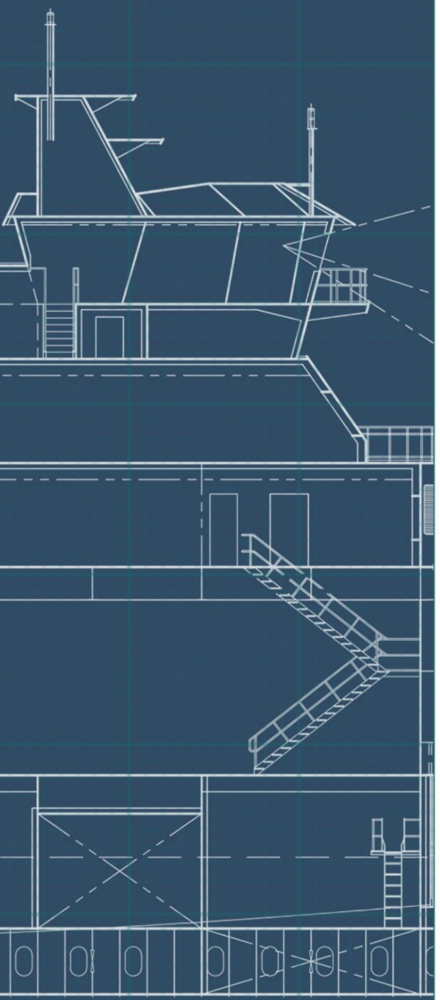

better to build · better to operate

SSA Hybrid Propulsion Study

Presented to Ferries Now!, Martha’s Vineyard Commission

March 31, 2023

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OUR TEAM IS YOUR TEAM

PURPOSE

UPDATE STUDY ON FERRY ALTERATIVE PROPULSION

- EBDG Hybrid Propulsion Study 05-13-2022
- Letter From Martha's Vineyard Commission dated 08-24-2022
- Revised EBDG Hybrid Propulsion Study dated 03-24-2023

- EBDG's Experience
- Scope of Study
- Key Assumptions
- Findings

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EBDG'S EARLY HISTORY WITH GREEN INITIATIVES

- Early studies on use of compressed natural gas for Pierce County (1998)
- Involvement with the EPA Tier 4 regulatory development (Cummins 2006)
- Presentation on LEED-type certification for marine industry (Tugnology in 2007)
- Emission studies for both tug and ferry operators (Moran & others, 2009)

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ALTERNATIVE FUELS

- Design of ATB to transport LNG and use LNG as a fuel (2013)
- Presentation on LNG Bunkering (Marine Log 2013)
- Concept design of towboat using LNG as a fuel (Informa 2014)
- Hydrogen Studies for Sandia National Laboratories (2015 & 2016)
- Case Study on LNG Tug Propulsion (Marine Log 2017)
- Case Study on Ammonia as a Ferry Fuel (Marine Log 2022)
- Contract design of methanol fuelled towboat (2021)

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ENERGY STORAGE SYSTEMS

- Jumbo Mark II Hybrid Cost Study (J17071)
- New Lummi Island Ferry (J17098.01)
- Casco Bay Lines (J18045 for all-electric vessel)
- Hybrid Olympic Class (2019)
- WSF Electrification Study (J19097)
- Hart Island Electric Ferry (J19022)
- Hybrid Ferry for Governors Island (J19098)
- Hybrid Ferry for Cameron Parish (J20006)
- DRBA Marine Master Plan (20075)
- Low Emission Ferry Study (J22027)
- New Ferry for Texas DOT (J22048)

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SCOPE OF STUDY

M/V WOODS HOLE

- 235 ft x 64 ft x 18.5 ft ferry
- Built in 2015 by Conrad Shipbuilding
- Original EBDG Cost estimate $41.3 million
- Shipyard Bid Price $36.4 million (11/18/14)
- Diesel mechanical propulsion with ship service generators
- Current price estimate $49 to $54 million

