Appendix G

Life Cycle Cost Analysis – Summary
Life Cycle Cost Analysis – Calculations
Conversion Cost Estimate

LIFE CYCLE COST ANALYSIS – SUMMARY

Three Vessels and Four Docks

	Diesel Price Projections	
	EIA Reference Case	Conservative Case
Hybridizing	$271,034,715	$271,034,715
Not Hybridizing	$324,121,623	$267,705,961
Savings	$53,086,909	-$3,328,754
Savings, %	16.4%	-1.2%

Three Vessels and Two Docks

	Diesel Price Projections	
	EIA Reference Case	Conservative Case
Hybridizing	$215,523,956	$215,523,956
Not Hybridizing	$277,232,452	$229,126,355
Savings	$61,708,496	$13,602,399
Savings, %	22.3%	5.9%

Two Vessels and Two Docks

	Diesel Price Projections	
	EIA Reference Case	Conservative Case
Hybridizing	$169,949,605	$169,949,605
Not Hybridizing	$224,493,460	$185,304,172
Savings	$54,543,856	$15,354,567
Savings, %	24.3%	8.3%

LIFE CYCLE COST ANALYSIS – CALCULATIONS

Three Vessels and Four Docks

Conversion of the TACOMA and WENATCHEE: EIA Reference Case

Discount Rate	4 %

ASSUMPTIONS (Per Vessel)

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,550,683	$1,225,207
Periodic Diesel	$1,506,178	$1,190,043
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	365 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	2007500 gal/yr
Boiler Diesel for Heating	1.8 %
	36135 gal/yr
Periodic Diesel Usage	2.87 %
	57615 gal/yr
Total Annual Fuel Savings	1913750 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$36,910,724	$30,391,339	$2,896,621	$2,039,294		$14,696,465		$121,904,589	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,857,903	$1,529,981	$142,800	$55,156	$405	$0	$2.50	$4,784,374	$78,385	$0
2021		$1,858,383	$1,530,360	$142,800	$55,156	$386	$0	$2.56	$4,896,109	$78,385	$0
2022		$1,858,864	$1,530,740	$142,800	$55,156	$368	$0	$2.64	$5,056,808	$78,385	$0
2023		$1,859,344	$1,531,120	$142,800	$55,156	$349	$4,386,371	$2.69	$5,155,034	$78,385	$0
2024		$1,859,825	$1,531,499	$142,800	$55,156	$330	$0	$2.74	$5,245,092	$78,385	$0
2025		$1,860,305	$1,531,879	$142,800	$55,156	$312	$0	$2.82	$5,402,667	$78,385	$2,075,824
2026		$1,860,786	$1,532,259	$142,800	$55,156	$293	$0	$2.90	$5,548,106	$78,385	$0
2027		$1,861,266	$1,532,638	$142,800	$55,156	$274	$3,445,985	$2.95	$5,638,545	$78,385	$0
2028		$1,861,747	$1,533,018	$142,800	$55,156	$255	$0	$2.97	$5,681,131	$78,385	$0
2029		$1,862,227	$1,533,397	$142,800	$55,156	$237	$0	$3.01	$5,768,516	$78,385	$0
2030		$1,862,708	$1,533,777	$142,800	$55,156	$218	$0	$3.09	$5,922,198	$78,385	$0
2031		$1,863,188	$1,534,157	$142,800	$55,156	$218	$2,740,696	$3.17	$6,065,673	$78,385	$2,180,544
2032		$1,863,669	$1,534,536	$142,800	$55,156	$218	$0	$3.26	$6,235,667	$78,385	$0
2033		$1,864,149	$1,534,916	$142,800	$55,156	$218	$0	$3.26	$6,243,275	$78,385	$0
2034		$1,864,630	$1,535,296	$142,800	$55,156	$218	$0	$3.32	$6,356,394	$78,385	$0
2035		$1,865,110	$1,535,675	$142,800	$55,156	$218	$2,740,696	$3.34	$6,399,977	$78,385	$0
2036		$1,865,591	$1,536,055	$142,800	$55,156	$218	$0	$3.44	$6,578,163	$78,385	0
2037		$1,866,071	$1,536,434	$142,800	$55,156	$218	$0	$3.45	$6,610,953	$78,385	$2,075,824
2038		$1,866,551	$1,536,814	$142,800	$55,156	$218	$0	$3.49	$6,683,266	$78,385	$0
2039		$1,867,032	$1,537,194	$142,800	$55,156	$218	$2,740,696	$3.55	$6,790,652	$78,385	$0
2040		$1,867,512	$1,537,573	$302,800	$2,214,526	$218	$0	$3.58	$6,852,004	$78,385	$0
2041		$1,867,993	$1,537,953	$142,800	$55,156	$218	$0	$3.60	$6,894,364	$78,385	$0
2042		$1,868,473	$1,538,333	$142,800	$55,156	$218	$0	$3.61	$6,906,763	$78,385	0
2043		$1,868,954	$1,538,712	$142,800	$55,156	$218	$2,740,696	$3.63	$6,944,243	$78,385	$2,801,584
2044		$1,869,434	$1,539,092	$142,800	$55,156	$218	$0	$3.65	$6,978,192	$78,385	$0
2045		$1,869,915	$1,539,471	$142,800	$55,156	$218	$0	$3.67	$7,017,872	$78,385	$0
2046		$1,870,395	$1,539,851	$142,800	$55,156	$218	$0	$3.70	$7,077,620	$78,385	$0
2047		$1,870,876	$1,540,231	$142,800	$55,156	$218	$2,740,696	$3.74	$7,148,142	$78,385	$0
2048		$1,871,356	$1,540,610	$142,800	$55,156	$218	$0	$3.74	$7,163,214	$78,385	0
2049		$1,871,837	$1,540,990	$142,800	$55,156	$218	$0	$3.79	$7,253,828	$78,385	$2,075,824
2050		$1,872,317	$1,541,370	$142,800	$55,156	$218	$0	$3.82	$7,317,703	$78,385	$0
2051		$1,872,798	$1,541,749	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$0
2052		$1,873,278	$1,542,129	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2053		$1,873,759	$1,542,508	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2054		$1,874,239	$1,542,888	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	0
2055		$1,874,719	$1,543,268	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$2,180,544
2056		$1,875,200	$1,543,647	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2057		$1,875,680	$1,544,027	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2058		$1,876,161	$1,544,407	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2059		$1,876,641	$1,544,786	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						$177,653,584	LIFE CYCLE COST (ONE VESSEL)			$129,747,553
								LIFE CYCLE COST (TWO VESSELS)			$259,495,107

Conversion of the TACOMA and WENATCHEE: Conservative Case

Discount Rate	4 %

ASSUMPTIONS (Per Vessel)

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,550,683	$1,225,207
Periodic Diesel	$1,506,178	$1,190,043
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	365 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	2007500 gal/yr
Boiler Diesel for Heating	1.8 %
	36135 gal/yr
Periodic Diesel Usage	2.87 %
	57615 gal/yr
Total Annual Fuel Savings	1913750 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$36,910,724	$30,391,339	$2,896,621	$2,039,294		$14,696,465		$99,025,366	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,857,903	$1,529,981	$142,800	$55,156	$405	$0	$2.18	$4,171,974	$78,385	$0
2021		$1,858,383	$1,530,360	$142,800	$55,156	$386	$0	$2.21	$4,229,387	$78,385	$0
2022		$1,858,864	$1,530,740	$142,800	$55,156	$368	$0	$2.24	$4,286,799	$78,385	$0
2023		$1,859,344	$1,531,120	$142,800	$55,156	$349	$4,386,371	$2.27	$4,344,212	$78,385	$0
2024		$1,859,825	$1,531,499	$142,800	$55,156	$330	$0	$2.30	$4,401,624	$78,385	$0
2025		$1,860,305	$1,531,879	$142,800	$55,156	$312	$0	$2.33	$4,459,037	$78,385	$2,075,824
2026		$1,860,786	$1,532,259	$142,800	$55,156	$293	$0	$2.36	$4,516,449	$78,385	$0
2027		$1,861,266	$1,532,638	$142,800	$55,156	$274	$3,445,985	$2.39	$4,573,862	$78,385	$0
2028		$1,861,747	$1,533,018	$142,800	$55,156	$255	$0	$2.42	$4,631,274	$78,385	$0
2029		$1,862,227	$1,533,397	$142,800	$55,156	$237	$0	$2.45	$4,688,687	$78,385	$0
2030		$1,862,708	$1,533,777	$142,800	$55,156	$218	$0	$2.48	$4,746,099	$78,385	$0
2031		$1,863,188	$1,534,157	$142,800	$55,156	$218	$2,740,696	$2.51	$4,803,512	$78,385	$2,180,544
2032		$1,863,669	$1,534,536	$142,800	$55,156	$218	$0	$2.54	$4,860,924	$78,385	$0
2033		$1,864,149	$1,534,916	$142,800	$55,156	$218	$0	$2.57	$4,918,337	$78,385	$0
2034		$1,864,630	$1,535,296	$142,800	$55,156	$218	$0	$2.60	$4,975,749	$78,385	$0
2035		$1,865,110	$1,535,675	$142,800	$55,156	$218	$2,740,696	$2.63	$5,033,162	$78,385	$0
2036		$1,865,591	$1,536,055	$142,800	$55,156	$218	$0	$2.66	$5,090,574	$78,385	0
2037		$1,866,071	$1,536,434	$142,800	$55,156	$218	$0	$2.69	$5,147,987	$78,385	$2,075,824
2038		$1,866,551	$1,536,814	$142,800	$55,156	$218	$0	$2.72	$5,205,399	$78,385	$0
2039		$1,867,032	$1,537,194	$142,800	$55,156	$218	$2,740,696	$2.75	$5,262,812	$78,385	$0
2040		$1,867,512	$1,537,573	$302,800	$2,214,526	$218	$0	$2.78	$5,320,224	$78,385	$0
2041		$1,867,993	$1,537,953	$142,800	$55,156	$218	$0	$2.81	$5,377,637	$78,385	$0
2042		$1,868,473	$1,538,333	$142,800	$55,156	$218	$0	$2.84	$5,435,049	$78,385	0
2043		$1,868,954	$1,538,712	$142,800	$55,156	$218	$2,740,696	$2.87	$5,492,462	$78,385	$2,801,584
2044		$1,869,434	$1,539,092	$142,800	$55,156	$218	$0	$2.90	$5,549,874	$78,385	$0
2045		$1,869,915	$1,539,471	$142,800	$55,156	$218	$0	$2.93	$5,607,287	$78,385	$0
2046		$1,870,395	$1,539,851	$142,800	$55,156	$218	$0	$2.96	$5,664,699	$78,385	$0
2047		$1,870,876	$1,540,231	$142,800	$55,156	$218	$2,740,696	$2.99	$5,722,112	$78,385	$0
2048		$1,871,356	$1,540,610	$142,800	$55,156	$218	$0	$3.02	$5,779,524	$78,385	0
2049		$1,871,837	$1,540,990	$142,800	$55,156	$218	$0	$3.05	$5,836,937	$78,385	$2,075,824
2050		$1,872,317	$1,541,370	$142,800	$55,156	$218	$0	$3.08	$5,894,349	$78,385	$0
2051		$1,872,798	$1,541,749	$142,800	$55,156	$218	$2,740,696	$3.11	$5,951,762	$78,385	$0
2052		$1,873,278	$1,542,129	$142,800	$55,156	$218	$0	$3.14	$6,009,174	$78,385	$0
2053		$1,873,759	$1,542,508	$142,800	$55,156	$218	$0	$3.17	$6,066,587	$78,385	$0
2054		$1,874,239	$1,542,888	$142,800	$55,156	$218	$0	$3.20	$6,123,999	$78,385	0
2055		$1,874,719	$1,543,268	$142,800	$55,156	$218	$2,740,696	$3.23	$6,181,412	$78,385	$2,180,544
2056		$1,875,200	$1,543,647	$142,800	$55,156	$218	$0	$3.26	$6,238,824	$78,385	$0
2057		$1,875,680	$1,544,027	$142,800	$55,156	$218	$0	$3.29	$6,296,237	$78,385	$0
2058		$1,876,161	$1,544,407	$142,800	$55,156	$218	$0	$3.32	$6,353,649	$78,385	$0
2059		$1,876,641	$1,544,786	$142,800	$55,156	$218	$2,740,696	$3.35	$6,411,062	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						**$177,653,584**	**LIFE CYCLE COST (ONE VESSEL)**			**$106,868,330**
								LIFE CYCLE COST (TWO VESSELS)			**$213,736,661**

