:08	10:25	-27
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:57	12:57	0:10	1:07	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:07	0:17	13:24	0:10	0:27	13:35	28
	B3	Chebeague Island	Long Island	2.32	13:34	0:20	13:54	0:10	0:30	14:00	26
	B4	Long Island	Portland	4.45	14:04	0:34	14:38	1:37	2:11	14:20	16
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:30	16:45	0:10	0:40	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:55	0:14	17:09	0:10	0:24	17:05	10
	C3	Great Diamond	Little Diamond	0.71	17:19	0:09	17:28	0:10	0:19	17:15	-4
	C4	Little Diamond	Portland	1.85	17:38	0:17	17:55	1:20	1:37	17:20	-18
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:19	19:34	0:11	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:19	20:04	0:11	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:19	20:34	0:11	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:19	21:04	0:11	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:19	21:34	0:11	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:19	22:04	0:26	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:19	22:49	0:06	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:19	23:14		0:19	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: 10kt 6ft Profile		Date:	03NOV25	Checked:	JSS

10 Knot Transit Speed at a 6' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 196 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 431.20 HP 321.55 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

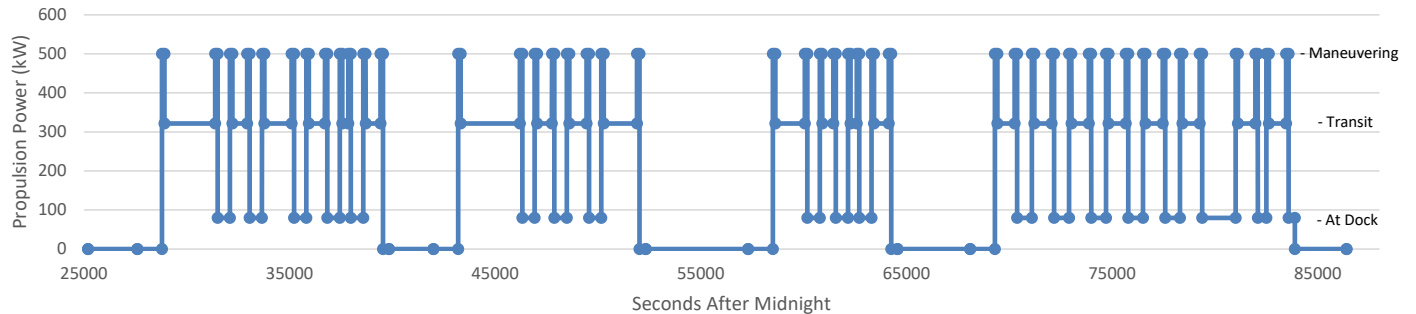
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



10 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:45	8:45	0:10	0:55	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:55	0:16	9:11	0:10	0:26	9:10	15
	A3	Cliff Island	Long Island	3.52	9:21	0:26	9:47	0:10	0:36	9:40	19
	A4	Long Island	Great Diamond	2.09	9:57	0:17	10:14	0:10	0:27	10:05	8
	A5	Great Diamond	Little Diamond	0.71	10:24	0:09	10:33	0:10	0:19	10:20	-4
	A6	Little Diamond	Portland	1.85	10:43	0:16	10:59	1:01	1:17	10:25	-18
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:52	12:52	0:10	1:02	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:02	0:16	13:18	0:10	0:26	13:35	33
	B3	Chebeague Island	Long Island	2.32	13:28	0:18	13:46	0:10	0:28	14:00	32
	B4	Long Island	Portland	4.45	13:56	0:31	14:27	1:48	2:19	14:20	24
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:28	16:43	0:10	0:38	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:53	0:13	17:06	0:10	0:23	17:05	12
	C3	Great Diamond	Little Diamond	0.71	17:16	0:09	17:25	0:10	0:19	17:15	-1
	C4	Little Diamond	Portland	1.85	17:35	0:16	17:51	1:24	1:40	17:20	-15
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:18	19:33	0:12	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:18	20:03	0:12	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:18	20:33	0:12	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:18	21:03	0:12	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:18	21:33	0:12	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:18	22:03	0:27	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:18	22:48	0:07	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:18	23:13		0:18	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL
CALC:	FERRY OPERATIONAL PROFILE CALCS: 10kt 6.5ft Profile		Date:	03NOV25	Checked:	JSS

10 Knot Transit Speed at a 6.5' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 215 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 473.00 HP 352.72 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

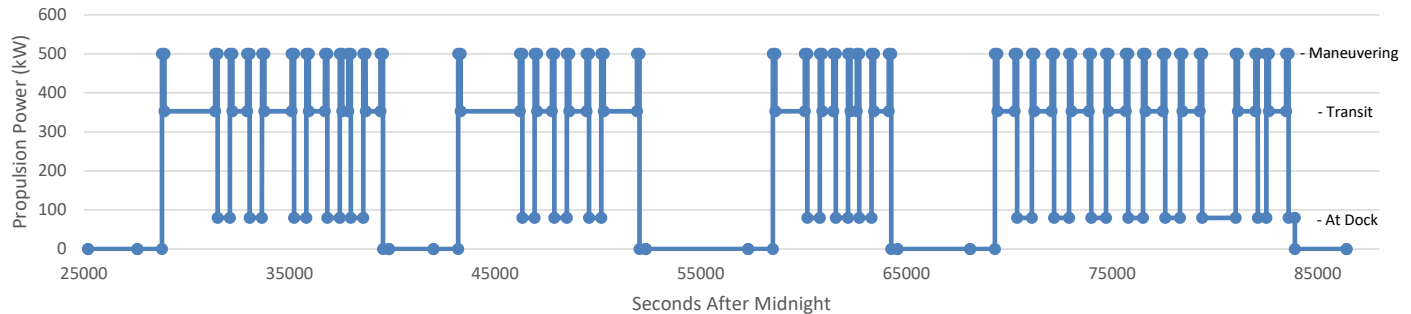
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



10 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:45	8:45	0:10	0:55	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:55	0:16	9:11	0:10	0:26	9:10	15
	A3	Cliff Island	Long Island	3.52	9:21	0:26	9:47	0:10	0:36	9:40	19
	A4	Long Island	Great Diamond	2.09	9:57	0:17	10:14	0:10	0:27	10:05	8
	A5	Great Diamond	Little Diamond	0.71	10:24	0:09	10:33	0:10	0:19	10:20	-4
	A6	Little Diamond	Portland	1.85	10:43	0:16	10:59	1:01	1:17	10:25	-18
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:52	12:52	0:10	1:02	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:02	0:16	13:18	0:10	0:26	13:35	33
	B3	Chebeague Island	Long Island	2.32	13:28	0:18	13:46	0:10	0:28	14:00	32
	B4	Long Island	Portland	4.45	13:56	0:31	14:27	1:48	2:19	14:20	24
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:28	16:43	0:10	0:38	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:53	0:13	17:06	0:10	0:23	17:05	12
	C3	Great Diamond	Little Diamond	0.71	17:16	0:09	17:25	0:10	0:19	17:15	-1
	C4	Little Diamond	Portland	1.85	17:35	0:16	17:51	1:24	1:40	17:20	-15
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:18	19:33	0:12	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:18	20:03	0:12	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:18	20:33	0:12	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:18	21:03	0:12	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:18	21:33	0:12	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:18	22:03	0:27	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:18	22:48	0:07	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:18	23:13		0:18	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 10kt 7ft Profile			Date:	03NOV25	Checked:	JSS

10 Knot Transit Speed at a 7' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 224 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 492.80 HP 367.49 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

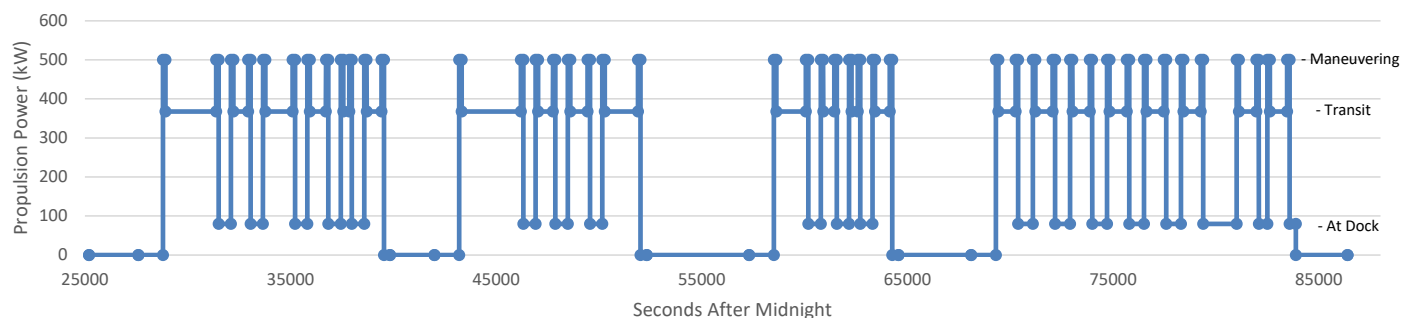
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



10 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/ Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:45	8:45	0:10	0:55	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:55	0:16	9:11	0:10	0:26	9:10	15
	A3	Cliff Island	Long Island	3.52	9:21	0:26	9:47	0:10	0:36	9:40	19
	A4	Long Island	Great Diamond	2.09	9:57	0:17	10:14	0:10	0:27	10:05	8
	A5	Great Diamond	Little Diamond	0.71	10:24	0:09	10:33	0:10	0:19	10:20	-4
	A6	Little Diamond	Portland	1.85	10:43	0:16	10:59	1:01	1:17	10:25	-18
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:52	12:52	0:10	1:02	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	13:02	0:16	13:18	0:10	0:26	13:35	33
	B3	Chebeague Island	Long Island	2.32	13:28	0:18	13:46	0:10	0:28	14:00	32
	B4	Long Island	Portland	4.45	13:56	0:31	14:27	1:48	2:19	14:20	24
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:28	16:43	0:10	0:38	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:53	0:13	17:06	0:10	0:23	17:05	12
	C3	Great Diamond	Little Diamond	0.71	17:16	0:09	17:25	0:10	0:19	17:15	-1
	C4	Little Diamond	Portland	1.85	17:35	0:16	17:51	1:24	1:40	17:20	-15
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:18	19:33	0:12	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:18	20:03	0:12	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:18	20:33	0:12	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:18	21:03	0:12	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:18	21:33	0:12	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:18	22:03	0:27	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:18	22:48	0:07	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:18	23:13		0:18	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 11kt 6ft Profile			Date:	03NOV25	Checked:	JSS

11 Knot Transit Speed at a 6' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 331 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 728.20 HP 543.03 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

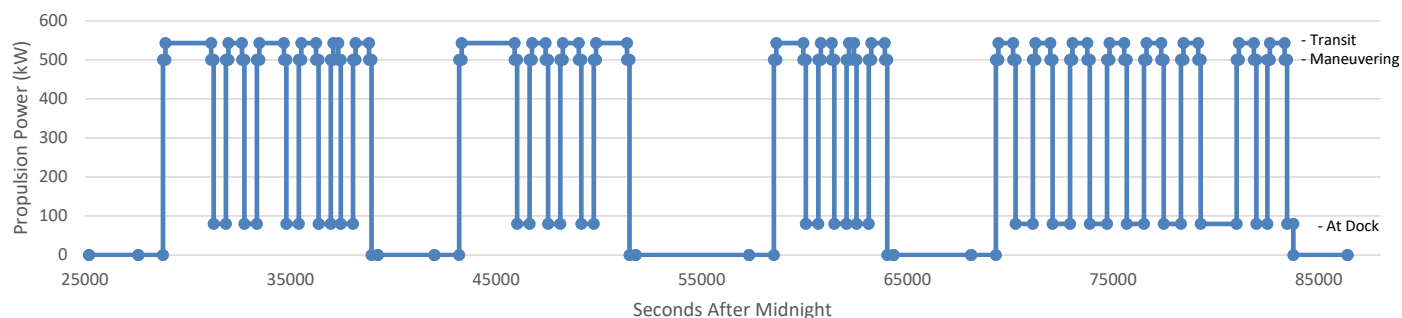
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



11 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:41	8:41	0:10	0:51	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:51	0:15	9:06	0:10	0:25	9:10	19
	A3	Cliff Island	Long Island	3.52	9:16	0:24	9:40	0:10	0:34	9:40	24
	A4	Long Island	Great Diamond	2.09	9:50	0:16	10:06	0:10	0:26	10:05	15
	A5	Great Diamond	Little Diamond	0.71	10:16	0:08	10:24	0:10	0:18	10:20	4
	A6	Little Diamond	Portland	1.85	10:34	0:15	10:49	1:11	1:26	10:25	-9
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:47	12:47	0:10	0:57	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	12:57	0:15	13:12	0:10	0:25	13:35	38
	B3	Chebeague Island	Long Island	2.32	13:22	0:17	13:39	0:10	0:27	14:00	38
	B4	Long Island	Portland	4.45	13:49	0:29	14:18	1:57	2:26	14:20	31
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:26	16:41	0:10	0:36	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:51	0:13	17:04	0:10	0:23	17:05	14
	C3	Great Diamond	Little Diamond	0.71	17:14	0:08	17:22	0:10	0:18	17:15	1
	C4	Little Diamond	Portland	1.85	17:32	0:15	17:47	1:28	1:43	17:20	-12
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:16	19:31	0:14	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:16	20:01	0:14	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:16	20:31	0:14	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:16	21:01	0:14	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:16	21:31	0:14	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:16	22:01	0:29	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:16	22:46	0:09	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:16	23:11		0:16	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 11kt 6.5ft Profile			Date:	03NOV25	Checked:	JSS

11 Knot Transit Speed at a 6.5' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 354 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 778.80 HP 580.76 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

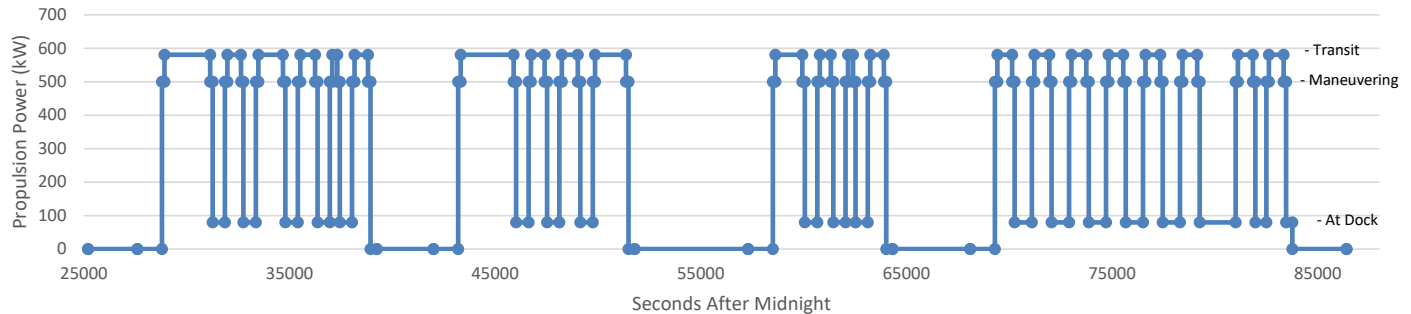
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



11 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:41	8:41	0:10	0:51	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:51	0:15	9:06	0:10	0:25	9:10	19
	A3	Cliff Island	Long Island	3.52	9:16	0:24	9:40	0:10	0:34	9:40	24
	A4	Long Island	Great Diamond	2.09	9:50	0:16	10:06	0:10	0:26	10:05	15
	A5	Great Diamond	Little Diamond	0.71	10:16	0:08	10:24	0:10	0:18	10:20	4
	A6	Little Diamond	Portland	1.85	10:34	0:15	10:49	1:11	1:26	10:25	-9
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:47	12:47	0:10	0:57	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	12:57	0:15	13:12	0:10	0:25	13:35	38
	B3	Chebeague Island	Long Island	2.32	13:22	0:17	13:39	0:10	0:27	14:00	38
	B4	Long Island	Portland	4.45	13:49	0:29	14:18	1:57	2:26	14:20	31
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:26	16:41	0:10	0:36	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:51	0:13	17:04	0:10	0:23	17:05	14
	C3	Great Diamond	Little Diamond	0.71	17:14	0:08	17:22	0:10	0:18	17:15	1
	C4	Little Diamond	Portland	1.85	17:32	0:15	17:47	1:28	1:43	17:20	-12
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:16	19:31	0:14	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:16	20:01	0:14	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:16	20:31	0:14	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:16	21:01	0:14	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:16	21:31	0:14	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:16	22:01	0:29	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:16	22:46	0:09	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:16	23:11		0:16	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: 11kt 7ft Profile			Date:	03NOV25	Checked:	JSS

11 Knot Transit Speed at a 7' Draft

Operating Profile Variables

Chosen transit speed = knots Enter speed between 7 and 11 knots

Draft = ft Enter a draft of 6, 6.5, or 7 feet

CFD required EHP = 375 HP

Added Resistance = -

Propulsive Efficiency = -

Transit required delivered power = 825.00 HP 615.21 kW

Maneuvering Power = 670.5 HP kW

At dock propulsion power = 107.28 HP kW

Maneuvering/Acceleration Time minutes

Transit time = varies minutes

Maneuvering/Deceleration Time = minutes

Time to Unload Load = minutes

Time house load starts = 7:00

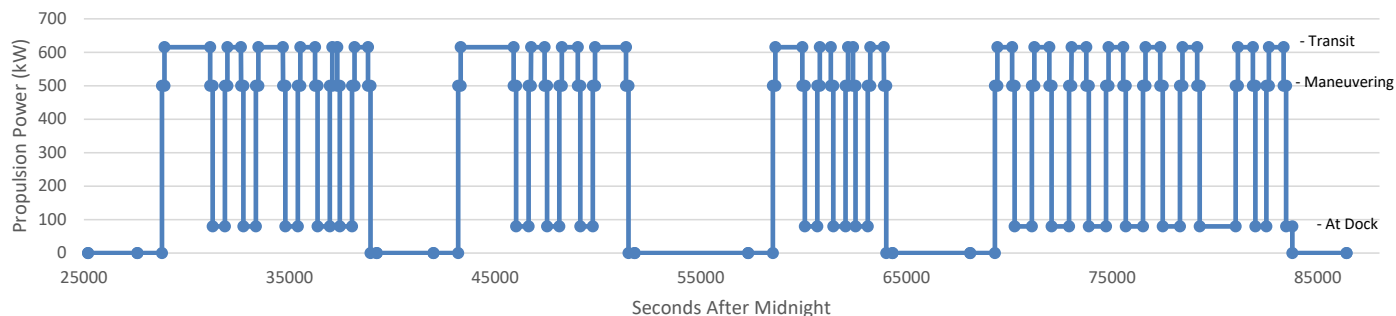
Time before depart. Main engs/gens are turned on = min

Time after Portland arrival main engs/gens turned off = min

Time after last trip engines/gen are turned off = min

If time at Portland >

Propulsion Delivered Power Profile



11 Knot Transit Speed Schedule

	Leg Label	Starting Location	Destination	Distance (nm)	Departure Time	Total Transit Time (hr:min)	Arrival Time	Unload/Load Time (hr:min)	Total Leg Duration (hr:min)	Previous Scheduled Departure Time	Diff. from Scheduled Departure time (min)
Trip A	A1	Portland	Chebeague Island	6.77	8:00	0:41	8:41	0:10	0:51	8:00	0
	A2	Chebeague Island	Cliff Island	1.93	8:51	0:15	9:06	0:10	0:25	9:10	19
	A3	Cliff Island	Long Island	3.52	9:16	0:24	9:40	0:10	0:34	9:40	24
	A4	Long Island	Great Diamond	2.09	9:50	0:16	10:06	0:10	0:26	10:05	15
	A5	Great Diamond	Little Diamond	0.71	10:16	0:08	10:24	0:10	0:18	10:20	4
	A6	Little Diamond	Portland	1.85	10:34	0:15	10:49	1:11	1:26	10:25	-9
Trip B	B1	Portland	Cliff Island	7.84	12:00	0:47	12:47	0:10	0:57	12:00	0
	B2	Cliff Island	Chebeague Island	1.93	12:57	0:15	13:12	0:10	0:25	13:35	38
	B3	Chebeague Island	Long Island	2.32	13:22	0:17	13:39	0:10	0:27	14:00	38
	B4	Long Island	Portland	4.45	13:49	0:29	14:18	1:57	2:26	14:20	31
Trip C	C1	Portland	Diamond Cove	3.88	16:15	0:26	16:41	0:10	0:36	16:15	0
	C2	Diamond Cove	Great Diamond	1.48	16:51	0:13	17:04	0:10	0:23	17:05	14
	C3	Great Diamond	Little Diamond	0.71	17:14	0:08	17:22	0:10	0:18	17:15	1
	C4	Little Diamond	Portland	1.85	17:32	0:15	17:47	1:28	1:43	17:20	-12
Trip D1*	D1	Portland	Peaks Island	2.2	19:15	0:16	19:31	0:14	0:30	19:15	0
	D2	Peaks Island	Portland	2.2	19:45	0:16	20:01	0:14	0:30	19:45	0
Trip D2*	D3	Portland	Peaks Island	2.2	20:15	0:16	20:31	0:14	0:30	20:15	0
	D4	Peaks Island	Portland	2.2	20:45	0:16	21:01	0:14	0:30	20:45	0
Trip D3*	D5	Portland	Peaks Island	2.2	21:15	0:16	21:31	0:14	0:30	21:15	0
	D6	Peaks Island	Portland	2.2	21:45	0:16	22:01	0:29	0:45	21:45	0
Trip D4*	D7	Portland	Peaks Island	2.2	22:30	0:16	22:46	0:09	0:25	22:30	0
	D8	Peaks Island	Portland	2.2	22:55	0:16	23:11		0:16	22:55	0

*Evening trips from Portland-Peaks Island occur Sunday-Thursday Only

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: Battery Only Operations			Date:	03NOV25	Checked:	JSS

Battery Only Operations

Assumptions:

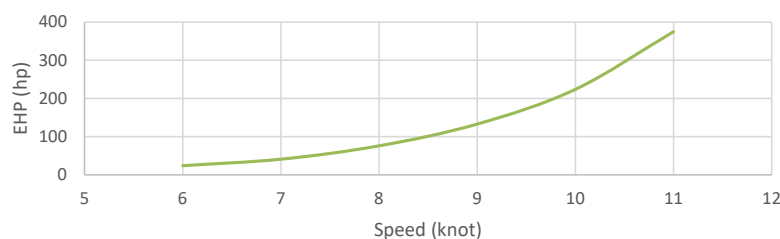
Draft	7	ft	
Added appendage resistance	1.1		
Prop efficiency	0.5		η_{prop}
Shaft efficiency	0.98		η_{shaft}
Gear box efficiency	0.98		η_{gear}
Motor efficiency	0.98		η_{motor}
Electrical efficiency	0.99		η_{elec}
Base house power demand	30	ekW	P_{house}
Battery cooling power demand	30	ekW	$P_{cooling}$
NMC battery efficiency	0.98		η_{batt}
NMC maximum sustained C-rate	1.5		C-rate _{ave max}
NMC maximum SoC	0.8		SoC _{max}
NMC minimum SoC	0.4		SoC _{min}
LFP battery efficiency	0.98		η_{batt}
LFP maximum sustained C-rate	0.5		C-rate _{ave max}
LFP maximum SoC	0.8		SoC _{max}
LFP minimum SoC	0.1		SoC _{min}

CFD Data

	108' Dbl Chine
CFD Run:	7' Draft
Length (ft)	108
Beam (ft)	33
Draft (ft)	7
Disp (LT)	374

Speed (kt)	EHP
6	24
7	41
8	76
9	133
10	224
11	375

Effective Horsepower Required at a 7' Draft



Battery Power Requirements

Speed (knots)	Effective Power Req. (kW)	Delivered Power Req. (kW)	Transit Propulsion Electrical Power Req. (ekW)	Transit Electrical Power Req. (ekW)	NMC Req. Battery Size for <1.5 C-rate (kWh)	LFP Req. Battery Size for <0.5 C-rate (kWh)
7	31	67	72	132	88	264
8	57	125	134	194	129	388
9	99	218	234	294	196	588
10	167	367	394	454	303	909
11	280	615	660	720	480	1441

Note: At slower speeds the maneuvering power requirements will increase the required battery size

PROJECT:	23494	CASCO BAY LINES	Rev:	0	By:	MDL	
CALC:	FERRY OPERATIONAL PROFILE CALCS: Battery Only Operations			Date:	03NOV25	Checked:	JSS

Energy Requirements

Assumes a total of 4 min of Maneuvering/Acceleration/Deceleration @ an average of 600 kW power requirement

Leg	Distance (nm)	<u>7 Knots</u> Energy		<u>8 Knots</u> Energy		<u>9 Knots</u> Energy		<u>10 Knots</u> Energy		<u>11 Knots</u> Energy	
		Transit time (min)	Usage (kWh)	Transit time (min)	Usage (kWh)	Transit time (min)	Usage (kWh)	Transit time (min)	Usage (kWh)	Transit time (min)	Usage (kWh)
Portland -Chebeague Island	6.77	58	168	51	204	45	261	41	348	37	483
Chebeague Island -Cliff Island	1.93	17	76	14	87	13	103	12	128	11	166
Cliff Island - Long Island	3.52	30	106	26	125	23	155	21	200	19	270
Long Island - Great Diamond	2.09	18	79	16	91	14	108	13	135	11	177
Great Diamond - Little Diamond	0.71	6	53	5	57	5	63	4	72	4	86
Little Diamond - Portland	1.85	16	75	14	85	12	100	11	124	10	161
Portland -Cliff Island	7.84	67	188	59	230	52	296	47	396	43	553
Cliff Island - Chebeague Island	1.93	17	76	14	87	13	103	12	128	11	166
Chebeague Island - Long Island	2.32	20	84	17	96	15	116	14	145	13	192
Long Island - Portland	4.45	38	124	33	148	30	185	27	242	24	331
Portland - Diamond Cove	3.88	33	113	29	134	26	167	23	216	21	294
Diamond Cove - Great Diamon	1.48	13	68	11	76	10	88	9	107	8	137
Portland - Peaks Island	2.2	19	82	17	93	15	112	13	140	12	184

To protect the batteries, only a percentage of the battery's capacity is usable. The required nominal battery size will depend on the battery chemistry and the allowable range of the battery state of charge. In this study we assume that NMC batteries must be kept between 40-80% and LFP between 10-80%. Other considerations such as minimum reserve power may increase these requirements.

Leg	Distance (nm)	<u>7 Knots</u>		<u>8 Knots</u>		<u>9 Knots</u>		<u>10 Knots</u>		<u>11 Knots</u>	
		NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.
		Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)
Portland -Chebeague Island	6.77	420	240	510	291	653	373	869	497	1208	690
Chebeague Island -Cliff Island	1.93	191	109	217	124	258	147	319	182	416	238
Cliff Island - Long Island	3.52	266	152	313	179	388	222	500	286	676	386
Long Island - Great Diamond	2.09	199	114	227	129	271	155	337	193	442	253
Great Diamond - Little Diamond	0.71	134	76	143	82	158	90	181	103	216	124
Little Diamond - Portland	1.85	187	107	212	121	251	144	310	177	403	230
Portland -Cliff Island	7.84	470	269	575	328	741	423	991	566	1383	790
Cliff Island - Chebeague Island	1.93	191	109	217	124	258	147	319	182	416	238
Chebeague Island - Long Island	2.32	210	120	241	137	290	165	364	208	480	274
Long Island - Portland	4.45	310	177	370	211	464	265	606	346	828	473
Portland - Diamond Cove	3.88	283	162	335	191	417	238	541	309	735	420
Diamond Cove - Great Diamon	1.48	170	97	190	108	221	126	268	153	342	196
Portland - Peaks Island	2.2	204	116	233	133	280	160	350	200	460	263

Required Battery Size to Operate Battery Only for Each Leg

The following table list the battery sizes needed to operate the legs of the trip accounting for both energy and power requirements.

Leg	Distance (nm)	<u>7 Knots</u>		<u>8 Knots</u>		<u>9 Knots</u>		<u>10 Knots</u>		<u>11 Knots</u>	
		NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.	NMC Req.	LFP Req.
		Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)	Battery Size (kWh)
Portland -Chebeague Island	6.77	420	264	510	388	653	588	869	909	1208	1441
Chebeague Island -Cliff Island	1.93	191	264	217	388	258	588	319	909	480	1441
Cliff Island - Long Island	3.52	266	264	313	388	388	588	500	909	676	1441
Long Island - Great Diamond	2.09	199	264	227	388	271	588	337	909	480	1441
Great Diamond - Little Diamond	0.71	134	264	143	388	196	588	303	909	480	1441
Little Diamond - Portland	1.85	187	264	212	388	251	588	310	909	480	1441
Portland -Cliff Island	7.84	470	269	575	388	741	588	991	909	1383	1441
Cliff Island - Chebeague Island	1.93	191	264	217	388	258	588	319	909	480	1441
Chebeague Island - Long Island	2.32	210	264	241	388	290	588	364	909	480	1441
Long Island - Portland	4.45	310	264	370	388	464	588	606	909	828	1441
Portland - Diamond Cove	3.88	283	264	335	388	417	588	541	909	735	1441
Diamond Cove - Great Diamon	1.48	170	264	190	388	221	588	303	909	480	1441
Portland - Peaks Island	2.2	204	264	233	388	280	588	350	909	480	1441

APPENDIX III

23494-199-3 Feasibility Study Calculations

REVISION HISTORY					
REV	ZONE	DESCRIPTION	DATE	BY	CHECK
0	-	1. Initial Release	03NOV25	MDL	JSS

GENERAL NOTES

5	23494-199-5	Propulsion Systems Simulation Results
4	23494-199-4	Propulsion System Reliability Calculations
3	23494-199-2	Ferry Operational Profile Calculations
2	23494-199-1	Ferry Propulsion System Analysis Calcs
1	23494-099-1	Ferry Propulsion System Feasibility Study
NO.	DRAWING	TITLE



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REFERENCES

TITLE: Feasibility Study Calculations		
FOR: Casco Bay Lines		
VESSEL:	MAQUOIT II Replacement	DRAWING NO: -
DATE	03NOV25	SCALE: N.T.S.
FWC. NO:	23494-199-3	REV: 0
DRAWN BY:	MDL	CHECK BY: JSS

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: Feasibility Study Scoring		Date:	03NOV25	Checked:	JSS

Feasibility Study Summary

A feasibility study was conducted on the propulsion systems under consideration for the MAQUOIT II Replacement Vessel. Criteria to evaluate the propulsion systems include operating expenses (OPEX), capital expenses (CAPEX), sustainability, serviceability, and reliability. OPEX was evaluated by the costs incurred due to frequent engine/generator maintenance, fuel consumption, and electricity usage. CAPEX was evaluated by vessel construction cost estimates and infrequent equipment maintenance costs including overhauls and replacements. Sustainability was evaluated by estimated daily CO₂ emissions. Serviceability was evaluated by five evaluation criteria. Reliability was evaluated by the relative availability of the propulsion systems to meet operational requirements. Each propulsion system received a raw score for each criterion. These criteria were assigned weightings to capture the level of importance to the client. The raw score for each criterion was multiplied by the criteria weightings to provide a weighted criteria score. These scores were summed together to calculate the total propulsion system score.

The raw scores for each criterion were calculated by dividing each criterion into sub-criteria. Within the criteria evaluations, the sub-criteria were assigned weightings to capture the importance of each sub-criteria to the overall criteria score.

The following abbreviations are used through out these calculations:

1. Diesel mechanical system with 2 C18 engines and 2 house generators (MECH)
2. Diesel electric system with 2 C18 generators and 1 house generator (DE 2xC18s)
3. Diesel electric system with 3 C18 generators and 1 house generator (DE 3xC18s)
4. Diesel electric system with 2 C18 generators and 1,000 kWh of NMC batteries (DEWB NMC)
5. Diesel electric system with 2 C18 generators and 1,000 kWh of LFP batteries (DEWB LFP)

Criteria Weightings:

Evaluation Criteria	Weighting of Overall Score
OPEX	39%
CAPEX	19%
Sustainability	12%
Serviceability	10%
Reliability	20%

Individual Criteria Scoring:

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	7.90	8.41	8.41	10.00	10.00
CAPEX	9.95	9.26	9.18	8.14	8.63
Sustainability	8.77	8.54	8.54	9.98	10.00
Serviceability	7.00	5.80	5.80	4.60	4.60
Reliability	7.18	4.40	8.43	10.00	10.00

Individual Criteria Scores Linearly Rescaled (Best Score Set Equal to 10):

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	7.90	8.41	8.41	10.00	10.00
CAPEX	10.00	9.31	9.22	8.18	8.67
Sustainability	8.77	8.54	8.54	9.98	10.00
Serviceability	10.00	8.29	8.29	6.57	6.57
Reliability	7.18	4.40	8.43	10.00	10.00

Weighted Scoring:

Evaluation Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	3.08	3.28	3.28	3.90	3.90
CAPEX	1.90	1.77	1.75	1.56	1.65
Sustainability	1.05	1.02	1.02	1.20	1.20
Serviceability	1.00	0.83	0.83	0.66	0.66
Reliability	1.44	0.88	1.69	2.00	2.00
Sum:	8.47	7.78	8.57	9.31	9.40

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: OPEX		Date:	03NOV25	Checked:	JSS

OPEX Criteria:

To evaluate the system's operational costs the yearly fuel, electricity, and frequent engine/generator maintenance costs were compared. Frequent engine/generator maintenance was defined as events occurring at less than 1000 hour intervals. These costs are broken down to a yearly cost and were evaluated for a 9-knot transit speed for the purpose of the feasibility study. Detailed calculations are provided in Reference 2.

OPEX Sub-Criteria:

OPEX Sub-Criteria Weightings:

OPEX Sub-Criteria:	Sub-Criteria Weighting
OPEX	100%

Scoring:

OPEX Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
OPEX	7.90	8.41	8.41	10.00	10.00

Sub-Criteria Scoring Procedure:

Typical procedure for scoring data:

Definitions: Bold letter represents a vector (i.e. **X**)
 x_i , represents the i^{th} component of the vector **X**
 $\|X\|$ is the L2 norm of the vector **X**

Procedure: Data Vector = **X**
Normalized Vector (Euclidean Norm) = **N**, where $n_i = x_i / \|X\|$
Inverted Vector (Reciprocal of each vector element) = **R** = $[1/n_1, 1/n_2, \dots, 1/n_n]$ (i.e. $r_i = 1/n_i$)
Score Vector = **S**, where $s_i = 10 * r_i / \max(R)$

OPEX

Defined as: Scoring based on calculated yearly frequent OPEX based on 9 knot operational profile.					
Power Plant:	Cost per year	Normalized	Inverted	Score	
MECH	\$ 339,886	0.50	2.00	7.90	
DE 2xC18s	\$ 319,014	0.47	2.13	8.41	
DE 3xC18s	\$ 319,014	0.47	2.13	8.41	
DEWB NMC	\$ 268,342	0.39	2.54	10.00	
DEWB LFP	\$ 268,386	0.39	2.54	10.00	

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: CAPEX		Date:	03NOV25	Checked:	JSS

CAPEX Criteria:

CAPEX for the propulsion systems was evaluated by comparing construction cost estimates and infrequent equipment maintenance costs including overhauls and replacements. Infrequent engine/generator maintenance was defined as events occurring at greater than 1000 hour intervals. Replacement costs of equipment included motors, batteries, and house generators. Equipment maintenance and replacement costs are broken down to a yearly cost and are evaluated for a 9-knot transit speed for the purpose of the feasibility study. Detailed calculations are provided in Reference 2.

CAPEX Sub-Criteria:

CAPEX Sub-Criteria Weightings:

CAPEX Sub-Criteria	Sub-Criteria Weighting
Construction Costs	90%
Equipment Overhaul and Replacement Costs	10%

Individual Sub-Criteria Scoring:

CAPEX Sub-Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Construction Costs	10.00	9.18	9.09	8.58	8.70
Overhaul and Replacement Costs	9.51	10.00	10.00	4.26	8.03

Weighted Scoring:

CAPEX Sub-Criteria	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Construction Costs	9.00	8.26	8.18	7.72	7.83
Overhaul and Replacement Costs	0.95	1.00	1.00	0.43	0.80
Sum:	9.95	9.26	9.18	8.14	8.63

Sub-Criteria Scoring Procedure:

Typical procedure for scoring data:

Definitions: Bold letter represents a vector (i.e. **X**)
 x_i , represents the i^{th} component of the vector **X**
 $\|X\|$ is the L2 norm of the vector **X**

Procedure: Data Vector = **X**
Normalized Vector (Euclidean Norm) = **N**, where $n_i = x_i / \|X\|$
Inverted Vector (Reciprocal of each vector element) = **R** = $[1/n_1, 1/n_2, \dots, 1/n_n]$ (i.e. $r_i = 1/n_i$)
Score Vector = **S**, where $s_i = 10 * r_i / \max(R)$

Construction Costs

Defined as: Scoring based on relative capital costs.				
Power Plant:	Construction Costs	Normalized	Inverted	Score
MECH	\$15,200,000	0.41	2.47	10.00
DE 2xC18s	\$16,554,000	0.44	2.26	9.18
DE 3xC18s	\$16,726,000	0.45	2.24	9.09
DEWB NMC	\$17,724,000	0.47	2.11	8.58
DEWB LFP	\$17,474,000	0.47	2.14	8.70

Equipment Overhaul and Replacement Costs

Defined as: Scoring based on infrequent maintenance costs (annualized).				
Power Plant:	Cost per year	Normalized	Inverted	Score
MECH	\$39,761	0.33	3.03	9.51
DE 2xC18s	\$37,819	0.31	3.19	10.00
DE 3xC18s	\$37,819	0.31	3.19	10.00
DEWB NMC	\$88,775	0.74	1.36	4.26
DEWB LFP	\$47,071	0.39	2.56	8.03

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: Sustainability		Date:	03NOV25	Checked:	JSS

Sustainability Criteria:

Sustainability was evaluated for the propulsion systems by comparing the daily CO₂ emissions. The vessel emissions were evaluated at a 9-knot transit speed for the purpose of the feasibility study. Detailed calculations are provided in Reference 2.

Sustainability Sub-Criteria:

Sustainability Sub-Criteria Weightings:

Sustainability Sub-Criteria:	Sub-Criteria Weighting
Carbon Dioxide (CO ₂) Emissions	100%

Scoring:

Sustainability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Carbon Dioxide (CO ₂) Emissions	8.77	8.54	8.54	9.98	10.00

Sub-Criteria Scoring Procedure:

Typical procedure for scoring data:

Definitions: Bold letter represents a vector (i.e. **X**)
 x_i , represents the i^{th} component of the vector **X**
 $\|\mathbf{X}\|$ is the L2 norm of the vector **X**

Procedure: Data Vector = **X**
Normalized Vector (Euclidean Norm) = **N**, where $n_i = x_i / \|\mathbf{X}\|$
Inverted Vector (Reciprocal of each vector element) = **R** = $[1/n_1, 1/n_2, \dots, 1/n_n]$ (i.e. $r_i = 1/n_i$)
Score Vector = **S**, where $s_i = 10 * r_i / \max(\mathbf{R})$

Carbon Dioxide (CO₂) Emissions

Defined as: Scoring based on calculated daily CO ₂ emissions based on 9 knot operational profile.				
Power Plant:	Simulated Avg. Daily CO ₂ Emissions (kilograms/day)	Normalized	Inverted	Score
MECH	3081	0.46	2.16	8.77
DE 2xC18s	3167	0.48	2.10	8.54
DE 3xC18s	3167	0.48	2.10	8.54
DEWB NMC	2707	0.41	2.46	9.98
DEWB LFP	2703	0.41	2.46	10.00

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: Serviceability		Date:	03NOV25	Checked:	JSS

Serviceability Criteria:

Serviceability was evaluated for five criteria. These criteria include spare parts requirements, replacement part availability, service technician availability, downtime for repairs, and fleet similarity.

Serviceability Sub-Criteria:

Serviceability Sub-Criteria Weightings:

Serviceability Sub-Criteria:	Sub-Criteria Weighting
Spare Parts Requirements	20%
Replacement Part Availability	20%
Service Technician Availability	20%
Downtime for Repairs	20%
Fleet Similarity	20%

Individual Sub-Criteria Scoring:

Serviceability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Spare Parts Requirements	7.00	5.00	5.00	4.00	4.00
Replacement Part Availability	7.00	5.00	5.00	4.00	4.00
Service Technician Availability	7.00	6.00	6.00	4.00	4.00
Downtime for Repairs	7.00	7.00	7.00	5.00	5.00
Fleet Similarity	7.00	6.00	6.00	6.00	6.00

Weighted Scoring:

Serviceability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Spare Parts Requirements	1.40	1.00	1.00	0.80	0.80
Replacement Part Availability	1.40	1.00	1.00	0.80	0.80
Service Technician Availability	1.40	1.20	1.20	0.80	0.80
Downtime for Repairs	1.40	1.40	1.40	1.00	1.00
Fleet Similarity	1.40	1.20	1.20	1.20	1.20
Sum:	7.00	5.80	5.80	4.60	4.60

Sub-Criteria Scoring Procedure:

Sub-criteria were scored subjectively with a possible ranking from 1-10. In general TSGI did not evaluate any sub-criteria as extremely low or high as the technology being proposed has been industry proven and Casco Bay Lines has an existing ferry or a new build ferry that utilize all the technologies being proposed. If CBL uses the same vendors utilized on their recent new build on the proposed ferry then serviceability and fleet integration should not vary much across the candidate propulsion systems.