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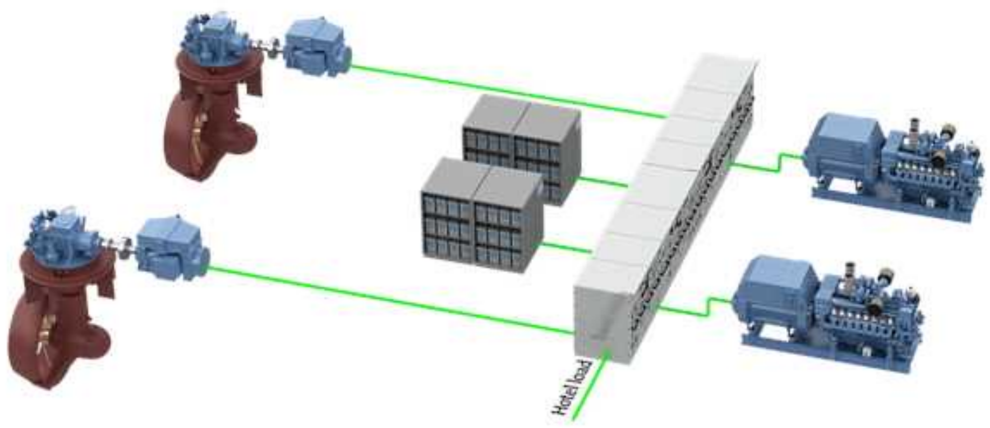
SYSTEMS EXAMINED

PROPULSION & ELECTRICAL

1. Geared diesel engines with CP propellers & 3 diesel generators (baseline)
2. Diesel-electric with 3 diesel generators, 2 propulsion motors with FP propellers, & small battery (180 kWh) for zero emission at berth
3. Diesel-electric with 3 diesel generators, 2 propulsion motors with FP propellers, & medium battery (1900 kWh) for peak shaving
4. Diesel-electric with 3 diesel generators, 2 propulsion motors with FP propellers, & larger battery (2500 kWh) for 50% power
5. Diesel-electric with 1 diesel generators, 2 propulsion motors with FP propellers, & largest battery (5400 kWh) for all-electric with rapid charging at each terminal
6. Diesel-electric with 2 diesel generators, 2 propulsion motors with FP propellers, & larger battery (2800 kWh) for plug-in hybrid with rapid charging at each terminal

