Evaluating the Use of Liquefied Natural Gas in Washington State Ferries

Final Report

Prepared For:

Joint Transportation Committee

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The cover photo shows the Norwegian ferry operator Fjord1's newest LNG fueled ferry.

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).

Liquefied natural gas (LNG) provides an opportunity to significantly reduce WSF fuel costs and can also have a positive environmental effect by eliminating sulfur oxide and particulate matter emissions and reducing carbon dioxide and nitrous oxide emissions from WSF vessels.

This report recommends that the Legislature consider transitioning from diesel fuel to liquefied natural gas for WSF vessels, making LNG vessel project funding decisions in the context of an overall LNG strategic operation, business, and vessel deployment and acquisition analysis. The report addresses the following questions:

- *Security.* What, if any, impact will the conversion to LNG fueled vessels have on the WSF Alternative Security Plan?
- *Vessel acquisition and deployment plan.* What are the implications of LNG for the vessel acquisition and deployment plan?
- *Vessel design and construction.* What design and construction constraints should be considered in making LNG decisions?
- *Vessel operation.* How will LNG fueled vessels affect bunkering and other WSF operations?
- *Business case.* What is the most cost-effective scenario to introduce LNG fueled vessels to the WSF fleet considering both operation cost savings and capital project costs?

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.

There are currently few LNG marine applications in use in the world. LNG carriers, that carry LNG as cargo and use the boil-off from the storage tanks and oil as fuel sources, have been in service since 1959 and there are more than 300 in use around the world. The first LNG passenger vessel did not begin service until 2000 in Norway, the only country currently operating LNG passenger vessels. There are LNG passenger vessels under construction or in design for service in Argentina-Uruguay, Quebec, and Finland-Sweden. Norway also operates a small number of LNG offshore supply and coast guard vessels.

LNG Fueled Ferries - Norway

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; and Fosen Namos

Sjo which has one. Norway provides various tax incentives, primarily through carbon tax credits, and access to special funding that supports the construction and operation of LNG ferries.

The consultants met with representatives of Fjord1, Tide Sjo, and Gasnor, a Norwegian LNG supplier, in Norway finding:

- *Capital cost.* The cost of building the LNG ferries is 15-20 percent higher than diesel ferries. Norwegian ferry operators are eligible for a subsidy of up to 80 percent of the cost for projects that reduce NOx emissions from the NOx Foundation.
- *Carbon tax credits*. Norwegian ferry operators are able to avoid carbon taxes on natural gas that is used in lieu of diesel, which lowers the operations cost for LNG fueled vessels.
- *Maintenance and operation cost*. Fjord1 and Tide Sjo state that while maintenance costs were initially higher on the first LNG vessels they are now comparable between the two types of vessels.
- *Crew size and training.* Crew size is the same as on the diesel-powered ferries. Crew training for Fjord1 includes a gas course including risk aspects, emergency shutdown (ESD) philosophy, gas plant and demonstration of gas explosions. All Tide Sjo crew members on the LNG powered ferries must take a two-day gas training course then go through familiarization on the vessel before taking part in the bunkering process.
- *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.
- *LNG Supply.* The LNG used by the three Tide Sjo vessels is delivered from Bergen, a 322 mile drive, the longest distance Gasnor delivers LNG with their fleet of 16 supply trucks. They also have supply vessels that deliver LNG to coastal facilities.
    - *Testing.* It is important to test the vessel engines with the LNG that will be used as the gas composition varies by source. These three vessels were built in France and they brought LNG from Norway to test the engines.
    - *Shoreside fixed fueling facilities and tanks*. Shoreside fixed fueling facilities can save money and ease concerns about on-time delivery, but it only makes sense if there is enough LNG consumption to justify the capital expense.
    - *Contracts*. Gasnor generally enters into long-term 7-10 year contracts that have a fixed side that adjusts with the consumer price index and a commodity side that adjusts with the fluctuations in gas price.
- *Security planning and community outreach.* Security planning is much less elaborate than will be required in the United States. Tide Sjo officials indicated no significant public outreach effort regarding safety was needed. Gasnor, their LNG supplier, led the safety planning, which consisted of a four-hour planning meeting with local fire and police officials to develop an emergency response plan.
- *Vessel design.* All of Tide Sjo and Fjord1s LNG fueled ferries are built to emergency shutdown (ESD) standards for the engine room and have the LNG storage tanks below deck.

LNG Fueled Ferries – North America

BC Ferries and Staten Island Ferries are analyzing retrofitting vessels from diesel to LNG fuel. The Société des traversiers du Québec (STQ) – the Quebec Ferries Company – has contracted for three new LNG ferries.

CNG

Compressed natural gas (CNG) has not been found to be a viable marine fuel for vessels of WSF size and fueling requirements because it is not volume efficient. However, recent local developments may make it a possibility for WSF. While CNG has advantages (it is a non-cryogenic product and does not have the potential to create a vapor cloud) it would require daily fueling, which may not be feasible.

SECURITY AND OPERATION PLANNING

Security and operation planning and the associated public outreach are critical to WSF's ability to operate LNG fueled vessel.

The security planning process anticipated by WSF is a modified version of the process the United States Coast Guard (USCG) uses for the review of waterfront liquefied natural gas facilities. The process is outlined in the USCG's Navigation and Vessel Inspection Circular (NVIC) No. 01-2011 Guidance Related to Waterfront Liquefied Natural Gas Facilities and would be coordinated by the USCG. The process will allow inter-agency coordination between federal, state, and local public safety officials, encompass the entire WSF service area, and can include stakeholders such as members of the public and/or representatives of the Ferry Advisory Committees.

WSF will support the security planning process with public outreach. There is no U.S. experience with the introduction of a LNG passenger vessel or ferry to U.S. waters. LNG terminals have been very controversial, but are different from the introduction of a LNG fueled ferry.

The security planning process and associated public outreach are anticipated to take 18 months at a cost of $1.0 million.

Until the security planning review is complete it will also be difficult to know what, if any, additional operation cost may be incurred by WSF or the Washington State Patrol. A full cost-benefit analysis cannot be developed until this information is available.

WSF VESSEL ACQUISITION AND DEPLOYMENT PLAN

WSF has 22 vessels that serve its ten 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.

Funding has been provided in the 2011-13 biennium for the construction of a new 144-car vessel with a diesel engine. WSF has awarded the contract for this vessel with delivery in February 2014. The 16-year plan (2011- 2027) anticipates a second new 144-car 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 and for service expansions. The WSF Long-Range Plan calls for five additional new 144-car vessels to be built between 2025-2031, which will allow for the retirement of the two remaining Evergreen State class vessels and three Super class vessels.

The first Issaquah class retrofit vessel will have a total project time of 28 months, including 8 months out-of-service time for construction, staff training and sea trials. The second new 144-car vessel will take an extra year if funding is provided for the vessel and it is built as a LNG rather than a diesel fueled vessel.

Impact of LNG Retrofits or New Construction on Vessel Acquisition & Deployment Plan

Retrofitting the Issaquah class vessels will have a greater impact on the fleet acquisition and deployment plan than constructing a new 144-car vessel as an LNG vessel. The retrofits cannot begin until the fall of 2014 following the return of the Super class *Hyak* to service from its major renovation. If the Issaquah class retrofits begin before the second new 144-car vessel is in the fleet, WSF plans to retain the *Evergreen State* in service to provide coverage. If not for the retrofit of the Issaquah class vessels, the Evergreen State would retire when the first new 144-car diesel fueled ferry comes on line in 2014.

Once a second new 144-car vessel is in the fleet, WSF can both retrofit the Issaquah class vessels and retire the *Evergreen State.* To avoid disrupting service during the peak summer months, WSF plans to retrofit one Issaquah class vessel per year taking the vessel out-of-service during the fall through early spring. It will therefore take at least six years to complete the full retrofit of the Issaquah class vessels.

Delaying the delivery of the second new 144-car vessel by one year to accommodate its conversion to LNG will delay the planned service improvements and retirement of the *Hiyu* and will require the *Evergreen State* to stay in service if WSF proceeds with the retrofit of the Issaquah class vessels.

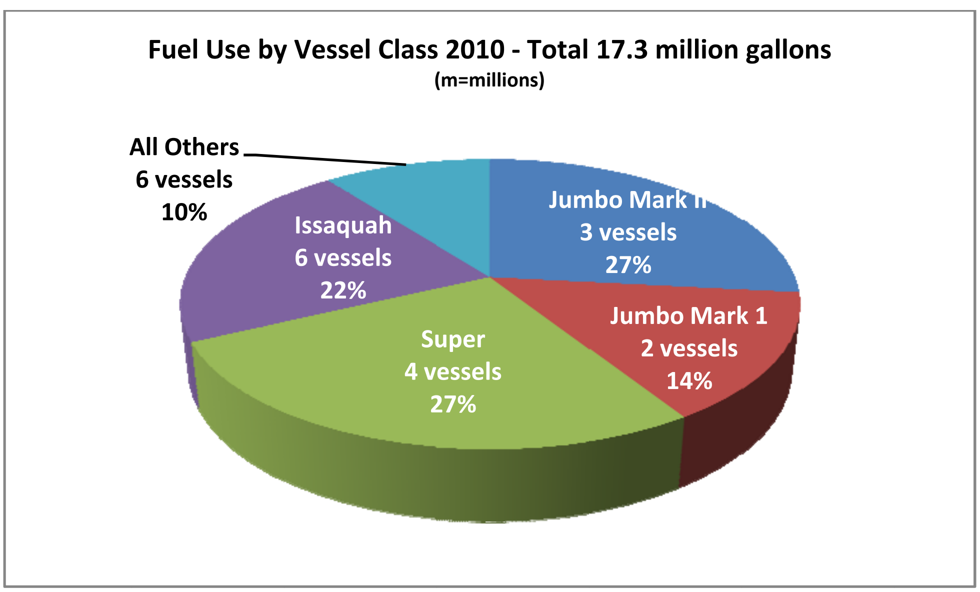
Designing a new 144-car vessel as a LNG fueled vessel could be considered in the context of the next planned procurement of five new 144-car vessels. If funding were available, a new 144-car LNG vessel could be viewed as the first of six such vessels.

WSF DIESEL FUEL AND LNG FUEL

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.



In 2010 WSF had 21 vessels. As of 2011 the fleet has 22 vessels.

Diesel Fuel Cost

Diesel fuel represents 29.2 percent of the 2011-13 biennium operation budget for WSF or $135.2 million. Using the September 2011 forecast by the Transportation Revenue Forecast Council diesel fuel costs of $3.77 per gallon with taxes and allowance for biodiesel are projected for FY 2012. The cost per gallon will drop to $3.59 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 $3.59 per gallon in FY 2014 to $4.03 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.

LNG Fuel Price Forecasts – National and State of Washington

National forecasts by the U.S. Energy Information Administration (USEIA) and other independent analysts 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.

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

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

Price forecasts by the five 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.

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.

There are six liquefaction and/or storage facilities in the Pacific Northwest, all of which are limited to supporting gas utilities. There are no LNG terminals in the Pacific Northwest.

Three 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 outside the Pacific Northwest
- Truck LNG from within the Pacific Northwest

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 have developed two price forecasts for WSF LNG: the first assumes trucking LNG from outside the Pacific Northwest and the second assumes a Pacific Northwest supplier. If LNG can be obtained from a facility in the Pacific Northwest, it will lower the cost of transportation and provide less supply chain risk than a more distant alternative.

For the forecast assuming trucking from outside the Pacific Northwest, the consultants worked with the Transportation Revenue Forecast Council's Henry Hub long-term natural gas forecast 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.

The consultants used pricing information provided by FortisBC, a Canadian supplier of peak shaving natural gas to utilities that is expanding production and delivery capabilities, to develop the forecast for trucking from within the Pacific Northwest. The Henry Hub pricing and other factors from the outside the Pacific Northwest forecast were also used in the trucking from within the Pacific Northwest forecast.

Fuel Savings

Based on the two LNG price forecasts developed by the consultants, retrofitting all six Issaquah class vessels could save between $139.9 million and $195.5 million in fuel costs over the remaining life of the vessels. For a new 144-car vessel the savings range from $86.3 million to $120.0 million over the life of the vessel.

The consultants also considered the potential savings if the three Jumbo Mark IIs could be converted to LNG. The savings range from $355.0 to $494.6 million over the remaining life of these vessels.

LNG VESSEL BUNKERING AND MAINTENANCE

Bunkering

Refueling or bunkering of LNG is a more complex operation than diesel fueling and may require operational adjustments.

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, 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 observed the fueling of vessels in Norway. In Oslo for the Tide Sjo passenger only ferries fueling takes place by truck, the same as the WSF LNG vessels would under current plans. We also observed the fueling of an Issaquah class vessel at Bremerton. The safety precautions, requirements for crew safety attire, and monitoring devices are more sophisticated with LNG than with the current diesel fueling process.

Classification

Classification of operating vessels involves inspections by the classification society to determine if the vessel operation and status are in compliance with applicable rules. WSF does not maintain class on its diesel vessels nor do the Norwegian ferry operators the consultants interviewed for their diesel vessels. The Norwegian ferry operators that were interviewed have maintained class on their LNG fueled vessels because of the relative sophistication of the vessels and limited experience with operating them. The classification society Det Norske Veritas (DNV) has provided an estimated cost of $15,000 per vessel per year for on-going classification services. By maintain classification during operation WSF will have an independent annual assessment of the safety of its LNG vessels.

Maintenance Costs and Crew Staffing

Consultant interviews with Fjord1 in October 2011 and interviews with Tide Sjo in Oslo indicate that maintenance costs for the LNG vessels are now projected to be the same as for their diesel vessels.

The Norwegians are finding that oil changes can be possibly extended to 30,000 service hours from the normal 8,000 service hours because the engine is so clean.

The USCG makes the determination on minimum staffing levels in the United States. The Norwegians have no additional staffing on their LNG vessels when compared to their diesel vessels. This analysis assumes that no changes in staffing levels will be required by the USCG when it issues the Certificate of Inspection.

VESSEL DESIGN AND CONSTRUCTION

Design Regulatory Requirements

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 to use LNG fuel, 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 International Maritime Organization (IMO) and, to some extent, Det Norske Veritas (DNV) rules. IMO is also revising its rules for LNG fueled passenger vessels and has extended the deadline for completion of rule changes from 2012 to 2014.

WSF submitted two requests for regulatory review to the USCG: one for the new 144-car vessel and separately, in September 2011, for the Issaquah class vessel retrofit. The USCG has responded to both requests with letters 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, 144-Auto and December 19, 2011 Issaquah Class)*

Design Considerations

DNV has identified three main safety challenges using LNG as a marine fuel: explosion risk, the low temperature of LNG which can cause cracking if released onto the deck, and the LNG storage tanks which must be protected from external fire, mechanical impact, and from the ship side and bottom in the event of a collision or grounding. Two considerations for WSF if they receive funding for detailed design are the engine room standard to which the ship will be constructed and the location of the storage tanks, which are now planned above deck.

Design Expertise

WSF has discussed the potential for designing the LNG Issaquah class retrofit in-house. For conversion of at least the first Issaquah class vessel, WSF should contract with an outside firm that has specialized expertise in LNG fueled systems design. Washington State naval architectural firms would have to sub-contract with firms that are experienced in the design of LNG fueled passenger vessels to meet the requirements.

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 the Issaquah class retrofit is a major conversion WSF would be required to update the vessel to meet all current regulatory requirements which would add considerable cost.

U.S. Shipyard Experience

No U. S. shipyards have experience with the construction of LNG fueled passenger vessels, which will add risk to the project. WSF should require the shipyard to retain someone with LNG construction experience.

CAPITAL PROJECT COST ESTIMATE

The consultants sub-contracted with an experienced shipyard estimator and consulted with a shipyard in Norway that has experience with constructing new LNG vessels and is retrofitting a vessel that is similar in size to the Issaquah class ferries.

The consultants estimate the cost for the conversion of all six Issaquah class vessels in year of expenditure dollars at $143.6 million, which is 40 percent higher than WSF's estimate of $103.0 million.

The new-144 car vessel cost estimate compares the existing new 144-car vessel design with an adaption of that design to a LNG fueled vessel. The consultants' estimate for the additional cost to construct a new 144-car LNG vessel is $18.9 million, which is 31 percent higher than WSF's estimate of $14.5 million in current dollars. If constructed in the 2013-15 biennium, our estimate is that a new 144-car LNG vessel would cost $20.3 million more than a diesel-fueled new 144-car vessel and the comparable WSF estimate would be $15.5 million.

The WSF and the consultants' cost estimates include the same amount for WSF non-vessel projects or soft costs. These costs were not included in previous WSF estimates. They are:

- *First Issaquah class conversion* - $1.7 million for security planning, training, and replacement service

- *Subsequent Issaquah class conversion* - $0.3 million to $1.0 million depending on whether the *Evergreen State* is used for replacement service
- *New 144-car vessel* - $1.1 million for security planning and training that would be in addition to the diesel fueled vessel.

The difference between the estimates is from:

- *Classification.* The consultants' estimate includes $0.3 million to retain a classification society during construction which is not included in the WSF estimate.
- *Design.* The consultants' estimates assume outside designers for the Issaquah class retrofit as well as the new 144-car LNG vessel. WSF included outside designers only for the new 144-car LNG vessel.
- *Shipyard supervision.* The consultants' estimate assumes greater shipyard supervision from within the yard and the retention of an outside LNG construction expert.