Conversion of the PUYALLUP: EIA Reference Case

Discount Rate	4 %

ASSUMPTIONS

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #3 (MV Puyallup)	$33,400,000
Edmonds Terminal	$6,909,570
Kingston Terminal	$6,909,570
Edmonds Utility	$10,800,000
Kingston Utility	$2,500,000
Total	$60,519,141

Year 2017	Edmonds Electricity	Kingston Electricity
Energy	$293,893	$284,249
Periodic Diesel	$285,459	$276,091
Demand	$325,784	$227,740

DIESEL ELECTRIC

Days of Operation	208 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	225 gal/hr
Annual Fuel Consumption	935100 gal/yr
Boiler Diesel for Heating	1.8 %
	16832 gal/yr
Periodic Diesel Usage	2.87 %
	26837 gal/yr
Total Annual Fuel Savings	891431 gal/yr

NPV	Installation	Edmonds Electricity	Kingston Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$60,519,141	$12,129,687	$10,002,684	$1,448,311	$1,933,077		$7,348,233		$56,783,552	$1,551,460	$6,291,504
2019						$487					
2020	$60,519,141	$611,516	$504,095	$71,400	$55,156	$405	$0	$2.50	$2,228,577	$78,385	$0
2021		$611,607	$504,184	$71,400	$55,156	$386	$0	$2.56	$2,280,624	$78,385	$0
2022		$611,698	$504,272	$71,400	$55,156	$368	$0	$2.64	$2,355,477	$78,385	$0
2023		$611,789	$504,360	$71,400	$55,156	$349	$2,193,185	$2.69	$2,401,232	$78,385	$0
2024		$611,880	$504,448	$71,400	$55,156	$330	$0	$2.74	$2,443,181	$78,385	$0
2025		$611,971	$504,536	$71,400	$55,156	$312	$0	$2.82	$2,516,580	$78,385	$2,075,824
2026		$612,062	$504,624	$71,400	$55,156	$293	$0	$2.90	$2,584,326	$78,385	$0
2027		$612,153	$504,712	$71,400	$55,156	$274	$1,722,993	$2.95	$2,626,453	$78,385	$0
2028		$612,244	$504,800	$71,400	$55,156	$255	$0	$2.97	$2,646,289	$78,385	$0
2029		$612,335	$504,888	$71,400	$55,156	$237	$0	$3.01	$2,686,993	$78,385	$0
2030		$612,426	$504,976	$71,400	$55,156	$218	$0	$3.09	$2,758,579	$78,385	$0
2031		$612,518	$505,064	$71,400	$55,156	$218	$1,370,348	$3.17	$2,825,410	$78,385	$2,180,544
2032		$612,609	$505,152	$71,400	$55,156	$218	$0	$3.26	$2,904,594	$78,385	$0
2033		$612,700	$505,240	$71,400	$55,156	$218	$0	$3.26	$2,908,138	$78,385	$0
2034		$612,791	$505,329	$71,400	$55,156	$218	$0	$3.32	$2,960,829	$78,385	$0
2035		$612,882	$505,417	$71,400	$55,156	$218	$1,370,348	$3.34	$2,981,130	$78,385	$0
2036		$612,973	$505,505	$71,400	$55,156	$218	$0	$3.44	$3,064,130	$78,385	0
2037		$613,064	$505,593	$71,400	$55,156	$218	$0	$3.45	$3,079,403	$78,385	$2,075,824
2038		$613,155	$505,681	$71,400	$55,156	$218	$0	$3.49	$3,113,087	$78,385	$0
2039		$613,246	$505,769	$71,400	$55,156	$218	$1,370,348	$3.55	$3,163,108	$78,385	$0
2040		$613,337	$505,857	$151,400	$1,972,482	$218	$0	$3.58	$3,191,686	$78,385	$0
2041		$613,428	$505,945	$71,400	$55,156	$218	$0	$3.60	$3,211,417	$78,385	$0
2042		$613,519	$506,033	$71,400	$55,156	$218	$0	$3.61	$3,217,193	$78,385	0
2043		$613,610	$506,121	$71,400	$55,156	$218	$1,370,348	$3.63	$3,234,651	$78,385	$2,801,584
2044		$613,701	$506,209	$71,400	$55,156	$218	$0	$3.65	$3,250,464	$78,385	$0
2045		$613,792	$506,297	$71,400	$55,156	$218	$0	$3.67	$3,268,948	$78,385	$0
2046		$613,883	$506,385	$71,400	$55,156	$218	$0	$3.70	$3,296,778	$78,385	$0
2047		$613,974	$506,473	$71,400	$55,156	$218	$1,370,348	$3.74	$3,329,628	$78,385	$0
2048		$614,066	$506,562	$71,400	$55,156	$218	$0	$3.74	$3,336,648	$78,385	0
2049		$614,157	$506,650	$71,400	$55,156	$218	$0	$3.79	$3,378,856	$78,385	$2,075,824
2050		$614,248	$506,738	$71,400	$55,156	$218	$0	$3.82	$3,408,610	$78,385	$0
2051		$614,339	$506,826	$71,400	$55,156	$218	$1,370,348	$3.82	$3,403,998	$78,385	$0
2052		$614,430	$506,914	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	$0
2053		$614,521	$507,002	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	$0
2054		$614,612	$507,090	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	0
2055		$614,703	$507,178	$71,400	$55,156	$218	$1,370,348	$3.82	$3,403,998	$78,385	$2,180,544
2056		$614,794	$507,266	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	$0
2057		$614,885	$507,354	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	$0
2058		$614,976	$507,442	$71,400	$55,156	$218	$0	$3.82	$3,403,998	$78,385	$0
2059		$615,067	$507,530	$71,400	$55,156	$218	$1,370,348	$3.82	$3,403,998	$78,385	$0
	LIFE CYCLE COST (ONE VESSEL)						$93,381,131	LIFE CYCLE COST (ONE VESSEL)			$64,626,517

Conversion of the PUYALLUP: Conservative Case

Discount Rate	4 %

ASSUMPTIONS

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #3 (MV Puyallup)	$33,400,000
Edmonds Terminal	$6,909,570
Kingston Terminal	$6,909,570
Edmonds Utility	$10,800,000
Kingston Utility	$2,500,000
Total	$60,519,141

Year 2017	Edmonds Electricity	Kingston Electricity
Energy	$293,893	$284,249
Periodic Diesel	$285,459	$276,091
Demand	$325,784	$227,740

DIESEL ELECTRIC

Days of Operation	208 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	225 gal/hr
Annual Fuel Consumption	935100 gal/yr
Boiler Diesel for Heating	1.8 %
	16832 gal/yr
Periodic Diesel Usage	2.87 %
	26837 gal/yr
Total Annual Fuel Savings	891431 gal/yr