COURTESY OF KONGSBERG

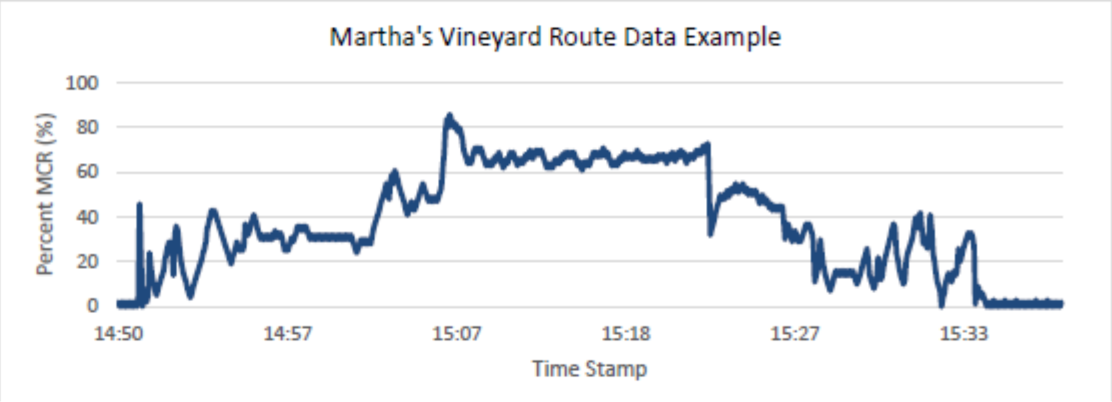


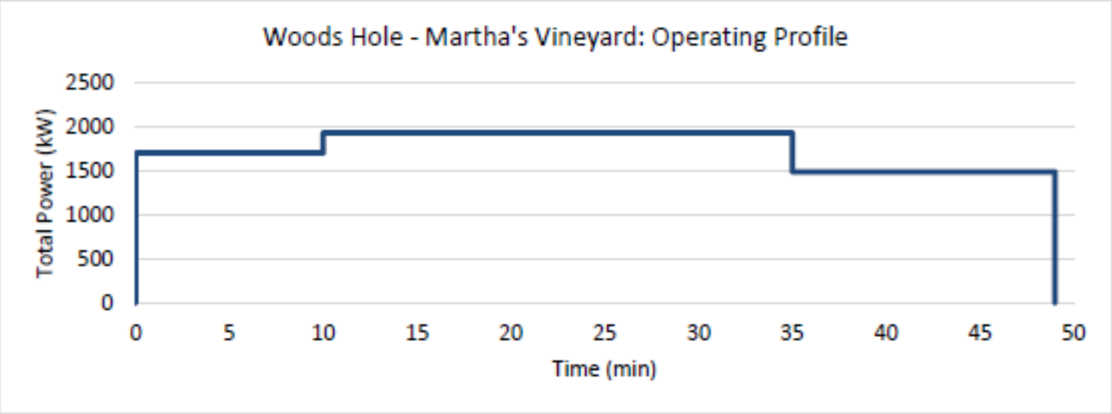
PROCESS

ASSUMPTIONS

- Vessel schedule and speed similar to current operations
- Examine operating costs over a 20-year horizon
  - Maintenance, Fuel, & Battery Replacement
  - Labor, cost of capital, overhead, etc. not included
- Consumables
  - Fuel $2.15/gal
  - Lube Oil $8.00/gal
  - Batteries $650/kWh
  - Urea $3.23/gal
- Capital costs include propulsion differences and shoreside rapid charging systems
- Emissions assumes 5% operation in all-electric configuration

ACTUAL AND ASSUMED ENERGY PROFILES





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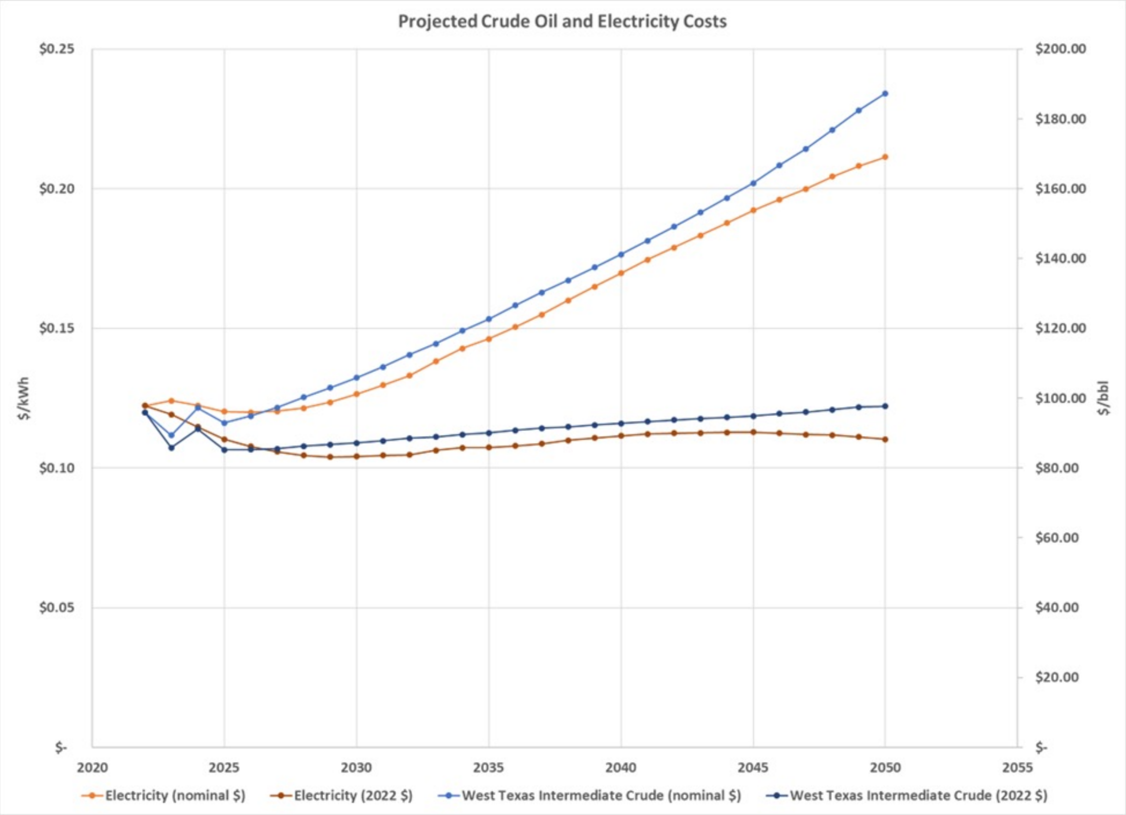
COSTS OF ENERGY