The consultants, based on their interviews in Norway with an experienced shipyard, believe that the LNG project is more complex than WSF anticipates. WSF has based their estimate on the assumption that the project is comparable to other motor replacement projects.

CONCLUSIONS AND RECOMMENDATIONS

The consultants' conclusions and recommendations are outlined by policy question below.

Consultants' Conclusion	**Consultants' Recommendations**
What, if any, impact will the conversion to LNG fueled vessels have on the WSF Alternative Security Plan?	
Security and operation planning with its associated public outreach should be the next step in the consideration of LNG for WSF vessels. A final legislative decision on LNG fuel should not be made until this planning is sufficiently complete to: 1) assess the impact of LNG on the Alternative Security Plan and on WSF and Washington State Patrol staffing; and 2) gauge public reaction.	**Recommendation 1. Security and Operational Planning Funding** The consultants recommend that the Legislature provide funding for security and operational planning and the associated public outreach of $1.0 million in the FY 2013 budget.
What are the implications of LNG for the vessel acquisition and deployment plan?	
• **The decision whether to build a new 144-car vessel as a LNG fueled vessel should not be made until the security planning is complete.** Assuming funding in FY 2013, the security planning could be completed by January 1, 2014 at which point a decision could be made on whether to proceed with the new 144-car vessel as a LNG fueled vessel. If funded in FY 2014, the new 144-car LNG vessel could potentially come on line in 2017. • **A new 144-car LNG vessel should be purpose built as a LNG vessel.** The most economical action would be to consider the first new 144-car LNG vessel as part of a series of six such vessels or so many as the Legislature decides to fund. This would allow WSF to acquire a purpose built LNG design. A purpose built design would result in safety improvements from the engine room being designed specifically for LNG. It would also allow WSF to achieve the economies of scale of purchasing more than one vessel at a time. • **Retrofitting the Issaquah class ferries will take at least six years and require the Evergreen State to stay in service unless a second new 144-car vessel comes on line.** Under the most aggressive schedule the retrofitted Issaquah class vessels would come on line between 2015 and 2020. The *Evergreen State* would have to remain in service past its projected 2014 retirement for up to six additional years at which point it will be 66 years old. Funding for preservation of the *Evergreen State* is not included in the 2011-27 16-year financial plan because it is expected to retire.	**Recommendation 2. New 144-Car Vessel** The consultants recommend that the Legislature proceed with construction of the second new 144-car vessel as a diesel fueled vessel, with delivery in 2015 if funding is available, if it is more important to improve service on the schedule anticipated in the WSF Long-Range Plan than to potentially reduce operations costs. If the Legislature considers construction of a LNG fueled vessel it should consider the investment only after the completion of security planning and in the context of the planned procurement of five new 144-car vessels to allow for the acquisition of a purpose built LNG design and potential economies of scale in ship building. **Recommendation 3. Issaquah Class Retrofit** If the Legislature considers retrofitting the Issaquah class vessels, it should do so only after the completion of security planning. Design and construction should follow recommendations 4-7 below. The legislature should also recognize that funding will need to be provided for preservation of the *Evergreen State* estimate an additional $0.4 million until 2018, at which point it would potentially need propulsion controls replaced at a cost of $5.7 million.

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<tr><th>Consultants' Conclusion</th><th>Consultants' Recommendations</th></tr>
<tr><td colspan="2">What design and construction constraints should be considered in making LNG decisions?</td></tr>
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Safety in the design and construction of LNG vessels is of paramount importance. Other nations, particularly Norway, and the classification societies can help overcome the lack of U.S. experience with LNG fueled passenger vessel design and construction. If a vessel is constructed to class it means that the classification society guidelines have been followed and the classification society has inspected the construction and certified it. This is in essence a quality inspection.
The pre-design process will allow the Legislature to review the design options before making a final decision. The Legislature requires that all vessel improvement projects and vessel preservation projects over $5 million include a pre-design study (ESHB 3209 adopted in the 2010 session). The pre-design study can provide the Legislature with additional information prior to appropriating funds for construction of a LNG fueled vessel.
A major conversion decision should be sought from the USCG prior to starting construction. If the USCG decides that the Issaquah class retrofits are major conversions, it could make the retrofit prohibitively expensive because the vessel would be required to meet all USCG equipment and ADA regulations as if it were a new build.

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Recommendation 4. Design
If the Legislature decides to pursue a LNG fueled vessel, the Legislature should provide funding and require WSF to:

Contract with an outside design firm that has previous LNG fueled passenger vessel design experience rather than design the LNG vessels in-house. As a practical matter, Washington state naval architects would have to sub-contract with firms that are experienced in the design of LNG fueled systems to meet this requirement
Design LNG vessels to a classification society rules (which could be DNV or another classification society) and have them classed during construction.

Recommendation 5. Construction
The Legislature should consider amending the bid process to require bidders to include an expert from a shipyard with LNG fueled vessel construction experience in their bid that WSF could qualitatively evaluate.
Recommendation 6: Regulatory Determination for Issaquah class retrofit
WSF should request a ruling from the USCG on whether the Issaquah class retrofits will constitute a major conversion before proceeding with more detailed design and construction.
Recommendation 7. Construction
The LNG fuel supply contract should be in place before the shipyard construction contract is let. This will allow the engine to be tested with the actual LNG fuel that will be used in operation and ensure supply and price.
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<tr><th>Consultants’ Conclusion</th><th>Consultants’ Recommendations</th></tr>
<tr><td colspan="2">How will LNG fueled vessels affect bunkering and other WSF operations?</td></tr>
<tr><td>• Bunkering will be more complex than diesel but this should not pose a problem for WSF other than requirements that may be part of the security plan. Bunkering is more complex but with adequate training WSF should be able to accommodate it. However, bunkering requirements may also be a part of the safety plan and those requirements may add additional costs that cannot yet be anticipated.
• Maintenance and staffing costs should be the same as for the diesel-fueled vessels. This is consistent with the experience in Norway. However, staffing costs may change when the USCG issues the Certificate of Inspection.
• The cost of classification services at $15,000 per year per vessel would be a worthwhile investment. Maintaining classification services for LNG vessels will help ensure safe operation.</td><td>Recommendation 8. Operation Classification
WSF should maintain classification services for the operation of their LNG vessels during at least the first 10 years of operation.</td></tr>
<tr><td colspan="2">What is the most cost-effective scenario to introduce LNG fueled vessels to the WSF fleet considering both operation cost savings and capital project costs?</td></tr>
<tr><td>• The security planning and outreach costs for LNG are substantial and the more vessels these costs cover the more cost effective the investment will be. The financial analysis is independently done for the Issaquah class retrofit and for the new 144-car vessel. But the one-time costs for security planning will not be repeated if both projects are done or if the Legislature eventually funds more LNG fueled vessels.
• The Issaquah class retrofit is not a sound economic investment as the project is now structured. Although the economic viability of the Issaquah class retrofit will depend largely on the final design and the USCG major conversion decision, it would be more viable after a second new 144-car vessel is on line. Having a second new 144-car vessel would mean that the retrofit project would not include operating costs of the Evergreen State.
• The investment in a new 144-car LNG vessel is economically viable. The investment would be even better if it is done for a class of LNG vessels with the consequent economies of scale from purchasing more than one vessel at a time.</td><td>Recommendation 9. Pre-Design and Business Case Funding
At the same time WSF is engaged in security planning, the Legislature should provide funding for WSF to develop a more refined business case and pre-design report for the LNG conversion which would consider the potential to retrofit the Jumbo Mark II vessels and provide updated CNG information.</td></tr>
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Consultants' Conclusion	Consultants' Recommendations
• **It would be worthwhile to invest in an exploration of the potential retrofit of the Jumbo Mark IIs.** The potential fuel savings are sufficiently large to justify the cost of developing a concept design to see if the Jumbo Mark IIs can be retrofit. • **Development with CNG should be tracked to see if it becomes a viable option for marine fuel for WSF.**CNG may have some advantages that should be considered including a local supply and potentially less hazardous operation. However, the operational implications of daily fueling would have to be considered.	

Contents

INTRODUCTION

Washington State Ferries serves 22.6 million riders on 10 routes in Puget Sound and the San Juan Islands with a fleet of 22 diesel fueled vessels. WSF operation and capital finances are a significant concern to the Legislature, a concern that has been exacerbated by rising fuel prices.

Liquefied natural gas (LNG) provides an opportunity to significantly reduce WSF fuel costs, which in the 2011-13 biennium are $135.2 million or 29 percent of WSF operation costs. LNG can also have a positive environmental effect by eliminating sulfur oxide and particulate matter emissions and reducing carbon dioxide and nitrous oxide emissions from WSF vessels.

This report recommends that the Legislature consider transitioning from diesel fuel to liquefied natural gas for WSF vessels, making LNG vessel project funding decisions in the context of an overall LNG strategic operation, business, and vessel deployment and acquisition analysis that addresses:

- *Security.* What, if any, impact will the conversion to LNG fueled vessels have on the WSF Alternative Security Plan?
- *Vessel acquisition and deployment plan.* What are the implications of LNG for the vessel acquisition and deployment plan?
- *Vessel design and construction.* What design and construction constraints should be considered in making LNG decisions?
- *Vessel operation.* How will LNG fueled vessels affect bunkering and other WSF operations?
- *Business case.* What is the most cost-effective scenario to introduce LNG fueled vessels to the WSF fleet considering both operation cost savings and capital project costs?

This report addresses these questions to the extent that they can be addressed at this stage in planning.

The greatest unknown is the security question, the answer to which will require completion of a U.S. Coast Guard security planning process. The business case, vessel acquisition and deployment, and vessel operation planning may change depending on the outcome of security planning.

SECTION I. PURPOSE AND APPROACH

A. PURPOSE

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 Identified the following areas for inclusion in the study: (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.

B. APPROACH

This report relies on information available from WSF's studies, the consultants' research and interviews with outside agencies and experts, and consultations with Norwegian vessel owners and a Norwegian shipyard.

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:

- Air Products
- American Strategic Group
- BC Ferries
- Clean Energy
- FortisBC
- Phoenix Public Transit
- Puget Sound Energy
- Shell Oil
- United States Coast Guard
- Vista Natural Gas
- Williams Northwest Pipeline
- World CNG

In Norway the consultants meant with representatives of:

- Fjord1
- Gasnor
- STX Langstein
- Tide Sjo

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 (quadrillion cubic feet).

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. LNG AS MARINE FUEL

This section reviews the use of LNG as a marine fuel. Norway is the world leader in LNG fueled passenger vessels and today operates the only LNG fueled ferries in the world. The consultants met with representatives of Norwegian ferry operators Fjord1 and Tide Sjo and with a Tide Sjo's LNG supplier Gasnor. A summary of findings is included in this section.

This section also provides an overview of three North American ferry operators who are considering LNG: BC Ferries, Staten Island Ferries, and the Quebec Ferries Company. The Quebec Ferries Company has ordered three LNG ferries.

Compressed natural gas (CNG) has been used only infrequently as a marine fuel primarily because LNG is more volume-effective, with LNG requiring approximately two times the fuel volume of oil and CNG approximately five times. Interviews with two companies interested in supplying CNG to WSF as a marine fuel are included in this section.

A. Liquefied Natural Gas

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.

B. 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.

C. LNG Ferries in Norway

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

1. History of LNG Fueled Ferries in Norway

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 types of gas-operated car and passenger ferries; one operating on LNG and one on compressed natural gas (CNG). The CNG project was never started.[1]

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.[2]

2. Norwegian LNG Ferries - 2011

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

3. Tide Sjo and Fjord1Experience

The consultants met with representatives of Fjord1,Tide Sjo, and Gasnor, an LNG supplier, in Norway. Fjord1's experience with LNG ferries was also summarized in a presentation by their Operations Manager at the Ferries 2010 Conference in Seattle in November, 2010.[3]

a. Fjord1

Fjord1 was formed in 2001 after the merger of two parent companies. Fjord1 has a total of seven subsidiaries that handle sea, bus, and freight services. Ferries are operated throughout the coastal regions of Norway by a fleet of over 60 vessels, including 12 LNG auto-passenger ferries. Fjord1, like Tide Sjo and other Norwegian operators, is a private company that operates ferry service for the government on a contractual basis.

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[1] Oscar Bergheim, Operations Manager Fjord1 Fylkesbaatane, presentation at Ferries 2010 Conference in Seattle, WA November 2010.
[2] 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.
[3] Oscar Bergheim, "Fjord1's Experience with LNG Fueled Ships" presentation at Ferries 2010 Conference, Seattle WA. Nov. 2010.

b. Tide Sjo

Tide Sjo is a 160-year-old Norwegian transit operator that operates buses and ferries throughout Norway. Since 2009, Tide has operated the passenger ferry service between Oslo and Nesodden. There are currently three 600-passenger LNG ferries operating out of central Oslo. The municipal government mandated LNG operation as part of the contract for the service over this route and Tide won the 15-year contract with two five-year options at the end. Tide Sjo receives a monthly subsidy as part of this contract and in turn is responsible for all operational and capital costs.

c. Gasnor

Gasnor is one of two Norwegian LNG suppliers. It was established in 1989 and made its first gas delivery in 1994. Gasnor is owned by a conglomeration of six energy companies and serves a diverse set of customers in industry, transportation, and a residential distribution network in Karmoy, Norway. They operate 3 LNG production plants, 16 LNG semitrailer delivery trucks, 13 CNG semitrailers, 30 terminals, and 2 coastal LNG supply tankers. Total production capacity is 300,000 tons a year and 50,000 deliveries have been made without incident.

d. Summary of Findings

This is a summary of the findings from Fjord1, Tide Sjo, and Gasnor. Additional information is provided at the appropriate section in the remainder of this report.

- *Capital cost.* The cost of building the LNG ferries is 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."[4]
    - *Capital subsidy.* Norwegian ferry operators are eligible for a subsidy of up to 80 percent of the cost for projects that reduce NOx emissions from the NOx Foundation. These projects can include the cost differential of LNG vs. diesel construction, which for Tide Sjo were about $3.6 million per ship.
- *Carbon tax credits*. Norwegian ferry operators are able to avoid carbon taxes on natural gas that is used in lieu of diesel, which lowers the operations cost for LNG fueled vessels.
- *Maintenance and operation cost*. Fjord1 and Tide Sjo state that while maintenance costs were higher on the first LNG vessels they are now comparable between the two types of vessels.[5] Maintenance issues on the LNG ferries have included "black outs," or engine room shutdown, due more to human than technical error; three instances of pipe leakage due to poor welding, and some issues with the thrusters but close to none with the main engines.
- *Crew size and training.* Crew size is the same as on the diesel-powered ferries. Crew training for Fjord1 includes a gas course including risk aspects, emergency shutdown (ESD) philosophy, gas engine operation, and demonstration of gas explosions. The course takes two to five days, and the instructors are from the company. The remainder is familiarization training conducted on board the vessel. An officer needs about one week training before being on duty. All Tide Sjo crew members on the LNG powered ferries must take a two-day gas training course then go

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[4] DNV, *Greener Shipping in North America*, February 2011, p. 10.

[5] Oscar Bergheim's 2010 presentation "Fjord1's Experience with LNG Fueled Ships" stated that 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. Interviews in Norway indicate that maintenance costs are now believed to be the same.

through familiarization on the vessel before taking part in the bunkering process. There is a four-person crew consisting of a captain, chief engineer, and two deckhands and all four take part in the bunkering process. In addition, the LNG truck driver takes part in the bunkering process.

- *Cost of LNG.* The cost of natural gas in Norway has been close to, or slightly above, diesel and the energy cost to operate 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. See Appendix A for further information.
- *LNG Supply.* The LNG used by the three Tide Sjo vessels is delivered from Bergen, a 322 mile drive, the longest distance Gasnor delivers LNG with their fleet of 16 supply trucks. They also have supply vessels that deliver LNG to coastal facilities. The official from Gasnor noted several key points for the supply:
    - *Testing.* It is important to test the vessel engines with the LNG that will be used, as the gas composition varies by source. These three vessels were built in France and they brought LNG from Norway to test the engines.
    - *Shoreside fixed fueling facilities and tanks*. Shoreside fixed fueling facilities can save money and ease concerns about on-time delivery, but it only make sense if there is enough LNG consumption to justify the capital expense. In the case of Tide Sjo, there is not enough LNG consumption to justify such an infrastructure expense and the vessels do not need to be refueled often.
    - *Contracts*. Gasnor generally enters into long-term 7-10 year contracts that have a fixed side that adjusts with the consumer price index and a commodity side that adjusts with the fluctuations in gas price.
- *Environmental impact.* The LNG vessels have been successful in reducing CO_2 emissions by 19 percent, NO_x by 91 percent, and SO_x and particulate matter by 100 percent. [6]
- *Security planning and community outreach.* Security planning is much less elaborate than will be required in the United States. Tide Sjo officials indicated no significant public outreach effort regarding safety was needed. Gasnor, their LNG supplier, led the safety planning, which consisted of a four-hour planning meeting with local fire and police officials to develop an emergency response plan.
- *Vessel design.* All of Tide Sjo and Fjord1's LNG fueled ferries are built to emergency shutdown (ESD) standards for the engine room and have the LNG storage tanks below deck.

D. 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.

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[6] Oscar Bergheim, "Fjord1's Experience with LNG Fueled Ships."

E. 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 LNG fueled vessels built for their Maritime Directorate, the equivalent of the USCG and four LNG fueled off-shore supply vessels.