Spare Parts Requirements

Defined as: Relative comparison of suggested spare parts to have on hand for the applicable propulsion plants		
Power Plant:	Score	Explanation
MECH	7.00	Baseline.
DE 2xC18s	5.00	Additional spare electrical parts recommended.
DE 3xC18s	5.00	Additional spare electrical parts recommended.
DEWB NMC	4.00	Additional spare electrical parts and spare batteries recommended.
DEWB LFP	4.00	Additional spare electrical parts and spare batteries recommended.

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: Serviceability		Date:	03NOV25	Checked:	JSS

Serviceability Criteria Calculations Continued:

Replacement Part Availability

Defined as: How quickly replacement parts can be received		
Power Plant:	Score	Explanation
MECH	7.00	Baseline.
DE 2xC18s	5.00	More specialized parts.
DE 3xC18s	5.00	More specialized parts.
DEWB NMC	4.00	Additional specialized parts.
DEWB LFP	4.00	Additional specialized parts.

Service Technician Availability

Defined as: Availability of qualified service technicians to service propulsion system.		
Power Plant:	Score	Explanation
MECH	7.00	Baseline.
DE 2xC18s	6.00	Additional vendor required in the case of work on a propulsion motor.
DE 3xC18s	6.00	Additional vendor required in the case of work on a propulsion motor.
DEWB NMC	4.00	Additional vendor required in the case of work on a propulsion motor or the battery system.
DEWB LFP	4.00	Additional vendor required in the case of work on a propulsion motor or the battery system.

Downtime for Repairs

Defined as: Frequency of specialized vendors required to perform unscheduled service of vessel.		
Power Plant:	Score	Explanation
MECH	7.00	Baseline.
DE 2xC18s	7.00	Baseline.
DE 3xC18s	7.00	Baseline.
DEWB NMC	5.00	There will be additional nuisance alarms during the break in period but significantly less hours will be put on the generators over the vessel's life
DEWB LFP	5.00	There will be additional nuisance alarms during the break in period but significantly less hours will be put on the generators over the vessel's life

Fleet Similarity

Defined as: Similarity to propulsion systems on vessels operated by Casco Bay Lines.		
Power Plant:	Score	Explanation
MECH	7.00	Majority of fleet.
DE 2xC18s	6.00	Recent new build (Batttery Steele) utilizes very similar technology
DE 3xC18s	6.00	Recent new build (Batttery Steele) utilizes very similar technology
DEWB NMC	6.00	Recent new build is similar (Batttery Steele)
DEWB LFP	6.00	Recent new build is similar (Batttery Steele)

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Feasibility Study Calculations: Reliability		Date:	03NOV25	Checked:	JSS

Reliability Criteria:

Reliability was defined as the ability of the propulsion system to function safely and consistently without failure. Reliability was measured by the expected availability of the propulsion system to meet operational conditions. The process to calculate the reliability metrics and any assumptions made to can be found in Reference 4.

Reliability Sub-Criteria:	Sub-Criteria Weighting
Availability	100%

Scoring

Reliability Sub-Criteria:	MECH	DE 2xC18s	DE 3xC18s	DEWB NMC	DEWB LFP
Availability	7.18	4.40	8.43	10.00	10.00

Sub-Criteria Scoring Procedure:

Typical procedure for scoring availability data:

Definitions: Bold letter represents a vector (i.e. **X**)
 x_i , represents the i^{th} component of the vector **X**
 $\|\mathbf{X}\|$ is the L2 norm of the vector **X**

Procedure: Availability Vector = **A**
Data Vector (Probability not Available) = **X** = (1-**A**)
Transformed Data (Log Transformation) = **T** = $\text{abs}(\log(\mathbf{X}))$
Normalized Vector (Euclidean Norm) = **N**, where $n_i = x_i / \|\mathbf{X}\|$
Score Vector = **S**, where $s_i = 10 * n_i / \max(\mathbf{N})$

Availability

Defined as: Scoring based on the availability of the system to power both shafts (Ref 4.).					
Power Plant:	Availability	(1 - A_i)	Log Transform	Normalized	Score
MECH	99.9904%	9.62E-05	4.02	0.39	7.18
DE 2xC18s	99.6551%	3.45E-03	2.46	0.24	4.40
DE 3xC18s	99.9981%	1.93E-05	4.72	0.46	8.43
DEWB NMC	99.9997%	2.55E-06	5.59	0.54	10.00
DEWB LFP	99.9997%	2.55E-06	5.59	0.54	10.00

APPENDIX IV

23494-199-4 Propulsion System Reliability Calculations

REVISION HISTORY					
REV	ZONE	DESCRIPTION	DATE	BY	CHECK
0	-	1. Initial Release	03NOV25	MDL	JSS

GENERAL NOTES

5	Department of the Army: TM 5-698-5	
4	23494-199-3	Feasibility Study Calculations
3	23494-199-2	Ferry Operational Profile Calculations
2	23494-199-1	Ferry Propulsion System Analysis Calcs
1	23494-099-1	Ferry Propulsion System Feasibility Study
NO.	DRAWING	TITLE

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REFERENCES		
TITLE:	Propulsion System Reliability Calculations	
FOR:	Casco Bay Lines	
VESSEL:	MAQUOIT II Replacement	BULL NO: -
DATE	03NOV25	SCALE: N.T.S.
DOC. NO:	23494-199-4	REV: 0
DRAWN BY:	MDL	CHECK BY: JSS

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date:	03NOV25	Checked:	JSS

Propulsion Systems Reliability Calculations

Probabilistic reliability of five propulsion systems were calculated in support of the feasibility study of propulsion system options for the Casco Bay Down Bay Ferry. Each system was modeled so that all major equipment was considered. The availability of the individual components (from reference 5) was used to model the probability of the overall system availability using Monte Carlo simulations. The availability is evaluated for an operational state where the ferry has power to both shafts and will be able to perform normal operations. This takes into account component redundancy and system robustness.

The propulsions options analyzed in the feasibility study were:

1. Diesel mechanical system with 2 C18 engines and 2 house generators (MECH)
2. Diesel electric system with 2 C18 generators and 1 house generator (DE 2xC18s)
3. Diesel electric system with 3 C18s generators and 1 house generator (DE 3xC18s)
4. Diesel electric system with 2 C18 generators and 1,000 kWh of NMC batteries (DEWB NMC)
5. Diesel electric system with 2 C18 generators and 1,000 kWh of LFP batteries (DEWB LFP)

These calculations do not represent the true reliability of the entire propulsion systems. Only the major equipment was considered. Minor equipment such as breakers were not included. This study only looks at components that are specific to each architecture. This means that components used uniformly in all of the systems studied were not included. For example everything after and including the reduction gear is not considered. Equipment after the high voltage distribution were not included as they would be the same across all propulsion systems. Reliability of the subsystems that are required for engines/generators/batteries to operate were also not considered. It should be noted that these subsystems should also have redundancy built into them. These calculations assume that each component modeled fail independently from each other. The electric systems are modeled as having split busses to provide additional redundancy and is how TSGI would recommend designing the system.

Inherent availability is assumed implying all significant preventative maintenance would be accomplished during scheduled shipyard visits and all minor preventive maintenance will be accomplished with no impact to operations.

System Major Components

To evaluate the availability of each propulsion system the major equipment was identified. The following components were considered and are depicted by block diagrams in the following pages.

Component	Mechanical	DE 2xC18s	DE 3xC18s	DEWBs
Diesel Engine	2	0	0	0
Diesel Generator	2	3	4	2
Batteries	0	0	0	2
Motors	0	2	2	2
Drive	0	4	4	4
Switchgear	2	4	4	4
Rectifier	0	2	3	2
Inverter	0	6	6	6
Total	6	21	23	22

PROJECT:	23494	Casco Bay Lines	Rev:	0	By:	MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date:	03NOV25	Checked:	JSS

Definitions (per reference 5)

- MTBF =

Mean time before failures: The mean exposure time between consecutive failures of a component. MTBF is a measurement used for calculating inherent availability.
- MTTR =

Mean time between repairs. The mean time to replace or repair a failed component. Logistics delay time associated with the repair, such as parts acquisitions, crew mobilization, are not included
- $A_{i, comp}$ =

Availability, inherent: The instantaneous probability that a component will be up. A_i considers only downtime for repair due to failures. No logistics delay time, preventative maintenance, etc. is included

Note: The data published in reference 5 is the most comprehensive data set available. However, the reliability data is collected from land-based installations and may skew failure rates and repair time. The data is also dated and component dependence on software and use of solid-state electronics may not be accounted for. These calculations are done as a comparison tool and should not be applied to any maintenance forecasting. Any data used will be dependent on the frequency of preventative maintenance. In this study we assume motor replacements at the vessels half-life therefore decreasing the likelihood of catastrophic component failure. Additionally, it must be reiterated that these values assume that replacement parts are on hand and ready for installation at time of failure.

Component Data

Component	MTBF	MTTR	Notes
Diesel Engine	87334.15	4.06	Per TM 5-698-5: Engine, Diesel
Diesel Generator	15033.8	25.74	Per TM 5-698-5: Generator, Diesel Engine, packaged, continuous
Batteries	1248161	12.11	Per TM 5-698-5: Battery, Rechargeable
Motors	791448	1	Per TM 5-698-5: Motor, Electric, Induction, ≤ 600 Volts
Drive	396929	16.55	Per TM 5-698-5: Drive
Switchgear	923068.2	7.29	Per TM 5-698-5: Switchgear, Bare Bus, ≤600V, Bkrs. Not Incl.
Rectifier	1960032	16	Per TM 5-698-5: Rectifiers, All Types
Inverter	1817016	26	Per TM 5-698-5: Inverters All Types

Component Inherent Availability

Component	$A_{i, comp}$	Variable	Probability Comp. Not Available	Variable
Diesel Engine	0.999953514	$A_{i, E}$	4.6486E-05	$P_{i, E}$
Diesel Generator	0.998290784	$A_{i, G}$	0.001709216	$P_{i, G}$
Batteries	0.999990298	$A_{i, B}$	9.70218E-06	$P_{i, B}$
Motors	0.999998736	$A_{i, M}$	1.26351E-06	$P_{i, M}$
Drive	0.999958307	$A_{i, D}$	4.16934E-05	$P_{i, D}$
Switchgear	0.999992102	$A_{i, S}$	7.89751E-06	$P_{i, S}$
Rectifier	0.999991837	$A_{i, R}$	8.16307E-06	$P_{i, R}$
Inverter	0.999985691	$A_{i, I}$	1.4309E-05	$P_{i, I}$

$$A_{i, comp} = \frac{MTBF}{MTBF + MTTR}$$

Monte Carlo Simulations

The candidate propulsion systems were modeled and the scenarios that result in the ferry maintaining full operational capacity were mapped out. Then a Monte Carlo simulation was performed for each system. For each run of the simulation a pseudorandom number generator was used to assign each individual component a numerical value. The component's assigned value is then evaluated against the component's availability data to determine the component status for that run. The system's status is determined based on which components are available. This is repeated many times and is used to estimate the total availability of the system.

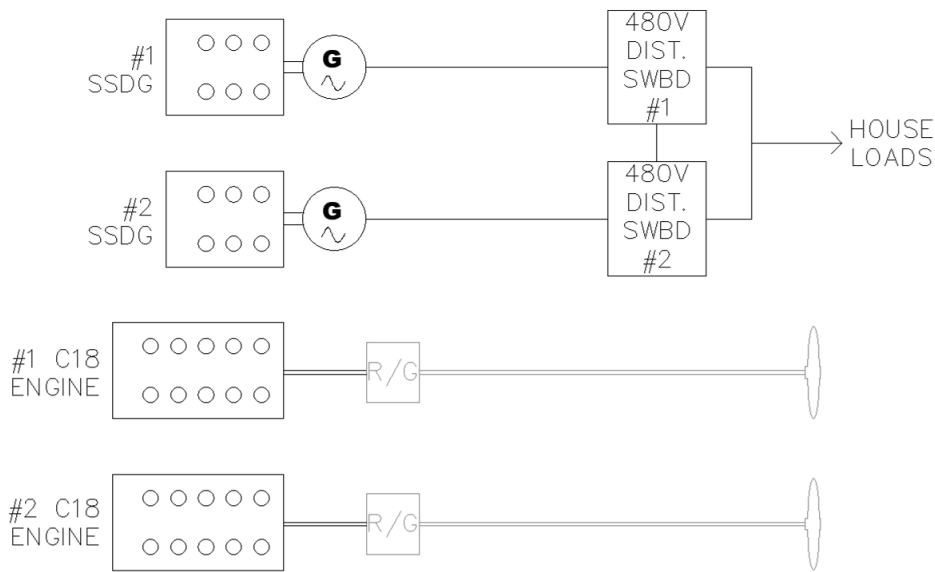
Summary of Monte Carlo Simulation Results

System	Availability	Probability Not Available
Mechanical	0.999904	9.622E-05
DE 2xC18s	0.996551	3.449E-03
DE 3xC18s	0.999981	1.926E-05
DEWB	0.999997	2.551E-06

PROJECT:	23494	Casco Bay Lines	Rev: 0	By: MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date: 03NOV25	Checked: JSS

Option 1
Block Diagram:

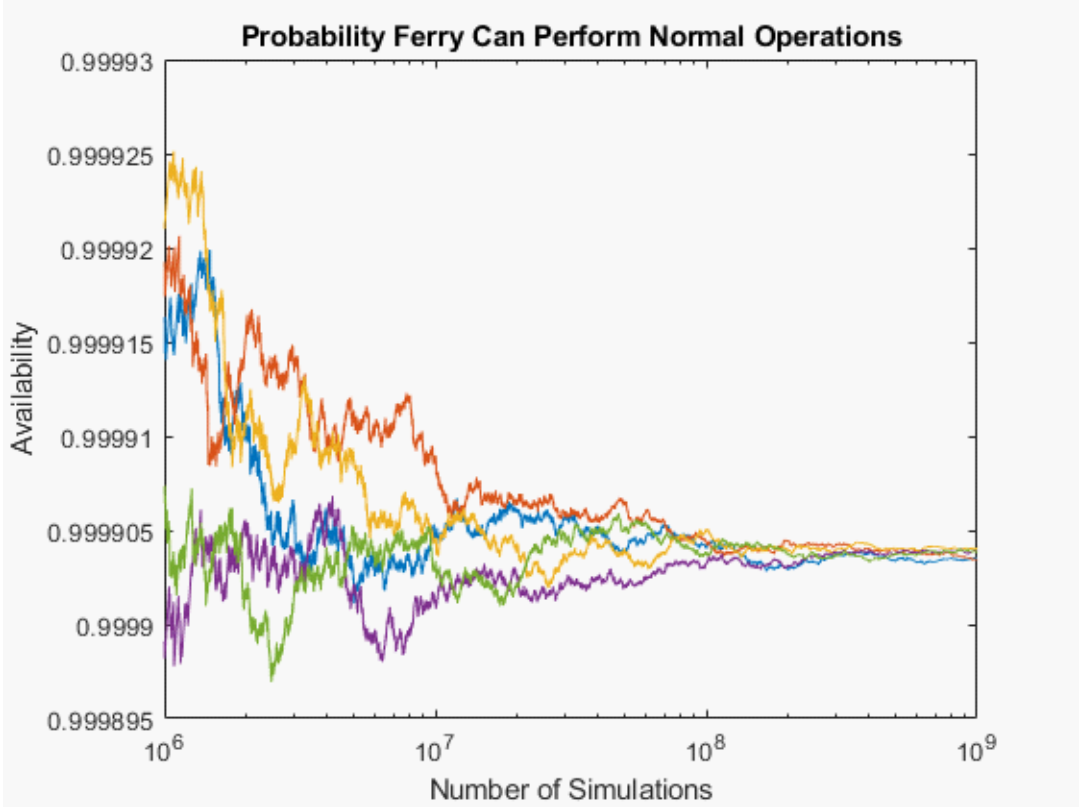
DIESEL MECHANICAL: 2x C18s AND 2x SSDG



Monte Carlo Simulations

Full power is achieved when both engines are online and providing power to both shafts & at least one SSDG is providing power to at least one 480V switchboards. The mechanical system was checked in 10⁹ simulations and repeated 5 times to converge to an average availability.

Average Final Result: 0.999903781503878

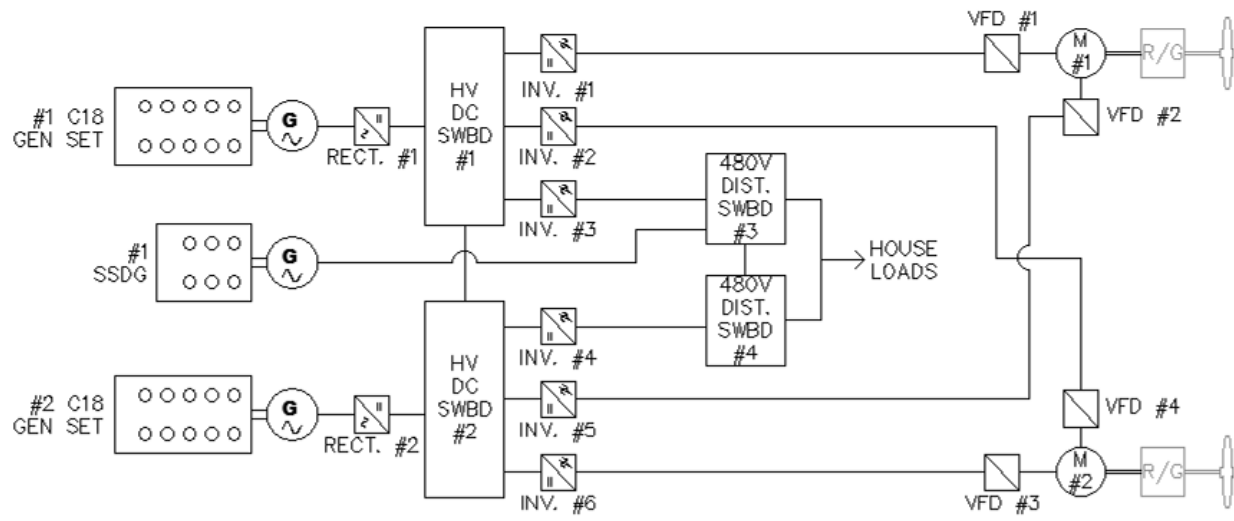


PROJECT:	23494	Casco Bay Lines	Rev: 0	By: MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date: 03NOV25	Checked: JSS

Option 2

Block Diagram:

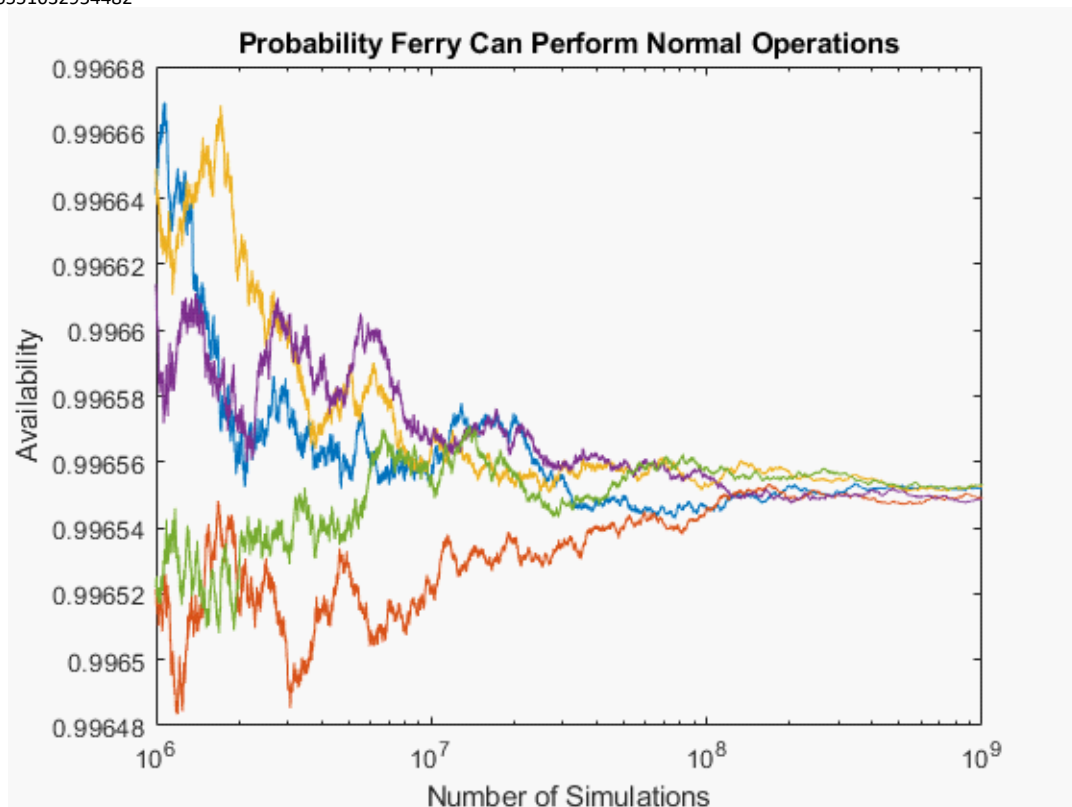
DIESEL ELECTRIC: 2x C18s AND 1x SSDG



Monte Carlo Simulations

Full power is achieved when both main generators are online and providing power to both motors and at least one 480V switchboard has power. The diesel electric system with 2xC18s was checked in 10^9 simulations and repeated 5 times to converge to an average availability.

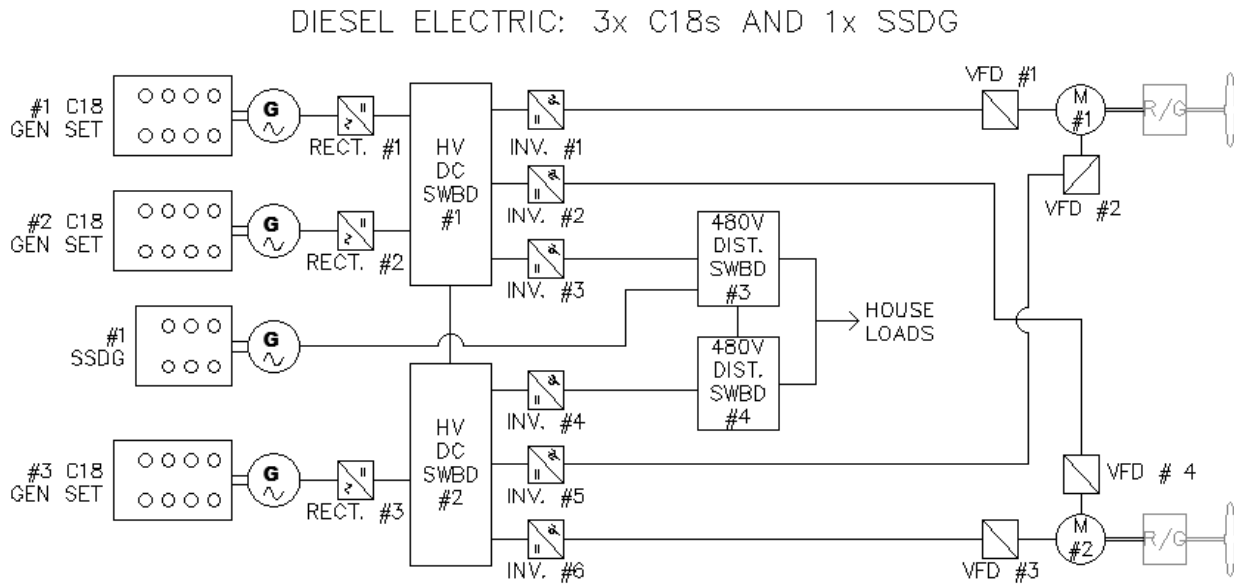
Average Final Result: 0.996551032954482



PROJECT:	23494	Casco Bay Lines	Rev: 0	By: MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date: 03NOV25	Checked: JSS

Option 3

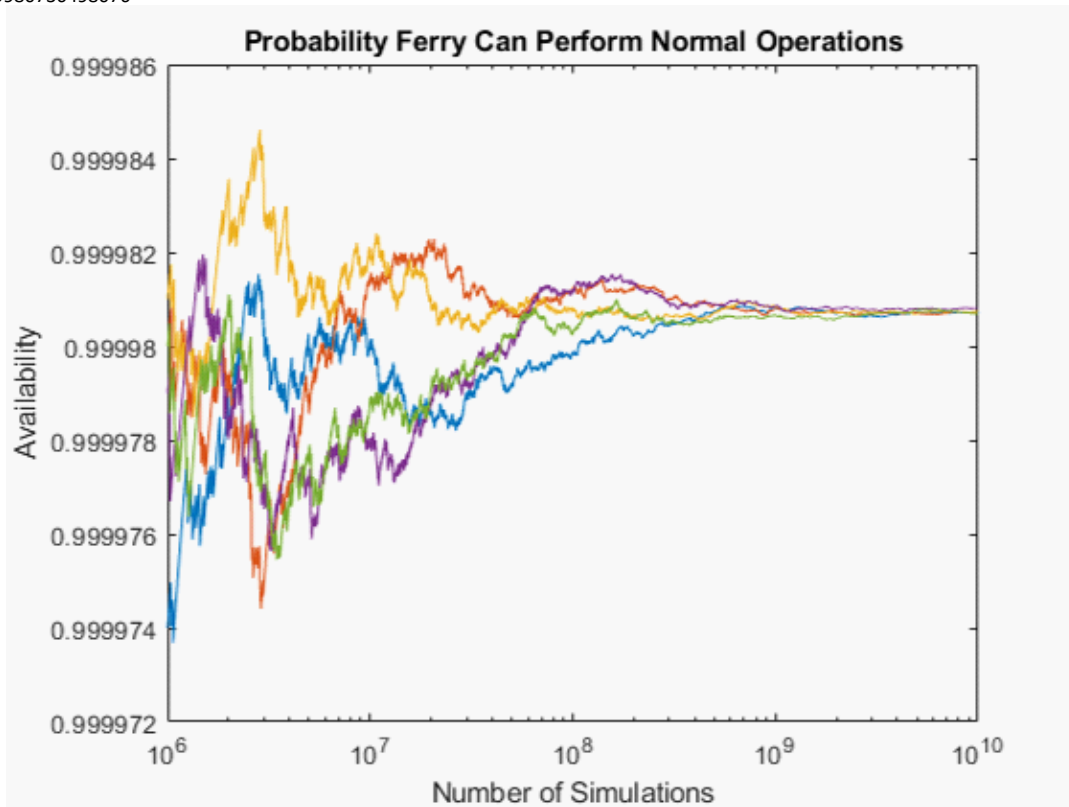
Block Diagram:



Monte Carlo Simulations

Full power is achieved when at least two main generators are online and providing power to both motors and at least one HV switchboard has power. The diesel electric system with 3xC18s was checked in 10^{10} simulations and repeated 5 times to converge to an average availability.

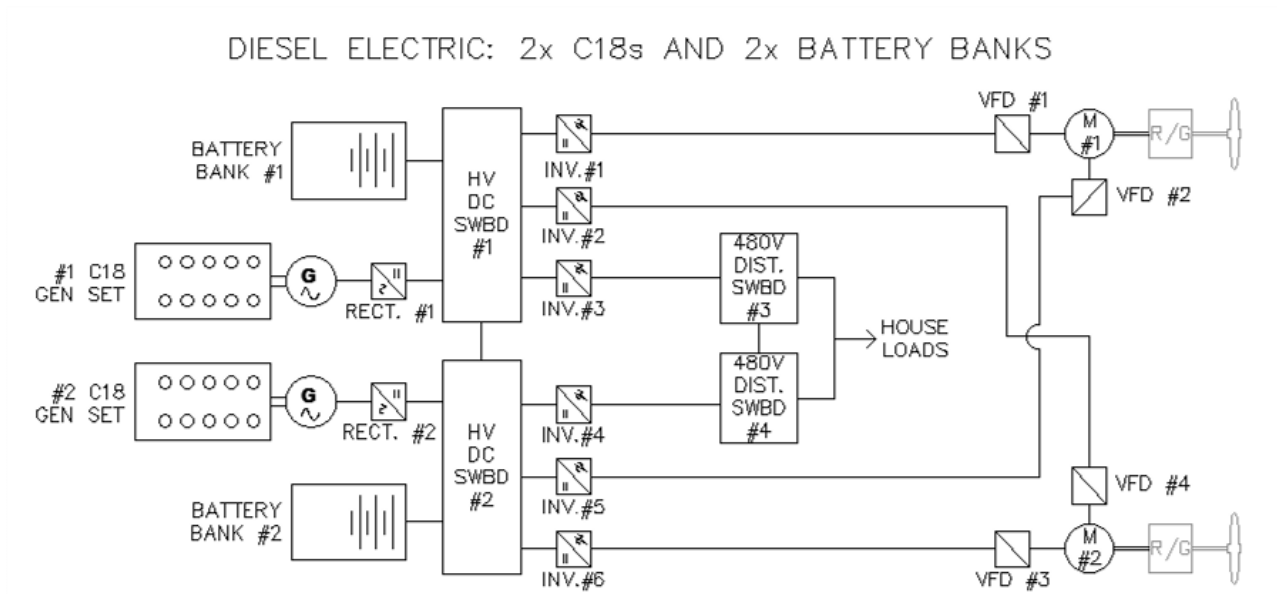
Average Final Result: 0.999980736498076



PROJECT:	23494	Casco Bay Lines	Rev: 0	By: MDL
CALC:	Propulsion System Reliability Calculations: Reliability Calcs		Date: 03NOV25	Checked: JSS

Option 4 & 5

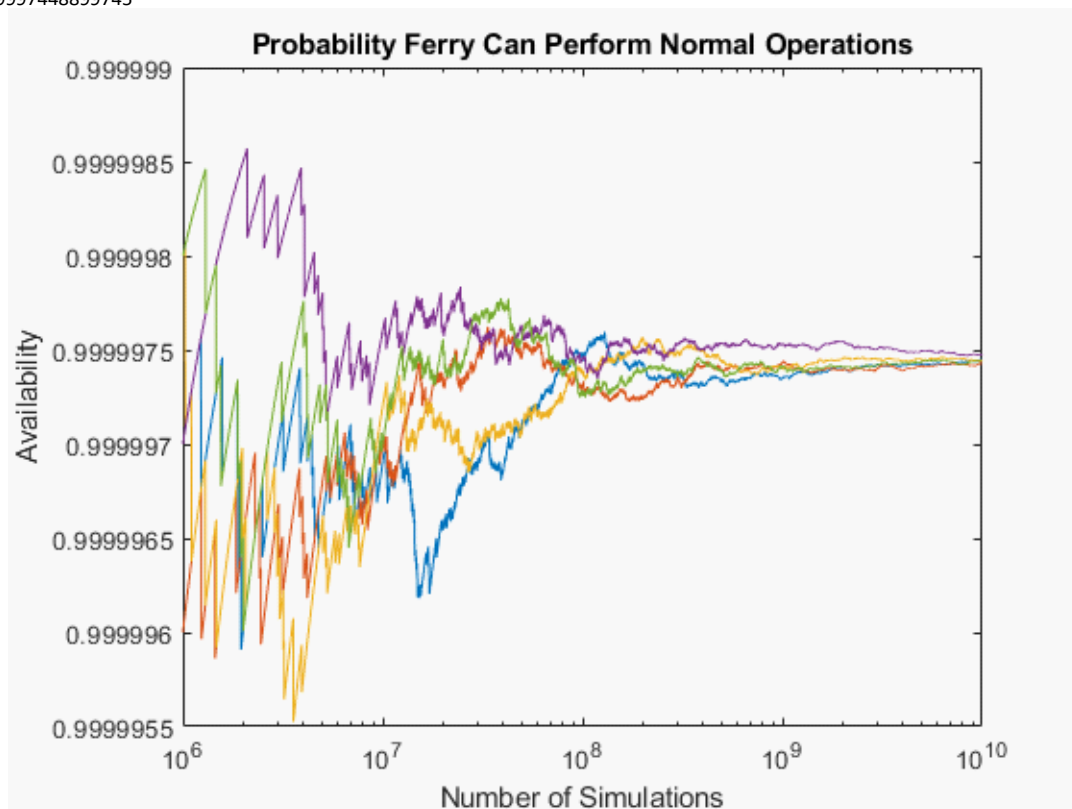
Block Diagram:



Monte Carlo Simulations

Full power is achieved when at least two main generators, a battery pack and a generator, or both battery packs are online and providing power to both motors and at least one 480V switchboard has power. The diesel electric system with C18s and batteries was checked in 10^{10} simulations and repeated 5 times to converge to an average availability.

Average Final Result: 0.999997448899745



APPENDIX V

23494-199-5 Propulsion Systems Simulation Results

REVISION HISTORY					
REV	ZONE	DESCRIPTION	DATE	BY	CHECK
0	-	1. Initial Release	03NOV25	MDL	JSS

GENERAL NOTES

-

4	23494-199-3	Feasibility Study Calculations
3	23494-199-2	Ferry Operational Profile Calculations
2	23494-199-1	Ferry Propulsion System Analysis Calcs
1	23494-099-1	Ferry Propulsion System Feasibility Study
NO.	DRAWING	TITLE

REFERENCES

TITLE: Propulsion Systems Simulation Results		
FOR: Casco Bay Lines		
VESSEL:	MAQUOIT II Replacement	DRAWING NO: -
DATE	03NOV25	SCALE: N.T.S.
FWC. NO:	23494-199-5	REV: 0
DRAWN BY:	MDL	CHECK BY: JSS



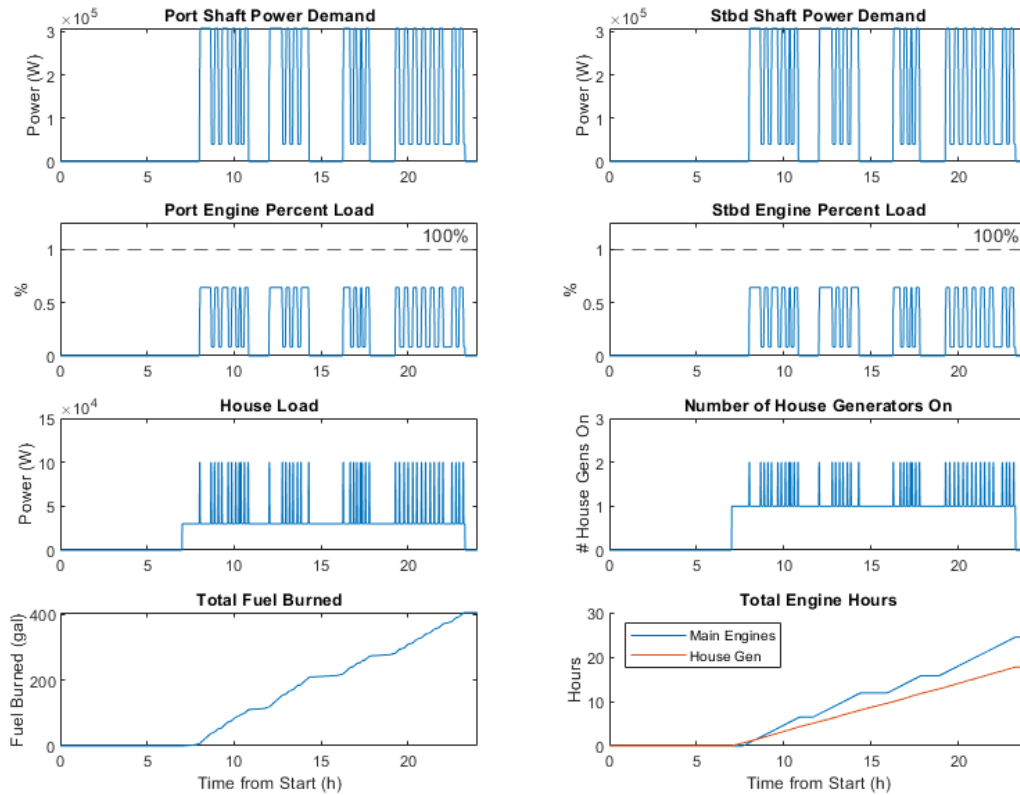
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THE SHEARER GROUP

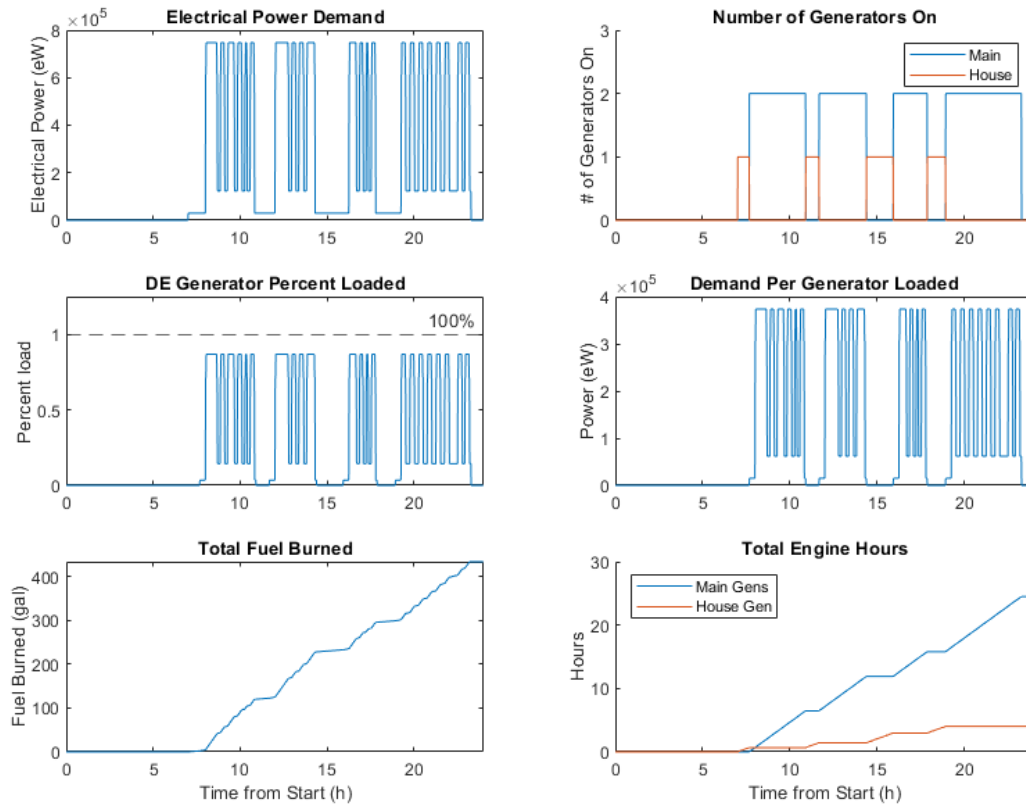
2301 COMMERCE STREET, SUITE 160, HOUSTON TX 77002
TEL: (281) 532-2080 ~ FAX (281) 326-1615
www.shearer-group.com

