

Improving power plant energy efficiency

BUSINESS WHITE PAPER



With up-to-date equipment, well-planned maintenance and skilled operation, a power plant's energy efficiency can be kept on a high level throughout its lifecycle. With customized lifecycle upgrades, its energy efficiency can even be considerably increased, which improves the installation's performance. In addition, a boost in energy efficiency decreases emissions, reducing negative environmental impacts.

CONTENTS

Drivers for improving energy efficiency	2
Benefits: improved profitability and reduced emissions	4
How to improve power plant energy efficiency.....	5
Maintaining efficiency over the lifecycle	6
Modernising and upgrading power plants.....	8
Summary and future outlook	12

Drivers for improving energy efficiency

— Renewables and more traditional energy production must both function efficiently in order to secure a sufficient supply for consumers and industry.

The energy industry today and tomorrow

The global economy in 2017 is still quite uncertain, and businesses in all industries are cautious about making investments. The return on investment must be attractive and materialise quickly in order to convince business owners that the investment is worth making.

However, while many businesses choose caution, there are those who think this is the right time to seize new opportunities. As new innovations emerge, older production methods are increasingly threatened by disruptive new business models. Consumers are already showing interest in producing their own electricity and selling the surplus. This trend, and the role of consumers, will only strengthen as new small-scale solar and wind technology becomes more easily available and affordable.

Different energy sources complement each other

At the same time, the ongoing and strengthening shift towards renewable energy forms is changing the dynamic in the power industry. There is increasing political pressure to favour renewables in many parts of the world. In flexible power generation, renewables and more traditional energy production complement each other. Both must function efficiently in order to secure a sufficient supply for consumers and industry.

While renewable energy forms are advancing and gaining in popularity, power generation with renewables is still subject to weather conditions and can fluctuate. This is where load balancing power plants will continue to be needed – to ensure that the total energy output meets the demand. These plants are also necessary during consumption peaks. Plants powered by gas engines are often used for these important tasks, as they are quickly activated. To secure their competitiveness, they must be energy-efficient. Keeping fuel costs down means better cost-to-output ratio.

Digital innovations improve predictability

As digitalisation advances, collecting and analysing installation data will give power plant operators access to information that used to be more difficult to obtain. With this information, they will be able to forecast power consumption and maintenance needs more accurately and adjust their operations accordingly. New solutions in energy storage and virtual technology will in all likelihood impact the energy sector, as well.

Energy efficiency is an opportunity

In an uncertain economic environment, increases in profitability are often sought through tightened cost control. Fuel costs form a major part of a power plant's operating costs – up to 80%. The most effective way to reduce operating costs is therefore to improve fuel efficiency.

In industry installations that support, for example, a mine or manufacturing facility, cost reductions are a way of improving competitiveness, as power generation costs are a major factor in total operating expenses. Energy efficiency can therefore give a competitive edge.

— Fuel costs form up to **80%** of a power plant's operating costs.

Cost-to-output ratio defines competitive position

For power plants that provide energy for a centralised, e.g. national grid, merit order lists are used to rank energy producers according to marginal costs, so that plants with the lowest costs are the first ones to be brought online. Here, again, cost-efficiency pays off and installations with the best cost to output ratio are the most successful. Older installations tend to fall on the lists as their efficiency declines and newer, more efficient competitors enter the market. Improving the output of the installation can give a welcome boost and improve its position.

Regulation drives towards better environmental performance

Increasing regulation is another strong driver of equipment modernisation. Older power plants have been built in a time of less stringent legislation and may need to be modernised, as emission limits become tighter. A stronger focus on safety may also be a factor that encourages operators of older installations to consider upgrading their equipment.

Environmental impacts caused by power plants receive increased attention as renewables gain momentum. With the increase of renewable energy in the market, oil or gas engine-based power plants must renew their social license to operate by improving their environmental performance. Emissions from older plants are higher than those from plants with more modern equipment. Modernisation not only increases energy efficiency, but reduces emissions as well, which is more and more important to plant operators as environmental regulations become more stringent.

Benefits: improved profitability and reduced emissions

Improvements in energy efficiency reduce operating costs, but the financial rationale is not the only one that speaks for the investment. Measures that affect energy efficiency have a variety of other benefits that should be considered when making the investment decision. Enhanced operational efficiency, extended lifecycle of the equipment and a more sustainable brand image are valid reasons for considering an energy efficiency improvement project.

