

Technical Approach

The purpose of this study is to review and assess Washington State Ferries' (WSF's) work and studies on LNG-use in WSF vessels; to identify the full range of issues that must be addressed to successfully implement LNG and the cost, risk, timeline, and related implications for doing so for both a retrofit of an existing Issaquah class vessel and incorporating LNG into the new 144-car vessel design. The study will address legislative concerns regarding the full potential costs 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.

The scope of work identifies four tasks with three primary deliverables: 1) a white paper on LNG as an energy source for passenger-vessel propulsion; 2) an evaluation of the costs, opportunities and risks of LNG vs. diesel use; and 3) an evaluation of WSF LNG implementation issues. We propose to review and provide an initial assessment of WSF LNG work with the Task 1 white paper. This will provide an understanding of the issues that have been addressed by WSF, new 144-car LNG design and Issaquah retrofit project status, and areas of focus for the ensuing consultant work.

The legislature requires that all vessel improvement projects include a pre-design study (ESHB 3209 adopted in the 2010 session). We anticipate the requirements for a pre-design study will be addressed within this scope, which should allow the pre-design process to be expedited if the legislature funds a LNG retrofit or re-design of the new 144-car vessel. Our final report will include a cross-walk to the pre-design requirements.

Our team's expertise will allow us to focus the bulk of our effort on the WSF specific tasks – analyzing the costs, opportunities, and risks of LNG use and implementation issues. The schedule and approach allows ample time for review and discussion with the staff workgroup prior to presentations to the JTC.

Task 1. White Paper on LNG as an Energy Source for Vessel Propulsion - Complete by October 19, 2010

The first deliverable is a white paper that reviews existing research and describes LNG as an energy source for passenger-vessel propulsion. We propose to add to the items identified in the RFP: 1) an analysis of the findings of other retrofit or new building analysis that resulted in a decision that the project was not economic; 2) a review of other auto-passenger ferry systems, particularly in the United States, that are considering LNG; and 3) a discussion of environmental considerations.

The work on this white paper will be done primarily by John Boylston and Cedar River Group, utilizing to the maximum extent possible analysis that Boylston and Marine Service have already done on other projects and for publication. Some of this work is summarized in Boylston's article *LNG as a Fuel for Vessels – Some Design Notes* that has been accepted by the Society of Naval Architects and Marine Engineers (SNAME) for publication in October 2011 and in the article *Zero Emissions Vessels* he co-authored and presented at the SNAME annual meeting in August 2010.

a. History of LNG use in vessels and ferries, worldwide and in the United States

There are approximately 375 LNG-fueled vessels worldwide and more than 90 percent of these are LNG carriers. About 20 vessels are auto-passenger vessels, comparable to the WSF fleet.

- *International LNG auto-passenger ferries.* As of 2011, about 20 LNG fueled ferries are in operation in Norway with more being phased into service in the coming years. The first Norwegian LNG-fueled ferry was built in 2000 with support from the Norwegian government and following an increase in the supply of LNG to the west coast of Norway in 1997.¹ This ship, the Glutra, was expanded in 2011. Torghatten Nord AS has three (3) LNG auto-passenger ferries and another under construction and Fjord1 operates two (2) LNG auto-passenger ferries and has a 242-car LNG auto-passenger vessel under construction with completion anticipated in November 2011. The world's largest LNG powered ferry with a capacity of 1,000 passengers and 150 cars is currently under construction at Incat shipyard in Tasmania for operator Buquebus in Argentina.
- *United States LNG vessels.* The only LNG fueled American flagged vessel that is currently operating is a tug designed by Glosten Associates as a pilot project for Crowley Maritime. There are no LNG fueled United States flagged passenger or auto-passenger vessels.²

b. Economics of LNG Use Compared to Ultra Low Sulfur Diesel/Compressed Natural Gas Review