F. 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 (New York City)*. 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 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, FortisBC, 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*). La Société des Traversiers du Québec (the Quebec Ferries Company) is purchasing three LNG ferries: two to ply the Tadoussac/ Baie-Sainte-Catherine Saguenay River fjord about 100 miles northeast of Quebec, and one for the Matane and Baie-Comeau/Godbout crossing even farther east, at the mouth of the St. Lawrence River. The new boats will have dual-fuel engines by Wärtsilä with delivery slated for fall 2013 and spring 2014. Fuel will be supplied via LNG tanker trailers operated by Transport Robert – using LNG tractors if logistics allow. A third new LNG ferry for the Matane–Baie-Comeau–Godbout crossing in eastern Canada will hold 800 passengers and 180 automobiles.
- *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 (Massachusetts).* 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 (New Jersey).* Cape May had some interest, but do not have enough funding to explore LNG. They are looking at new high speed ferries that are not suitable for LNG due to space considerations.
- *Maine State.* Not considered.
- *Alaska Marine Highways.* Not considering at this time.

G. 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 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 projects. 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.

H. LNG Emissions

In Norway the primary impetus to have LNG fueled ferries is the reduction in emissions. LNG will also provide improved emissions control for WSF, even beyond those required by the new North American Emissions Control Area. The International Maritime Organization formed the North American Emissions Control Area in 2010. 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.

WSF's use of ULSD means that it is already in compliance with the North American Emissions Control Area requirements. LNG will provide emissions control beyond these requirements. "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."[7] The table below shows the LNG emission comparison to the ULSD used by WSF.

Exhibit 1.
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

I. Compressed Natural Gas (CNG) Fueled Vessels

1. CNG as a Marine Fuel

When the LNG ferry *Glutra* was built in Norway the intent of the Norwegian government 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

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

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."[8] 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 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 of the CNG 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 paddlewheel vessels, each of which accommodates 150 passengers for a five minute trip. One of the vessels is CNG powered.

There are five 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 scarcity 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.[9]

2. CNG Potential for WSF

There is however reason to believe CNG could be a viable option for WSF vessels in the future. The consultants met with representatives of two local companies, Vista Natural Gas and American Strategic Group, regarding the potential for CNG to fuel WSF vessels. Two aspects of CNG make it worthy of consideration for WSF: 1) a gas pipeline connected CNG plant is being completed just south of Tacoma, providing a closer, more assured delivery to WSF ferries than is presently possible from LNG sources; and 2) while the volume requirement for CNG is greater and often discounted for marine vessels because of space limitations, a daily fueling would allow the tanks to be about the same size as the proposed LNG tanks. Fueling could be done while the ferries are idle nightly, but the impacts on crew, who may be required to monitor the process instead of accomplishing other tasks, would need to be examined.

The advantages of CNG are that it is a non-cryogenic product and does not have the potential to create a vapor when released. Unlike LNG, if released CNG will not create brittle fractures in steel, has less hazardous fueling procedures, the storage and distribution systems onboard the vessel are less costly, and permanent fueling stations are less costly and may be easier to permit. The disadvantages of CNG, in addition to the volume requirements, are that it is also a highly compressed gas and hazardous to carry, fueling requires compression and is not as efficient as LNG with a great deal left in the tank, and fueling for equivalent energy amounts would take longer than for LNG.

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[8] 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.
[9] Ibid., p. 9-12.

SECTION IV. SECURITY AND OPERATION PLANNING

Security and operation planning and the associated public outreach are critical to WSF's ability to operate LNG fueled vessel.

The security planning process anticipated by WSF is a modified version of the process the United States Coast Guard (USCG) uses for the review of waterfront liquefied natural gas facilities. The process is outlined in the USCG's Navigation and Vessel Inspection Circular (NVIC) No. 01-2011 Guidance Related to Waterfront Liquefied Natural Gas Facilities and would be coordinated by the USCG. The process will allow inter-agency coordination between federal, state, and local public safety officials, encompass the entire WSF service area, and can include stakeholders such as members of the public and/or representatives of the Ferry Advisory Committees.

WSF has said they will support the security planning process with public outreach. There is no U.S. experience with the introduction of a LNG passenger vessel or ferry to U.S. waters. LNG terminals have been very controversial, but are different from the introduction of a LNG fueled ferry.

The security planning process and associated public outreach are anticipated to take 18 months at a cost of $1.0 million, which includes $0.7 million for security planning and $0.3 million for public outreach.

Until the security planning review is complete it will also be difficult to know what, if any, additional operation cost may be incurred by WSF or the Washington State Patrol. A full cost-benefit analysis cannot be developed until this information is available.

A. U.S. Coast Guard

The United States Coast (USCG) has the ultimate authority over maritime safety. The local Officer in Charge of Marine Inspection (OCMI) determines the vessels safe operation and is responsible for the issuance of the Certification of Inspection (COI) before the vessel is authorized to sail.

Security is provided by the Washington State Patrol (WSP) and WSF operating under an Alternative Security Plan which has been approved by USCG.

1. LNG Planning Process

The USCG process for LNG terminal approval is outlined in the Navigation and Vessel Inspection Circular (NVIC) No. 01-2011 Guidance Related to Waterfront Liquefied Natural Gas Facilities. It is not clear whether the USCG will require WSF to comply fully with NVIC No. 01-2011 which is designed for review and approval of LNG terminals accepting large deliveries of LNG into U.S. waters.

WSF has said they will seek approval of the USCG to use a modified version of NVIC No. 01-2011. The guidelines allow the Captain of the Port (COTP) to convene an ad-hoc working group of existing security committees - Harbor Safety Committees and Area Maritime Security Committee - and other stakeholders including state and local governments and members of the public to review waterway suitability assessments required of applicants for LNG terminals. WSF will be required to prepare a Waterway Suitability Assessment. Applicants are also encouraged but not required to develop transit management plans.

The primary advantages of this process are:

- *Inter-agency coordination*. The process provides a way to coordinate federal, state, and local public safety and fire reviews across the WSF service area.

- *Encompasses entire WSF service area.* The Puget Sound Harbor Safety Committee encompasses all the WSF routes.
- *Able to incorporate other stakeholders.* The process is designed to encompass other stakeholders include members of the public. There would be an opportunity, for example, to include representatives from the Ferry Advisory Committees.
- *Coordinated by the USCG*. The local COTP would be in charge of the process.

This is anticipated to be a one-time process that would encompass all WSF LNG fueled vessels. WSF's cost estimate for this process is $0.7 million.

Exhibit 2.
LNG Security Planning Cost Estimate
($ in millions)

Security Planning Detail	Cost
WSF Project Manager – 18 months	**$0.1**
Consultant Support	
Labor: Work to be preformed for researching and writing the Waterway Suitability Assessment. The work would be split between two risk assessment specialists.	Estimated Hours:
Port Characterization	80
Characterization of the facilities, vessel routes, and vessels	240
Safety Risk Assessment	160
Security Risk Assessment	240
Threat Assessment	80
Vulnerability Assessment	80
Consequence Analysis	160
Risk Management Strategies	240
Report on Resource Needs for Safety, Security and Response	160
Final report with conclusions	160
Participation In Area Maritime Security Committee & or Harbor Safety Committee	240
Presentation on request	80
Travel Time	160
Total hours for two risk assessment specialists	2,080
Total Cost for Security Consultant	**$0.5**
Non-Labor and ancillary costs	**$0.1**
Total Labor and Non-Labor Cost to research, and facilitate a Waterway Suitability Assessment and produce a product that meets the requirement of Coast Guard Navigation and Vessel Inspection Circular 01-11.	**$0.7**

B. Public Outreach

Public outreach and communication will be an important component of the planned introduction of LNG fueled vessels. It is anticipated that public outreach will occur both during the security planning and as part of the introduction of each LNG vessel to a new route.

1. Public Concerns

There is no U.S. experience with the introduction of a LNG passenger vessel or ferry to U.S. waters. All of the public experience is associated with the approval of LNG terminals and/or trucking LNG to and from such large terminals, which are often very controversial. Public concerns regarding LNG terminal facilities in Oregon and Washington have been one of the most significant reasons that these projects have not moved forward. In the last two years, there has been significant public opposition to re-opening truck capacity at the LNG terminal in Savannah, Georgia and to the construction of a LNG terminal in Maine.

The amount of LNG associated with fueling WSF ferries is much smaller than that associated with a large import terminal. There are also opportunities with WSF ferries for reduced costs and environmental benefits that are not associated with the placement and permitting of LNG terminal facilities.

The issues that have been raised with regards to LNG terminals that could be raised with WSF's use of LNG include the risk of fire and the burden on the community of disaster prevention and relief.

2. Public Outreach Budget

WSF's budget for each LNG vessel project for public outreach is $0.3 million, which includes communications consultant support ($0.15 million) and communications staff ($0.15 million).

C. Implications for LNG Schedule

There is no way to predict the outcome of the security and operation planning review nor is there a way to predict the degree of public support for the conversion. Until the security planning review is complete it will also be difficult to know what, if any, additional operation cost may be incurred by WSF or the Washington State Patrol. A full cost-benefit analysis cannot be developed until this is known.

SECTION V. VESSEL ACQUISTION AND DEPLOYMENT PLAN

This section reviews how the introduction of LNG fueled vessels could affect the vessel acquisition and deployment plan developed as part of WSF's Long-Range Plan.

This section concludes that retrofitting the Issaquah class vessels will have a greater impact on the fleet acquisition and deployment plan than constructing a new 144-car vessel as an LNG vessel. The retrofits cannot begin until the fall of 2014 following the return of the Super class *Hyak* to service from its major renovation. If the Issaquah class retrofits begin before the second new 144-car vessel is in the fleet, WSF plans to retain the *Evergreen State* in service to provide coverage. If not for the retrofit of the Issaquah class vessels, the Evergreen State would retire when the first new 144-car diesel fueled ferry comes on line in 2014.

Once a second new 144-car vessel is in the fleet, WSF can both retrofit the Issaquah class vessels and retire the *Evergreen State.* To avoid disrupting service during the peak summer months, WSF plans to retrofit one Issaquah class vessel per year taking the vessel out-of-service during the fall through early spring. It will therefore take at least six years to complete the full retrofit of the Issaquah class vessels.

Delaying the delivery of the second new 144-car vessel by one year to accommodate its conversion to LNG will delay the planned service improvements and retirement of the *Hiyu* and will require the Evergreen State to stay in service if WSF proceeds with the retrofit of the Issaquah class vessels.

Designing a new 144-car vessel as a LNG fueled vessel could be considered in the context of the next planned procurement of five new 144-car vessels. If funding were available, a new 144-car LNG vessel could be viewed as the first of six such vessels.

A. Current Fleet

WSF has 22 vessels that serve its ten routes in Puget Sound and the San Juan Islands[10]. WSF's Long-Range Plan assumes a 22 vessel fleet through 2030 and establishes a route service plan based on a vessel acquisition and deployment plan.

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 (new 64-car) class vessel. WSF will then have three Jumbo Mark II, two Jumbo Mark I, four Super, six Issaquah, three Evergreen State, three Kwa-di Tabil, and one 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.[11] The *Hyak* is scheduled for a major renovation and will be out-of-service from September 2013 to July 2014.

The 2012 fleet is shown in Exhibit 3 below.

[10]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.

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

Exhibit 3.
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 / 2014
	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

2. New 144-Car Vessel Construction

The Legislature's 16-year (2011-2027) financial plan includes the construction of two new 144-car vessels. Funding has been provided in the 2011-13 biennium for the construction of the first vessel with a diesel engine. WSF has awarded the contract for this vessel with delivery in February 2014.

The 16-year plan anticipates a second vessel which may be LNG or diesel. If funding is provided in 2012 and the vessel is constructed as a diesel fueled vessel, delivery could occur in 2015.

As shown in the exhibit below 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.

3. 2025-2031 Planned Vessel Acquisition

The WSF Long-Range Plan calls for five new-144 car vessels to be built between 2025-2031, which will allow for the retirement of the two remaining Evergreen State class vessels and three Super class vessels, as shown in Exhibit 4 below.

Exhibit 4.
Final Long-Range Plan Fleet Plan

VESSEL ASSIGNMENTS & PROCUREMENT IMPACTS - FINAL LRP PLAN SUMMER

	2009-11	2011-13	2013-2025	2025 - 2031
Anacortes - Sidney (Vessel makes two daily round-trips to Sidney & one to San Juans)	124	124	144 (+ 20)	124
Anacortes - San Juan Islands	144, 144, 144	144, 144, 144	144, 144, 144 New	144 New, 144 New, 144 New
Interisland	87	87	90	90
Port Townsend - Keystone	64, 64 (+ 64)	64, 64 (+ 64)	64, 64 (+ 64)	64, 64 (+ 64)
Mukilteo - Clinton	124, 124	124, 124	144 New, 124 (+ 20)	144 New, 144 New (+ 40)
Edmonds - Kingston	202, 188	202, 188	202, 188	202, 188
Seattle - Bainbridge	202, 202	202, 202	202, 202	202, 202
Seattle - Bremerton	124, 188	124, 188	124, 188	144 New, 188 (+ 20)
Fauntleroy - Vashon - Southworth	87, 87, 124	87, 87, 124	124, 87, 124 (+ 37)	124, 124, 124 (+ 74)
Pt. Defiance - Tahlequah	48	64 (+ 16)	64 (+ 16)	64 (+ 16)
Standby (emergency reserve)	34	34	87 (+ 53)	144 (+ 110)
Maintenance Reserve	144, 90	144, 90	144, 124	144 New, 124

KEY

- 202, 188 — Jumbo Vessel
- 144 — Large Vessel
- 124 — Medium Vessel
- 90, 87 — Mid-Size Vessel
- 64, 34 — Small Vessel
- No Change
- Change in Capacity
- + 16 — Change in vehicle capacity

2009-11

- **Two 64-car vessel (Island Home) are delivered**
- **Funding for one 64-car vessels (under construction)**
- Two new 64-car vessels are delivered; one in 2010 & one in 2011 (Port Townsend - Keystone)

2011-13

- **64-car vessel program is complete; delivery of final 64-car vessel**
- **Start new 144-car vessel program**
- One new 64-car vessel is delivered (Pt. Defiance - Tahlequah) in 2012
- Rhododendron is retired

2013-2025

- **Two new 144-car vessels are delivered**
- One new 144-car vessel is delivered in 2014 (Mukilteo - Clinton)
- 124 from Mukilteo - Clinton moves to Fauntleroy - Vashon - Southworth and increases route capacity
- One new 144-car vessel to San Juan Domestic in 2014. 144 from San Juan Domestic moves to Sidney and increases route capacity to both Sidney and San Juan Domestic routes
- 124 from Sidney moves to Fauntleroy - Vashon - Southworth and increases route capacity
- 87 bumped from Fauntleroy - Vashon - Southworth increases standby capacity
- Evergreen State and Hiyu are retired

2025 - 2031

- **Five new 144-car vessels are delivered**
- One new 144-car vessel is delivered in 2027 (Mukilteo - Clinton)
- 124 from Mukilteo - Clinton moves to Fauntleroy - Vashon - Southworth and increases route capacity
- Two new 144-car vessels are delivered in 2028 and 2029 (San Juan Domestic)
- One new 144-car vessel to maintenance in 2028 moves Hyak to standby and retires Klahowya
- One new 144-car vessel is delivered in 2029 to Bremerton.
- 124 from Bremerton moves up to Sidney
- Tillikum and three 144-car vessels are retired (Elwha, Kaleetan, and Yakima)

B. LNG Vessel Construction

WSF has developed construction schedules for the new 144-car vessel as a LNG fueled vessel and for the retrofit of the Issaquah class vessels to LNG. These schedules have been reviewed by the consultants and we concur with the construction timeline.

1. Issaquah Class Vessels

The first vessel will take longer due to design requirements and regulatory review. WSF estimates that the total project time will be 28 months, including:

- *Engine procurement.* Six months to issue a RFP and award an engine contract. Engine delivery takes approximately one year following award.
- *Detail design and regulatory review*. The detail design, which could be undertaken at the same time as the engine procurement RFP, would be complete within a year with phased submittals to the United States Coast Guard's Marine Safety Center for approval. The largest risk factor in this schedule is regulatory review which is discussed in the section on LNG fueled vessel design and construction.
- *Bid*. The bid package would be produced as the drawings are developed. The award of the construction contract could occur 20 months after funding is received.
- *Out-of-service.* The vessel would be out-of-service for 8 months.
    - *Construction.* Construction is anticipated to take six months so the vessel would be complete in 26 months from when funding was available.
    - *Training and sea trials*. Two months following construction.

Subsequent vessels could be built in a shorter time frame because design and regulatory review would be complete. Each vessel being retrofit would be out-of-service for 6 months for construction and one to two months for training and sea trials.

2. New 144-Car Vessel

The new 144-car vessel if constructed as an LNG vessel will require at least an extra year for detailed design and regulatory review than it would for construction as a diesel fueled vessel. If funding were provided in 2013 following security planning, the vessel could be complete in 2017 in contract to 2015 as a diesel fueled vessel.

C. Impact of LNG Fuel Vessel Construction on the Fleet Acquisition and Deployment Plan

Retrofitting the Issaquah class vessels has a greater impact on the fleet acquisition and deployment plan than constructing a new 144-car vessel as an LNG vessel. The retrofits increase out-of-service time of existing vessels, whose service time must be provided from elsewhere in the fleet. If the Issaquah class retrofits begin before the second new 144-car vessel is in the fleet, WSF plans to retain the *Evergreen State* in service to provide coverage. Once a second new 144-car vessel is in the fleet, WSF could both retrofit the Issaquah class vessels and retire the *Evergreen State.*

1. Issaquah Class Retrofit

Retrofitting the Issaquah class vessels cannot begin until after the *Hyak* returns to service and would require that the *Evergreen State* remain in service to provide coverage for the Issaquah class out-of-service periods for retrofits until the second new 144-car vessel is built.

