

Presentation Materials Prepared for the
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“The CNG Revolution in Transportation: Natural Gas as A Marine Fuel”

American Strategic Group
210 Hudson Street, Seattle, WA 98134

Scott Peterson, CEO
peterson@americanstrategicgroup.com

Stephen Lambo, President
lambo@americanstrategicgroup.com

Fernando Rosero, Chief Technology Officer
rosero@americanstrategicgroup.com

THE CNG REVOLUTION IN TRANSPORTATION

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NATURAL GAS AS A MARINE FUEL

Experience and Projects:

- American Strategic Group (ASG Energy) is a Seattle-based integrator of compressed natural gas storage, transportation, and fueling solutions.
- The principals and staff of ASG have extensive natural gas project experience in the USA, South America, and Asia.
- ASG sister company MC2 Energia is a pioneer in large-scale CNG transportation projects including the conversion of 17,000 vehicles to CNG.
- MC2 Energia is currently managing the conversion of 30 Panama Canal diesel-electric tugboats to CNG.

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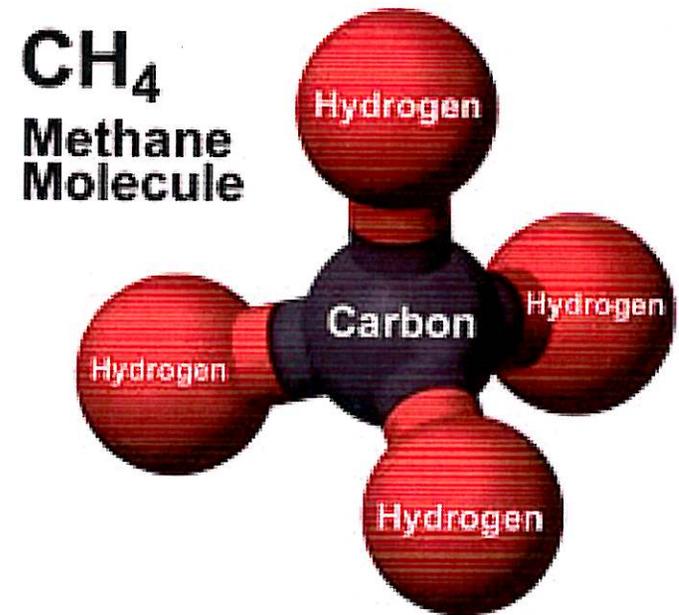
What is Natural Gas?

Safe • Non-Toxic • Lighter-than-Air

- *Natural gas is up to 98% methane.*
- *Natural gas is a low-carbon fuel.*
- *75% of combustion energy comes from the hydrogen reaction.*
- *Natural gas for engines is 130 octane.*
- *Natural gas is lighter than air.*
- *Natural gas is non-toxic.*

What Natural Gas is Not

- *Natural gas is **not** refined from crude oil.*
- *Natural gas is **not** propane (LPG).*



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How Natural Gas is Transported

1) *Pressurized natural gas pipelines.*



2) *Compressed natural gas (CNG) tubes.*



3) *Liquefied natural gas (LNG) super-cold cryogenic vessels.*



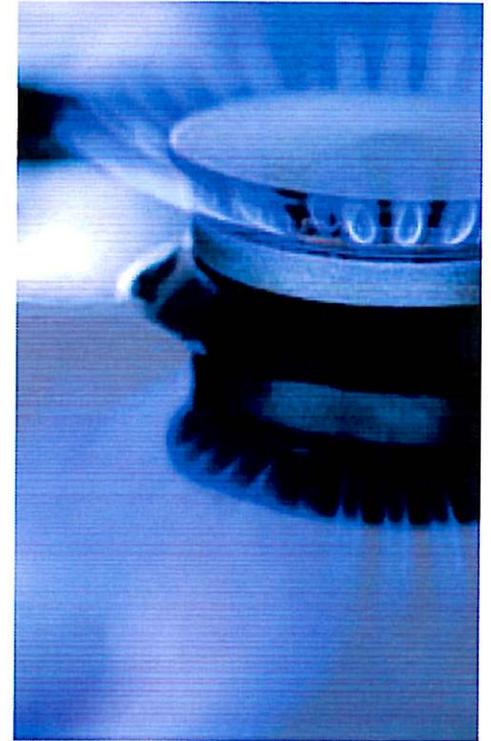
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Clean Air: Ultra-Low Emissions Clean Burning, Just Like Your Kitchen Stove

