Evaluating the Use of Liquefied Natural Gas in Washington State Ferries

Prepared For:

Joint Transportation Committee

Consultant Team

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The Cover Photo shows the Norwegian ferry operator Fjord1's latest ferry, the design and construction of which will be the world's largest LNG-fueled ferry, with delivery scheduled for November 30, 2011.

EXECUTIVE SUMMARY

The 2011 legislature directed the Joint Transportation Committee to investigate the use of liquefied natural gas (LNG) on existing Washington State Ferry (WSF) vessels as well as the new 144-car class vessels and report to the legislature by December 31, 2011 (ESHB 1175 204 (5)); (Chapter 367, 2011 Laws, PV).

This white paper sets the context for the study. It includes a review of the WSF fleet; background information on the use of LNG as a marine fuel; an overview of WSF's studies on implementing LNG use; and an identification of the full range of issues that need to be considered.

WSF Fleet

Vessel Acquisition and Retirement Plan

WSF has 22 vessels that serve its nine (9) routes in Puget Sound and the San Juan Islands. WSF's Long-Range Plan assumes a 22 vessel fleet through 2030 and establishes a route service plan based on a vessel acquisition and retirement plan.

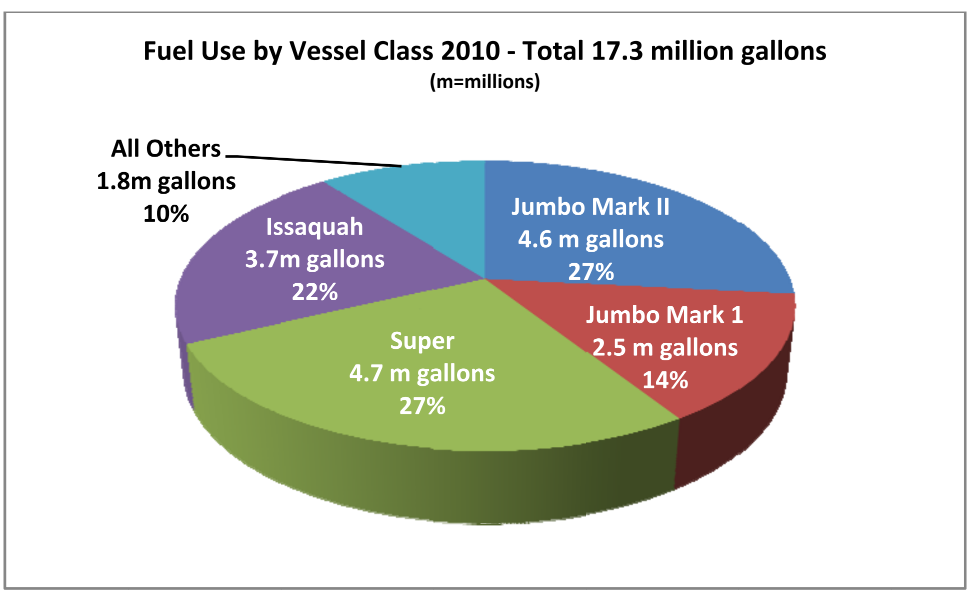
The legislature's 16-year (FY 2011-FY 2027) financial plan includes the construction of two (2) new 144-car vessels. Funding has been provided in the 2011-13 biennium budget for the construction of the first vessel with a diesel engine. The 16-year plan anticipates a second vessel which may be LNG or diesel.

According to the WSF Long-Range Plan, the first new 144-car vessel will allow the *Evergreen State* to retire. The second new 144-car vessel allows the *Hiyu* to retire, a larger Evergreen State class vessel to take its place as a reserve vessel, and for expansion of service capacity on the San Juan Islands-Sidney, Fauntleroy-Vashon-Southworth, and Mukilteo-Clinton routes.

Diesel Fuel Use

WSF fuels its fleet with a blend of biodiesel and ultra low sulfur diesel (ULSD). Fuel consumption is affected by the size of the vessel, the route the vessel is assigned to, and the speed of the vessel.

In 2010 WSF used 17.3 million gallons of fuel. The breakdown by vessel class is shown in the chart below.



If the two (2) new 144-car vessels are built as diesel fueled vessels, total fuel consumption will increase to 18.2 million gallons per year as smaller vessels are replaced with larger vessels.

Fueling Locations

On the routes with planned service by an Issaquah class or new 144-car vessel, WSF currently fuels by truck at the Bremerton terminal for the Seattle-Bremerton route, the Southworth terminal for the Fauntleroy-Vashon-Southworth route, the Clinton terminal for the Mukilteo-Clinton route, and the Anacortes terminal for the San Juan Islands-Sidney routes. If a new 144-car vessel or an Issaquah class vessel is LNG fueled, LNG will need to be provided to at least one (1) of these locations.

Diesel Fuel Cost

Diesel fuel represents 29 percent of the FY 2011-13 biennium operation budget for WSF or $135.2 million. The June 2011 forecast by the Transportation Revenue Council projected diesel fuel costs of $4.30 per gallon with tax and allowance for biodiesel in FY 2012. The cost per gallon will drop to $4.01 in FY 2014 as a result of legislative action to eliminate WSF's fuel sales tax effective July 2013. The price of ULSD is expected to increase from $4.01 per gallon in FY 2014 to $4.33 per gallon by the end of the 16-year financial plan in FY 2027.

Diesel fuel costs have been very volatile, peaking in the 2007-09 biennium at nearly $4.80 per gallon. For the 2011-13 biennium the legislature authorized WSF to enter into a distributor controlled fuel hedging program (ESHB 1175, Section 221 (11)). WSF has entered into a hedging contract and, as of October 2011, had hedged approximately 6.2 million gallons of fuel for FY 2012 at an average pre-tax price of $3.20 per gallon or $3.67 per gallon with tax and allowance for biodiesel.

North American Emissions Control Area

The International Maritime Organization (IMO), an agency of the United Nations, formed the North American Emissions Control Area (ECA) in 2010 in response to a joint proposal from the United States, Canada, and France. The control area requires ships operating up to 200 nautical miles off the North American coast to meet more stringent fuel sulfur content requirements than are required in non-ECA waters. It also provides for progressively more stringent requirements for nitrogen oxide (NO_x), which are achieved by requiring more efficient engines (i.e. Tier I, Tier II, Tier III with each tier being a more efficient engine).

The North American ECA will become enforceable in August 2012 through regulations adopted by the United States Coast Guard (USCG) and Environmental Protection Agency (EPA).

The imposition of the North American ECA is anticipated to have a substantial effect on United States ship owners. However, it will have little impact on WSF because WSF is already in compliance with the restriction on sulfur oxide (SO_x) through its use of ULSD and WSF does not anticipate major engine conversions prior to 2016 that would be affected by the requirements for more efficient engines.

LNG AS A MARINE FUEL SOURCE

Liquefied natural gas (LNG) is natural gas that has been cooled to -259 degrees Fahrenheit at which point it is condensed into a liquid, which is colorless, odorless, non-corrosive, and non-toxic. LNG is a cryogenic liquid meaning that it must be kept cooled to -259^{o} F or it returns to its gaseous state.

LNG takes up about 1/600th of the volume of natural gas in the gaseous state. This makes it cost efficient to transport in specially designed cryogenic LNG carriers over long distances opening up market access to areas where pipelines do not exist and/or are not practical to construct.

The environmental qualities of LNG are superior to those of any liquid petroleum fuel and will provide even fewer emissions that those from the ULSD used by WSF.

There are approximately 300 LNG cargo carrier vessels worldwide – none of which are U.S. flagged. LNG carriers can dock at U.S. terminals on the east and gulf coasts, subject to U.S. Coast Guard requirements.

LNG Fueled Ferries

Norway is the world leader in LNG fueled passenger vessels and today operates the only LNG fueled ferries in the world.

The first Norwegian LNG ferry, Fjord1's *Glutra,* was built in 2000 with government assistance. In 2011, Fjord1 has 12 LNG ferries operating in Norwegian waters and more under construction. Other Norwegian ferry operators also have LNG ferries including: Tide Sjo which has three (3); and Fosen Namos Sjo which has one (1). Norway provides various tax incentives, primarily through carbon tax credits, and access to special funding that supports the construction and operation of LNG ferries.

Fjord1's experience with LNG ferries is:

- *Capital cost*. The cost of building the LNG ferries has been 15-20 percent higher than diesel ferries, with the additional cost due to the sophisticated LNG storage tanks, the fuel piping system, and in some cases a slightly larger ship.
- *Engine*. Fjord1's ferries operate on single fuel (LNG only) Rolls Royce engines.
- *Maintenance costs.* Normal maintenance costs of the *Glutra* have been 20 percent higher than a similar-sized diesel vessel, and maintenance costs of its five (5) sister ships in operation since 2007 have been 10 percent higher.
- *Crew size and training.* Crew size is the same as on the diesel powered ferries. Crew training includes a gas course that takes two (2) to five (5) days, and the instructors are from the company. The rest of the training is on board. An officer needs about one (1) week of familiarization training before being on duty.
- *Cost of LNG.* The cost of natural gas in Norway has been close to, or slightly above, diesel and the fuel cost of the LNG ferries has been slightly higher than diesel ferries. The cost of natural gas and diesel rise and fall together in Norway, which has not been the case in the United States.
- *Environmental impact.* The LNG vessels have been successful in reducing carbon dioxide (CO2) emissions by 19 percent, NO_x by 91 percent, and SO_x and particulate matter by 100 percent.
- *Fueling/bunkering*. LNG fueling takes place from trucks and in some cases from storage tanks at the ferry terminal.
- *Storage tank placement*. In Norway the LNG fuel tanks are located below decks. For WSF, the United States Coast Guard prefers that the fuel tanks be above the passenger decks.

BC Ferries and Staten Island Ferries are analyzing retrofitting vessels from diesel to LNG fuel. The Société des traversiers du Québec (STQ) in Québec is pursuing a new build LNG vessel. The consultants did not find any other North American ferry systems that are considering LNG. BC Ferries is further along with their conversion than Staten Island, with the largest concern in British Columbia being the potential public reaction to LNG fuel.

Economics of LNG Use

National Supply and Cost Projections

The economics of marine LNG use in Washington will be different than Norway's because LNG is much less expensive in the U.S. and, unlike Norway, the cost of natural gas does not track with the cost of petroleum.

Projections by the U.S. Energy Information Administration (USEIA) and other independent analysts suggest that the U.S. has a robust supply of natural gas, which currently provides 25 percent of the nation's total energy supply. Eighty-nine percent (89%) of the natural gas consumed in the U.S. is domestically produced, 9 percent comes by pipeline from Canada and Mexico, and 2 percent is imported by LNG carriers largely from Trinidad and Tobago.

Forecasts project a stable and growing source of domestic supply with relative price stability, largely as the result of the discovery of substantial new supplies of shale gas in the Mountain West, the South and throughout the Northeast's Appalachian Basin. The USEIA anticipates that imports of LNG will decline over time. As a consequence of the increase in domestic natural gas production, the U.S. government is allowing LNG import facilities to export domestically produced LNG.

Prices for natural gas, from which LNG prices are derived, are anticipated to remain relatively low compared to ULSD.

Washington State Supply and Cost Projections

Gas utilities operating in Washington State are required to file Integrated Resource Plans (IRP) with the Washington State Transportation and Utilities Commission every two (2) years.

Price forecasts by the five (5) utilities that file an IRP are based on the Henry Hub gas price forecast, which is the one used on the New York Mercantile Exchange. The price forecasts in the 2010-2011 IRPs are lower than in the IRPs filed in 2008-9, reflecting the national trends.

Natural gas in the Pacific Northwest has been trading at a discount to the Henry Hub prices, which means that the long-term forecast for natural gas prices is lower than the Henry Hub, and the forecasts by all Washington State natural gas utilities are for relatively stable prices through 2030.

Volatility in Natural Gas Prices

While natural gas prices are more stable than diesel prices, they also experience volatility. Natural gas prices rose in 2000-01 with the energy crisis, in 2005 from the impact of hurricanes Katrina and Rita, and in 2008 with oil speculation and high demand. Major factors that could make future natural gas prices volatile include: difficulties in extracting shale oil, drilling restrictions, and the potential for U.S. policy to encourage the use of natural gas in automobiles.

LNG Supply Facilities

There are three types of LNG facilities that are involved in the supply of LNG: LNG terminals which handle import and export of LNG; liquefaction facilities where natural gas is converted to LNG; and storage facilities where LNG is stored for future use.

LNG facilities are primarily in the eastern United States and on the Gulf Coast. There are relatively few in the western United States and very few in the Pacific Northwest.

There are eleven (11) United States LNG terminals, none of which are on the west coast. The closest import facility that has received Federal Energy Regulatory Commission (FERC) approval is in Coos Bay Oregon, but the project is subject to state and local permitting and is so controversial that none of the IRPs include gas from the facility in their base forecasts.

There are approximately 100 liquefaction and storage facilities in the United States, with most of them in the east. There are six (6) liquefaction and/or storage facilities in the Pacific Northwest, all of which are limited to supporting gas utilities.

Two options have been identified by those interviewed for this report to supply LNG for WSF needs:

- Participate in the construction and/or operation of a LNG liquefaction and storage facility.
- Truck LNG in from out-of-state

The consultants recommend that the State assume that LNG will be trucked to WSF terminals. Discussions with suppliers indicate that LNG is available in sufficient quantities. Trucking LNG to the terminal is consistent with the practice in Norway, and other major transit agencies, such as Phoenix Public Transit which has a large LNG bus fleet. Constructing a liquefaction facility is not a viable option in the short term consideration of LNG fueled vessels because of the costs, schedule implications, and permitting difficulties.

LNG Price Forecast for WSF

The consultants developed an independent LNG price forecast for WSF use, based on the Transportation Revenue Council's forecast of the Henry Hub long-term natural gas price forecast and in consultation with Poten & Partners, an energy consulting firm. The price forecast assumes that LNG is trucked from California or Wyoming. If LNG can be obtained from a facility closer to the Puget Sound it will lower the cost of transportation and provide less risk than a more distant alternative.

Poten & Partners cautioned that the initial delivery cost would be up to six cents a gallon higher per gallon due to the small initial demand as the LNG ferries come on line. They also believe LNG suppliers are likely to try and peg their price to the alternative source available, in this case, ultra low sulfur diesel.

The consultants' forecast of delivered LNG fuel, which adjusts for the greater volume of LNG required to obtain comparable energy output to diesel, shows that WSF could save 47 percent per gallon on fuel in 2014 narrowing to 40 percent by 2027. The annual savings will depend on which vessels on which routes use LNG fuel.

The consultants discussed the price history and forecasting with Phoenix Public Transit, who have been using LNG in their bus fleet for a number of years, and BC Ferries, who are undertaking a feasibility study for the conversion of a diesel ferry to LNG.

Phoenix Transit is paying $1.05 per gallon pre-tax for LNG delivered in 2011. Phoenix has experienced considerable volatility in LNG fuel costs, with costs peaking in 2008 at $1.60 per gallon.

BC Ferries solicited input from three forecasting firms and found that all three came back showing stable prices going forward, with a small narrowing of the price gap between natural gas and diesel. They have discussed a price including taxes and delivery with their potential local supplier and currently forecast a 60 percent savings with LNG based on July, 2011 natural gas spot and diesel prices.

The consultants also interviewed five (5) potential suppliers or brokers of LNG. There is potential for greater capacity becoming available in Washington if demand materializes. This will allow lower prices through reduced transportation costs and lessen the potential risk of logistical challenges from long-distance trucking.

LNG Vessel Operations

Bunkering - Refueling

Bunkering (i.e. refueling) of LNG vessels is one of the significant areas that needs to be addressed when considering LNG. There are two basic alternatives for fueling ferries – fueling by tanker truck or from a fixed shore facility. In Norway vessels are re-fueled both ways. The differences between the two approaches include the fact that there is some site development needed for a fixed facility and depending on the number and location of the facilities, there may be extra sailing time required for refueling. Norwegian ferry owners given a choice prefer a fixed terminal because it provides more consistent fueling.

Impact of LNG on Vessel Speed, Performance, and Maintenance

The impact of LNG on vessel speed and performance should be minimal, but, based on Norway's experience, maintenance costs can be expected to be higher. The consultants analyzed the impact of the proposed new 144-car LNG design on the weight, draft, speed, and stability of the vessel and found little impact. The Norwegian experience has been that maintenance costs on LNG fueled systems are 10-20 percent higher than on similar sized diesel fueled engine systems. This makes sense as there is a lot more equipment with the LNG fueled option and much of that equipment requires higher technology repair and maintenance.

LNG Vessel Design Considerations

A primary design consideration is the type of engine – whether single fuel/LNG only engine or a dual fuel engine which can run on either LNG or diesel. Rolls-Royce manufactures a single fuel/LNG only engine and Wärtsilä manufactures a dual fuel engine in the size category required for the new 144-car ferry or a retrofit of an Issaquah class vessel. Neither engine has been approved for use in the U.S. by the EPA. Both manufacturers anticipate approval in the first quarter of 2012. Other manufacturers are also working on marine gas fueled engines.

A single fuel/LNG only engine provides greater emissions reduction, is more fuel efficient, and may provide greater operationally reliability for ferries. The advantage of a dual fuel engine is that it can run on either diesel or LNG so that it in the event of a large price disparity, or supply shortage, the operator has the option to switch to a single fuel option.

Regulatory Requirements – Operations and Design

There are regulatory differences between diesel and LNG fueled ferries. The USCG has not developed rules governing the design, construction and operation of LNG fueled passenger vessels. This introduces an element of regulatory uncertainty that is not present when designing and building a diesel fueled vessel.

WSF's conceptual design work for the re-design of the new 144-car ferry, much of which has been done by their contracted naval architect The Glosten Associates, and for the Issaquah class retrofit is the most advanced design work that has been done in the United States on a LNG fueled passenger vessel. If the new 144-car ferry is built as an LNG fueled vessel or an Issaquah retrofit is undertaken it will most likely be the first LNG fueled passenger vessel subject to U.S. regulations.

In the absence of specific rules, the USCG can review and approve alternative designs under 46 CFR 50.20-30 - Alternative materials or methods of construction. In using its authority under 46 CFR 50.20-30 to review LNG fueled passenger vessels, the USCG is relying on IMO and, to some extent, Det Norske Veritas (DNV) rules.

WSF submitted two requests for regulatory review to the USCG: one for the new 144-car vessel and separately for the Issaquah class vessel retrofit. The USCG has responded to the new 144-car vessel request with a letter that will serve as a regulatory design basis. “The Marine Safety Center (section of the USCG) will use the regulatory design basis letter and applicable regulations and standards to complete plan review. Please note that due to your proposed use of LNG fueled propulsion systems, MSC may identify additional detailed design requirements in areas not addressed in this regulatory review design basis agreement during the course of plan review. As always, the Officer in Charge, Marine Inspection may impose additional requirements should inspection during construction reveal the need for further safety measures or changes in construction or arrangement (USCG July 1, 2011).”

The IMO and DNV require a risk analysis to be developed as part of the design process that shows how the LNG fuel and storage systems effect vessel structure and other systems. The designer is to show how these risks are to be eliminated or minimized. An operating manual is required in which these risks and reactions/mitigations are to be detailed. The reason for this additional requirement is the complexity involved in designing a fueling system with a great deal more risk than an oil fuel system.

Under USCG rules, if a vessel undergoes a certain level of re-design or change, it may be classified as a “major conversion”. If the USCG decides that a proposed conversion is a major conversion then the ship owner is required to update the vessel to meet all current regulatory requirements. For a 30-year vessel such as the Issaquah class vessels, this could add considerable cost.

Operations are the least defined aspect of a LNG fueled ferry project from a regulatory standpoint. Operational requirements have not been discussed with the USCG, but they will have to be as part of the ultimate operation of the vessel and the issuance of the Certification of Inspection (COI) before the vessel is authorized to sail.