NEW ENGLAND REGION

- Based on US Energy Information Agency (EIA)
  - Crude oil will increase by 95%
  - Electrical costs will increase by 73%
- Levelized Cost of Energy
  - Offshore Wind
    - $136.51/kWh in 2027
    - $98.01/kWh in 2040
  - Combined Cycle Gas
    - $44.05/kWh in 2040
  - Solar
    - $45.54/kWh in 2040

CRUDE OIL V. ELECTRICITY COSTS



FINDINGS FOR MARTHA'S VINEYARD OVER 20 YEARS

CAPITAL COST PER VESSEL

OPTION	DESCRIPTION	COST
1	Diesel Mechanical	$ 53,601,630
2	Berth Battery	$ 58,495,908
3	Peak Shave	$ 60,113,591
4	50% Battery	$ 60,689,833
5	All Electric	$ 61,460,801
6	Plug-In Hybrid	$ 60,635,638

OPERATING COST

OPTION	DESCRIPTION	COST
1	Diesel Mechanical	$ 29,866,000
2	Berth Battery	$ 29,524,000
3	Peak Shave	$ 31,798,000
4	50% Battery	$ 32,358,000
5	All Electric	$ 33,864,000
6	Plug-In Hybrid	$ 32,115,000

EMISSIONS

OPTION	DESCRIPTION	CO_2 (MT/YR)	NOX (MT/YR)	CO (KG/YR)	PM (KG/YR)
1	Diesel Mechanical	3849	22	909	175
2	Berth Battery	3565	14	258	87
3	Peak Shave	3538	13	467	82
4	50% Battery	3544	11	2118	101
5	All Electric	187	1.1	45	8.7
6	Plug-In Hybrid	1615	5.3	774*	43.7

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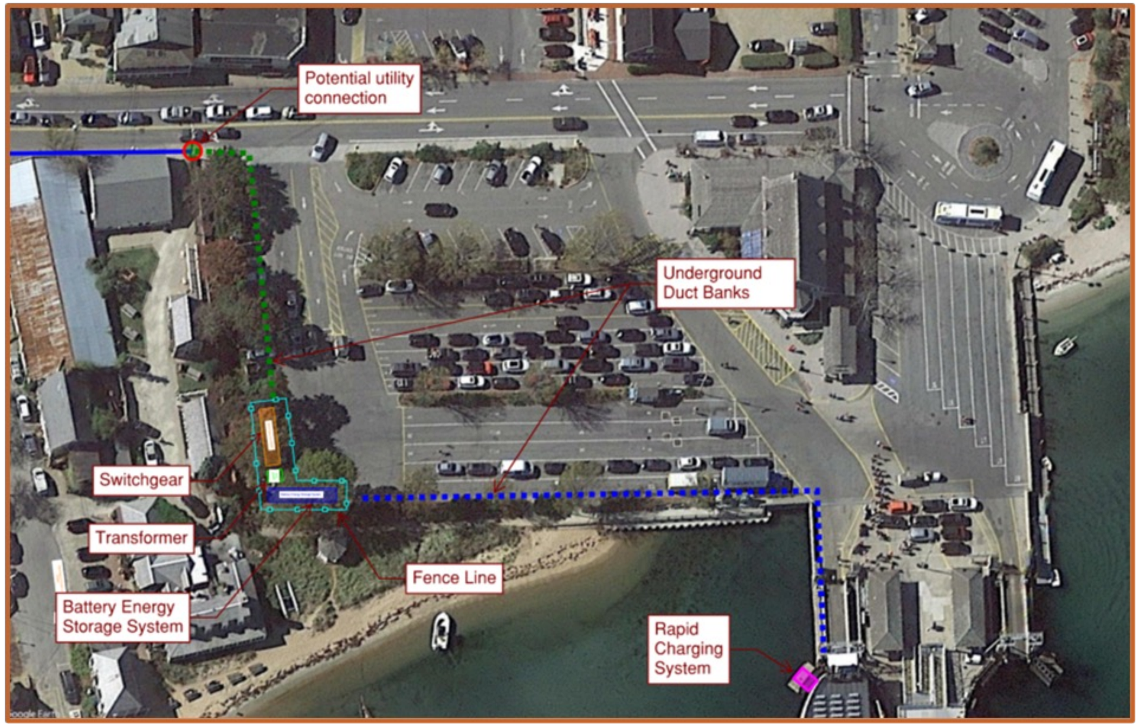
ITEMS TO NOTE