NPV	Installation	Edmonds Electricity	Kingston Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$60,519,141	$12,129,687	$10,002,684	$1,448,311	$1,933,077		$7,348,233		$46,126,336	$1,551,460	$6,291,504
2019						$487					
2020	$60,519,141	$611,516	$504,095	$71,400	$55,156	$405	$0	$2.18	$1,943,319	$78,385	$0
2021		$611,607	$504,184	$71,400	$55,156	$386	$0	$2.21	$1,970,062	$78,385	$0
2022		$611,698	$504,272	$71,400	$55,156	$368	$0	$2.24	$1,996,805	$78,385	$0
2023		$611,789	$504,360	$71,400	$55,156	$349	$2,193,185	$2.27	$2,023,548	$78,385	$0
2024		$611,880	$504,448	$71,400	$55,156	$330	$0	$2.30	$2,050,291	$78,385	$0
2025		$611,971	$504,536	$71,400	$55,156	$312	$0	$2.33	$2,077,034	$78,385	$2,075,824
2026		$612,062	$504,624	$71,400	$55,156	$293	$0	$2.36	$2,103,777	$78,385	$0
2027		$612,153	$504,712	$71,400	$55,156	$274	$1,722,993	$2.39	$2,130,520	$78,385	$0
2028		$612,244	$504,800	$71,400	$55,156	$255	$0	$2.42	$2,157,263	$78,385	$0
2029		$612,335	$504,888	$71,400	$55,156	$237	$0	$2.45	$2,184,006	$78,385	$0
2030		$612,426	$504,976	$71,400	$55,156	$218	$0	$2.48	$2,210,748	$78,385	$0
2031		$612,518	$505,064	$71,400	$55,156	$218	$1,370,348	$2.51	$2,237,491	$78,385	$2,180,544
2032		$612,609	$505,152	$71,400	$55,156	$218	$0	$2.54	$2,264,234	$78,385	$0
2033		$612,700	$505,240	$71,400	$55,156	$218	$0	$2.57	$2,290,977	$78,385	$0
2034		$612,791	$505,329	$71,400	$55,156	$218	$0	$2.60	$2,317,720	$78,385	$0
2035		$612,882	$505,417	$71,400	$55,156	$218	$1,370,348	$2.63	$2,344,463	$78,385	$0
2036		$612,973	$505,505	$71,400	$55,156	$218	$0	$2.66	$2,371,206	$78,385	0
2037		$613,064	$505,593	$71,400	$55,156	$218	$0	$2.69	$2,397,949	$78,385	$2,075,824
2038		$613,155	$505,681	$71,400	$55,156	$218	$0	$2.72	$2,424,692	$78,385	$0
2039		$613,246	$505,769	$71,400	$55,156	$218	$1,370,348	$2.75	$2,451,435	$78,385	$0
2040		$613,337	$505,857	$151,400	$1,972,482	$218	$0	$2.78	$2,478,178	$78,385	$0
2041		$613,428	$505,945	$71,400	$55,156	$218	$0	$2.81	$2,504,921	$78,385	$0
2042		$613,519	$506,033	$71,400	$55,156	$218	$0	$2.84	$2,531,664	$78,385	0
2043		$613,610	$506,121	$71,400	$55,156	$218	$1,370,348	$2.87	$2,558,406	$78,385	$2,801,584
2044		$613,701	$506,209	$71,400	$55,156	$218	$0	$2.90	$2,585,149	$78,385	$0
2045		$613,792	$506,297	$71,400	$55,156	$218	$0	$2.93	$2,611,892	$78,385	$0
2046		$613,883	$506,385	$71,400	$55,156	$218	$0	$2.96	$2,638,635	$78,385	$0
2047		$613,974	$506,473	$71,400	$55,156	$218	$1,370,348	$2.99	$2,665,378	$78,385	$0
2048		$614,066	$506,562	$71,400	$55,156	$218	$0	$3.02	$2,692,121	$78,385	0
2049		$614,157	$506,650	$71,400	$55,156	$218	$0	$3.05	$2,718,864	$78,385	$2,075,824
2050		$614,248	$506,738	$71,400	$55,156	$218	$0	$3.08	$2,745,607	$78,385	$0
2051		$614,339	$506,826	$71,400	$55,156	$218	$1,370,348	$3.11	$2,772,350	$78,385	$0
2052		$614,430	$506,914	$71,400	$55,156	$218	$0	$3.14	$2,799,093	$78,385	$0
2053		$614,521	$507,002	$71,400	$55,156	$218	$0	$3.17	$2,825,836	$78,385	$0
2054		$614,612	$507,090	$71,400	$55,156	$218	$0	$3.20	$2,852,579	$78,385	0
2055		$614,703	$507,178	$71,400	$55,156	$218	$1,370,348	$3.23	$2,879,322	$78,385	$2,180,544
2056		$614,794	$507,266	$71,400	$55,156	$218	$0	$3.26	$2,906,065	$78,385	$0
2057		$614,885	$507,354	$71,400	$55,156	$218	$0	$3.29	$2,932,807	$78,385	$0
2058		$614,976	$507,442	$71,400	$55,156	$218	$0	$3.32	$2,959,550	$78,385	$0
2059		$615,067	$507,530	$71,400	$55,156	$218	$1,370,348	$3.35	$2,986,293	$78,385	$0
	LIFE CYCLE COST (ONE VESSEL)						$93,381,131	LIFE CYCLE COST (ONE VESSEL)			$53,969,300

Three Vessels and Two Docks

Conversion of the TACOMA and WENATCHEE: EIA Reference Case

Discount Rate	4 %

ASSUMPTIONS (Per Vessel)

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,550,683	$1,225,207
Periodic Diesel	$1,506,178	$1,190,043
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	365 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	2007500 gal/yr
Boiler Diesel for Heating	1.8 %
	36135 gal/yr
Periodic Diesel Usage	2.87 %
	57615 gal/yr
Total Annual Fuel Savings	1913750 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$36,910,724	$30,391,339	$2,896,621	$2,039,294		$14,696,465		$121,904,589	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,857,903	$1,529,981	$142,800	$55,156	$405	$0	$2.50	$4,784,374	$78,385	$0
2021		$1,858,383	$1,530,360	$142,800	$55,156	$386	$0	$2.56	$4,896,109	$78,385	$0
2022		$1,858,864	$1,530,740	$142,800	$55,156	$368	$0	$2.64	$5,056,808	$78,385	$0
2023		$1,859,344	$1,531,120	$142,800	$55,156	$349	$4,386,371	$2.69	$5,155,034	$78,385	$0
2024		$1,859,825	$1,531,499	$142,800	$55,156	$330	$0	$2.74	$5,245,092	$78,385	$0
2025		$1,860,305	$1,531,879	$142,800	$55,156	$312	$0	$2.82	$5,402,667	$78,385	$2,075,824
2026		$1,860,786	$1,532,259	$142,800	$55,156	$293	$0	$2.90	$5,548,106	$78,385	$0
2027		$1,861,266	$1,532,638	$142,800	$55,156	$274	$3,445,985	$2.95	$5,638,545	$78,385	$0
2028		$1,861,747	$1,533,018	$142,800	$55,156	$255	$0	$2.97	$5,681,131	$78,385	$0
2029		$1,862,227	$1,533,397	$142,800	$55,156	$237	$0	$3.01	$5,768,516	$78,385	$0
2030		$1,862,708	$1,533,777	$142,800	$55,156	$218	$0	$3.09	$5,922,198	$78,385	$0
2031		$1,863,188	$1,534,157	$142,800	$55,156	$218	$2,740,696	$3.17	$6,065,673	$78,385	$2,180,544
2032		$1,863,669	$1,534,536	$142,800	$55,156	$218	$0	$3.26	$6,235,667	$78,385	$0
2033		$1,864,149	$1,534,916	$142,800	$55,156	$218	$0	$3.26	$6,243,275	$78,385	$0
2034		$1,864,630	$1,535,296	$142,800	$55,156	$218	$0	$3.32	$6,356,394	$78,385	$0
2035		$1,865,110	$1,535,675	$142,800	$55,156	$218	$2,740,696	$3.34	$6,399,977	$78,385	$0
2036		$1,865,591	$1,536,055	$142,800	$55,156	$218	$0	$3.44	$6,578,163	$78,385	$0
2037		$1,866,071	$1,536,434	$142,800	$55,156	$218	$0	$3.45	$6,610,953	$78,385	$2,075,824
2038		$1,866,551	$1,536,814	$142,800	$55,156	$218	$0	$3.49	$6,683,266	$78,385	$0
2039		$1,867,032	$1,537,194	$142,800	$55,156	$218	$2,740,696	$3.55	$6,790,652	$78,385	$0
2040		$1,867,512	$1,537,573	$302,800	$2,214,526	$218	$0	$3.58	$6,852,004	$78,385	$0
2041		$1,867,993	$1,537,953	$142,800	$55,156	$218	$0	$3.60	$6,894,364	$78,385	$0
2042		$1,868,473	$1,538,333	$142,800	$55,156	$218	$0	$3.61	$6,906,763	$78,385	$0
2043		$1,868,954	$1,538,712	$142,800	$55,156	$218	$2,740,696	$3.63	$6,944,243	$78,385	$2,801,584
2044		$1,869,434	$1,539,092	$142,800	$55,156	$218	$0	$3.65	$6,978,192	$78,385	$0
2045		$1,869,915	$1,539,471	$142,800	$55,156	$218	$0	$3.67	$7,017,872	$78,385	$0
2046		$1,870,395	$1,539,851	$142,800	$55,156	$218	$0	$3.70	$7,077,620	$78,385	$0
2047		$1,870,876	$1,540,231	$142,800	$55,156	$218	$2,740,696	$3.74	$7,148,142	$78,385	$0
2048		$1,871,356	$1,540,610	$142,800	$55,156	$218	$0	$3.74	$7,163,214	$78,385	$0
2049		$1,871,837	$1,540,990	$142,800	$55,156	$218	$0	$3.79	$7,253,828	$78,385	$2,075,824
2050		$1,872,317	$1,541,370	$142,800	$55,156	$218	$0	$3.82	$7,317,703	$78,385	$0
2051		$1,872,798	$1,541,749	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$0
2052		$1,873,278	$1,542,129	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2053		$1,873,759	$1,542,508	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2054		$1,874,239	$1,542,888	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2055		$1,874,719	$1,543,268	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$2,180,544
2056		$1,875,200	$1,543,647	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2057		$1,875,680	$1,544,027	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2058		$1,876,161	$1,544,407	$142,800	$55,156	$218	$0	$3.82	$7,307,802	$78,385	$0
2059		$1,876,641	$1,544,786	$142,800	$55,156	$218	$2,740,696	$3.82	$7,307,802	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						$177,653,584	LIFE CYCLE COST (ONE VESSEL)			$129,747,553
								LIFE CYCLE COST (TWO VESSELS)			$259,495,107

Conversion of the TACOMA and WENATCHEE: Conservative Case

Discount Rate	4 %

ASSUMPTIONS (Per Vessel)