Some information can be gleaned from the USCG rules regarding LNG carriers and tankers while in U.S. waters which include specific bunkering supervision, special crew training, and length of duty restriction on bunkering personnel among other requirements. In addition, the July 1, 2011 USCG letter in response to the request for regulatory review states that the USCG will most likely require that the vehicle deck be empty of passengers and cars during fueling.

WSF LNG STATUS

WSF has conducted in-house and consultant studies on the use of LNG as a fuel source for the new 144-car vessel and for the retrofit of its Issaquah class vessels. The consultants will compare WSF work with its own independent findings in the final report.

A concept design has been completed for the new 144-car vessel, Key features of the design concept include: LNG fuel tanks above the passenger deck on the bridge deck; installation of either a dual fuel (LNG/diesel) or a single fuel/LNG only engine; bunkering by truck at night; and auxiliary generators that continue under either engine option to be diesel fueled.

A request for regulatory review has been developed by WSF staff for the retrofit of an Issaquah class vessel. The review was submitted to the USCG in September 2011.

WSF estimates the additional capital cost for the new LNG 144-car ferry between $8.5 million (dual engine option) and $9.9 million (single fuel engine option) for equipment and construction per vessel plus a one-time design cost of $0.8 million. WSF estimates operations savings at $1.4 million to $1.8 million per year assuming an LNG price of $1.05 per gallon and diesel fuel costs of $3.65 per gallon. The differential between LNG and diesel is assumed to remain the same throughout the 30-year life cycle. The 30-year life-cycle cost analysis indicates that the single fuel engine (LNG only) has the lowest life-cycle cost.

WSF's analysis indicates that the retrofitting the six (6) Issaquah class vessels would cost $65 million, save $9.8 million a year in fuel costs with the capital cost repaid in 7 years.

LNG CONSIDERATIONS

The legislature directed the JTC to conduct this study because of concerns regarding the full potential cost of LNG. Key considerations that the consultants will consider in the final report include: vessel construction schedule and sequencing; impact on WSF's fleet acquisition and deployment plan; vessel and terminal design; capital costs; operations costs; security; and vessel and terminal life-cycle costs.

Contents

INTRODUCTION

The 2011 legislature directed the Joint Transportation Committee to investigate the use of liquefied natural gas (LNG) on existing Washington State Ferry (WSF) vessels as well as the new 144-car class vessels and report to the legislature by December 31, 2011 (ESHB 1175 204 (5)); (Chapter 367, 2011 Laws, PV).

The JTC report will: (1) assess WSF's work and studies on LNG use; (2) identify the full range of issues that must be addressed to successfully implement LNG use; and (3) analyze the cost, risk, timeline, and related implications of implementing LNG use for a retrofit of an existing Issaquah class vessel and for incorporating LNG into the new 144-car vessel design. The report is intended to address legislative concerns regarding the full potential cost of LNG, which is less expensive and its price less volatile than the ultra low sulfur diesel (ULSD) currently used by WSF, but may result in other significant costs.

This white paper sets the context for the study. It includes a review of the WSF fleet, background information on the use of LNG as a marine fuel; an overview of WSF's studies on implementing LNG use; and an identification of the range of issues that will be considered in the study.

SECTION I. APPROACH

This white paper relies on information available from WSF's studies and the consultants' research and interviews with outside agencies and experts.

WSF documents that have been reviewed include:

- LNG Use for Washington State Ferries March 2010
- 144-Car Ferry LNG Fuel Conversion – Regulatory Review of Concept – May 2011
- 144-Car Ferry LNG Fuel Conversion Feasibility Study – July 2011
- 144-Car Ferry LNG Fuel Conversion Feasibility Study – Life Cycle Cost Analysis – July 2011
- The Use of LNG as a Fuel on the Issaquah Class Passenger Ferries in Puget Sound – Sept. 2011
- Vessel fuel consumption reports – 2009 and 2010

The consultants also reviewed the following reports by others:

- California Energy Commission, West Coast LNG Projects and Proposals, June 2011
- Danish Ministry of the Environment, Natural Gas for Ship Propulsion in Denmark – Possibilities for Using LNG and CNG on Ferry and Cargo Routes, 2010
- Fjord1 Group, Fjord1's Experience with LNG Fueled Ships, 2010
- DNV, Greener Shipping in North America, Feb. 2011
- DNV, LNG as Fuel for Ship Propulsion, Nov. 2010
- Integrated Resource Plans – filed with the Washington State Utilities and Transportation Commission
    - Puget Sound Energy
    - NW Natural
    - Avista
    - Cascade Natural Gas
    - PacifiCorp
- MIT, The Future of Natural Gas, 2011
- Norwegian Marine Technology Research Institute and Norwegian Maritime Directorate, The Norwegian LNG Ferry, 2000
- Northwest Gas Association, Natural Gas Infrastructure in the Pacific Northwest, 2010
- The University of Texas at Austin, Introduction to LNG, January 2007
- United States Department of Homeland Security, United States Coast Guard, The Chesapeake Bay Liquefied Natural Gas Operations Management Plan, May 5, 2006
- United State Energy Information Administration 2011 Energy Outlook and web site materials
- United States Environmental Protection Agency, Global Trade and Fuels Assessment – Additional ECA Modeling Scenarios, May 2009
- Washington State Department of Commerce, Washington Natural Gas Supply, Sept. 2005
- Washington State Department of Commerce, 2004 Natural Gas Study, 2004.

Interviews were conducted with:

- BC Ferries
- Clean Energy
- Phoenix Public Transit
- Poten & Partners, Inc., LNG & Natural Gas Consulting
- Puget Sound Energy
- Shell Oil
- United States Coast Guard
- Williams Northwest Pipeline
- World CNG

SECTION II. GLOSSARY

Auto-refrigeration: The process in which LNG is kept at its boiling point, so that any added heat is countered by energy lost from boil off.

Boil off: A small amount of LNG evaporates from the tank during storage, cooling the tank and keeping the pressure inside the tank constant and the LNG at the boiling point. Rise in temperature is countered by LNG being vented from the storage tank.

Btu - British thermal unit: The Btu is the standard unit of measurement for heat. A Btu is defined as the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit from 58.5 to 59.5 degrees under standard pressure of 30 inches of mercury.

Bunkering: Act or process of supplying a ship with fuel.

Cf - Cubic Foot: A unit of measurement for volume. It represents an area one foot long, by one foot wide, by one foot deep. Natural gas is measured in cubic feet, but the measurements are usually expressed in terms of MMcf (million cubic feet), Bcf (billion cubic feet), Tcf (trillion cubic feet), or Quads.

Class Notation: Assigned to vessels in order to determine applicable rule requirements for assignment and retention of class. Vessels can be built to class only or built and maintained in a class.

Compression: Natural gas is compressed during transportation and storage. The standard pressure that gas volumes are measured at is 14.7 Pounds per Square inch (psi). When being transported through pipelines, and when being stored, gas is compressed to save space.

CNG - Compressed Natural Gas: Natural gas in its gaseous state that has been compressed between 2600 and 3900 psi.

Cryogenic Liquid or Cryogens: Cryogenic liquids are liquefied gases that are kept in their liquid state at very low temperatures and have a normal boiling point below -238 degrees Fahrenheit (-150 degrees Celsius). All cryogenic liquids are gases at normal temperatures and pressures. These liquids include methane, oxygen, nitrogen, helium and hydrogen. Cryogens normally are stored at low pressures.

Deliverability Rate: A measure of the amount of gas that can be delivered (withdrawn) from a storage facility on a daily basis, typically expressed in terms of millions of cubic feet per day (MMcf/day).

Emissions Control Area (ECA): Designated by International Maritime Organization (IMO) as areas that must reduce fuel sulfur and emissions beyond global standards. The North American ECA will extend 200 miles off the US coast and tiered implementation will begin in 2012.Beginning in 2015, fuel used by all vessels operating in these areas cannot exceed 0.1 percent fuel sulfur (1000 ppm). This requirement is expected to reduce PM (particulate matter) and SO_x (sulfurous oxides) emissions by more than 85 percent. Beginning in 2016, new engines on vessels operating in these areas must use emission controls that achieve an 80 percent reduction in NO_x (nitrous oxides) emissions.

FERC - Federal Energy Regulatory Commission: The federal agency that regulates interstate gas pipelines and interstate gas sales under the Natural Gas Act. The FERC is considered an independent regulatory agency responsible primarily to Congress, but it is housed in the Department of Energy.

Hydrocarbon: An organic compound containing only carbon and hydrogen. Hydrocarbons often occur in petroleum products, natural gas, and coals.

Liquefaction: The process by which natural gas is converted into liquid natural gas.

Liquefied Natural Gas (LNG): Natural gas (predominantly Methane, CH_4) that has been cooled to -259 degrees Fahrenheit (-161 degrees Celsius) and at which point it is condensed into a liquid which is colorless, odorless, non-corrosive and non-toxic. Characterized as a cryogenic liquid.

Liquefied Petroleum Gas (LPG): Gas consisting primarily of propane, propylene, butane, and butylene in various mixtures. Stored as a liquid by increasing pressure.

MMcf: A volume measurement of natural gas; one million cubic feet.

MMtpa: Million tons per annum - one ton (or metric ton) is approximately 2.47 cubic meter of LNG.

Peak-Shaving: Using sources of energy, such as natural gas from storage, to supplement the normal amounts delivered to customers during peak-use periods. Using these supplemental sources prevents pipelines from having to expand their delivery facilities just to accommodate short periods of extremely high demand.

Peak-Shaving Facility: A facility which stores natural gas to be used to supplement the normal amount of gas delivered to customers during peak-use periods.

Regasification: The process by which LNG is heated, converting it into its gaseous state.

Storage Facilities: Facilities used for storing natural gas. These facilities are generally found as gaseous storage facilities and liquefied natural gas (LNG) storage facilities.

Ultra Low Sulfur Diesel: Ultra Low Sulfur Diesel is the primary highway diesel fuel produced. ULSD is a cleaner-burning diesel fuel that contains 97% less sulfur than low-sulfur diesel (LSD). ULSD was developed to allow the use of improved pollution control devices that reduce diesel emissions more effectively but can be damaged by sulfur.

SECTION III. WASHINGTON STATE FERRIES FLEET

This section reviews the WSF vessel fleet plan, the current and projected consumption and price of WSF's diesel fuel, and the impact on the fleet of the new Emissions Control Area in North American waters.

A. Fleet

WSF has 22 vessels that serve its nine (9) routes in Puget Sound and the San Juan Islands[1]. WSF's Long-Range Plan assumes a 22 vessel fleet through 2030 and establishes a route service plan based on a vessel acquisition and retirement plan. The impact of converting the design of the new-144 car vessel to LNG and/or of retrofitting an Issaquah class vessel on WSF's route service plan will be assessed in the final report.

1. 2012 Fleet

In early 2012, the 63-year old *Rhododendron* will retire from the fleet when it is replaced by the third Kwa-di Tabil class vessel. WSF will then have three (3) Jumbo Mark II, two (2) Jumbo Mark I, four (4) Super, six (6) Issaquah, three (3) Evergreen State, three (3) Kwa-di Tabil, and one (1) Hiyu class vessels.

One vessel, the *Evergreen State*, is in poor condition and will be retired with the construction of the first new 144-car vessel. [2] The *Hyak* is scheduled for a major rebuild in the 2011-13 biennium.

The 2012 fleet is shown in Exhibit 1 below.

2. New 144-Car Vessel Construction

The legislature's 16-year (FY 2011-FY 2027) financial plan includes the construction of two (2) new 144-car vessels. Funding has been provided in the 2011-13 biennium budget for the construction of the first vessel with a diesel engine. The 16-year plan anticipates a second vessel which may be LNG or diesel.

The contracted shipyard, Vigor, has completed production drawings for the diesel fueled vessel. WSF and Vigor are in price and schedule negotiations. The parties expect to have a final price for the first vessel in October 2011 along with a price for an optional second diesel fueled vessel. The first vessel is anticipated to be delivered in 2014 and the second vessel, if it is constructed as a diesel fueled vessel, would be delivered in 2015.

As shown in Exhibit 2 from WSF's Long Range Plan, the first new 144-car vessel will allow the *Evergreen State* to retire. The second new 144-car vessel allows the *Hiyu,* currently the emergency reserve vessel, to retire and a larger Evergreen State class vessel to take its place (the *Hiyu* is in a good state of repair but is too small for reasonable service). The second new 144-car vessel also allows WSF to expand service capacity on the San Juan Islands-Sidney, Fauntleroy-Vashon-Southworth, and Mukilteo-Clinton routes.

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[1] From the retirement of the four (4) Steel Electric class vessels in 2007 until the addition of the second Kwa-di Tabil class vessel, the *Salish,* in 2011, WSF operated with a 21 vessel fleet. During this period WSF did not operate a second vessel on the Port Townsend-Coupeville route in the spring, shoulder, summer, and fall seasons as it had done prior to the retirement of the Steel Electrics. With the addition of the Salish second vessel service was restored to the Port Townsend-Coupeville route.

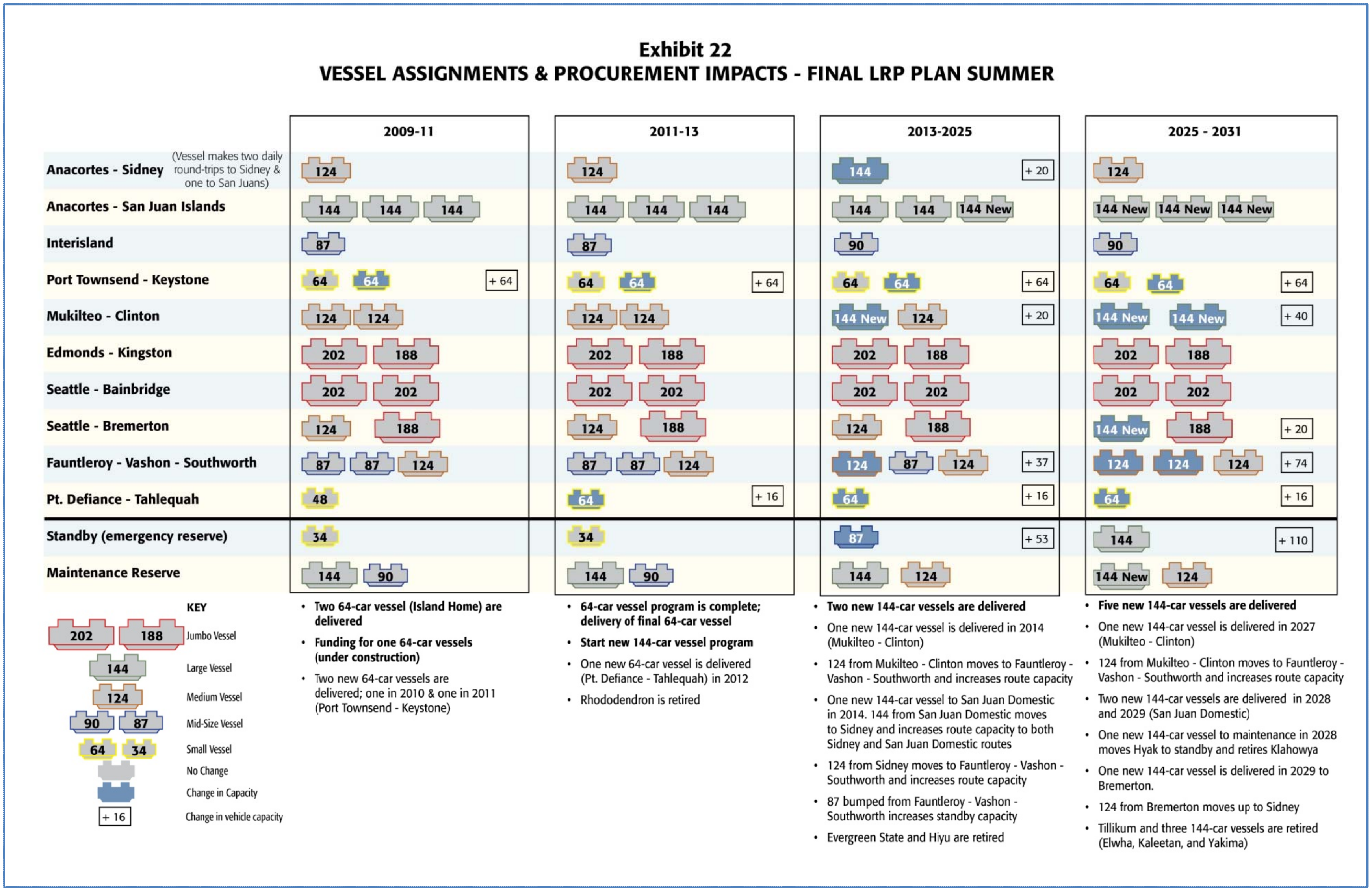
[2] See discussion of Evergreen State*, Joint Transportation Committee Ferry Financing Study II Vessel Preservation and Replacement Final Report*, 2008, p. 5

Exhibit 1.
WSF 2012 Fleet

Class	Vessel	Vehicle Capacity	Year Built / Rebuilt
Evergreen State	*Evergreen State*	87	1954 / 1988
	Klahowya	87	1958 / 1995
	Tillikum	87	1959 / 1994
Super	*Elwha*	144	1967 / 1991
	Hyak	144	1967 / 2011-13 biennium
	Kaleetan	144	1967 / 1999
	Yakima	144	1967 / 2000
Hiyu	*Hiyu*	34	1967
Jumbo Mark I	*Spokane*	188	1972 / 2004
	Walla Walla	188	1973 / 2003
Issaquah	*Issaquah*	124	1979 / ongoing
	Kitsap	124	1980 / ongoing
	Kittitas	124	1980 / ongoing
	Cathlamet	124	1981 / ongoing
	Chelan	124	1981 / ongoing
	Sealth	90	1982 / ongoing
Jumbo Mark II	*Tacoma*	202	1997 / 2027
	Puyallup	202	1998 / 2028
	Wenatchee	202	1998 / 2028
Kwa-di Tabil	*Chetzemoka*	64	2010
	Salish	64	2011
	*Kennewick**	64	2012 (service)

*Replaces the 63-year old *Rhododendron,* which will retire from the feet.