- *-95% reduction of PM2.5 airborne particulates*
- *-75% reduction of carbon monoxide*
- *-49% reduction of nitrogen oxide (NO_x)*
- *-30% reduction of green house gasses (GHG)*
- *Minimal sulfur and greatly reduced sulfur oxide (SO_x)*



(Source: US Dept. of Energy Alternative Fuels Data Center, 2011)

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Clean Water

No fuel spills, no groundwater contamination

- *CNG is lighter-than-air, non-toxic, and cannot contaminate water.*
- *Natural gas is gentle on engines and reduces lubrication leaks from wear.*
- *Natural gas fuel systems do not produce sludge and do not need cleaning.*



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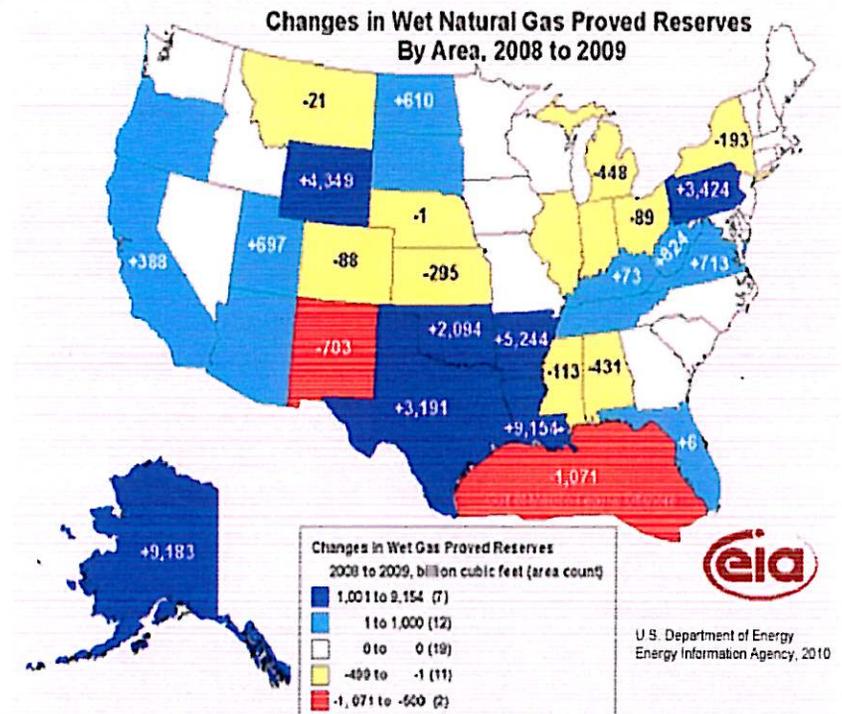
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Natural Gas is an Abundant American Resource

140+ Years of Proven U.S. Natural Gas Reserves

- USA has largest natural gas reserves in the world
- USA is world's largest producer of natural gas
- 98% of US usage comes from North America
- US proven reserves have increased by 35%



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Natural Gas is Safe!



- *Natural gas only burns in a narrow 5% to 15% concentration in air.*
Diesel, gasoline, and propane have wider flammability ranges hence BBQ ignition flash.
- *The autoignition temperature (the lowest temperature at which a substance will spontaneously ignite without an ignition source) of natural gas is very high: 1076 °F.*
The autoignition temperatures of diesel and gasoline are 410 °F and 536 °F.
- *Natural gas will not explode unconfined in the atmosphere.*
Propane, gasoline, and diesel spills can explode.
- *Natural gas is less dense than air, meaning that any release will rise up into the air column.*
Evaporating vapors from leaks of propane, gasoline, or diesel are more dense than air presenting the risk that the vapors will hug the ground to an ignition source and flash back to the source.
- *Compressed natural gas tanks have a 60-year safety record around the world under the harshest physical and atmospheric conditions.*