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,550,683	$1,225,207
Periodic Diesel	$1,506,178	$1,190,043
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	365 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	2007500 gal/yr
Boiler Diesel for Heating	1.8 %
	36135 gal/yr
Periodic Diesel Usage	2.87 %
	57615 gal/yr
Total Annual Fuel Savings	1913750 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$36,910,724	$30,391,339	$2,896,621	$2,039,294		$14,696,465		$99,025,366	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,857,903	$1,529,981	$142,800	$55,156	$405	$0	$2.18	$4,171,974	$78,385	$0
2021		$1,858,383	$1,530,360	$142,800	$55,156	$386	$0	$2.21	$4,229,387	$78,385	$0
2022		$1,858,864	$1,530,740	$142,800	$55,156	$368	$0	$2.24	$4,286,799	$78,385	$0
2023		$1,859,344	$1,531,120	$142,800	$55,156	$349	$4,386,371	$2.27	$4,344,212	$78,385	$0
2024		$1,859,825	$1,531,499	$142,800	$55,156	$330	$0	$2.30	$4,401,624	$78,385	$0
2025		$1,860,305	$1,531,879	$142,800	$55,156	$312	$0	$2.33	$4,459,037	$78,385	$2,075,824
2026		$1,860,786	$1,532,259	$142,800	$55,156	$293	$0	$2.36	$4,516,449	$78,385	$0
2027		$1,861,266	$1,532,638	$142,800	$55,156	$274	$3,445,985	$2.39	$4,573,862	$78,385	$0
2028		$1,861,747	$1,533,018	$142,800	$55,156	$255	$0	$2.42	$4,631,274	$78,385	$0
2029		$1,862,227	$1,533,397	$142,800	$55,156	$237	$0	$2.45	$4,688,687	$78,385	$0
2030		$1,862,708	$1,533,777	$142,800	$55,156	$218	$0	$2.48	$4,746,099	$78,385	$0
2031		$1,863,188	$1,534,157	$142,800	$55,156	$218	$2,740,696	$2.51	$4,803,512	$78,385	$2,180,544
2032		$1,863,669	$1,534,536	$142,800	$55,156	$218	$0	$2.54	$4,860,924	$78,385	$0
2033		$1,864,149	$1,534,916	$142,800	$55,156	$218	$0	$2.57	$4,918,337	$78,385	$0
2034		$1,864,630	$1,535,296	$142,800	$55,156	$218	$0	$2.60	$4,975,749	$78,385	$0
2035		$1,865,110	$1,535,675	$142,800	$55,156	$218	$2,740,696	$2.63	$5,033,162	$78,385	$0
2036		$1,865,591	$1,536,055	$142,800	$55,156	$218	$0	$2.66	$5,090,574	$78,385	$0
2037		$1,866,071	$1,536,434	$142,800	$55,156	$218	$0	$2.69	$5,147,987	$78,385	$2,075,824
2038		$1,866,551	$1,536,814	$142,800	$55,156	$218	$0	$2.72	$5,205,399	$78,385	$0
2039		$1,867,032	$1,537,194	$142,800	$55,156	$218	$2,740,696	$2.75	$5,262,812	$78,385	$0
2040		$1,867,512	$1,537,573	$302,800	$2,214,526	$218	$0	$2.78	$5,320,224	$78,385	$0
2041		$1,867,993	$1,537,953	$142,800	$55,156	$218	$0	$2.81	$5,377,637	$78,385	$0
2042		$1,868,473	$1,538,333	$142,800	$55,156	$218	$0	$2.84	$5,435,049	$78,385	$0
2043		$1,868,954	$1,538,712	$142,800	$55,156	$218	$2,740,696	$2.87	$5,492,462	$78,385	$2,801,584
2044		$1,869,434	$1,539,092	$142,800	$55,156	$218	$0	$2.90	$5,549,874	$78,385	$0
2045		$1,869,915	$1,539,471	$142,800	$55,156	$218	$0	$2.93	$5,607,287	$78,385	$0
2046		$1,870,395	$1,539,851	$142,800	$55,156	$218	$0	$2.96	$5,664,699	$78,385	$0
2047		$1,870,876	$1,540,231	$142,800	$55,156	$218	$2,740,696	$2.99	$5,722,112	$78,385	$0
2048		$1,871,356	$1,540,610	$142,800	$55,156	$218	$0	$3.02	$5,779,524	$78,385	$0
2049		$1,871,837	$1,540,990	$142,800	$55,156	$218	$0	$3.05	$5,836,937	$78,385	$2,075,824
2050		$1,872,317	$1,541,370	$142,800	$55,156	$218	$0	$3.08	$5,894,349	$78,385	$0
2051		$1,872,798	$1,541,749	$142,800	$55,156	$218	$2,740,696	$3.11	$5,951,762	$78,385	$0
2052		$1,873,278	$1,542,129	$142,800	$55,156	$218	$0	$3.14	$6,009,174	$78,385	$0
2053		$1,873,759	$1,542,508	$142,800	$55,156	$218	$0	$3.17	$6,066,587	$78,385	$0
2054		$1,874,239	$1,542,888	$142,800	$55,156	$218	$0	$3.20	$6,123,999	$78,385	$0
2055		$1,874,719	$1,543,268	$142,800	$55,156	$218	$2,740,696	$3.23	$6,181,412	$78,385	$2,180,544
2056		$1,875,200	$1,543,647	$142,800	$55,156	$218	$0	$3.26	$6,238,824	$78,385	$0
2057		$1,875,680	$1,544,027	$142,800	$55,156	$218	$0	$3.29	$6,296,237	$78,385	$0
2058		$1,876,161	$1,544,407	$142,800	$55,156	$218	$0	$3.32	$6,353,649	$78,385	$0
2059		$1,876,641	$1,544,786	$142,800	$55,156	$218	$2,740,696	$3.35	$6,411,062	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						$177,653,584	LIFE CYCLE COST (ONE VESSEL)			$106,868,330
								LIFE CYCLE COST (TWO VESSELS)			$213,736,661

Conversion of the PUYALLUP: EIA Reference Case

Discount Rate	4 %

ASSUMPTIONS

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #3 (MV Puyallup)	$33,400,000
Edmonds Terminal	$0
Kingston Terminal	$0
Edmonds Utility	$0
Kingston Utility	$0
Total	$33,400,000

Year 2017	Edmonds Electricity	Kingston Electricity
Energy	$0	$0
Periodic Diesel		
Demand	$0	$0

DIESEL ELECTRIC

Days of Operation	207.8 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	225 gal/hr
Annual Fuel Consumption	935100 gal/yr
Boiler Diesel for Heating	0 %
	0 gal/yr
	0 %
	0 gal/yr
	935100 gal/yr
Hybrid Fuel Savings, Peak Shavi	21 %
	196371 gal/yr

NPV	Installation	Edmonds Electricity	Kingston Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$33,400,000	$0	$0	$1,448,311	$106,217		$2,915,845		$12,508,702	$1,034,307	$4,194,336
2019						$487					
2020	$33,400,000	$0	$0	$71,400	$0	$405	$0	$2.50	$490,928	$52,257	$0
2021		$0	$0	$71,400	$0	$386	$0	$2.56	$502,393	$52,257	$0
2022		$0	$0	$71,400	$0	$368	$0	$2.64	$518,882	$52,257	$0
2023		$0	$0	$71,400	$0	$349	$0	$2.69	$528,961	$52,257	$0
2024		$0	$0	$71,400	$0	$330	$0	$2.74	$538,202	$52,257	$0
2025		$0	$0	$71,400	$0	$312	$0	$2.82	$554,371	$52,257	$1,383,883
2026		$0	$0	$71,400	$0	$293	$0	$2.90	$569,294	$52,257	$0
2027		$0	$0	$71,400	$0	$274	$1,722,993	$2.95	$578,574	$52,257	$0
2028		$0	$0	$71,400	$0	$255	$0	$2.97	$582,944	$52,257	$0
2029		$0	$0	$71,400	$0	$237	$0	$3.01	$591,911	$52,257	$0
2030		$0	$0	$71,400	$0	$218	$0	$3.09	$607,680	$52,257	$0
2031		$0	$0	$71,400	$0	$218	$0	$3.17	$622,402	$52,257	$1,453,696
2032		$0	$0	$71,400	$0	$218	$0	$3.26	$639,846	$52,257	$0
2033		$0	$0	$71,400	$0	$218	$0	$3.26	$640,626	$52,257	$0
2034		$0	$0	$71,400	$0	$218	$0	$3.32	$652,233	$52,257	$0
2035		$0	$0	$71,400	$0	$218	$1,370,348	$3.34	$656,705	$52,257	$0
2036		$0	$0	$71,400	$0	$218	$0	$3.44	$674,989	$52,257	0
2037		$0	$0	$71,400	$0	$218	$0	$3.45	$678,354	$52,257	$1,383,883
2038		$0	$0	$71,400	$0	$218	$0	$3.49	$685,774	$52,257	$0
2039		$0	$0	$71,400	$0	$218	$0	$3.55	$696,793	$52,257	$0
2040		$0	$0	$151,400	$242,044	$218	$0	$3.58	$703,088	$52,257	$0
2041		$0	$0	$71,400	$0	$218	$0	$3.60	$707,435	$52,257	$0
2042		$0	$0	$71,400	$0	$218	$0	$3.61	$708,707	$52,257	0
2043		$0	$0	$71,400	$0	$218	$1,370,348	$3.63	$712,553	$52,257	$1,867,723
2044		$0	$0	$71,400	$0	$218	$0	$3.65	$716,036	$52,257	$0
2045		$0	$0	$71,400	$0	$218	$0	$3.67	$720,108	$52,257	$0
2046		$0	$0	$71,400	$0	$218	$0	$3.70	$726,239	$52,257	$0
2047		$0	$0	$71,400	$0	$218	$0	$3.74	$733,475	$52,257	$0
2048		$0	$0	$71,400	$0	$218	$0	$3.74	$735,022	$52,257	0
2049		$0	$0	$71,400	$0	$218	$0	$3.79	$744,320	$52,257	$1,383,883
2050		$0	$0	$71,400	$0	$218	$0	$3.82	$750,874	$52,257	$0
2051		$0	$0	$71,400	$0	$218	$1,370,348	$3.82	$749,858	$52,257	$0
2052		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2053		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2054		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2055		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$1,453,696
2056		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2057		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2058		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
2059		$0	$0	$71,400	$0	$218	$0	$3.82	$749,858	$52,257	$0
	LIFE CYCLE COST (ONE VESSEL)						$37,870,372	LIFE CYCLE COST (ONE VESSEL)			$17,737,345

Conversion of the PUYALLUP: Conservative Case

Discount Rate	4 %

HYBRID ELECTRIC

ASSUMPTIONS

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #3 (MV Puyallup)	$33,400,000
Edmonds Terminal	$0
Kingston Terminal	$0
Edmonds Utility	$0
Kingston Utility	$0
Total	$33,400,000

Year 2017	Edmonds Electricity	Kingston Electricity
Energy	$0	$0
Periodic Diesel		
Demand	$0	$0