Simulation Results for a 11 knot Transit Speed at a 7ft Draft: Sunday - Thursday

Mechanical Results: 11 knots at a 7ft Draft: Sunday - Thursday

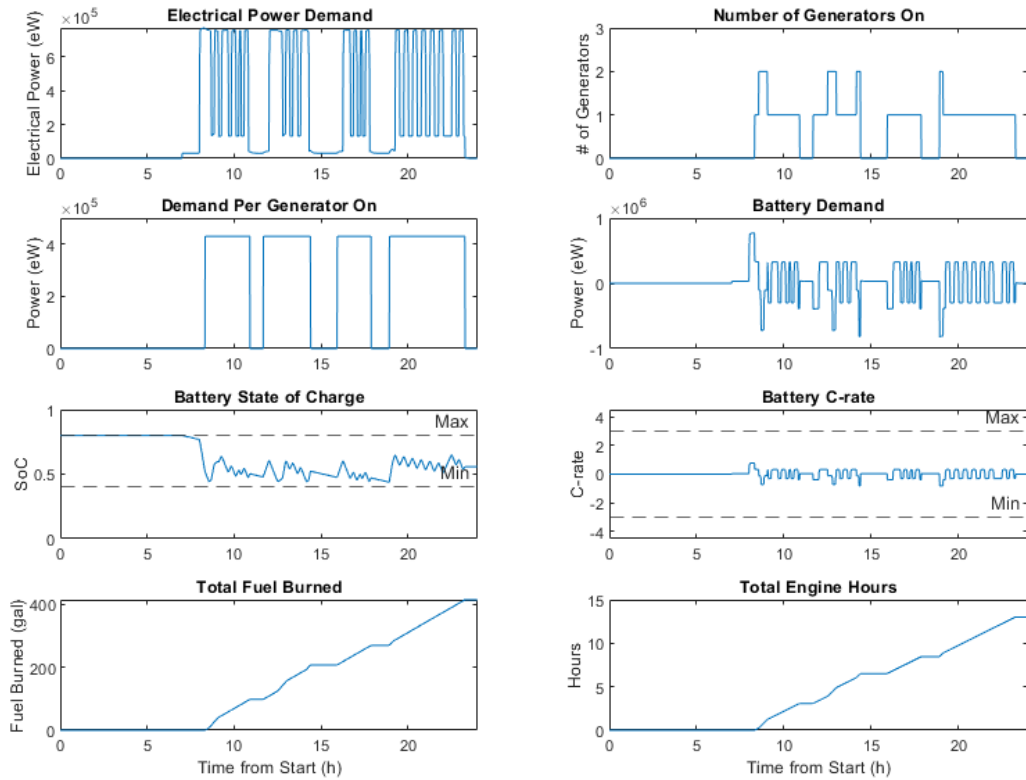


Diesel Electric with C18s Results: 11 knots at a 7ft Draft: Sunday - Thursday

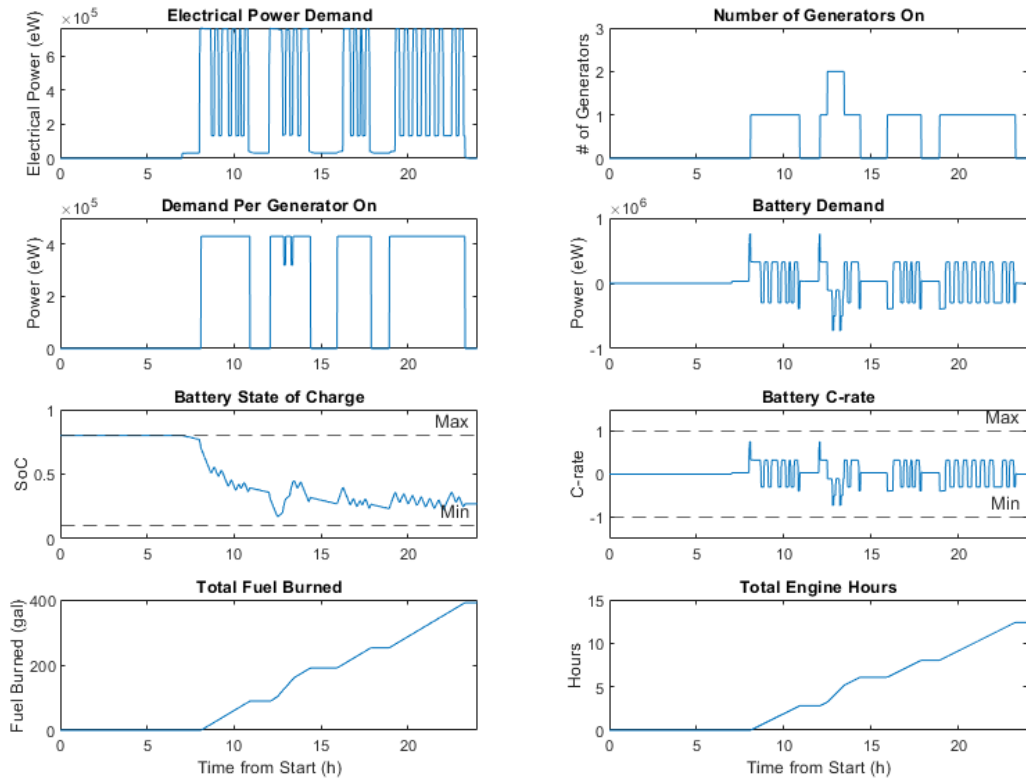


Simulation Results for a 11 knot Transit Speed at a 7ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 11 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

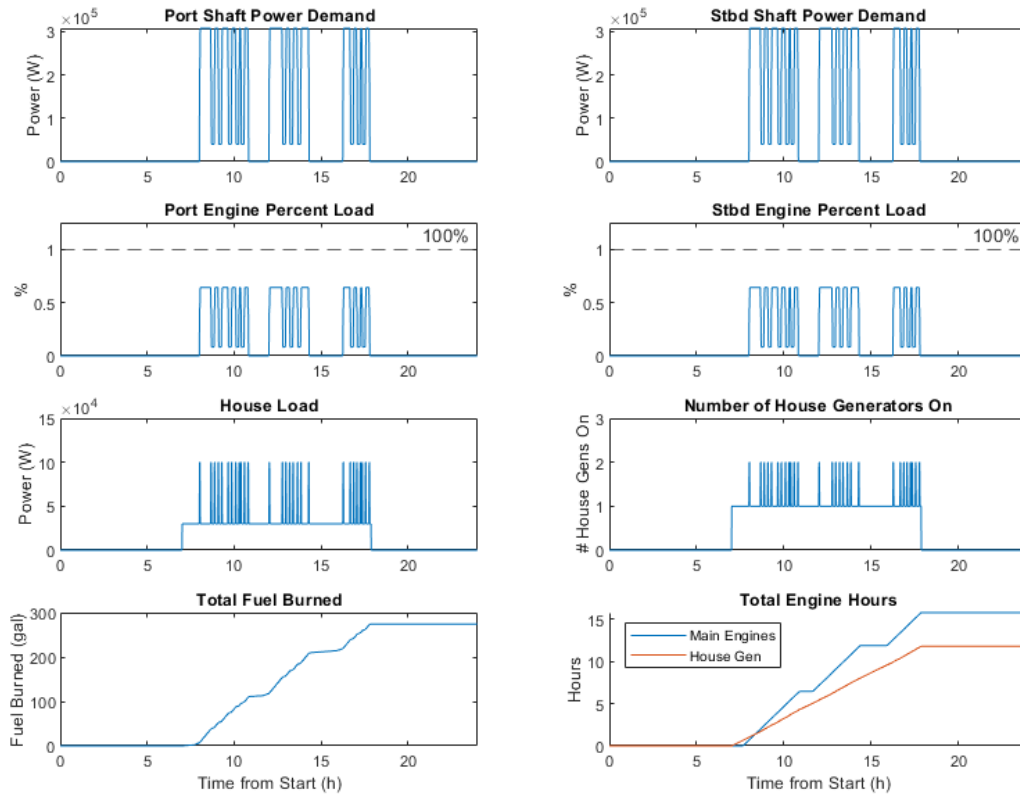


Diesel Electric with Batteries Results: 11 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

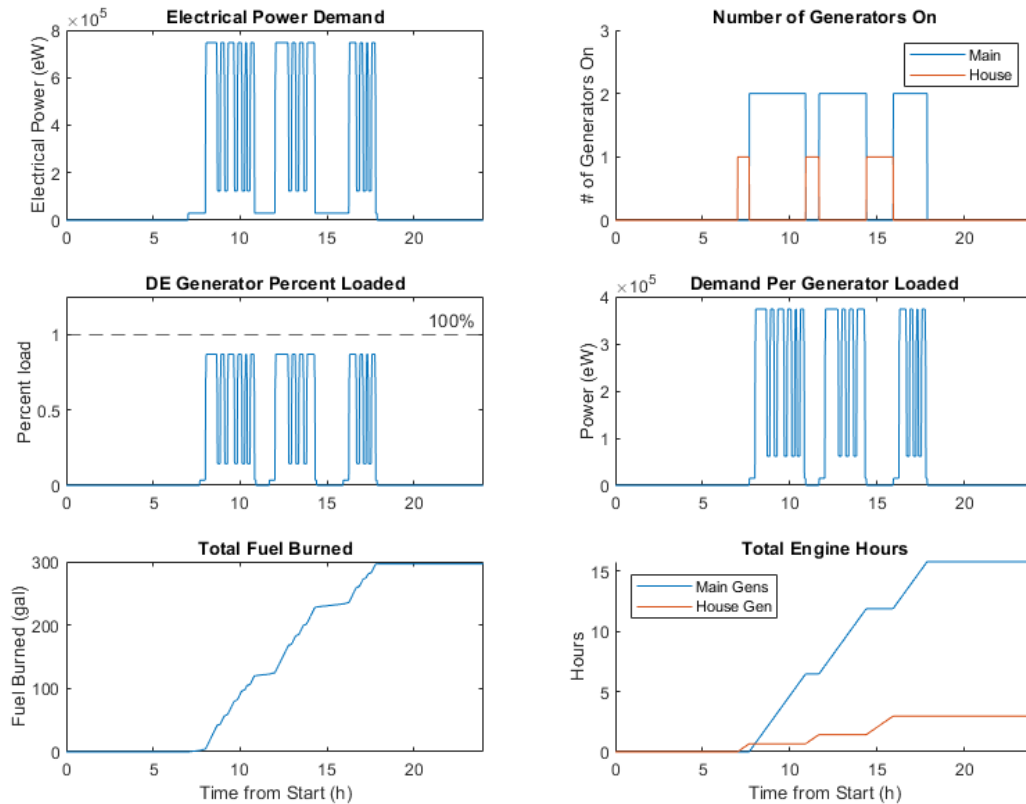


Simulation Results for a 11 knot Transit Speed at a 7ft Draft: Friday - Saturday

Mechanical Results: 11 knots at a 7ft Draft: Friday - Saturday

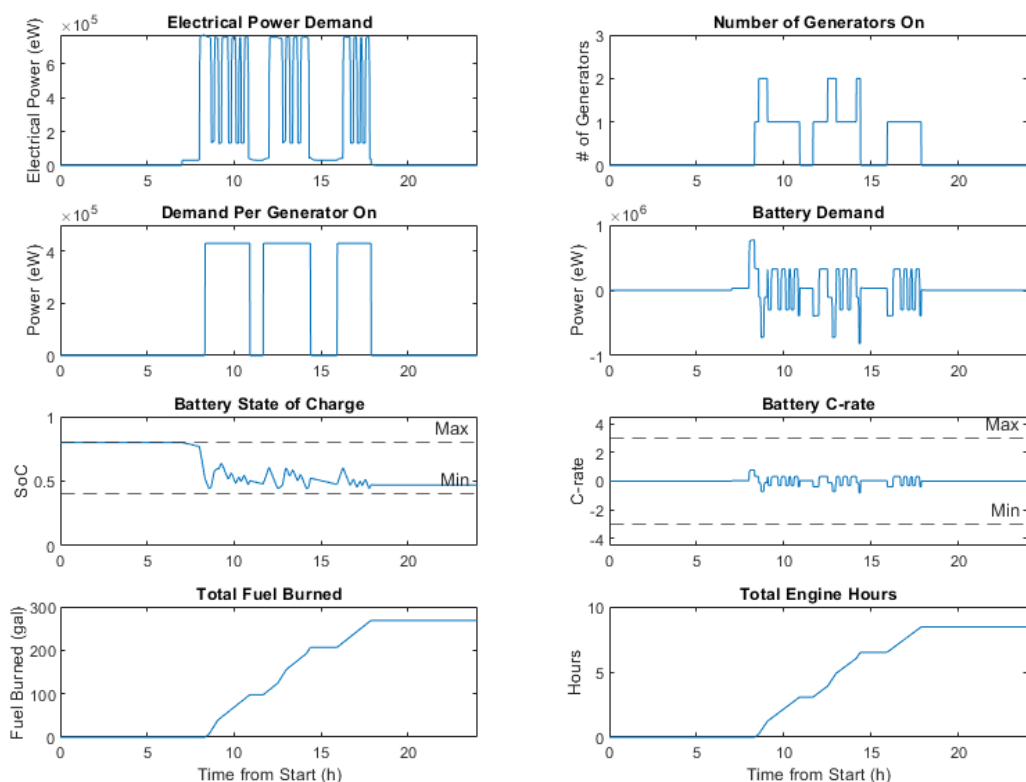


Diesel Electric with C18s Results: 11 knots at a 7ft Draft: Friday - Saturday

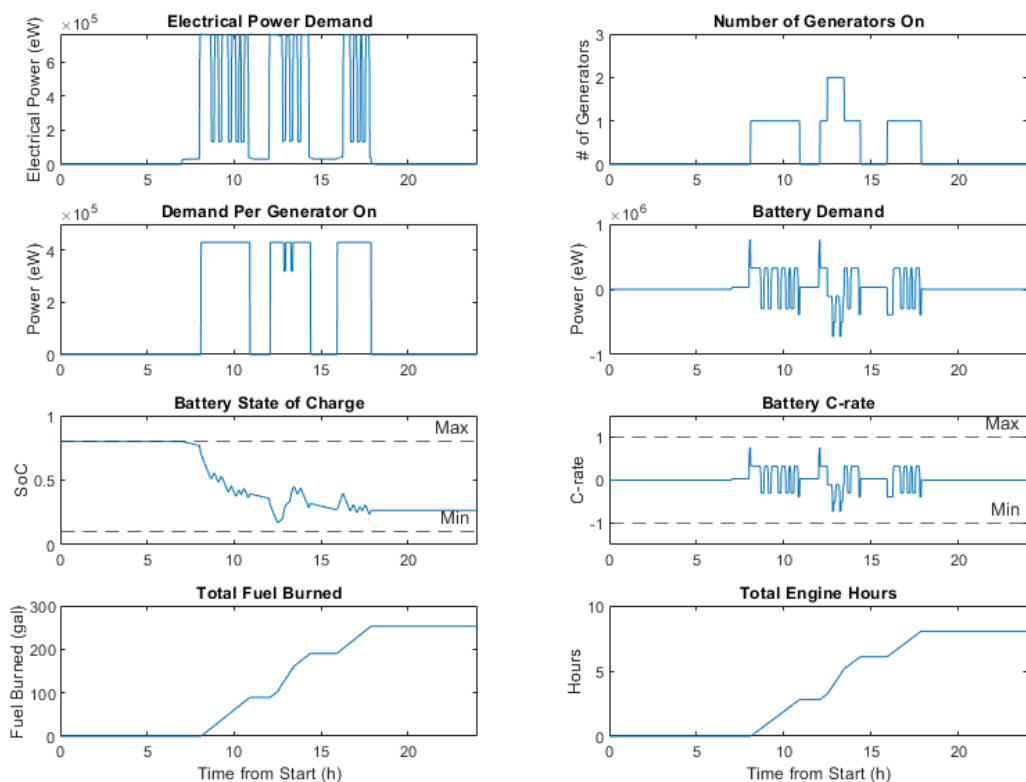


Simulation Results for a 11 knot Transit Speed at a 7ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 11 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

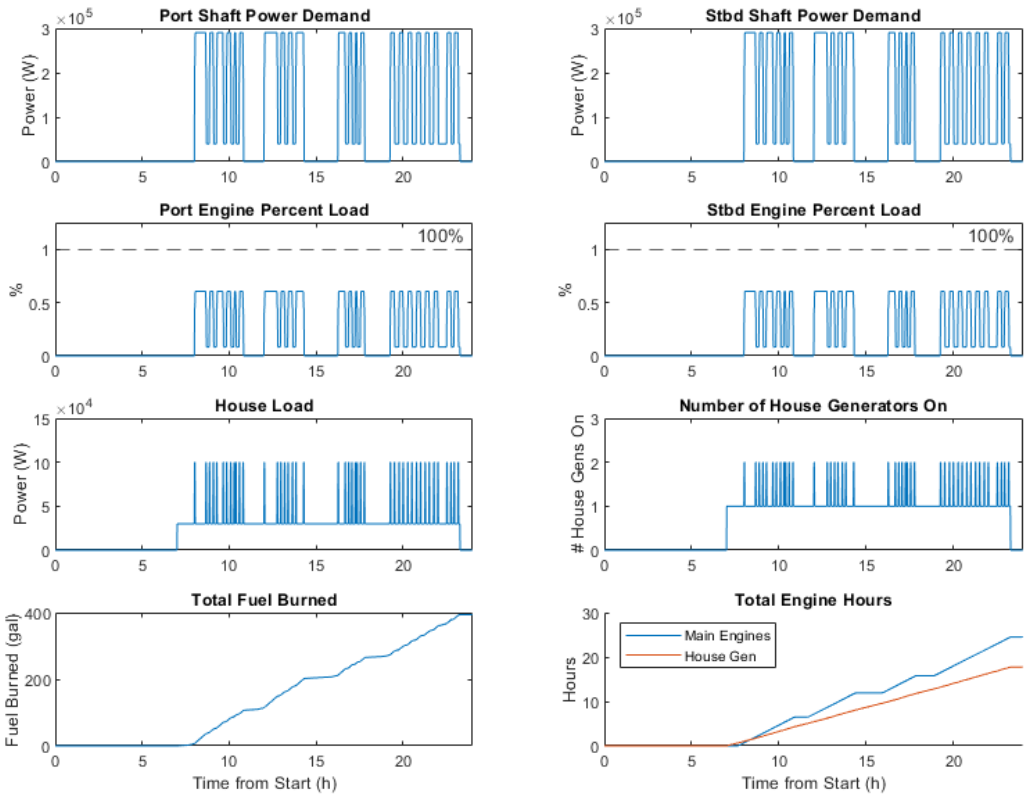


Diesel Electric with Batteries Results: 11 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

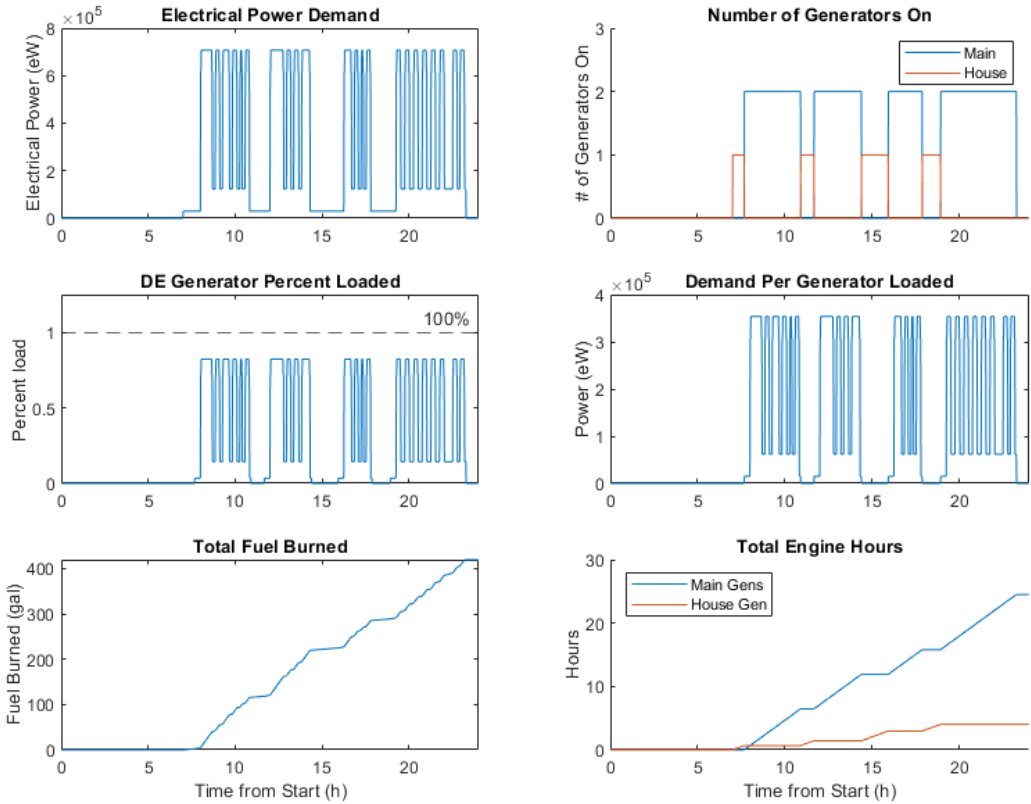


Simulation Results for a 11 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday

Mechanical Results: 11 knots at a 6.5ft Draft: Sunday - Thursday

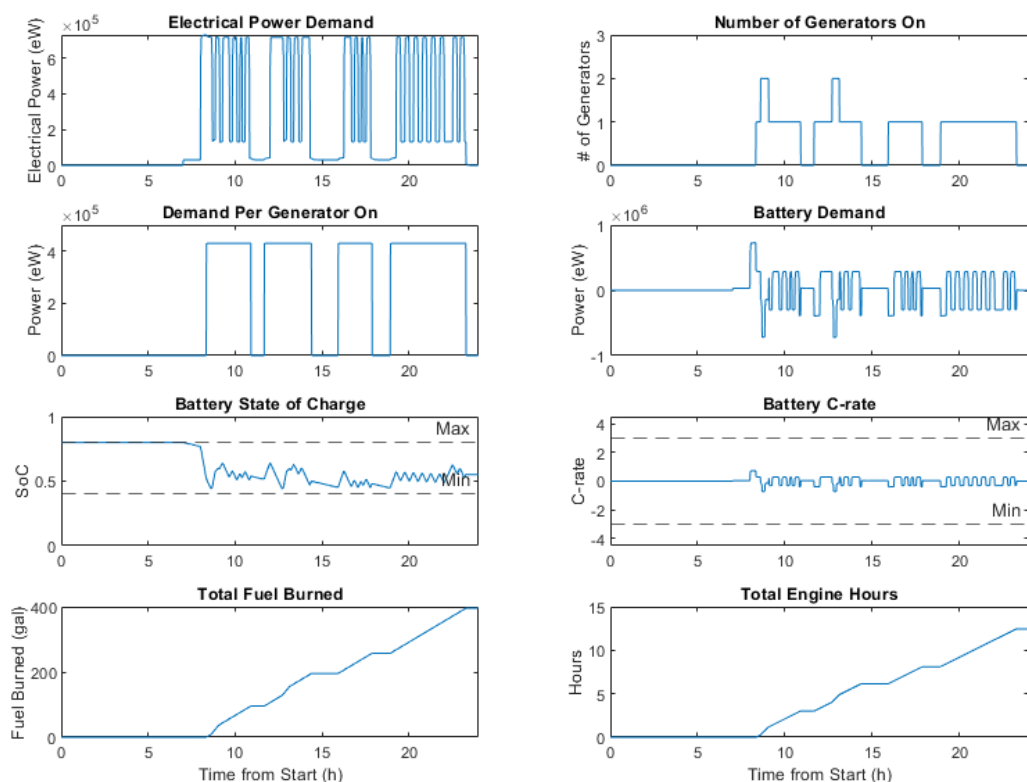


Diesel Electric with C18s Results: 11 knots at a 6.5ft Draft: Sunday - Thursday

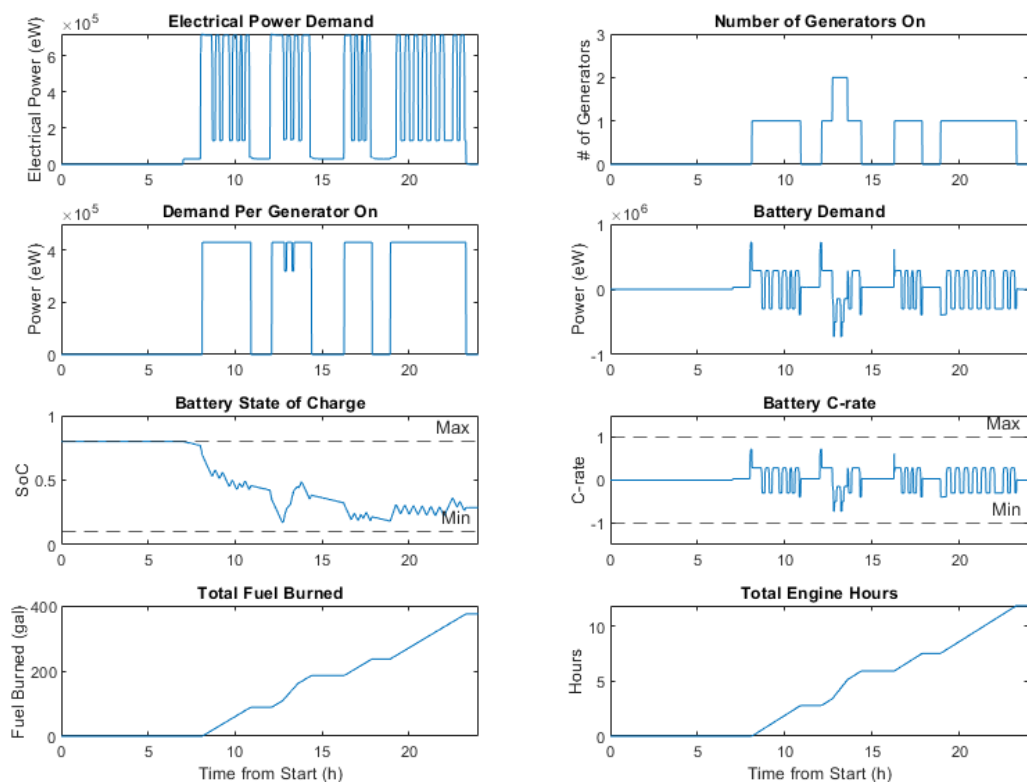


Simulation Results for a 11 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 11 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

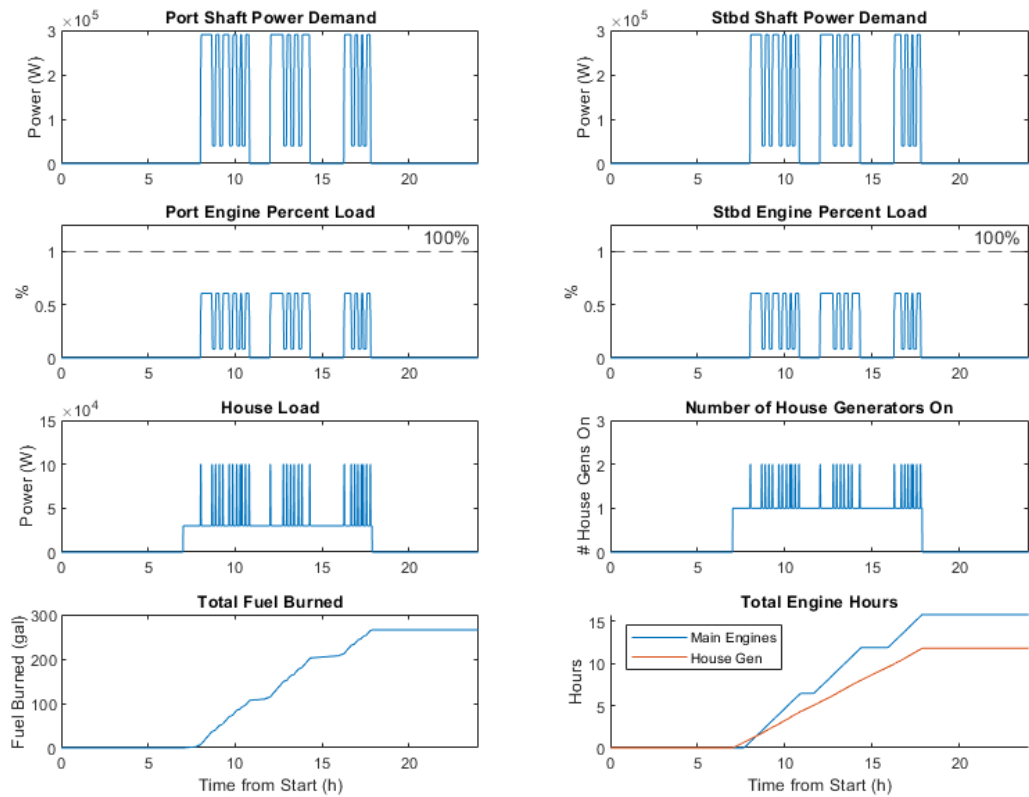


Diesel Electric with Batteries Results: 11 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

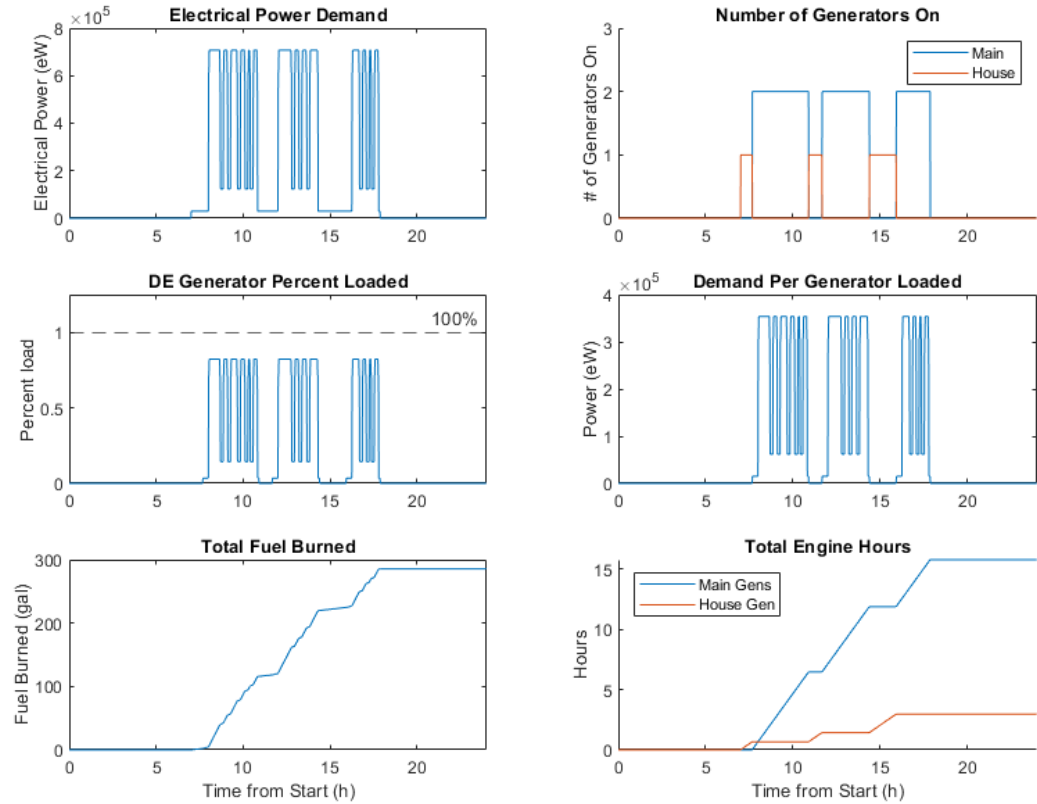


Simulation Results for a 11 knot Transit Speed at a 6.5ft Draft: Friday - Saturday

Mechanical Results: 11 knots at a 6.5ft Draft: Friday - Saturday

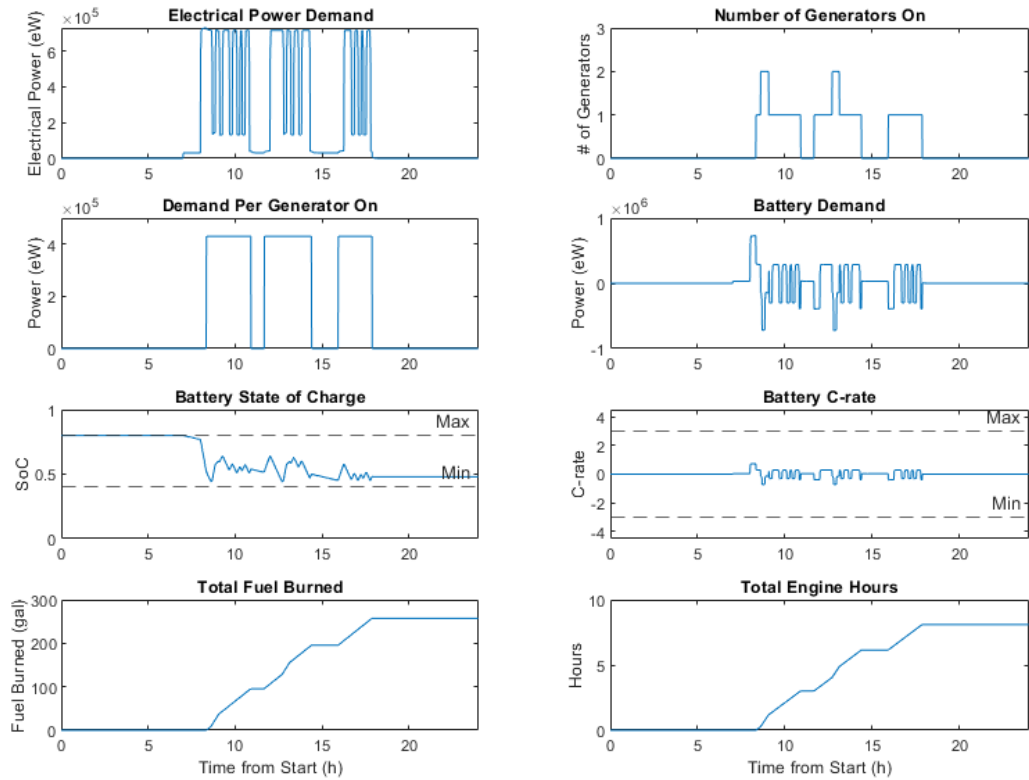


Diesel Electric with C18s Results: 11 knots at a 6.5ft Draft: Friday - Saturday

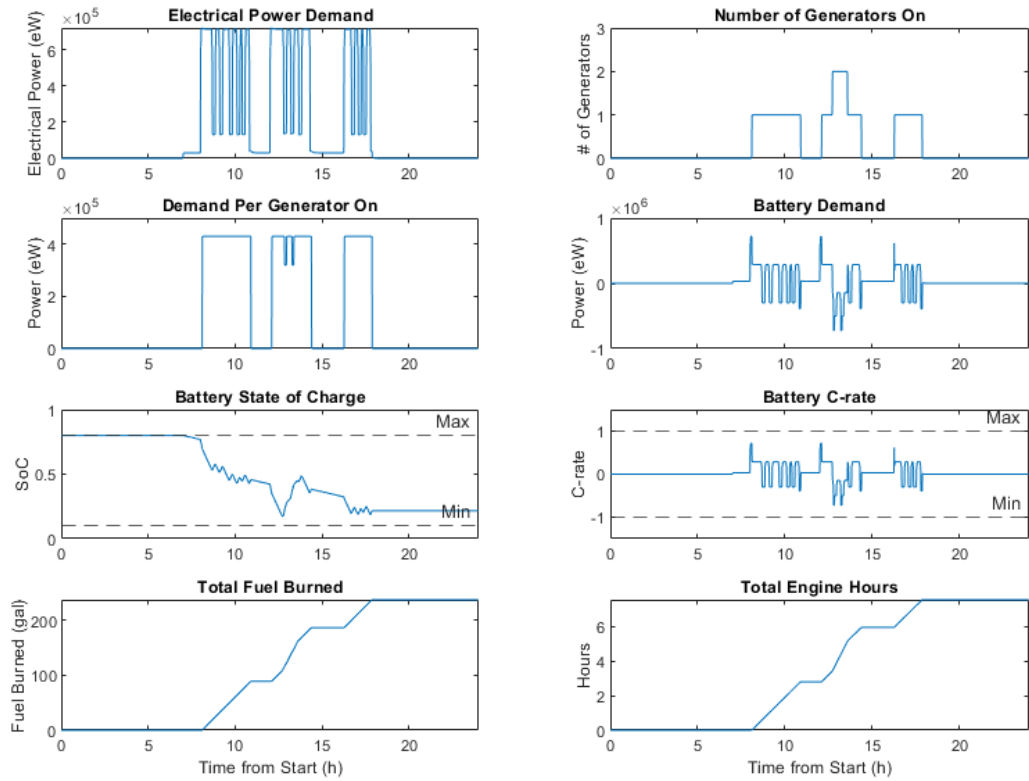


Simulation Results for a 11 knot Transit Speed at a 6.5ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 11 knots at a 6.5ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

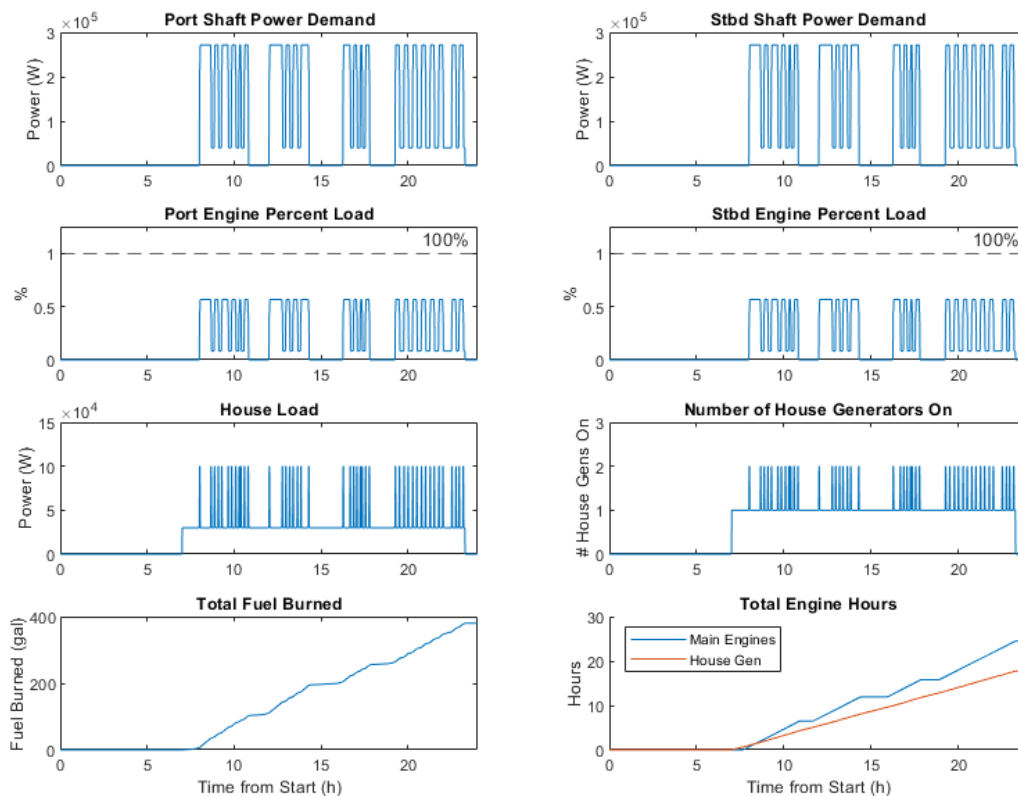


Diesel Electric with Batteries Results: 11 knots at a 6.5ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