Exhibit 2.
Final Long-Range Plan Fleet Plan



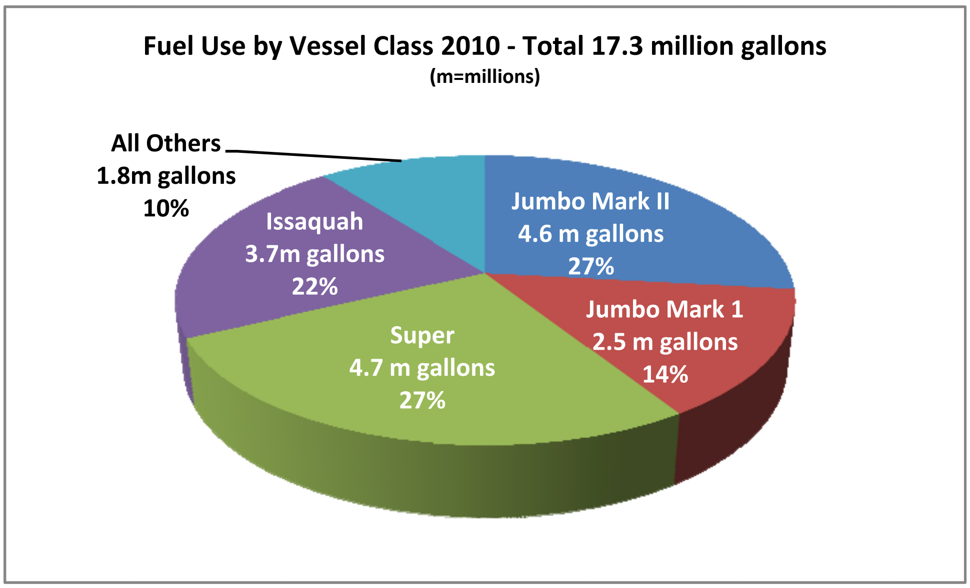
B. WSF Fleet Fuel

WSF fuels its fleet with ultra low sulfur diesel (ULSD)[3]. RCW 43.19.642 requires state agencies to use a minimum of 20 percent biodiesel blend fuel.[4] In 2011 WSF is using a ULSD that has 5 percent biodiesel with a sulfur maximum content of 0.1 percent.[5]

1. Total Fleet Fuel Consumption

In 2010 WSF used 17.3 million gallons of fuel. Fuel consumption is affected by the size of the vessel, the route the vessel is assigned to, and the speed of the vessel.[6] The five (5) largest vessels in the fleet - the three (3) 202-car Jumbo Mark IIs and the two (2) 188-car Jumbo Mark Is – accounted for 41 percent of total fuel used in 2010. The four (4) relatively fuel inefficient 144-car Super class vessels accounted for another 27 percent of the fuel consumed in 2010 and the six (6) relatively fuel efficient Issaquah class ferries accounted for 22 percent. The remaining six (6) small vessels in service in 2010 accounted for 10 percent of the fuel used.[7]

Exhibit 3.
Fuel Use by Vessel Class 2010



[3]Ultra Low Sulfur Diesel is the primary highway diesel fuel produced to meet federal requirements. It can have a sulfur content of no more than 15 parts per million (ppm). ULSD was developed to allow the use of improved pollution control devices that reduce diesel emissions more effectively but can be damaged by sulfur. Most large vessels use bunker fuel, which has sulfur content of approximately 4.5 percent or 45,000 ppm.

[4]In the 2009-11 biennium WSF was exempted from this requirement and instead required to use 5 percent biodiesel provided that it did not cost more than 5 percent more than diesel fuel. This provision was vetoed by the Governor in the 2011-13 biennium, with the result that WSF is mandated by law to use 20 percent biodiesel. The legislature had exempted WSF from even the 5 percent biodiesel fuel requirements when it passed the transportation budget. As a consequence the 2011-13 biennium budget assumes no biodiesel fuel even though WSF is required to use fuel with 20 percent biodiesel The Governor has directed WSF to use only as much biodiesel as the fuel appropriation allows.

[5]Product Specification for Ultra Low Sulfur Diesel Fuel #2 Product Code 085 (1).

[6] See the Joint Transportation Committee's *Vessel Sizing and Timing Final Report*, 2009 for further information.

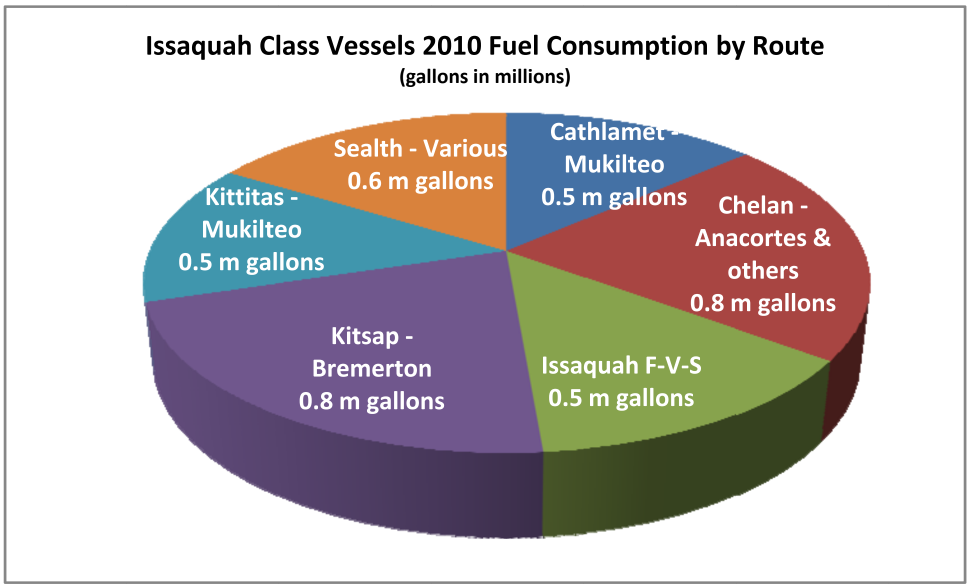
[7] The six (6) vessels are the three (3) Evergreen State class vessels, the Steilacoom II borrowed from Pierce County to operate on the Port Townsend-Coupeville route, the *Chetzemoka* which replaced the Steilacoom II, and the *Hiyu*.

Fuel consumption in FY 2012 is anticipated to increase to 17.5 million gallons with the addition of the *Salish* and the restoration of two (2) vessel service to the Port Townsend-Coupeville route. In FY 2013 fuel consumption will increase to 17.6 million gallons when the *Kennewick* begins service on the Pt. Defiance-Tahlequah route and the *Rhododendron* retires. In 2014, when the first new 144-car vessel is delivered and the *Evergreen State* retires, annual fuel consumption will increase to 17.9 million gallons. If a second new-144 car diesel vessel is constructed and delivered in 2015, annual fuel consumption will increase to 18.2 million gallons.

2. Issaquah Class Ferries Fuel Consumption

The five (5) 124-car Issaquah class ferries were utilized on four (4) routes in 2010: Mukilteo-Clinton (2 vessels); Fauntleroy-Vashon-Southworth Triangle (1 vessel); Seattle-Bremerton (1 vessel); and Anacortes-Sidney (1 vessel). The 90-car *Sealth* was used as a maintenance reserve vessel on these four (4) routes plus the Pt. Defiance-Tahlequah route. Annual vessel fuel consumption per vessel ranged from 0.5 million to 0.8 million gallons varying with the route and days in service.

Exhibit 4.
Issaquah Class Vessels 3.7 Million Gallons Fuel Consumption by Route



Fuel consumption by service hour by route was 77 gallons per service hour for Mukilteo-Clinton; 96 for Fauntleroy-Vashon-Southworth; 145 for Seattle-Bremerton; and 149 for Anacortes-Sidney.

In WSF's Long-Range Plan the Issaquah class vessels are to be re-deployed as the new 144-car ferries come on line. When a second 144-car vessel is built two rather than one of the Issaquah class vessels will be assigned to the Fauntleroy-Vashon-Southworth route; one to the Mukilteo-Clinton route rather than two; one (the 90-car Sealth) becomes the Interisland ferry in the San Juans; one remains on the Seattle-Bremerton route; and one is a maintenance reserve vessel.

3. Issaquah and 144-car Fueling Locations

On the routes with planned service by an Issaquah class or 144-car vessel, WSF currently fuels by truck at the Bremerton terminal for the Seattle-Bremerton route, Southworth terminal for the Fauntleroy-

Vashon-Southworth route, the Clinton terminal for the Mukilteo-Clinton route, and the Anacortes terminal for all the San Juans routes. The consultants will review the logistics of supplying LNG to these locations.

4. Diesel Fuel Cost

a. Diesel fuel cost projected

Diesel fuel represents 29.2 percent of the FY 2011-13 biennium operations budget for WSF or $135.2 million.

The cost delivered to WSF of diesel fuel is adjusted from the forecast by the use of biodiesel which costs more and by taxes.

- *Biodiesel*. The adopted budget did not anticipate any use of biodiesel because the legislature waived the biodiesel requirement for WSF when it adopted the 2011-13 biennium budget. The Governor vetoed that section of ESHB 1175 and directed WSF to use only as much biodiesel fuel as its fuel budget allowed. In practice WSF is following the 2009-11 biennium requirement to use 5 percent biodiesel provided that it does not cost more than 5 percent more than diesel even though state law currently requires 20 percent biodiesel fuel.
- *Taxes.* 2ESSB 5742 adopted in the 2011 legislative session eliminates the requirement for WSF to pay sales tax on its diesel or special fuel purchases effective July 1, 2013.

In the June 2011 forecast by the Transportation Revenue Council in the exhibit below, total diesel fuel costs by gallon range from $4.30 per gallon in FY 2012, then drop in FY 14 to $4.01 with the elimination of the sales tax, increasing to $4.33 in FY 2027.

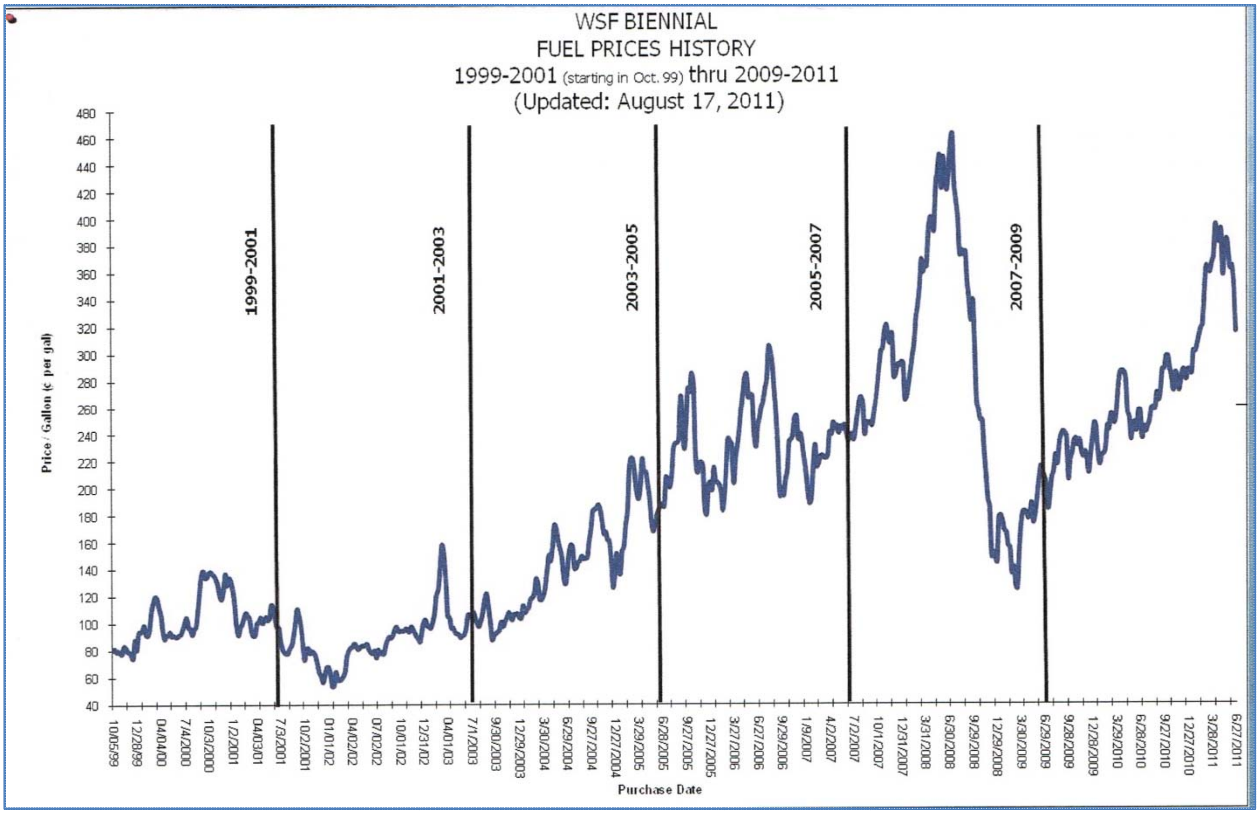
Exhibit 5.
WSF ULSD 16-Year Price Forecast

Before taxes and fees:		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Diesel (from June 2011 forecast)		$ 3.75	$ 3.77	$ 3.81	$ 3.84	$ 3.93	$ 4.00	$ 4.05	$ 4.09	$ 4.03	$ 4.01	$ 4.07	$ 4.09	$ 4.10	$ 4.10	$ 4.11	$ 4.11
With 5% biodiesel		$ 3.94	$ 3.96	$ 4.00	$ 4.03	$ 4.13	$ 4.20	$ 4.25	$ 4.29	$ 4.23	$ 4.21	$ 4.27	$ 4.29	$ 4.31	$ 4.31	$ 4.32	$ 4.32
Sales Tax @ 8.9%	8.90%	$ 0.35	$ 0.35	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Federal Oil Spill Recovery Fee @ $0.0019/gal.	0.19%	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002	$ 0.002
Leaking Underground Storage Tank Fee @ $0.001/gal.	0.10%	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001
Washington State Oil Spill Tax @ $0.001/gal.	0.10%	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001	$ 0.001
WA State Hazardous Substance Tax @ $0.007/gal.	0.70%	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007	$ 0.007
Spill Prevention Costs @ $5,200/month		$ 0.004	$ 0.004	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003	$ 0.003
Total taxes and fees		$ 0.36	$ 0.37	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01	$ 0.01
Average Cost per Gallon (including taxes and fees)		$ 4.30	$ 4.33	$ 4.01	$ 4.05	$ 4.14	$ 4.21	$ 4.27	$ 4.31	$ 4.25	$ 4.22	$ 4.29	$ 4.31	$ 4.32	$ 4.32	$ 4.33	$ 4.33

b. Diesel fuel price volatility

As shown in the exhibit below WSF diesel costs have been quite volatile in the past, with costs per gallon peaking in the 2007-09 biennium.

Exhibit 6.
WSF Diesel Fuel Prices 1999-2011



Source: Washington State Ferries, LNG Fuel Application Seminars, August 31, 2011

Legislative actions to stabilize WSF diesel prices and reduce the impact of spikes in fuel prices on WSF finances are:

- *Fuel hedging program.* For the 2011-13 biennium the legislature authorized WSF to enter into a distributor controlled fuel hedging program, which it is anticipated will result in lower and more stable WSF diesel prices over time (ESHB 1175, Section 221 (11)). WSF has entered into a hedging contract, and as of October 2011, had hedged approximately 6.2 million gallons of fuel for FY 2012 at an average pre-tax price of $3.20 per gallon or $3.67 per gallon with tax and biodiesel.
- *Fuel surcharge.* The Washington State Transportation Commission has adopted a fuel surcharge mechanism for implementation in October 2011 as a way to pay for unexpected spikes in fuel prices not funded under the current budget. The surcharge mechanism will only be triggered when fuel costs exceed the currently funded average fuel price by 2.5 percent. WSF will review fuel costs on a quarterly basis and, depending on fuel prices at the time of the review the surcharge may be applied, removed or adjusted higher or lower. The maximum surcharge amount is capped at 10 percent. Any changes to the surcharge will require a 30-day advance notice to customers

C. Emission Control Area - Impact on WSF Fleet

The imposition of the new North American Emission Control Area (ECA) is anticipated to have a substantial affect on United States ship owners. However, it will have little impact on WSF because WSF is already in compliance with the restriction on sulfur oxide (SO_x) through its use of ULSD and WSF does not anticipate major engine conversions prior to 2016 that would be affected by the requirements for more efficient engines.

1. IMO and ECA Requirements

The International Maritime Organization (IMO) is an agency of the United Nations formed in 1948 to promote maritime safety. IMO controls pollution from ships through the International Convention on the Prevention of Pollution from Ships known as MARPOL. MARPOL Annex VI provides progressively more stringent limits for sulfur oxide (SO_x) primarily through control of sulfur content in fuels. It also provides for progressively more stringent requirements for nitrogen oxide (NO_x), which are achieved by requiring more efficient engines (i.e. Tier I, Tier II, Tier III with each tier being a more efficient engine).

a. North American Emission Control Area (ECA).

IMO formed the North American ECA on March 26, 2010, in response to a joint proposal from the United States, Canada, and France. The control area requires ships operating up to 200 nautical miles off the coasts of the U.S., Canada, the French territories of Saint-Pierre and Miquelon, and the eight largest Hawaiian Islands to reduce their emissions of NO_x and meet more stringent fuel sulfur content requirements than are required in non-ECA waters.[8] The North American ECA will become enforceable in August 2012.

b. United States Law.

It is up to each IMO member nation to adopt rules to implement ECA or other emission requirements. In the United States, MARPOL Annex VI is implemented through the Act to Prevent Pollution from Ships (APPS). U.S. regulations incorporate both the NO_x standards and fuel provisions from Annex VI (CFR Part 1043 and Part 80, Subpart 1).

A June 27, 2011, joint letter from the Environmental Protection Agency (EPA) and the U.S. Coast Guard (USCG) outlines the APPS ECA requirements. These requirements include limits on the sulfur content of fuel and standards for engines to meet NO_x emissions. The engine requirements state: "Each marine diesel engine with a power output of more than 130 kW (i.e. which includes all WSF vessels) that is installed on a ship constructed on or after January 1, 2000, and each existing marine diesel engine with a power output of more than 130kW that undergoes a major engine conversion on or after January 1, 2000, must be operated in conformance with the Annex VI NO_x emission limits. These standards apply to both main propulsion and auxiliary engines. A major conversion includes: 1) a replacement of an existing engine or installation of an additional engine; 2) any substantial modification of an engine; and 3) an increased engine rating of more than 10 percent."

The APPS requirements within the North American ECA that are applicable to vessels of the size that WSF has are summarized in the exhibit below.

[8] "Designation of North American Emission Control Area to Reduce Emissions from Ships: Regulatory Announcement." Environmental Protection Agency, March 2010 http://www.dieselnet.com/standards/inter/imo.php.

Exhibit 7.
Emission Control Area Requirements

Nitrous Oxide (WSF anticipates no affect before 2016)		Applicable to WSF	
NO_x Tier	**Ship Build Date or Major Conversion**	**Engine RPM**	
		130-2,000	**2,000+**
Tier I	On or after 1-1-2000	45.0.n (-0.20)	9.8
Tier II	On or after 1-1-2011	44.0.n (-0.23)	7.7
Tier III	On or after 1-1-2016	9.0.n (-0.20)	2.0
Sulfur Oxide – Sulfur Standard in Fuel (max % by weight) WSF Already Meets			
	Before 1-1-10		1.50%
	On & after 7-1-10		1.00%
	On & after 1-1-15		0.10%

Additional requirements under Annex VI and APPS include:

- *Engine International Air Pollution Prevention Certificates*. U.S. flagged vessels built after January 1, 2000 are required to have a certificate documenting that the engine meets Annex VI NO_x standards. U.S. vessels built before January 1, 2000, that undergo a major conversion after January 1, 2000, must also have a certificate.
- *Recordkeeping and fuel samples*. Bunker delivery notes must be maintained onboard as well as a technical file for each installed diesel engine.
- *Surveys*. Initial and periodic surveys to acquire and maintain the air pollution certificate are required.

2. Impact of the ECA on WSF Fleet

WSF will have very little impact from the ECA, unlike many other ship owners. Few ship owners use ULSD fuel. For those owners the practical alternatives are switching to low sulfur diesel fuel, installing exhaust gas scrubbers and continuing to use marine bunker fuel, or converting to LNG.

Sulfur standards. WSF is already in compliance with the new sulfur standards. The sulfur content of the fuel currently used by WSF has sulfur content within the limits to be imposed on Jan. 1, 2015.

NO_x– New Construction. WSF has historically supplied owner furnished engines for new vessel construction projects to take advantage of federal grants. Tier II compliant engines have been purchased for the first new diesel 144-car vessel, which will be constructed under the requirement for Tier II engines. WSF will be required to install Tier III compliant engines in vessels constructed after 2016.

NO_x– Existing Vessels. When WSF replaces the engines, substantially modifies the engines, or adds 10 percent or more power to an engine on or after January 1, 2011 the engines will have to be Tier II compliant. After January 1, 2016, the engines undergoing such modifications will have to be Tier III compliant. In addition, any major conversions occurring from January 1, 2000, to December 31, 2011, must be Tier I compliant. WSF does not plan on any major engine conversions between now and 2016 on any of its vessels. The Issaquah class vessel engines are Tier I compliant and were installed between 2000 and 2002 when the original engines were replaced. A major conversion of the engines is not anticipated before their retirement, unless the LNG conversion is carried out.