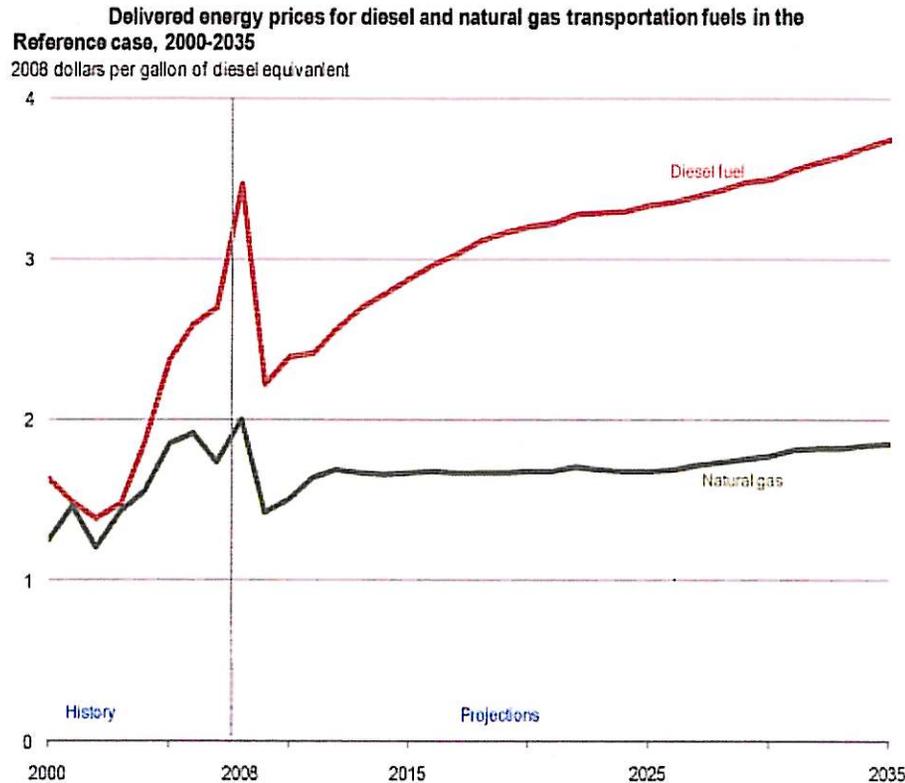
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Cost Savings and Price Stability of Natural Gas as an Engine Fuel 30% to 50% Cheaper Per Gallon Price Trend Through 2035.

(Source: U.S. Department of Energy, Energy Information Agency, "2010 International Energy Outlook.")



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NATURAL GAS AS A MARINE FUEL

Natural Gas Has a Better Risk Profile

- *Diesel prices are tied to limited refinery capacity and OPEC oil prices.*
- *The west coast has not constructed a new refinery in 28 yrs.*
- *China's consumption of oil is increasing dramatically.*
- *Oil exploration and transportation have greater vulnerabilities to environmental accidents and international security.*