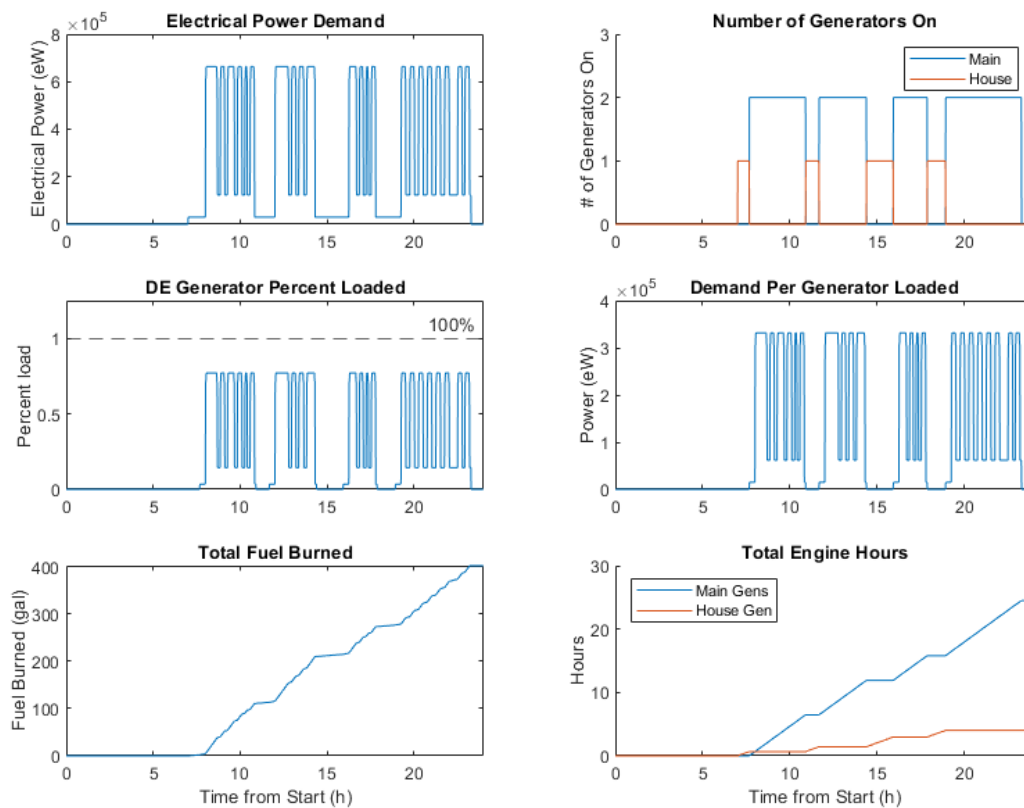


Simulation Results for a 11 knot Transit Speed at a 6ft Draft: Sunday - Thursday

Mechanical Results: 11 knots at a 6ft Draft: Sunday - Thursday

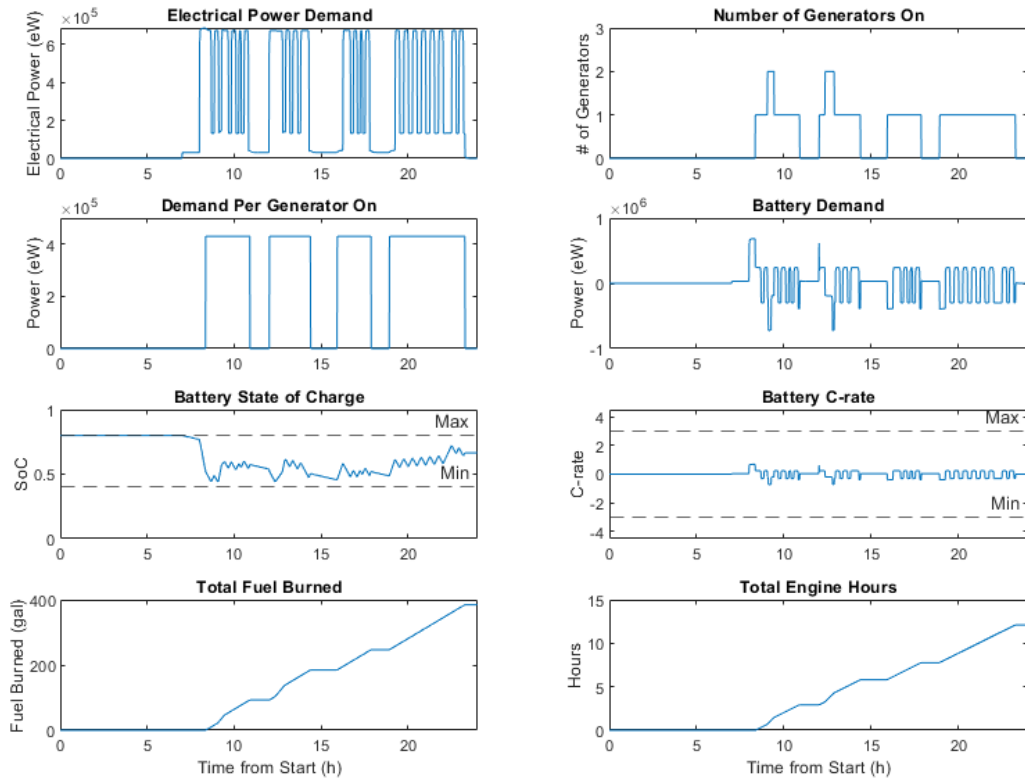


Diesel Electric with C18s Results: 11 knots at a 6ft Draft: Sunday - Thursday

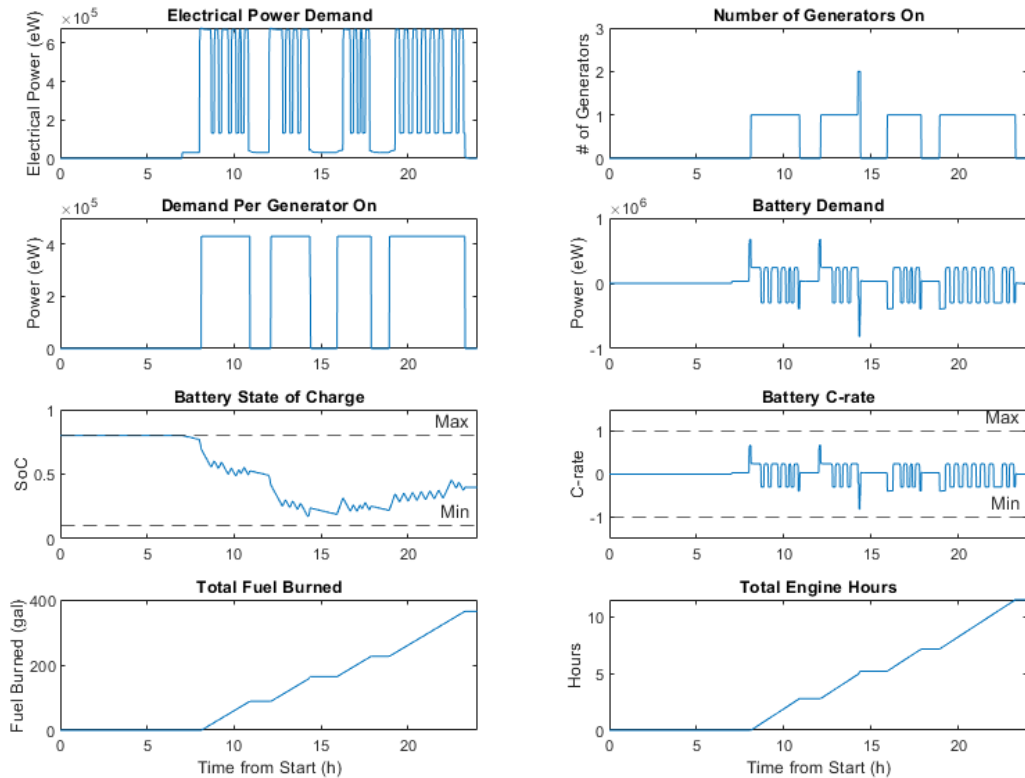


Simulation Results for a 11 knot Transit Speed at a 6ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 11 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

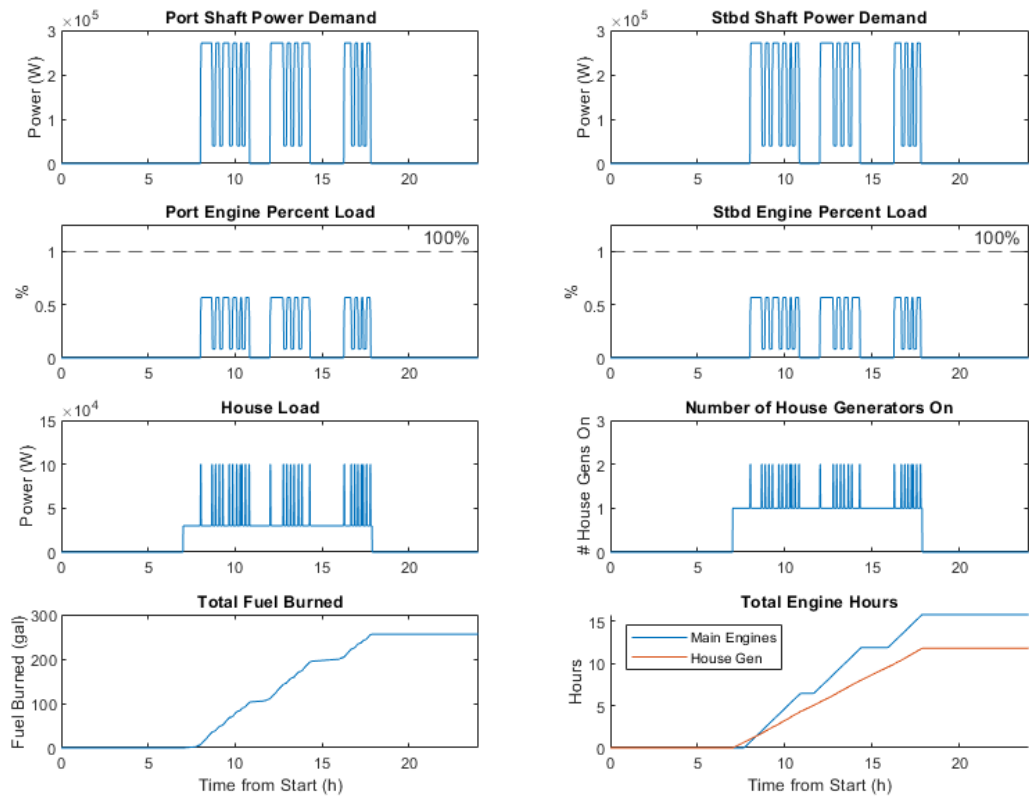


Diesel Electric with Batteries Results: 11 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

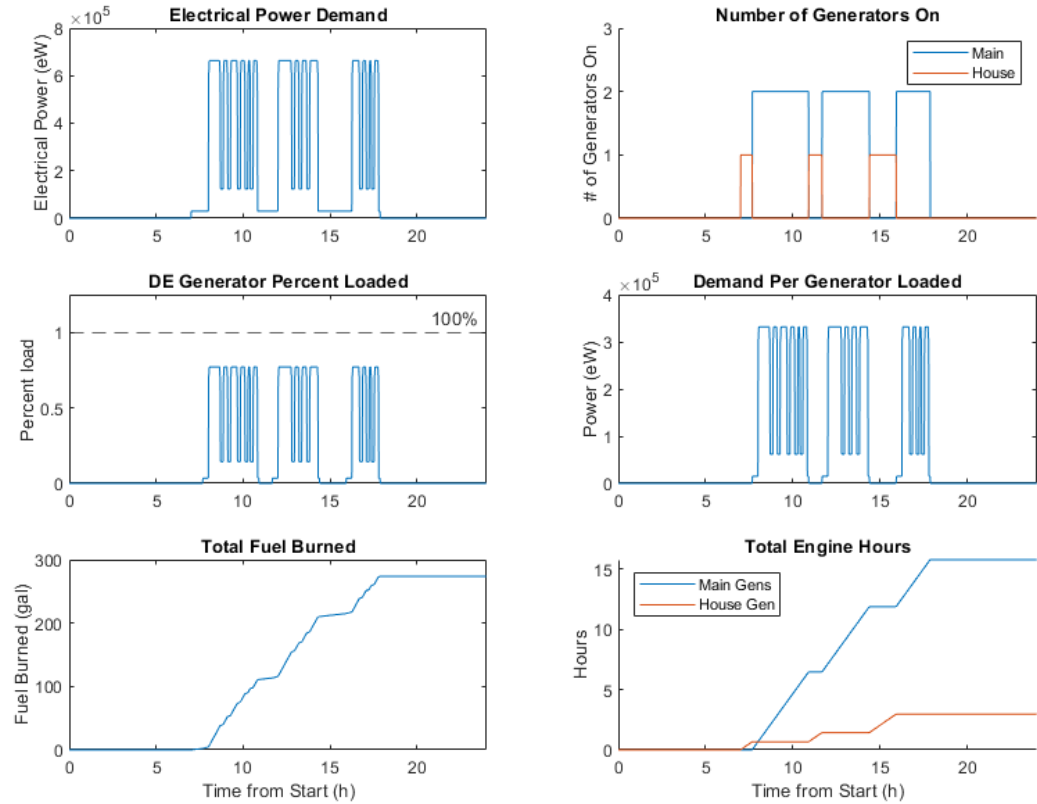


Simulation Results for a 11 knot Transit Speed at a 6ft Draft: Friday - Saturday

Mechanical Results: 11 knots at a 6ft Draft: Friday - Saturday

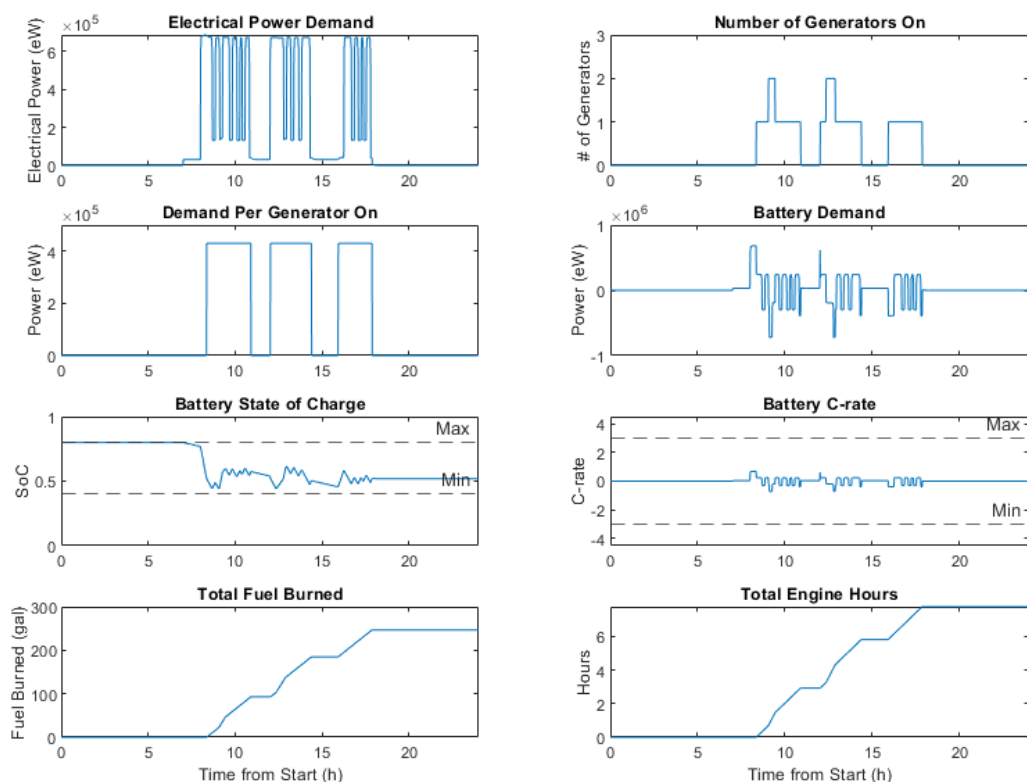


Diesel Electric with C18s Results: 11 knots at a 6ft Draft: Friday - Saturday

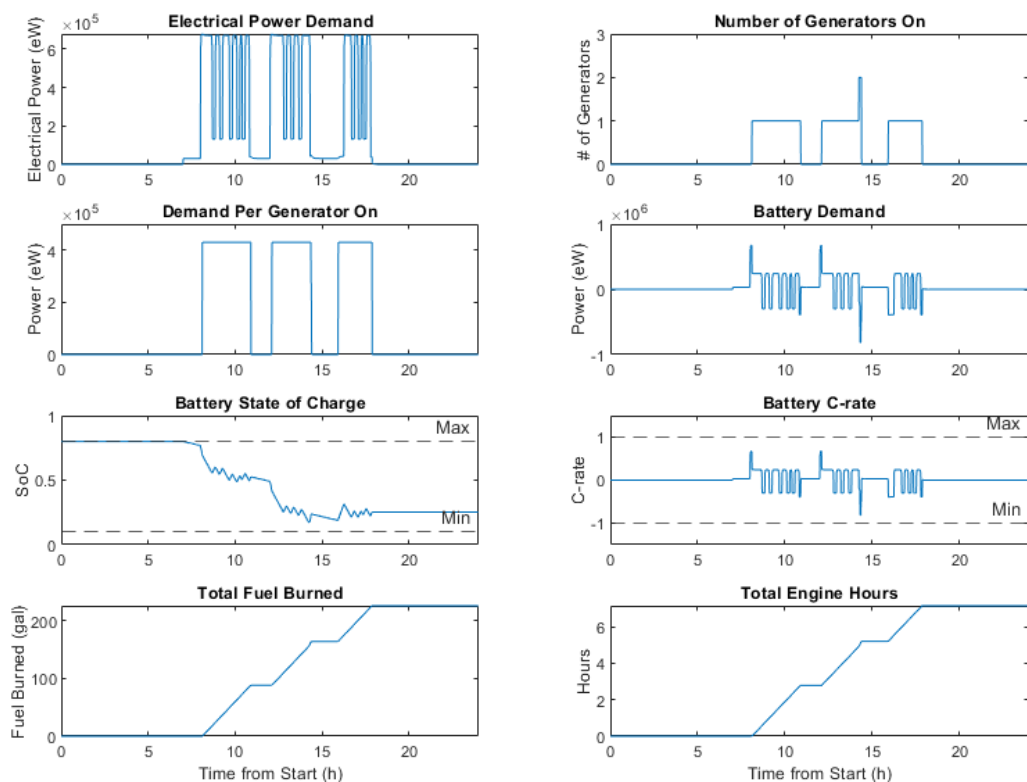


Simulation Results for a 11 knot Transit Speed at a 6ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 11 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

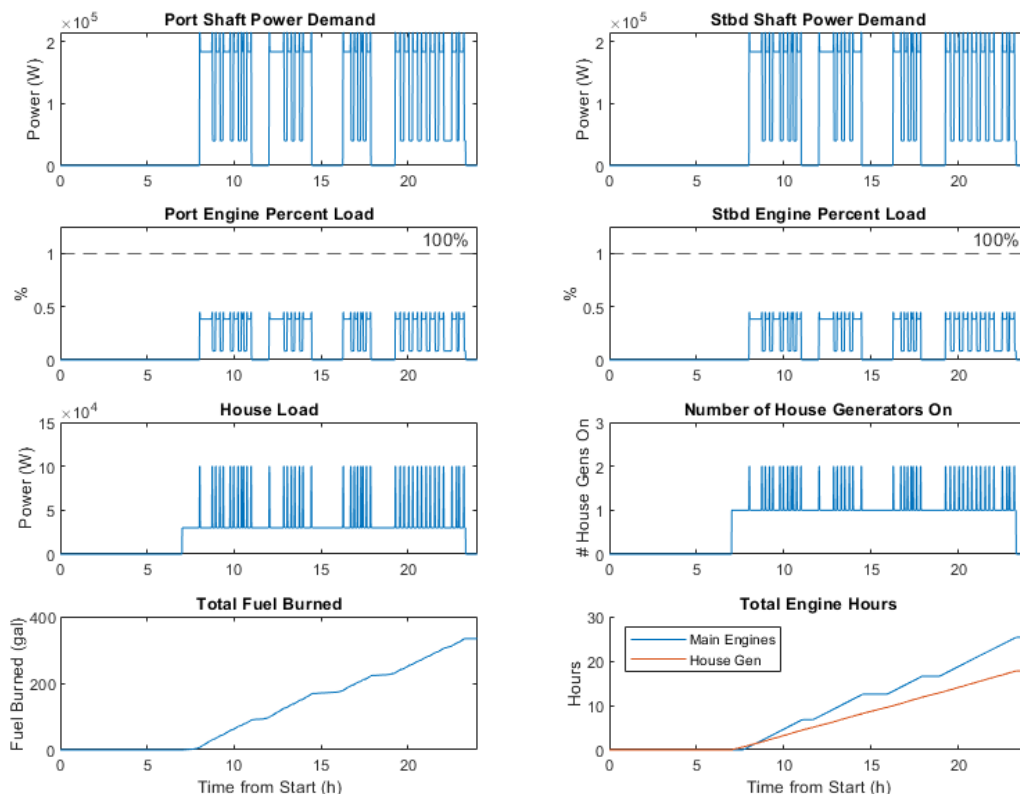


Diesel Electric with Batteries Results: 11 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

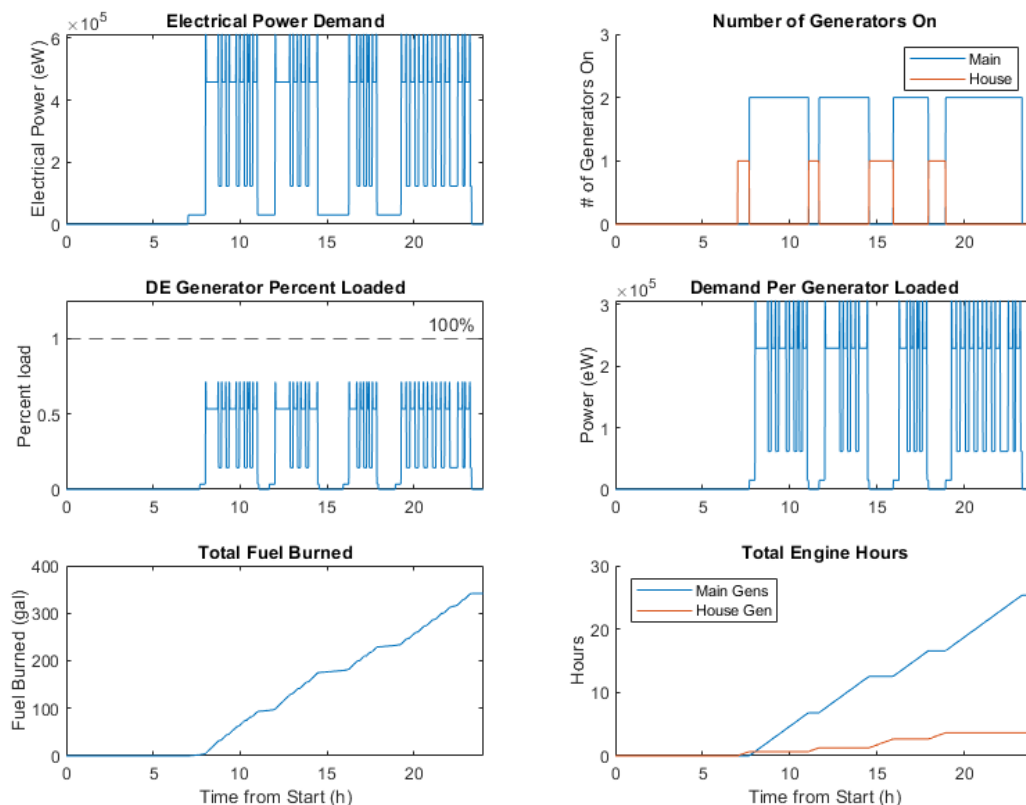


Simulation Results for a 10 knot Transit Speed at a 7ft Draft: Sunday - Thursday

Mechanical Results: 10 knots at a 7ft Draft: Sunday - Thursday

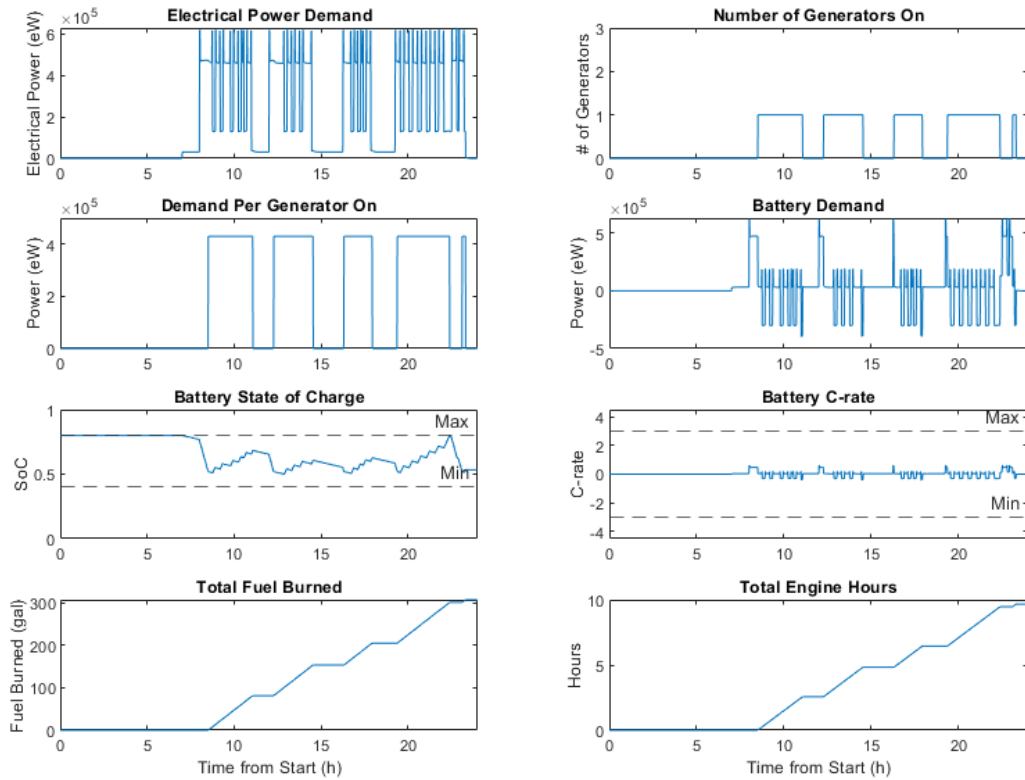


Diesel Electric with C18s Results: 10 knots at a 7ft Draft: Sunday - Thursday

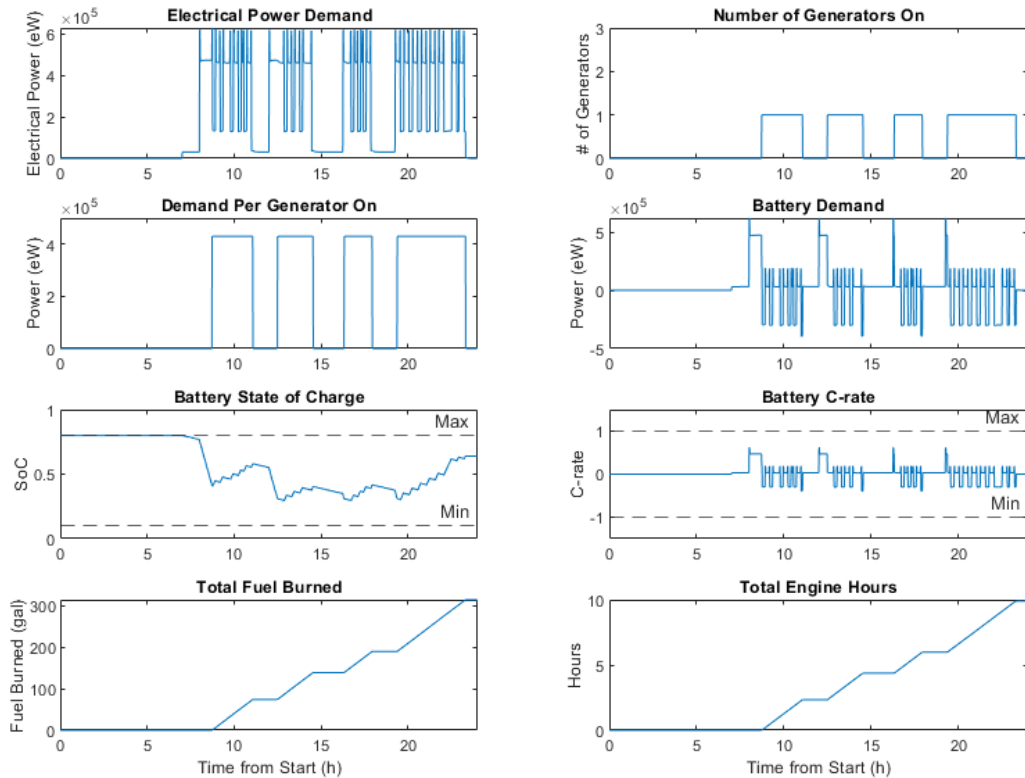


Simulation Results for a 10 knot Transit Speed at a 7ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 10 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

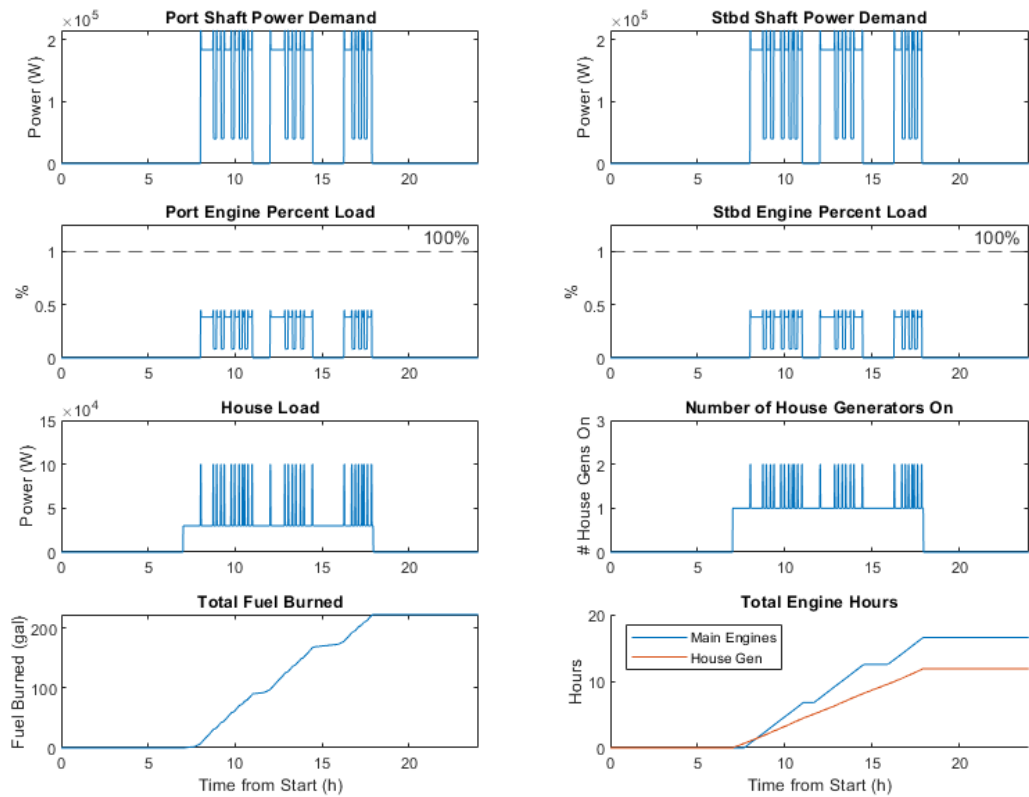


Diesel Electric with Batteries Results: 10 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

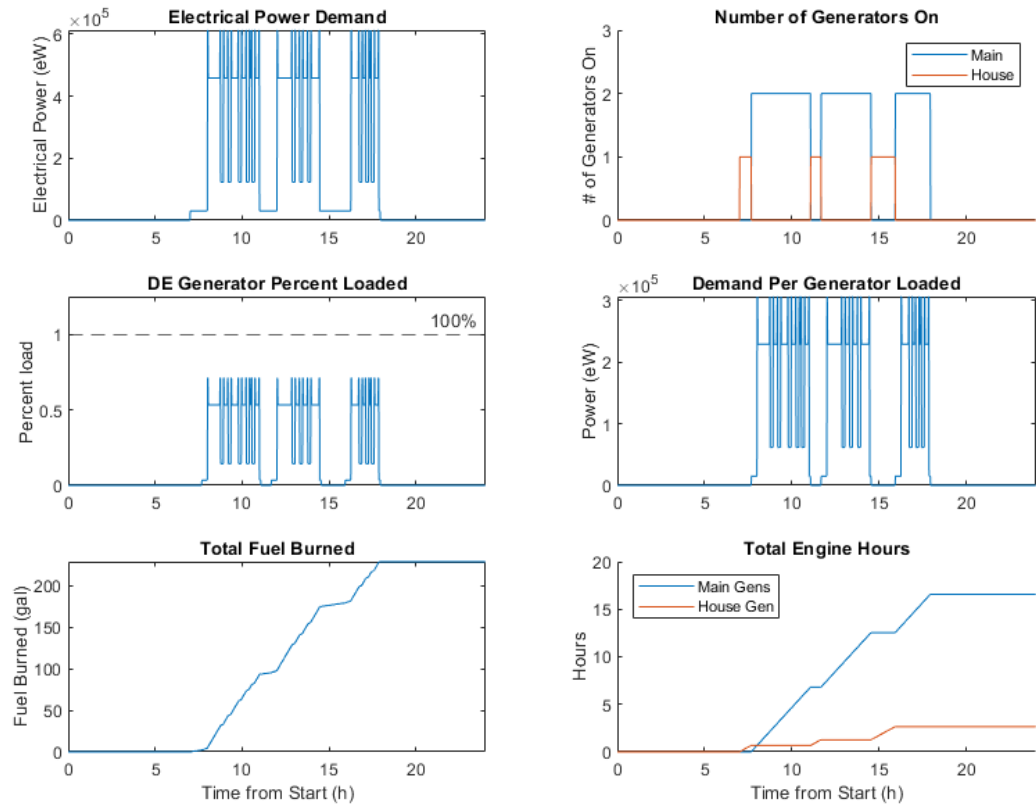


Simulation Results for a 10 knot Transit Speed at a 7ft Draft: Friday - Saturday

Mechanical Results: 10 knots at a 7ft Draft: Friday - Saturday

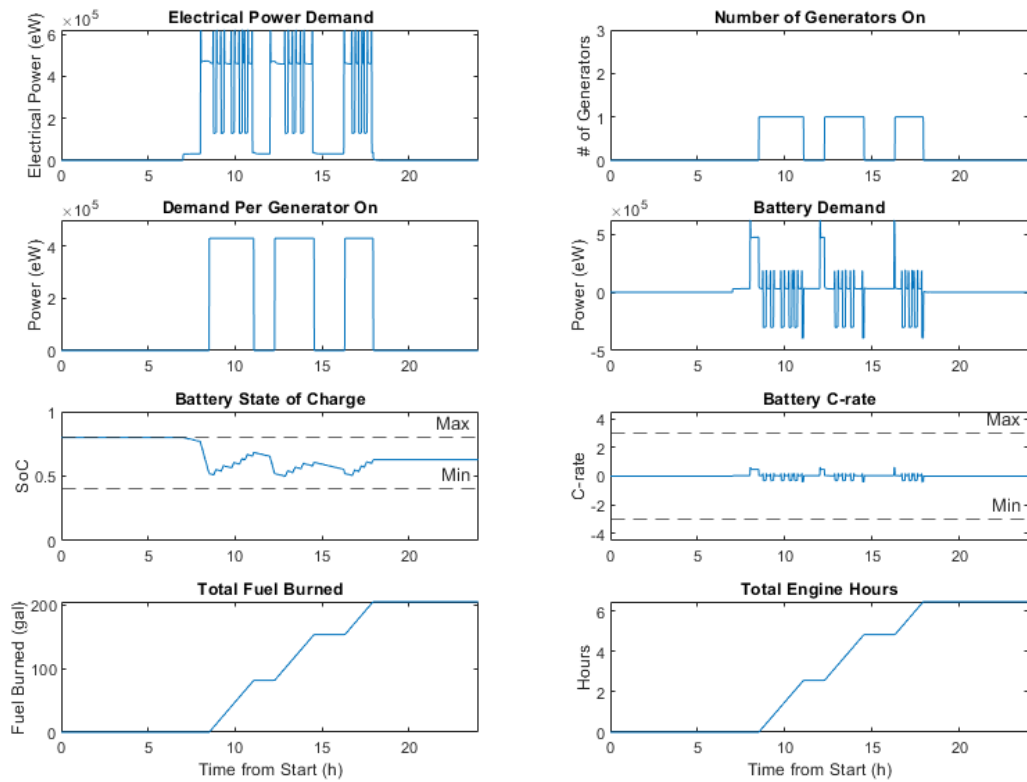


Diesel Electric with C18s Results: 10 knots at a 7ft Draft: Friday - Saturday

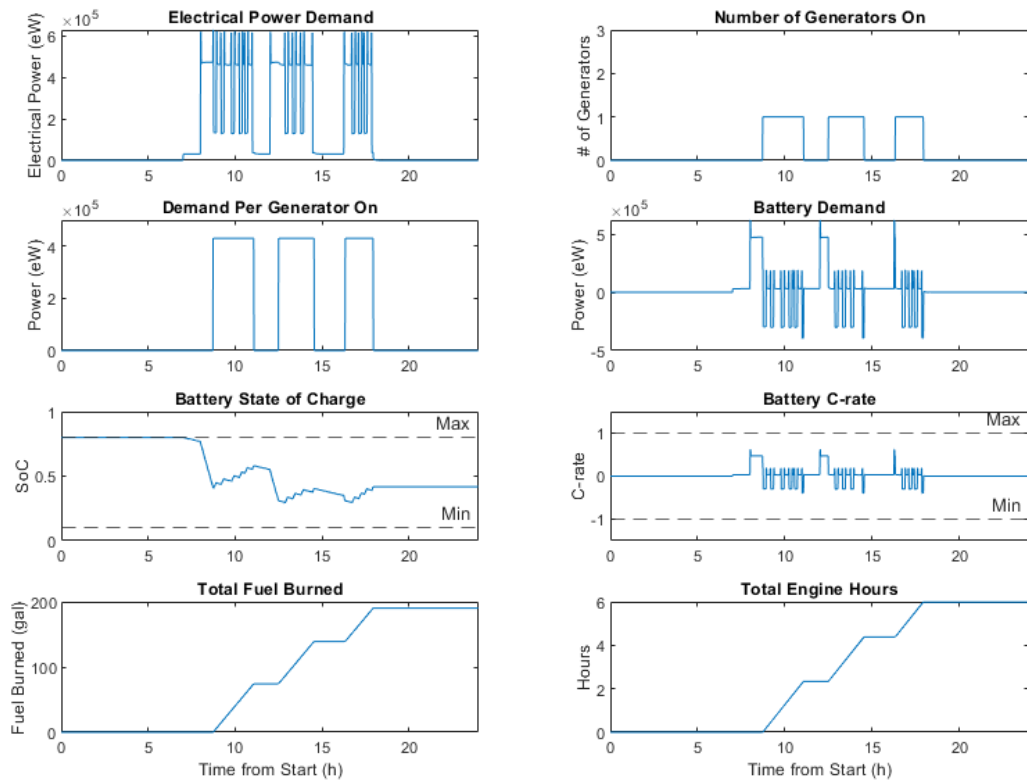


Simulation Results for a 10 knot Transit Speed at a 7ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 10 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

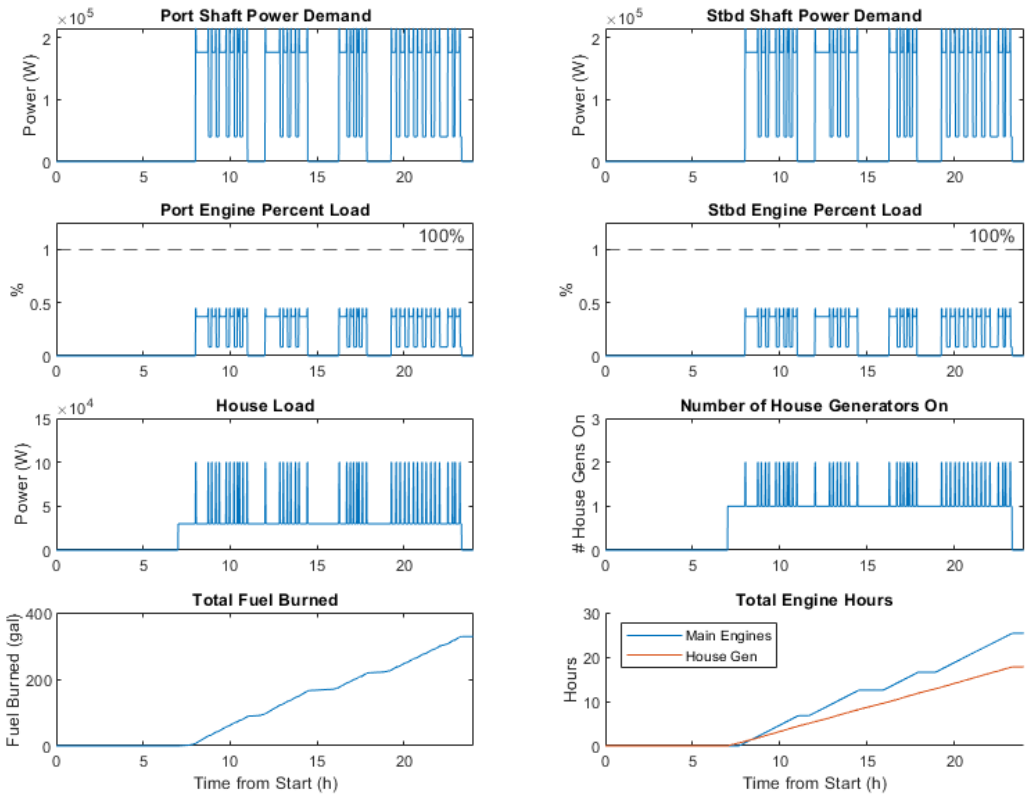


Diesel Electric with Batteries Results: 10 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

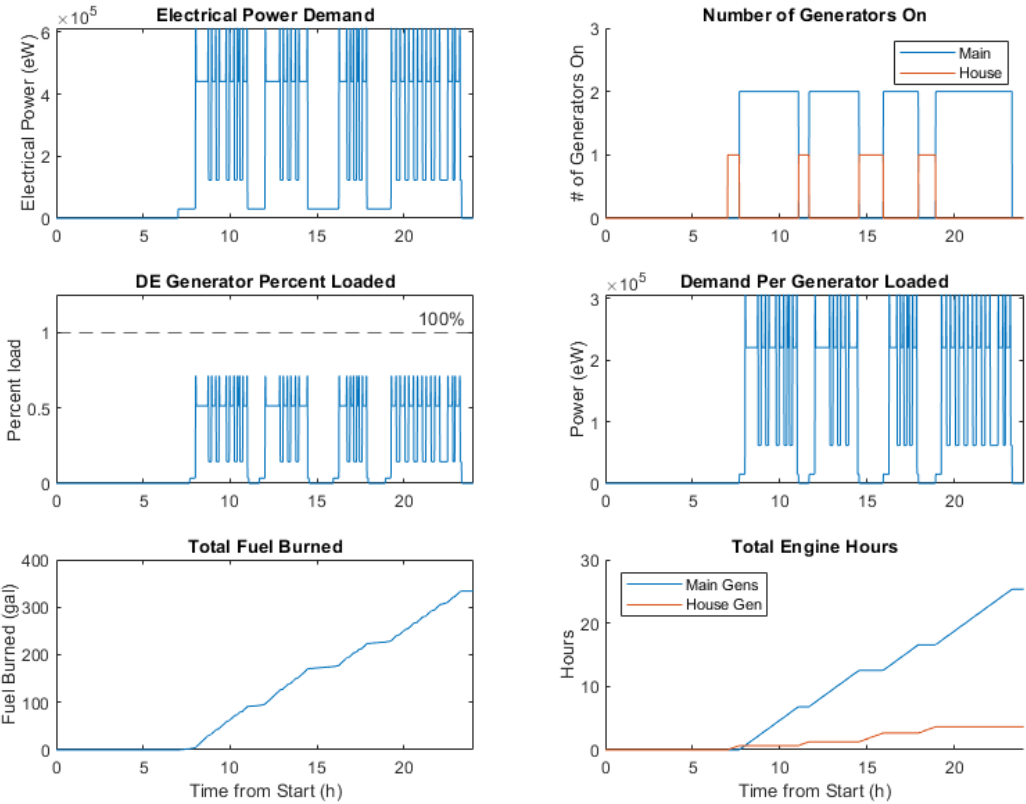


Simulation Results for a 10 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday

Mechanical Results: 10 knots at a 6.5ft Draft: Sunday - Thursday

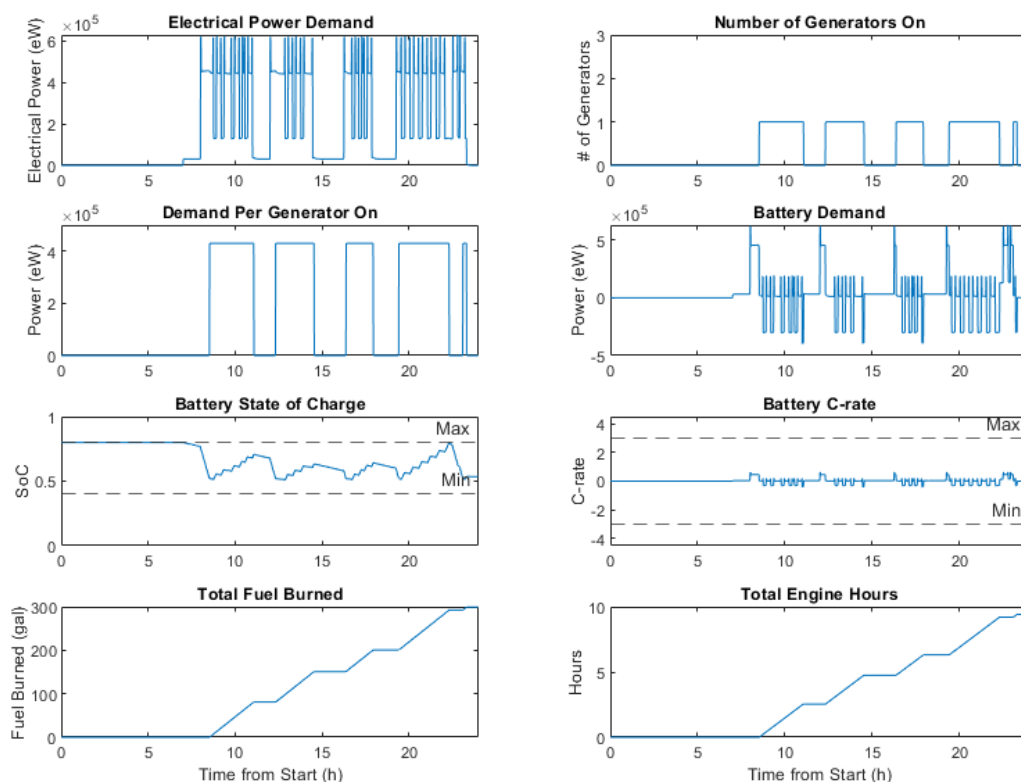


Diesel Electric with C18s Results: 10 knots at a 6.5ft Draft: Sunday - Thursday

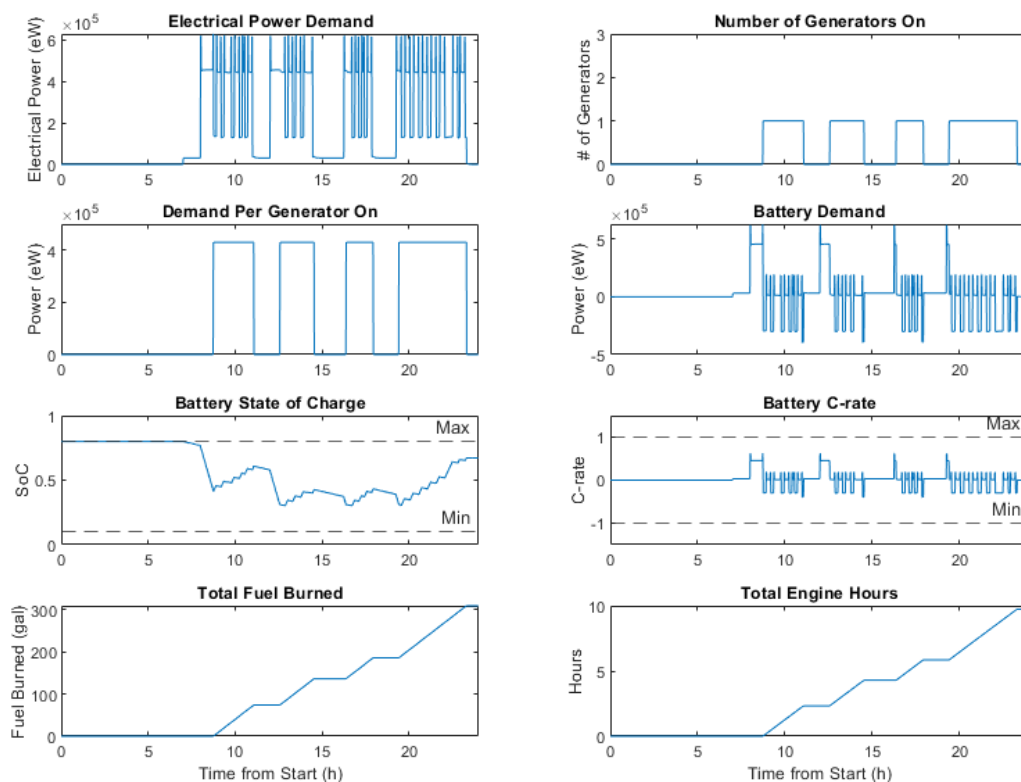


Simulation Results for a 10 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 10 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

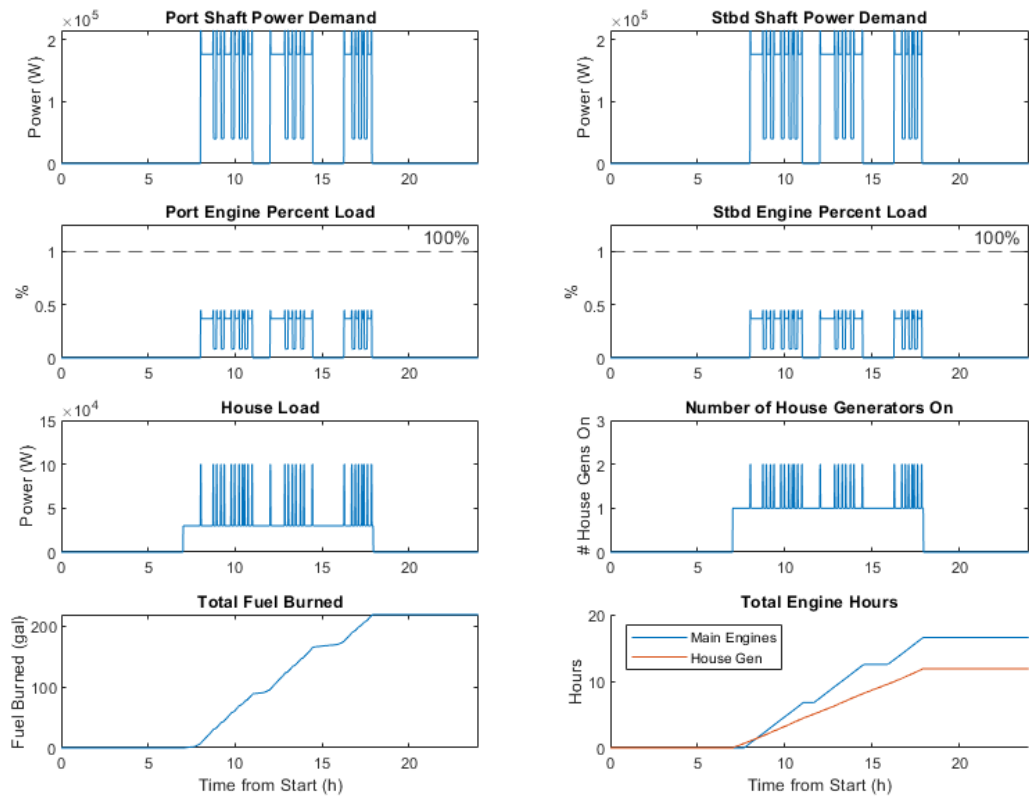


Diesel Electric with Batteries Results: 10 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

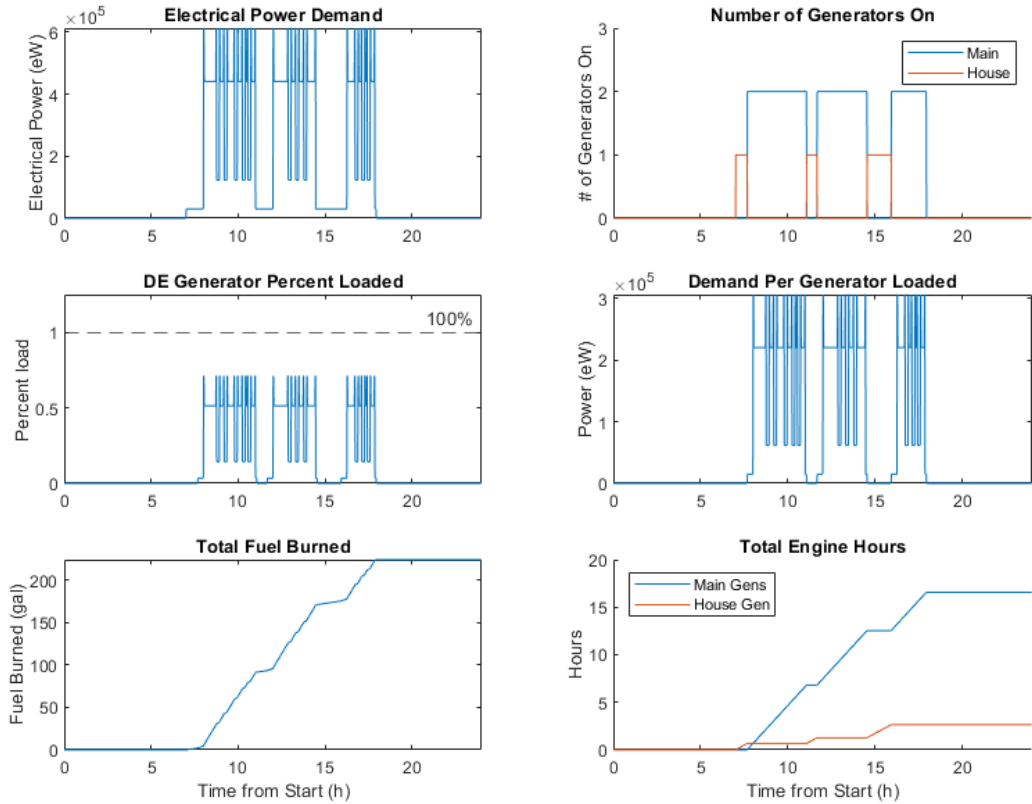


Simulation Results for a 10 knot Transit Speed at a 6.5ft Draft: Friday - Saturday

Mechanical Results: 10 knots at a 6.5ft Draft: Friday - Saturday

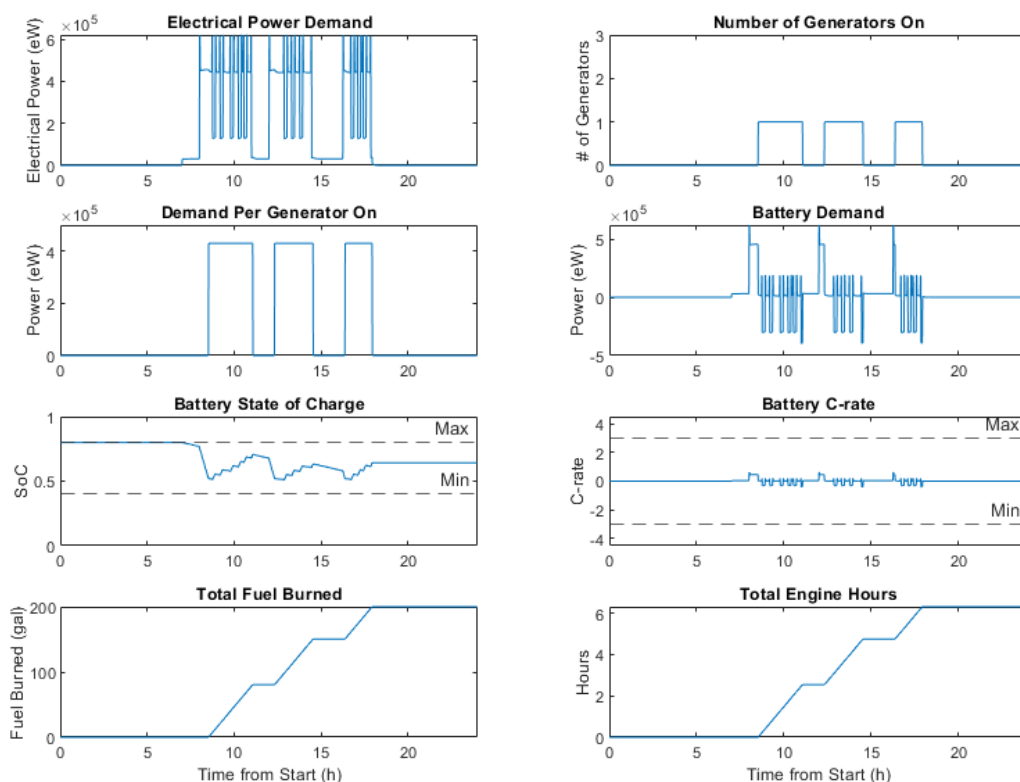


Diesel Electric with C18s Results: 10 knots at a 6.5ft Draft: Friday - Saturday

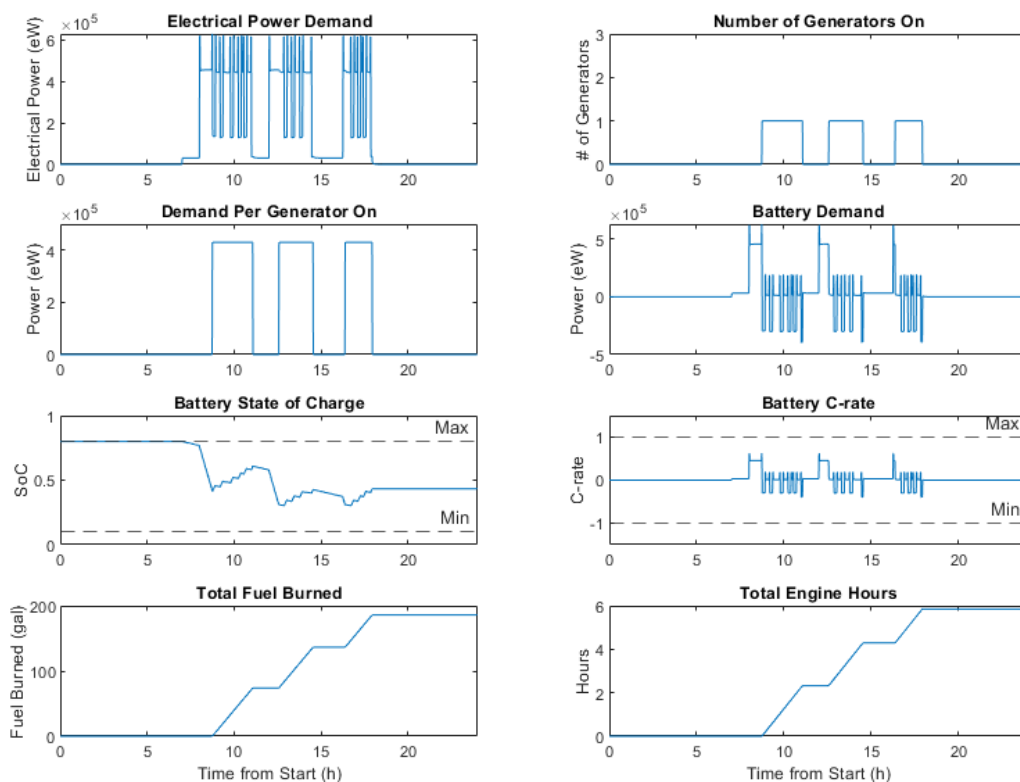


Simulation Results for a 10 knot Transit Speed at a 6.5ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 10 knots at a 6.5ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

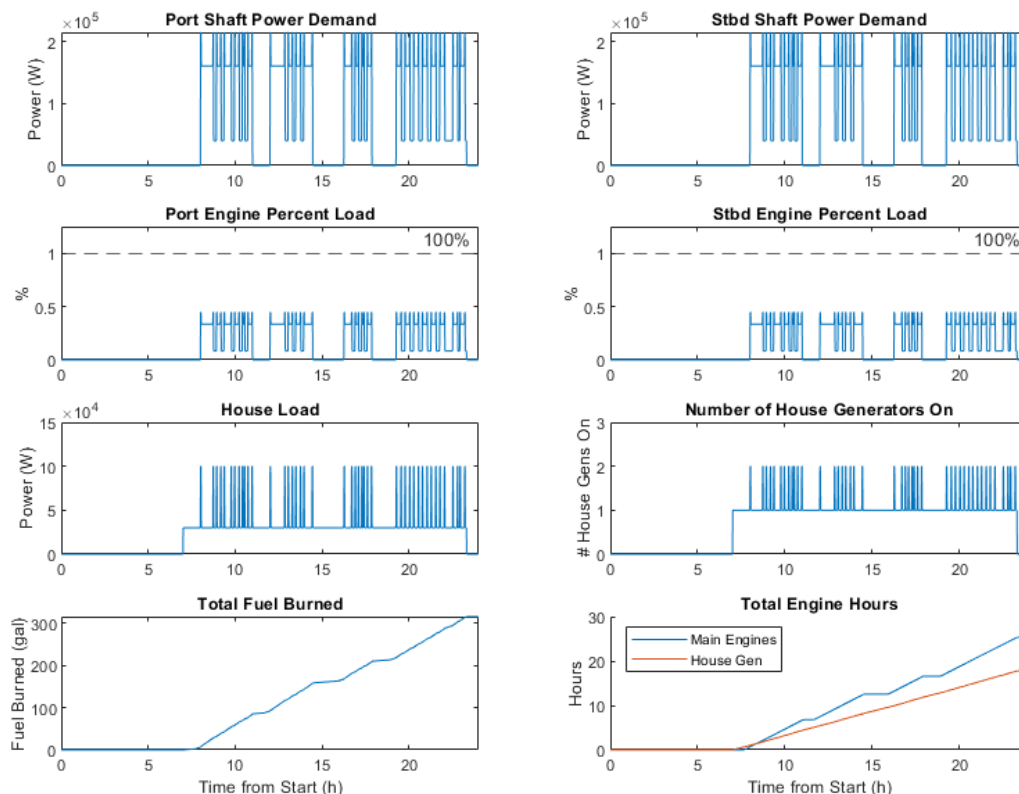


Diesel Electric with Batteries Results: 10 knots at a 6.5ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

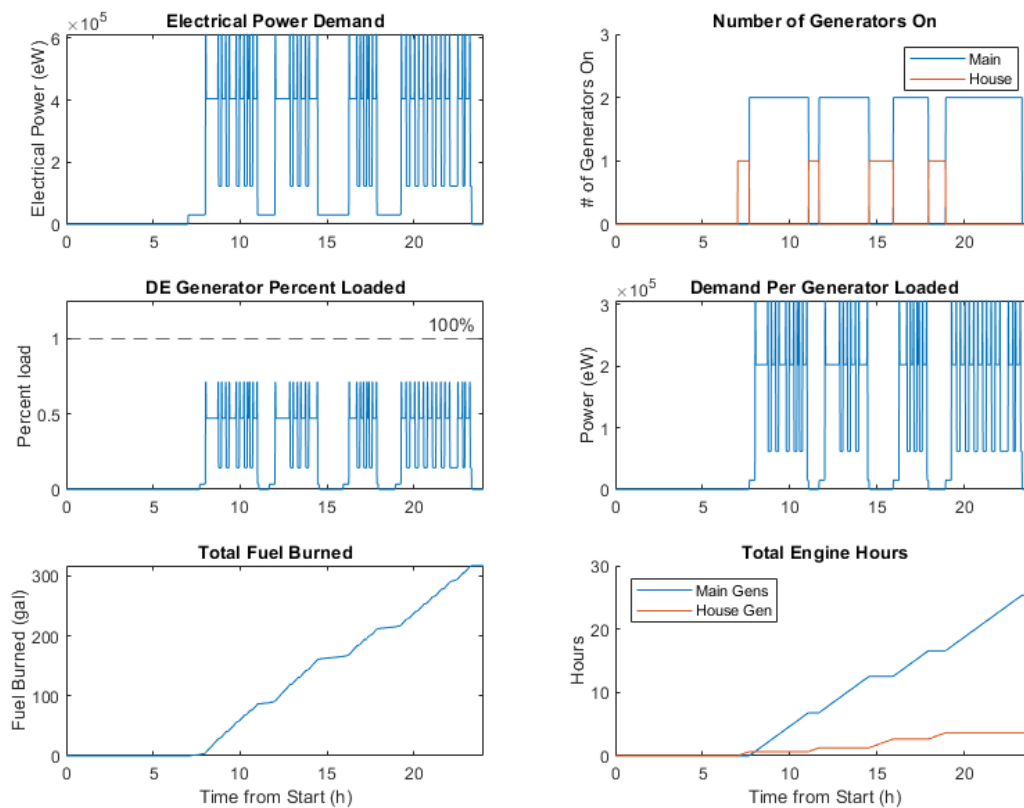


Simulation Results for a 10 knot Transit Speed at a 6ft Draft: Sunday - Thursday

Mechanical Results: 10 knots at a 6ft Draft: Sunday - Thursday

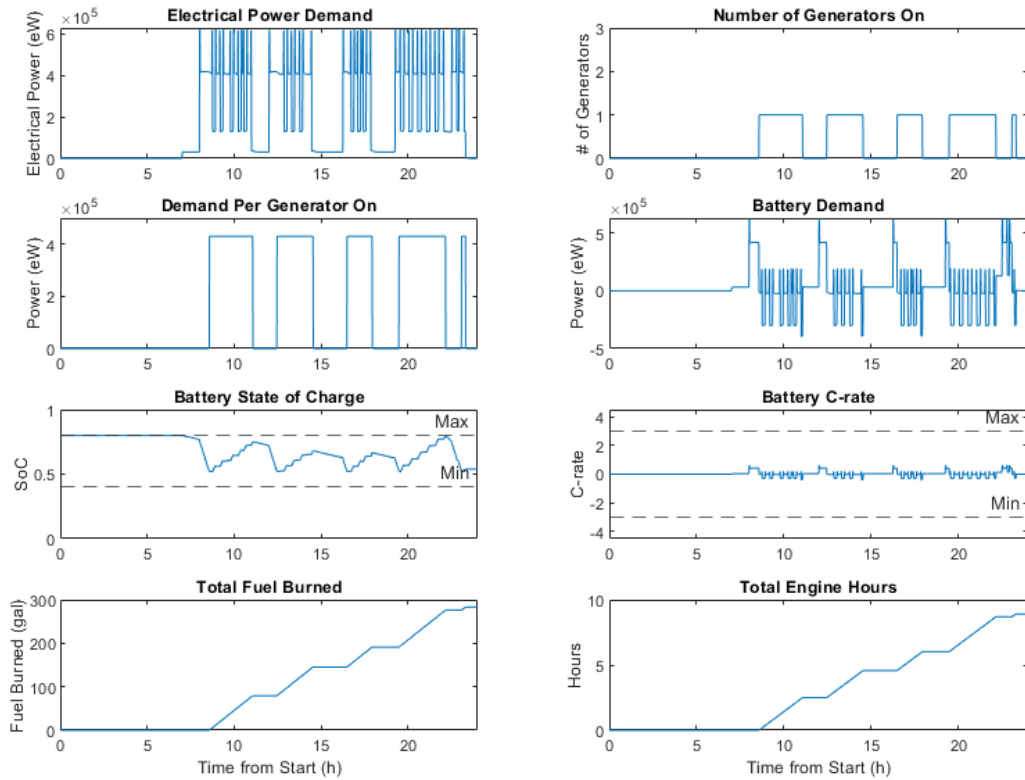


Diesel Electric with C18s Results: 10 knots at a 6ft Draft: Sunday - Thursday

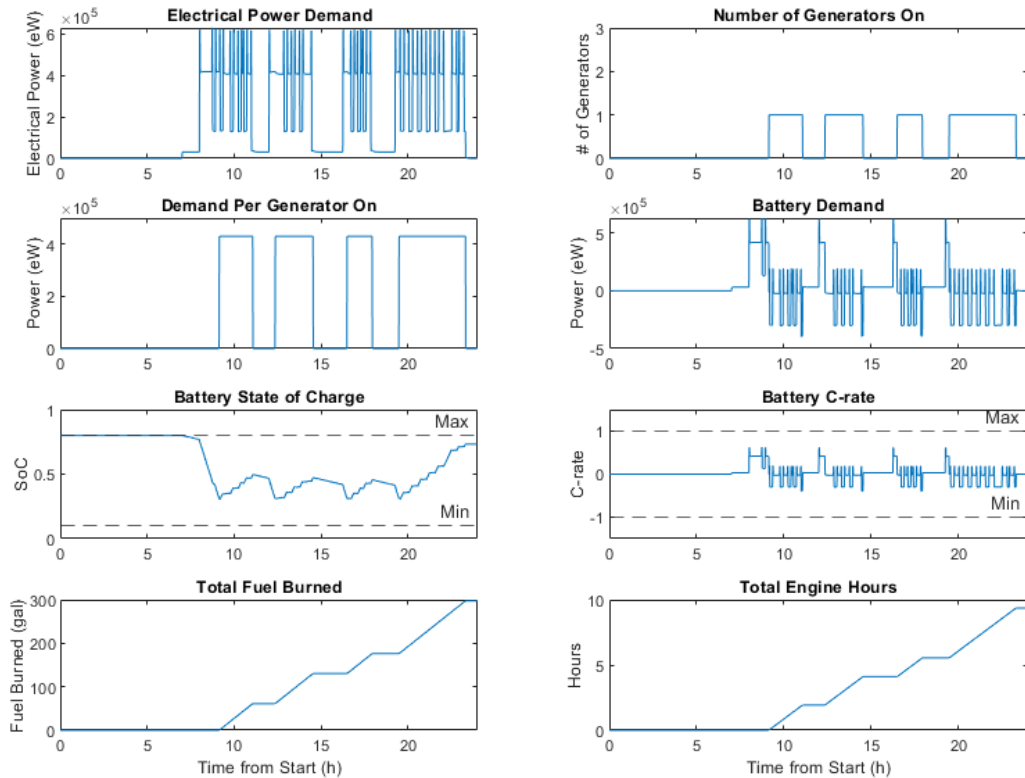


Simulation Results for a 10 knot Transit Speed at a 6ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 10 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

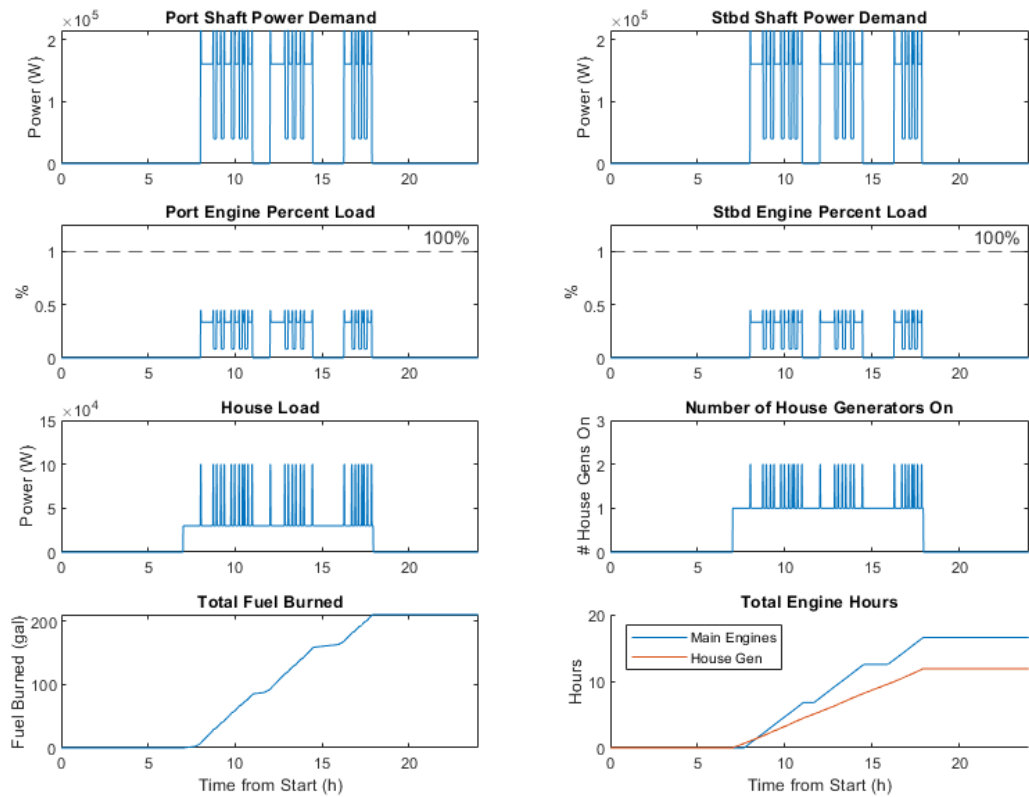


Diesel Electric with Batteries Results: 10 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

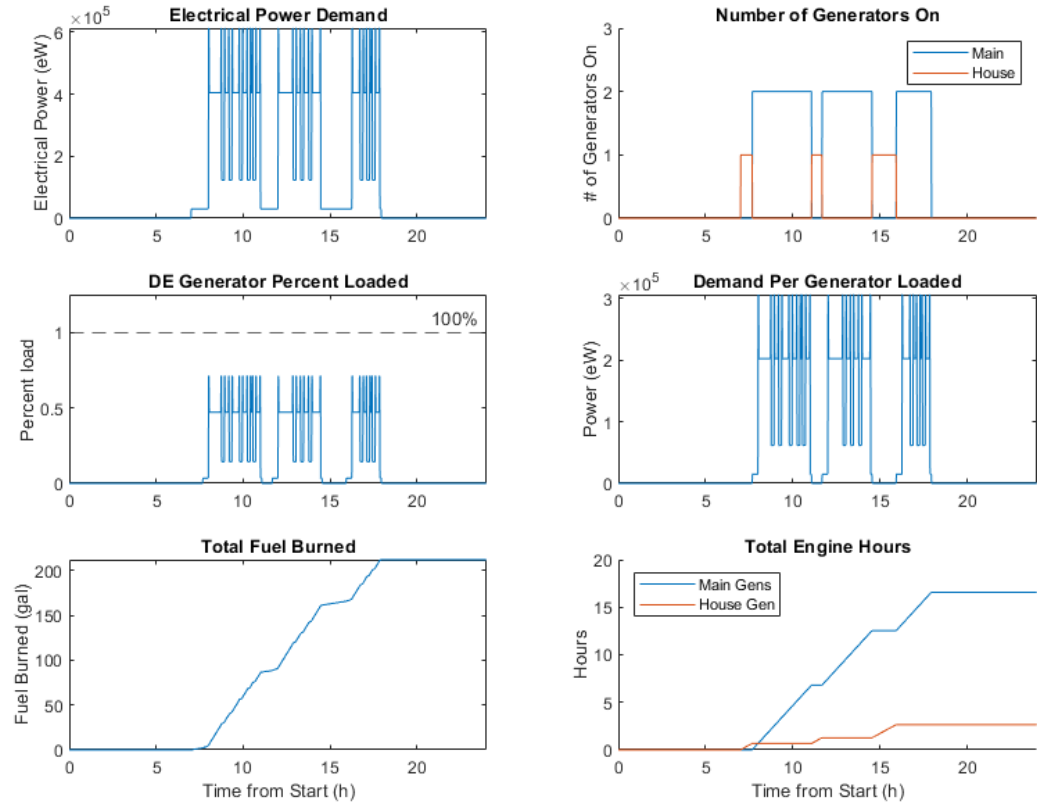


Simulation Results for a 10 knot Transit Speed at a 6ft Draft: Friday - Saturday

Mechanical Results: 10 knots at a 6ft Draft: Friday - Saturday

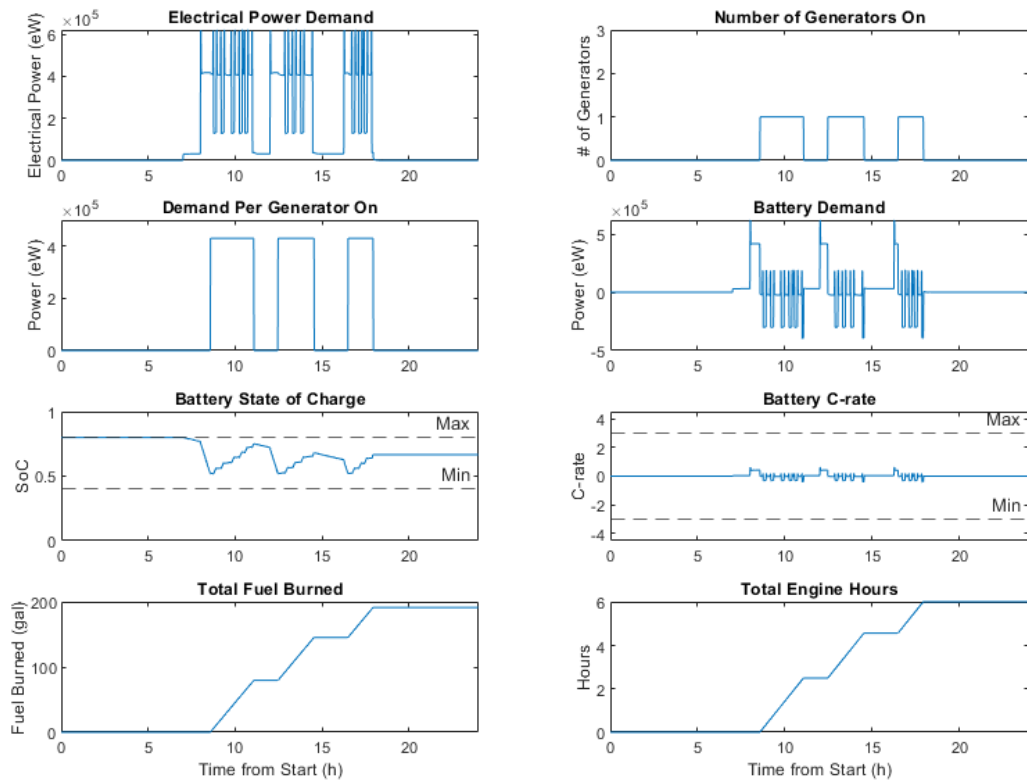


Diesel Electric with C18s Results: 10 knots at a 6ft Draft: Friday - Saturday

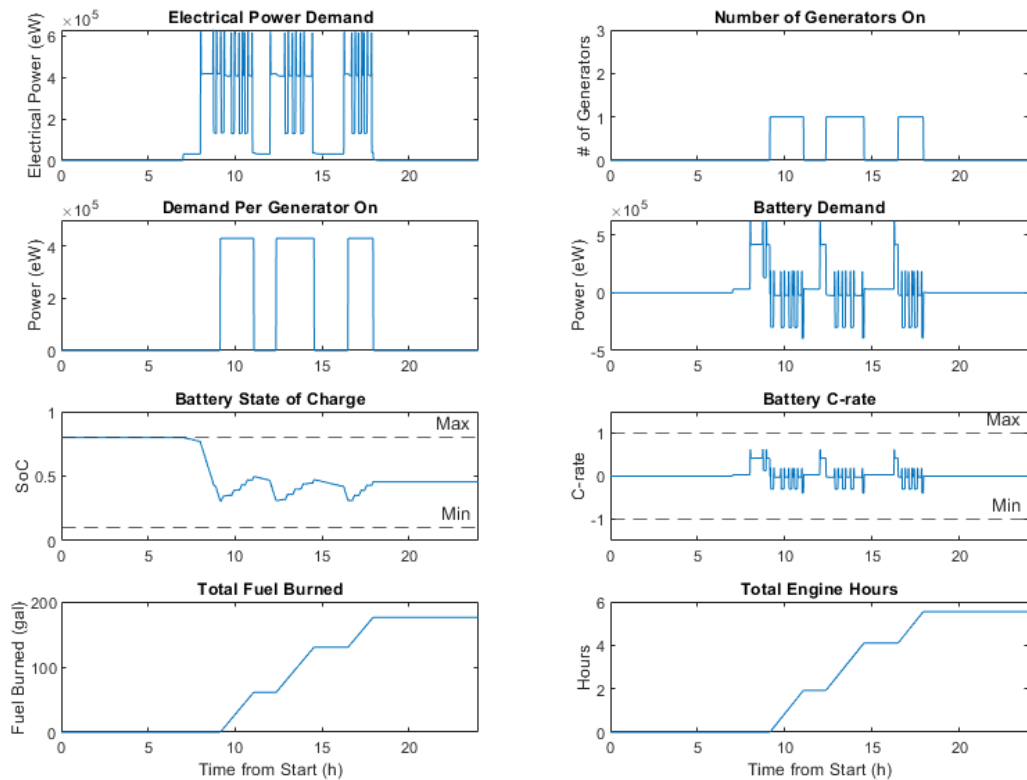


Simulation Results for a 10 knot Transit Speed at a 6ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 10 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

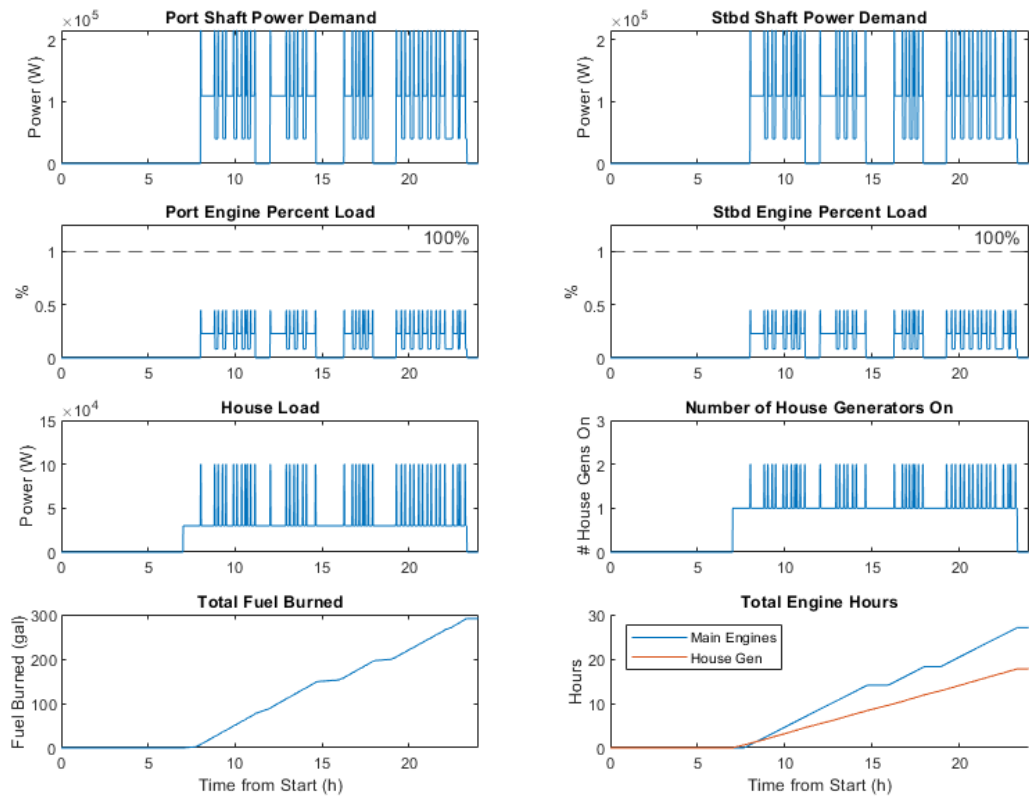


Diesel Electric with Batteries Results: 10 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