- *Construction of the first retrofit cannot begin until the fall of 2014.* The *Hyak* is anticipated to be out-of-service from September 2013 to July 2014. WSF vessels are fully deployed during the peak summer months, which means as a practical matter that construction of the first Issaquah class vessel retrofit cannot begin until the fall of 2014.[12]
- *Evergreen State.* WSF's Long-Range Plan anticipates retiring the Evergreen State in 2014 when the first new 144-car vessel is delivered. To accommodate the projected 8 month out-of-service time for the first Issaquah class renovation and 7 to 8 month out-of-service of each subsequent vessel, WSF would leave the *Evergreen State* in service until a second new 144-car vessel is delivered.
- *Subsequent Issaquah class retrofits.* To avoid disrupting service during the peak summer months, WSF plans to retrofit one Issaquah class vessel per year taking the vessel out-of-service during the fall through early spring. It will therefore take at least six years to complete the full retrofit of the Issaquah class vessels.

2. Second new 144-car vessel

- *Issaquah class retrofit impact*. The construction of the second new 144-class vessel is a critical path element for the Issaquah class retrofit since until this vessel is available, the Issaquah class retrofits cannot proceed without retention of the *Evergreen State* in the fleet.
- *Delay in service improvements and Hiyu retirement.* Delaying the second new 144-car vessel will delay the service improvements anticipated in the Long-Range Plan and delay the retirement of the *Hiyu*.
- *2025-31 procurement.* Designing a new 144-car vessel as a LNG fueled vessel could be considered in the context of the next planned procurement of five new 144-car vessels. If funding were available, a new 144-car LNG vessel could be viewed as the first of six such vessels.

[12] WSF's initial schedule anticipated the first Issaquah class retrofit to begin in the fall of 2013, which is not possible.

SECTION VI. WSF DIESEL FUEL AND LNG FUEL

This section reviews WSF use of diesel fuel and the potential savings from using LNG fuel.

This section concludes that, based on two LNG price forecasts developed by the consultants, retrofitting all six Issaquah class vessels could save between $139.9 million and $195.5 million in fuel costs over the remaining life of the vessels. For a new 144-car vessel the savings range from $86.3 million to $120.0 million over the life the vessel.

The consultants also considered the potential savings if the three Jumbo Mark IIs could be converted to LNG. The savings range from $355.0 to $494.6 million over the remaining life of these vessels.

Having the LNG fuel contract in place before vessel construction is important both to secure the supply at a known price and to test the motors during construction with the actual fuel to be used. The latter was one of the recommendations from Gasnor and Tide Sjo in Norway.

A. Diesel Fuel

WSF fuels its fleet with ultra low sulfur diesel (ULSD)[13]. RCW 43.19.642 requires state agencies to use a minimum of 20 percent biodiesel blend fuel.[14] In 2011, WSF is using a ULSD that has 5 percent biodiesel with a sulfur maximum content of 0.1 percent.[15]

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.[16] The five largest vessels in the fleet - the three 202-car Jumbo Mark IIs and the two 188-car Jumbo Mark Is – accounted for 41 percent of total fuel used in 2010. The four relatively fuel inefficient 144-car Super class vessels accounted for another 27 percent of the fuel consumed in 2010 and the six relatively fuel efficient Issaquah class ferries accounted for 22 percent. The remaining six small vessels in service in 2010 accounted for 10 percent of the fuel used.[17]

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[13] 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.

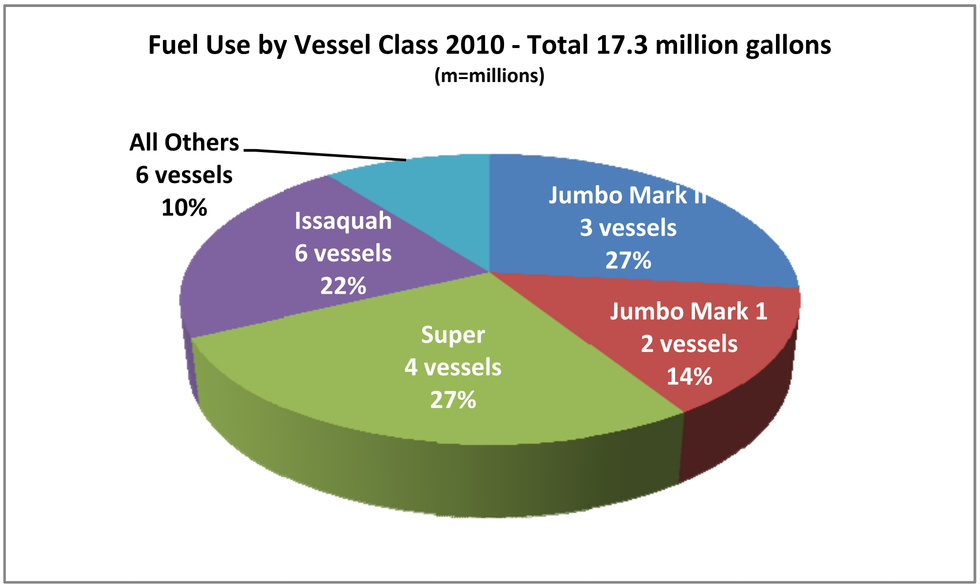
[14] In the 2009-11 biennium WSF was exempted from this requirement and instead required to use 5 percent biodiesel provided that it did not cost more than 5 percent more than diesel fuel. This provision was vetoed by the Governor in the 2011-13 biennium, with the result that WSF is mandated by law to 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.

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

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

[17] The six vessels are the three 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*.

Exhibit 5.
Fuel Use by Vessel Class 2010



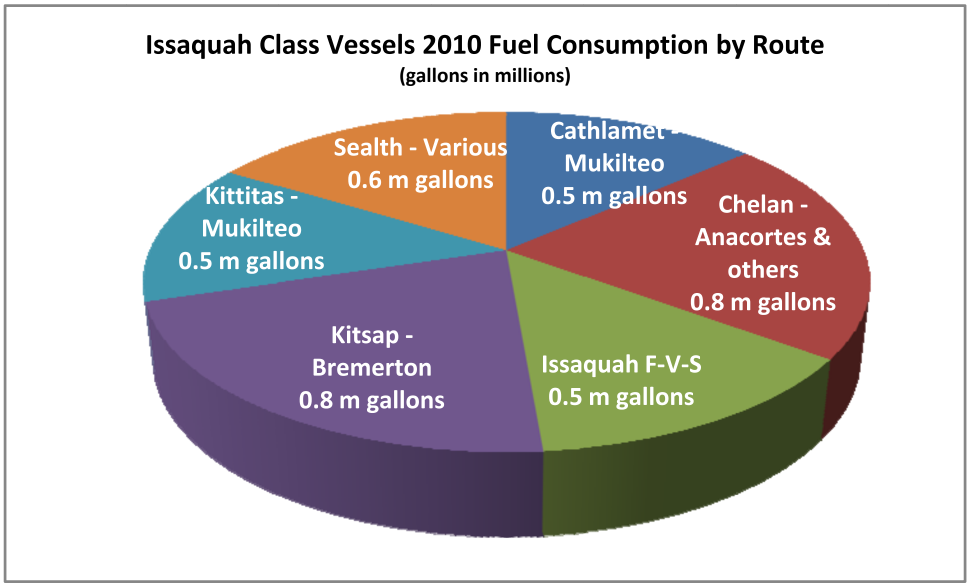
In 2010 WSF had 21 vessels. As of 2011 the fleet has 22 vessels.

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 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 if 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 124-car Issaquah class ferries were utilized on four 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 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 6.
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 new 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. Diesel Fuel Cost

a. Diesel fuel cost projected

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

The cost delivered to WSF of diesel fuel is adjusted from the Transportation Revenue Forecast Council's 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.

Using the September 2011 forecast by the Transportation Revenue Forecast Council in the exhibit below, total diesel fuel costs by gallon are $3.77 in FY 2012, dropping to $3.59 in FY 2014 with the elimination of the sales tax, and increasing to $4.03 in FY 2027.

Exhibit 7.
WSF ULSD 16-Year Price Forecast September 2011

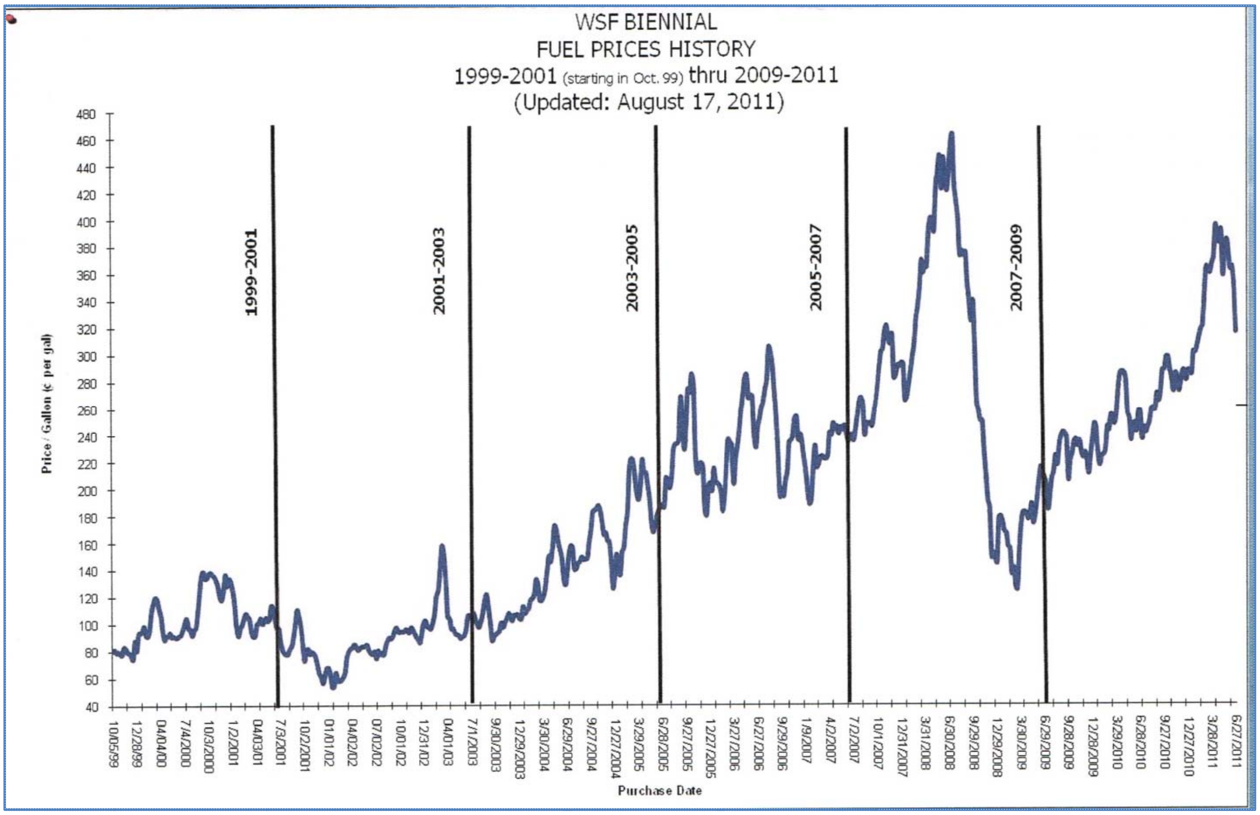
Before taxes and fees:		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Diesel (from September 2011 forecast)		$ 3.28	$ 3.30	$ 3.41	$ 3.39	$ 3.48	$ 3.56	$ 3.61	$ 3.64	$ 3.59	$ 3.57	$ 3.61	$ 3.62	$ 3.65	$ 3.70	$ 3.76	$ 3.82
With 5% biodiesel		$ 3.45	$ 3.47	$ 3.58	$ 3.56	$ 3.66	$ 3.74	$ 3.79	$ 3.82	$ 3.77	$ 3.75	$ 3.79	$ 3.80	$ 3.83	$ 3.89	$ 3.95	$ 4.01
Sales Tax @ 8.9%	8.90%	$ 0.307	$ 0.308	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Federal Oil Spill Recovery Fee	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 Ta	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	0.10%	$ 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 T	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/mon		$ 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		$ 0.32	$ 0.32	$ 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 anc		$ 3.77	$ 3.79	$ 3.59	$ 3.57	$ 3.67	$ 3.76	$ 3.80	$ 3.83	$ 3.78	$ 3.76	$ 3.81	$ 3.81	$ 3.84	$ 3.90	$ 3.96	$ 4.03

Gallons assumptions
Assumes Kennewick replaces Rhod. In 2012
New 144 in FY 2014 and retirement of E. State
2nd 144 in 2015 diesel

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 8.
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 effective October 2011 as a way to pay for unexpected spikes in fuel costs. The surcharge mechanism will only be triggered when fuel costs exceed the 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 requires a 30-day advance notice to customers

B. LNG Fuel

National forecasts by the U.S. Energy Information Administration (USEIA) and other independent analysts 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.

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

1. 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 years.[18] 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).

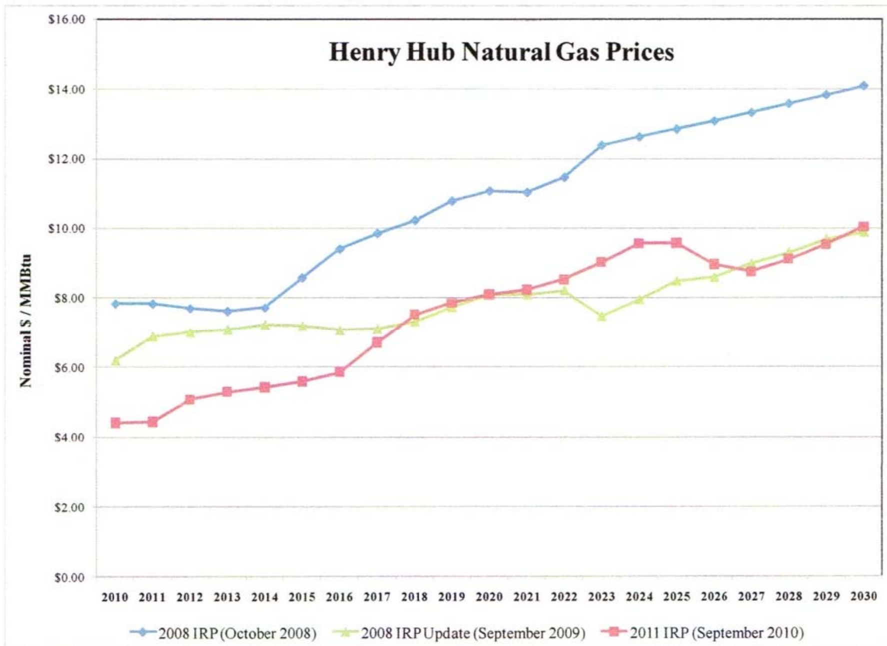
The shift in natural gas prices began in 2007 and 2008 "thanks to an unprecedented and unexpected burst of growth from unconventional domestic supplies across the lower 48 states" (PacifiCorp 2011 IRP, p. 29). Price forecasts by all five utilities are based in part on the Henry Hub gas price forecast.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

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

Exhibit 9. 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.

Figure 7.6 – Comparison of Henry Hub Gas Price Forecasts used for Recent IRPs

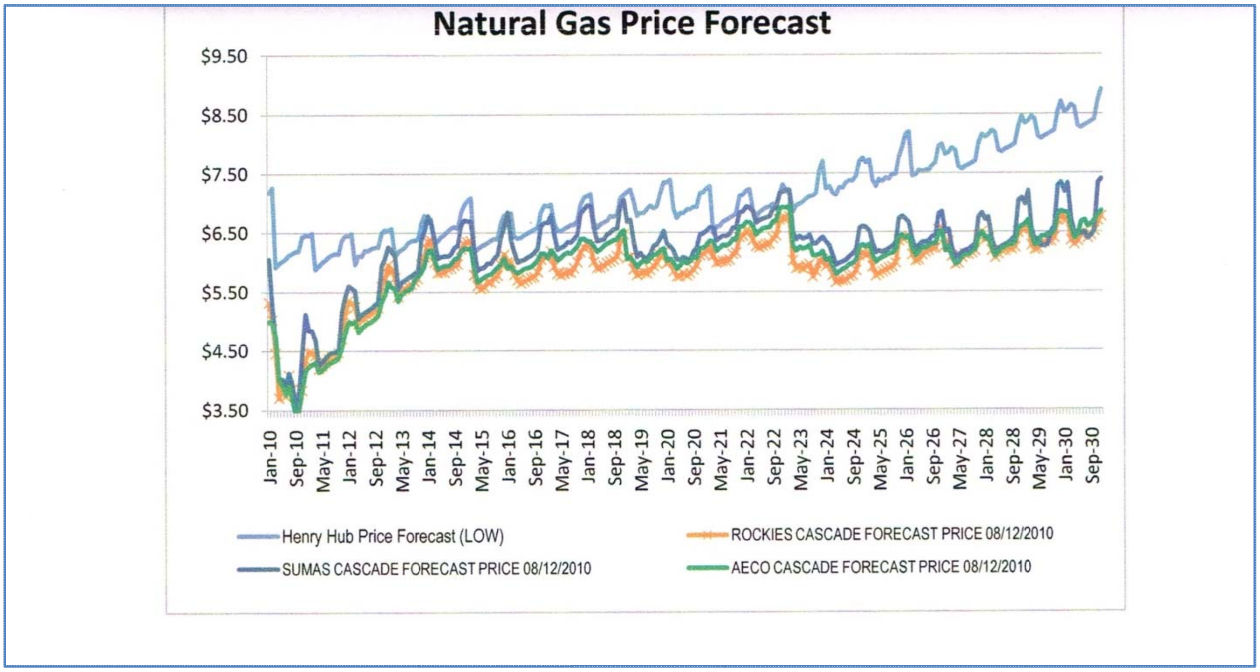


Source: PacifiCorp 2011 Integrated Resource Plan

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, 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 10.
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.