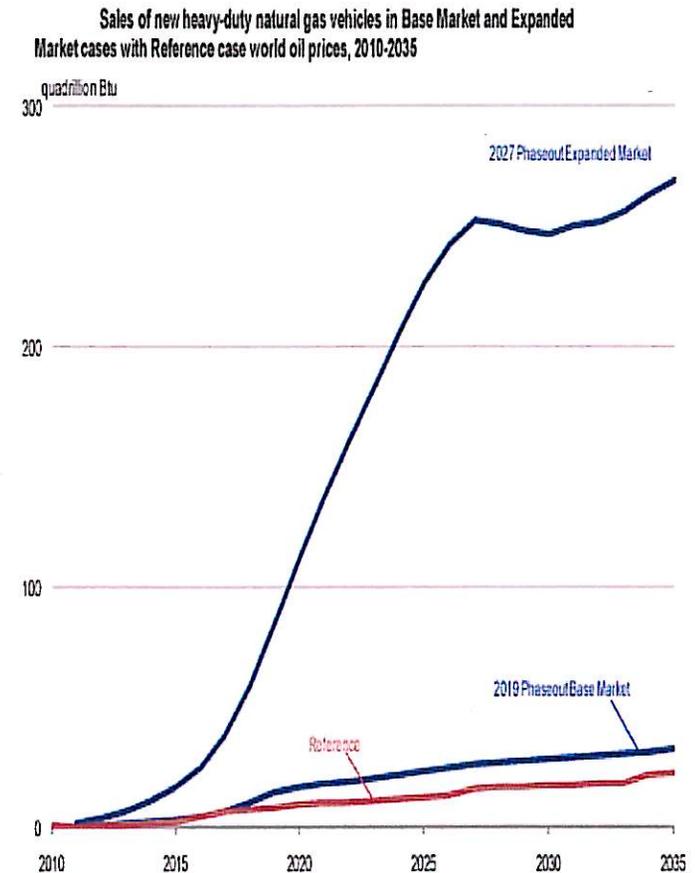
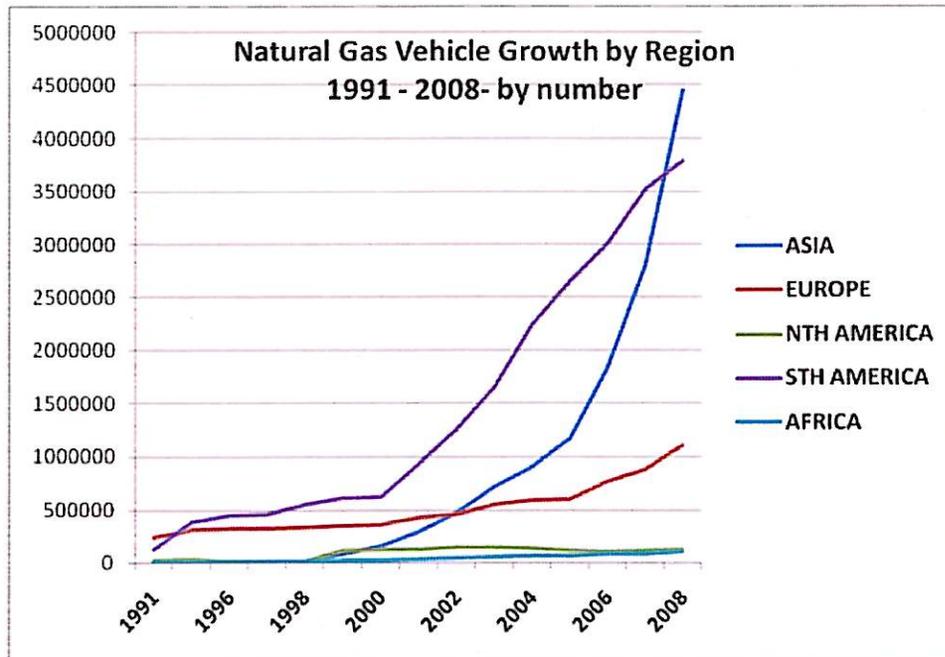
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Road Vehicles are the Leading Edge of the CNG Revolution in Transportation

(Source: U.S. Department of Energy, "2010 International Energy Outlook.")



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CNG is the Natural Gas Fuel Storage Solution for Washington