- *Near-term and long-term source.* The consultants will provide an overview of the sources of United States LNG and specifically sources that could service WSF vessels and terminals. This is a major concern of the study and the consultants will identify a specialized fuel supply expert to assist with the supply chain review.
 - *National and regional projections:* The consultants will summarize information available from the Energy Information Administration (EIA) and other sources that project LNG supply in the relatively near-term and in the longer-term. The EIA projects the availability of LNG through 2025 and also provides an analysis of the factors that affect supply including: world-wide LNG demand, which over the short-term has been affected by Japan's increased reliance on LNG with the closure of its nuclear power plants; the construction of new LNG terminals in the United States; and the level of imports.
 - *Local projections.* The logistics of LNG fueling is a significant consideration. As noted in Boylston's *LNG as a Fuel for Vessels* article: "The logistics of LNG fueling and the final cost of the LNG delivered to the vessel has been the major factor killing a number of proposed European LNG fueled vessel studies. It is thus suggested that the logistics and cost of LNG be determined before substantial engineering is started" (p. 2). The consultants will provide an analysis of the logistics of delivering LNG to WSF vessels based on discussions with LNG area providers and the work of our supply chain expert.³ We will also provide a discussion of Pacific Northwest LNG storage facilities of which there are

¹ Per Magne Einang and Konrad Magnus Haavik, *The Norwegian LNG Ferry*, Norwegian Marine Technology Research Institute and the Norwegian Maritime Directorate.

² There are no longer United States flagged LNG carriers. They have either retired or been re-flagged.

³ We understand that WSF and its design team have already had some discussions with area providers. We will determine what WSF has already done before engaging in active discussions with local providers.

currently four (Plymouth, Washington; Nampa, Idaho; Portland, Oregon and Newport, Oregon).

- *Evaluation.* We will independently evaluate the supply forecast, particularly for the particular type of LNG that is required as marine fuel.
- *Compressed Natural Gas (CNG).* CNG is used as a marine fuel in some passenger vessels, including two (2) small ferries in Canada. We will review the differences between CNG, LNG, and ULSD and evaluate WSF's preference for LNG over CNG.
- *Cost comparison with ultra low sulfur diesel (ULSD).* We will compare LNG costs with the costs of ULSD using as a baseline the 16-year financial plan projection for ULSD fuel costs and existing projections for LNG costs.
 - *Deployment.* We will provide the comparison based on the 2012 deployment and planned deployment when the new 144-car vessels are on line. This is important because the cost-benefit analysis for conversion of an Issaquah class vessel provided as part of the RFP compares the cost of ULSD and LNG on the Bremerton route, on which route an Issaquah class vessel uses 142 gallons per service hour (GPSH) compared to 75 GPSH on the Mukilteo route. As discussed in the JTC's *Vessel Sizing and Timing Report*, deployment has a large effect on actual fuel consumption.
 - *Costs.* As noted in Boylston's *LNG as a Fuel for Vessels* article there are many projections of LNG future costs. We will therefore provide a range of projections, highlighting the major considerations such as the impact on demand for ULSD as the Emission Control Area (ECA) requirements come into effect, world-wide demand, and importation.
 - *Local Costs.* The general cost of LNG will not be the cost of LNG at every U.S. location and it will be important to determine the projected cost of LNG delivered to WSF vessels.
 - *Energy Costs.* LNG has about 58percent of the BTU (British Thermal Unit) content of an equivalent volume of ULSD. We will provide a comparison of the energy costs of LNG and ULSD.

c. *Desirability of dual-fuel option versus solely LNG as a fuel source*

We will provide an overview of these two fuel options, focusing particularly on Norway's experience where there are both dual and sole source LNG ferries in operation.⁴As part of the analysis, we will examine the design issues and capital and operating differences between the two options.

d. *Impact of LNG on vessel speed, performance, and maintenance*

An LNG propulsion system will have limited impacts on a vessel's speed or performance. The primary considerations are shipyard visits and dry-docking, fueling, and the potential for changes in preservation costs.