Commercial benefits

- An investment in energy efficiency, involving both technology and maintenance, pays itself back quickly in both reduced fuel costs, which are a major factor in a plant's operating costs, and better availability.
- Increased profitability, brought on by fuel cost savings, improves the plant's competitiveness.
- Improving a plant's energy efficiency may offer an opportunity to change its operating profile from e.g. load balancing to base load.

Operative benefits

- Monitoring and data analysis allow dynamic maintenance planning, which supports not only energy efficiency but the entire installation's efficiency and reduces overall maintenance costs.
- Well-planned maintenance operations that improve energy efficiency can also extend the plant's lifecycle.
- Regulatory compliance is necessary for a power plant to operate.

Environmental benefits

- Energy efficiency improvements involve better fuel efficiency, which leads to reduced emissions per produced kW.
- Improving the plant's energy efficiency contributes to a more sustainable brand image.

How to improve power plant energy efficiency

Key factors to consider are fuel consumption, fuel and electricity prices and the maximum output of the plant.

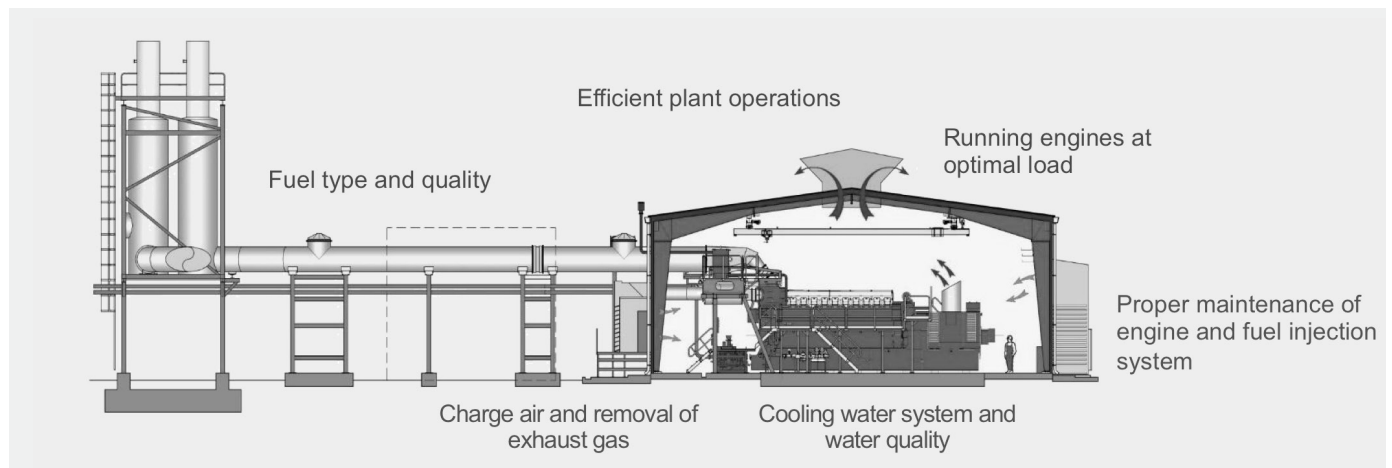
There are many means of improving the energy efficiency of a power plant – from the replacement of a single component to complete modernisation or operation and maintenance solutions. There are also many aspects that affect a plant's energy efficiency, and these need to be examined before choosing the suitable improvement solution. Some key factors are fuel consumption, fuel price, price of electricity in the operating area and the maximum output of the plant.

The first thing to look at is the engine – specifically the fuel system. What fuel does the plant use – oil or gas? What quality is the fuel, and does it correspond to the original parameters used in the construction phase of the plant? The condition of the engine and the fuel injection system is also very important – have they been properly maintained or left to gather dirt and crust? Charge air and removal of exhaust gas, as well as the condition of the boiler play a role too. The cooling system, specifically the quality of the cooling water, can also impact energy efficiency. Has it been purified to a sufficient extent?

The next aspect is the operation of the plant. Is it operated according to the original parameters, or has the plant operator changed the operating profile to match changed needs? Does the number of engines match the customer need, and are they being run at an optimal load or is the load too high or low? Regular maintenance is naturally an important factor, as well.

