Fuel Efficiency in Gas Conversions

More Flexibility, Less Emissions and Lower Fuel Costs

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Introduction
With steeply climbing fuel prices and increasingly stringent environmental regulation, the question of fuel efficiency has become a key issue for the power and marine industries. A reciprocating engine still is, and will remain so in the foreseeable future, the most efficient way of converting liquid or gaseous fuels into power. There are, however, differences between fuel types. In order to maximise fuel efficiency, conversions of existing engines for gas operation are increasingly being looked into.

There are a number of reasons why a gas conversion makes sense, though customer needs naturally vary. Such needs can be everything from emphasising the green image of the company, to purely economic reasons. However, in the majority of cases, the main drivers for converting to gas are the significant emission reductions, the consequentially reduced fees, and the reductions in fuel costs, i.e. fuel efficiency.

Fuel Efficiency
*Fuel efficiency is a form of thermal efficiency. It can be defined as the efficiency of a process that converts chemical potential energy contained in a carrier fuel into kinetic energy or work. Wärtsilä has taken a leading role in developing combustion engine technologies that offer both outstanding efficiencies and the flexibility to use virtually any fuel.*

Wärtsilä’s gas and diesel combustion engines have shaft efficiencies of around 45–48 percent. By comparison, larger conventional gas turbines can achieve efficiencies of around 40 per cent, and smaller turbines (around 10 MW) typically used in many applications, have an efficiency of some 30 percent or less, depending on operating conditions. Also, unlike combustion turbines, combustion engines do not derate over time but maintain full output throughout their lifetime.

A reciprocating engine is the most efficient way to convert liquid or gaseous fuels into power. And, as far as we can see, its position will not be contested in the near future. There are however differences in the efficiencies achieved between different fuels. Natural gas is the most efficiently burning fossil fuel, and many times converting an existing engine to operate on gas can offer significant benefits both economically and environmentally.

Converting a combustion engine to operate on gaseous fuel improves fuel efficiency in three ways
- **Natural gas burns efficiently** – highest energy content fossil fuel
- **Natural gas burns cleanly** – lower maintenance costs and emissions (reduced fees, carbon finance)
- **Natural gas is attractively priced** – more power for the same money

A dual or multifuel solution offers additional efficiency through fuel flexibility. These technologies, pioneered by Wärtsilä, allow the engines to be run on crude oil and other liquid fuels as well as gas of varying quality. The ability to burn various liquid or gas fuels can help to drastically reduce the cost of fuel when fuel prices and availability fluctuate.
Benefits of gas as a fuel

Typically, the two main drivers for converting an engine to gas operation are reduced emissions and environmental fees and the reduction of fuel costs. Natural gas offers a number of important advantages.

Efficient combustion
Natural gas is the highest energy content fossil fuel, offering significant benefits when used instead of oil or coal.

Pricing
The price difference between natural gas and oil often makes gas an attractive alternative. The feasibility of a gas conversion is, however, always installation specific, depending on the price spread between gas and existing fuel, the amount of fuel consumed, and the efficiency and output of the converted installation.

Compliance with environmental regulations
One of the main drivers for converting to gas operation is reducing emissions to save on fees and comply with more stringent environmental regulations. One example of these are the Emission Control Areas (ECAs) for marine traffic that come into effect in 2015.

Plentiful supply
Natural gas is plentiful. IEA estimates suggest there are nearly 182 trillion cubic meters of proven reserves of natural gas today, which equates to about 60 years of supply at the current rate of consumption. The estimate does not include significant gas reserves which are believed yet to be discovered.

Availability
With the steadily increasing demand for gas, the availability and infrastructure are rapidly growing all over the world. Liquefied Natural Gas (LNG)* and long distance pipelines have transformed global gas markets. Through liquefaction, gas can be transported by ship all over the world to meet demand wherever it arises.

The cleanest fossil fuel
Natural gas is the cleanest of the fossil fuels. The combustion of natural gas releases virtually no sulphur dioxide and ash or particulate matter, and very small amounts of nitrogen oxides. Natural gas emits 22% less carbon dioxide than oil and 40% less than coal. NOx is reduced by more than 90% and SOx by more than 95%.

* Liquefied Natural Gas (LNG)
Cooling natural gas to about -260°F at normal pressure results in the condensation of the gas into liquid form. LNG takes up about one six hundredth of the volume of gaseous natural gas. Because it is transportable, LNG can make even remote natural gas deposits economically feasible.
Fossil fuel emission levels
- Pounds per billion btu of energy input

<table>
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<th>Pollutant</th>
<th>Natural gas</th>
<th>Oil</th>
<th>Coal</th>
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<tr>
<td>Mercury</td>
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<td>0.007</td>
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Source: EIA - Natural Gas Issues and Trends 1998

Savings in engine maintenance costs
Cleaner combustion also means that with a gas fuelled engine maintenance costs can be lower than with other fuels.