⁴The Torghatten Nord AS's four (4) LNG ferries have two (2) gas generators with a diesel back-up. The propulsion system is of Gas/Diesel Electric type with azimuth thrusters mounted on each end of the vessel. The electricity is produced by three generating sets: two of them LNG gas fuelled and one spare – regular diesel type. The new 242-car Norwegian LNG ferry is LNG gas fuelled only with three (3) Rolls-Royce LNG gas engines and generators.

- *Shipyard visits and dry-docking.* As noted in Boylston's article, current Coast Guard regulations require LNG cargo tanks to arrive at a shipyard for dry-docking or major work in a gas-free condition. If these same requirements are applied to a LNG auto-passenger ferry, then it would be necessary to manage the LNG fuel amount when scheduling out-of-service time and additional time allowed to get LNG fuel tanks in an empty and inerted condition. The ship is then towed to the dock.
- *Preservation.* We will review the life-cycle of cryogenic tanks and LNG piping to determine if there are any differences in the replacement cycle or other preservation cost changes.
- *Fueling.* Fueling the LNG vessels will require special training, but in general should not add time to the schedule since fueling is anticipated to take place when the vessel is tied up for the night.

e. Regulatory requirements

One of the complicating factors for WSF is that the U.S. Coast Guard has not adopted regulations for LNG passenger vessels so the work that WSF has done to date has been done to comply with the *2011 DNV Rules for Gas Fueled Engine Installations* and IMO Resolution MSC.285(86), *Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations in Ships*. We will summarize the following:

- *Existing DNV and IMO guidelines.* WSF reports include a summary of the rules which we will use as a starting point.
- *U.S. Coast Guard rules for LNG carriers.* An overview of the rules for LNG carriers will be provided to highlight the difference in requirements for LNG carriers and auto-passenger ferries.
- *U.S. Coast Guard process for adopting rules.* We will describe how the U.S. Coast Guard adopts rules and the procedures they use when reviewing vessels for which they do not have adopted rules. We will also provide a range of the time it might take for the Coast Guard to either conduct a review and/or adopt rules.
- *U.S. Coast Guard rules on major conversions.* One of the concerns with the retrofit project is whether the Coast Guard will consider the retrofit a major conversion that then requires that the ship meet current codes. We will provide a description of the major conversion rules.

f. Other considerations

- *Findings of conversion or new construction studies.* Marine Services and John Boylston each have conducted studies of conversions or new construction of LNG vessels where the owner has concluded that the economics of the conversion or construction were unfavorable. Most all of the work done by Marine Services and Boylston is for private companies which will not allow the analyses to be shared. We will, however, be able to list the factors in the studies that led the owners to determine that the projects were not economically viable. Issues have included: the impact of the LNG tanks on the number of available car spaces (which is a greater concern if the tanks are below decks since the tanks are larger than diesel tanks), bunkering, particularly where the ship refuels more than once a day, and the logistics of securing LNG supply. While some of these issues may not apply to WSF, it will be helpful to have a catalog of them to ensure a thorough review.

- *Other auto-passenger ferry systems.* It will be helpful to know what other ferry systems, particularly in the United States, are considering LNG. If other U.S. ferry systems are looking at LNG propulsion, it may speed up the Coast Guard’s rule making process.
- *Environmental considerations.* We will describe the pending environmental requirements and the differences in emission levels between LNG and ULSD and summarize other federal, state and local environmental requirements.