SECTION IV. LNG AS A MARINE FUEL

A. LNG and the ECA

LNG is an alternative way for vessel owners other than WSF to meet the new marine emission control standards while potentially reducing costs.

For WSF LNG will provide improved emissions control, beyond that required by the ECA. "The environmental qualities of LNG are superior to those of any liquid petroleum fuel. The use of LNG effectively eliminates the need for exhaust gas after-treatment, due to very low NO_x formation in the engines, as well as the absence of sulfur."[9] The table below shows the LNG emission comparison to the ULSD used by WSF.

Exhibit 8.
LNG Emission Comparison
(g/kWh)

Fuel Type	Sulfur Oxide	Nitrous Oxide	Particulate Matter	Carbon Dioxide
Marine ultra low sulfur diesel oil, 0.1%	0.4	8-11	1.5	580-630
LNG	0	2	0	430-482

Source: Boylston, John LNG as a Fuel Source for Vessels – Some Design Notes

B. History of LNG Use in Vessels and Ferries

Liquefied natural gas (LNG) is natural gas that has been cooled to -259 degrees Fahrenheit at which point it is condensed into a liquid, which is colorless, odorless, non-corrosive, and non-toxic. LNG is a cryogenic liquid meaning that it must be kept cooled to -259^{o} F or it returns to its gaseous state.

LNG takes up about 1/600th of the volume of natural gas in the gaseous state. This makes it cost efficient to transport in specially designed cryogenic LNG carriers over long distances opening up market access to areas where pipelines do not exist and/or are not practical to construct.

1. LNG Carriers

The first LNG carrier began service in 1959 with a shipment from Lake Charles, Louisiana to the United Kingdom. Beginning in 1964 LNG carriers began using the boil-off of LNG as the fuel source for the vessel's propulsion system. (A small volume of LNG is naturally boiled off to keep the bulk of the LNG in its liquid form.) All current LNG carrier vessels use this method of fueling, which is not available for any other type of vessel.

There are approximately 300 LNG carrier vessels worldwide – none of which are U.S. flagged.

LNG carriers dock at four (4) shoreside U.S. terminals, which are located in Everett, Massachusetts, Cove Point, Maryland, Elba Island, Georgia, and Lake Charles, Louisiana. In addition there are offshore LNG terminals in United States waters located near Boston, the Gulf of Mexico, Freeport, Texas, Sabine, Louisiana, and Peñuelas, Puerto Rico. The USCG has rules and regulations that govern LNG carriers in United States waters.

[9] Boylston, John, *LNG as a Fuel for Vessels – Some Design Notes,* p. 2.

2. LNG Ferries

Norway is the world leader in LNG fueled passenger vessels and today operates the only LNG fueled ferries in the world.

The discovery of large quantities of natural gas on Norway's west coast in 1997 allowed LNG to be available at an acceptable cost for ferry operation to be feasible. Before this discovery Norwegian studies started in 1989 had concluded natural gas ferries were not cost effective.

The Norwegian government decided in 1997 to build two (2) types of gas-operated car and passenger ferries; one (1) operating on LNG and one (1) on compressed natural gas (CNG). The CNG project was never started.[10]

Beginning in 1997 the Norwegian equivalent to the Coast Guard, the Norwegian Maritime Directorate, spent three years with a task force that included ferry operators, other public agencies and consultants developing regulations for LNG fueled passenger ships after some initial concerns about their safety were satisfied by studies and calculations. The issues that needed to be resolved for gas engines included:

- Reducing the risk of explosion in areas where gas was held
- Redundancy of fuel storage, power generation, transmission and propellers
- Separation of engines into two engine rooms and fuel supply
- Double piping of all gas pipes
- No danger to passenger life in case of fire or explosion and ability of the ship to get to port
- Detection of gas leakage in all areas where gas is in place.

The first Norwegian LNG ferry, Fjord1's *Glutra,* was built in 2000 with government assistance. The ferry, which was built to carry 100 cars and 300 passengers, cost 30 percent more than a comparable diesel powered vessel. This cost was thought to be acceptable given the fact that the knowledge gained in its construction would bring down the cost of ensuing LNG ferries.[11]

The *Glutra* was lengthened in 2010 and now accommodates 182 cars and 350 passengers. In 2011, Fjord1 has 12 LNG ferries operating in Norwegian waters and more under construction. Other Norwegian ferry operators also have LNG ferries including: Tide Sjo which has three (3); and Fosen Namos Sjo which has one (1). Another operator, Torghatten Nord, is undertaking a program to build three (3) new LNG ferries and convert four (4) existing vessels to LNG.

Fjord1's experience with LNG ferries was summarized in a presentation by their Operations Manager at the Ferries 2010 Conference in Seattle in November, 2010.[12] The consultants have also corresponded with him to gather more detailed information. Based on this presentation and discussions to date, Fjord1's LNG vessels cost more to build and to operate and maintain. The additional cost is offset by Norwegian tax advantages which include a carbon credit and access to special funding reserved for projects that reduce emissions. The primary advantage of LNG beyond the tax credits is the reduction in emissions.

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[10] Oscar Bergheim, Operations Manager Fjord1 Fylkesbaatane, presentation at Ferries 2010 Conference in Seattle, WA November 2010.

[11] Per Magne Einang and Konrad Magnus Haavik, *The Norwegian LNG Ferry*, Norwegian Marine Technology Research Institute and the Norwegian Maritime Directorate, Paper A-095 NGV 2000 Yokohama.

[12] Oscar Bergheim, "Fjord1's Experience with LNG Fueled Ships" presentation at Ferries 2010 Conference, Seattle WA. Nov. 2010.

- *Capital cost*. The cost of building the LNG ferries is still 15-20 percent higher than diesel ferries. DNV, the classification society, notes that "New ships with LNG propulsion typically have an added investment cost of 10-20 percent. The additional cost is mainly due to the sophisticated LNG storage tanks, the fuel piping system, and in some cases a slightly larger ship."[13]
- *Engine*. Fjord1's ferries operate on single fuel (LNG only) Rolls Royce Bergen engines.
- *Maintenance costs.* Normal maintenance costs of the *Glutra* have been 20 percent higher than a similar-sized diesel vessel and maintenance costs of its five (5) sister ships in operation since 2007 have been 10 percent higher. Maintenance issues on the LNG ferries have included "black outs," or engine room shutdown, due more to human than technical error, three (3) instances of pipe leakage due to poor welding, and some issues with the thrusters but close to none with the main engines. There are also higher maintenance costs for the gas engines and gas systems.
- *Crew size and training.* Crew size is the same as on the diesel-powered ferries. Crew training includes a gas course including risk aspects, emergency shutdown (ESD) philosophy, gas plant and demonstration of gas explosions. The course takes two (2) to five (5) days, and the instructors are from the company. The remainder is familiarization training conducted on board the vessel. An officer needs about one (1) week training before being on duty. There is a detailed program in order to be considered qualified.
- *Cost of LNG.* The cost of natural gas in Norway has been close to, or slightly above, diesel and the energy cost of the LNG ferries has been slightly higher than diesel ferries. The cost of natural gas and diesel rise and fall together in Norway, which has not been the case in the United States.
- *Environmental impact.* The LNG vessels have been successful in reducing CO2 emissions by 19 percent, NO_x by 91 percent, and SO_x and particulate matter by 100 percent. [14]
- *Fueling/bunkering*. Delivery of LNG to the vessel takes place from trucks and in some cases from dedicated storage tanks at the ferry terminal.
- *Storage tank placement on vessel*. In Norway the LNG fuel tanks are located below the vessels auto decks. For WSF, the United States Coast Guard prefers that the fuel tanks be located above the passenger decks.

3. Other LNG Fueled Passenger Vessels

The world's largest LNG fueled passenger ship is currently being constructed for the Viking Line system that operates in Finland, Norway, and the Baltic countries. The vessel will be a cruise liner with capacity for 2,800 passengers, 200 crew, 1,300 lane meters for trucks, and 500 lane meters for cars. The vessel will operate on a relatively short route between Stockholm and Turku, Finland, allowing it to be refueled with LNG. It is scheduled for delivery in 2013.

A high speed LNG catamaran is currently under construction in Australia and will go into service next year between Buenos Aires and Montevideo. The ship will be dual-fuel, capable of operating on LNG or diesel; have capacity for 153 vehicles and 1,000 passengers; and be capable of speeds up to 50 knots.

4. Other LNG Fueled Vessels

There are no American flagged LNG vessels. Glosten Associates did the design for a pilot LNG-powered tug for Crowley Maritime in the Los Angeles Harbor but the project remains on hold due to cost concerns. Norway has three (3) LNG fueled vessels built for their Maritime Directorate, the equivalent of the USCG and four (4) LNG fueled off-shore supply vessels.

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[13] DNV, *Greener Shipping in North America*, February 2011, p. 10.
[14] Oscar Bergheim, "Fjord1's Experience with LNG Fueled Ships."

5. Other North American Ferry Systems

The consultants contacted several other North American ferry systems to see if they are considering LNG fueled ferries. The three currently considering LNG for ferries are the Staten Island Ferry system, BC Ferries, and Société des traversiers du Québec (STQ) in Québec.

- *Staten Island Ferry*. The Staten Island Ferry system has received a $2.3 million federal grant to study LNG retrofit of an existing ferry.
- *BC Ferries*. The consultants and WSF staff held a conference call with BC Ferries officials. BC Ferries is conducting a feasibility study of converting the 85-car *Queen of Capilano* to LNG, with hopes of expanding the conversions to other existing vessels, including the 410-auto Spirit class vessels, and new construction. CNG was not considered a viable fuel source due to the volume needed. Officials noted the two (2) vessels that used CNG in Canada before were smaller vessels for a river crossing and were later converted back to diesel. BC Ferries staff believe their biggest challenge will be the potential public reaction to LNG. They are working closely with a potential Canadian supplier of LNG, Fortis, on a public outreach and communications plan to help alleviate fears about the use of LNG in communities surrounding the bunkering of the fuel, which they plan to do onboard via truck delivery. They are in discussions with the classification society American Bureau of Shipping and Transport Canada (equivalent of the USCG) regarding regulatory approval and do not currently foresee it being a major obstacle.
- *Société des traversiers du Québec (STQ)*. STQ in Québec is pursuing a new build LNG vessel.
- *North Carolina Ferries*- LNG retrofit is too expensive to implement on their older ferries and no new LNG ferries are being considered. North Carolina Ferries is concerned about other regulatory impacts on older ferry conversions.
- *Woods Hole.* Their new 64-car vessels the Island Homes are the basis for the design of WSF's Kwa-di Tabil class ferries. The vessels are too new to consider retrofitting them and Woods Hole is concerned about stability and draft. Their older ferries are too old to justify the investment. They are also concerned about the supply of LNG and uncertain about the public reaction.
- *Cape May*. Cape May had some interest, but do not have enough funding to do anything. They are looking at high speed new ferries that are not suitable for LNG due to space concerns.
- *Maine State*- Not considered.
- *Alaska Marine Highways.* Not considering at this time.

6. LNG Retrofits

All of the current Norwegian LNG ferries were new construction. Fjord1 is retrofitting a 20-year old vessel at the end of this year at an estimated cost of 8 million euro and Torghatten Nord has plans to convert three (3) vessels to LNG. The reasons why vessels are seldom retrofitted include:

- *Vessel life.* Most vessels are assumed to have a life of 30 years rather than the 60 years that WSF aims for. As a consequence of the shorter remaining life of a vessel there is less time to amortize the investment.
- *Impact on car space or other economics.* In some instances vessel owners have decided against a retrofit because in Europe the fuel tanks are in the vessel's hold. LNG requires more volume for the same energy output than diesel and as a consequence vessel owners face the possibility of losing car space because of the additional space needed for the larger fuel storage tanks.

C. Compressed Natural Gas (CNG) Fueled Vessels

When the *Glutra* was built in Norway the intent was to also construct a CNG vessel. The CNG vessel project did not proceed.

A 2010 study by the Danish Ministry of the Environment considered the possibility of using LNG and CNG on ferry and cargo routes. The study notes that the primary disadvantage of CNG when compared to LNG is that LNG is more volume-effective. "LNG requires approximately 2 times the fuel volume of oil, and CNG (at 200 bar) requires 5 times the volume of oil."[15] As a consequence the tanks on CNG fueled vessel would have to be much larger to get the same distance as an LNG fueled vessel and/or the vessel would have to re-fuel more frequently.

The Danish study identified three (3) small ferries that are fueled by CNG. These ferries are not comparable to the new 144-car vessel or the Issaquah class ferries operated by WSF.

- *Vancouver B.C. Translink.* Two (2) of the ferries were operated in Vancouver B.C. These K-class ferries carried 26 cars and 146 passengers and were refueled twice a day using about 3-4 minutes each time. The *Kullee*t and the *Klatawa* operated by the Albion Ferry on the Fraser River until July 31, 2009 when the Golden Ears Bridge opened and the ferry route was discontinued. Before their retirement and subsequent sale the ferries had been re-converted to diesel.
- *Virginia Paddlewheel Passenger-Only Ferry.* The Elizabeth River Ferry system has three (3) paddlewheel vessels, each of which accommodates 150 passengers for a five (5) minute trip. One (1) of the vessels is CNG powered.

There are five (5) other small pleasure or tourist boats in the world that operate on CNG and one (1) cargo ship, a limestone carrier built to operate in the coastal waters of Australia.

Given the relative paucity of CNG fueled vessels, the Danish study noted that "for CNG the development of the shipping sector appears not to have progressed much over the last decade" with, relative to LNG a lack of developed technology. As a consequence the study concluded, "LNG will presumably be the de facto choice at least for 5 – 10 years over CNG.[16]

D. Economics of LNG Use

The economics of marine LNG use for WSF will be different than Norway's because LNG is much less expensive in the U.S. and, unlike Norway, the cost of natural gas does not track with the cost of petroleum. The difference in LNG cost, which is based on the spot price of natural gas, between Europe and the United States over the last five (5) years is shown in the exhibit below.

A spot price is the current price at which a particular commodity can be bought or sold at a specified time and place. The prices in the exhibit below are for two European trading points (TTF Netherlands and UK NBP Spot Britain) and two U.S. (Henry Hub and Algonquin Spot).[17] While the Algonquin Spot

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[15] Litehauz, IncentivePartners, DNV, and Ramboil Oil & Gas*, Natural Gas for Ship Propulsion in Denmark – Possibilities for Using LNG and CNG on Ferry and Cargo Routes,* Danish Ministry of the Environment, 2010, p. 27.

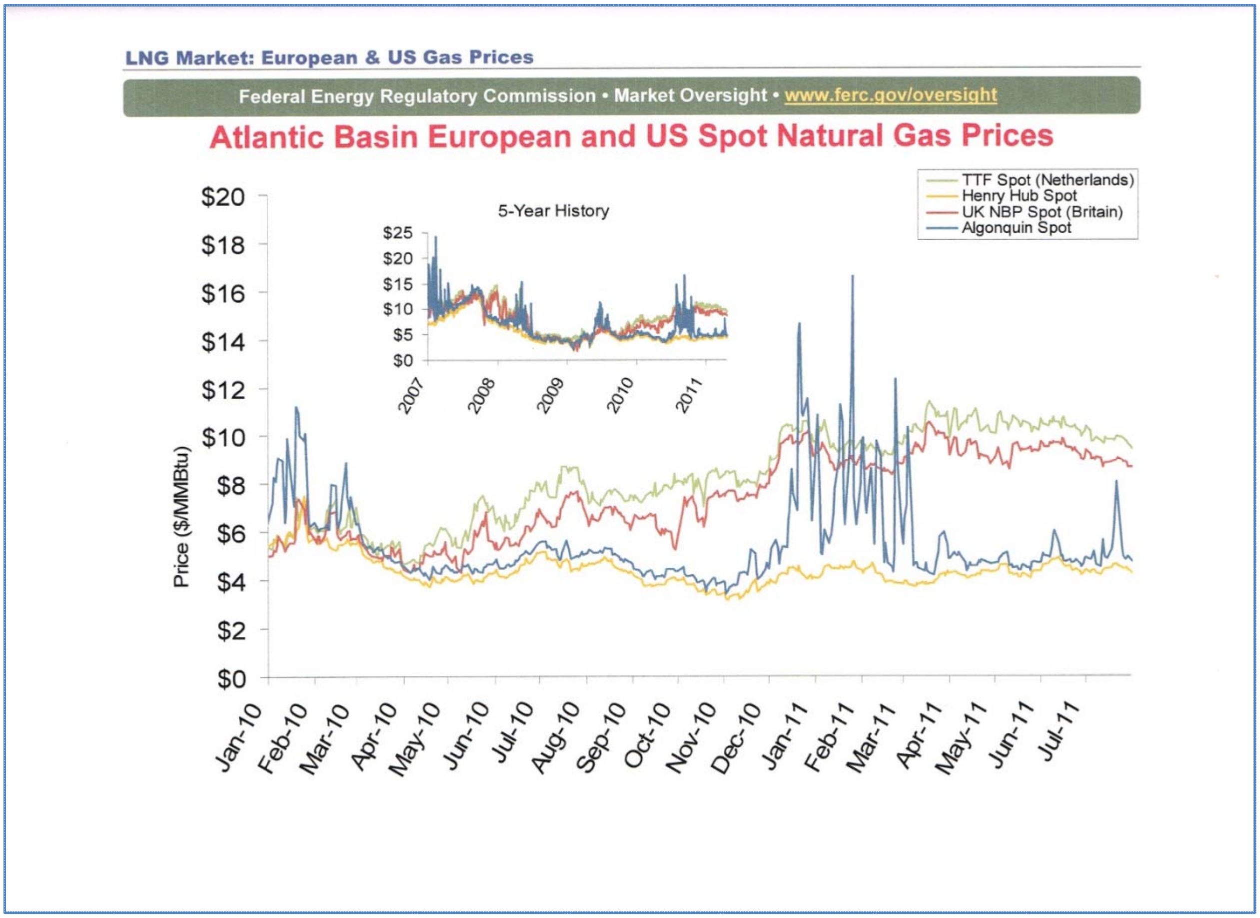
[16] Ibid., p. 9-12.

[17] TTF Spot (Netherlands) is the Title Transfer Facility (TTF) is a virtual trading point for natural gas in the Netherlands, which allows gas to be traded within the Dutch network.UK NBP (Spot) Britain is the National Balancing Point, commonly referred to as the NBP, is a virtual trading location for the sale and purchase and exchange of UK natural gas. It is the pricing and delivery point for the Intercontinental Exchange (ICE) natural gas futures contract. Henry Hub Spot is the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange. It is a point on the natural gas pipeline system in Erath,

price in the northeastern U.S. sometimes spikes above the European prices, the Henry Hub price for LNG delivered to Sabine Terminal in Louisiana is always lower. The Henry Hub price is the more important price point as it is the price used on the New York Mercantile Exchange and the forecasts for natural gas prices in Washington State are premised on the Henry Hub price.

Exhibit 9.
World LNG Fuel Price Comparison

This exhibit shows the difference in natural gas prices between Europe and the United States. The Henry Hub and Algonquin lines are United States prices and TTF and UK NBP lines are Europe.