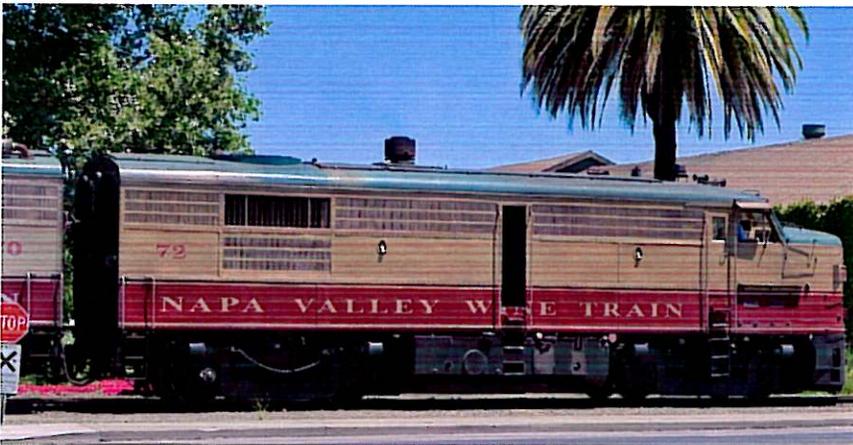
- *CNG can be locally produced, stored, and distributed.*
- *CNG tanks come in a variety of sizes for ferry retrofitting.*
- *LNG must be trucked in from out-of-state and must be kept cold at an extra cost.*
- *LNG fueling requires special handling.*
- *CNG fueling is performed daily by the general public all over the world.*
- *Operational requirements of Washington ferries can be provided for with CNG.*
- *CNG is the focus of the greatest amount of global technological innovation.*

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Any Internal Combustion Engine can be Converted to Run on Natural Gas



AMERICA'S CLEAN FUEL GOES PRIME TIME

THE WORLD'S FIRST NATURAL GAS-POWERED CHOPPER MAKES ITS DEBUT.

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Washington Has Been Early Adopter of Natural Gas as a Transportation Fuel



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Technical Studies are Available on Natural Gas as a Fuel for Ferries

Natural Gas as a Marine Propulsion Fuel: Energy and Environmental Benefits in Urban Ferry Service

By Alex Farrell & Mark Glick. Published in *Transportation Research Record: Journal of the Transportation Research Board*, 2007.

Demonstration of a Selective Catalytic Reduction System on a Marine Passenger Ferry

By Christopher Weaver, P.E. (President of Engine, Fuel, and Emissions Engineering, Inc.). Presented to the California Air Resources Board, July 2010.

Natural Gas as a Ferry Fuel

By Per Magne Einang & Konrad Magnus Haavik (Norwegian Marine Technology Research Institute). Published in *Gastech*, December 1996.

The use of Natural Gas in Marine Engines

By Ian A. Smart (Ministry of Transportation of Highways, Canada). White paper published in 1990.

Gas Treatment Requirements for Marine Transportation of Natural Gas

By M. Abdi & K. Hawboldt. Presented to the 2005 International Marine CNG Standard Forum, August 2005.

Controlling air pollution from passenger ferries: cost-effectiveness of seven options (including CNG)

By Alexander E. Farrell & James J. Corbett & James J. Winebrake. A (Technical Paper) published in the *Journal of the Air & Waste Management Association*, December 2002.

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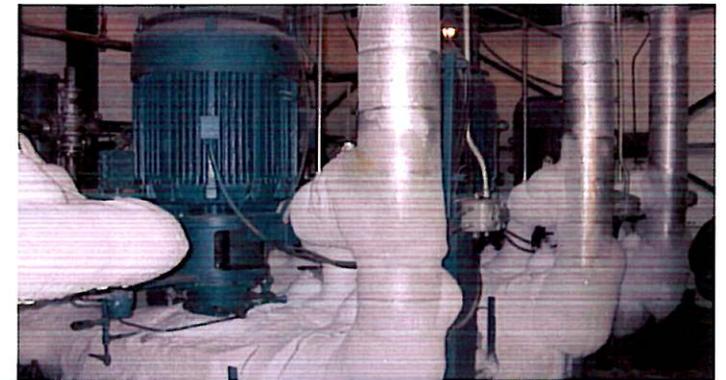
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LNG has Higher Structural Costs than CNG

Production and transportation of LNG is much more energy-intensive than CNG

- *10% of the energy content of LNG is used to liquefy it adding to the CO2 life cycle burden and GHG emissions:*
- *1 % of the energy content of LNG is used to vaporize it.*
- *Stored LNG begins to “boil off” immediately and energy must be added to maintain the cryogenic equilibrium.*
- *Long-haul LNG tankers require energy and time and increase emissions and congestion on I-5, SR 101, and Columbia Gorge Scenic Area.*
- *LNG is not produced in the Puget Sound area.*