Task 2. Evaluate the Costs, Opportunities and Risks of LNG vs. Diesel Use
Overview and Initial Assessment of WSF Studies and Reports – Complete October 19, 2011
Evaluation – Complete November 16, 2011

a. Overview and Initial Assessment of WSF Studies and Reports

We will provide an overview and initial assessment of WSF studies and reports at the same time as the white paper on LNG as an energy source for vessel propulsion. By reviewing WSF’s work early in the study we can insure that we don’t “reinvent the wheel” by undertaking research that WSF has already done adequately and also ensure that the workgroup and the JTC have a common understanding of what WSF has done and will be doing during the course of the study. If, for example, Phase 1 of the Glosten new 144-car vessel study results in a Phase 2 project, it will be important for this study to be in synch with that one. We also want to identify for the staff workgroup and the JTC the key issues we will be focusing on.

An initial list of documents/information that we will request is provided below.

Document/Information Requested
New-144 car Vessel
<ul style="list-style-type: none"> • 144-Car Ferry LNG Fuel Conversion – Regulatory Review of Concept • Phase I Glosten Feasibility Study report (have from RFP) • Vigor schedule for the new 144-car construction • New 144-car vessel specifications, including the specifications for engine fuel consumption and speed • Details of 2011-13 budget estimates for the new 144-car vessel
Issaquah Retrofit
<ul style="list-style-type: none"> • Issaquah LNG Cost-Benefit Analysis – detail of calculations if available • LNG Use for Washington State Ferries – The Glosten Associates – (have from RFP) • Vessel fuel consumption reports for the Issaquah class vessels 2009 and 2010 • Details of budget estimates for retrofit of Issaquah class vessel
General Information
<ul style="list-style-type: none"> • 2011-13 16-year financial plan projection for fuel costs. From our work for the legislature during the 2011 session we have the fuel cost projection we made. We would like to see the final used in the 16-year financial plan. • Assessments by WSF, if any, of crewing, security, or insurance implications of LNG.

b. Evaluation

The evaluation will be based on the information provided in the Task 1 White Paper, our review and initial assessment of WSF's reports, and the expert knowledge provided by John Boylston and Marine Service. We have provided an allowance in the budget for additional technical advice that may be needed for terminals, security, or other specific concerns that arise. We have provided resumes for two expert resources: Robert Collier who has worked with us on terminal costs in the WSF Ferry Financing Studies and Robert Agnew, a security consultant with whom we have worked in the past.

- **Capital costs.** Boylston and Marine Services have the expertise and background to review and comment on the vessel capital cost estimates developed by WSF. This will be similar to work Boylston has done for the JTC in previous studies. Robert Collier can, if needed, review any terminal costs identified by WSF and can also provide an estimate for the costs of any terminal modifications that may not have been identified by WSF. All estimates will assume:
 - *Procurement under existing WSF agreements and processes.* The new 144-car vessel is already under contract and costs will assume Vigor shipyard construction. The retrofit of an Issaquah class vessel will be assumed to be bid under existing state procurement processes.
 - *Design.* Design estimates for the new 144-car vessel redesign and for the retrofit of an Issaquah class ferry will be based on the existing design staff capacity at WSF supplemented by outside designers. Although we have previously recommended that WSF utilize more outside design staff, this estimate will be based on existing processes.
- **Operating and preservation costs.** Cedar River Group will work with Boylston and Marine Services to address fuel and staffing costs, utilizing in particular our familiarity with WSF's collective bargaining agreements and history of grievances. We propose to work with OFM's Risk Management Division to assess impacts on the marine insurance program. We will also work to determine if there is any greater risk of crew injury that would potentially affect the cost of Jones Act claims. We propose in the Task 1 White Paper to provide an assessment of the life cycle of cryogenic tanks and LNG piping systems, which will be used to project the preservation costs of LNG vessels compared to existing ferries.
- **Fuel market.** We propose to address the fuel market delivered to WSF vessels primarily in the Task 1 White Paper.
- **Dual-fuel option vs. solely LNG as fuel source.** We will review Glosten's preference for LNG as the sole fuel source for the Issaquah retro-fit and provide an analysis of the alternative of a dual-fuel option including differences in capital and operating costs for both the new 144-car vessel and the Issaquah class retrofit.
- **Return on investment.** Cedar River Group will review the cost-benefit analysis in the Glosten reports. As discussed above, one thing that should be considered is the variance in fuel consumption by route and by vessel speed. The less fuel that is consumed the longer it will take to amortize the investment. Another consideration is including the cost of capital, which is not normally done in public sector cost-benefit analyses. We

recommend considering the cost of capital given the relatively scarce capital resources available for WSF vessel procurement and improvement.⁵