COSTS ARE DYNAMIC

- The Op-Ex spread between the lowest vessel cost (Berth Battery) and the highest vessel cost (All Electric) is only 14.7%.
- The Cap-Ex for the All Electric and the Plug-In Hybrid include $1 million in vessel costs for the re-charging arm and shipboard receptacle.
- Cap-Ex for shoreside rapid charging and battery energy storage systems are approximately $10 million per installation.
- Shipyard costs are increasing faster than the rate of inflation. Competition for labor, materials, and equipment are all drivers plus there are fewer shipyards every year.

BESS FOR MARTHA'S VINEYARD TERMINAL



ANSWERS TO QUESTIONS

1. Cost estimates now show total vessel cost.
2. Plug-in Hybrid was evaluated. Future proofing a design for conversion to Plug-in Hybrid was not evaluated. (DRBA Preliminary Design)
3. Time frame of the study was re-cast at a 20-year horizon.
4. Future energy costs were adjusted to suit the March 2023 EIA report.
5. Actual maintenance data from SSA not discrete to show 20-year costs for diesel mechanical. Used a consistent methodology across the different options based on vendor information.
6. Battery pricing was revisited with $650/kWh for marine batteries and $400/kWh for shoreside batteries. Battery replacements and generator rebuilds included in NPV Op-Ex
7. Monetizing the emission reductions is beyond the scope of this study as there is no robust mechanism for emissions trading or carbon credits.
8. Vessel Cap-Ex was vetted by third party with extensive experience in vessel cost estimating.
9. Exploring funding sources was outside of the scope of this study. Other public agencies are using a combination of FTA funds, Marad Grants, and regional DOT funds
10. SSA is preparing a strategic plan outside of this study effort.

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SSA FLEET

FLEET CHANGES

- Three freight boats (*) being replaced by 15 year old offshore supply vessels
- Average age of current 10 vessel fleet is 33.6 years. New vessels will reduce average age to 28.2 years.
- Typical retirement age for ferry boats in the US is between 50 and 60 years.
- Allowing for new technologies is an essential part of a fleet long range plan.
- Disruptors
  - Energy Costs
  - Climate Change
  - New Fuels/Battery Technologies
  - Remote Work
  - Package Freight

CURRENT FLEET

Vessel Name	Year Built	Vessel Age (Years)	Registered Length	Car Capacity	Passenger & Crew Capacity
GOVERNOR	1954	69	242.0	42	256
NANTUCKET	1974	49	216.6	50	768
GAY HEAD *	1981	42	217.9	39	147
KATAMA *	1982	41	215.8	39	150
EAGLE	1987	36	218.7	52	768
MARTHA'S VINEYARD	1993	30	216.5	54	1274
SANKATY	1994	29	220.3	39	300
MV IYANOUGH	2006	17	144.5	N/A	400
ISLAND HOME	2007	16	235.2	76	1210
WOODS HOLE	2016	7	224.5	55	453
Average		*33.6*			