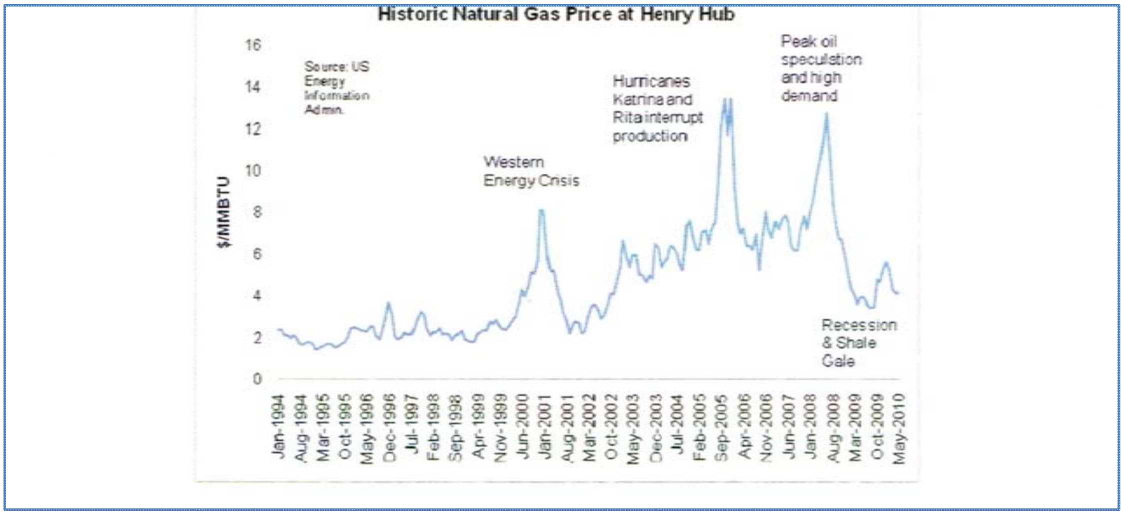


Source: Cascade Natural Gas Corporation 2010 Integrated Resource Plan

2. 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 11.
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.[19]

3. 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 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.[20] In addition to the U.S. import terminals, there is one terminal in Canada and two terminals in Mexico that supply the U.S. natural gas market.

[19] 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.
[20] One facility, the Gulf Gateway, handles a specialized LNG carrier that does the regasification on board.

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. [21]

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

There are 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.[22] 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.[23] 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.

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

[22] There are three 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.

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

- *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). Plymouth is not currently authorized by FERC to sell to customers other than utilities.
- *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.
- *British Columbia.* FortisBC owns and operates two LNG production and storage facilities, one at Tilbury on Vancouver Island and one at Mt. Hayes. This is the supplier that BC Ferries is working with. FortisBC is in the process of expanding production capacity. In consultant interviews, FortisBC representatives have indicated that they anticipate having sufficient supply to meet WSF's initial LNG requirements.

Terasen Gas is constructing an additional LNG peak shaving facility in Vancouver, Washington, 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 peak capacity and some are considering additional satellite LNG storage facilities.

Permitting for U.S. 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)."

4. Liquid Natural Gas Supply for WSF

In interviews with potential suppliers and with others, three options have been identified to supply LNG for WSF needs.

- *Participate in the construction and/or operation of a LNG liquefaction and storage facility.* 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 from outside the Pacific Northwest.* Another option is to contract for LNG from a broker or supplier who would supply LNG by trucking it from out-of-state. This source would be available today.

- *Truck LNG from within the Pacific Northwest.* Discussions with FortisBC indicate that they could be a potential supplier for WSF. There are also other entities considering expanding capacity in the Pacific Northwest.

The consultants' analysis is based on the assumption that, in the worst case, WSF would have to truck LNG in from outside the Pacific Northwest or, in a better case, LNG could be trucked from FortisBC or another Pacific Northwest supplier. 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.[24]

5. Liquid Natural Gas Price Forecasts for WSF

The consultants have developed two price forecasts for WSF LNG: the first assumes trucking LNG from outside the Pacific Northwest and the second assumes a Pacific Northwest supplier. If LNG can be obtained from a facility in the Pacific Northwest it will lower the cost of transportation and provide less supply chain risk than a more distant alternative.

a. Trucking from outside Pacific Northwest forecast

The consultants worked with the Transportation Revenue Forecast 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 assumed a 15 percent return on investment for liquefaction. 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 of one gallon of LNG by 1.7 to create an equivalent cost per gallon of LNG.

As shown in Exhibit 12, the forecast shows that WSF could save 40 percent per gallon on fuel in 2015 narrowing to 36 percent by 2027. The annual savings will depend on which vessels on which routes use LNG fuel.

[24] 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.

Exhibit 12.
LNG 16-Year Price Forecast Outside the Pacific NW Delivered for WSF Use

Year	2015	2020	2025	2027
WSF ULSD Sept. 2011 Forecast	**$3.57**	**$3.78**	**$3.90**	**$4.03**
Henry Hub Natural Gas Price per 1 million MMBTU	$5.04	$5.49	$6.09	$6.45
Conversion Factors for Henry Hub Natural Gas Commodity to LNG Price				
Gas Gallon	$0.50	$0.55	$0.61	$0.64
Liquefaction	$0.44	$0.47	$0.51	$0.53
Trucking	$0.31	$0.33	$0.34	$0.35
Price per LNG Gallon	**$1.25**	**$1.35**	**$1.46**	**$1.52**
ULSD Equivalent Price with 1.7 G LNG=1 G ULSD Adjustment	**$2.13**	**$2.30**	**$2.48**	**$2.58**
Savings Per Gallon	**$1.44**	**$1.48**	**$1.42**	**$1.44**
Percent Savings	**40%**	**39%**	**36%**	**36%**

b. Forecast for Delivery from Pacific Northwest Supplier

The consultants used pricing information provided by FortisBC, a Canadian supplier of peak shaving natural gas to utilities that is expanding production and delivery capabilities, to develop this forecast. FortisBC sells at regulated tariffs and provided information on their price per gallon of gas purchased with the Sumas Natural Gas Index. The consultants then inflated this going forward at the same rate as the Henry Hub Forecast. The Sumas Index is lower than the Henry Hub but the rate of increase is expected to be the same for both going forward. FortisBC provided their liquefaction and production rates and use the CPI as an inflation factor. Trucking was estimated at a ten-hour roundtrip at $100 an hour today, with the same inflation factor as was used for liquefaction and production applied. FortisBC believes they will have sufficient capability to meet WSF's initial demands and will have room to expand as regional demand grows in the future.

Exhibit 13.
LNG 16-Year Price Forecast Pacific NW Supplier Delivered for WSF Use

Year	2015	2020	2025	2027
WSF ULSD Sept. 2011 Forecast	**$3.57**	**$3.78**	**$3.90**	**$4.03**
Sumas Natural Gas Price Index Per Gigajoule	$4.50	$4.91	$5.44	$5.77
Conversion Factors for Sumas Natural Gas Commodity to LNG Price				
Gas Gallon	$0.39	$0.42	$0.47	$0.50
Liquefaction	$0.38	$0.44	$0.51	$0.54
Trucking	$0.11	$0.13	$0.15	$0.15
Price per LNG Gallon	**$0.87**	**$0.99**	**$1.12**	**$1.19**
ULSD Equivalent Price with 1.7 G LNG=1 G ULSD Adjustment	**$1.41**	**$1.59**	**$1.81**	**$1.92**
Savings Per Gallon	**$2.16**	**$2.19**	**$2.09**	**$2.11**
Percent Savings	**60%**	**58%**	**54%**	**52%**

Based on discussions with Canadian supplier assuming exchange rate 1 USD = 1.021 CD

c. 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 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 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 14.
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.

6. LNG Fuel Cost Saving Scenarios

a. Issaquah class fuel savings

WSF's vessel acquisition and deployment plan assumes that each vessel will have a 60-year life. The remaining life of the Issaquah class vessels at the point they are retrofit is a limiting factor in how much savings can be realized.

If the Issaquah class vessels are renovated on the fastest possible schedule, with the first retrofitted vessel in service in 2015 and then one vessel done each subsequent year, the remaining life of the Issaquah vessels at the point of their retrofit would be 23 to 25 years as shown in the exhibit below.

Exhibit 15.
Issaquah Class Vessel Life Remaining Following LNG Retrofit (Most Aggressive Schedule)

Vessel	Year Built	Year LNG Conversion	Remaining Life (years)
Issaquah	1979	2015	24
Kitsap	1980	2016	24
Kittitas	1980	2017	23
Cathlamet	1981	2018	24
Chelan	1981	2019	23
Sealth	1982	2020	22

With this retrofit plan, the fuel savings for the Issaquah class boats from the first 2015 conversion to the retirement of the last vessel in 2042 are $139.9 million based on outside the Pacific Northwest delivery price forecast or $195.5 million with Pacific Northwest delivery. By comparison, the diesel cost for the period is $381.4 million.

Exhibit 16.
Issaquah Class Six Vessel Fuel Savings Range 2015-2042

(YOE dollars in millions)

Forecast	2015	2020	2025	2030	2035	2040	2042	Total Savings
Out-of PNW Delivery Forecast	-$0.8	-$5.5	-$5.3	-$5.7	-$6.2	-$5.8	-$1.1	-$139.9
PNW Delivery Forecast	-$1.1	-$7.8	-$7.4	-$7.9	-$8.6	-$8.0	-$1.6	-$195.5

Fuel costs savings after the 2027 diesel fuel forecast are based on the assumption that the difference between LNG and diesel remains constant from 2027 forward. This is consistent with national projections through 2035 that the differences will remain constant.

The Issaquah class cost savings would be reduced if the vessels are renovated at a later date.

b. New 144-car Vessel

Projected savings for the new 144-car vessel assuming service on the Anacortes-San Juans route beginning in 2016 over the 60-year life the vessel are $86.3 million based on outside the Pacific Northwest delivery price forecast or $120.0 million with Pacific Northwest delivery. Diesel costs are estimated to be $238.6 million.

Exhibit 17.
New 144-Car Vessel Fuel Savings Range 60 Year Life (Begin 2016)

(YOE dollars in millions)

Forecast	2016	2026	2036	2046	2056	2066	2076	Total Savings
Out-of PNW Delivery Forecast	-$1.0	-$1.0	-$1.1	-$1.3	-$1.6	-$1.9	-$2.3	-$86.3
PNW Delivery Forecast	-$1.4	-$1.3	-$1.5	-$1.8	-$2.2	-$2.6	-$3.1	-$120.0

Fuel costs savings after the 2027 diesel fuel forecast are based on the assumption that the difference between LNG and diesel remains constant from 2027 forward. This is consistent with national projections through 2035 that the differences will remain constant.

c. Other Vessel Retrofits – Jumbo Mark IIs

The only other vessels that WSF could consider retrofitting for LNG fuel are the Jumbo Mark IIs. The Jumbo Mark 1 and Super class vessels are too old to justify a retrofit and the other smaller vessels consume too little diesel fuel to make a retrofit an economic investment.

Although retrofitting the Jumbo Mark IIs would be a more difficult project, the fuel cost savings could be very significant.

The three Jumbo Mark IIs consume 27 percent of WSF's fuel and would have, as of 2015, 41-42 years of remaining life.

Exhibit 18.
Jumbo Mark II Class Vessel Life Remaining Following Potential LNG Retrofit (Most Aggressive Schedule)

Vessel	Year Built	Year LNG Conversion	Remaining Life (years)
Tacoma	1997	2015	42
Puyallup	1998	2016	42
Wenatchee	1998	2017	41

With this retrofit plan, the fuel savings for the Jumbo Mark II class boats from the first 2015 conversion to the retirement of the last vessel in 2058 are $355.0 million based on outside the Pacific Northwest delivery price forecast or $494.6 million with the Pacific Northwest delivery forecast. Current estimated diesel costs are $975.7 million.

Exhibit 19.
Jumbo Mark II Class Three Vessel Fuel Savings Range 2015-2058

(YOE dollars in millions)

Forecast	2015	2025	2035	2045	2050	2058	Total
Out-of PNW Delivery Forecast	-$2.2	-$6.6	-$7.7	-$9.2	-$10.0	-$7.7	-$355.0
PNW Delivery Forecast	-$3.2	-$9.2	-$10.7	-$12.7	-$13.9	-$10.6	-$494.6

Fuel costs savings after the 2027 diesel fuel forecast are based on the assumption that the difference between LNG and diesel remains constant from 2027 forward. This is consistent with national projections through 2035 that the differences will remain constant.

7. Fuel and LNG Schedule

Having the LNG fuel contract in place before vessel construction is important both to secure the supply at a known price, and to test the motors during construction with the actual fuel to be used. The latter was one of the recommendations from Gasnor and Tide Sjo in Norway.

SECTION VII. LNG VESSEL BUNKERING AND MAINTENANCE

This section reviews LNG bunkering and maintenance costs. This section concludes that bunkering for LNG is a more complex operation than diesel fueling and may require operational adjustments. Maintenance costs are anticipated to be the same as for diesel fueled vessels, although the USCG could change required staffing when it issues the Certificate of Inspection. WSF should retain the services of a classification society to inspect and monitor the LNG vessels during the first at least ten years of operation.

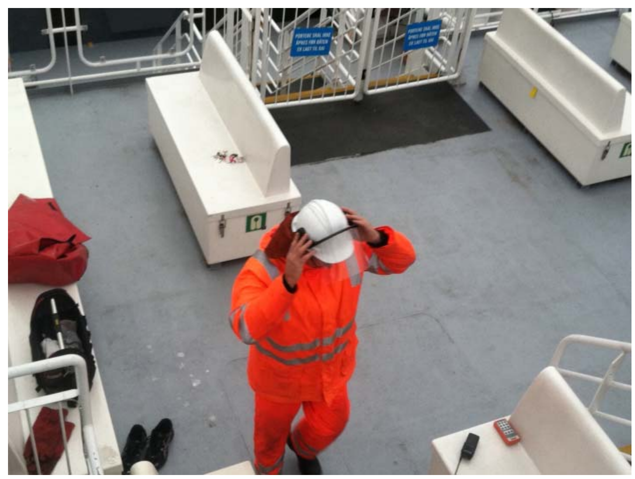
A. Bunkering

Refueling or bunkering of LNG is a more complex operation than diesel fueling and may require operational adjustments.

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, 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.

1. LNG Bunkering

The consultants observed the fueling of vessels in Norway. In Oslo for the Tide Sjo passenger only ferries fueling takes place by truck, the same as the WSF LNG vessels would under current plans.



Fueling takes place with an adjustable hose that is attached to the fueling truck. The line is cleared with nitrogen before and after the fuelings on each vessel to ensure that LNG does not leak into the atmosphere. As shown in the photo to the right, the driver and both deckhands monitoring the fueling, who are stationed at the above deck bunkering station, all wear fire protection suits with face shield. The Chief Engineer monitors the process from the deck and the fueling can be halted by any of the three, who are in radio contact, if necessary.

Upon completion of the fueling, the driver, the crew at the bunkering station and the Chief Engineer go through an extensive safety checklist as the nitrogen is venting the line and the hose is disconnected.

2. Diesel Fueling

The consultants also viewed a fueling by truck of one of the existing Issaquah class vessels on the Seattle-Bremerton route. Two trucks drove onto the ferry on the Seattle side and fueling took place at the end of the last sailing of the day at Bremerton. The Chief Engineer and engine room crew go through a short safety meeting before fueling to ensure the vessel is ready for fueling and all their communication equipment is working in case of emergency

They then lay out boom and devices on deck to stop any diesel fuel leaks from going overboard. The driver verifies the amount to be delivered, in this case 16,900 gallons, and the engine room staff plots how they will split the load between the fuel tanks to ensure proper ballast. During fueling the two truck drivers feed the diesel fuel by gravity to the vessel fuel tank. They were overseen by the Assistant Chief Engineer on the deck, while the oiler measured the height of fuel in the tanks as they fueled with a sounding tape. No hazardous material gear is required other than gloves. The process is less automated than LNG fueling, which requires the pressure to be constantly monitored and the fill level of the tanks is measured by computer.

Oiler (blue glove) Measuring diesel fuel tank level aboard WSF with measuring stick (left) and measurement system for LNG on Fjord1 vessel (right) that monitors whole system for pressure and potential leaks


Issaquah class fueling station *LNG bunkering station – Tide Sjo*

B. Classification

Classification of operating vessels involves inspections by the classification society to determine if the vessel operation and status are in compliance with applicable rules. WSF does not maintain class on its diesel vessels nor do the Norwegian ferry operators the consultants interviewed. The Norwegian ferry operators have maintained class on their LNG fueled vessels because of the relative sophistication of the vessels and limited experience with operating them. The classification society Det Norske Veritas (DNV) has provided an estimated cost of $15,000 per vessel per year for on-going classification services.