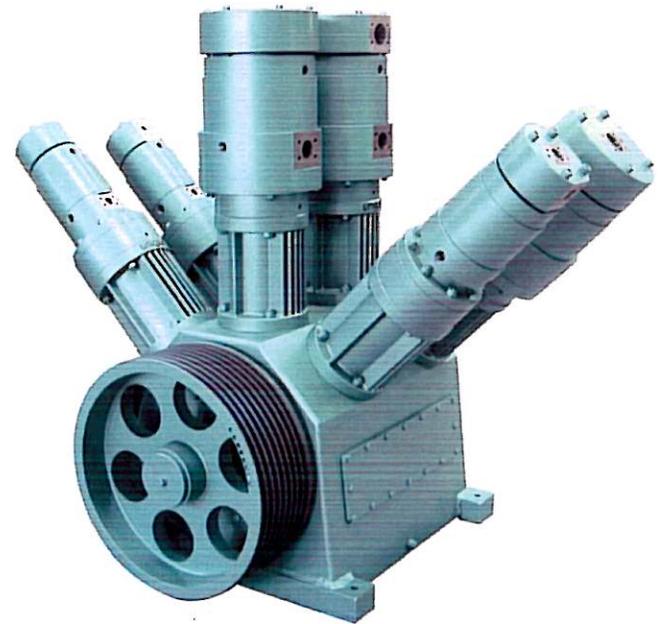
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Production of CNG is Always Less-Expensive

- 2% of energy content of CNG is used to compress it
- Since it is still in a gaseous state, CNG does not need to be warmed
- CNG can be stored indefinitely without loss of energy
- CNG is produced locally



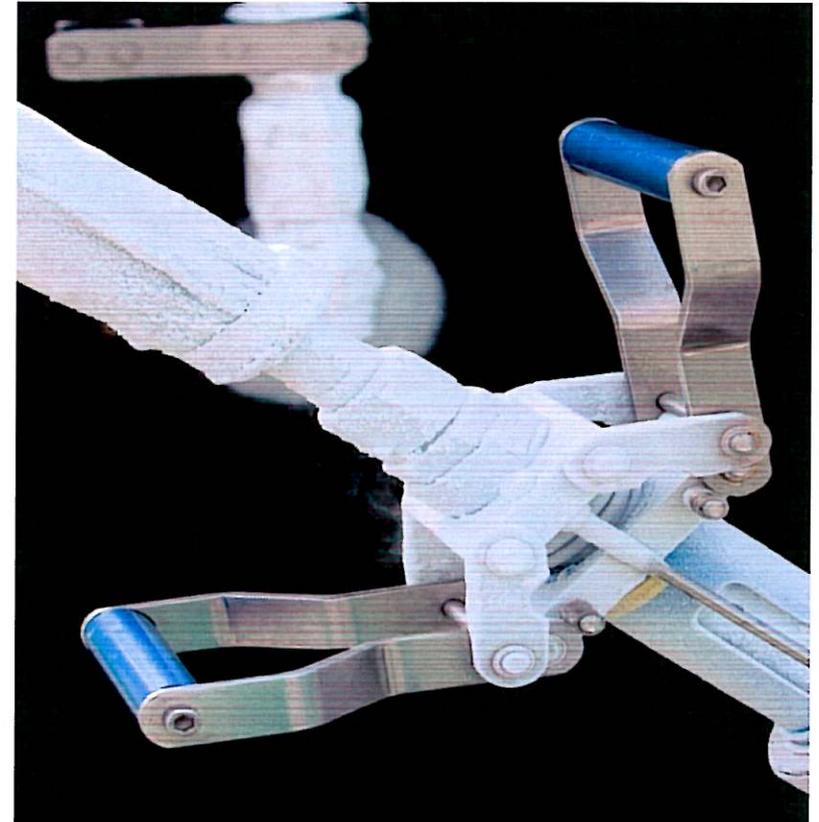
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Real-World LNG Fueling