Gas conversion technologies

Wärtsilä offers three gas conversion concepts for engines
- **SG (spark-ignited) gas-only engines**
- **DF (dual-fuel) engines capable of burning most fuels e.g. HFO (heavy fuel oil), LFO (light fuel oil) and natural gas**
- **GD (gas-diesel) engines that can run on HFO, LFO, crude, natural gas and associated gas**

Spark-ignited (SG) gas only engines
The SG engines are spark-ignited lean-burn otto cycle gas engines. In this process, the gas is mixed with air before the inlet valves. During the intake period, gas is also fed into a small prechamber, where the gas mixture is rich compared to the gas mixture in the cylinder. At the end of the compression phase the gas/air mixture in the prechamber is ignited by a spark plug. The flames from the nozzle of the prechamber ignite the gas/air mixture in the main combustion chamber. After the working phase the cylinder is emptied of exhaust and the process starts again.
Dual-fuel (DF) engines
The dual-fuel engine utilises a “lean-burn” otto combustion process when operating in gas mode. Here, the gas is mixed with air before the intake valves during the air intake period. After the compression phase, the gas/air mixture is ignited by a small amount of liquid pilot fuel (LFO). After the working phase the exhaust gas valves open and the cylinder is emptied of exhaust gases. The inlet air valves open when the exhaust gas valves close, and the process starts again.

The dual-fuel engine is also equipped with a backup fuel system. In the event of a gas supply interruption, the engine transfers from gas to fuel oil operation (LFO, HFO) at any load instantaneously and automatically. Furthermore, the separate backup fuel system makes it possible to switch over from LFO to HFO without load reduction. During fuel oil operation the DF engine utilizes the conventional diesel process.

Gas-diesel (GD) engines
The gas-diesel engine utilizes the diesel combustion process in all operational modes. In gas mode, the gas is injected at high pressure after the pilot fuel and is ignited by the flame from the pilot fuel injection.

The gas-diesel engine can be switched over instantly to liquid fuel mode operation. The liquid fuel can be light fuel oil, heavy fuel oil or crude oil. In this case, the process is the same as the conventional diesel process.

The gas-diesel process can tolerate big variations in the gas quality and is especially suitable for “non-pipeline quality gas”, such as associated gas in oil fields.

The GD concept requires very few engine modifications, and provides true fuel flexibility.
Gas conversions in power plants

In power plant installations, the economic viability of gas is becoming ever more apparent. At the same time, emission issues related to the use of liquid fuels are becoming more complex. Not surprisingly, therefore, the use of gas to generate power is rapidly increasing.

The challenges of complying with environmental legislation and addressing the global need for energy conservation – not to mention the soaring fuel prices – have made the efficiency of the prime movers used to deliver electrical power or mechanical drive increasingly important. In order to convert older LFO/HFO operated installations to operate on natural gas, there needs to be a reliable gas supply available. With the growing availability of gas, more and more power plants also outside the oil and gas industry are now starting to see new opportunities.

A Wärtsilä gas conversion of an existing power plant is not just about the engine conversion. All aspects from safety to reliability of the operation are considered, so that the conversion concept follows the same principles as a new built gas power plant made by Wärtsilä according to the latest design and engineering.

Associated gas as fuel

In order to save energy, reduce the environmental impact and lower costs, energy efficiency programmes are now common also in the production of oil and gas. More and more, oil and gas producers are looking into using associated gas* to power their prime movers, instead of it being continuously flared** into the atmosphere. With Wärtsilä’s gas-diesel technology, associated gas can be used for power generation or gas re-injection at the oil field. The fuel sharing technology allows the engines to cope with variations in gas quantity and quality.

Feasibility is always plant specific

In order to be successful, every conversion has to be carefully designed according to plant specific variables such as the plant owner’s requirements, costs, fuel availability and future fuel prices. A feasibility study can help plant owners decide which solution best meets their needs.

For example, some feasibility studies reveal that for a baseload plant switching from HFO to gas engines, it may be possible to achieve a 1 year payback on a €10 million investment. Maintenance savings can also be significant. For example, if the existing HFO engine has a high number of operating hours, performing a conversion instead of an overhaul could provide immediate savings.

Whatever, a plant owner’s needs – whether systems upgrades or gas conversions, Wärtsilä is able to collaborate to develop feasibility models in order to deliver the right solution.

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* Derived from crude oil at oil fields, the associated gases hold substantial concentrations of higher hydrocarbons and have high heating values. Earlier being simply flared at the oil fields, they can now be used for energy production. Due to their composition they are best utilised in the high efficiency gas-diesel engines.