C. Maintenance Costs

Projections for maintenance cost of a new 144-car diesel vessel are based on the maintenance costs for the Issaquah class vessels. Annual maintenance costs, excluding engine room labor, for each Issaquah class vessel and the new 144-car diesel vessel are approximately $0.7 million: $0.3 million for engine room non-labor supplies; $0.3 million for shipyard and other contract maintenance; and $0.1 for Eagle Harbor work.

1. Motor Repair/Overhaul

Fjord1 reported in 2010 that their costs for routine LNG vessel motor maintenance for the *Glutra,* their first LNG fueled passenger vessel, had been 20 percent higher than for a similar-sized diesel vessel. Fjord1 also report that maintenance costs of its five sister ships in operation since 2007 have been 10 percent higher. Consultant interviews with Fjord1 in October 2011 and interviews with Tide Sjo in Oslo indicate that maintenance costs for the LNG vessels are now projected to be the same as for their diesel vessels.

Cost estimates developed by The Glosten Associates for the new 144-car diesel vessel and the LNG fueled vessel show similar motor maintenance and repair costs for both versions of the vessel at $0.1 million per year in 2011 dollars assuming a center section overhaul every 30,000 hours, an intermediate overhaul every 60,000 hours, and a major overhaul every 120,000 hours for both types of engines.

The Norwegians are finding that oil changes can be possibly extended to 30,000 service hours from the normal 8,000 service hours because the engine is so clean.

D. Engine Room and Deck Staffing

The Issaquah class ferries operate with three staff in the engine room 24-hours a day and 11 deck staff when the vessel is in service. The 90-car Sealth has a deck staff of 10 rather than 11. The 16-year financial plan assumes that the new 144-car vessel will have the same staff requirements as the Issaquah class.

The USCG makes the determination on minimum staffing levels. This analysis assumes that there are no changes in staffing requirements with LNG fueled vessels.

SECTION VIII. VESSEL DESIGN AND CONSTRUCTION

This section reviews the regulatory requirements that will govern WSF LNG vessel design and construction and includes a discussion of important design and construction considerations. This section concludes that:

- The USCG design and construction regulatory process, which is in addition to the safety planning, will take longer than normal because there are no approved USCG rules. In the absence of specific rules, the USCG can review and approve alternative designs under 46 CFR 50.20-30.Using its authority under 46 CFR 50.20-30, the USCG responded to WSF's 144-car vessel *Regulatory Review of Concept* with a letter that will be the basis for the USCG design review. A request for *Regulatory Review of Concept* was submitted to the USCG for the Issaquah class retrofit in September 2011.
- The USCG could decide that the Issaquah class vessels are a major conversion, which would require WSF to bring these 30-year old vessels up to current standards. This would be cost prohibitive. It will be important for WSF to have a major conversion determination from the USCG before proceeding with the construction of an Issaquah class retrofit.
- Given the complexity of LNG systems, WSF should consider contracting for design with a firm (or firms) that have experience in LNG fueled systems and should consider requiring the shipyard to retain an expert with LNG construction experience.

A. Design Regulatory Requirements

There are regulatory differences between diesel and LNG fueled ferries. The USCG has not developed rules governing the design 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.

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.

The IGC code, the rules on how gas carriers can store, handle and use gas as a fuel, is being revised at the same time that a set of interim guidelines on the use of LNG as a fuel, known as the IGF code, in other vessels is being developed and solidified. The deadline for confirming the IGF code has been extended to 2014 from an original goal of 2012 in part to resolve contradictions between the two codes. This has increased the uncertainty about the direction of IMO rules.

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 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" until such time as USCG guidelines are adopted. The USCG has provided to WSF/Glosten significant additional guidance which is discussed below.

Design and vessel plan approval is a separate and distinct process from the safety planning process discussed above. This regulatory review will be required in addition to the safety planning process.

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 vessel, 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 does not 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.

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. Design Considerations

An October 2011 presentation by DNV[25] identified the main safety challenges using natural gas as marine fuel including:

- *Explosion risk.* LNG is flammable in a range of 5-15 percent mixture in the air with a temperature source of 563 deg C.
- *Low temperature of LNG.* LNG released onto normal ship steel will make that steel very brittle, which could result in cracking of the steel.
- *Gas tank large energy content.* The tank must be protected from external fire, mechanical impact, and from the ship side and bottom in the event of a collision or grounding.

Two considerations for WSF if it proceeds with detailed design are the engine room standard for its LNG vessels and the location of the LNG storage tank.

1. Engine Room Standard

There are two engine room design standards: intrinsically safe and emergency shutdown (ESD). The Glosten Associates *144-car Ferry LNG Feasibility Design Report* notes: "There are two safety categories of gas fueled propulsion systems: inherently safe or not inherently safe. An inherently safe gas engine is an engine where all of the on-engine gas supply piping is double walled pipe. Engines without the double walled gas pipe are not inherently safe. An engine that is not inherently safe must be located in an emergency shutdown (ESD) protected engine room. This means that if an abnormal condition involving a gas hazard is detected all equipment that is not explosion protected design, including the engine, must immediately shut down. This requires that all vital equipment located in an ESD protected engine room must be explosion proof. Because (the new 144-car vessel) is an almost completed detailed design and a substantial amount of equipment is located in the engine rooms, ESD protected engine rooms are not practical."[26]

The Norwegians exceed both the ESD and inherently safe engine room requirements by placing each gas fueled engine alone in its own steel enclosed space such that a fire or explosion in that space will not affect any other space and they use double wall piping.

The consultants corresponded with a German naval architecture firm that has extensive experience with LNG fueled vessels. Marine Service indicates that they prefer a system where gas is fed to the engines through double walled fuel lines and there is a valve hood room with ESD valves that cut off the fuel supply to the engines whenever there is a leakage in the primary gas fuel line. It allows you to have a conventional engine room arrangement, while sailing on gas and having conventional equipment in the engine room with not everything being explosion proof and expensive. It is in Marine Service's view more practical with conversions, as it allows the vessel to retain the old auxiliaries.

2. Storage Tank Location

WSF's concept design has the storage tanks on top. All of the Norwegian LNG ferries and the new one being built in Quebec have the storage tanks in the hull. IMO is developing international rules regarding the placement of LNG storage tanks. According to the October 2011 DNV presentation one of the

[25] DNV, *Gas fuelled engine installations in ships Background, status, safety, some solutions- Interferry Barcelona- October 2011.*
[26] The Glosten Associates, *Washington State Ferries 144-Car Ferry LNG Feasibility Design Report,* July 2011, p. 4.

primary questions being addressed in the IMO review is whether LNG tanks can be safely located below deck and below passenger spaces if properly contained.

a. Topside storage tank location

The primary reason to place the storage tank topside is because there is not enough room below deck. WSF indicates that in discussions with the USCG this is their preferred location. The letter from the USCG that provides the basis for regulatory review is based on the design submitted which has the storage tank on top.

The topside arrangement raises some potential concerns. When LNG is released in a cryogenic state (-259 F) the methane vapors are heavier than air and if a tank breach occurs, a vapor cloud of methane can form which, depending on the amount of methane released, could be several ferry lengths. Ventilation systems could pull this vapor into the ferry engine rooms and passenger spaces, which in the presence of an ignition source at the right methane mix, could result in a fire. LNG released in to the atmosphere at -259 deg F will be heavier than air until it reaches a temperature of -184 deg F where it will become lighter than air. The LNG in the tanks are under 7-10 BAR of pressure (101 – 145 psi) so any release will be in the form of a jet which will quickly mix with 50 deg F air and become lighter than air allowing it to drift off and dissipate into the atmosphere.

The topside arrangement requires that the storage tank be securely mounted and able to withstand rough seas and/or a vessel collision. The cryogenic stainless steel spillway under each tank should be designed to discharge over the side of the ferry and not to impinge on the deck.

The storage tank location requires expert design of the piping to ensure that the piping can withstand movement of the vessel superstructure in extreme conditions. One option for predicting superstructure movement is to use Finite Element Analysis (FEA) to determine, with good accuracy, what movement the piping must accommodate. WSF indicates that they have multiple experts in the use of FEA analysis and will develop the design to meet or exceed all dynamic and thermal loading conditions.

Having the storage tank on top requires piping through the passenger space walls, which is not required if the storage tank is in the hull. The gas lines to each engine are being run in the existing machinery casings in double walled piping. The casings are a secondary isolation of the piping from the passenger spaces.

b. LNG Storage Tank – Hull

The primary advantage to having the storage tank in the hull is that there is less movement in the hull than on the superstructure and less piping through the passenger areas. DNV is developing revised rules for the placement of tanks in hulls under passenger spaces that would increase the separation of the tank from the hull.

The disadvantages of having the LNG storage tank in the hull are that any gas is released into a more confined space and if there were an explosion it could affect the passenger areas. Additionally, having the gas located below deck could allow it to dissipate upwards into the passenger area in the event of a leak.

3. Design Expertise

WSF has discussed the potential for designing the LNG Issaquah class retrofit in-house. For at least the first vessel, WSF should contract the work to an outside firm that has specialized expertise in LNG fueled systems design. Washington State naval architectural firms would sub-contract with firms that are experienced in the design of LNG fueled passenger vessels to meet the requirements.

C. Construction and Inspection

1. Regulatory Review

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.

2. Major Conversion – Issaquah Class Vessels

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 and the decisions are not always consistent in the consultants' view.

3. U.S. Shipyard Experience

No U. S. shipyards have experience with the construction of LNG fueled passenger vessels, which will add risk to the project. When the U.S. built LNG carriers at General Dynamics, Newport News and Avondale shipyards, General Dynamics and Newport News hired foreign yards experienced in the LNG system installation to work together with US shipyard engineers and workers to accumulate all off the engineering and assembly experience they had gained. Avondale, to save money did not, and installed insulation on the LNG tanks incorrectly. When on sea trials, the insulation failed and the three ships valued at $500 million were determined by the USCG to be incapable of carrying LNG and therefore were considered to be constructive total losses, as it would cost as much to fix them as it cost to build them.

WSF should require the shipyard to retain someone with LNG construction experience.

4. Impact on LNG Schedule

The LNG fueled ferry construction schedule must take into account the time added for regulatory review of the design. WSF is estimating one year for regulatory review of the concept. It may also take additional time for USCG construction inspection.

One critical path consideration for the retrofit of the Issaquah class ferries is whether the USCG will decide that the retrofit is a major conversion. It will be important to get this decision before proceeding with construction of the Issaquah class retrofits.

SECTION IX. CAPITAL PROJECT COST ESTIMATE

The consultants sub-contracted with an experienced shipyard estimator and consulted with a shipyard in Norway that has experience with constructing new LNG vessels and with a retrofit of a vessel that is similar in size to the Issaquah class ferries.

The consultants' estimate the costs for the conversion of all six Issaquah class vessels in year of expenditure dollars at $143.6 million, which is 40 percent higher than WSF's estimate of $103.0 million.[27]

The new 144-car vessel cost estimate compares the existing new 144-car vessel design with an adaption of that design to a LNG fueled vessel. The consultants' estimate for the additional cost to construct a new 144-car LNG vessel is $18.9 million, which is 31 percent higher than WSF's estimate of $14.5 million in current dollars.[28] If constructed in the 2013-15 biennium, our estimate is that a new 144-car LNG vessel would cost $20.3 million more than a new 144-car diesel vessel and the comparable WSF estimate would be $15.5 million.

A. WSF Non-Vessel Costs or Project Soft Costs

Non-vessel or soft project costs are estimated as though the Issaquah class retrofit and new 144-car vessel projects were independent. If both were done, the security planning and communications costs would be a shared expense.

1. Issaquah Cass Retrofit

As shown in the exhibit below, WSF estimates that the costs for the first Issaquah class LNG conversion for non-vessel design and construction costs will be $1.7 million in FY 2012 dollars. On-going costs for subsequent vessels will be $0.3 million unless the *Evergreen State* is retained in service to cover out-of-service time. If the Evergreen State vessel is retained in service, the additional cost is $0.7 million.

[27] WSF's estimate is adjusted as explained below to include soft costs, staggering of vessel construction and inflation that were excluded from the original estimate.
[28] WSF's estimate is adjusted as explained below to include soft costs and contingency not included in WSF's original estimate.

Exhibit 20.
Issaquah Class Retrofit Project Soft Costs
(2012 $ million)

	Cost	One time
Equivalent of Waterways Suitability Assessment (WSA)	$0.6	$0.6
Training	$0.2	
Sea Trials	$0.1	
Replacement Service	$0.7	$0.7
Less: Partial de-crew of Issaquah class vessel while in the shipyard	($0.2)	
Communications consultant support	$0.1	
Staff:		
Project Manager for WSA , Transportation Tech Engineer 5	$0.2	$0.2
Communications Consultant/ Materials Designer/Web	$0.1	
Staff subtotal	$0.3	
Total Soft Costs	**$1.7**	**$1.4**
Ongoing for additional vessels after second 144-car ferry		**$0.3**
Ongoing for addition vessels until second 144-car ferry		**$1.00**

2. New 144-Car Vessel

As shown in the exhibit below, WSF estimates that the costs for a new 144-car vessel as an LNG vessel for non-vessel design and construction will be $1.1 million. The costs for sea trials would already be included in the new 144-car vessel construction budget and replacement service would not be required.

Exhibit 21.
New 144-car Vessel Retrofit Project Soft Costs
(2012 $ million)

	Cost
Equivalent of Waterways Suitability Assessment (WSA)	$0.6
Training (for LNG)	$0.2
Communications consultant support	$0.1
Staff:	
Project Manager for WSA , Transportation Tech Engineer 5	$0.2
Communications Consultant/ Materials Designer/Web	$0.1
Staff subtotal	$0.3
Total Soft Costs	**$1.1**

B. Design and Construction Cost Estimate

1. Cost Estimate Approach

a. Concept Design

The consultants' independent cost estimate is based on WSF's concept design. WSF has submitted two requests for regulatory review to the USCG: one for the new 144-car vessel and separately for the Issaquah class retrofit.

The Issaquah class retrofit request submitted to the USCG in September 2011 includes more detailed plans and engineering than were submitted with the earlier new 144-car vessel request for regulatory review. The Issaquah class retrofit drawings and accompanying calculations were used by the consultants to determine quantities and measurements used in the cost estimate for the Issaquah class retrofit. This estimate was then used to develop a corresponding estimate for the new 144-car vessel.

WSF is considering two engine options: a single fuel/LNG engine and a dual fuel (diesel and LNG) option. This cost estimate is based on the single fuel/LNG only option, which is the engine that is used in all currently operating LNG fueled ferries.

b. System Work Breakdown Structure (SWBS) Estimate

The consultants retained the services of a professional shipyard cost estimator who used an industry standard system work breakdown structure to estimate costs.

Quantities for the estimates were derived from WSF's drawings. Cost information came from vendor quotations. A shipyard labor rate of $60.00 per hour is used.[29] The SWBS estimates include:

- *Shipyard costs.* Shipyard costs for labor, material, and sub-contractors are included in the estimate.
- *Owner furnished equipment (OFE).* Historically WSF has owner supplied the propulsion systems to take advantage of federal grants. The SWBS estimate for the new 144-car vessel and the Issaquah class retrofit each include $7.7 million for propulsion system acquisition which will be owner furnished.
- *Regulatory review.* The estimates include the cost of regulatory review by DNV, estimated at $0.3 million in both estimates.
- *Outside engineering.* The estimates include an allowance for naval architectural services of $750,000 which would be contracted directly by WSF.

b. SWBS Estimate – Process

The consultants first developed the SWBS estimate for the Issaquah class retrofit using the more detailed information available from WSF's September 2011 *Request for Regulatory Review*. This estimate was refined by reviews with Vigor and with a Norwegian ferry operator and shipyard currently retrofitting a vessel that is similar in size to the Issaquah class vessels.

Vigor Review

The estimate was reviewed with the shipyard, which provided the labor rate and options for the use of internal shipyard staff and subcontractors.

Norwegian Review

Fjord 1 is converting a 20-year old diesel fueled ferry, the *Tresfjord*, to LNG. The *Tresfjord* is similar in size to an Issaquah class ferry (*Tresfjord* 318 ft. in length, an Issaquah class ferry 328 ft. in length) and has similar engine size (both about 2500 HP). The primary difference between the two vessels is that the *Tresfjord* is powered with one diesel engine powering two generators and thrusters while the Issaquah

[29] WSF studies included two shipyard labor rates. The Glosten Associates new 144-car LNG vessel estimate included a shipyard labor cost of $65 per hour. WSF's Issaquah class estimate used $72.00 per hour. On further review, WSF states that the shipyard labor rate should be $60 per hour.

class vessels have two diesel engines each powering one propeller. The *Tresfjord* had one engine compartment empty.

The retrofit, which is required by Fjord 1's contract with the Norwegian government[30], involves using the one empty engine compartment to install a 2500 HP LNG fueled engine, retaining the existing diesel engine for back-up. Both engines would be hooked through common shafting and clutches to the generators. The LNG engine will be a single fuel/LNG only engine. One LNG fuel storage tank and one LNG fueling station will be added.