LNG Requires Special Cryogenic Equipment and Safety Procedures



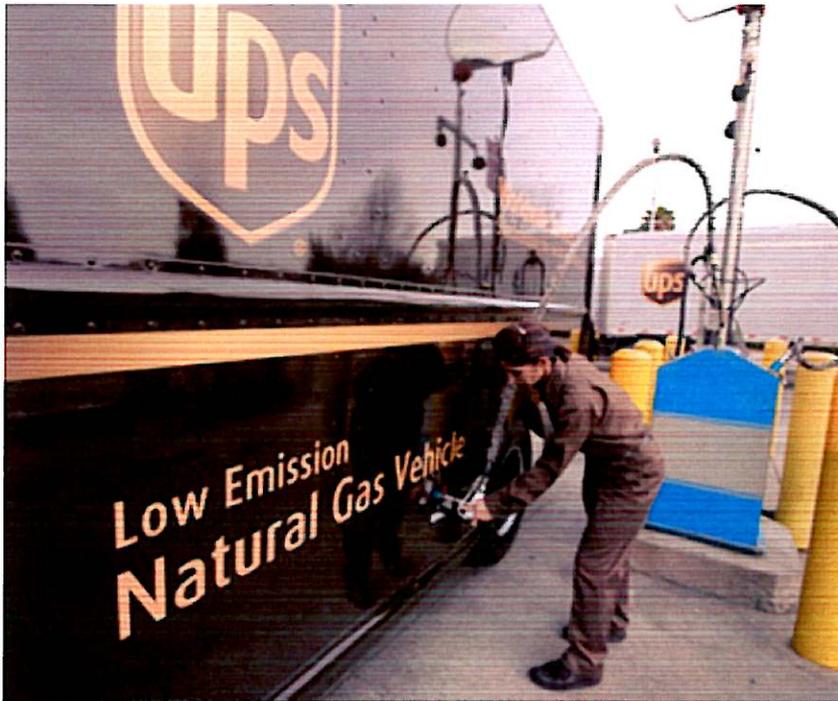
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Real-World CNG Fueling

CNG Has Simple and Safe Fueling Procedures and Equipment



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*Conversion of Tugs
from Marine Diesel
to CNG in the
Panama Canal*



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Conversion of Tugs from Marine Diesel to CNG in the Panama Canal

- The Panama Canal Authority –ACP- has a fleet of 30 Tugs that works exclusively in the Panama Canal area.*
- The average consumption of MD that ACP wants to substitute by CNG at a first stage is approximately 10.000 gallons per day, which represent approximately 1,5 MMSCFD.*
- The ACP expect to convert all the fleet to CNG once the Canal expansion project is finished, by 2014.*
- Alternatives for conversion of the engines that are now days in operation, or replacement programme for new technology engines, are under evaluation.*

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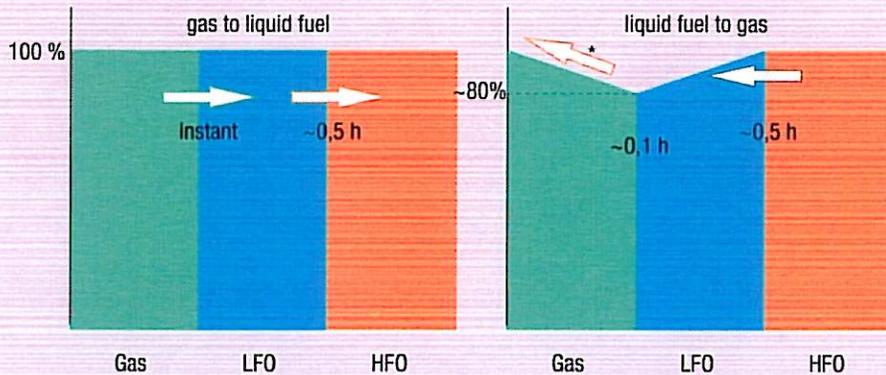
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Wartsila Now Offers A Bi-Fuel Engine Option Carry and Use both CNG and Diesel



"INSTANT" CHANGE OVER FROM GAS TO HFO MODE WITH THE TRI-FUEL SOLUTION



In the tri-fuel solution the twin injection nozzles are used also for HFO operation.
The LFO pilot is in use also during the HFO operation.
* The time to reach full load on gas depends on duration of HFO operation.