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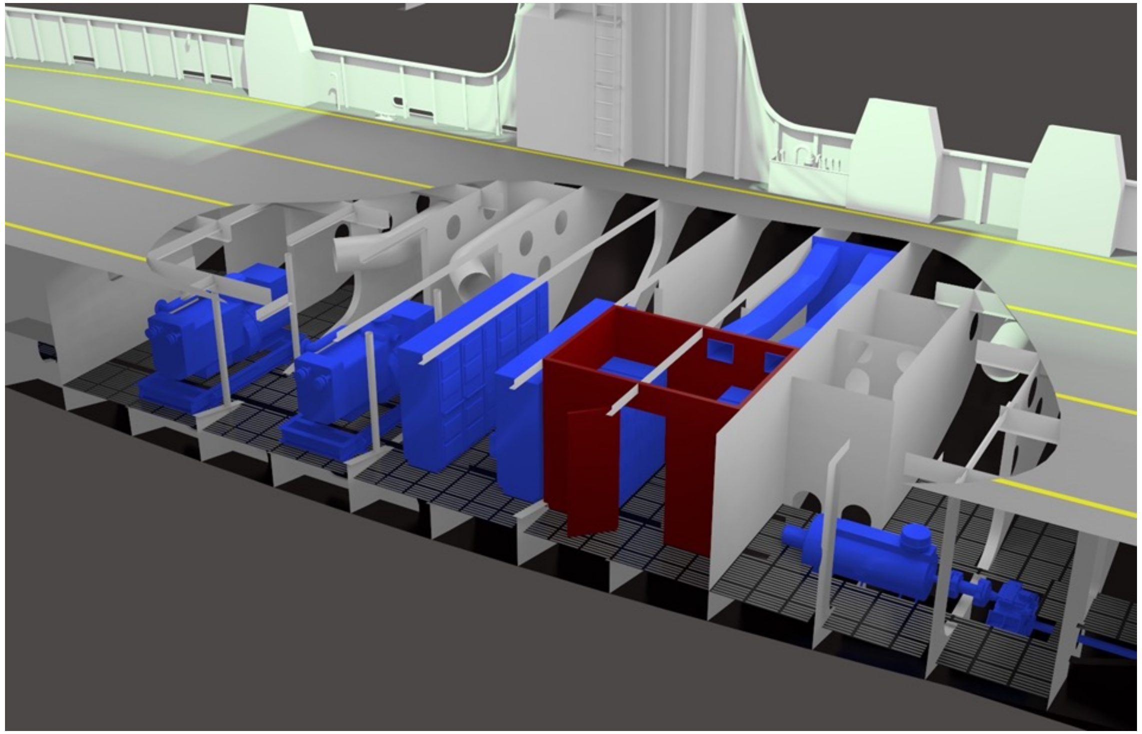
PHASING AN ALL-ELECTRIC FERRY

KEY COMPONENTS

- Propulsion Motors sized for service demand
- Switchgear and system architecture to support a variety of energy inputs
- Diesel generator sets to allow diesel-electric operation
  - Travel to a shipyard or more extended route
  - Resiliency in case electric grid is down
  - Allows "boost" speed if desired
- Energy Storage System (ESS)
  - Can replace a generator or two
  - Sized to suit different operational scenarios
  - Number of cycles/depth of discharge/Cost
- Rapid Charging System

PORT ARANSAS FERRY



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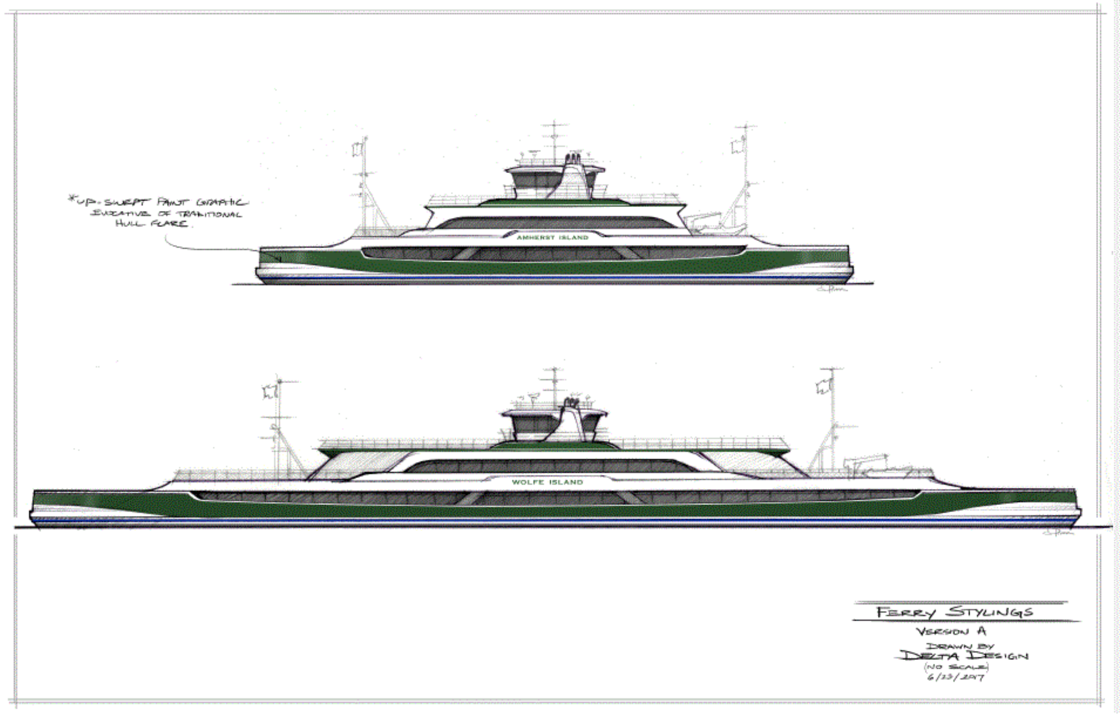
ENGINEERING COSTS