The STX Langstein shipyard in Norway is doing the retrofit under contract with Fjord 1. STX Langstein has previous experience constructing LNG fuelled vessels. The *Tresfjord* is the yard's first LNG conversion project. The *Tresfjord* conversion was expected to take 6 months. The contract was awarded in January 2011 with delivery expected in June 2011. Delivery is now expected in February 2012 because of problems encountered with the originally supplied LNG valves and piping that had to be re-ordered.

The consultants sent the SWBS estimate for the Issaquah class retrofit and WSF's engineering information from the Issaquah class retrofit request for regulatory review to STX Langstein. In subsequent meetings at the shipyard, the consultants were able to obtain man-hours used by STX Langstein on the *Tresfjord*. The consultants worked with the shipyard staff to adjust the STX Langstein man-hours for the Issaquah class vessel retrofit. Adjustments were for the extra man-hours incurred on the *Tresfjord* conversion from the faulty valves and piping; differences in the storage tank location; differing lengths in LNG filling and supply to engine piping; and for differences in engine room classification.

The consultants then compared the resulting man-hour estimate with the SWBS estimate for the Issaquah class retrofit. Taking into consideration the relatively lower efficiency of North American shipyards when compared to European shipyards, the consultants' estimate approximates the Norwegian experience.

Additional Costs

Two costs were added to the SWBS estimate:

- *Shipyard profit.* The consultants were not able to get an estimate for shipyard profit from Vigor. An industry standard assumption of 7 percent was used for this estimate. The profit was applied to shipyard costs only – excluding OFE and naval architect costs.
- *Contingency.* A 25 percent contingency was applied to the estimate.

2. Issaquah Class Retrofit Rough Order of Magnitude (ROM) Cost Estimate

a. First Issaquah Vessel Retrofit

The consultants' cost estimate for the first Issaquah class retrofit in FY 2012 dollars is $22.4 million. WSF has a lower cost estimate of $16.0 million or 40 percent lower.

The primary differences in the cost estimates result from the fact that the consultants believe that a LNG retrofit is more complicated than WSF does. Our estimate includes the use of a classification society, outside design consultants, and greater shipyard supervision. WSF has based their estimate on their experience with changing diesel engines on existing vessels.

[30] The contract required a LNG fueled vessel on the route. Fjord 1 elected to do the retrofit to meet this requirement.

Exhibit 22
First Issaquah Class Retrofit ROM Cost Estimate (FY 2012 $ in millions)

	WSF	Consultant	Difference	
Design (in-house)	$0.3		-$0.3	
Design - consultant		$0.8	$0.8	
Classification		$0.3	$0.3	
Shipyard Construction	$11.1	$15.4	$4.3	
Contingency @ 25%	$2.9	$4.1	$1.3	
Soft WSF Costs	$1.7	$1.7	$0.0	
Total	**$16.0**	**$22.4**	**$6.4**	**40%**

b. Issaquah Six Vessel Year of Expenditure Estimate

The year of expenditure estimate is based on the most aggressive possible retrofit schedule for the Issaquah class vessels. It assumes an inflation rate of 3.7 percent per year for vessel construction which is the inflation rate assumed in the 2011-13 biennium budget. The estimate assumes that each pair of engines is paid for separately one year before the start of construction.[31]

Soft costs include that the *Evergreen State* is deployed as a replacement vessel through the retrofit of the second Issaquah class vessel. *Evergreen State* operation costs are not included in the estimated costs to retrofit the third through sixth Issaquah class vessels.

Under the consultants' estimate the total year of expenditures Issaquah class retrofit cost is $143.6 million. Under WSF's estimate the total retrofit cost is $103.0 million.

Exhibit 23.
Issaquah Six Vessel Class Retrofit YOE ROM Estimated Cost ($ millions)

	WSF	Consultant	Difference	%
Retrofit six Issaquah class vessels	$103.0	$143.6	$40.6	40%

[31] Engines will most likely be ordered in one or two orders with staggered delivery dates.

3. New 144-Car Vessel Estimate Rough Order of Magnitude Cost Estimate

The consultants' cost estimate for the additional cost to build a new 144-car LNG vessel is $18.9 million, which is 31 percent higher than WSF's estimate of $14.5 million. This cost estimate compares the existing new 144-car vessel design with an adaption of that design to a LNG fueled vessel.

The consultants' estimate includes the use of a classification society and differences in shipyard labor. Other differences are in the estimate of shipyard manhours given the consultants' view of the complexity of the project.

Exhibit 24.
New 144-Car Vessel LNG ROM Cost Estimate (FY 2012 $ in millions)

	WSF	Consultant	Difference	%
Design	$0.8	$0.8		
Classification		$0.3		
Shipyard Construction	$9.9	$13.1		
Contingency @ 25%	$2.7	$3.6		
WSF Soft Costs	$1.1	$1.1		
Total	**$14.5**	**$18.9**	**$4.4**	**31%**
YOE Expenditure Dollars (2013-15 biennium)	**$15.5**	**$20.3**	**$4.8**	**31%**

SECTION X. CONCLUSIONS AND RECOMMENDATIONS

This section presents the consultants' conclusions and recommendations on the questions posed in the introduction to this report.

A. Security

What, if any, impact will the conversion to LNG fueled vessels have on the WSF Alternative Security Plan?

As discussed in Section IV on security and operational planning:

- *Security and operational planning and the associated public outreach are critical to WSF's ability to operate LNG fueled vessels*.
- *The proposed approach, which assumes the USCG will allow a modification to the process it uses for safety planning for LNG terminals, is anticipated to take 18 months and cost $1.0 million.*

Consultants' Conclusion

Security and operation planning with its associated public outreach should be the next step in the consideration of LNG for WSF vessels. A final legislative decision on LNG fuel should not be made until this planning is sufficiently complete to: 1) assess the impact of LNG on the Alternative Security Plan and on WSF and Washington State Patrol staffing; and 2) gauge public reaction.

Recommendation 1. Security and Operational Planning Funding

The consultants recommend that the Legislature provide funding for security and operational planning and the associated public outreach of $1.0 million in the FY 2013 budget.

B. Vessel Acquisition and Deployment Plan

What are the implications of LNG for the vessel acquisition and deployment plan?

As discussed in Section V:

- *Retrofitting the Issaquah class vessels will have a greater impact on the vessel acquisition and deployment plan than constructing a new 144-car vessel as an LNG vessel*. The retrofits cannot begin until the fall of 2014 following the return of the Super class *Hyak* to service from its major renovation. If the Issaquah class retrofits begin before the second new 144-car vessel is in the fleet, WSF plans to retain the *Evergreen State* in service to provide coverage. If not for the retrofit of the Issaquah class vessels, the *Evergreen State* would retire when the first new 144-car diesel fueled ferry comes on line in 2014.
- *Once a second new 144-car vessel is in the fleet, WSF can both retrofit the Issaquah class vessels and retire the Evergreen State.* To avoid disrupting service during the peak summer months, WSF plans to retrofit one Issaquah class vessel per year taking the vessel out-of-service during the fall through early spring. It would therefore take at least six years to complete the full retrofit of the Issaquah class vessels.

- *Delaying the delivery of the second new 144-car vessel by one year to accommodate its conversion to LNG will delay the planned service improvements and retirement of the Hiyu* and will require the Evergreen State to stay in service if WSF proceeds with the retrofit of the Issaquah class vessels*.*
- *Designing a new 144-car vessel as a LNG fueled vessel could be considered in the context of the next planned procurement of five new 144-car vessels starting in 2025.* If funding were available, a new 144-car LNG vessel could be viewed as the first of six such vessels.

Consultants' Conclusions

- **The decision whether to build a new 144-car vessel as a LNG fueled vessel should not be made until the security planning is complete.** Assuming funding in FY 2013, the security planning could be completed by January 1, 2014 at which point a decision could be made on whether to proceed with the new 144-car vessel as a LNG fueled vessel. If funded in FY 2014, the new 144-car LNG vessel could potentially come on line in 2017.
- **A new 144-car LNG vessel should be purpose built as a LNG vessel.** The most economical action would be to consider the first new 144-car LNG vessel as part of a series of six such vessels or so many as the Legislature decides to fund. This would allow WSF to acquire a purpose built LNG design. A purpose built design would result in safety improvements from the engine room being designed specifically for LNG. It would also allow WSF to achieve the economies of scale of purchasing more than one vessel at a time.
- **Retrofitting the Issaquah class ferries will take at least six years and require the Evergreen State to stay in service unless a second new 144-car vessel comes on line.** Under the most aggressive schedule the retrofitted Issaquah class vessels would come on line between 2015 and 2020. The *Evergreen State* would have to remain in service past its projected 2014 retirement for up to six additional years at which point it will be 66 years old. Funding for preservation of the *Evergreen State* is not included in the 2011-27 16-year financial plan because it is expected to retire.

Consultants' Recommendations

Recommendation 2. New 144-Car Vessel

The consultants recommend that the Legislature proceed with construction of the second new 144-car vessel as a diesel fueled vessel, with delivery in 2015 if funding is available, if it is more important to improve service on the schedule anticipated in the WSF Long-Range Plan than to potentially reduce operations costs. If the Legislature considers construction of a LNG fueled vessel it should consider the investment only after the completion of security planning and in the context of the planned procurement of five new 144-car vessels to allow for the acquisition of a purpose built LNG design and potential economies of scale in ship building.

Recommendation 3. Issaquah Class Retrofit

If the Legislature considers retrofitting the Issaquah class vessels, it should do so only after the completion of security planning. Design and construction should follow recommendations 4 -7 below. The legislature should also recognize that funding will need to be provided for preservation of the *Evergreen State*. WSF estimates preservation needs for the *Evergreen State* to be an additional $0.4 million until 2018, at which point it would potentially need propulsion controls replaced at a cost of $5.7 million.

C. LNG Design and Construction

What design and construction constraints should be considered in making LNG decisions?

As discussed in Section VI on vessel design and construction:

- *The USCG design and construction review process, which will be in addition to the security planning requirements, will take longer than normal.* This longer time period will occur because the USCG does not have LNG fueled passenger vessel rules and because it is likely that WSF would be one of the first, if not the first, to construct or retrofit a LNG fueled passenger vessel in the United States.
- *There is international regulatory uncertainty.* The IMO is in the process of revising its rules and has extended the deadline for completing their rules until 2014.
- *There are safety considerations in LNG design that are different than for a diesel fueled vessel.* These safety concerns include explosion risk, low temperature of LNG, and the large gas tank energy content. Two design considerations are the engine room standard, which can be either the emergency shutdown system that exists in all the Norwegian vessels and automatically shuts down any areas with a gas leak, or the inherently gas safe design planned by WSF that requires all gas supply piping to be double walled, and the location of the storage tank.
- *There is limited U.S. design or construction experience with LNG fueled passenger vessels.* All of the experience is elsewhere in the world. The Norwegians have the most extensive experience.
- *Major conversion.* The USCG could decide that the Issaquah class retrofits are major conversions, which would make the retrofit prohibitively expensive because the vessel would be required to meet all USCG equipment and ADA regulations as if it were a new build.

As discussed in Section VI on diesel and LNG fuel:

- *The fuel contract should be let before construction of the vessels.* This will allow the motors to be tested during the construction process with the actual fuel to be used in operation and it will ensure supply.

Consultants' Conclusions

- **Safety in the design and construction of LNG vessels is of paramount importance.** Other nations, particularly Norway, and the classification societies can help overcome the lack of U.S. experience with LNG fueled passenger vessel design and construction. If a vessel is constructed to class it means that the classification society guidelines have been followed and the classification society has inspected the construction and certified it.
- **The pre-design process will allow the Legislature to review the design options before making a final decision.** The Legislature requires that all vessel improvement projects and vessel preservation projects over $5 million include a pre-design study (ESHB 3209 adopted in the 2010 session). The pre-design study can provide the Legislature with additional information prior to appropriating funds for construction of a LNG fueled vessel.
- **A major conversion decision should be sought from the USCG prior to starting construction.** If the USCG decides that the Issaquah class retrofits are major conversions, it could make the retrofit prohibitively expensive because the vessel would be required to meet all USCG equipment and ADA regulations as if it were a new build.

Consultants' Recommendations

Recommendation 4. Design

If the Legislature decides to pursue a LNG fueled vessel, the Legislature should provide funding and require WSF to:

- Contract with an outside design firm that has previous LNG fueled passenger vessel design experience rather than design the LNG vessels in-house. As a practical matter Washington state naval architects would have to sub-contract with firms that are experienced in the design of LNG fueled systems to meet this requirement.
- Design LNG vessels to a classification society rules (which could be DNV or another classification society) and have them classed during construction.

Recommendation 5. Construction

The Legislature should consider amending the bid process to require bidders to include an expert from a shipyard with LNG fueled vessel construction experience in their bid that WSF could qualitatively evaluate.

Recommendation 6: Regulatory Determination for Issaquah class retrofit

WSF should request a ruling from the USCG on whether the Issaquah class retrofits will constitute a major conversion before proceeding with more detailed design and construction.

Recommendation 7. Construction

The LNG fuel supply contract should be in place before the shipyard construction contract is let. This will allow the engine to be tested with the actual LNG fuel that will be used in operation and ensure supply and price.

D. Vessel Operation

How will LNG fueled vessels affect bunkering and other WSF operations?

As discussed in Section VII on vessel bunkering and maintenance:

- *LNG bunkering is anticipated to be more complex than with diesel fueling which WSF will need to take into account in its operational planning*.
- *Maintenance and staffing costs are not anticipated to increase although the USCG could require additional staffing with its Certification of Inspection*.
- *Given the complexity of the systems involved WSF should consider retaining a classification society to inspect and report on the condition of the LNG vessels for at least the first 10 years of their operation.* The Norwegian ferry operators interviewed have maintained classification services for the operation of their LNG vessels even though, as is the case with WSF, they do not maintain classification services for the operation of their diesel vessels. The vessels discussed are two to four years old and those interviewed indicated that they did not plan to keep classification for the life of the vessel but would phase it out at some point.

Consultants' Conclusions

- **Bunkering will be more complex than diesel but this should not pose a problem for WSF other than requirements that may be part of the security plan.** Bunkering is more complex but with adequate training WSF should be able to accommodate it. However, bunkering requirements may also be a part of the safety plan and those requirements may add additional costs that cannot yet be anticipated.
- **Maintenance and staffing costs should be the same as for the diesel-fueled vessels.** This is consistent with the experience in Norway. However, staffing costs may change when the USCG issues the Certificate of Inspection.
- **The cost of classification services at $15,000 per year per vessel would be a worthwhile investment.** Maintaining classification services for LNG vessels will help ensure safe operation.

Consultants' Recommendation 8. Operation Classification

WSF should maintain classification services for the operation of their LNG vessels during at least the first 10 years of operation**.**

E. Business Case

What is the most cost-effective scenario to introduce LNG fueled vessels to the WSF fleet considering both operation cost savings and capital project costs?

Determining the most cost-effective scenario to introduce LNG fueled vessels to the WSF fleet hinges in part on the security planning to be undertaken and the decision the Legislature makes on whether to delay construction of a new 144-car vessel to allow it to be constructed as a LNG fueled vessel. Also key is the decision whether to retain the *Evergreen State* in order to allow for the retrofit of the Issaquah class vessels.

As discussed in Section VI on fuel costs and Section IX on capital project cost estimate:

- *There are substantial potential fuel savings from building a new 144-car LNG vessel and/or from retrofitting the Issaquah class vessels.* For one new 144-car vessel the savings is between $86 million and $120 million over the life of the vessel. For the Issaquah class vessels the savings are between $140 and $191 million over the life the six vessels.
- *The capital cost for the conversion of the Issaquah class vessels is close to the fuel cost savings without taking into account the potential cost to preserve the Evergreen State.* The consultants' estimate the costs to convert all six Issaquah class vessels in year of expenditure dollars is $143.6 million, which is 40 percent higher than WSF's estimate of $103.0 million. This does not take into account any potential costs to preserve the *Evergreen State*. It does include costs to operate the *Evergreen State* for the first two retrofits. The net present value of the Issaquah class investment under these assumptions is negative except for the case that assumes the lowest projected fuel cost and the lowest projected vessel cost in which case the net present value is positive.
- *The investment in LNG fuel for the second new 144-car vessel is cost-effective.* The consultants estimated the additional cost for the construction of the second new 144-car as an LNG vessel in the 2013-15 biennium is $20.3 million and the comparable WSF estimate is $15.5 million with

fueling savings of between $86.3 million and $120.0 million. The net present value of the new 144-car vessel is positive under all scenarios.

- *There are potentially large savings from retrofitting the three Jumbo Mark II vessels.* Retrofitting these three 202-car vessels which use 27 percent of WSF's fuel could result in savings of between $355 and $494 million in fuel costs over the life of the vessels.
- *There is recent activity in the availability of CNG that may make it more viable as a marine fuel source*.

Consultants' Conclusions

- **The security planning and outreach costs for LNG are substantial and the more vessels these costs cover the more cost effective the investment will be.** The financial analysis is independently done for the Issaquah class retrofit and for the new 144-car vessel. But the one-time costs for security planning will not be repeated if both projects are done or if the Legislature eventually funds more LNG fueled vessels.
- **The Issaquah class retrofit is not a sound economic investment as the project is now structured.** The retrofit would be more viable after a second new 144-car vessel is on line because the project would not have to bear the costs of operating the *Evergreen State*. Depending on when the new 144-car vessel comes on line, the remaining life of the Issaquah class vessels might be reduced from that contemplated in the current economic analysis.
- **The investment in a new 144-car LNG vessel is economically viable.** The investment would be even better if it is done for a class of LNG vessels with the consequent economies of scale from purchasing more than one vessel at a time.
- **It would be worthwhile to invest in an exploration of the potential retrofit of the Jumbo Mark IIs.** The potential fuel savings are sufficiently large to justify the cost of developing a concept design to see if the Jumbo Mark IIs can be retrofit.
- **Development with CNG should be tracked to see if it becomes a viable option for marine fuel for WSF.** CNG may have some advantages that should be considered including a local supply and potentially less hazardous operation. However, the operational implications of daily fueling would have to be considered.

