

# Evaluating the Use of Liquefied Natural Gas in Washington State Ferries

Final Report Executive Summary



**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° 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 Sjø 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.

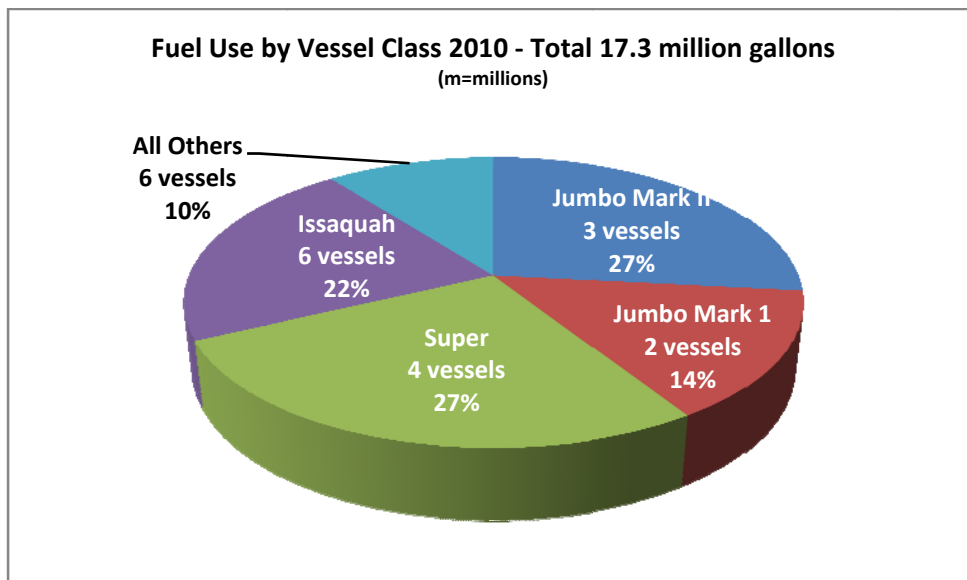
Designing a new 144-car vessel as a LNG fueled vessel could be considered in the context of the next planned procurement of five new 144-car vessels. If funding were available, a new 144-car LNG vessel could be viewed as the first of six such vessels.

### 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 Fautleroy-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
<i>What, if any, impact will the conversion to LNG fueled vessels have on the WSF Alternative Security Plan?</i>	
<p><b>Security and operation planning with its associated public outreach should be the next step in the consideration of LNG for WSF vessels.</b> 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.</p>	<p><b>Recommendation 1. Security and Operational Planning Funding</b></p> <p>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.</p>
<i>What are the implications of LNG for the vessel acquisition and deployment plan?</i>	
<ul style="list-style-type: none"> <li>• <b>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.</b> 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.</li> <li>• <b>A new 144-car LNG vessel should be purpose built as a LNG vessel.</b> 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.</li> <li>• <b>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.</b> Under the most aggressive schedule the retrofitted Issaquah class vessels would come on line between 2015 and 2020. The <i>Evergreen State</i> 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 <i>Evergreen State</i> is not included in the 2011-27 16-year financial plan because it is expected to retire.</li> </ul>	<p><b>Recommendation 2. New 144-Car Vessel</b></p> <p>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.</p> <p><b>Recommendation 3. Issaquah Class Retrofit</b></p> <p>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 <i>Evergreen State</i> 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.</p>

Consultants' Conclusion	Consultants' Recommendations
<i>What design and construction constraints should be considered in making LNG decisions?</i>	
<ul style="list-style-type: none"> <li>• <b>Safety in the design and construction of LNG vessels is of paramount importance.</b> 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.</li> <li>• <b>The pre-design process will allow the Legislature to review the design options before making a final decision.</b> 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.</li> <li>• <b>A major conversion decision should be sought from the USCG prior to starting construction.</b> 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.</li> </ul>	<p><b>Recommendation 4. Design</b></p> <p>If the Legislature decides to pursue a LNG fueled vessel, the Legislature should provide funding and require WSF to:</p> <ul style="list-style-type: none"> <li>• 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</li> <li>• Design LNG vessels to a classification society rules (which could be DNV or another classification society) and have them classed during construction.</li> </ul> <p><b>Recommendation 5. Construction</b></p> <p>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.</p> <p><b>Recommendation 6: Regulatory Determination for Issaquah class retrofit</b></p> <p>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.</p> <p><b>Recommendation 7. Construction</b></p> <p>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.</p>

Consultants' Conclusion	Consultants' Recommendations
<i>How will LNG fueled vessels affect bunkering and other WSF operations?</i>	
<ul style="list-style-type: none"> <li>• <b>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.</b> 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.</li> <li>• <b>Maintenance and staffing costs should be the same as for the diesel-fueled vessels.</b> This is consistent with the experience in Norway. However, staffing costs may change when the USCG issues the Certificate of Inspection.</li> <li>• <b>The cost of classification services at \$15,000 per year per vessel would be a worthwhile investment.</b> Maintaining classification services for LNG vessels will help ensure safe operation.</li> </ul>	<p><b>Recommendation 8. Operation Classification</b></p> <p>WSF should maintain classification services for the operation of their LNG vessels during at least the first 10 years of operation.</p>
<i>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?</i>	
<ul style="list-style-type: none"> <li>• <b>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.</b> 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.</li> <li>• <b>The Issaquah class retrofit is not a sound economic investment as the project is now structured.</b> 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 <i>Evergreen State</i>.</li> <li>• <b>The investment in a new 144-car LNG vessel is economically viable.</b> 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.</li> </ul>	<p><b>Recommendation 9. Pre-Design and Business Case Funding</b></p> <p>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.</p>

Consultants' Conclusion	Consultants' Recommendations
<ul style="list-style-type: none"><li>• <b>It would be worthwhile to invest in an exploration of the potential retrofit of the Jumbo Mark IIs.</b> 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.</li><li>• <b>Development with CNG should be tracked to see if it becomes a viable option for marine fuel for WSF.</b>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.</li></ul>	