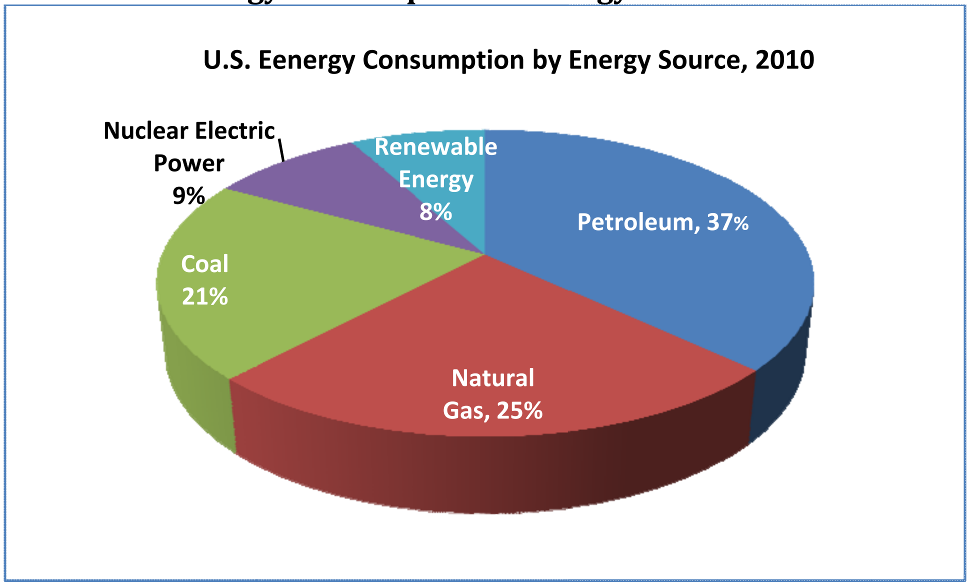
Source: Federal Energy Regulatory Commission

1. National Outlook for Natural Gas Supply and Price

Projections by the U.S. Energy Information Administration and other independent analysts all suggest that the United States' supply of natural gas is robust. Natural gas provides 25 percent of the United States total energy supply.

Louisiana owned by Sabine Pipe Line LLC. Algonquin Spot United States is the point for natural gas delivered to the Algonquin City-Gates, used for commodities trading. Algonquin City-Gates is in Massachusetts.

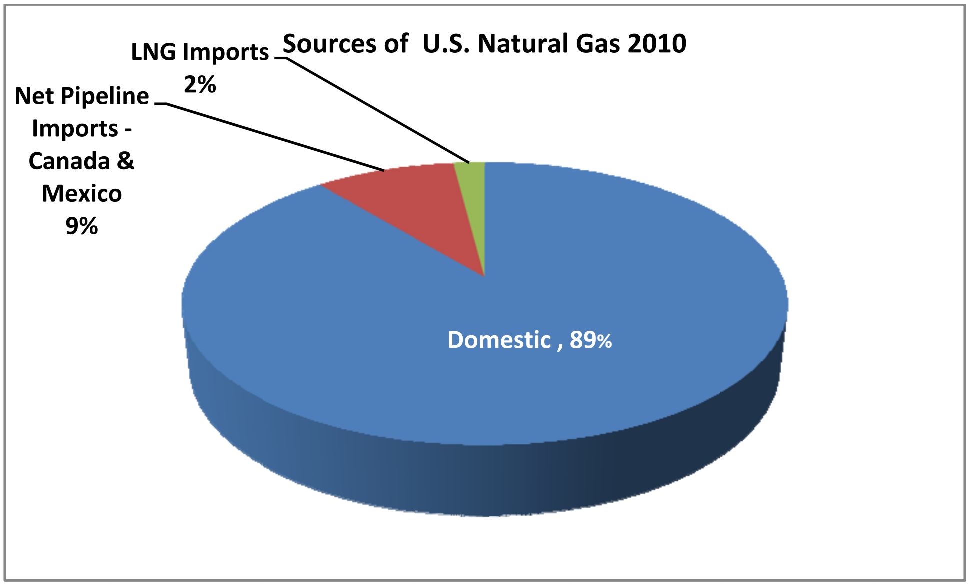
Exhibit 10.
U.S. Energy Consumption of Energy Source 2010



Source: U.S. Energy Information Administration

Most of the natural gas consumed in the United States is produced in the United States. Some is imported by pipeline from Canada and Mexico, with the same pipelines used for exports of United States natural gas to these countries. Canada accounts for 99 percent of our net imports and Mexico, to which we export more natural gas, 1 percent. A small portion of our natural gas, 2 percent in 2010, is shipped to the United States as liquefied natural gas (LNG) primarily from Trinidad and Tobago. LNG imported to the U.S. is usually regasified at the import facility.

Exhibit 11.
Sources of U.S. Natural Gas 2010



Source: U.S. Energy Information Administration

Forecasts for the nation's future natural gas supplies project a stable and growing source of domestic supply with relative price stability. "The recent emergence of substantial new supplies of natural gas in the U.S. primarily as a result of the remarkable speed and scale of shale gas development has heightened awareness of natural gas as a key component of indigenous energy supply and has lowered prices well below recent expectations. Instead of the anticipated growth of natural gas imports, the scale of domestic production had led producers to seek new markets for natural gas, such as an expanded role in transportation."[18] Shale gas has been discovered in the Mountain West, the South and throughout the Northeast's Appalachian Basin.

The U.S. Energy Information Administration Outlook 2011 projects as its reference case (i.e. the most likely scenario) that U.S. natural gas production will increase almost fourfold from 2009 to 2035, with total domestic production growing from 21.0 trillion cubic feet in 2009 to 26.3 trillion cubic feet in 2035. Shale gas is anticipated to make up 47 percent of the total natural gas production in 2035, up from its 16 percent share in 2009. Under this scenario U.S. imports of natural gas are expected to decline from both net pipeline imports and LNG shipments.

As a consequence of the increase in domestic natural gas production, the U.S. government is allowing LNG import terminals to also export domestically produced LNG. In May 2011 the Department of Energy provided provisional authorization for the Sabine Pass LNG Terminal to export LNG. "This is the first long-term authorization to export natural gas from the lower 48 states as LNG to all U.S. trading partners." [19] The Lake Charles and Freeport LNG import terminals are under regulatory review to export domestic LNG. The LNG terminal at Kenai Alaska is the only existing LNG terminal that has exported LNG but it has been shut down.

As shown in the exhibit below, prices for natural gas are anticipated to remain relatively low compared to low sulfur diesel. "Unlike crude oil prices, natural gas prices do not return to the higher levels recorded before the 2007-09 recession. Although some supply factors continue to relate the two markets loosely, the two do not track directly."[20]

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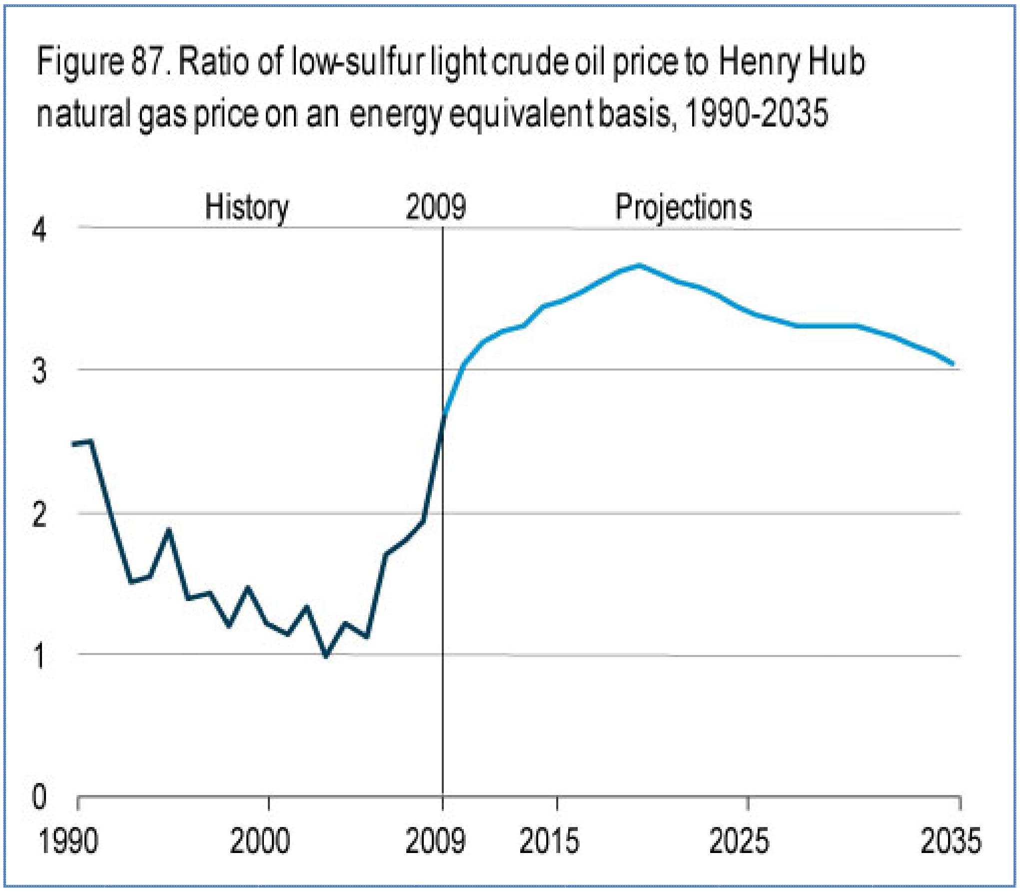
[18] MIT*, Natural Gas Outlook* 2011, pg. 1.
[19] (www.fossil.energy.gov/news/techlines/2011/11023-DOE_Approves _LNG_Export
[20] U.S. Energy Information Administration, *Energy Outlook 2011*, pg 38

Exhibit 12.
Ratio of ULSD to Natural Gas Prices 1990-2035

This exhibit shows that prior to 2009 ULSD prices were the same as or up to 2.5 times higher than natural gas prices. Projections through 2035 are that ULSD prices will be at least 3 times higher than natural gas. The projections are on an energy equivalent basis, which means that they are adjusted for the higher volume of natural gas needed to generate the same amount of energy.



Source: U.S. Energy Information Administration, 2011 Energy Outlook

The *Energy Outlook 2011* alternatives to the reference case consider variables related to the production of shale gas, the rate of economic growth, and the rapidity of change in technology for gas extraction. In the five scenarios considered, the price of natural gas ranged from 31 percent higher (low shale gas production, slow economic growth, and slow technology) to 24 percent lower (high shale gas production, high economic growth, and rapid technology) based on assumed price elasticity in electrical power and industrial uses of natural gas. In all scenarios the price of natural gas remains lower than diesel.

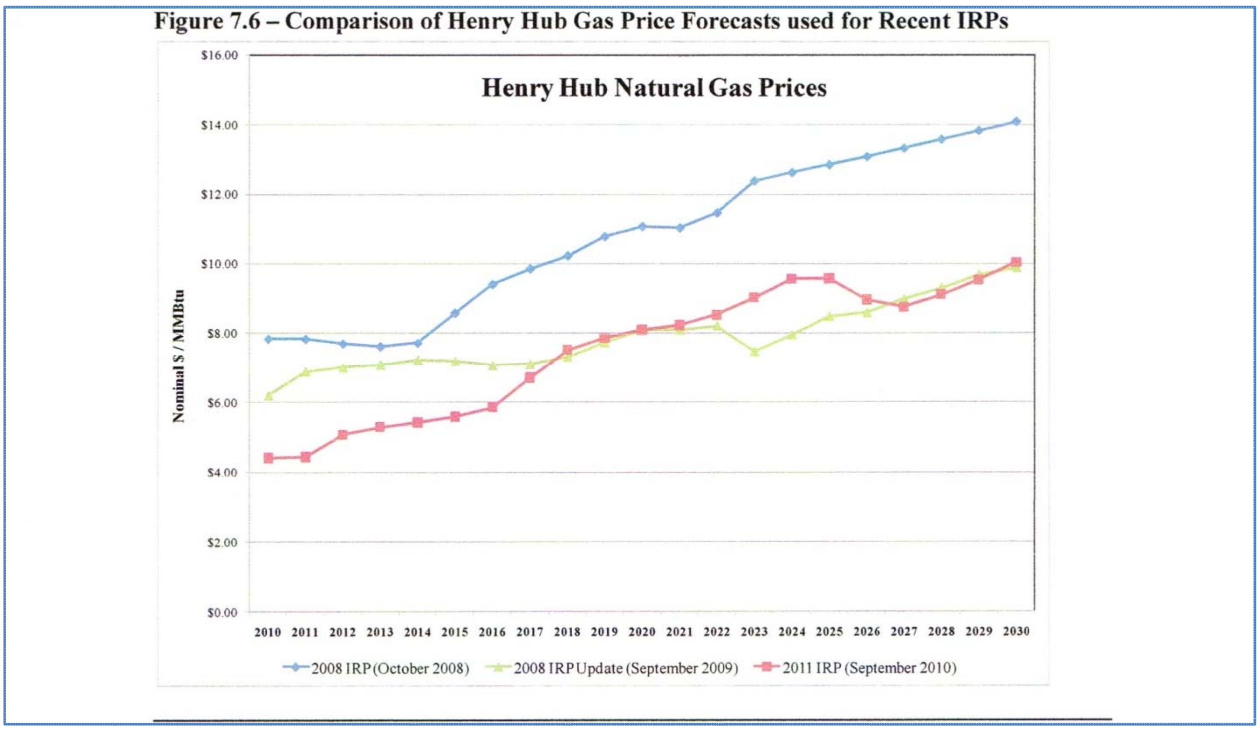
2. Washington State Projections of Natural Gas Supply and Price

Gas utilities operating in Washington State are required to file Integrated Resource Plans (IRP) with the Washington State Transportation and Utilities Commission every two (2) years.[21] Those filed in 2010 and 2011 reflect the national projections for lower natural gas prices. "The projected costs for natural gas have declined significantly and long-term prices are estimated to range between $5 to $6 per MMBtu over the planning horizon compared to the $8 to $10 forecasted in the 2008 IRP. This improvement to the long-term gas supply outlook is a stark contrast to the diminishing supply outlook that was prevalent during the development of the Company's 2008 IRP" (Cascade Natural Gas 2010 IRP pg. 7).

The shift in natural gas prices began in 2007 and 2008 "thanks to an unprecedented and unexpected burst of growth from unconventional domestic supplies across the lower 48 states" (PacifiCorp 2011 IRP, p. 29). Price forecasts by all five (5) utilities are based in part on the Henry Hub gas price forecast. As shown in the exhibit below, the Henry Hub forecast is much lower than it was in 2008.

Exhibit 13.
Comparison of the 2008 Henry Hub Natural Gas Price Forecast through 2035 to a 2011 Forecast

This exhibit shows that the projected price for natural gas through 2035 is lower in the 2011 forecasts than was forecasted in 2008.



Source: PacifiCorp 2011 Integrated Resource Plan

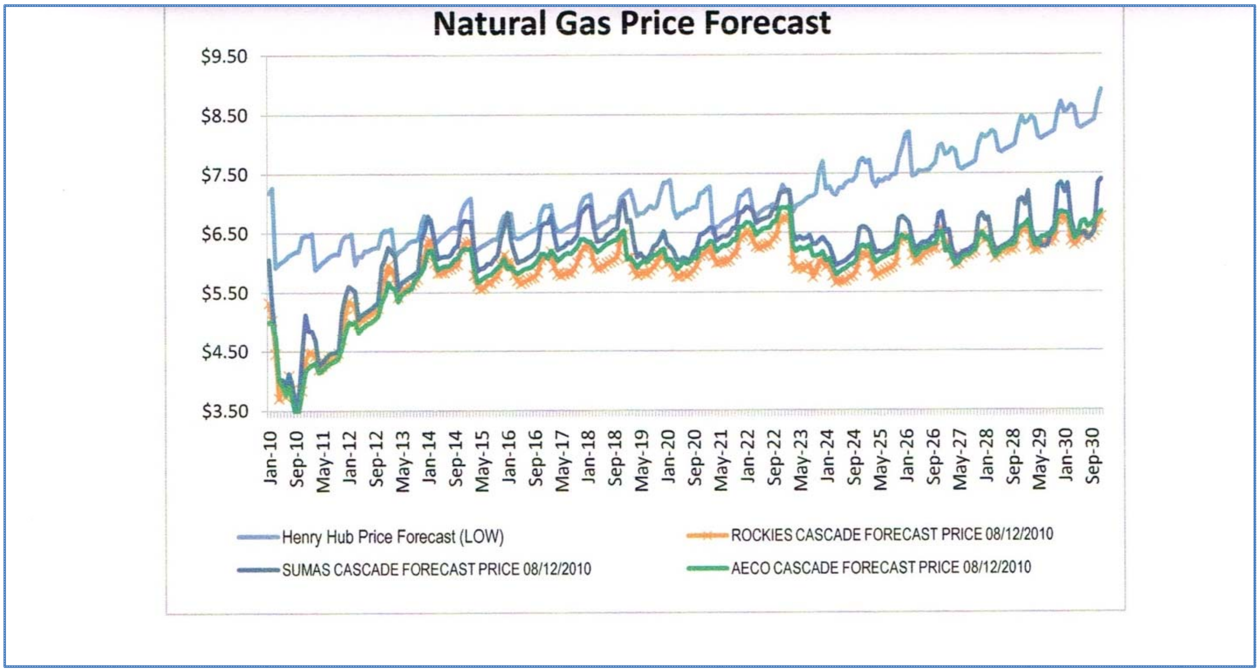
Natural gas in the Pacific Northwest has been trading at a discount to the Henry Hub prices, which means that the long-term forecast price for natural gas is lower than the Henry Hub natural gas prices. This occurs because the natural gas market in the Pacific Northwest is affected by, among other things,

[21] IRPs are required to be filed by Avista Corporation, Cascade Natural Gas Corporation, NW Natural, PacifiCorp, and Puget Sound Energy.

production and imports from Canada. The 2010 forecast by Cascade Natural Gas Corporation shows this differential. The Henry Hub prices are projected to be higher than those from Sumas Cascade, Rockies Cascade, and AECO Cascade hubs where most northwest natural gas is purchased. The forecast also shows that prices are anticipated to remain relatively stable through 2030. Price forecasts by the other natural gas utilities show a similar pattern.

Exhibit 14.
Sample Washington State Natural Gas Price Forecast

This exhibit shows that natural gas prices in Washington State are anticipated to remain relatively stable through 2030 and are lower than the Henry Hub price forecast.

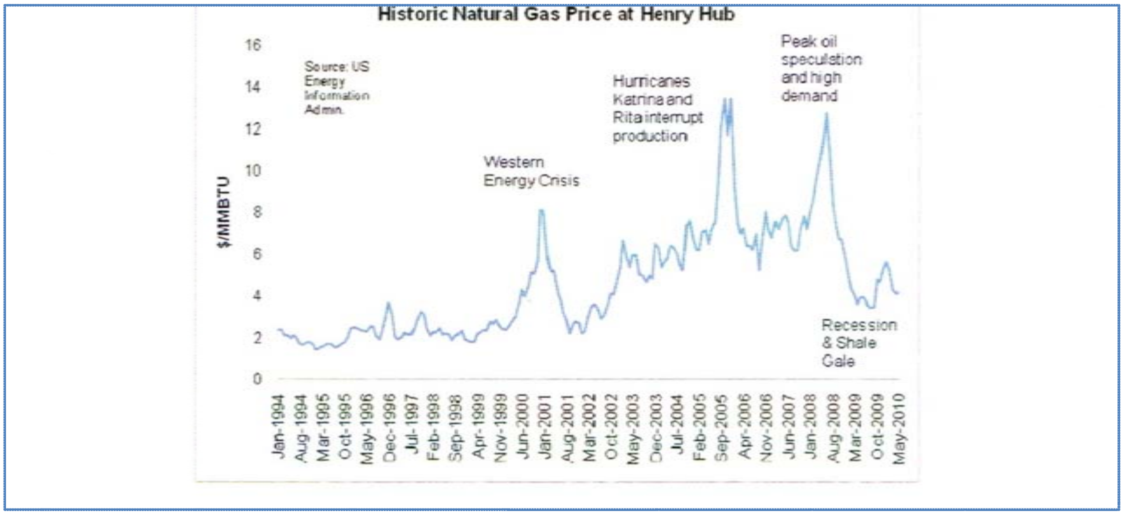


Source: Cascade Natural Gas Corporation 2010 Integrated Resource Plan

3. Volatility in Natural Gas Prices

While natural gas prices are more stable than diesel prices, they also experience volatility. As shown in the exhibit below, natural gas prices spiked in 2000-2001 with the energy crisis, in 2005 from the impact of hurricanes Katrina and Rita, and in 2008 with oil speculation and high demand.