DIESEL ELECTRIC

Days of Operation	207.8 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	225 gal/hr
Annual Fuel Consumption	935100 gal/yr
Boiler Diesel for Heating	0 %
	0 gal/yr
	0 %
	0 gal/yr
	935100 gal/yr
Hybrid Fuel Savings, Peak Shavi	21 %
	196371 gal/yr

NPV	Installation	Edmonds Electricity	Kingston Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$33,400,000	$0	$0	$1,448,311	$106,217		$2,915,845		$10,161,052	$1,034,307	$4,194,336
2019						$487					
2020	$33,400,000	$0	$0	$71,400	$0	$405	$0	$2.18	$428,089	$52,257	$0
2021		$0	$0	$71,400	$0	$386	$0	$2.21	$433,980	$52,257	$0
2022		$0	$0	$71,400	$0	$368	$0	$2.24	$439,871	$52,257	$0
2023		$0	$0	$71,400	$0	$349	$0	$2.27	$445,762	$52,257	$0
2024		$0	$0	$71,400	$0	$330	$0	$2.30	$451,653	$52,257	$0
2025		$0	$0	$71,400	$0	$312	$0	$2.33	$457,544	$52,257	$1,383,883
2026		$0	$0	$71,400	$0	$293	$0	$2.36	$463,436	$52,257	$0
2027		$0	$0	$71,400	$0	$274	$1,722,993	$2.39	$469,327	$52,257	$0
2028		$0	$0	$71,400	$0	$255	$0	$2.42	$475,218	$52,257	$0
2029		$0	$0	$71,400	$0	$237	$0	$2.45	$481,109	$52,257	$0
2030		$0	$0	$71,400	$0	$218	$0	$2.48	$487,000	$52,257	$0
2031		$0	$0	$71,400	$0	$218	$0	$2.51	$492,891	$52,257	$1,453,696
2032		$0	$0	$71,400	$0	$218	$0	$2.54	$498,782	$52,257	$0
2033		$0	$0	$71,400	$0	$218	$0	$2.57	$504,673	$52,257	$0
2034		$0	$0	$71,400	$0	$218	$0	$2.60	$510,565	$52,257	$0
2035		$0	$0	$71,400	$0	$218	$1,370,348	$2.63	$516,456	$52,257	$0
2036		$0	$0	$71,400	$0	$218	$0	$2.66	$522,347	$52,257	0
2037		$0	$0	$71,400	$0	$218	$0	$2.69	$528,238	$52,257	$1,383,883
2038		$0	$0	$71,400	$0	$218	$0	$2.72	$534,129	$52,257	$0
2039		$0	$0	$71,400	$0	$218	$0	$2.75	$540,020	$52,257	$0
2040		$0	$0	$151,400	$242,044	$218	$0	$2.78	$545,911	$52,257	$0
2041		$0	$0	$71,400	$0	$218	$0	$2.81	$551,803	$52,257	$0
2042		$0	$0	$71,400	$0	$218	$0	$2.84	$557,694	$52,257	0
2043		$0	$0	$71,400	$0	$218	$1,370,348	$2.87	$563,585	$52,257	$1,867,723
2044		$0	$0	$71,400	$0	$218	$0	$2.90	$569,476	$52,257	$0
2045		$0	$0	$71,400	$0	$218	$0	$2.93	$575,367	$52,257	$0
2046		$0	$0	$71,400	$0	$218	$0	$2.96	$581,258	$52,257	$0
2047		$0	$0	$71,400	$0	$218	$0	$2.99	$587,149	$52,257	$0
2048		$0	$0	$71,400	$0	$218	$0	$3.02	$593,040	$52,257	0
2049		$0	$0	$71,400	$0	$218	$0	$3.05	$598,932	$52,257	$1,383,883
2050		$0	$0	$71,400	$0	$218	$0	$3.08	$604,823	$52,257	$0
2051		$0	$0	$71,400	$0	$218	$1,370,348	$3.11	$610,714	$52,257	$0
2052		$0	$0	$71,400	$0	$218	$0	$3.14	$616,605	$52,257	$0
2053		$0	$0	$71,400	$0	$218	$0	$3.17	$622,496	$52,257	$0
2054		$0	$0	$71,400	$0	$218	$0	$3.20	$628,387	$52,257	0
2055		$0	$0	$71,400	$0	$218	$0	$3.23	$634,278	$52,257	$1,453,696
2056		$0	$0	$71,400	$0	$218	$0	$3.26	$640,169	$52,257	$0
2057		$0	$0	$71,400	$0	$218	$0	$3.29	$646,061	$52,257	$0
2058		$0	$0	$71,400	$0	$218	$0	$3.32	$651,952	$52,257	$0
2059		$0	$0	$71,400	$0	$218	$0	$3.35	$657,843	$52,257	$0
	LIFE CYCLE COST (ONE VESSEL)						$37,870,372	LIFE CYCLE COST (ONE VESSEL)			$15,389,695

Two Vessels and Two Docks

Conversion of the TACOMA and WENATCHEE: EIA Reference Case

Discount Rate	4 %

ASSUMPTIONS (Per Vessel)

HYBRID ELECTRIC

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,328,064	$1,049,314
Periodic Diesel	$1,289,949	$1,019,199
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	313 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	1719300 gal/yr
Boiler Diesel for Heating	1.8 %
	30947 gal/yr
Periodic Diesel Usage	2.87 %
	49344 gal/yr
Total Annual Fuel Savings	1639009 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$32,607,084	$26,990,999	$2,896,621	$2,039,294		$14,696,465		$104,403,766	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,641,467	$1,358,973	$142,800	$55,156	$405	$0	$2.50	$4,097,522	$78,385	$0
2021		$1,641,878	$1,359,298	$142,800	$55,156	$386	$0	$2.56	$4,193,216	$78,385	$0
2022		$1,642,290	$1,359,623	$142,800	$55,156	$368	$0	$2.64	$4,330,844	$78,385	$0
2023		$1,642,701	$1,359,948	$142,800	$55,156	$349	$4,386,371	$2.69	$4,414,969	$78,385	$0
2024		$1,643,113	$1,360,273	$142,800	$55,156	$330	$0	$2.74	$4,492,098	$78,385	$0
2025		$1,643,524	$1,360,598	$142,800	$55,156	$312	$0	$2.82	$4,627,051	$78,385	$2,075,824
2026		$1,643,936	$1,360,924	$142,800	$55,156	$293	$0	$2.90	$4,751,610	$78,385	$0
2027		$1,644,347	$1,361,249	$142,800	$55,156	$274	$3,445,985	$2.95	$4,829,066	$78,385	$0
2028		$1,644,759	$1,361,574	$142,800	$55,156	$255	$0	$2.97	$4,865,538	$78,385	$0
2029		$1,645,170	$1,361,899	$142,800	$55,156	$237	$0	$3.01	$4,940,378	$78,385	$0
2030		$1,645,582	$1,362,224	$142,800	$55,156	$218	$0	$3.09	$5,071,998	$78,385	$0
2031		$1,645,993	$1,362,549	$142,800	$55,156	$218	$2,740,696	$3.17	$5,194,875	$78,385	$2,180,544
2032		$1,646,405	$1,362,874	$142,800	$55,156	$218	$0	$3.26	$5,340,465	$78,385	$0
2033		$1,646,816	$1,363,199	$142,800	$55,156	$218	$0	$3.26	$5,346,980	$78,385	$0
2034		$1,647,228	$1,363,525	$142,800	$55,156	$218	$0	$3.32	$5,443,860	$78,385	$0
2035		$1,647,639	$1,363,850	$142,800	$55,156	$218	$2,740,696	$3.34	$5,481,186	$78,385	$0
2036		$1,648,051	$1,364,175	$142,800	$55,156	$218	$0	$3.44	$5,633,791	$78,385	$0
2037		$1,648,462	$1,364,500	$142,800	$55,156	$218	$0	$3.45	$5,661,874	$78,385	$2,075,824
2038		$1,648,874	$1,364,825	$142,800	$55,156	$218	$0	$3.49	$5,723,806	$78,385	$0
2039		$1,649,285	$1,365,150	$142,800	$55,156	$218	$2,740,696	$3.55	$5,815,775	$78,385	$0
2040		$1,649,697	$1,365,475	$302,800	$2,214,526	$218	$0	$3.58	$5,868,319	$78,385	$0
2041		$1,650,108	$1,365,800	$142,800	$55,156	$218	$0	$3.60	$5,904,598	$78,385	$0
2042		$1,650,520	$1,366,126	$142,800	$55,156	$218	$0	$3.61	$5,915,217	$78,385	$0
2043		$1,650,931	$1,366,451	$142,800	$55,156	$218	$2,740,696	$3.63	$5,947,316	$78,385	$2,801,584
2044		$1,651,343	$1,366,776	$142,800	$55,156	$218	$0	$3.65	$5,976,391	$78,385	$0
2045		$1,651,754	$1,367,101	$142,800	$55,156	$218	$0	$3.67	$6,010,375	$78,385	$0
2046		$1,652,166	$1,367,426	$142,800	$55,156	$218	$0	$3.70	$6,061,545	$78,385	$0
2047		$1,652,577	$1,367,751	$142,800	$55,156	$218	$2,740,696	$3.74	$6,121,943	$78,385	$0
2048		$1,652,988	$1,368,076	$142,800	$55,156	$218	$0	$3.74	$6,134,851	$78,385	$0
2049		$1,653,400	$1,368,401	$142,800	$55,156	$218	$0	$3.79	$6,212,456	$78,385	$2,075,824
2050		$1,653,811	$1,368,727	$142,800	$55,156	$218	$0	$3.82	$6,267,161	$78,385	$0
2051		$1,654,223	$1,369,052	$142,800	$55,156	$218	$2,740,696	$3.82	$6,258,682	$78,385	$0
2052		$1,654,634	$1,369,377	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2053		$1,655,046	$1,369,702	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2054		$1,655,457	$1,370,027	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2055		$1,655,869	$1,370,352	$142,800	$55,156	$218	$2,740,696	$3.82	$6,258,682	$78,385	$2,180,544
2056		$1,656,280	$1,370,677	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2057		$1,656,692	$1,371,002	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2058		$1,657,103	$1,371,328	$142,800	$55,156	$218	$0	$3.82	$6,258,682	$78,385	$0
2059		$1,657,515	$1,371,653	$142,800	$55,156	$218	$2,740,696	$3.82	$6,258,682	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						$169,949,605	LIFE CYCLE COST (ONE VESSEL)			$0
								LIFE CYCLE COST (TWO VESSELS)			$224,493,460