** Gas flaring is a practice that is coming increasingly under the spotlight due to environmental concerns and the need for energy conservation. In 2010 Wärtsilä became the first prime mover manufacturer to become a member of the World Bank’s Global Gas Flaring Reduction Partnership (GGFR).
Case: Aksa Samsun

Gas conversion for reduced emissions and lowered operational costs

With the tightening of Turkey’s environmental legislation, Aksa Enerji Uretim A.S wanted Wärtsilä to convert the Wärtsilä 46 engines in their Aksa Samsun power plant to use more environmentally friendly fuel. The project was finalised in the autumn 2011. Wärtsilä’s GD concept was found to be able to cope with all the requirements with improved engine efficiency, yet still be able to provide not only back-up fuel flexibility with HFO and LFO, but also natural gas/HFO fuel sharing.

Testing and commissioning took place in autumn 2011, engine by engine, by the Wärtsilä commissioning team assisted by the Aksa Enerji team. After a few days tuning, 17 MW was reached with very good heat rate figures. Furthermore, the key issue, the exhaust gas emissions, were accepted by the local authorities. The gas conversion lowered the operation costs, reduced exhaust gas emissions, and provided real fuel flexibility, with a short payback time.

Case: Eden Yuturi

Gas conversion transforms gas flaring into electricity

The conversion of the Eden Yuturi power plant, owned and operated by Petroamazonas EP and located in the Ecuador Oriente jungle, from crude oil fuelled to associated gas fuelled operation enabled PAM to utilise associated gas that was being flared. Four 18-cylinder Wärtsilä Vasa 32 low NOx gas (LNGD) engines in V-configuration generating 20 - 24 MW power were converted, and the hand-over to PAM took place in November 2011.

Every 1 million cubic foot per day of flare gas optimised for power generating represents approximately 160 barrels of crude oil per day. Thus, PAM expects to save up to 640 barrels thanks to the project. As PAM likes to say: it increased the net crude oil production by an average of one well without having gone through the drilling process.
The year 2015 is rapidly approaching, and with it the new emission reduction requirements within Emission Control Areas (ECAs).

Gas conversions in the marine industry

The two key drivers in the increasing interest in LNG as a marine fuel are the fuel price and the focus on reducing emissions. Just like the power sector, the marine industry is also seeking ways to comply with new environmental regulations. The most pressing issues at the moment are those relating to operating within Emission Control Areas (ECAs) that come into effect in 2015.

For shipowners and charterers operating in these areas, converting to liquid natural gas (LNG) fuelled propulsion is an increasingly viable option. Other available solutions include low sulphur fuel (MDF) and SOx scrubbers. Fuel price is the most important parameter that has to be analysed in order to build a solid business case. At the moment, fuel efficiency and fast payback are making LNG very cost competitive.

Gas availability is another crucial issue. The rising interest in LNG as a marine fuel has resulted in a boom in the interest in expanding the existing gas distribution infrastructure, with investment proposals for small scale LNG facilities being reported almost daily.

Feasibility considerations

In practice, all vessels can be converted where available space exists for the LNG tank. Nevertheless, the prime target vessel types can be listed as being: RoRo/RoPax, product/chemical tankers, container vessels with LNG containers, and bulkers.

The next step is to check whether or not the existing engines onboard can be converted, or if they should be exchanged for new Wärtsilä dual-fuel engines. Generally speaking, converting an existing engine is recommended and is economically more feasible than installing new ones - especially when keeping in mind that a conversion basically brings the same benefits as new engines.

In whichever way the customer prefers to address future trends regarding fuel prices or emission abatement methods, Wärtsilä can meet such needs for both new buildings as well as gas conversions.

Complete vessel conversion

- Engine conversion
- LNG tank(s) and foundation
- LNG/NG double walled piping
- Gas detection and fire suppression Inert plant/N2 storage and control air
- Bunkering station(s)
- Automation and control system
- Exhaust pipe gas burst disc(s)
Summary
Converting to fuel efficient gas operation is an increasingly viable alternative for power plants and ships. Wärtsilä engines are flexible and easily adaptable for utilising gas as a main fuel, which makes converting to gas operation very interesting, for example in terms of lower operation costs, less exhaust gas emissions, fuel flexibility, and short payback time. Especially now, as gas grids are expanding and emission levels are being tightened globally, conversion to operate on natural gas offers significant benefits.
What are your specific needs?
With more than 16,000 MW under service agreements, Wärtsilä is recognized as the preferred service supplier by customers, ensuring the availability and cost-efficient operation of their installations. We operate and maintain more than 500 installations covering a wide variety of land-based, marine and offshore installations.

Wärtsilä offers four types of standardized agreements ranging from supply agreements to technical management, as well as maintenance agreements and complete asset management. However, all agreements are customised to fulfill each customer’s specific needs.

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