Exhibit 15.
Volatility in Natural Gas Prices 1994-2010



Source: NW Natural 2011 Integrated Resource Plan

The IRPs point to further price uncertainty in the mid- to long-term including the potential for prices to increase due to difficulties in extracting shale oil, potential drilling restrictions due to environmental concerns, and the potential of a "concerted U.S. policy effort to shift the transportation sector away from oil toward natural gas which would significantly increase demand, and thus natural gas prices" (PacifiCorp IRP 2011, pg. 29). Other factors that affect natural gas prices include oil price volatility, the global economy, electric generation, hurricanes and other weather conditions, and the potential environmental moves to shift from coal-generated electricity to natural gas.[22]

4. Liquid Natural Gas Supply

There are three types of LNG facilities that are involved in the supply of LNG: LNG terminals which handle import and export of LNG; liquefaction facilities where natural gas is converted to LNG; and storage facilities where LNG is stored for future use.

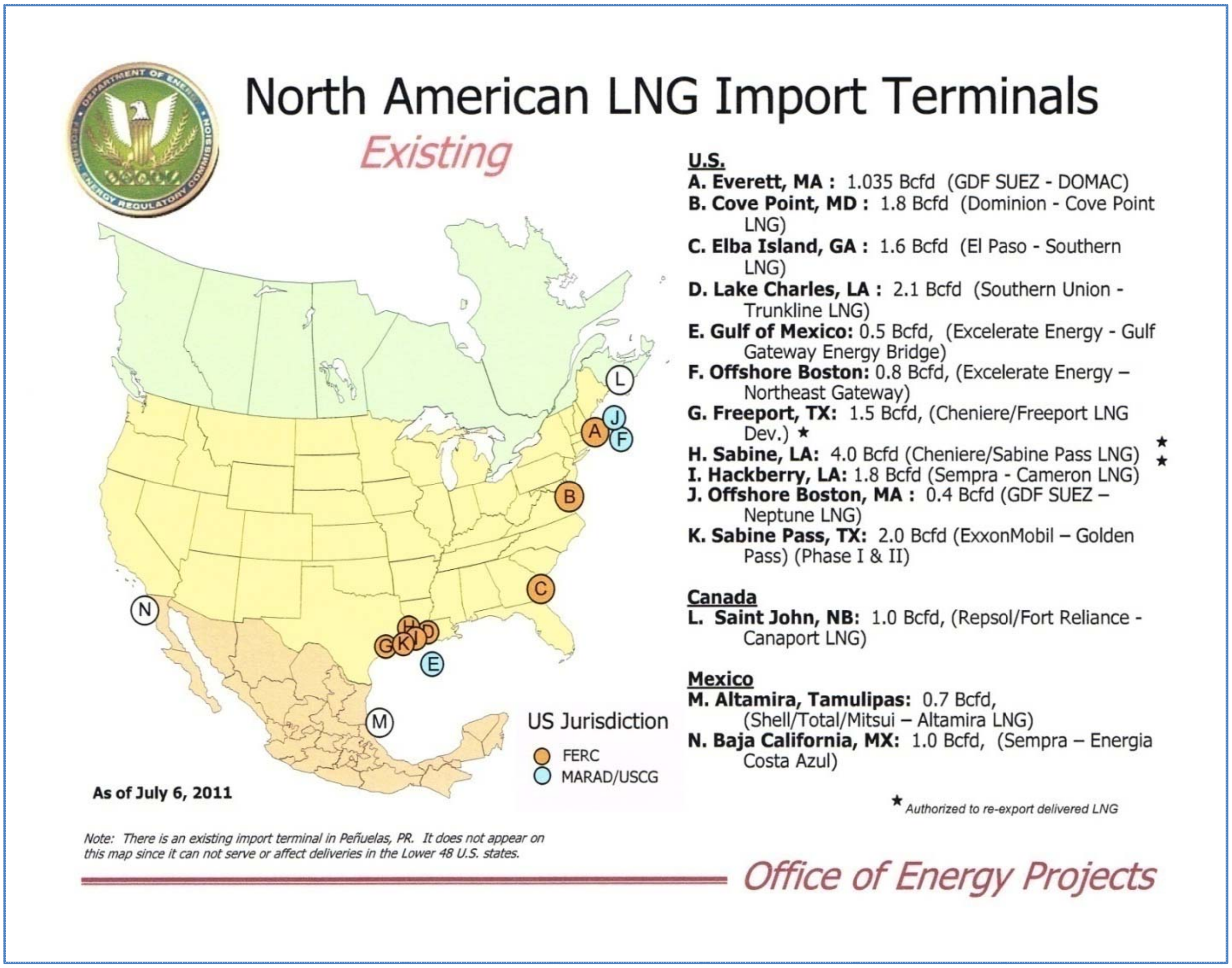
LNG facilities are primarily in the eastern United States and on the Gulf Coast. There are relatively few in the western United States and very few in the Pacific Northwest.

a. LNG import terminals

There are eleven (11) U.S. LNG import terminals in the Gulf and East Coasts, some of which are also authorized to export LNG. Each of the import facilities, with the exception of Gulf Gateway, has a regasification facility or capability to support the distribution of gas by pipeline.[23] In addition to the U.S. import terminals there is one (1) terminal in Canada and two (2) terminals in Mexico that supply the U.S. natural gas market.

[22] Centralia's Big Hanaford power plant is a major coal-fired power plant supplemented with newer natural-gas-fired units. It is the only commercial coal-fired power plant in Washington State. During the 2011 legislative session an agreement was made that will result in both coal boilers being shut down by 2025.
[23] One facility, the Gulf Gateway, handles a specialized LNG carrier that does the regasification on board.

Exhibit 16.
North American LNG Import Terminals



In addition, Sabine LA has been given provisional authority to export domestic LNG.

The Federal Energy Regulatory Commission (FERC) has the primary authority for the approval of import and export LNG terminals under the federal Natural Gas Act. But that authorization is conditioned on the applicant's satisfaction of other statutory requirements for various aspects of the project. Substantial authority exists through current federal statutes pertaining to those aspects of the project for states to authorize or block and thereby effectively veto development of an LNG facility. State permits must be issued under the Clean Air Act (Section 502), Clean Water Act (Section 401), and the Coastal Zone Management Act (Section 307A). In addition states may be a cooperating agency with FERC during the review of a project under the National Environmental Policy Act (NEPA), and can contribute to the complete environmental review of the proposal. [24]

There are two additional LNG import terminals under construction in Elba Island, Georgia, which is expanding its current location and Pascagoula, Mississippi that have met all approval processes.

[24] http://www.ferc.gov/industries/gas/indus-act/lng/state-rights.asp

There are eleven (11) import terminals that have been approved by FERC but are not under construction for a variety of reasons, including permitting difficulties, local opposition, and/or changes in market conditions that are projected to limit LNG imports with the discovery of U.S. shale gas reserves.

The closest import facility to Washington State that has FERC approval is in Coos Bay, Oregon – the Jordan Cove LNG Terminal Project.[25] The terminal would include two LNG storage tanks each with a capacity of 1 million barrels, a turbine power plant, and a single LNG carrier unloading berth. The project would connect to the Pacific Connector Gas Pipeline. A notice of intent was submitted to FERC for this project in November 2004 and the project is still in the permitting process with the State of Oregon. In June 2011, the Western Environmental Law Center asked FERC to conduct a new analysis of the LNG project, saying the developers were considering exports. In August 2011 the developers indicated that they make seek FERC approval for a dual-use import/export facility.[26] The project is controversial; with significant environmental opposition. None of the IRPs include gas from Jordon Cove in their base forecast.

b. Liquefaction and storage facilities

There are approximately 100 liquefaction and storage facilities in the United States, with most of them located in the east. Relatively few facilities are located in the west and most of those are peak-shaving facilities, which are facilities that store surplus natural gas for utilities that is to be used to meet the requirements of peak consumption later during winter or summer. Each peak-shaving facility has a regasification unit attached, but may, or may not, have a liquefaction unit. Facilities without a liquefaction unit depend upon tank trucks to bring LNG from other nearby sources to them.

There are very few liquefaction and/or storage facilities in the Pacific Northwest and those that exist are supporting the gas utilities.

- *Plymouth LNG.* NWP (Williams-Northwest Pipeline) owns and operates a liquefaction, storage, and regasification facility at Plymouth Washington. Gas from Plymouth is currently fully contracted and used primarily to meet needle peak demand, which means that it is used during periods of extremely high demand over a relatively short time (i.e. 10 days or less).
- *Gig Harbor LNG.* Puget Sound Energy owns and operates a satellite LNG facility that services its Gig Harbor area market. The plant receives, stores, and vaporizes LNG that is liquefied elsewhere.
- *Newport LNG facility.* NW Natural owns and operates a liquefaction and LNG storage facility in Newport, Oregon, which supplies the Gig Harbor LNG storage facility. NW Natural is considering the addition of a compressor that would increase output at the plant.
- *GASCO LNG facility.* NW Natural also owns and operates a LNG liquefaction and storage facility in Portland, Oregon.
- *Nampa LNG facility.* Intermountain Gas Company owns and operates a LNG facility in Nampa, Idaho.

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[25] There are three (3) other possible LNG facilities in Oregon but none of them have FERC approval at this point and all three are facing substantial financing and other problems. These include the Port Westward LNG facility, the Northern Star LNG facility at Bradwood, and the Oregon LNG facility at Astoria. An export LNG facility is proposed for Kitimat British Columbia. That project has received environmental approvals and should come on line in 2013. See *West Coast LNG Projects and Proposals* California Energy Commission June 2011 for more information.

[26] http://www.firstenercastfinancial.com/news/story/44336-williams-official-strong-interest-lng-exports-jordan-cove

- *Tilbury.* Fortis BC owns and operates a LNG facility at Tilbury on Vancouver Island. This is the supplier that BC Ferries is working with.

Terasen Gas is constructing an additional LNG peak shaving facility in Vancouver, which is scheduled to open this year. There is discussion among utilities serving Washington State of participating in a regional LNG storage facility to provide additional needed peaking capacity and some are considering additional satellite LNG storage facilities.

Permitting for liquefaction and storage facilities is subject to FERC requirements if the natural gas is intended for use in interstate commerce. There are constraints on the use of such gas. Section 4 of the Natural Gas Act (15 U.S.C. 717c) was amended in 2005 to allow FERC to grant authority to natural gas companies to "provide storage and storage-related services at market-based rates for new storage capacity related to a specific facility placed in service after the date of enactment of the Energy Policy Act of 2005, notwithstanding the fact that the company is unable to demonstrate that the company lacks market power, if the Commission determines that: 1) market-based rates are in the public interest and necessary to encourage the construction of the storage capacity in the area needing storage services; and 2) customers are adequately protected (Section 4f)."

5. Liquid Natural Gas Supply for WSF

In interviews with potential suppliers and with others, two (2) options have been identified to supply LNG for WSF needs.

- *Participate in the construction and/or operation of a LNG liquefaction and storage facility.* All of the LNG currently produced in Washington State and the Pacific Northwest is used by the utilities for peak supply or, as in the case of Plymouth, is currently fully contracted. Some of those interviewed have suggested that WSF could consider participating in the construction and operation of liquefaction and storage facility to meet its needs.
- *Truck LNG in from out-of-state.* The other option is to contract for LNG from a broker or supplier who would supply LNG by trucking it from out-of-state. New liquefaction facilities in Washington State or the Pacific Northwest might be built to meet WSF and/or demand from other sources in the future.

The consultants recommend that the State assume that LNG will be trucked to WSF terminals. Discussions with supplier indicate that LNG is available in sufficient quantities. Trucking LNG to the terminal is consistent with the practice in Norway, and other major transit agencies, such as Phoenix Public Transit which has a large LNG bus fleet. Constructing a liquefaction facility is not a viable option in the short term consideration of LNG fueled vessels because of the costs, schedule implications, and permitting difficulties.[27]

6. Liquid Natural Gas Price Forecast for WSF

The consultants have worked with the Transportation Revenue Council that provides the ULSD price forecast to develop a LNG price forecast. The consultants used the Henry Hub long-term natural gas forecast provided by WSDOT and then worked with Poten & Partners, an energy consulting firm, to develop the base price per gallon, and additional cost factors for liquefaction and transport. Poten & Partners provided a cost estimate of 30 cents a gallon for trucking LNG from Boron, California and

[27] Interviews have suggested that a small liquefaction facility could be cost approximately $15 million. However, without knowing the site or potential partners it is difficult to estimate the exact cost.

assumed a 15 percent return on investment for liquefaction. If LNG can be obtained from a facility closer to the Puget Sound it will lower the cost of transportation and provide less supply chain risk than a more distant alternative.

The consultants used the Henry Hub forecast to estimate the cost of gas going forward and then inflated the cost of liquefaction at 1.5 percent annually, a figure recommended by Poten & Partners, and used the WSDOT diesel fuel retail forecast as a basis for inflating the cost of trucking transportation. Poten & Partners cautioned that the initial delivery cost would be up to six cents a gallon higher per gallon due to the small initial demand as the LNG ferries come on line. They also believe LNG suppliers are likely to try and peg their price to the alternative source available, in this case, ultra low sulfur diesel.

In comparing LNG costs to ULSD the energy basis of the costs are compared. LNG has approximately 58 percent of the BTU content of an equivalent volume of ULSD, meaning that it takes more LNG to produce the same amount of energy as ULSD produces. The consultants multiplied the price one gallon of LNG by 1.7 to create an equivalent cost per gallon of LNG.

The forecast shows that WSF could save 47 percent per gallon on fuel in 2014 narrowing to 40 percent by 2027. The annual savings will depend on which vessels on which routes use LNG fuel.

Exhibit 17.
LNG 16-Year Price Forecast for WSF Use

Year	2014	2018	2022	2027
WSF ULSD Forecast	**$4.01**	**$4.27**	**$4.29**	**$4.33**
Henry Hub Natural Gas Price per 1 million MMBTU	$5.04	$5.68	$5.63	$6.45
Conversion Factors for Henry Hub Natural Gas Commodity to LNG Price				
Gas Gallon	$0.50	$0.57	$0.56	$0.64
Liquefaction	$0.43	$0.46	$0.49	$0.53
Trucking	$0.31	$0.33	$0.33	$0.35
Price per LNG Gallon	**$1.25**	**$1.36**	**$1.38**	**$1.52**
ULSD Equivalent Price with 1.7 G LNG=1 G ULSD Adjustment	**$2.12**	**$2.31**	**$2.35**	**$2.58**
Savings Per Gallon	**$1.89**	**$1.96**	**$1.94**	**$1.75**
Percent Savings	**47%**	**46%**	**45%**	**40%**

a. Liquid Natural Gas Price Forecasting for Other Agencies

The consultants discussed LNG price history and forecasting with Phoenix Public Transit, who have been using LNG in their bus fleet for a number of years, and BC Ferries, who are undertaking a feasibility study for the conversion of a diesel ferry to LNG.

Phoenix Transit uses 11.5 million gallons of LNG annually, which is approximately twice the amount WSF would use in a year if all six (6) Issaquah class ferries were converted to LNG. Phoenix does not forecast LNG prices other than for short term budgeting. In the near term for budgeting they assume a 5 percent per year increase.

The price per gallon they have paid for LNG delivered, excluding taxes, is shown in the exhibit below. Phoenix is paying $1.05 per gallon before tax in 2011 and is at the end of a three (3) year contract with Clean Energy.

As shown in the exhibit below, Phoenix has experienced considerable volatility in LNG fuel costs, with costs peaking in 2008.

Exhibit 18.
Phoenix Transit LNG Cost per Gallon FY 2004-2011

Fiscal Year	2004	2005	2006	2007	2008	2009	2010	2011
Price	$0.63	$0.68	$0.69	$0.70	$1.60	$0.87	$0.99	$1.05
Increase		**8%**	**1%**	**1%**	**129%**	**-46%**	**14%**	**6%**

BC Ferries solicited input from three forecasting firms and found that all three came back showing stable prices going forward, with a small narrowing of the price gap between natural gas and diesel. They have discussed a price including taxes and delivery with their potential local supplier and currently forecast a 60 percent savings with LNG based on July, 2011 natural gas spot and diesel prices.

b. Interviews with Suppliers and Brokers

The consultants also interviewed five (5) potential suppliers and brokers of LNG.

There is capacity to truck LNG from California or Wyoming currently but the suppliers indicated it would be less cost-efficient than if there were a local source available. All five mentioned that they were pursuing, or knew of potential plans for, expanded LNG facilities in the northwest that could potentially supply LNG to WSF if there is enough overall market demand.

E. LNG Vessel Operations

1. Bunkering

Bunkering (i.e. refueling) of LNG vessels is one of the significant areas that needs to be addressed when considering LNG. There are two basic alternatives for fueling ferries:

- Fueling by tanker truck, where the truck drives on to the vessel when it is docked or,
- Fueling from a fixed shore facility constructed especially for that purpose with a fixed tank, pier, chicksan arms and all associated terminal systems.

In Norway vessels are re-fueled both ways. The differences between the two approaches include:

- *Site development.* While there is little site development to accommodate a tanker truck at a WSF terminal, a fixed terminal requires funding, design, permitting, and construction.
- *Disruption of the WSF fleet*. Tanker trucks can fuel LNG ferries at most locations as is done with the current diesel fleet. If WSF were not able to provide a fixed terminal installation at each terminal at which it fuels vessels, a vessel would be required to travel to a central fuel facility to fuel. This could have the effect of diminishing the fuel cost saving by requiring the ferries to perform non-revenue trips.
- *Norway.* Norwegian Ferry owners, given a choice, prefer the fixed terminal to ensure delivery (provided they do not have to go too far to get to the terminal). The fixed terminal personnel handle all fuelings and as that is all they do, the fuelings are carried out on a consistent basis.

2. Impact of LNG on Vessel Speed, Performance, and Maintenance

The impact of LNG on vessel speed and performance should be minimal, but based on Norway's experience maintenance costs can be expected to be higher. The best way to address the impact of LNG on vessel speed, performance, and maintenance is to analyze its impact on a specific vessel. The consultants used the new 144-car vessel design as the test case.

Converting the present 144-car design from diesel fueled main engines to LNG fueled main engines requires the addition of LNG tanks and supporting structure, LNG processing equipment and some machinery additions. LNG fueled main engines are heavier than the exiting proposed diesel main engines.

In the present 144-car design, the auxiliary engines which supply electrical power to the vessel remain diesel because no LNG engine manufacturer has engines in the needed power range. This means that diesel fuel will still need to be carried on the vessel.

a. Weight, Draft, Speed and Stability Changes

As proposed by WSF, the LNG fueled new 144-car ferry will have a slightly larger draft than the diesel powered new 144-car ferry. The additional LNG tanks, machinery and processing equipment will increase the vessel weight when empty (lightship) by about 4 percent which will be offset to some extent by the reduction in fuel weight. This will result in 60 to 80 tons of displacement.