- Breakdown for a Large Hybrid Ferry

SWBS 000, PM & Admin	4.8%
SWBS 100 Structure	21.6%
SWBS 200 Propulsion	5.1%
SWBS 300 Electrical	14.4%
SWBS 400 Electronics & IC	1.5%
SWBS 500 Aux. Systems	13.1%
SWBS 600 Outfitting	14.2%
SWBS 800 Integration & Eng.	5.4%
SWBS 900 SY Support Svcs.	6.8%
Margins	**13.0%**



Ferry Concepts for Ontario

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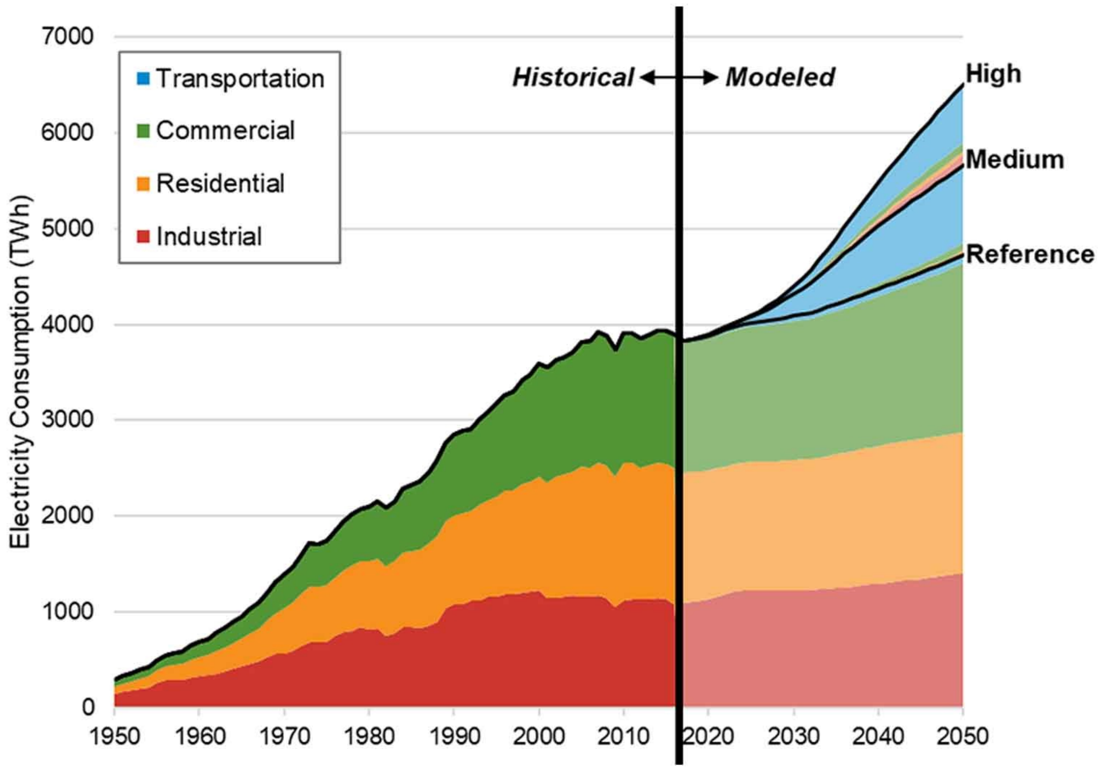
FUTURE CONSIDERATIONS

- New battery technologies offer the potential for lower cost, better energy density, and greater safety.
- Hybrid propulsion can bring added redundancy, lower maintenance costs, and lower emissions.
- Risks include greater cost, crew training, reliance on vendors, and complexity.
- There will be competition for funding, resources, equipment, and maintenance personnel.