- **Regulatory costs.** We will provide an analysis of the Coast Guard's conversion considerations in the Task 1 White Paper and provide an estimate of the cost of conversion in the event upgrades of the Issaquah class vessel are required. We will use Boylston's and Marine Services expertise to assess the additional costs for fuel handling and storage that may result from the use of LNG.

Task 3. LNG Implementation Issues for WSF Complete November 16, 2011

In our discussion of implementation issues we will identify potential problems and also make recommendations on how the problems might be best addressed.

- Regulatory issues.** A primary concern is the Coast Guard review and other regulatory reviews. In the Task 1 White Paper we will examine the Coast Guard processes. In this task, we will discuss the likely timeframe for Coast Guard review and approval of these specific projects. We will consider if there are ways in which the new-144 car ferry construction could be phased to allow for Coast Guard review of the LNG components. For example, could work start on the hull or other ship components prior to final approval of the LNG engines? We will also provide an analysis of other regulatory environmental considerations.
- Refueling.** We will provide an analysis of LNG fueling issues and work, if needed, with Robert Collier to identify any terminal issues. We note that Glosten is assuming truck delivery of LNG, with the truck driving onto the ferry for fueling when the ferry is tied up overnight. We will identify any security concerns that might be posed by this process and also identify other refueling options.
- Labor and collective bargaining issues.** Cedar River Group will provide an analysis of the likely timeframe for resolving training and collective bargaining issues, which are anticipated to primarily involve bargaining the impact on workers responsibilities and duties if LNG is a fuel source rather than purely diesel.
- Vessel and facility security issues.** We will review WSF's plan to address security issues and engage, as needed, our security sub-consultant in that review. Based on their experience, Boylston and Marine Services will be asked to identify external security issues that should be considered. Robert Agnew will use his expertise to identify potential solutions to these threats (i.e. alarms, manning etc.). An example is any threats posed by the external location of the LNG tanks.
- Routes.** We will examine any zoning or other issues that should be considered as well as the possible implications of LNG for the Sidney route which must meet SOLAS standards.
- Timeframe/schedule implications.** We will provide a schedule and timeframe implications under at least three scenarios: 1) retrofitting an Issaquah class ferry only; 2) re-designing the new 144-car vessel; and 3) doing both. We will provide an analysis of the procurement delay, the impact on the level-of- service from retrofitted vessels being out-of-service, and of the delay in service improvements anticipated with the new 144-car program. We will also assess the impact of the delay in the new 144-car vessel program on the preservation budget since such a delay will delay the retirement of existing vessels.

⁵The Glosten Life Cycle Cost Analysis for the 144-car Ferry LNG Fuel Conversion Feasibility Study assumes that the cost of capital and the discount rate cancel each other out for initial capital expenditures.

- g. Other vessels.** Although not required as part of the RFP, we will be prepared to provide an assessment of the potential for retrofitting WSF's Jumbo Mark I and Jumbo Mark II ferries to LNG. These vessels are newer meaning that there will be more time to amortize a retrofit investment.

Task 4: Draft and Final Report

Based on the discussion at the November 16, 2011 JTC meeting, the consultants will prepare a draft report by November 28, 2011 and incorporate the results of the staff workgroup review in a final draft report by December 16, 2011. We have allocated funds in the budget for presentations to the House and Senate Transportation Committees in January, 2012.

The draft and final reports will include a crosswalk to the OFM pre-design study requirements to facilitate the use of report information to meet the pre-design requirements should the legislature fund an LNG project.