This larger draft will have a minimal effect on the vessel. The consultants do not believe this will have a significant effect on the service life margin, on the allowance for additional weight of added equipment in response to regulatory changes or operational need, speed, stability (may have slightly more roll but would be undetectable on most routes), or steering. See Appendix A for a more detailed discussion of the impacts.

b. Stopping Distance and Acceleration/Deceleration

The added 60 to 80 tons of displacement should have a minimal effect on stopping distance as it is only about a 1 percent difference. The response time of LNG fueled engines is longer than conventional diesel fueled engines, thus the LNG fueled ferry might require slightly more time to stop (in an equivalent distance) than the diesel fueled ferry.

c. Maintenance

Several factors must be considered in evaluating the effect of LNG use on maintenance. First, the LNG manufacturers contend that the cleaner burning LNG fueled engines should have longer intervals between overhauls, which could reduce out of service time.

Second, the Norwegian experience has been that maintenance costs on LNG fueled systems are 10-20 percent higher than on similar sized diesel fueled engine systems due to the additional equipment required for LNG operation, and the fact that much of that equipment requires higher technology repair and maintenance than diesel equipment. On the other hand, the same Norwegian operators have reported increased intervals between LNG fueled overhauls. They have been opening up the engines at the present recommended intervals for diesel engines, 16,000-20,000 operating hours, and discovering that the valves and valve seats (that usually need repair when running on diesel) look like new. Fjord1 has asked the manufacturers to extend the interval period for LNG engines to 30,000 operating hours, but nothing has been done yet.

Third, there will be additional maintenance costs related to the cryogenic piping and LNG storage tanks.

F. LNG Vessel Design Considerations

1. Engines Sole or Dual (with ULSD) Options

There are two (2) types of LNG fueled engines – single fuel/LNG only engines and dual fuel engines which can run on either LNG or diesel. Rolls-Royce manufactures a single fuel/LNG only engine and Wärtsilä manufactures a dual fuel engine in the size category required for the new 144-car ferry or a retrofit of an Issaquah class vessel. Neither engine has been approved for use in the U.S. by the EPA. Both manufacturers anticipate approval in the first quarter of 2012. Other manufacturers are also working on marine gas fueled engines.

As discussed below, a single fuel/LNG only engine provides greater emissions reduction, is more fuel efficient, and may be more operationally reliable for ferries. The advantage of a dual fuel engine is that it can run on either diesel or LNG so that it in the event of a large price disparity, or supply shortage, the operator has the option to switch to a single fuel option.

a. Fuel Flexibility

The dual engine can be run in the diesel mode only or in the LNG mode with a small (i.e. <1 percent) amount of diesel as an ignition source when operating in the LNG mode. This provides greater flexibility to the operator for variations in fuel source. As noted by DNV in their February 2011 article *Greener Shipping in North America:* "The dual fuel engine, which runs on both LNG and conventional fuel, is a flexible solution when the availability of LNG fuel is uncertain. In LNG mode these engines only consume a minor fraction of conventional fuel. The lean burn mono fuel engine gives a simpler installation onboard and is a good choice when LNG availability is secure and there will not be a need for alternative fuel."

In correspondence with the consultants, Rolls Royce notes that their single fuel/LNG only engines have been derived from an existing diesel engine. Therefore, their gas engines can be converted to diesel operation by changing certain components relative to fuel supply and combustion.[28]

b. Emissions

While both engines meet the Tier III requirements, the single fuel/LNG only engine has lower emissions. A primary reason for this is the use of diesel fuel when a dual fuel engine is operating at low RPM's. Ferries idle while in port keeping the propellers moving forward at low speed to keep the ferry in the berth. For a dual fuel engine, the exhaust from the engine in this mode contains more pollutants, as the engine is running largely on ULSD, than would be the case for the single fuel/LNG only engine which is running solely on gas in all modes of operation.

c. Reliability – Ferries Operation

Double-ended ferries, such as WSF's and those that have been built in Norway are powered from each end and dock many times a day. The low speed maneuvering response time is better in a single fuel/LNG only engine than in a dual fuel engine, which is particularly important when docking. Correspondence with Fjord1 indicates that they would not consider a dual fuel engine because of this potential reliability constraint.

For a technical discussion, see Appendix A.

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[28] Rolls Royce also represented that they would consider converting the engine back to diesel at their expense if WSF decided to do that. That however would be subject to WSF's engine decision and subsequent negotiations.

d. Fuel Efficiency

Dual fuel engines have lower fuel efficiency than the single fuel/LNG only engines. Under the present new 144 re-design concept for either option, the auxiliary engines remain diesel fueled because there are no LNG auxiliaries presently available that fit within the power range needed. The consultants understand the USCG prefers the existing type of engine room selected but this will complicate maintenance and operation with two fueling systems and the full cost savings of powering all machinery with LNG will not be realized

G. Regulatory Requirements – Operations and Design

There are regulatory differences between diesel and LNG fueled ferries. The USCG has not developed rules governing the design, construction and operation of LNG fueled passenger vessels. This introduces an element of regulatory uncertainty that is not present when designing and building a diesel fueled vessel.

WSF's conceptual design work for the re-design of the new 144-car ferry, much of which has been done by their contracted naval architect The Glosten Associates, is the most advanced design work that has been done in the United States on a LNG fueled passenger vessel. If the new 144-car ferry is built as an LNG fueled vessel or an Issaquah retrofit is undertaken it will most likely be the first LNG fueled passenger vessel subject to U.S. regulations.

This section discusses the major regulatory agencies, regulations regarding the design and construction of LNG vessels, and operational regulations.

1. International Maritime Organization (IMO)

IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. IMO, through working groups comprised of all interested countries, produces International Codes governing the carriage of all manner of cargoes. IMO Resolution (MSC.5 (48) covers the construction and equipment of ships carrying liquefied gases in bulk. One of those liquefied gases is LNG.

IMO has passed Resolution MSC.285(86) (reference (b)), "Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations in Ships", but it is a guideline, and not considered an international convention as it has not been vetted; as such, it is at the discretion of the flag state as to whether to accept these rules.

DNV rules, discussed below, very closely follow these guidelines.

2. Det Norske Veritas (DNV)

DNV is a Norwegian classification society organized as a foundation, with the objective of "safeguarding life, property, and the environment." DNV describes itself as a provider of services for managing risk. Together with Lloyd's Register and American Bureau of Shipping, DNV is one of the three major companies in the classification society business.

DNV has classed (i.e. developed applicable rule requirements and certified that the vessels conform to those requirements) all existing LNG fueled vessels, including ferries, and therefore has the most experience and the best established rules concerning LNG fueled vessels. In their rules, Part 6, chapter 3 of "Gas Fueled Engine Installations", under paragraph A100 on page 107, entitled "Application", Guidance note 1, they note that the use of gas as a fuel in ships, other than LNG tanker ships, is not presently covered by international conventions and thus such installations will need additional acceptance by the flag state.

3. United States Coast Guard (USCG)

The USCG's roles are maritime safety, maritime security, and maritime stewardship. To carry out those roles the Coast Guard has 11 statutory missions as defined in 6 U.S.C. § 468. When DNV indicates LNG fueled vessels need additional acceptance by the flag state that means by the USCG for U.S. flagged vessels.

The USCG does not have rules for LNG fueled passenger vessels, but has agreed to recognize IMO Resolution MSC.285(86), "Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations in Ships". The USCG has provided to WSF/Glosten significant additional guidance which is discussed below.

a) Design and Plan Approval

In the absence of specific rules, the USCG can review and approve alternative designs under 46 CFR 50.20-30 - Alternative materials or methods of construction which states:

> (a) When new or alternative procedures, designs, or methods of construction are submitted for approval and for which no regulations have been provided, the Commandant will act regarding the approval or disapproval thereof.
>
> (b) If, in the development of industrial arts, improved materials or methods of construction are developed, their use in lieu of those specified will be given consideration upon formal application to the Commandant, with full information as to their characteristics, together with such scientific data and evidence as may be necessary to establish the suitability of such materials or methods of construction for the purpose intended.

Because the USCG has not yet adopted rules in the Code of Federal Regulations (CFR) addressing the design of LNG fueled passenger vessels and must instead rely on 46 CFR 50.20-30, American ship builders and designers have an uncertain regulatory environment within which to design and construct LNG fueled passenger ferries.

In using its authority under 46 CFR 50.20-30 to review LNG fueled passenger vessels, the USCG is relying on IMO and, to some extent, DNV rules.

With CFR and classification rules in place the process, such as with a diesel fueled passenger vessels, involves designing the vessel to those rules and submitting the developed design to the USCG and classification society for approval. In these circumstances the USCG will not start review of a design until there is a letter of intent or contract with a shipyard as they have limited resources to carry out plan approval. In recent years, to reduce the plan approval and inspection load on the USCG, the Alternate Compliance Program has been developed where the classification society takes over most of the USCG design approval and shipyard inspection role. Depending on the type of vessel, the USCG might still reserve approval and inspection rights for certain systems.

For LNG fueled passenger vessels, the lack of specific regulations will mean that the USCG will play a larger role in plan approval. WSF/Glosten submitted a *Regulatory Review of Concept* for the new 144-car vessel which contains a general narrative of the intended design. The review concludes with conclusions and critical review items to show the USCG where the greatest uncertainties lie and, most importantly, the review contains appendices that tabularize DNV and IMO rules with comments as to how the design meets, or cannot meet, those rules.

The USCG responded to the 144-car vessel *Regulatory Review of Concept* with a letter that will be the basis for the USCG design review of the new 144-car LNG fueled ferry. This letter states: "The Marine Safety Center (MSC) will use this regulatory design basis letter and applicable regulations and standards to complete plan review. Please note that due to your proposed use of LNG fueled propulsion systems, MSC may identify additional detailed design requirements in areas not addressed in this regulatory design basis agreement during the course of plan review. As always, the Officer in Charge, Marine Inspection may impose additional requirements, should inspection during construction reveal the need for further safety measures or changes in construction or arrangement" (USCG letter July 1, 2011).

This is an important aspect in contracting for the first new build, or conversion, of a LNG fueled ferry in the U.S., as it is doubtful the contracting shipyard would accept the normal responsibility to build a vessel to the various rules as their responsibility. Thus, there is more cost liability in the construction, or conversion, of the first U.S. LNG fueled ferry than would be the case for a conventionally fueled ferry, or a subsequently built LNG fueled ferry.

The same *Regulatory Review of Concept* was sent to DNV for review which also responded.

A *Regulatory Review of Concept* was submitted to the USCG for the Issaquah class vessels in September 2011.

The IMO rules (Chapter 2, paragraphs 2.1.1 and 2.1.2), and the similar DNV rules, require something that is not normally carried out in contract design, that of a risk analysis of how the LNG fuel and storage systems affect vessel structure and other systems. The designer is to show how these risks are to be eliminated or minimized. An operating manual is required in which these risks and reactions/mitigations are to be detailed.

The reason for this additional requirement is the complexity involved in designing a fueling system with a great deal more risk than an oil fuel system. The operation of LNG fueled vessels requires greater training, critical detection systems and emergency shutdown systems that operate 100 percent of the time, and, in general, a higher level of formalized operation and maintenance.

It should also be expected that the creation of plans and specifications dealing with a LNG fueled ferry and the relevant approval process will take significantly longer for the first U.S. LNG fueled ferry than it would for a conventionally fueled ferry, or subsequent LNG fueled ferries.

b) Construction and Inspection

As the USCG will play a significant role in plan approval, the use of the Alternative Compliance Plan (ACP) in which the classification society takes the role of plan approval on behalf of USCG is not possible. In this case, both the classification society and USCG will have to approve construction.

ACP came about through complaints from U.S. ship owners and shipyards that the cost of dual USCG/ classification approval and inspection was one reason U.S. vessels cost more than those built elsewhere. Thus, some additional confusion and resultant cost can be expected from the dual inspection.

c) Major Conversion

Under USCG rules, if a vessel undergoes a certain level of re-design or change, it may be classified as a "major conversion". If the USCG decides that a proposed conversion is a major conversion then the ship owner is required to update the vessel to meet all current regulatory requirements. For a 30-year vessel such as the Issaquah class vessels, this could add considerable cost. Title 46, United States Code (USC), 2101 (14a) defines major conversion as an action that:

a. Substantially changes the dimensions or carrying capacity of the vessel;
b. Changes the type of vessel;
c. Substantially prolongs the life of the vessel; or
d. Otherwise so changes the vessel that it is essentially a new vessel

The legal arm of the USCG, the office involved with vessel documentation, makes these determinations. Many have resulted in prolonged legal cases, such as Matson conversion, and the decisions are not always consistent in the consultants' view.

d) Operations

This is the least defined aspect of a LNG fueled ferry project from a regulatory standpoint. Operational requirements have not formally been discussed with the USCG. The local OCMI (Officer in Charge of Marine Inspection) will have to be engaged about vessel operations as he determines the vessels safe operation and is responsible for the issuance of the Certification of Inspection (COI) before the vessel is authorized to sail.

Some information about possible USCG requirements for LNG ferry operation can be gleaned from the USCG rules regarding LNG carriers and tankers while in U.S. waters.

4. USCG LNG Carrier Operations Rules

The USCG Captain of the Port establishes rules for the operation of LNG carriers at each Port. As an example of one such set of rules, the consultants have reviewed the Cove Point Maryland LNG Tanker COTP (USCG Captain of the Port) regulations which cover both vessels and waterfront facilities.[29] These regulations are incorporated in *the Chesapeake Bay Liquefied Natural Gas (LNG) Operations Management Plan*.

This approximately 50 page document is a developed set of rules under which LNG carriers are unloaded at a Chesapeake Bay LNG facility. The operation of LNG from a carrier is not equal to fueling a ferry with LNG; however, there are some similarities.

It is likely that the USCG will require a COTP plan for LNG fueling of any LNG powered vessel.

Based on the Chesapeake Bay Management Plan areas that could be covered for LNG powered vessels include:

- Bunkering (i.e. re-fueling)
  - USCG supervision of re-fueling and testing of shut down and gas detection systems.
  - Training of ship crews and shore personnel
  - Specification of a person in charge.
  - Requirements for having specified positions covered during fueling.
  - Length of duty restrictions for those involved in fueling.
  - Restricted areas of operation during fueling.

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[29]The United States Coast Guard derives its authority to develop regulations governing LNG vessels and waterfront facilities from the following: (1) Port and Tanker Safety Act of 1978 (46 United States Code (USC) § 3703 and 46 USC § 3305); (2) Ports and Waterways Safety Act of 1972 (33 USC §1221 et seq.); (3) The Magnuson Act (50 USC § 191); (4) Executive Order 10173 (as amended by Executive Orders 10277, 10352nd 11249); (5) Transportation Safety Act (49 USC § 1671 et seq.); and (6) Maritime Transportation Security Act of 2002 (Public Law 107-295)

- o Transit – vessel operations
- o Special crew training or staffing requirements

The July 2011 letter from the USCG that provides the basis for design review notes that the vessels Certificate of Inspection will most likely include a condition that “at a minimum LNG bunkering operations are not allowed while vehicles or passengers are on the vehicle deck” (USCG July 1, 2011 pg. 2).

SECTION V. WSF LNG STATUS

This section provides an overview of work done by WSF on the use of LNG, which is a combination of efforts by WSF staff and The Glosten Associates, a Seattle based naval architecture firm. The consultants will compare WSF work with its own independent findings in the final report.

WSF reports reviewed are:

- *LNG Use for Washington State Ferries March 2010, The Glosten Associates.* This report provided an initial assessment and overview of the use of LNG for WSF vessels concluding that retrofitting an existing vessel to LNG technology would likely not be cost effective with the storage tanks below the main deck. (The report was done before the decision to place the storage tanks above the passenger deck.) The report concluded that a redesign of the new 144-car vessel for LNG use would most likely be cost-effective.
- *144-Car Ferry LNG Fuel Conversion – Regulatory Review of Concept – May 2011, The Glosten Associates.* This report was submitted to the USCG and DNV for review and led to the USCG letter that provides the basis for the re-design of the new 144-car vessel.
- *144-Car Ferry LNG Fuel Conversion Feasibility Study –Design Report– July 2011, The Glosten Associates.* This report provides a concept design for the conversion.
- *144-Car Ferry LNG Fuel Conversion Feasibility Study – Life Cycle Cost Analysis – July 2011*, *The Glosten Associates.* This report provides a 30-year life cycle cost analysis comparing the LNG 144-car ferry options with the current diesel design.
- *The Use of LNG as a Fuel on the Issaquah Class Passenger Ferries in Puget Sound – Sept. 2011, WSF Engineering Staff.* This document was submitted by WSF to the USCG and DNV for review of the retrofit of an Issaquah class vessel. In this design the storage tank is above the passenger deck.

A. New 144-Car Vessel

1. Design

The conceptual design of the new 144-car vessel with LNG is shown in the exhibit below.

Exhibit 19.
New 144-Car Vessel with LNG Concept

Key features of the new 144-car vessel design are:

- *Design basis.* The Seattle-Bremerton route was used as the design route for the tank sizing and endurance calculations.
- *Engine room.* There are two (2) types of engine room design: intrinsically safe and emergency shutdown (ESD) WSF design is for an intrinsically safe engine room. Fjord1's engine rooms are ESD.
- *Engine options.* The design report studied two engine options, both of which provide gas fueled inherently safe engines of appropriate power: a dual fuel (LNG/diesel) design with equipment provided by Wärtsilä; and a single fuel (LNG) design with equipment provided by Rolls Royce. The power output of the gas engines was selected to be compatible with the gears, propellers and shafting already purchased by WSF.
- *LNG fuel storage tank and fuel delivery.* The tank is above the passenger deck on the bridge deck with a capacity of 7.5 days of endurance, which requires approximately 50,000 gallons of tank capacity. "In the next phase of the design it will be necessary to revisit the vessel endurance. Working closely with the tank manufacturer(s) it will be necessary to determine the maximum endurance that can be achieved while keeping the fuel sufficiently cold. Working closely with the LNG supplier(s) it will be necessary to structure the fuel delivery such that the fuel can be delivered reliably without interruptions (pg. 8)."
- *Bunkering.* Bunkering is assumed to be by truck at night between the last run of the day and the first run of the next day. The assumed bunkering schedule is fueling every two (2) to three (3)

days with a truckload of approximately 10,000 gallons of LNG. The bunker station will be located at both ends of the vessel on the main deck at the side shell.

- *Auxiliary generators.* The auxiliary generators are assumed to be diesel fueled. The design report notes that "there is a possibility that a significant fuel cost savings could be achieved using shaft generators, however this will need to be investigated further in a separate study" (p. 26).
- *Impacts to existing design- future design studies.* The design report notes impacts on the current design and identifies areas where further modifications may be necessary. Examples of areas that may require further design include: removal of existing diesel tank structure to reduce construction costs; utilizing waste heat from the low temperature cooling circuit to meet hot water requirements; structural modifications to support either the single or dual LNG storage tanks.
- *Regulatory review.* In the regulatory review and design report documents Glosten noted a dialogue was established with the Coast Guard and the classification society DNV. The Coast Guard indicated a gas fueled vessel may be submitted for review and approval as an alternative design under 46 CFR 50.20.30. Both the Coast Guard and DNV provided letters that will provide a basis for future review and approval of a gas fueled vessel design.

2. Life-Cycle Cost

In its life-cycle cost analysis Glosten looked at capital costs using vendor supplied estimates, shipyard installation, design engineering, existing equipment owned by WSF as part of the original 144 procurement, other design changes, and operational and maintenance costs. The report found that LNG would necessitate a higher capital expenditure but estimated a cost savings of approximately $1 million annual operational cost savings for a payback of approximately 6 years assuming operation on an average route.

Capital costs

The capital costs included in the Glosten analysis are shown in the exhibit below. For the dual fuel Wärtsilä engine option additional capital costs are estimated at $9.3 million, for the single fuel engine by Rolls Royce at $10.7 million, and for the current design $2.5 million.