ELECTRICITY CONSUMPTION BY SECTOR



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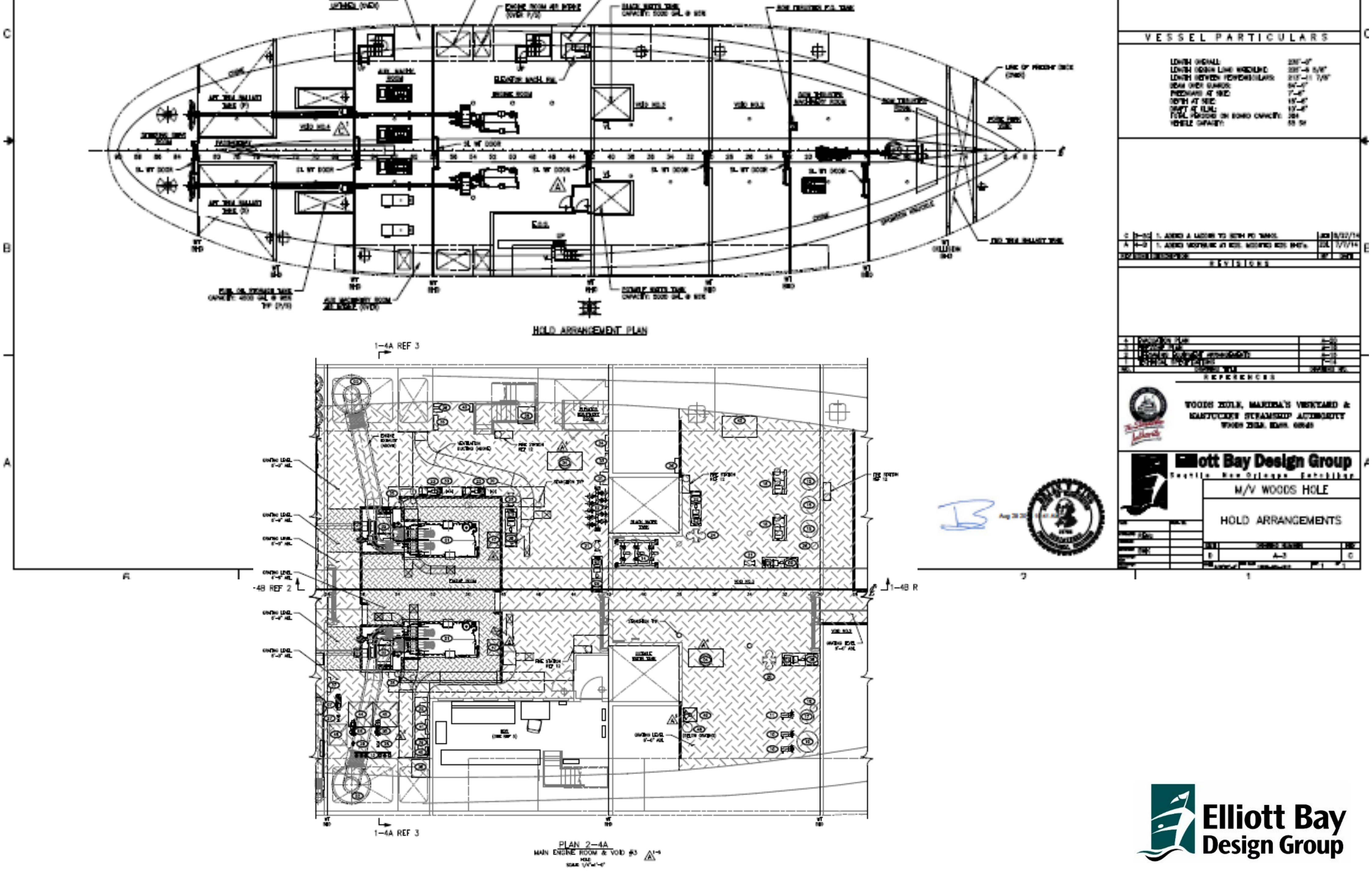

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