Consultants' Recommendation
Recommendation 9. Pre-Design and Business Case Funding
At the same time WSF is engaged in security planning, the Legislature should provide funding for WSF to develop a more refined business case and pre-design report for the LNG conversion which would consider the potential to retrofit the Jumbo Mark II vessels and provide updated CNG information.

APPENDIX A. INTERNATIONAL AND NATIONAL LNG FUEL PRICE FORECASTS

International

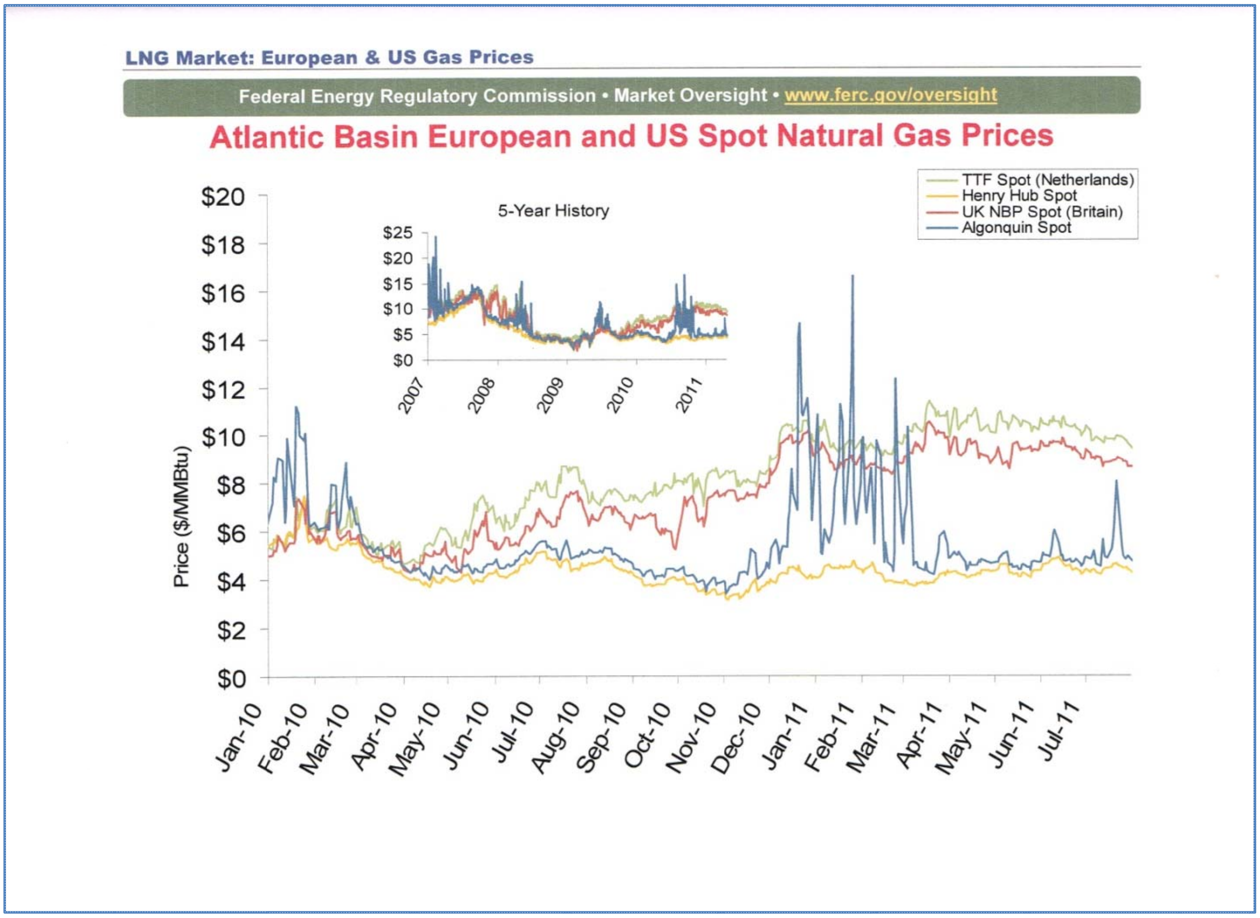
The economics of marine LNG use for WSF will be different than Norway's because LNG is much less expensive in the U.S. and, unlike Norway, the cost of natural gas does not track with the cost of petroleum. The difference in LNG cost, which is based on the spot price of natural gas, between Europe and the United States over the last five 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).[32] While the Algonquin Spot 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.

[32] 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, 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 A-1.
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.

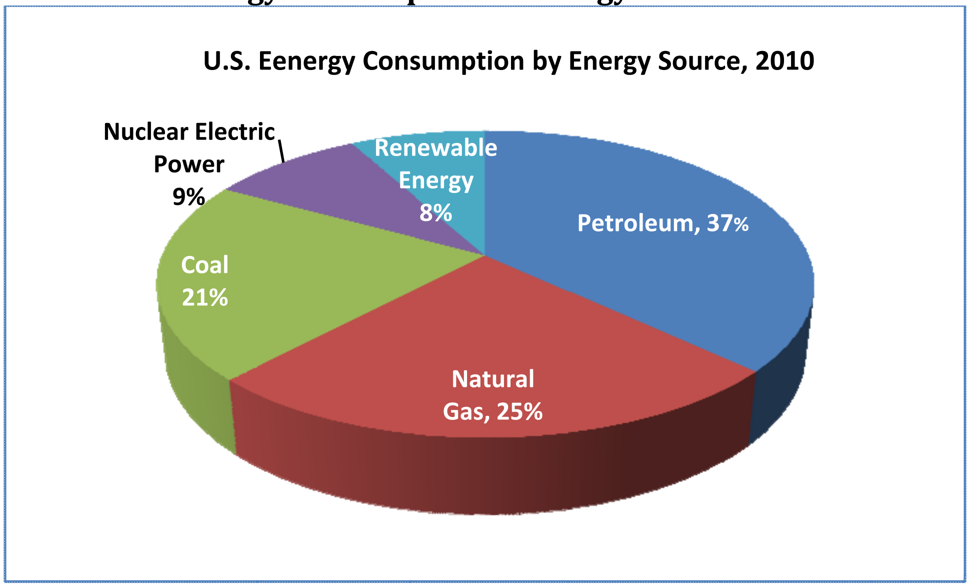


Source: Federal Energy Regulatory Commission

B. 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.

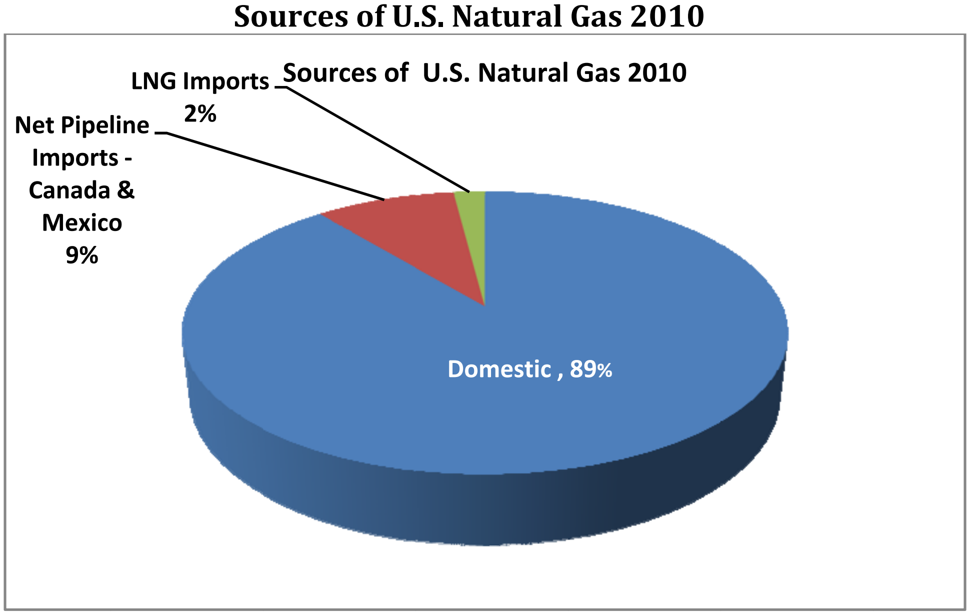
Exhibit A-2.
U.S. Energy Consumption of Energy Source 2010



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 A-3.
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."[33] 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.

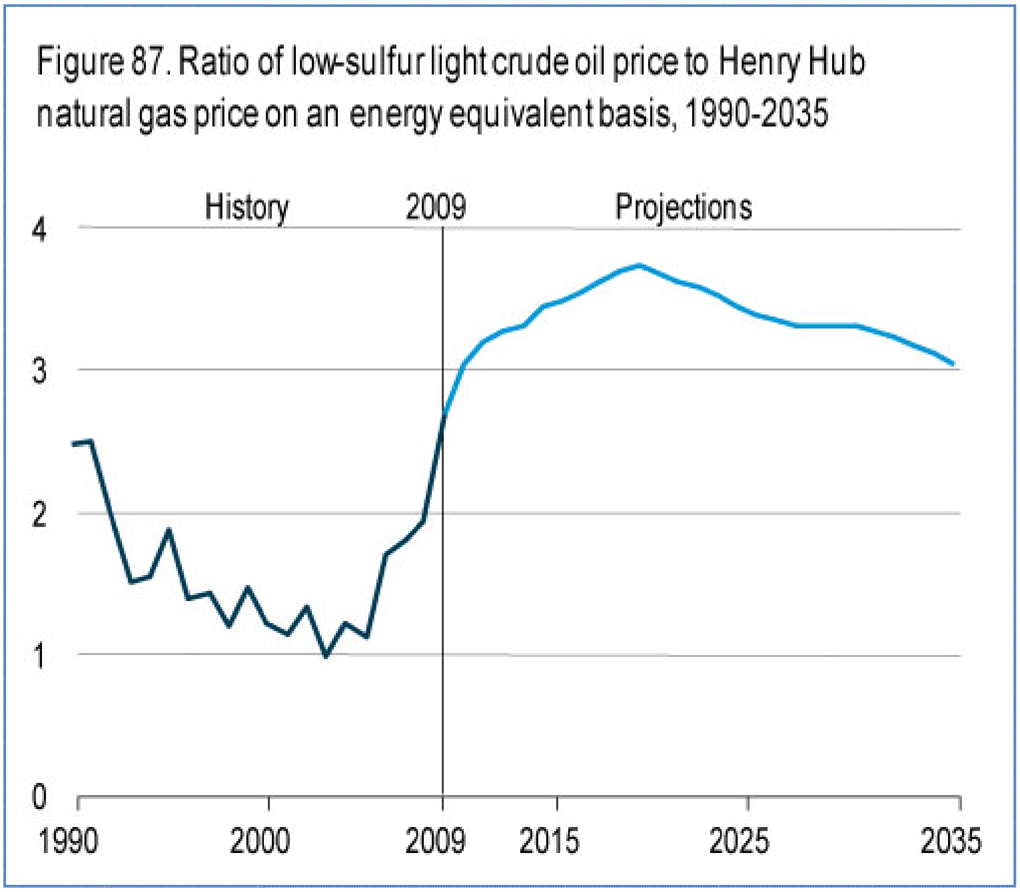
As a consequence of the increase in domestic natural gas production, the U.S. government is allowing LNG import terminals to also export domestically produced LNG. In May 2011 the Department of Energy provided provisional authorization for the Sabine Pass LNG Terminal to export LNG. "This is the first long-term authorization to export natural gas from the lower 48 states as LNG to all U.S. trading partners." [34] 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."[35]

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

Exhibit A-4.
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.

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

1. Weight and Draft

The empty weight (lightship) of an LNG fueled vessel 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

APPENDIX C. WASHINGTON STATE FERRIES RESPONSE

Washington State Department of Transportation

Paula J. Hammond, P.E.
Secretary of Transportation

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David H. Moseley
Assistant Secretary for
Washington State Ferries

January 3, 2012

Ms. Mary Fleckenstein, JTC Coordinator
Joint Transportation Committee
3309 Capitol Blvd SW
PO Box 40937
Olympia, WA 98504-0937

RE: Response to Cedar River Group Study
"Evaluating the Use of Liquefied Natural Gas in Washington State Ferries"

Dear Ms. Fleckenstein:

At the request of the Joint Legislative Transportation Committee (JTC), the Cedar River Group (CRG) has prepared a study titled, "Evaluating the Use of Liquefied Natural Gas in Washington State Ferries". The study summarizes its recommendations as follows:

"This report recommends that the Legislature consider transitioning from diesel fuel to liquefied natural gas for WSF vessels, making LNG vessel project funding decisions in the context of an overall LNG strategic operation, business and vessel deployment and acquisition analysis."

The Washington State Department of Transportation, Ferries Division (WSF) agrees with this recommendation. As the report details, we believe the transition to LNG is essential for financial and environmental reasons.

The report details nine separate recommendations. Below we will respond to each of these recommendations.

Recommendation 1 - Security and Operational Planning Funding
WSF agrees that the Legislature should provide funding for security and operational planning and the associated public outreach. We are currently developing a work plan and schedule for a security and operational planning process and will have this available for legislative review early in the session.

Washington State Ferries

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Recommendation 2 – New 144-Car Vessel
WSF agrees that the second new 144-car vessel should be a diesel fueled vessel.

Recommendation 3 – Issaquah Class Retrofit
WSF agrees that consideration of retrofitting the Issaquah class vessels should not be made until the completion of the security and operational planning process. If the decision is made to proceed with retrofitting the Issaquah class vessels, the best construction sequencing and continued use of the *Evergreen State* vessel should be made at that time.

Recommendation 4 – Design
While we are in conceptual agreement with this recommendation, WSF would offer a slightly modified approach. WSF agrees that it would be useful to use DNV or another classification society in the detail design process for the LNG retrofits. The use of a classification society should continue throughout the design process up to and including design acceptance and approval by the United States Coast Guard (USCG). WSF believe we should reserve judgment on whether it is beneficial to continue to classify the vessel until after design development has been completed and approved.

Recommendation 5 – Construction
WSF agrees with the benefits of having construction expertise in LNG fueled vessels. In concept, WSF will develop an RFP to purchase the LNG engines and LNG tanks and delivery system. As part of this RFP, WSF will require the contractor to provide integration expertise and assistance throughout the retrofit construction and will have responsibility for the successful integration of the propulsion system.

Recommendation 6 – Regulatory Determination for Issaquah Class Retrofit
WSF agrees with the need to obtain a ruling from the USCG on whether the Issaquah class retrofit would constitute a major conversion. WSF will formally request this with the Marine Safety Center.

Recommendation 7 – Construction
WSF agrees that a LNG fuel supply contract should be in place before the shipyard construction contract is awarded.

Recommendation 8 – Operation Classification
As noted in our response to Recommendation 4, WSF believe that this decision should be reserved until the detail design development process has been completed and approved. We will be in a better position to analyze the usefulness and benefits of this expenditure at that time.

Recommendation 9 – Pre-Design and Business Case Funding
WSF agrees that, at the same time that we are engaged in the security and operational planning process, the Legislature should provide funding for WSF to develop a more refined business case and pre-design study.

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WSF would like to make a final comment on the construction estimates provided in the report. WSF continues to believe that the cost of retrofitting Issaquah and 144-car vessels is much closer to our estimate provided in the report ($16.0 million for Issaquah/$15.5 million for 144-car) than to the consultant's sub-contract estimator's cost ($22.4 million for Issaquah/ $20.3 million for 144-car). As can be seen in the cost estimate comparison provided on pages 53 and 54 of the report, the vast majority of the estimated differences is in shipyard construction and contingency costs. This is driven largely by the very high estimate of man-hours required to complete the construction work by the consultant's estimator (112,000 man hours) verses WSF's estimate (34,000 man hours) and by the estimate of steel needed to complete the retrofit. The estimator provided an estimate of 158,000 pounds of steel verses WSF's estimate of 14,800 pounds of steel. Because of the large discrepancy in steel work, other associated work related to insulation, paint and preservation resulted in those being overestimated as well.

We believe our estimates of man-hours and use of steel is much closer to what the actual cost will be. WSF has a proven track record in construction cost estimating. In recent construction estimates for the 144-car vessel and the Keller ferry the WSF estimate was very close to the final bid price. The 144-car ferry was within 2% of the awarded contract and the Keller ferry was within 1% of the awarded bid. In addition, WSF has installed new engines in all six of the Issaquah class vessels and has this experience to draw on. While WSF acknowledges that a LNG retrofit is somewhat more complex than our previous experience, the engine work, alarm and monitoring and engine control work is very similar. We do not believe the installation of the LNG fuel system justifies such high assumptions on man-hour and steel use. We believe our estimates take that additional complexity into consideration.

Sincerely,

David H. Moseley
WSDOT Assistant Secretary
Ferries Division

cc: Kathy Scanlan, CRG