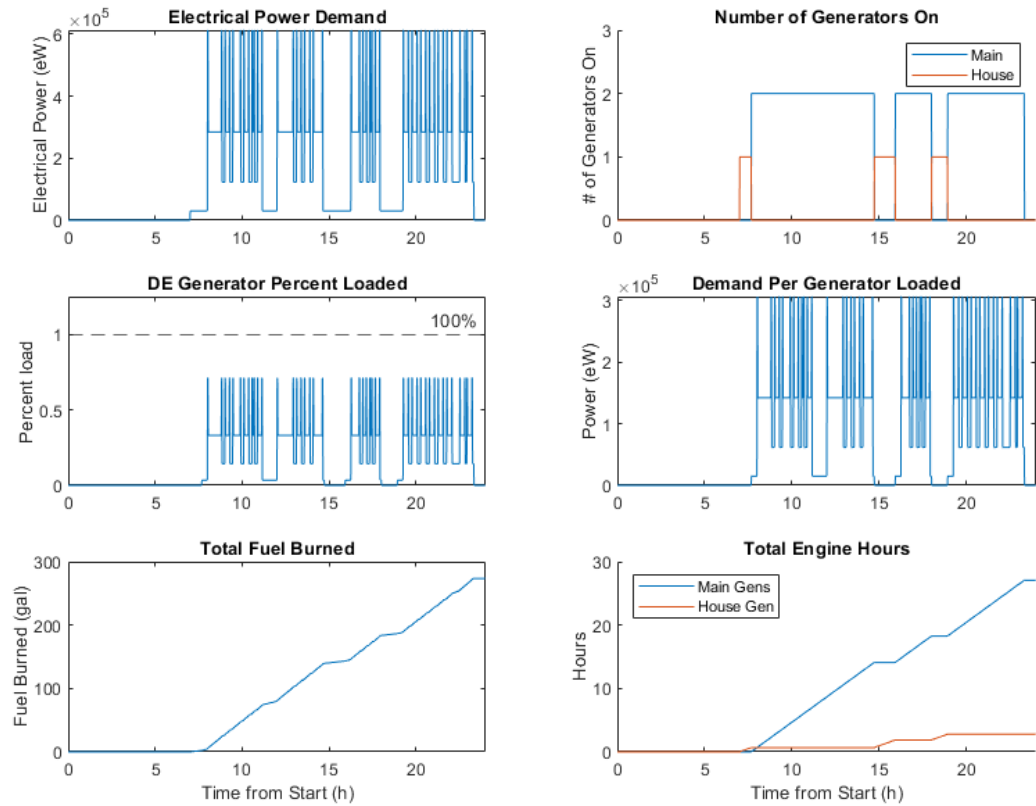


Simulation Results for a 9 knot Transit Speed at a 7ft Draft: Sunday - Thursday

Mechanical Results: 9 knots at a 7ft Draft: Sunday - Thursday

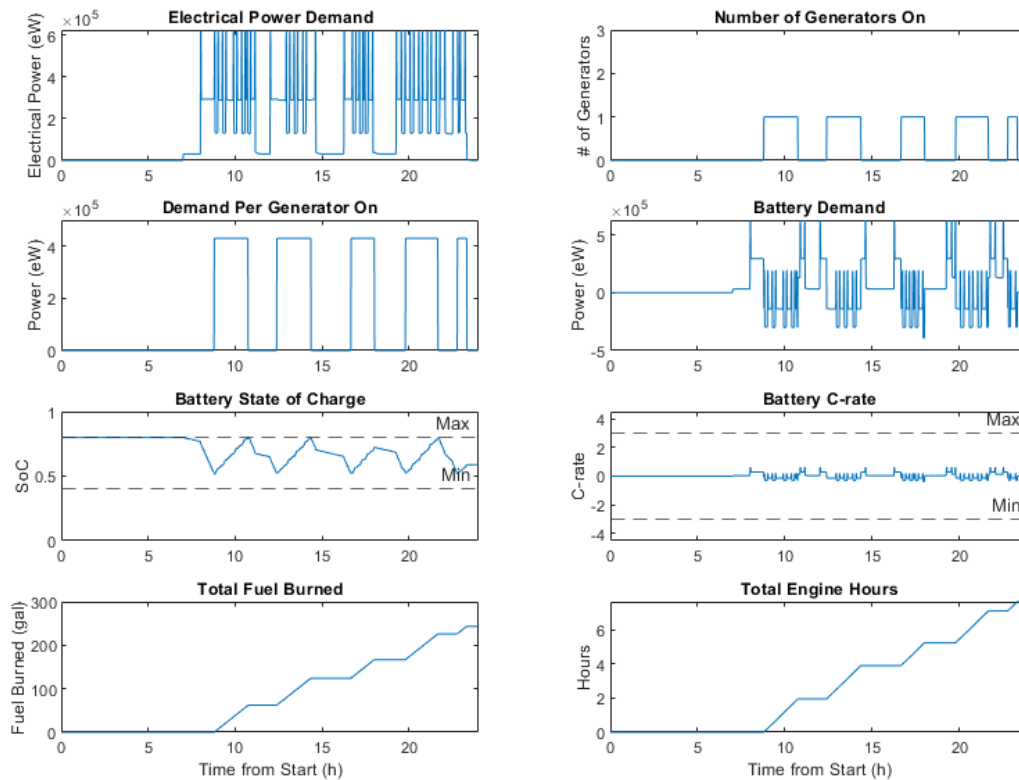


Diesel Electric with C18s Results: 9 knots at a 7ft Draft: Sunday - Thursday

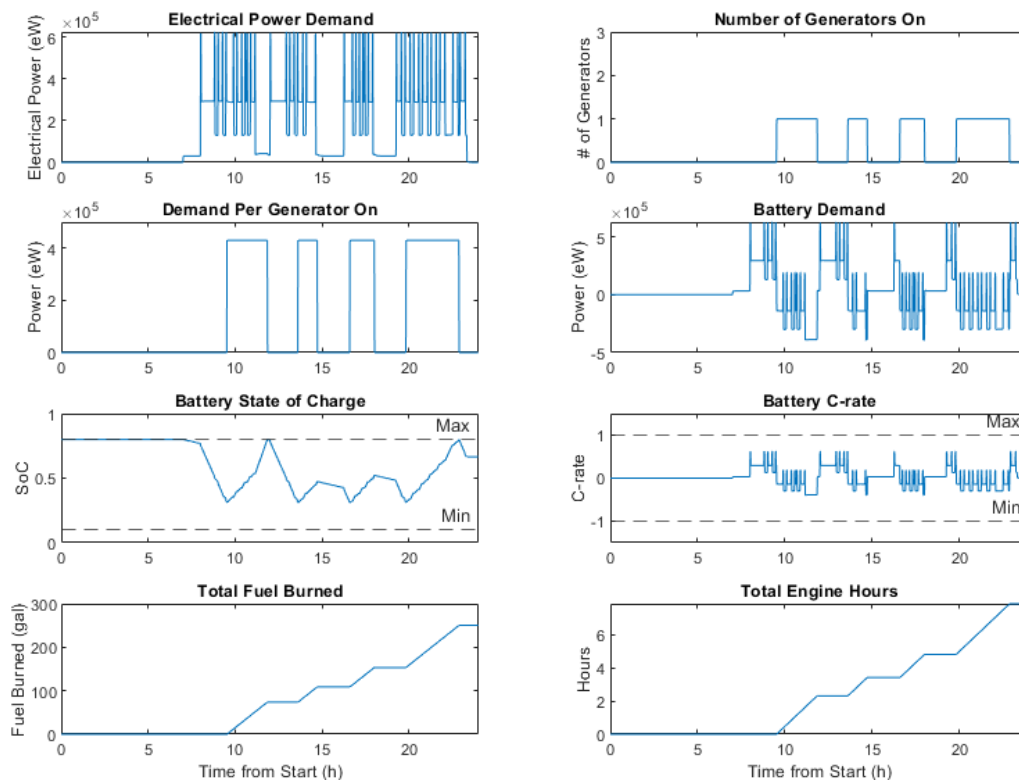


Simulation Results for a 9 knot Transit Speed at a 7ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 9 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

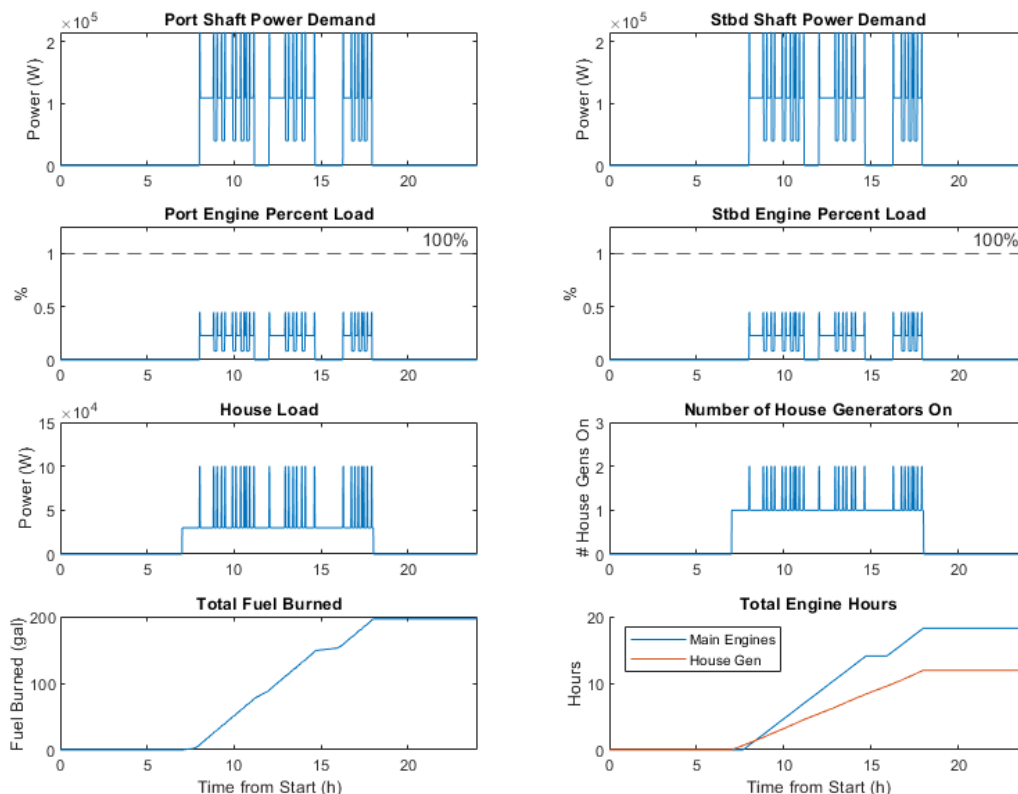


Diesel Electric with Batteries Results: 9 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

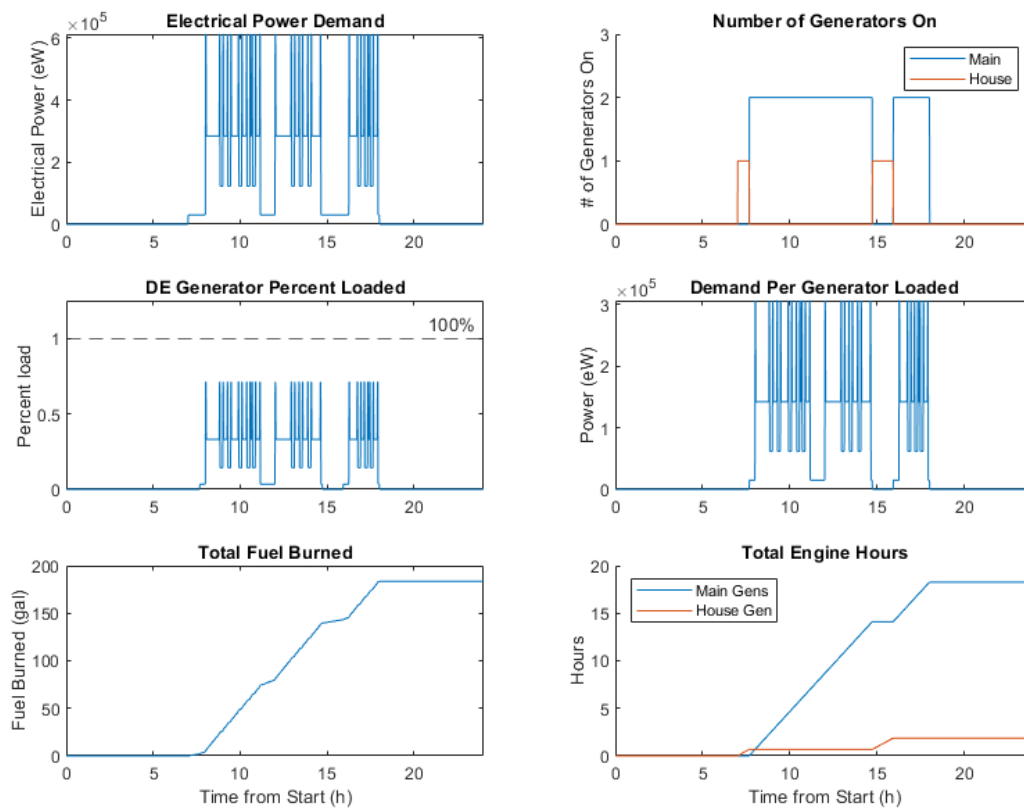


Simulation Results for a 9 knot Transit Speed at a 7ft Draft: Friday - Saturday

Mechanical Results: 9 knots at a 7ft Draft: Friday - Saturday

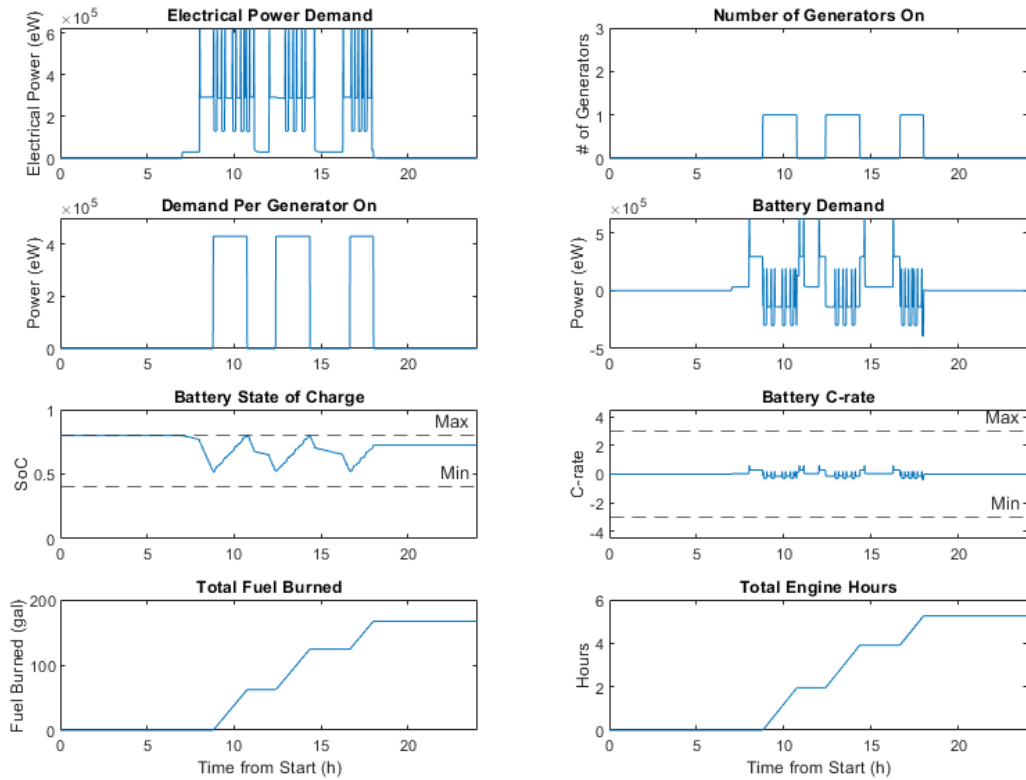


Diesel Electric with C18s Results: 9 knots at a 7ft Draft: Friday - Saturday

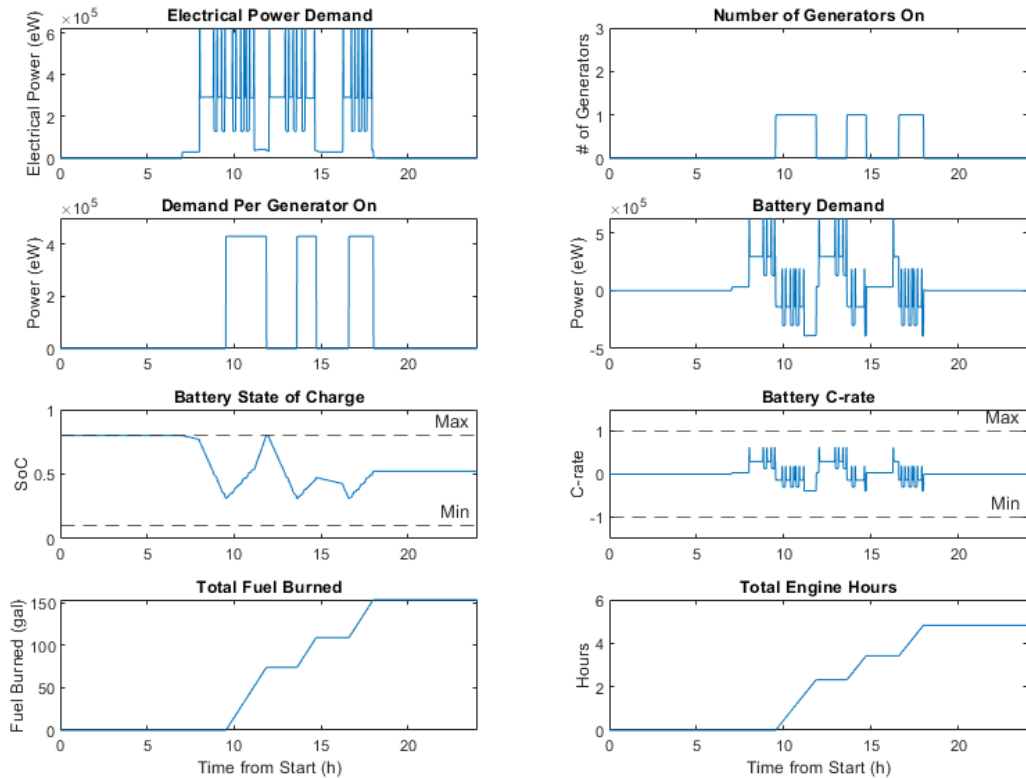


Simulation Results for a 9 knot Transit Speed at a 7ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 9 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

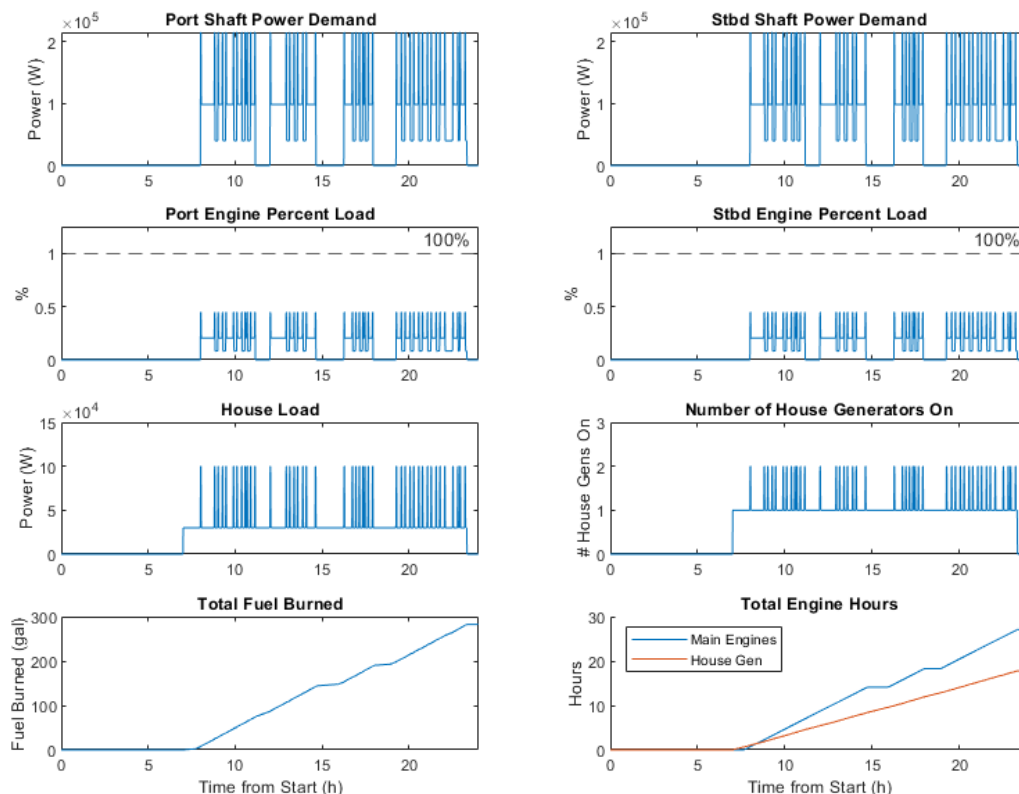


Diesel Electric with Batteries Results: 9 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

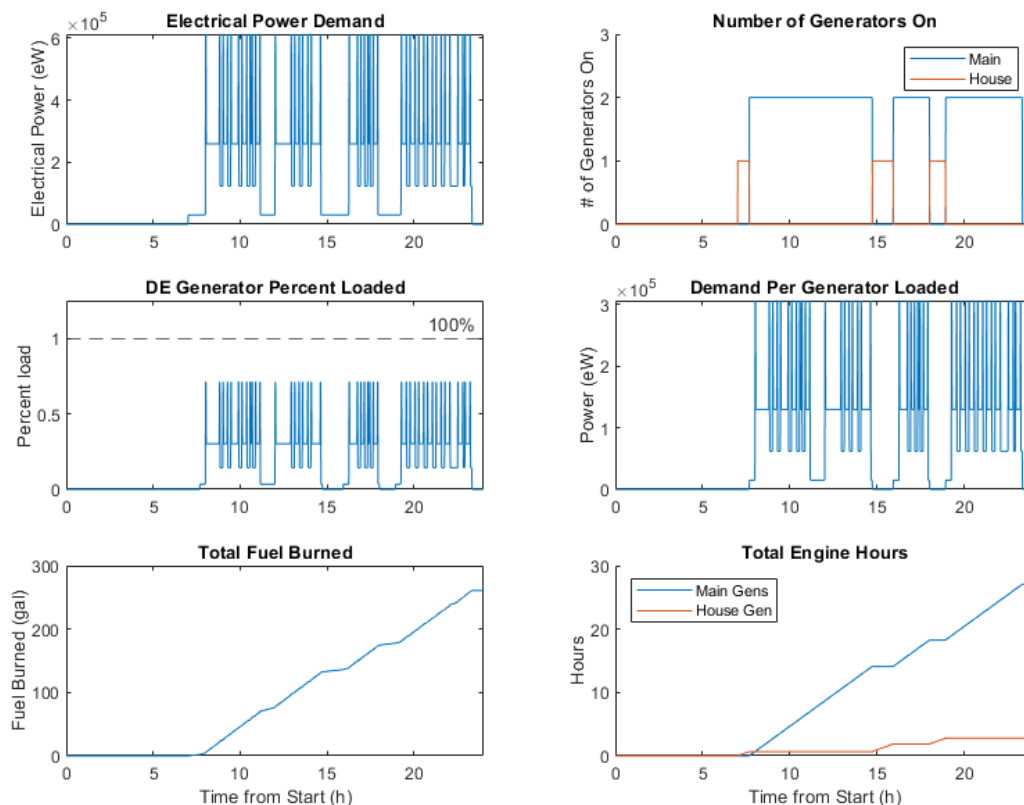


Simulation Results for a 9 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday

Mechanical Results: 9 knots at a 6.5ft Draft: Sunday - Thursday

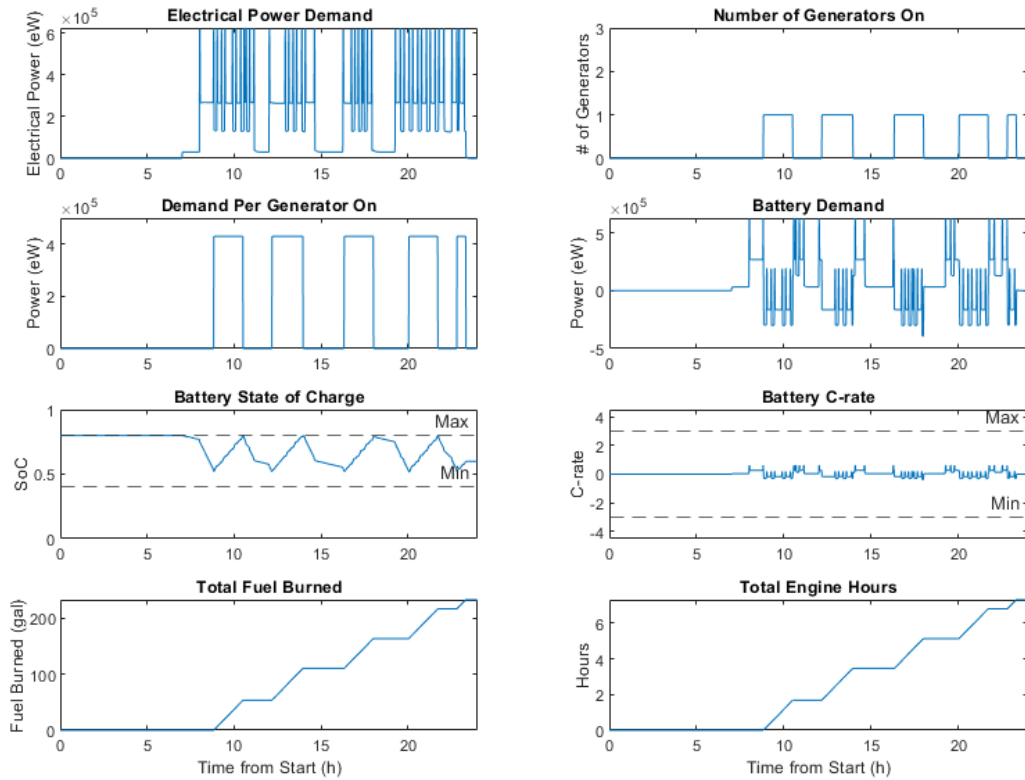


Diesel Electric with C18s Results: 9 knots at a 6.5ft Draft: Sunday - Thursday

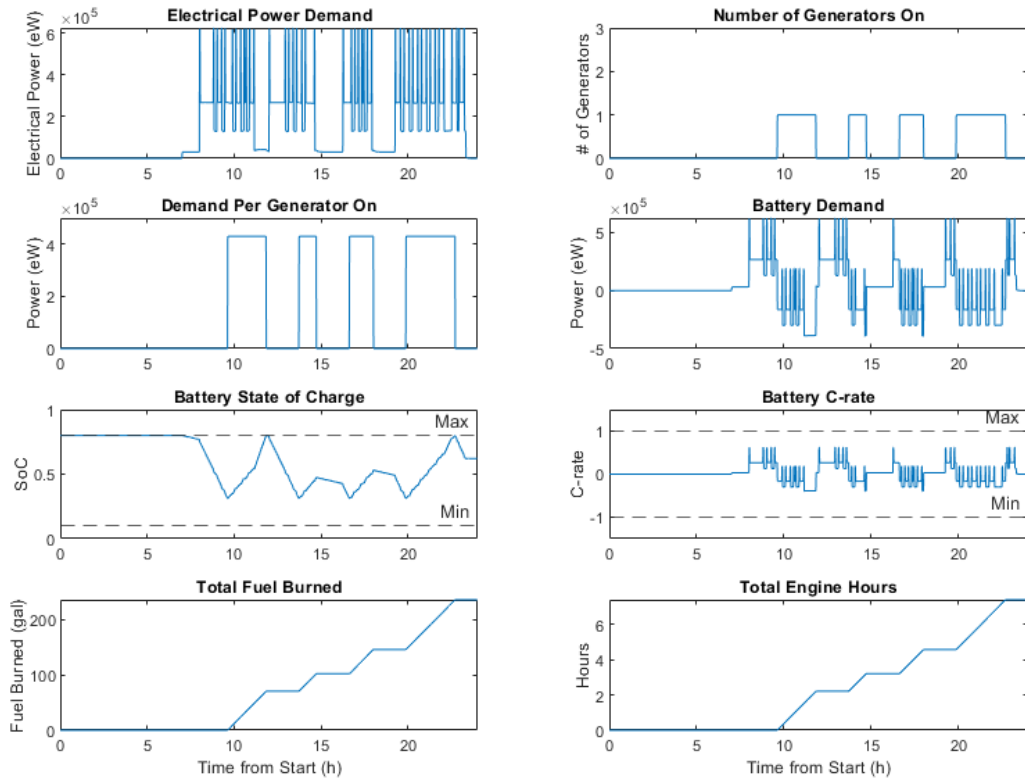


Simulation Results for a 9 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 9 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

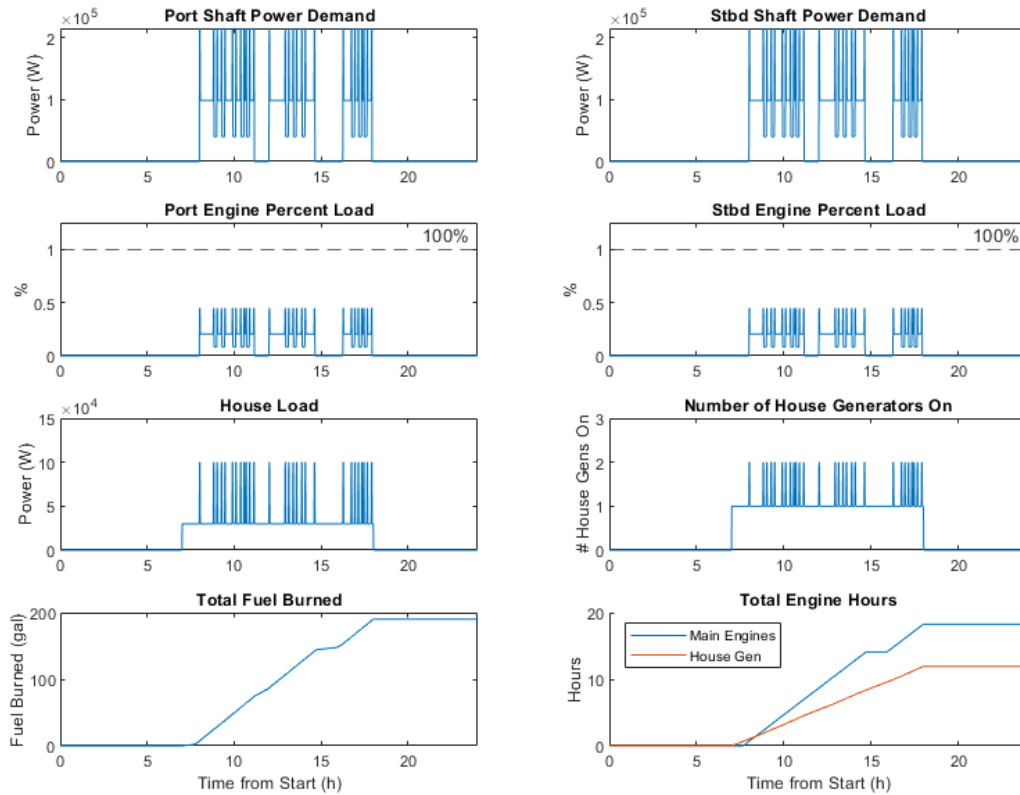


Diesel Electric with Batteries Results: 9 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

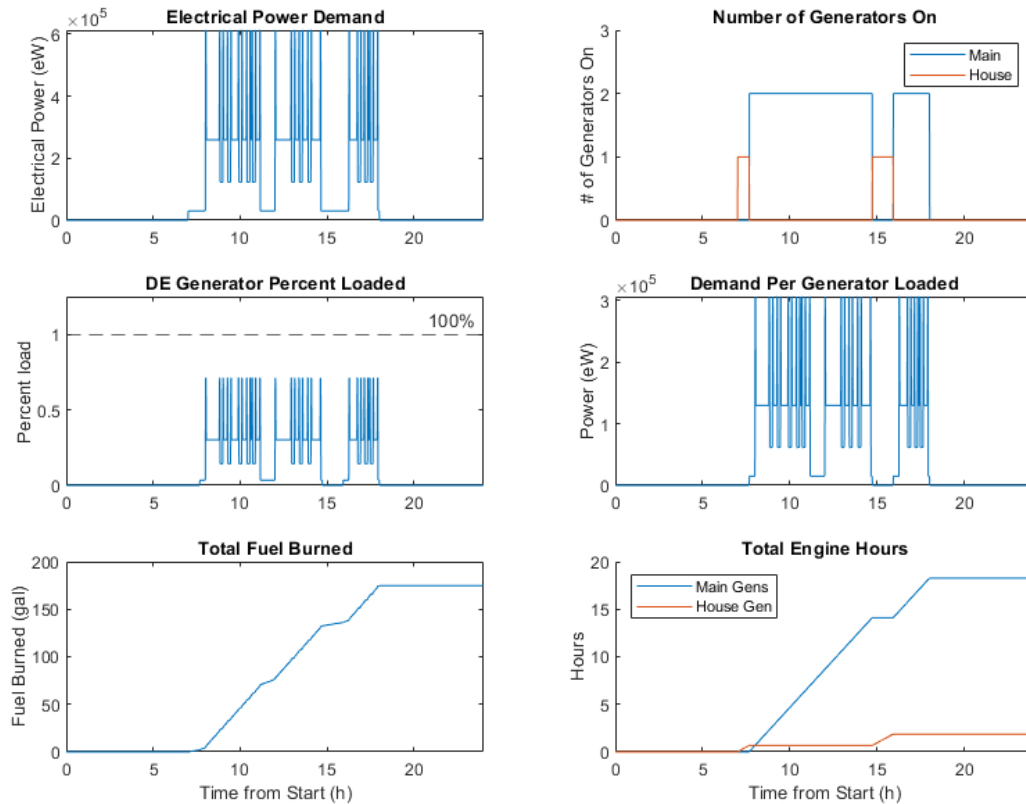


Simulation Results for a 9 knot Transit Speed at a 6.5ft Draft: Friday - Saturday

Mechanical Results: 9 knots at a 6.5ft Draft: Friday - Saturday



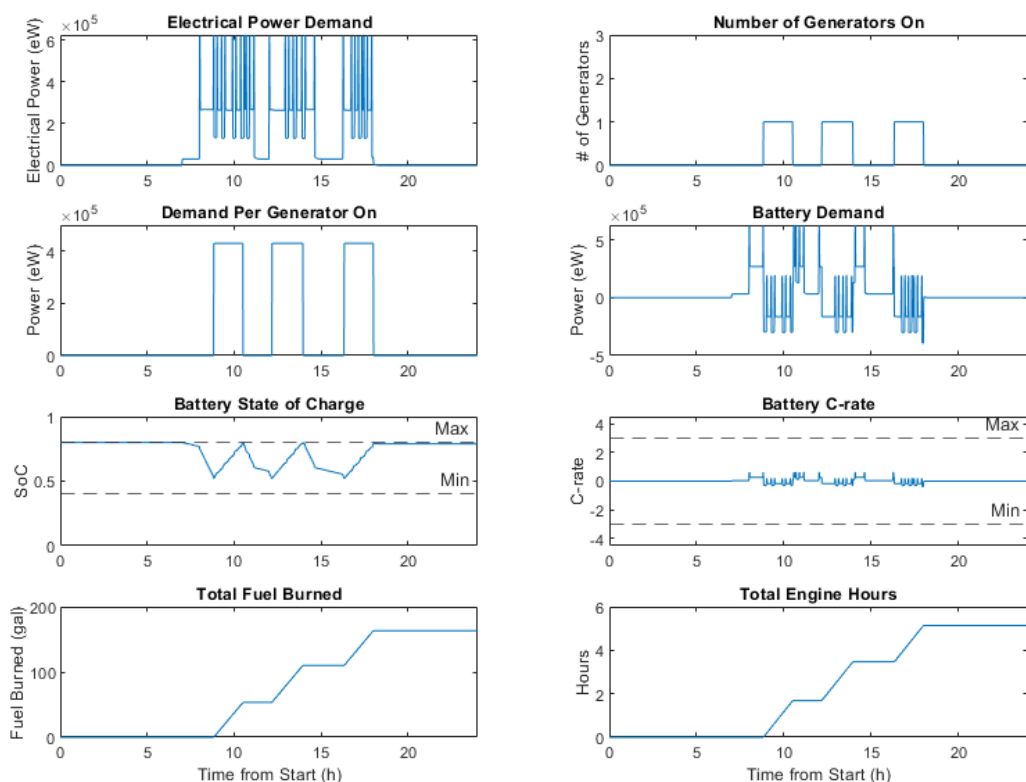
Diesel Electric with C18s Results: 9 knots at a 6.5ft Draft: Friday - Saturday



Simulation Results for a 9 knot Transit Speed at a 6.5ft Draft: Friday - Saturday, Continued

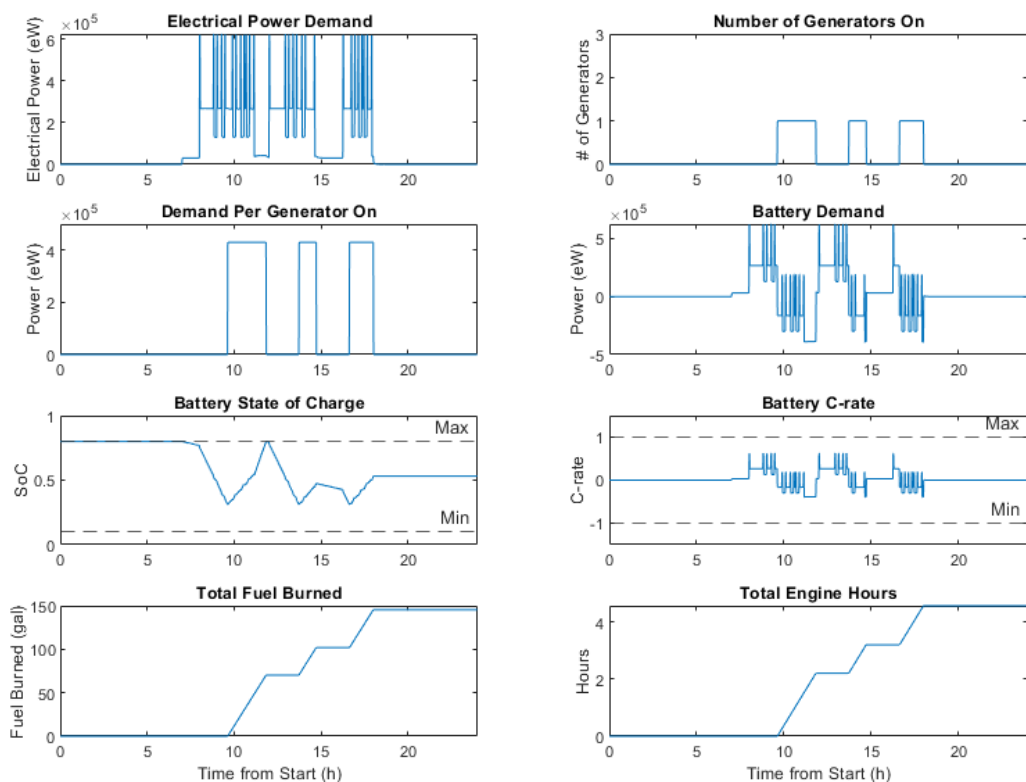
Diesel Electric with Batteries Results: 9 knots at a 6.5ft Draft: Friday - Saturday

Battery Size: 1,000kWh, Battery Type = NMC



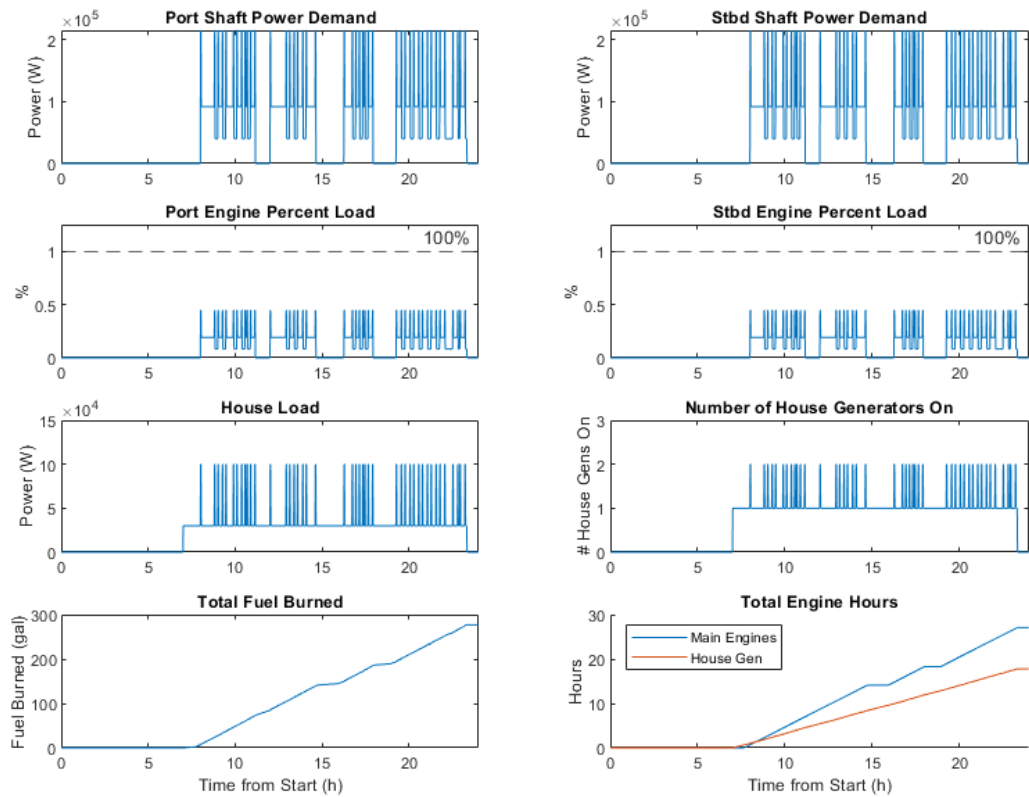
Diesel Electric with Batteries Results: 9 knots at a 6.5ft Draft: Friday - Saturday