Conversion of the TACOMA and WENATCHEE: Conservative Case

Discount Rate	4 %

HYBRID ELECTRIC

ASSUMPTIONS (Per Vessel)

Elec Annual Increase	0.0319 cents/yr
Assumed size of NMC pack	6286 kWh
Conversion Costs	
Vessel #1 (MV Wenatchee)	$35,900,000
Vessel #2 (MV Tacoma)	$34,100,000
Seattle Terminal	$6,909,570
Bainbridge Terminal	$6,909,570
Seattle Utility	$4,400,000
Bainbridge Utility	$2,500,000
Total	$90,719,141

Year 2017	Seattle Electricity	Bainbridge Electricity
Energy	$1,328,064	$1,049,314
Periodic Diesel	$1,289,949	$1,019,199
Demand	$350,284	$338,799

DIESEL ELECTRIC

Days of Operation	313 day/yr
Engine Operation	20 hr/day
Engine Fuel Consumption	275 gal/hr
Annual Fuel Consumption	1719300 gal/yr
Boiler Diesel for Heating	1.8 %
	30947 gal/yr
Periodic Diesel Usage	2.87 %
	49344 gal/yr
Total Annual Fuel Savings	1639009 gal/yr

NPV	Installation	Seattle Electricity	Bainbridge Electricity	Inverter & Batt. Maint.	Shore Power Maint.	Battery Cost, $/kWh	Battery Replacement	Diesel/gal	Annual Diesel Cost	Engine Minor Maintenance	Engine Major Maintenance
	$90,719,141	$32,607,084	$26,990,999	$2,896,621	$2,039,294		$14,696,465		$84,809,122	$1,551,460	$6,291,504
2019						$487					
2020	$90,719,141	$1,641,467	$1,358,973	$142,800	$55,156	$405	$0	$2.18	$3,573,039	$78,385	$0
2021		$1,641,878	$1,359,298	$142,800	$55,156	$386	$0	$2.21	$3,622,209	$78,385	$0
2022		$1,642,290	$1,359,623	$142,800	$55,156	$368	$0	$2.24	$3,671,379	$78,385	$0
2023		$1,642,701	$1,359,948	$142,800	$55,156	$349	$4,386,371	$2.27	$3,720,550	$78,385	$0
2024		$1,643,113	$1,360,273	$142,800	$55,156	$330	$0	$2.30	$3,769,720	$78,385	$0
2025		$1,643,524	$1,360,598	$142,800	$55,156	$312	$0	$2.33	$3,818,890	$78,385	$2,075,824
2026		$1,643,936	$1,360,924	$142,800	$55,156	$293	$0	$2.36	$3,868,061	$78,385	$0
2027		$1,644,347	$1,361,249	$142,800	$55,156	$274	$3,445,985	$2.39	$3,917,231	$78,385	$0
2028		$1,644,759	$1,361,574	$142,800	$55,156	$255	$0	$2.42	$3,966,401	$78,385	$0
2029		$1,645,170	$1,361,899	$142,800	$55,156	$237	$0	$2.45	$4,015,571	$78,385	$0
2030		$1,645,582	$1,362,224	$142,800	$55,156	$218	$0	$2.48	$4,064,742	$78,385	$0
2031		$1,645,993	$1,362,549	$142,800	$55,156	$218	$2,740,696	$2.51	$4,113,912	$78,385	$2,180,544
2032		$1,646,405	$1,362,874	$142,800	$55,156	$218	$0	$2.54	$4,163,082	$78,385	$0
2033		$1,646,816	$1,363,199	$142,800	$55,156	$218	$0	$2.57	$4,212,252	$78,385	$0
2034		$1,647,228	$1,363,525	$142,800	$55,156	$218	$0	$2.60	$4,261,423	$78,385	$0
2035		$1,647,639	$1,363,850	$142,800	$55,156	$218	$2,740,696	$2.63	$4,310,593	$78,385	$0
2036		$1,648,051	$1,364,175	$142,800	$55,156	$218	$0	$2.66	$4,359,763	$78,385	$0
2037		$1,648,462	$1,364,500	$142,800	$55,156	$218	$0	$2.69	$4,408,933	$78,385	$2,075,824
2038		$1,648,874	$1,364,825	$142,800	$55,156	$218	$0	$2.72	$4,458,104	$78,385	$0
2039		$1,649,285	$1,365,150	$142,800	$55,156	$218	$2,740,696	$2.75	$4,507,274	$78,385	$0
2040		$1,649,697	$1,365,475	$302,800	$2,214,526	$218	$0	$2.78	$4,556,444	$78,385	$0
2041		$1,650,108	$1,365,800	$142,800	$55,156	$218	$0	$2.81	$4,605,614	$78,385	$0
2042		$1,650,520	$1,366,126	$142,800	$55,156	$218	$0	$2.84	$4,654,785	$78,385	$0
2043		$1,650,931	$1,366,451	$142,800	$55,156	$218	$2,740,696	$2.87	$4,703,955	$78,385	$2,801,584
2044		$1,651,343	$1,366,776	$142,800	$55,156	$218	$0	$2.90	$4,753,125	$78,385	$0
2045		$1,651,754	$1,367,101	$142,800	$55,156	$218	$0	$2.93	$4,802,295	$78,385	$0
2046		$1,652,166	$1,367,426	$142,800	$55,156	$218	$0	$2.96	$4,851,466	$78,385	$0
2047		$1,652,577	$1,367,751	$142,800	$55,156	$218	$2,740,696	$2.99	$4,900,636	$78,385	$0
2048		$1,652,988	$1,368,076	$142,800	$55,156	$218	$0	$3.02	$4,949,806	$78,385	$0
2049		$1,653,400	$1,368,401	$142,800	$55,156	$218	$0	$3.05	$4,998,977	$78,385	$2,075,824
2050		$1,653,811	$1,368,727	$142,800	$55,156	$218	$0	$3.08	$5,048,147	$78,385	$0
2051		$1,654,223	$1,369,052	$142,800	$55,156	$218	$2,740,696	$3.11	$5,097,317	$78,385	$0
2052		$1,654,634	$1,369,377	$142,800	$55,156	$218	$0	$3.14	$5,146,487	$78,385	$0
2053		$1,655,046	$1,369,702	$142,800	$55,156	$218	$0	$3.17	$5,195,658	$78,385	$0
2054		$1,655,457	$1,370,027	$142,800	$55,156	$218	$0	$3.20	$5,244,828	$78,385	$0
2055		$1,655,869	$1,370,352	$142,800	$55,156	$218	$2,740,696	$3.23	$5,293,998	$78,385	$2,180,544
2056		$1,656,280	$1,370,677	$142,800	$55,156	$218	$0	$3.26	$5,343,168	$78,385	$0
2057		$1,656,692	$1,371,002	$142,800	$55,156	$218	$0	$3.29	$5,392,339	$78,385	$0
2058		$1,657,103	$1,371,328	$142,800	$55,156	$218	$0	$3.32	$5,441,509	$78,385	$0
2059		$1,657,515	$1,371,653	$142,800	$55,156	$218	$2,740,696	$3.35	$5,490,679	$78,385	$0
	LIFE CYCLE COST (TWO VESSELS)						$169,949,605	LIFE CYCLE COST (ONE VESSEL)			$92,652,086
								LIFE CYCLE COST (TWO VESSELS)			$185,304,172

CONVERSION COST ESTIMATE PER VESSEL

						Systems Integrator Labor					
Hybrid Item Description	% *	Qty	Unit	Unit Price	Equipment Cost	Design	Manuf	Comm	Other	Labor Cost	Per Vessel Cost
Lithium-ion Battery Racks, NMC, Water-Cooled	100	6286	kWh	$650	$4,085,714			160		$22,400	$4,108,114
Lithium-ion Battery Room BMS PLC Panels	100	2		$10,000	$20,000	80		40		$16,800	$36,800
Li-ion Battery Water-Cooling & Heat Exchanger	100	2		$7,500	$15,000	80		20		$14,000	$29,000
Li-ion Battery NOVEC Fire Suppression	100				$80,000	80		40		$16,800	$96,800
Inverters, PWM, low-voltage	100	2			$1,500,000			200		$40,000	$1,540,000
Inverter Step-Up Transformers, VPI	100	2			$180,000					$0	$180,000
Battery-Inverter Switchgear, 15kV, 1200A	100	2		$110,000	$220,000			100		$20,000	$240,000
Battery-Inverter PLC Panels	100	2		$10,000	$20,000			40		$5,600	$25,600
Shore Power Receiving Equipment	100	2		$161,363	$322,725					$0	$322,725
At ShorePower Connection Swgr, 15kV, 1200A	100	2		$80,000	$160,000			80		$16,000	$176,000
ShorePower Isolation Transformer(s), VPI	100	2			$180,000					$0	$180,000
ShorePower Eng Rm Switchgear, 15kV, 1200A	100	2		$110,000	$220,000			100		$20,000	$240,000
Bus Ducts for Switchgear Extensions	100	2			$35,000	80		20		$14,000	$49,000
Main Switchgear I/O, Comm, hardwire interface	20				$0	100		100		$28,000	$28,000
Pilothouse Additional Operators & Metering	100	2		$2,500	$5,000	120		120		$33,600	$38,600
EOS Console Mods, I/O, Metering, and HMI	50	1		$7,500	$7,500	150		150		$42,000	$49,500
Additional Hybrid System Equipment	100	1		$10,000	$10,000	120		40		$22,400	$32,400
Shipchecking and iba Data Analyzing	50				$0	80		80		$32,000	$32,000
System Design	50				$0	2000				$280,000	$93,333
Control System Programming	20				$0	200				$28,000	$9,333
Hybrid I/O and Cable Database	35				$0	175				$35,000	$11,667
Construction Bid Support	60				$0	1200				$168,000	$56,000
USCG Submittals and Interface	60				$0				240	$38,400	$12,800
Factory Acceptance Testing	100				$0		320			$57,600	$19,200
ABS/DNV Surveying	100	1		100000	$100,000					$0	$33,333.33
Dock and Sea Trials	50				$0			1200		$216,000	$144,000
Training	60				$0				480	$76,800	$25,600
Operating Manuals	50				$0				200	$28,000	$9,333
Spare Parts	40	1		$60,000	$60,000				80	$11,200	$71,200
As-Built Drawings	25				$0				40	$5,600	$5,600
Miscellaneous Contract Labor	60	1		$120,000	$120,000					$0	$40,000.00
Travel and Living	50	1		$50,000	$50,000					$0	$50,000
Supplies and Rentals	50	1		$5,000	$5,000					$0	$5,000
Project Management	20				$0				600	$150,000	$150,000
Contingencies	75	1		$75,000	$75,000					$0	$25,000
SUBTOTALS					$7,470,939	4,465	320	2,490	1,640	$1,438,200	$8,165,939
Return on Investment, 10%											$816,594
GRAND TOTAL											$8,982,533