INTRODUCTION

The WÄRTSILÄ® 34DF tri-fuel engine is the ultimate 'fuel flexibility' engine.

The Wärtsilä 34DF is a four-stroke dual-fuel engine that can be run on natural gas, light fuel oil (LFO) or heavy fuel oil (HFO). Moreover, the engine can switch over from gas to LFO/HFO and vice versa smoothly during engine operation. The Wärtsilä 34DF is manufactured in configurations from 6L up to 20V giving 435/450 kW per cylinder and a total maximum mechanical output of 9000 kW. The engine speed is 720 or 750 rpm for use with 50 or 60 Hz applications.

WÄRTSILÄ Engines

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New Natural Gas Ships in Operation



Ship name	Ship type	Owner	Year built	Installed power
Glutra	Ferry	Fjord1 (NO)	2000	2 700 kW
Viking Energy	PSV	Eidesvik (NO)	2003	8 080 kW
Stril Pioneer	PSV	Simon Mokster (NO)	2003	8 080 kW
Pioneer Knutsen	LNGC	Knutsen OAS (NO)	2004	1 280 kW
Bergensfjord	Ferry	Fjord1 (NO)	2006	12 370 kW
Fanafjord	Ferry	Fjord1 (NO)	2007	12 370 kW
Raunefjord	Ferry	Fjord1 (NO)	2007	12 370 kW
Stavangerfjord	Ferry	Fjord1 (NO)	2007	5 300 kW
Mastrafjord	Ferry	Fjord1 (NO)	2007	5 300 kW

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British Columbia Natural Gas Ferries Provided 20+ Years of Reliable Service

Two Canadian passenger/auto ferries, M.V.'s "KLATAWA" and "KULLEET" operated for twenty years in the Vancouver, Canada area beginning in 1985. They were recently retired after a bridge was built.

These two ferries operated successfully for sixteen hours nonstop daily, 365 days a year.

The ferries are double ended, 155 ft. in length and are propelled by two 300-hp 3406B Caterpillar diesel engines converted to dual fuel natural gas.



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CNG: The Fuel of the Future, Today!

A solution for both the economy and the environment

**AMERICAN NATURAL GAS
MEANS AMERICAN JOBS.**

2.8 MILLION JOBS
The natural gas industry supports nearly 3 million Americans,
far more than other energy sources.
And in just over three past two years,
jobs in natural gas grew by 17%.

37 STATES
Natural gas is produced in 37 states -
in that many jobs will witness the coming.
And natural gas pipelines connect to 41 states.

FUTURE JOBS
Our abundant supply of domestic natural gas -
100 years and growing -
promises more jobs for years to come.

We commend President Obama for recognizing the White House Forum on
Jobs and Economic Growth and stand ready to work with the White House and
Congress to secure sustainable American jobs and restore our nation's economy.
Discover the economic benefits of natural gas at ngajobs.org.

AMERICA'S NEW NATURAL GAS
cleaner, smarter energy

Source: BEI Energy Group Study 2008

CONVERT YOUR TANK!

CLEAN. ABUNDANT. AMERICAN.

Natural Gas

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Conclusions

- Natural gas is a proven engine fuel that behaves well in the marine environment.
- Diesel engines can be converted to run on natural gas or vendors offer marine engine replacements which can run on both natural gas and diesel.
- Natural gas prices are substantially lower and less-volatile than diesel, potentially saving \$20 million a year in fuel costs over the Ferry System's long-term planning horizon.
- Natural gas provides a 95% reduction in particulate matter emissions and has intrinsic qualities which lend themselves to environmental protection.

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Notes

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