Battery Size: 1,000kWh, Battery Type = LFP

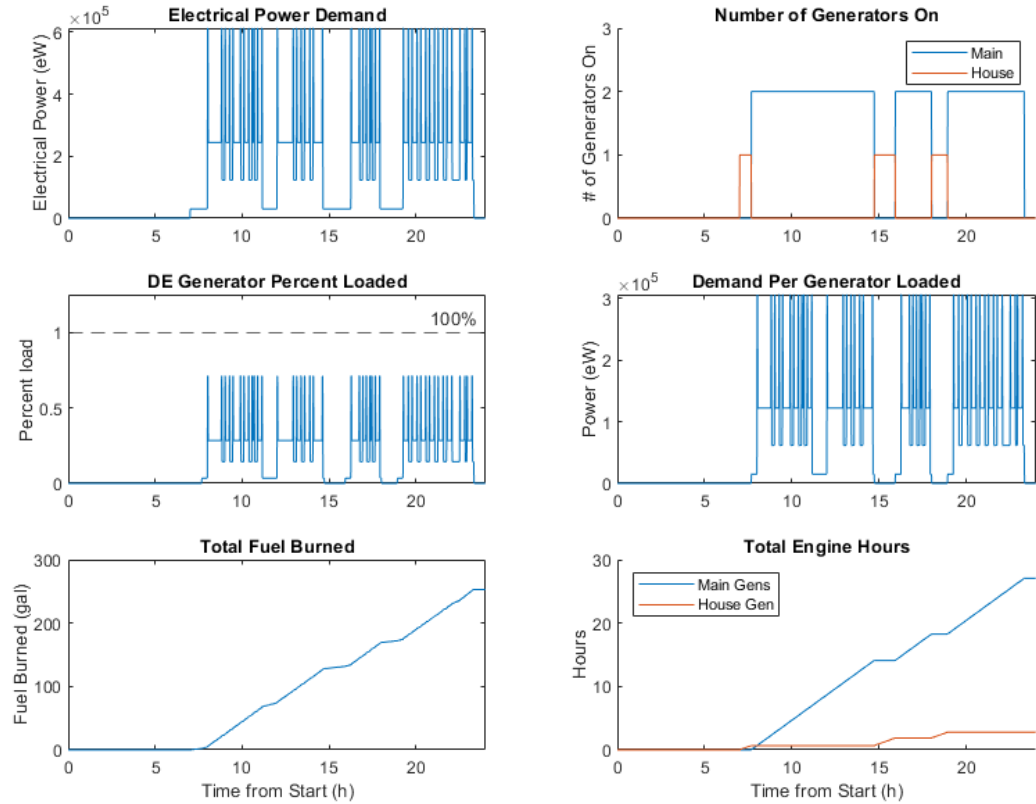


Simulation Results for a 9 knot Transit Speed at a 6ft Draft: Sunday - Thursday

Mechanical Results: 9 knots at a 6ft Draft: Sunday - Thursday

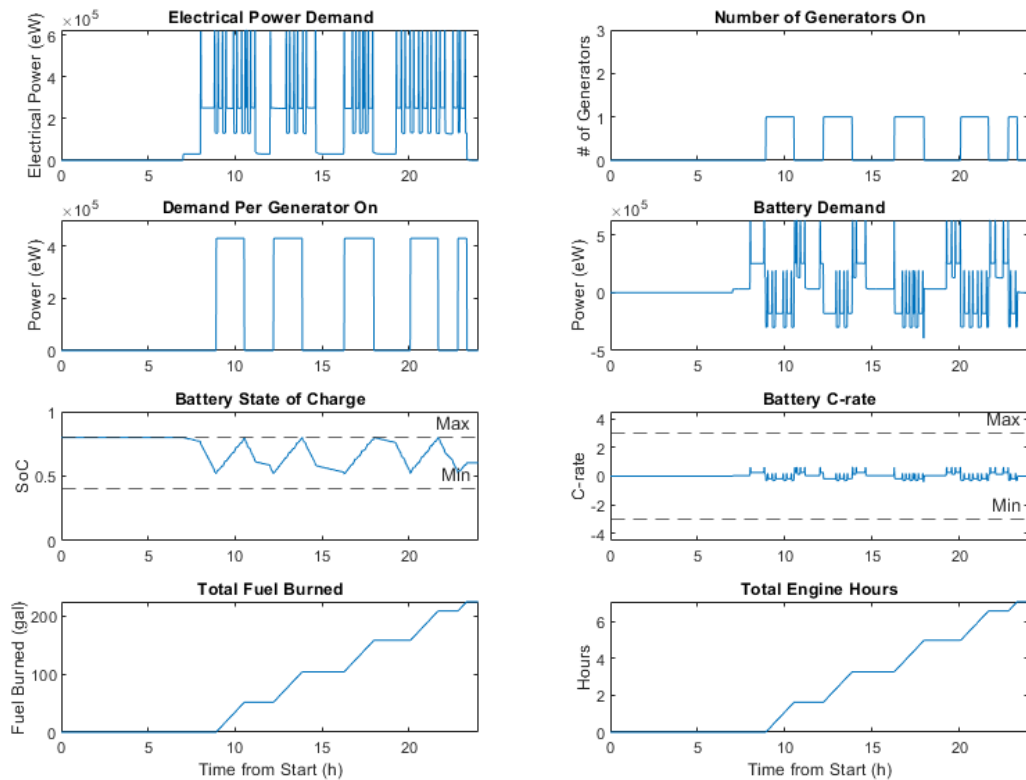


Diesel Electric with C18s Results: 9 knots at a 6ft Draft: Sunday - Thursday

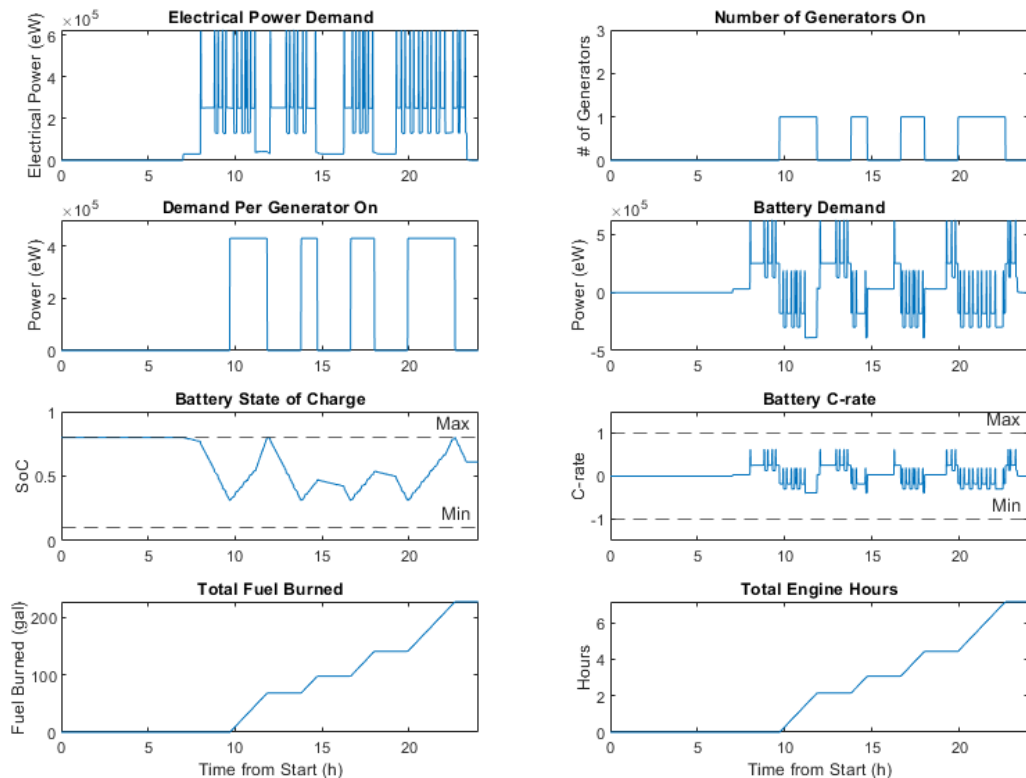


Simulation Results for a 9 knot Transit Speed at a 6ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 9 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

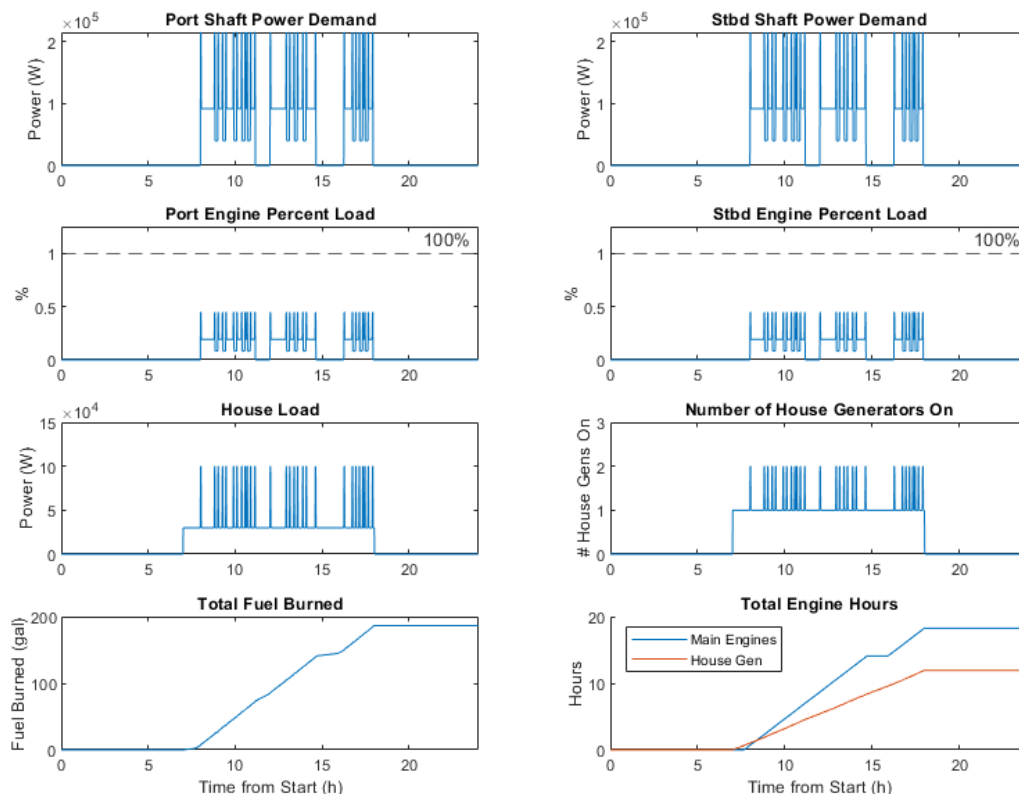


Diesel Electric with Batteries Results: 9 knots at a 6ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

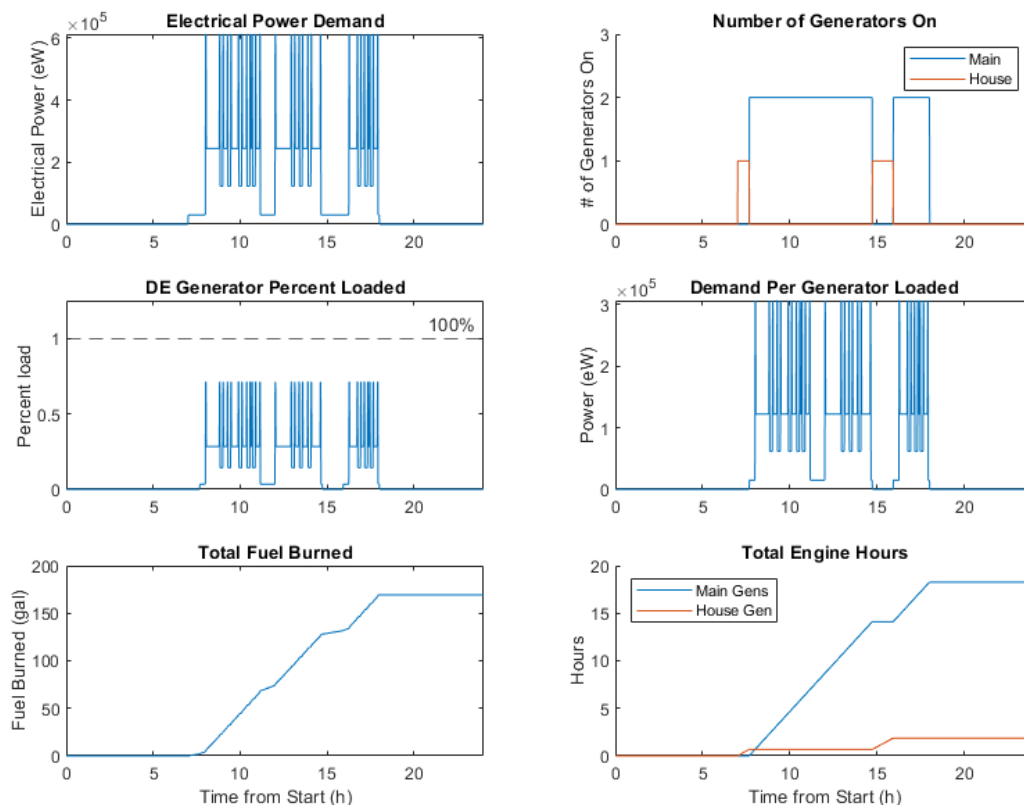


Simulation Results for a 9 knot Transit Speed at a 6ft Draft: Friday - Saturday

Mechanical Results: 9 knots at a 6ft Draft: Friday - Saturday

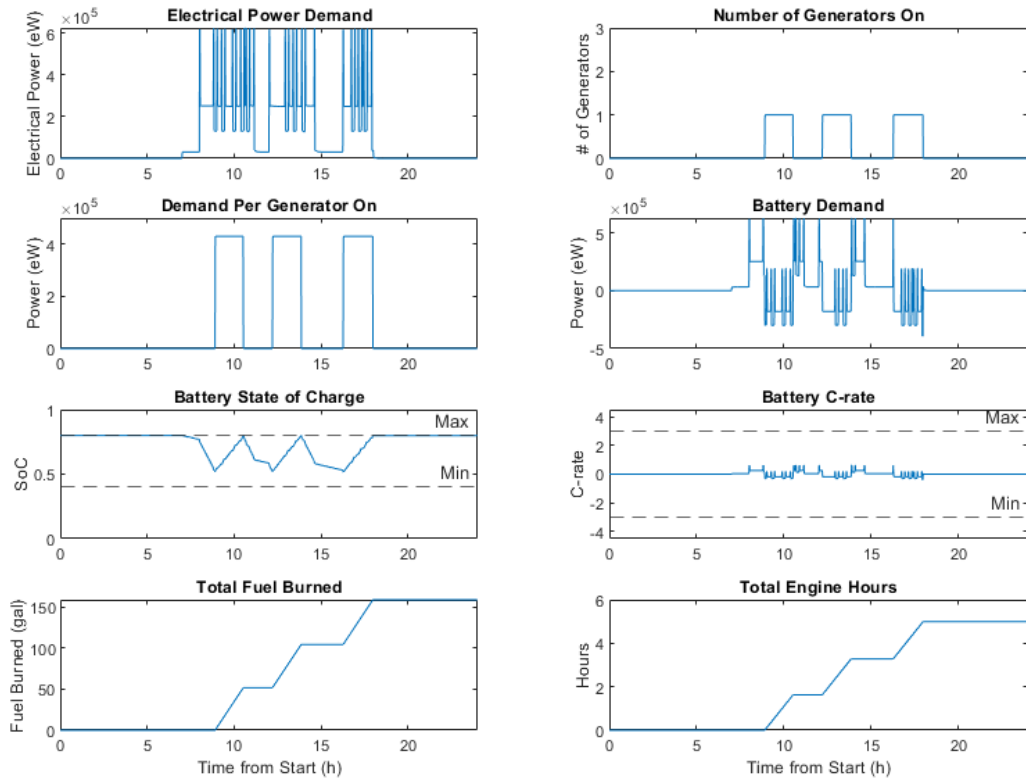


Diesel Electric with C18s Results: 9 knots at a 6ft Draft: Friday - Saturday

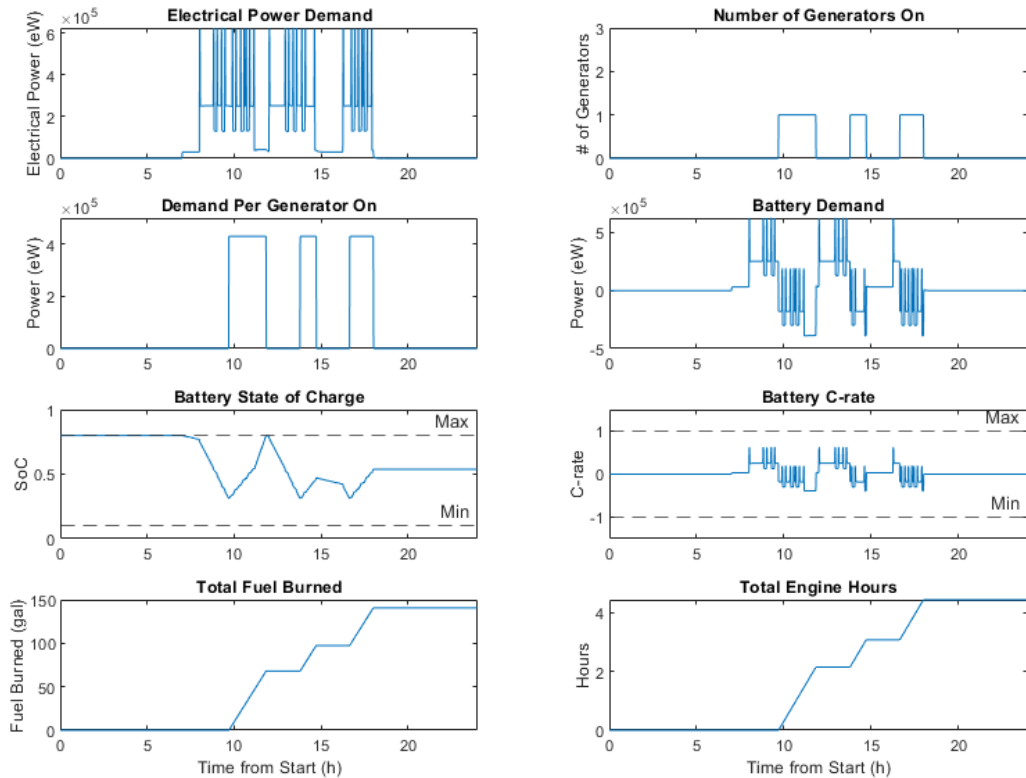


Simulation Results for a 9 knot Transit Speed at a 6ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 9 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

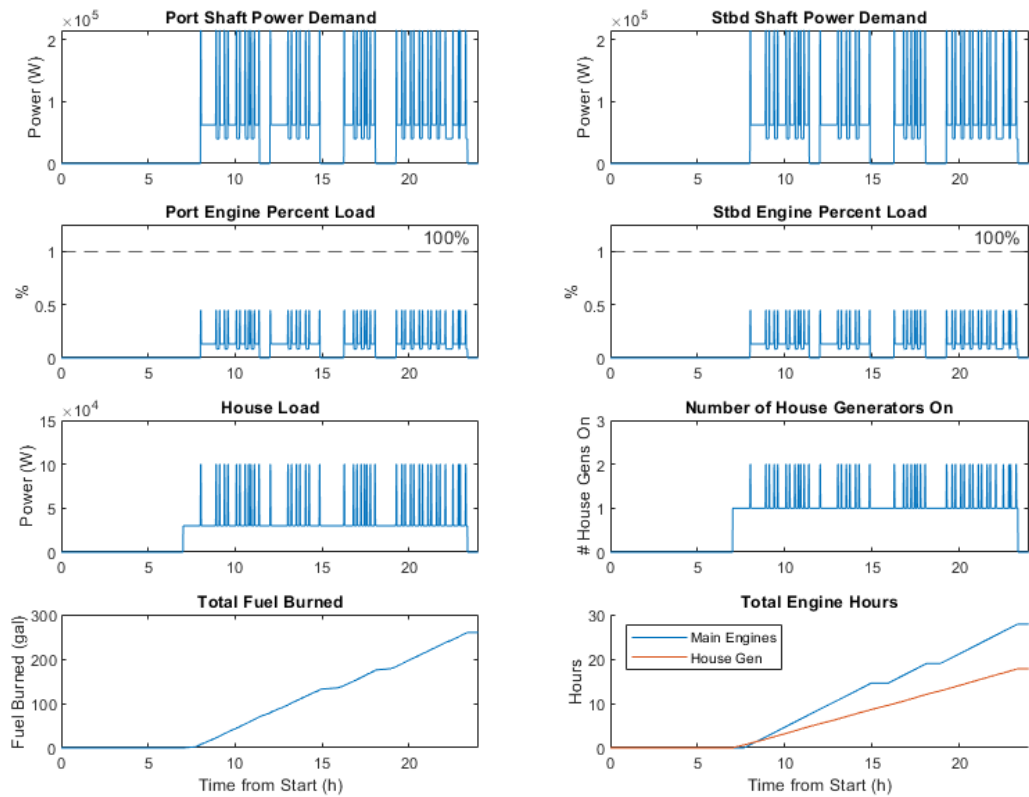


Diesel Electric with Batteries Results: 9 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

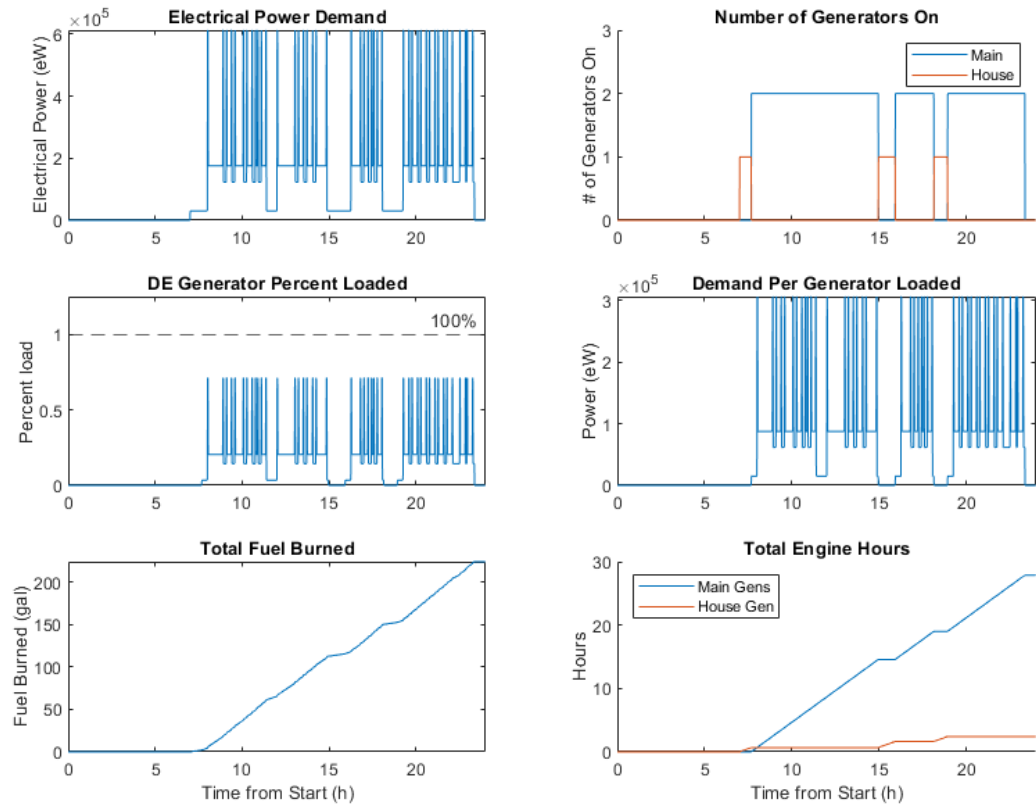


Simulation Results for a 8 knot Transit Speed at a 7ft Draft: Sunday - Thursday

Mechanical Results: 8 knots at a 7ft Draft: Sunday - Thursday

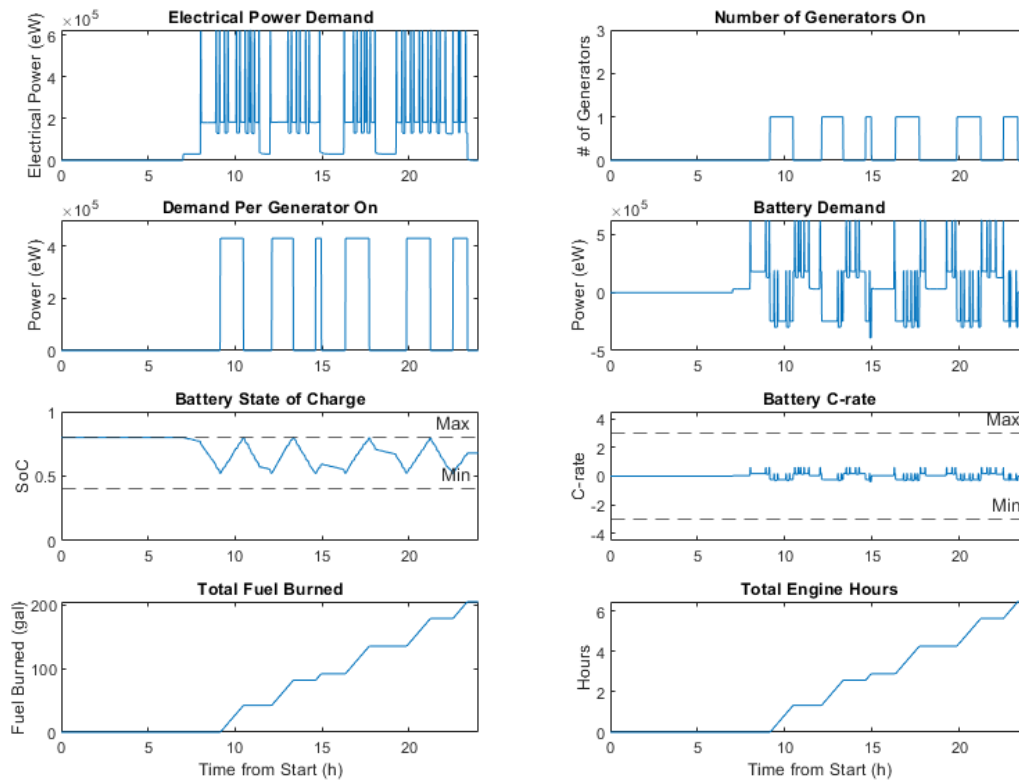


Diesel Electric with C18s Results: 8 knots at a 7ft Draft: Sunday - Thursday

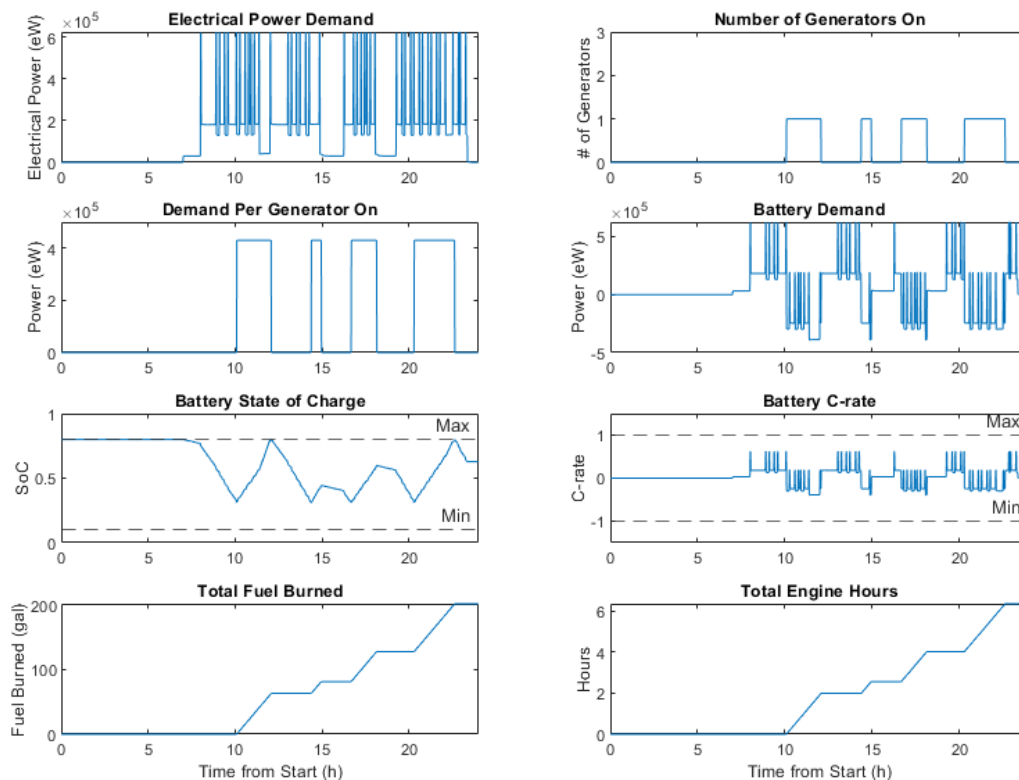


Simulation Results for a 8 knot Transit Speed at a 7ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 8 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

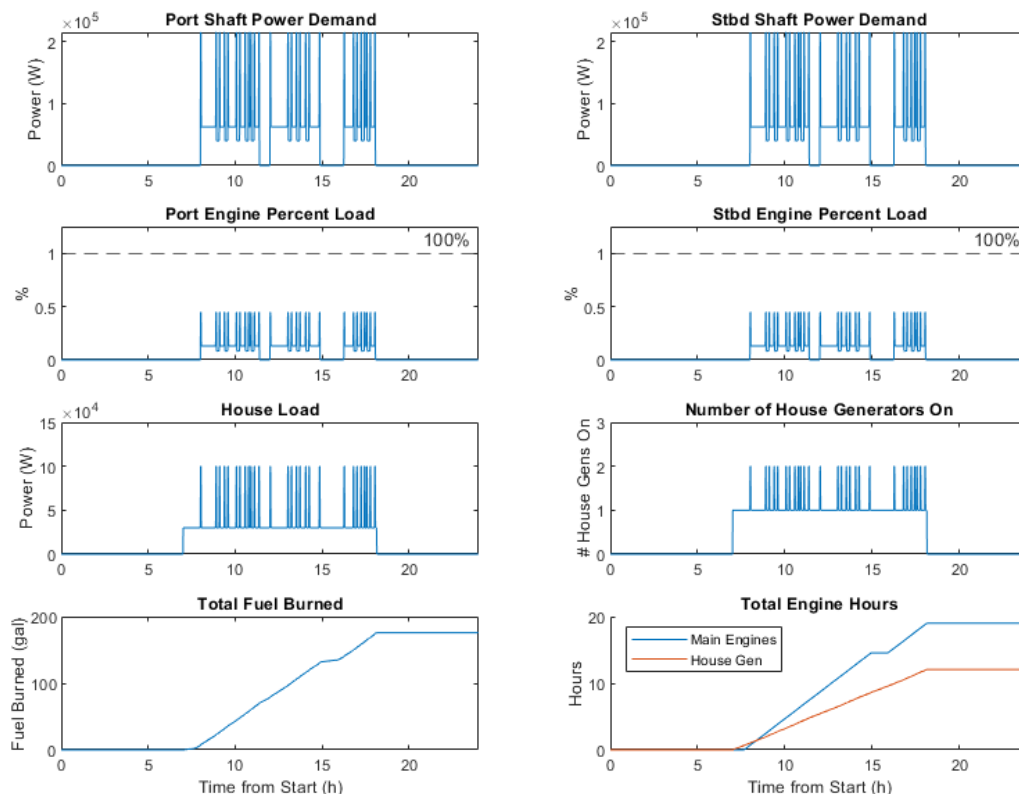


Diesel Electric with Batteries Results: 8 knots at a 7ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

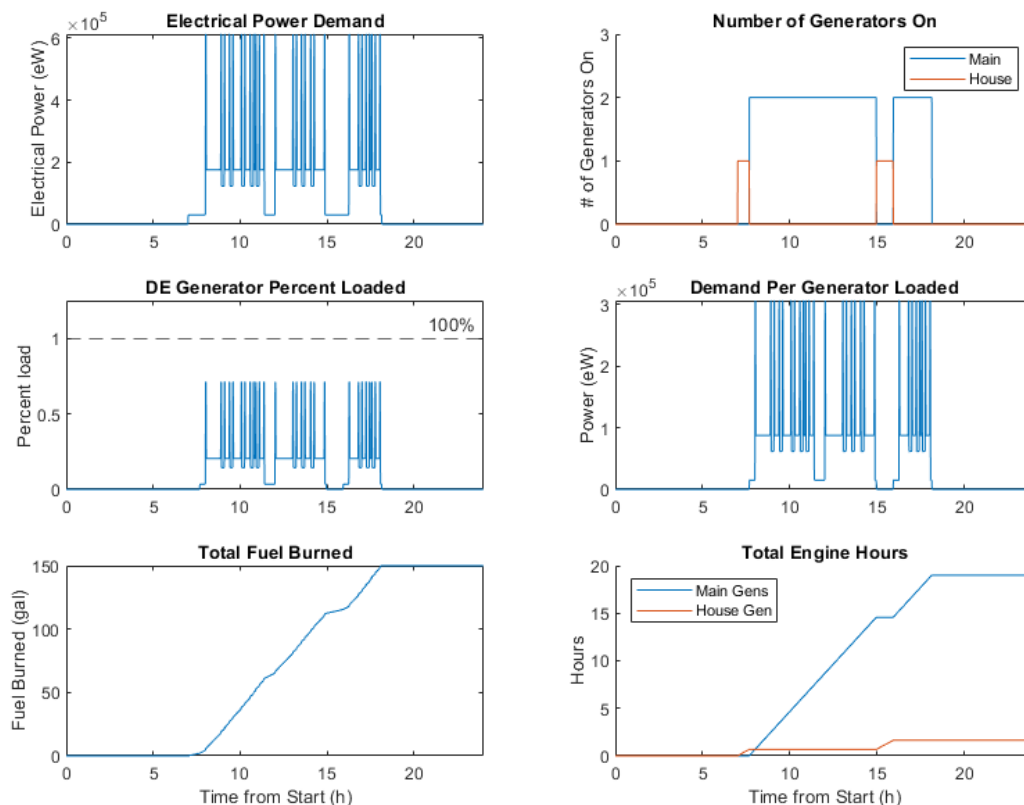


Simulation Results for a 8 knot Transit Speed at a 7ft Draft: Friday - Saturday

Mechanical Results: 8 knots at a 7ft Draft: Friday - Saturday

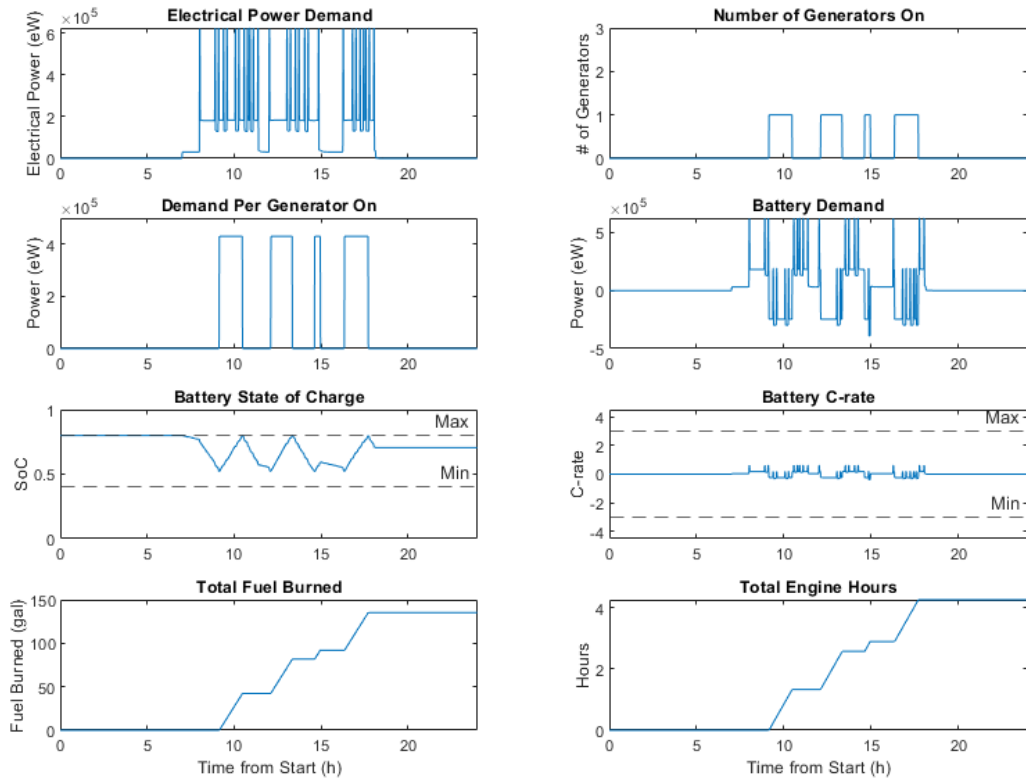


Diesel Electric with C18s Results: 8 knots at a 7ft Draft: Friday - Saturday

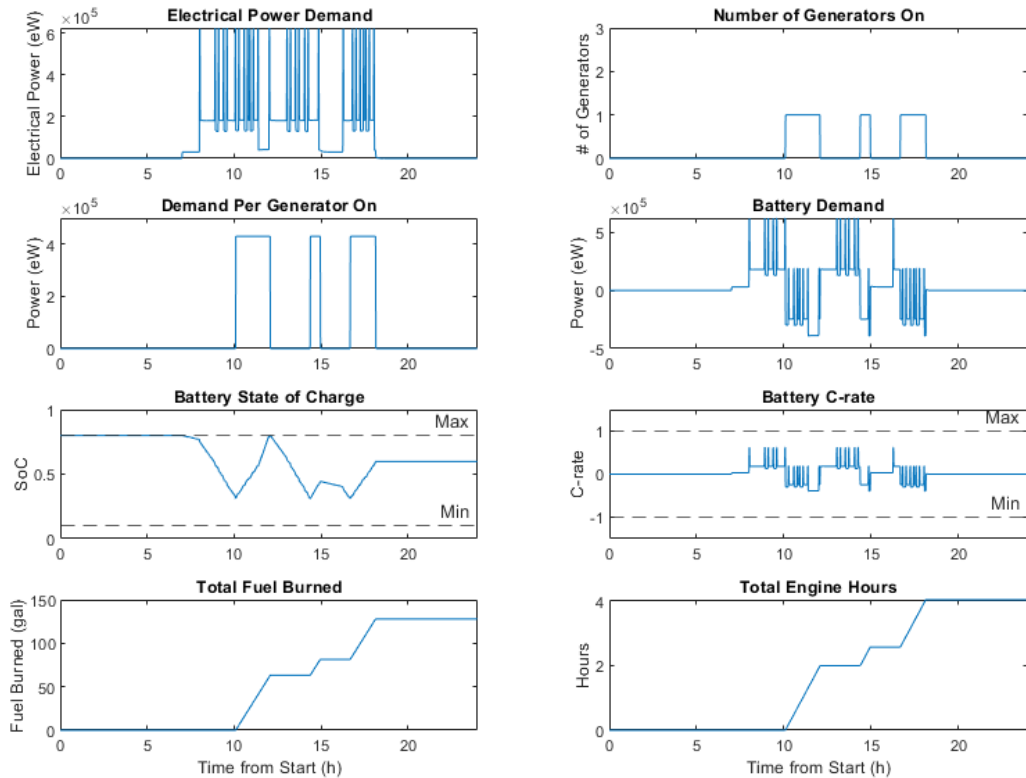


Simulation Results for a 8 knot Transit Speed at a 7ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 8 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC

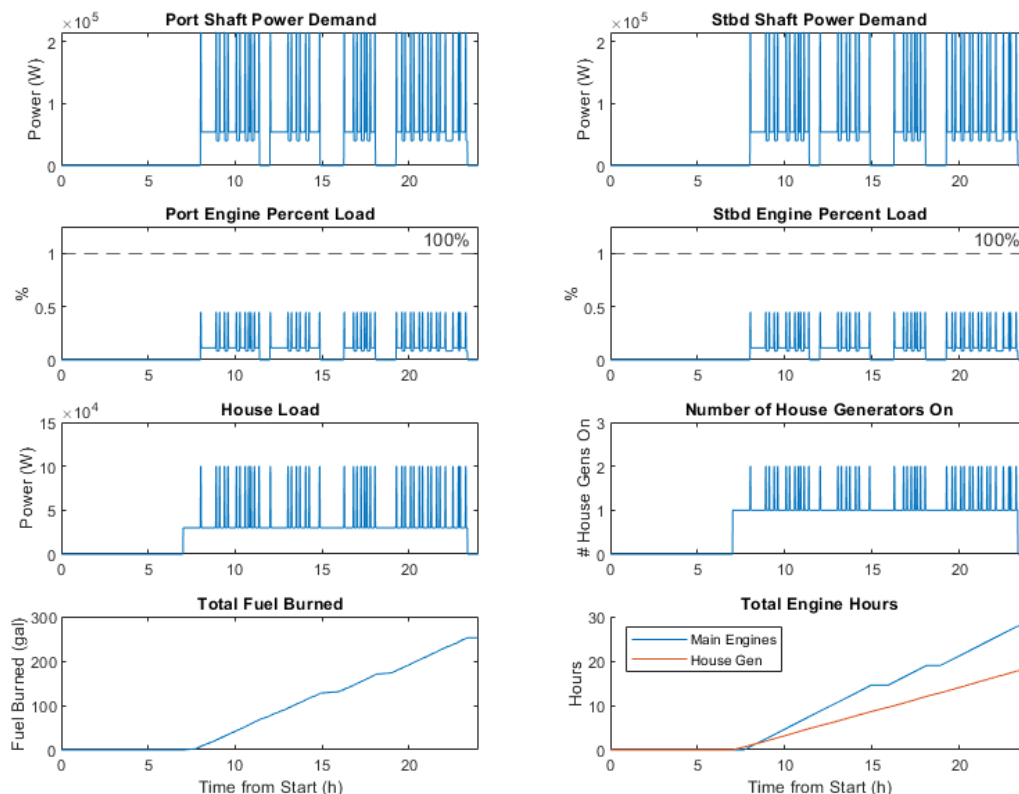


Diesel Electric with Batteries Results: 8 knots at a 7ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

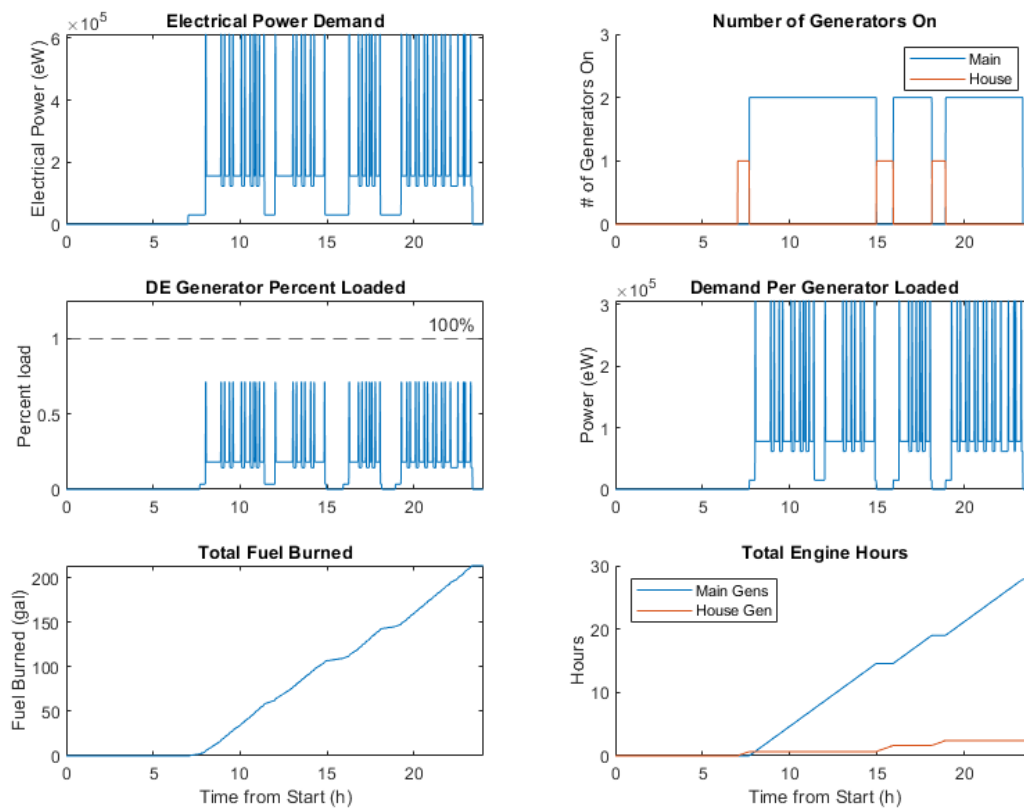


Simulation Results for a 8 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday

Mechanical Results: 8 knots at a 6.5ft Draft: Sunday - Thursday

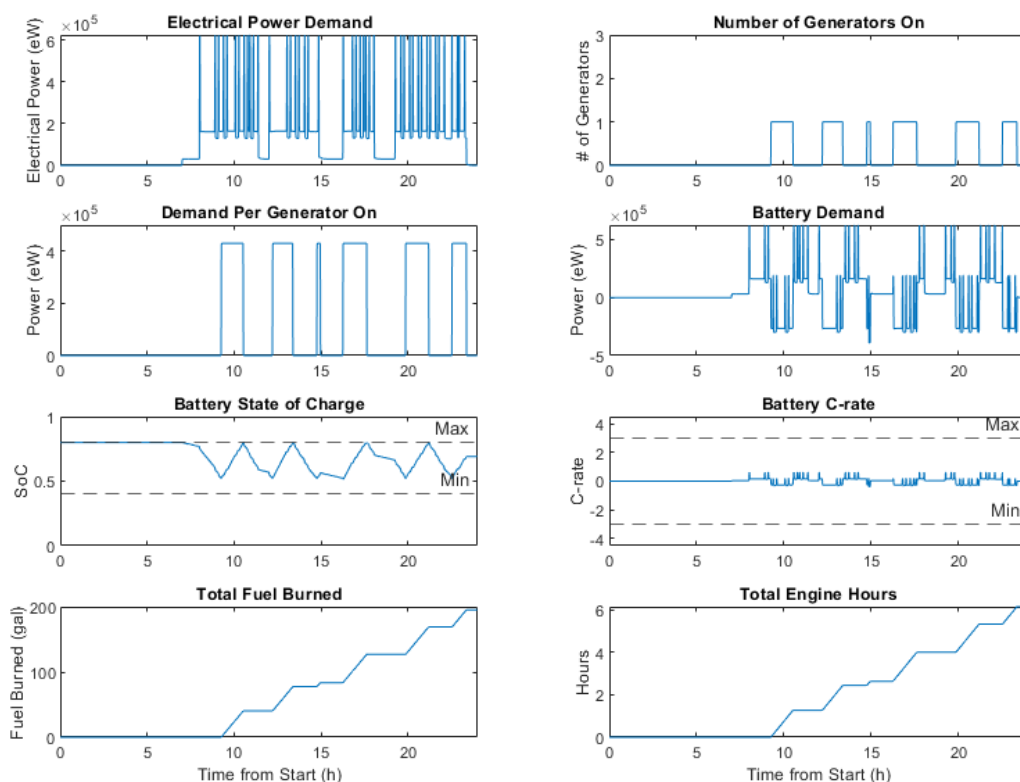


Diesel Electric with C18s Results: 8 knots at a 6.5ft Draft: Sunday - Thursday

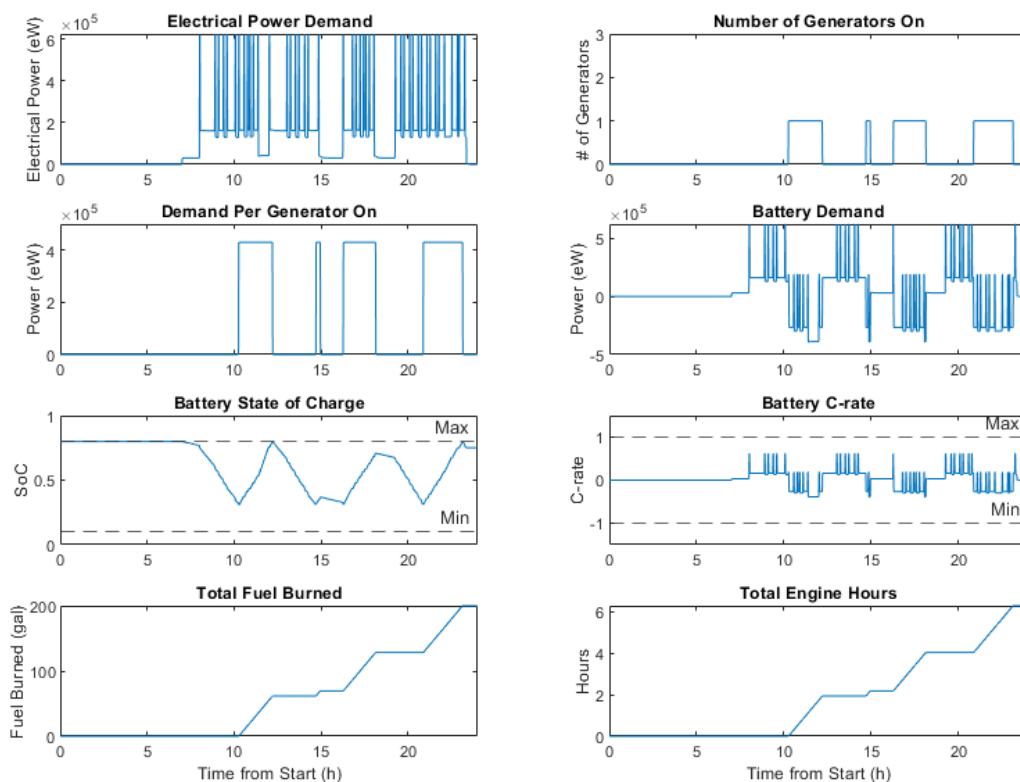


Simulation Results for a 8 knot Transit Speed at a 6.5ft Draft: Sunday - Thursday, Continued

Diesel Electric with Batteries Results: 8 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = NMC

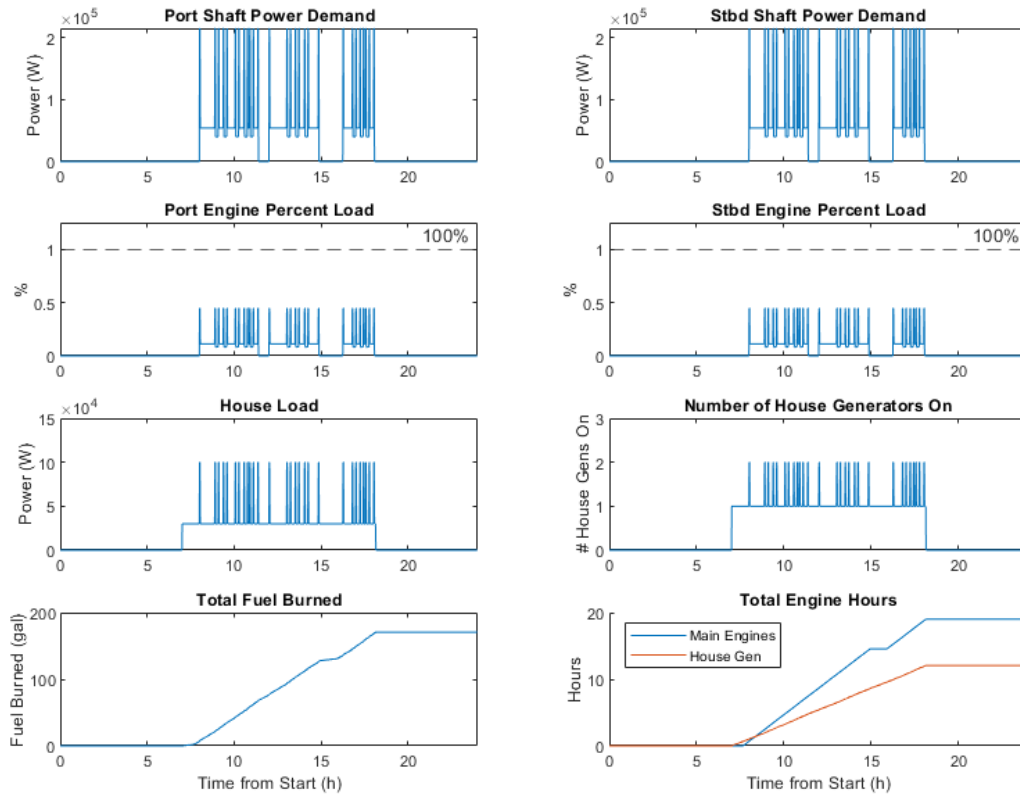


Diesel Electric with Batteries Results: 8 knots at a 6.5ft Draft: Sunday - Thursday
Battery Size: 1,000kWh, Battery Type = LFP

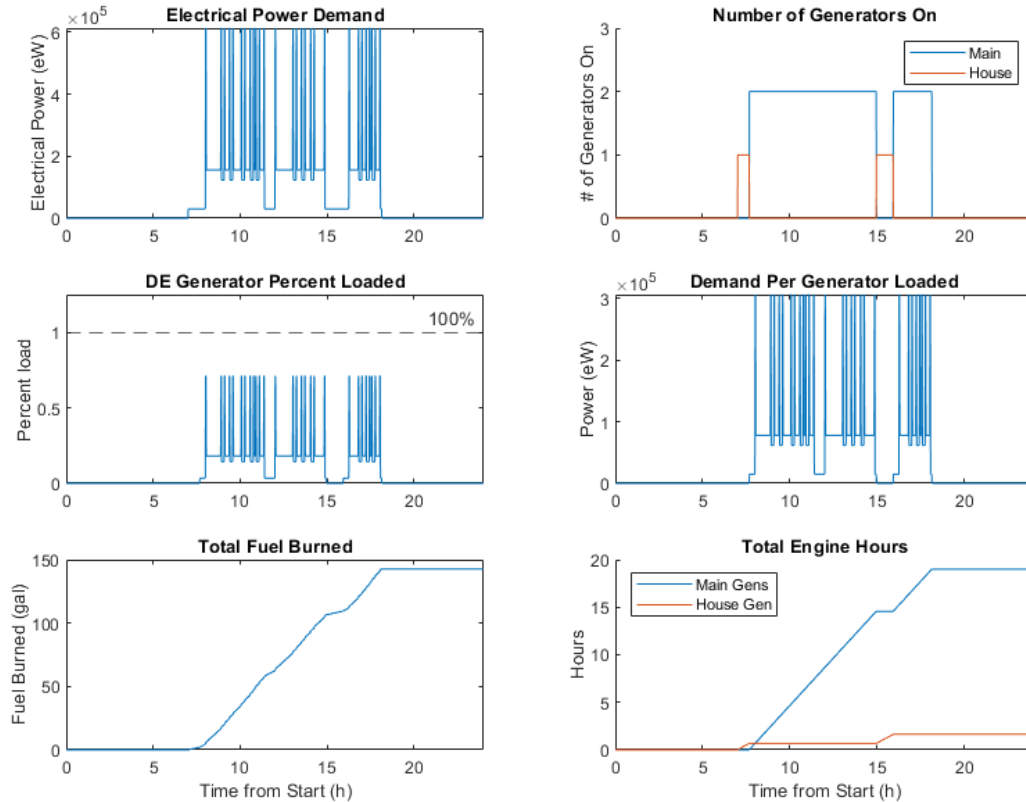


Simulation Results for a 8 knot Transit Speed at a 6.5ft Draft: Friday - Saturday

Mechanical Results: 8 knots at a 6.5ft Draft: Friday - Saturday



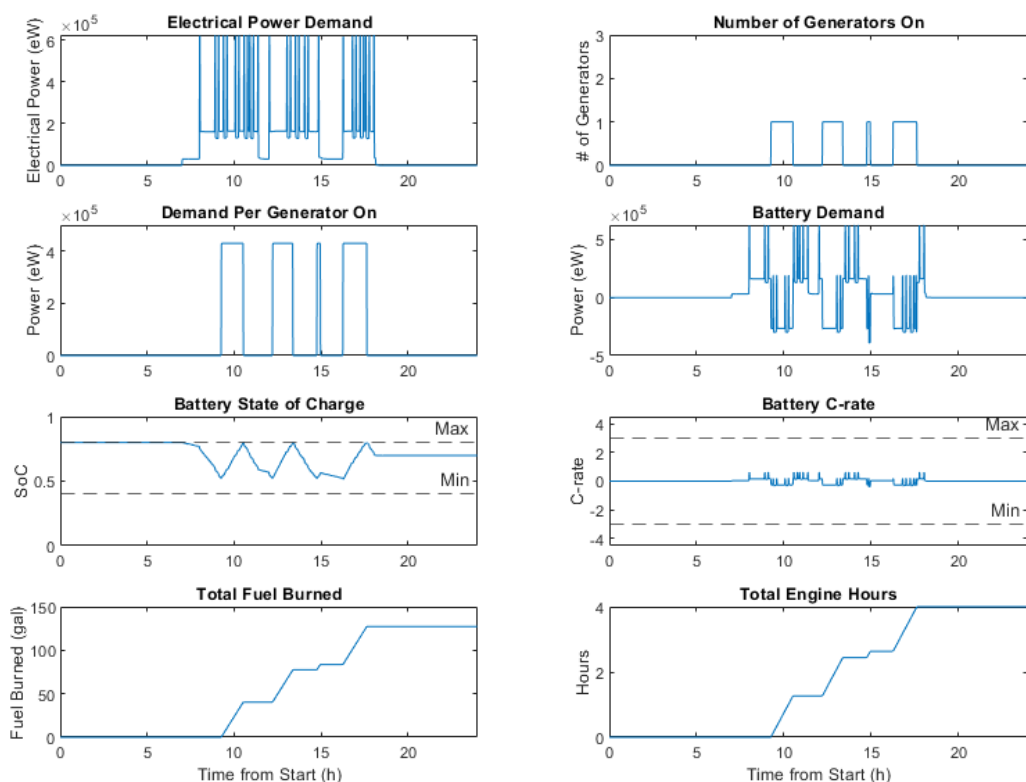
Diesel Electric with C18s Results: 8 knots at a 6.5ft Draft: Friday - Saturday



Simulation Results for a 8 knot Transit Speed at a 6.5ft Draft: Friday - Saturday, Continued

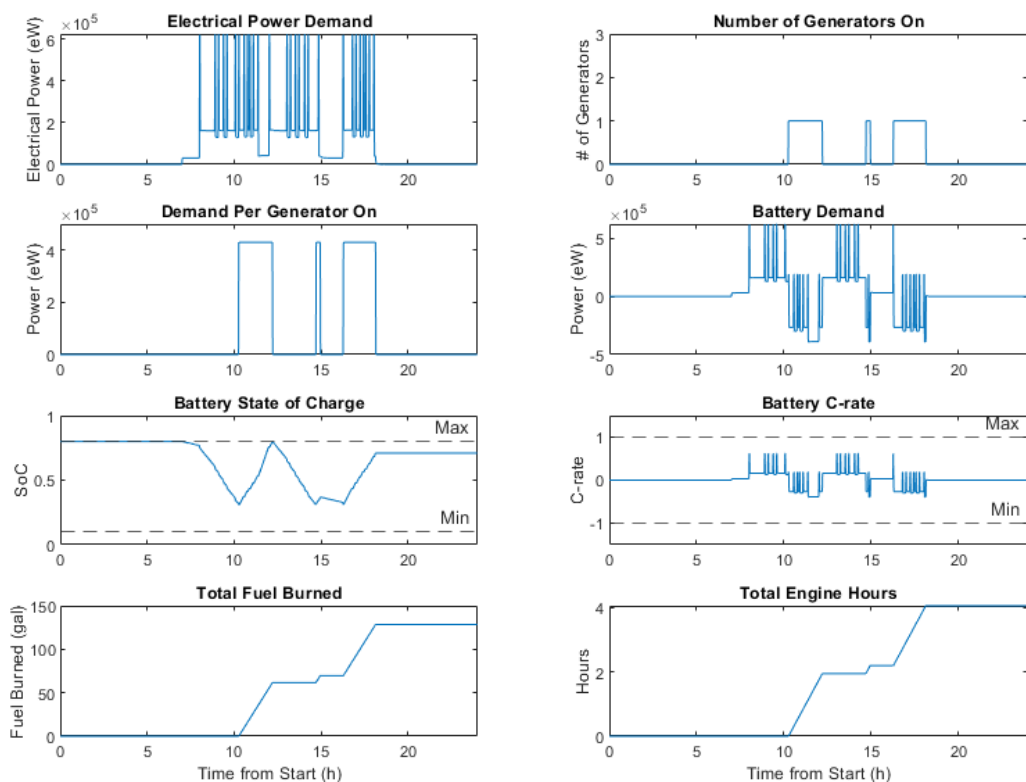
Diesel Electric with Batteries Results: 8 knots at a 6.5ft Draft: Friday - Saturday

Battery Size: 1,000kWh, Battery Type = NMC



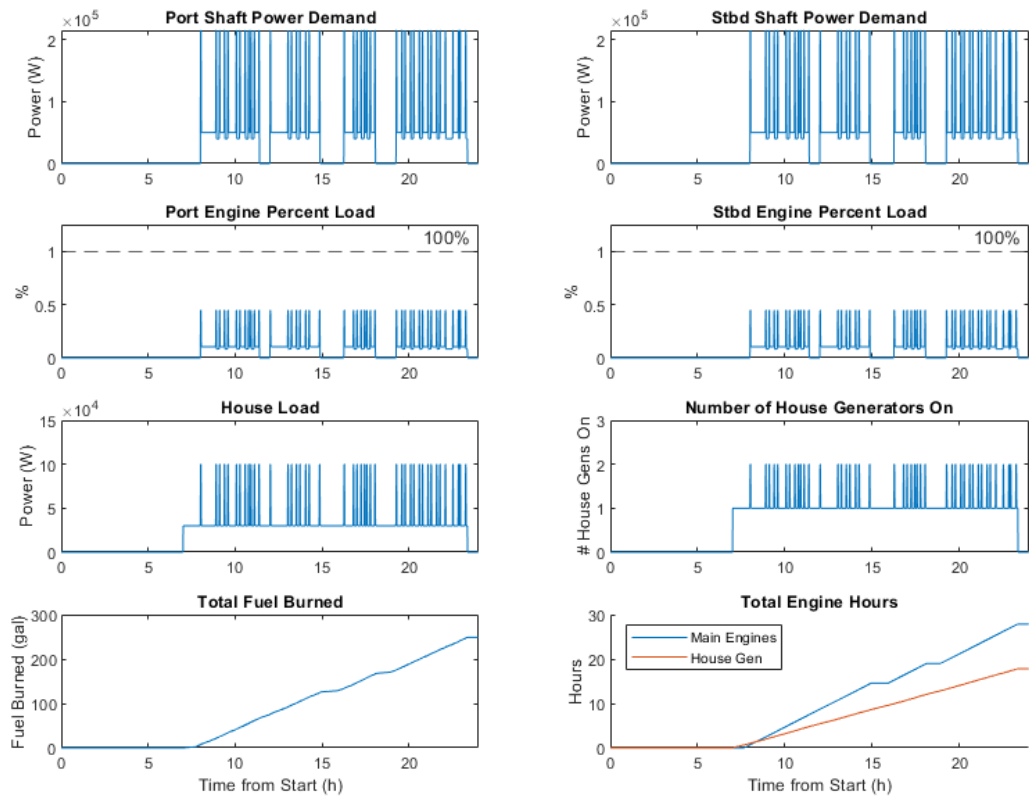
Diesel Electric with Batteries Results: 8 knots at a 6.5ft Draft: Friday - Saturday

Battery Size: 1,000kWh, Battery Type = LFP

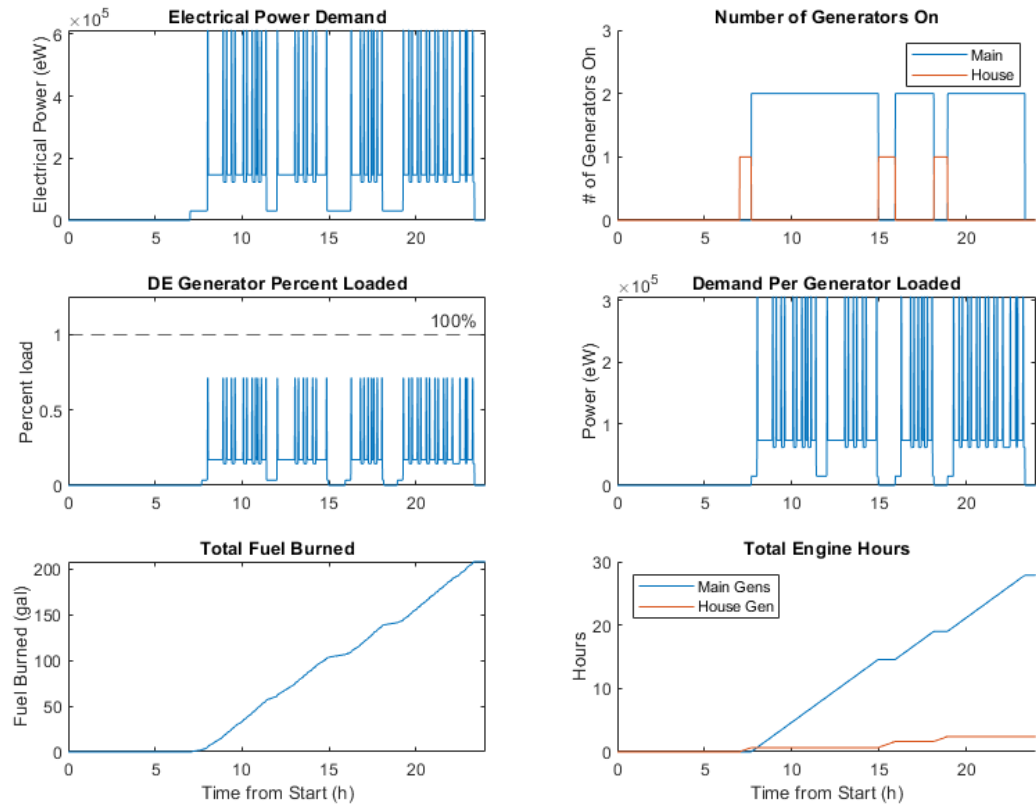


Simulation Results for a 8 knot Transit Speed at a 6ft Draft: Sunday - Thursday

Mechanical Results: 8 knots at a 6ft Draft: Sunday - Thursday



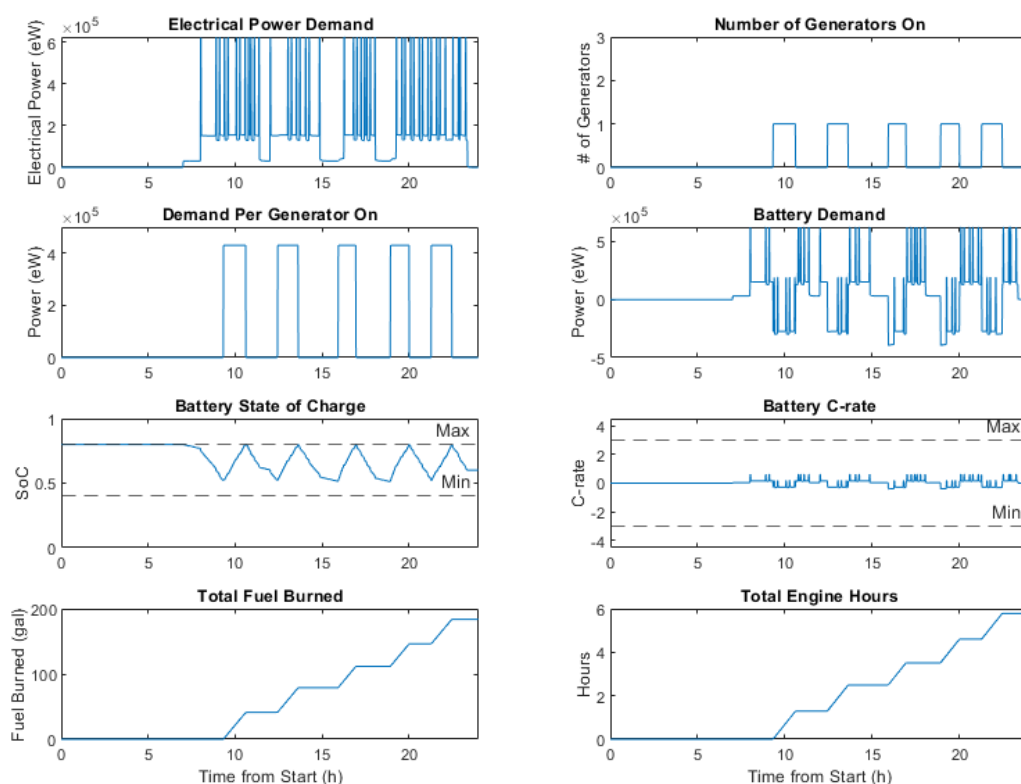
Diesel Electric with C18s Results: 8 knots at a 6ft Draft: Sunday - Thursday



Simulation Results for a 8 knot Transit Speed at a 6ft Draft: Sunday - Thursday, Continued

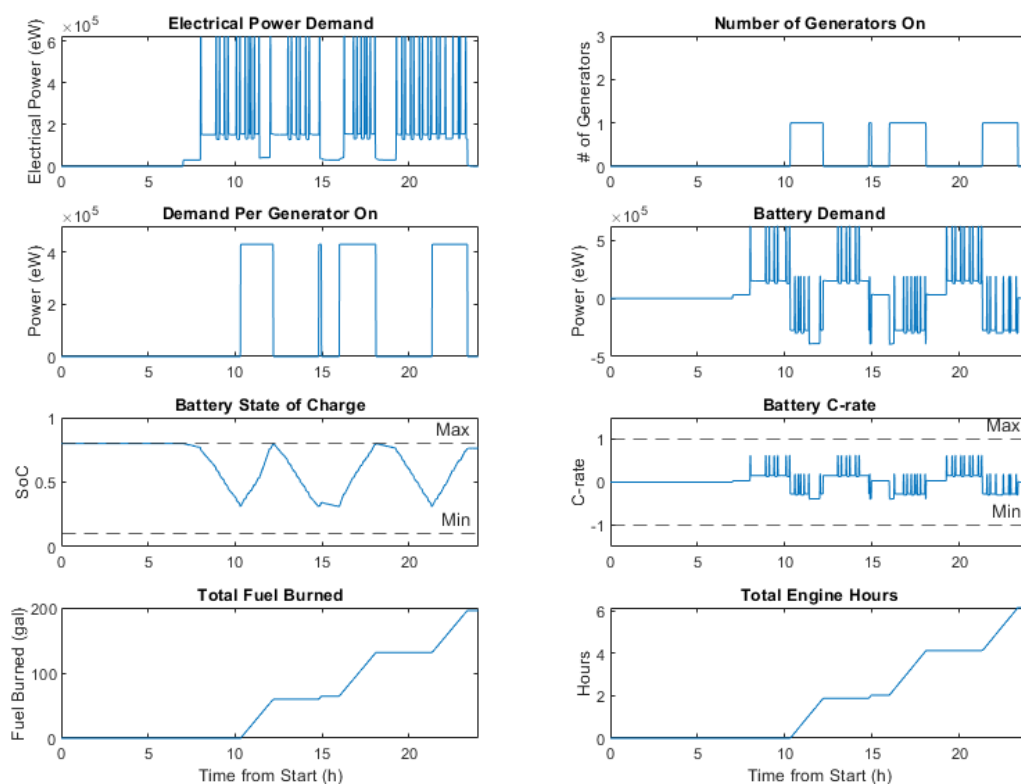
Diesel Electric with Batteries Results: 8 knots at a 6ft Draft: Sunday - Thursday

Battery Size: 1,000kWh, Battery Type = NMC



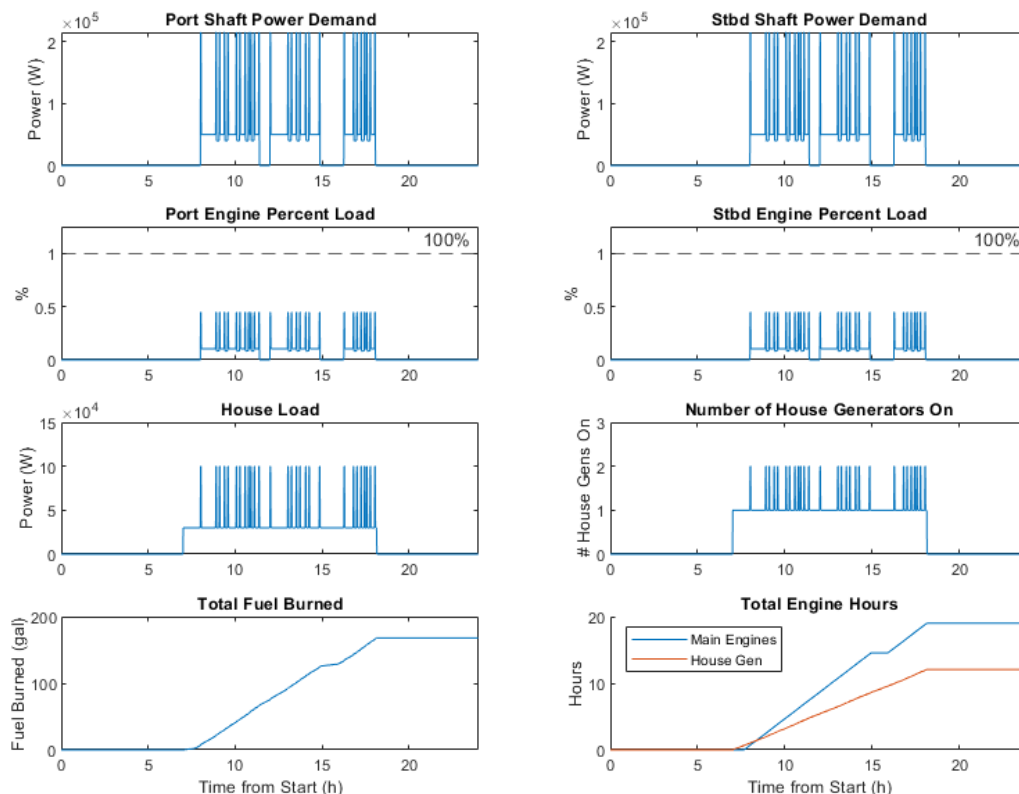
Diesel Electric with Batteries Results: 8 knots at a 6ft Draft: Sunday - Thursday

Battery Size: 1,000kWh, Battery Type = LFP

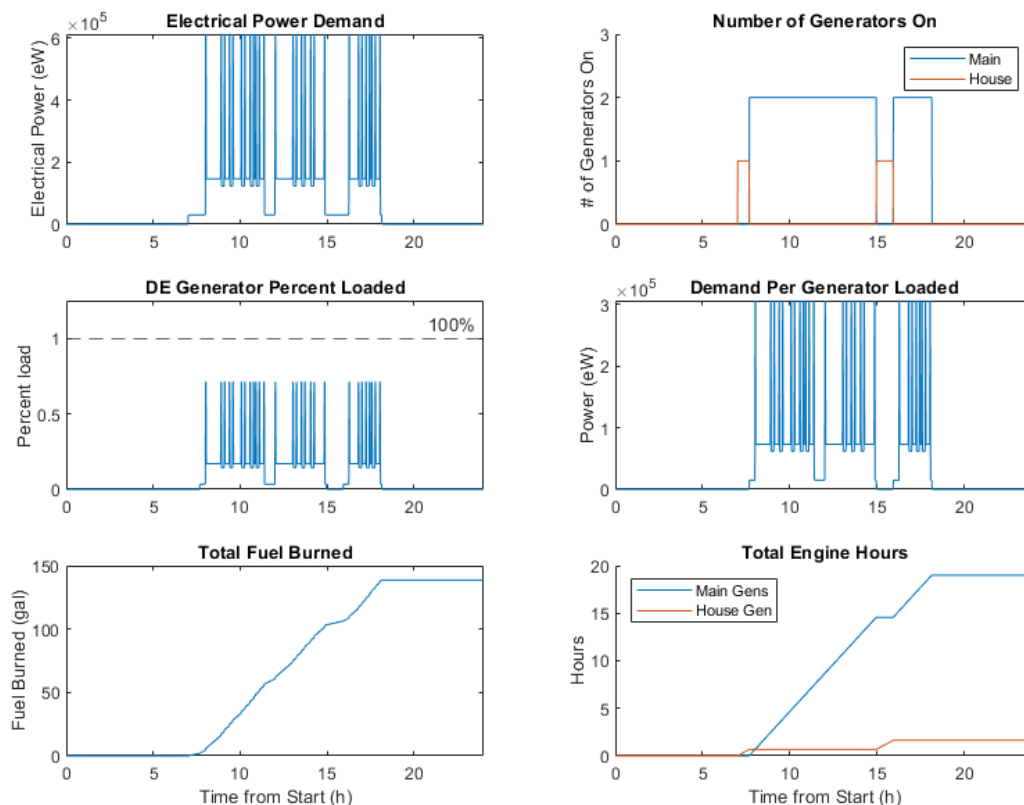


Simulation Results for a 8 knot Transit Speed at a 6ft Draft: Friday - Saturday

Mechanical Results: 8 knots at a 6ft Draft: Friday - Saturday

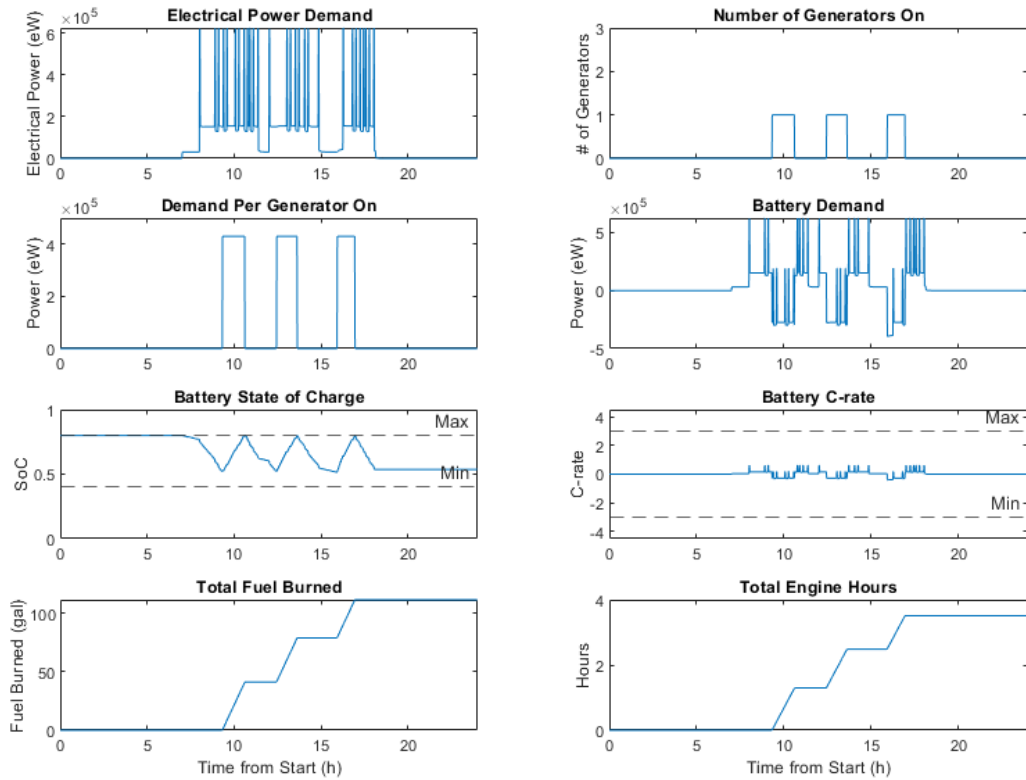


Diesel Electric with C18s Results: 8 knots at a 6ft Draft: Friday - Saturday



Simulation Results for a 8 knot Transit Speed at a 6ft Draft: Friday - Saturday, Continued

Diesel Electric with Batteries Results: 8 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = NMC



Diesel Electric with Batteries Results: 8 knots at a 6ft Draft: Friday - Saturday
Battery Size: 1,000kWh, Battery Type = LFP