* Some items share costs with modernization effort, percentage shown is hybrid portion of total cost

Appendix H

Hybrid and All-Electric Car Ferries

SIGNIFICANT HYBRID AND ALL-ELECTRIC CAR FERRIES

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Fjord 1 ZeroCat 120	Page 142

PRINSESSE BENEDIKTE

IMO:	9144421
Year Built:	1997[1]
Year Modified:	2013
Owner:	Scandlines
Route:	Puttgarden – Rødby (18.5 km)
Principal Dimensions:	143 m x 25.4 m x 5.5 m (draft)
Cruise Speed:	18.5 knot
Car/Passenger Complement:	364 car / 1,140 passengers
Propulsion Power:	17,440 kW
Battery Capacity:	2.6 MWh[2]
Charge Time:	30 min
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

Retrofitted in 2013, the PRINSESSE BENEDIKTE was the world's first 1,000 plus passenger hybrid ferry. A 2.6 MWh battery pack can power the ship for up to 30 minutes and can recharge from the onboard generators in 30 minutes.

Figure 35: PRINSESSE BENEDIKTE Ferry[2]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/prinsesse-benedikte.aspx
[2] http://corvusenergy.com/marine-project/prinsesse-benedikte-ferry/

PRINS RICHARD

IMO:	9144419
Year Built:	1997[1]
Year Modified:	2014
Owner:	Scandlines
Route:	Puttgarden – Rødby (18.5 km)
Principal Dimensions:	142 m x 25.4 m x 5.5 m (draft)
Cruise Speed:	18.5 knot
Car/Passenger Complement:	364 car / 1,140 passengers
Propulsion Power:	17,440 kW
Battery Capacity:	2.6 MWh[2]
Charge Time:	30 min
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

Figure 36: PRINS RICHARD Ferry[2]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/prins-richard.aspx
[2] http://corvusenergy.com/portfolio/prins-richard/

DEUTSCHLAND

IMO:	9151541
Year Built:	1997[1]
Year Modified:	2014
Owner:	Scandlines
Route:	Puttgarden – Rødby (18.5 km)
Principal Dimensions:	142 m x 25.4 m x 6 m (draft)
Cruise Speed:	18.5 knot
Car/Passenger Complement:	364 car / 1,200 passengers
Propulsion Power:	15,840 kW
Battery Capacity:	1.6 MWh[2]
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

Figure 37: DEUTSCHLAND Ferry[3]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/deutschland
[2] http://corvusenergy.com/energy-storage-system-order-for-two-new-scandlines-battery-hybrid-ferries/
[3] https://www.scandlines.dk

SCHLESWIG-HOLSTEIN

IMO:	9604378
Year Built:	1997[1]
Year Modified:	2014
Owner:	Scandlines
Route:	Puttgarden – Rødby (18.5 km)
Principal Dimensions:	142 m x 25.4 m x 6 m (draft)
Cruise Speed:	18.5 knot
Car/Passenger Complement:	364 car / 1,200 passengers
Propulsion Power:	15,840 kW
Battery Capacity:	1.6 MWh[2]
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

Figure 38: SCHLESWIG-HOLSTEIN Ferry[3]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/schleswig-holstein
[2] http://corvusenergy.com/portfolio/schleswig-holstein/
[3] https://www.scandlines.dk

BERLIN

IMO:	9587855
Year Built:	2016[1]
Owner:	Scandlines
Route:	Rostock – Gedser (48.9 km)
Principal Dimensions:	169.5 m x 25.4 m x 5 m (draft)
Cruise Speed:	21 knot
Car/Passenger Complement:	460 car / 1,300 passengers
Propulsion Power:	18,000 kW
Battery Capacity:	1.5 MWh[2]
Charge Time:	30 min
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

The battery bank is used in lieu of an extra on board generator that would be used in normal non-hybrid operation.

Figure 39: BERLIN Ferry[3]

[11] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/berlin
[2] http://corvusenergy.com/energy-storage-system-order-for-two-new-scandlines-battery-hybrid-ferries/
[3] https://www.scandlines.dk

COPENHAGEN

IMO:	9587867
Year Built:	2016[1]
Owner:	Scandlines
Route:	Rostock – Gedser (48.9 km)
Principal Dimensions:	169.5 m x 25.4 m x 5 m (draft)
Cruise Speed:	21 knot
Car/Passenger Complement:	460 car / 1,300 passengers
Propulsion Power:	18,000 kW
Battery Capacity:	1.5 MWh[2]
Charge Time:	30 min
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

The battery bank is used in lieu of an extra on board generator that would be used in normal non-hybrid operation.

Figure 40: COPENHAGEN Ferry[3]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/copenhagen
[2] http://corvusenergy.com/energy-storage-system-order-for-two-new-scandlines-battery-hybrid-ferries/
[3] https://www.scandlines.dk

TYCHO BRAHE

IMO:	9007116
Year Built	1991[1]
Year Modified:	2017
Owner:	Scandlines / HH Ferries
Route:	Helsingborg – Helsingör (4 km)
Principal Dimensions:	111 m x 28 m x 5.3 m (draft)
Cruise Speed:	14.5 knot
Car/Passenger Complement:	240 car / 1,250 passengers
Propulsion Power:	9,840 kW
Battery Capacity:	4.16 MWh
Charge Time:	9 min / 5.5 min
Integrator:	ABB
Battery Manufacturer:	Plan B Energy Storage (PBES)
Charging System:	ABB robotic stations

As of the time of this report, the ABB high power charging system is not yet functional.

Figure 41: TYCHO BRAHE Ferry[2]

[1] https://www.scandlines.com/about-scandlines/about-scandlines-frontpage/ferries-and-ports/tycho-brahe.aspx
[2] HH Ferries – www. hhferriesgroup.com

AURORA

IMO:	9007128
Year Built	1992[1]
Year Modified:	2017
Owner:	Scandlines / HH Ferries
Route:	Helsingborg – Helsingör (4 km)
Principal Dimensions:	111 m x 28 m x 5.5 m (draft)
Cruise Speed:	14.5 knot
Car/Passenger Complement:	240 car / 1,250 passengers
Propulsion Power:	9,840 kW
Battery Capacity:	4.16 MWh
Charge Time:	9 min / 5.5 min
Integrator:	ABB
Battery Manufacturer:	Plan B Energy Storage (PBES)
Charging System:	ABB robotic stations

Figure 42: AURORA Ferry[2]

[1] http://hhferriesgroup.com/about-hh-ferries-group/ferries/
[2] HH Ferries – www. hhferriesgroup.com

AMPERE

IMO:	9683611
Year Built:	2015
Owner:	Norled
Route:	Lavik – Oppedal, Norway (5.6 km)
Principal Dimensions:	80 m x 21 m x 3 m (draft)
Cruise Speed:	10 knot
Car/Passenger Complement:	120 car / 360 passengers
Propulsion Power:	2 x 450 kW
Battery Capacity:	1040 kWh[1]
Charge Time:	10 min
Integrator:	Siemens
Battery Manufacturer:	Corvus
Charging System:	Cavotec APSTowers (1.2 MW)[2]

Introduced in 2015, the AMPERE was the first all-electric, battery powered ferry in the world. The grid was not strong enough to handle a rapid charge at either location, so additional battery packs were installed at both Lavik and Oppedal. The shore-side batteries rapidly recharge the onboard batteries, while the grid can slowly recharge the shore-side batteries.

Figure 43: AMPERE Ferry[3]

[1] http://corvusenergy.com/marine-project/mf-ampere-ferry/
[2] http://www.cavotec.com/uploads/2017/11/15/cavotec-moormaster-references-as-per-q4-201715112017ld.pdf
[3] https://www.siemens.com/press/IM2015050750PDEN

ELEKTRA

IMO:	9806328
Year Built:	2017[1]
Owner:	FinFerries
Route:	Nauvo – Parainen, Finland (1.6 km)
Principal Dimensions:	98 m x 15.2 m x 3.5 m (draft)
Cruise Speed:	11 knot
Car/Passenger Complement:	90 car / 375 passengers
Propulsion Power:	2 x 900 kW
Battery Capacity:	1 MWh
Charge Time:	5 min
Integrator:	Siemens
Charging System:	Cavotec APSTowers (1 MW)[2]

The ELEKTRA is an electric ferry operating in Finland with an ice class notation. Following the AMPERE, the ELEKTRA is the second battery-powered ferry operating in Europe. The propulsion system was designed to operate solely on battery power for the majority of the year. A diesel generator is included onboard to assist in more challenging operations, such as ice conditions or a shore-side power failure.