Exhibit 20.
WSF New 144-Car Vessel Capital Cost Comparison LNG Options and Diesel
($ millions)

Description	Dual Fuel Engine LNG/Diesel	Single Fuel Engine LNG	Diesel (current design)
Construction (per vessel)	$8.5	$9.9	$2.5
Design Costs (one-time)	$0.8	$0.8	$0
Total	**$9.3**	**$10.7**	**$2.5**

Operations costs

Glosten used a LNG price per gallon of $1.05 and $3.65 per gallon for marine diesel. An assumption of 3 percent annual inflation was used for both diesel and LNG.

Maintenance and repair costs for the engines were compared based on information from Rolls Royce and EMD, the supplier of the diesel engine. Maintenance and repair costs were also estimated for the gas system. An annual 6,000 hour maintenance interval was assumed for routine maintenance and it was assumed that all tanks, gasification equipment, and gas supply units would undergo an overhaul every 30,000 hours or 5 years.

Exhibit 21.
WSF New 144-Car Vessel First Year Operations Cost Comparison LNG and Diesel Per Vessel
($ millions)

Description	Dual Fuel Engine LNG/Diesel	Single Fuel Engine LNG	Diesel (current design)
Fuel Oil	$0.1		$2.5
Fuel Gas	$1.4	$1.3	
Engine M&R	$0.3	$0.1	$0.2
Total Nominal	**$1.8**	**$1.4**	**$2.7**
Present Value (3%)	**$1.7**	**$1.4**	**$2.6**
Present Value (5%)	**$1.7**	**$1.3**	**$2.6**

Life-Cycle Cost

Glosten found the following 30 year lifecycle cost not including sunk capital or additional non-recurring initial design costs of $0.8 million for the two gas options compared to the diesel fueled engine design. The single fuel engine LNG option as the lowest life-cycle cost.

Exhibit 22.
WSF 30 Year-Life Cycle Cost Summary per Vessel
($ millions)

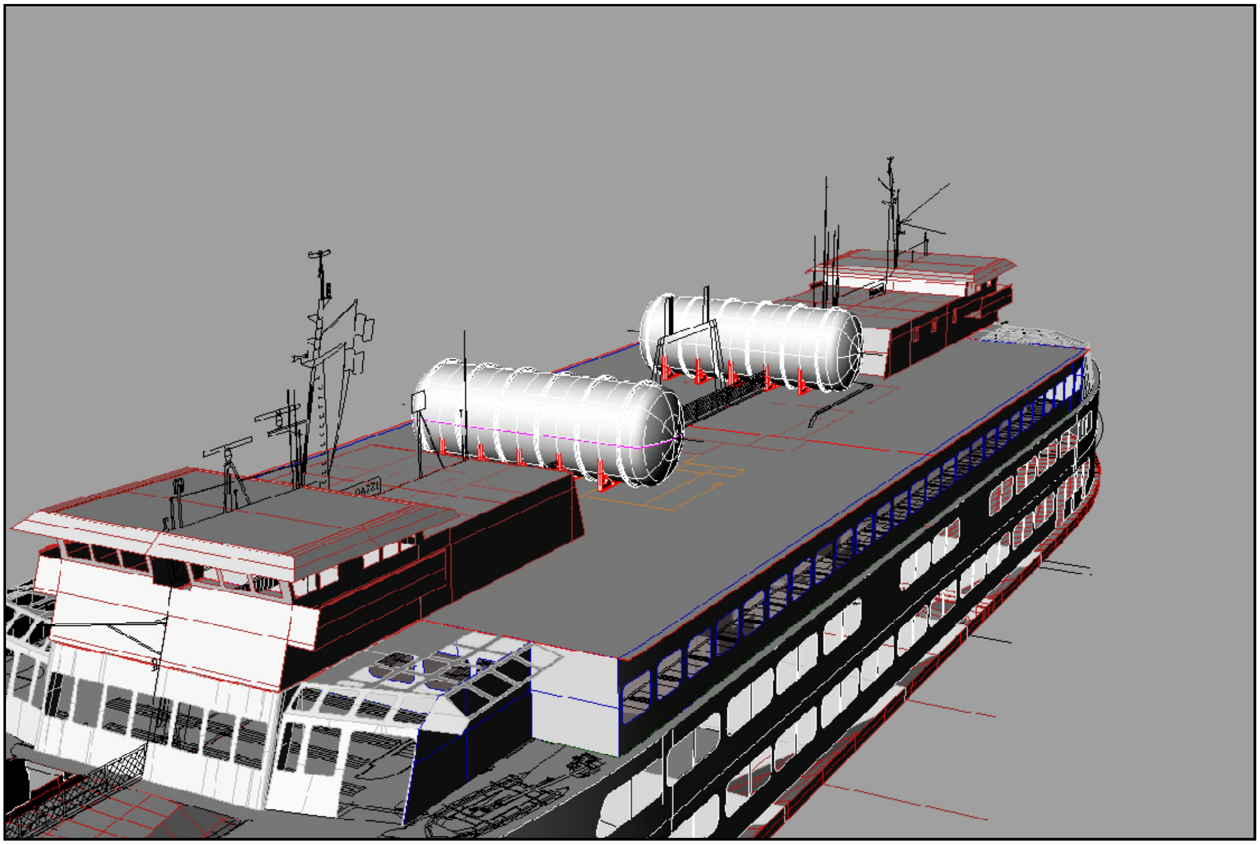
Description	Dual Fuel Engine LNG/Diesel	Single Fuel Engine LNG	Diesel (current design)
Projected cost (nominal)	$93.1	$77.0	$130.0
Present value cost (3% discount)	$60.3	$51.0	$80.6
Present value cost (5% discount)	$47.5	$40.8	$61.2

B. Issaquah Conversion

The design basis for the Issaquah class retrofit is the same as the new 144-car vessel. WSF submitted the regulatory review report to the Coast Guard and DNV in mid-September.

The concept for the storage tanks in the Issaquah class retrofit it shown in the exhibit below.

Exhibit 23.
Issaquah Class Vessel LNG Retrofit Concept Drawing



WSF estimates that retrofitting all six (6) Issaquah class vessels will cost $65.0 million and generate annual fuel savings of $9.8 million. The estimated payback period is 7 years. The present value of the savings over 30 years is $75.9 million.

C. Schedule

The exhibits below shows WSF estimated schedule for the new 144-car vessel construction under the current legislative assumption of one (1) new 144-car diesel vessel and one (1) LNG and the schedule for the retrofit of the first Issaquah class vessel.

Under the LNG schedule, the second new 144-car vessel would be delivered in 2016 assuming funding and authorization were received to start design in February 2012.

For the Issaquah class retrofits, WSF's schedule assumes a six (6) month construction for each vessel, following an approximately 18 month design, regulatory review, and bid process.

Exhibit 24.
WSF Two (2) New 144-car Vessel Timeline – One (1) Diesel and One (1) LNG

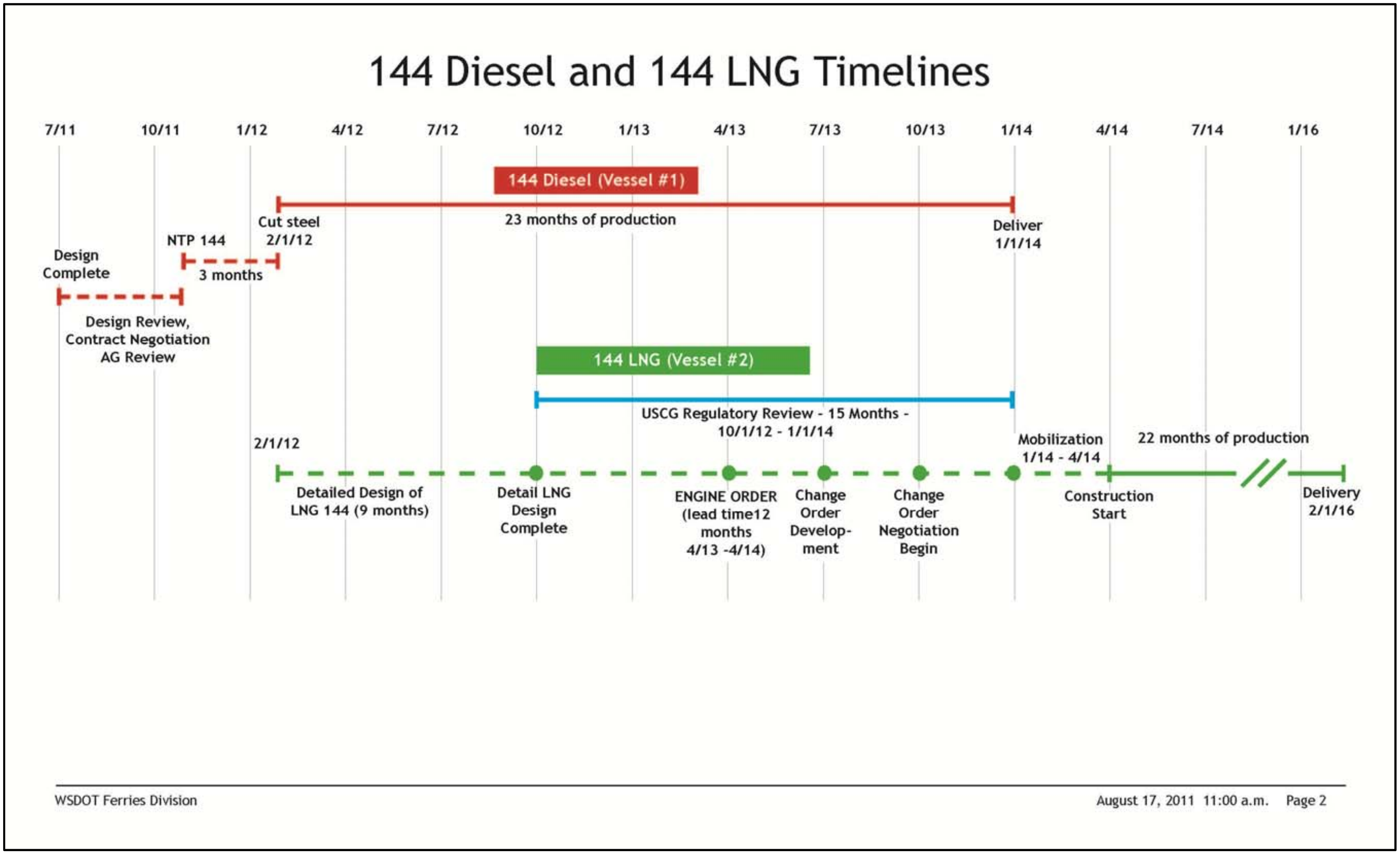
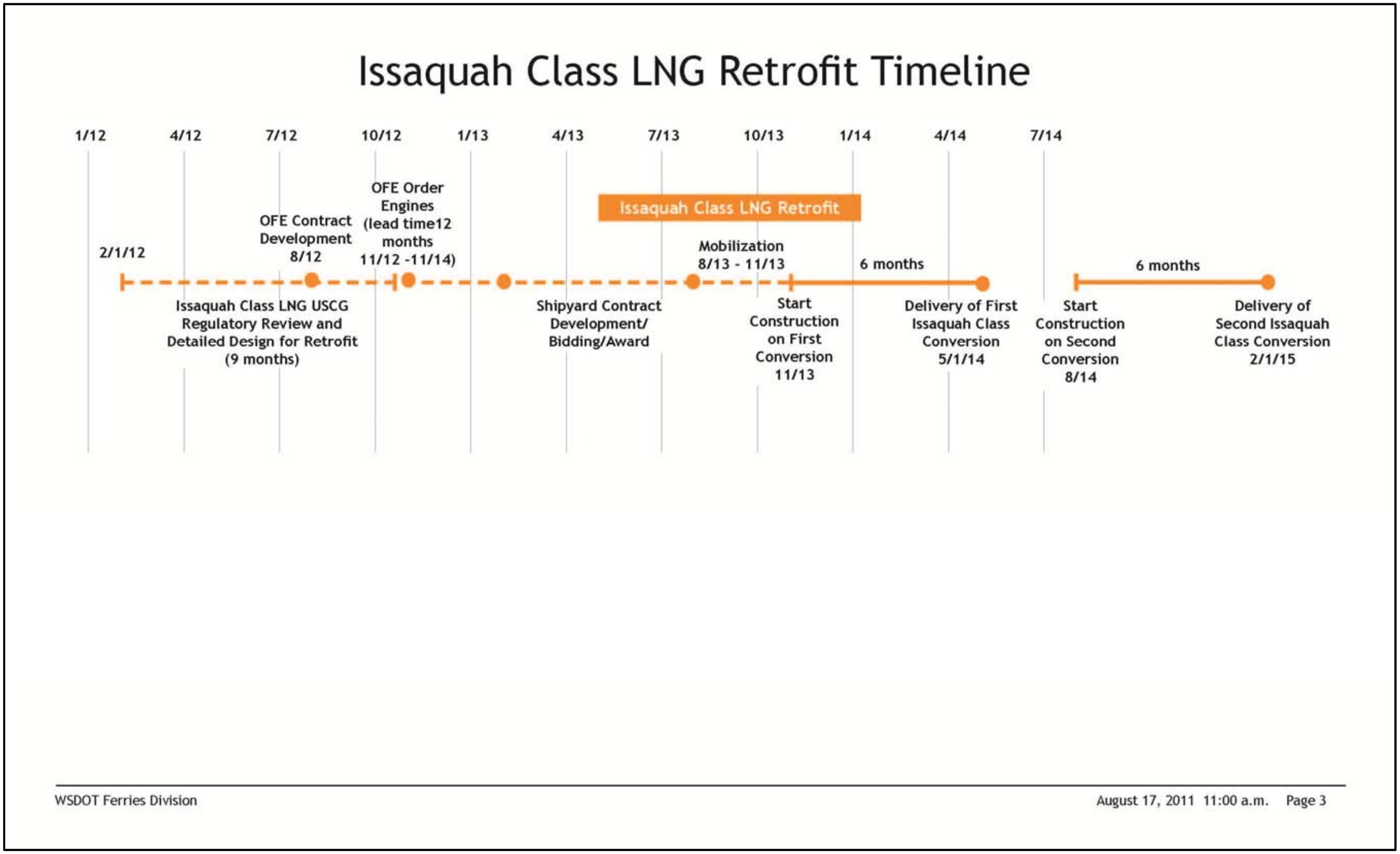


Exhibit 25.
WSF Issaquah Class LNG Retrofit Timeline



SECTION VI. LNG CONSIDERATIONS

The legislature directed the JTC to conduct this study because of concerns regarding the full potential cost of LNG. The consultants have outlined below the key considerations for LNG.

Area	Consideration	How Address
WSF Fleet Plan	New 144-Car Vessel • Impact on fleet acquisition& deployment • Impact on service plan	• Independent review of schedule • Fjord1 review • Recommend sequencing to minimize fleet disruption
	Issaquah Class Retrofit • Fit within fleet maintenance schedule • Impact on service	
	New 144-Car Vessel & Issaquah • Sequencing	
	Other Vessels	• Other WSF vessel potential for LNG
Design	Vessel	• Engine options • Other technical recommendations
	Terminal	• Bunkering support
Capital Cost	Vessel	• Assess total project cost • Independent review
	Terminal	• Bunkering support costs
	Preservation – Vessel & Terminal	• Base on Norway experience • Relate to WSF Life-Cycle Cost Model
Operations Cost	LNG Fuel	• Supply review • Price projection • Contract terms • Assess fuel quality variability • Bunkering options review
	Maintenance	• Review Norway experience (10 to 20 percent higher)
	Staffing	• Crew training • Manning requirements • Pay rate
	USCG Operations Requirements	• Base on requirements for LNG carriers • Discussions with USCG
Security	Vessel Terminal	• Independent review • Emergency management review
Life-Cycle Cost	Vessel & Terminal	• Operations & capital costs • Independent review
Public Reaction	Concerns about LNG	• Review with operators & suppliers

APPENDIX A. IMPACT OF LNG USE ON VESSEL SPEED, PERFORMANCE

Weight and Draft

The empty weight (lightship) will be about 150 tons heavier than the presently designed diesel oil fueled main engine 144. Thus, the lightship weight will be increased by about 4 percent. As LNG fuel is about half the specific gravity of diesel oil, there are some reductions in fuel weight; however, overall, it appears the LNG fueled ferry will operate slightly deeper than the draft conditions presently estimated for the 144 diesel fueled design. The amount of draft overage depends on the load of passengers and cars, the route and other factors.

It is estimated that in all of the operating conditions possible that this additional draft would be about 1.5 to 2.0 inches or about 60 to 80 tons more displacement. This amount is considered to have no major effects on performance.

The Service Life Margin

The service life margin is an allowance for additional weight that might be added to a vessel during its life and allows weight modifications from regulatory changes, or other operating necessity, to be accommodated within the vessel without exceeding maximum draft, or stability limits.

The service life margin for the diesel fueled 144 the draft amounts to 338 tons and increases the design draft by about 8 inches. For the LNG fueled 144 design, you must add the 150 tons (above) and the 338 tons service life margin to get the LNG fueled 144 service life margin. This equates to about 500 tons additional displacement as an allowance, or about a 14% increase in displacement.

The worse case of a fully loaded LNG fueled 144, with service life margin applied, results in a departure draft of 17.6 feet and an arrival draft of 17.34 feet which is a 1.7 inches greater than the diesel fueled main engine 144, as presently designed. The consultants do not consider the differential between the diesel oil fueled and LNG fueled 144 to have a major effect on performance.

Power Installed for Propulsion

The present 144 diesel fueled main engine design shows 6000 HP as the installed power.

Both the Rolls Royce and Wärtsilä LNG fueled main engines provide about the same installed power, at about 5900 HP for the Rolls RoyceC26.33L9PG engine and 6168 HP for the Wärtsilä 6L34DF engine.

Speed

The models tests for the 144 design, carried out at SSPA, show, for a draft of 16.4 feet, that 4960 HP (3700 MW) of power is required for 17kts (the design speed) on trials (clean bottom, light sea). This equates to 82 percent of the installed power for propulsion.

Using 100 percent of the power installed for propulsion (6000 HP) would allow a speed of about 18knots, in the same trial condition. The consultants do not have model test data based upon 17+ feet of draft, so we have estimated that if there is sufficient installed power in the present diesel fueled 144 design to make the 17 knot design speed, including the effects of the Service Life Margin, then the LNG fueled option should perform the same.

Stability

The conversion of the 144 from diesel fueled to LNG fueled raises the center of gravity of the 144, in all cases. This has the effect of allowing the ferry to roll and heel slightly further in equivalent seas, or wind; however this effect also gives a motion that should be slightly easier (more comfortable).

There is not much additional wind bearing area of the above deck mounted LNG equipment as the equipment is mounted behind of existing structure.

In every case, the LNG fueled ferry will be considered to be well within the “safe area” as dictated by USCG stability requirements.

On most routes, the above effects would be undetectable.

Steering

The consultants think the small draft change and minimal added wind area will have not any effect on steering for the LNG fueled ferry when compared to the diesel fueled ferry. Turning circles should be the same for both.

Reliability of Vessel Operation

WSF ferries have engines and propellers at each end and when transiting from one terminal to another, the engine in the bow is run at very low speed (almost idle speed) so that it does not create propeller drag. To not create drag, this forward propeller must be operating in reverse. For a controllable pitch (C/P) propeller ferry such as the new 144-car vessel will have and the Issaquah class vessels have, the engine is still run forward, but the pitch of the propeller is reversed. When the ferry approaches the arrival terminal, rather than rely on the stern engine being quickly reversed to provide stopping power, the bow engine is increased in speed, quickly, which slows down the ferry. This requires the fixed pitch propeller ferry to stop the forward engine and to reverse it, before increasing the power to stop. For the C/P propeller, the engine does not have to be stopped, but the propeller must be reversed in pitch. The response of this bow engine is an important safety factor as reversing stern engines, gears or even C/P propellers, just in time, has not always happened; the method outlined is much safer. The single fuel/LNG only engine would meet this requirement reliably. It is less clear whether the dual fuel engine would meet this requirement reliably.