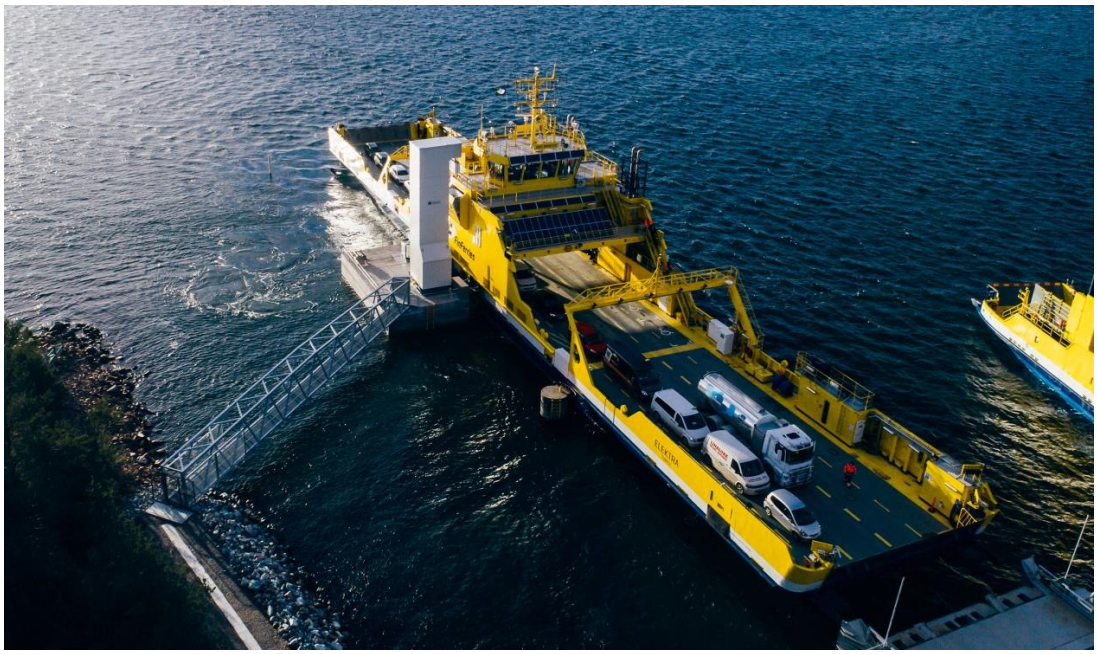

Figure 44: ELEKTRA Ferry[3]

[1] http://www.finferries.fi/media/elektra-technical-data.pdf
[2] http://www.cavotec.com/uploads/2017/11/15/cavotec-moormaster-references-as-per-q4-201715112017ld.pdf
[3] https://www.siemens.com/press/IM2017110066PDEN

FOLGEFONN

IMO:	9172090
Year Built:	1998[1]
Year Modified:	2014
Owner:	Norled
Route:	Jektevik – Hodnanes, Norway (2.3 km)
Principal Dimensions:	85 m x 15 m
Cruise Speed:	9.5 knot
Car/Passenger Complement:	76 car / 300 passengers
Propulsion Power:	2 x 750 kW
Battery Capacity:	1.4 MWh[2]
Charge Time:	10 min
Battery Manufacturer:	Corvus
Charging System:	Wartsila wireless induction [3]

The FOLGEFONN was originally retrofitted with a hybrid propulsion system in 2014.

Figure 45: FOLGEFONN Ferry[4]

[1] https://maritimecleantech.no/project/mf-folgefonn/
[2] http://corvusenergy.com/portfolio/folgefonn/
[3] https://www.wartsila.com/twentyfour7/innovation/hybrid-tech-gets-a-jolt-of-sea-air
[4] http://corvusenergy.com/wp-content/uploads/2015/08/Folgefonn_SDTC.jpg

MELSHORN AND VARDEHORN

IMO:	9210610 / 9210622
Year Built:	1999
Year Modified:	2016
Owner:	Torghatten Nord (Norway)
Principal Dimensions:	112m x 16m x 3.3m (draft)
Max Speed:	14 knot
Car/Passenger Complement:	120 car / 299 passengers
Power:	2,560 kW
Integrator:	Siemens

The MELSHORN and VARDEHORN are sister ships that were retrofitted with hybrid propulsion systems in 2016.

Figure 46: MELSHORN Hybrid Ferry Conversion

HALLAIG

IMO:	9652832
Year Built:	2012[1]
Owner:	Caledonian Maritime Assets Ltd (Scotland)
Route:	Sconser-Rasaay, Scotland (5 km)
Principal Dimensions:	43.5 m x 12.2 m x 1.73 m (draft)
Service Speed:	9 knot
Car/Passenger Complement:	23 car / 150 passengers
Propulsion Power:	2 x 375 kW
Battery Capacity:	2 x 350 kWh
Charging System:	Overnight shore charge

The first of a class of three vessels, the HALLAIG was one of the world's first hybrid vehicle ferries. The vessels typically operate as a hybrid with traditional diesel power supplemented with 20% electric battery energy. The battery banks are charged from the utility overnight.

Figure 47: HALLAIG Ferry[1]

[1] http://www.cmassets.co.uk/ferry/mv-hallaig-2/

LOCHINVAR

IMO:	9652844
Year Built:	2013[1]
Owner:	Caledonian Maritime Assets Ltd (Scotland)
Route:	Tarbert-Portavadie, Scotland (5.5 km)
Principal Dimensions:	43.5m x 12.2m x 1.73m (draft)
Service Speed:	9 knot
Car/Passenger Complement:	23 car / 150 passengers
Propulsion Power:	2 x 375 kW
Battery Capacity:	2 x 350 kWh
Charging System:	Overnight shore charge

As a sister ship to the HALLAIG, the vessels have similar particulars and operational profiles.

Figure 48: LOCHINVAR Ferry[1]

[1] http://www.cmassets.co.uk/project/mv-lochinvar/

CATRIONA

IMO:	9759862
Year Built:	2015[1]
Owner:	Caledonian Maritime Assets Ltd (Scotland)
Route:	Claonaig-Lochranza, Scotland (7.5 km)
Principal Dimensions:	43.5 m x 12.2 m x 1.73 m (draft)
Service Speed:	9 knot
Car/Passenger Complement:	23 car / 150 passengers
Propulsion Power:	2 x 375 kW
Battery Capacity:	2 x 350 kWh
Charging System:	Overnight shore charge

As a sister ship to the HALLAIG, the vessels have similar particulars and operational profiles.

Figure 49: CATRIONA Ferry[2]

[1] http://www.cmassets.co.uk/ferry/mv-catriona/
[2] http://www.ynfpublishers.com/wp-content/uploads/2015/12/Catriona-in-water.jpg

TEXELSTROOM

IMO:	9741918
Year Built	2016[1]
Owner:	Texels Eigen Stroomboot Onderneming (TESO)
Route:	Texel-Den Helder, Netherlands
Principal Dimensions:	135 m x 28 m x 4.4 m (draft)
Service Speed:	10 knot
Car/Passenger Complement:	350 car / 1,750 passengers
Propulsion Power:	2 x 4,000 kW
Battery Capacity:	1.6 MWh[2]
Battery Manufacturer:	Corvus
Charging System:	Solar panels

The TEXELSTROOM is a dual fuel hybrid ferry operating in the Netherlands. The propulsion system is able to operate on either diesel or compressed natural gas and is supplemented by electric batteries. A 150 kWh solar panel array is used to charge the batteries.

Figure 50: TEXELSTROOM Ferry[1]

[1] http://www.ship-technology.com/projects/texelstroom-ferry/
[2] http://corvusenergy.com/merchant_marine/

SEASPAN RELIANT AND SEASPAN SWIFT

IMO:	9764233 / 9764221
Delivery:	2016 / 2017
Owner:	Seaspan (Canada)
Routes:	Vancouver-Vancouver Island (~40 km)
Principal Dimensions:	148.9 m x 26 m x 7 m
Service Speed:	14 knot
Car/Passenger Complement:	59 Trailers
Battery Capacity:	546 kWh[1]
Battery Manufacturer:	Corvus
Charging System:	Onboard generators

The Seaspan cargo ferries transport trucks and cargo from Vancouver to Vancouver Island. The vessels are dual fuel with diesel, LNG, and supplemented by batteries. Seaspan recently ordered three more vessels of the class.

Figure 51: SEASPAN RELIANT Cargo Ferry[2]

[1] http://corvusenergy.com/merchant_marine/
[2] http://www.seaspan.com/seaspan-ferries-corporation-announces-arrival-second-new-liquefied-natural-gas-lng-fuelled-vessel

BC FERRIES

Expected Delivery:	2020
No. of Vessels:	2
Owner:	BC Ferries (Canada)
Routes:	Powell River-Texada Island, BC (8 km)
	Port McNeill-Alert Bay-Sointula, BC (11 km)
Principal Dimensions:	81.2 m LOA
Service Speed:	14 knot
Car/Passenger Complement:	44 car / 300 passengers

Two hybrid ferries are currently under construction for BC Ferries for service in the Salish Sea. The propulsion system is a true hybrid with engines that will operate on ultra-low Sulphur diesel fuel and a complement of batteries to supplement. Future expansion of the battery bank will be possible to potentially perform all-electric operations. The project is partially funded by the Government of Canada.

Figure 52: BC Ferries Illustration[1]

[1] https://www.bcferries.com/bcferries/faces/attachments?id=1043829

FJORD1

Expected Delivery:	2018
No. of Vessels:	3
Owner:	Fjord1 (Norway)
Routes:	Brekstad-Valset
	Husavik-Sandvikvag
Principal Dimensions:	66.4 m x 14.2 m[1]
Car/Passenger Complement:	50 car / 195 passengers
Battery Capacity:	1 MWh

Fjord1 has three all-electric ferries under construction at Havyard Shipyard in Norway.

Figure 53: Fjord1 Ferry Illustration[2]

[1] https://www.shippax.com/en/news/havyard-to-build-three-diesel-electric-ferries-for-fjord1.aspx
[2] multi-maritime.no

FJORD1

Expected Delivery:	2020
No. of Vessels:	5
Owner:	Fjord1 (Norway)
Routes:	Hareid-Sulesund[1]
	Magerholm-Sykkylven
Principal Dimensions:	111 m LOA
Car/Passenger Complement:	120 car
System Integrator	Norwegian Electric Systems

Fjord1 has five additional all-electric ferries under construction at Havyard Shipyard in Norway.

Figure 54: Fjord1 Ferry Illustration[2]

[1] https://www.norwegianelectric.com/news--media/all-time-high-order-reserve/
[2] http://www.fjord1.no/om-fjord1/presse/bors-og-pressemeldingar/nye-ferjer-til-austevoll

FJORD1 ZEROCAT 120

Expected Delivery:	2018
No. of Vessels:	1
Owner:	Fjord1 (Norway)
Routes:	Halhjem-Vage
Principal Dimensions:	87.5 m x 20.8 m
Car/Passenger Complement:	120 car / 296 passenger
System Integrator	Norwegian Electric Systems

A sister ship to the AMPERE, the ZeroCat 120 vessel will operate with an all-electric propulsion system.

Figure 55: Fjord1 ZeroCat 120 Illustration[1]

[1] http://www.fjord1.no/om-fjord1/presse/bors-og-pressemeldingar/nye-ferjer-til-austevoll