In some cases, the plant operator already knows where the challenges are, while in others, there are more open questions. In the latter situation, a site audit conducted by energy efficiency experts helps identify equipment and processes with improvement potential. In all cases, technical schematics of the plant and its designed operating parameters, as well as all available operational data are examined to ensure that there is sufficient information for selecting the best improvement solution.

Factors to consider when improving energy efficiency



A site audit by energy efficiency experts helps identify equipment and processes with improvement potential. The power plant's technical schematics, designed operating parameters and available operational data are examined as basis for selecting the best improvement solution.

Energy efficiency improvement is not a one-off operation but a continuous process.

MAINTAINING ENERGY EFFICIENCY OVER THE PLANT LIFECYCLE

Keeping up the energy efficiency of plants over their entire lifecycle can be achieved through partnering with an experienced service provider and conducting the most suitable lifecycle upgrades.

Optimised operations

By advising and training the power plant personnel to operate the equipment in an optimised way, operational and energy efficiency can be improved. Service agreements often include training modules to ensure that the plant personnel has the necessary knowhow. In full-scale operating services, personnel with the expertise needed to operate the installation in an energy-efficient way is provided as part of the agreement.

Optimised maintenance

With well-planned, data-driven high-quality services, the plant can be operated more efficiently and the lifecycle of the equipment can be extended. Service solutions can be scaled and customized to best serve the customer's operations, from spare parts to full operation and maintenance services. Continuous monitoring of the engines and equipment provides valuable data that can be used to determine where improvements can be carried out. Maintenance is also a key aspect in the upholding of a power plant's energy efficiency. A modernisation or conversion can give a considerable boost to energy efficiency, but keeping the energy consumption of the plant on the same low level continuously requires regular maintenance operations supported by operational data.

The increasing cost of declining efficiency

Engine type	1% eff decrease	2% eff decrease	3% eff decrease	4% eff decrease	5% eff decrease
Wärtsilä 34SG	0.4 MEUR	0.8 MEUR	1.2 MEUR	1.6 MEUR	2.0 MEUR
Wärtsilä 34DF	0.5 MEUR	1.0 MEUR	1.5 MEUR	2.0 MEUR	2.5 MEUR
Wärtsilä 32HFO	0.6 MEUR	1.2 MEUR	1.8 MEUR	2.4 MEUR	3.0 MEUR
Wärtsilä 46HFO	0.6 MEUR	1.2 MEUR	1.9 MEUR	2.6 MEUR	3.3 MEUR

Plant size approx 88 MW
6000 running hours per year

HFO EUR 400,00 / t
GAS EUR 7,00 / MMBtu

Source: Wärtsilä

Wärtsilä Guaranteed asset performance solution combined with Energy efficiency management

Wärtsilä Guaranteed asset performance is a lifecycle solution in which Wärtsilä guarantees the reliability or availability of a power plant. Performance targets are set together with the customer, and Wärtsilä ensures that they are reached by providing advanced performance analytics services combined with advisory and planned maintenance services that keep the equipment in good condition and prevents disruptions.

Wärtsilä Energy efficiency management is a service where fuel efficiency is measured and monitored, advisory for optimisation provided by centralised expertise and performance guarantees provided as a part of the Wärtsilä Guaranteed asset performance solution.

The first step is the establishment of remote heat rate monitoring. Based on the monitoring data, experts provide advice and recommendations to the customers' operators in order to ensure that the heat rate is kept on an optimal level. Wärtsilä guarantees the heat rate, which means that during the duration of the partnership, the heat rate will remain within an optimal window mutually agreed by the customer and Wärtsilä.

Another benefit of a lifecycle solution such as Wärtsilä Guaranteed asset performance is continuity. In a five or ten-year partnership, Wärtsilä monitors the level of energy consumption and reacts, if it begins to rise. In addition, Wärtsilä keeps proactively looking for new efficiency-enhancing solutions and introduces new advances to the customer as they come along. A continuous performance improvement plan is updated regularly as new potential products and solutions become available in the market. This way, energy efficiency improvement is not a one-off operation but a continuous process.

Wärtsilä Guaranteed asset performance can be applied to complement technological upgrade projects or new installations, supporting the investment for a longer time and extending the guarantee period of the original project.

— In a lifecycle upgrade actions are suggested to restore the plant's operating efficiency.

UPGRADING AND MODERNISING POWER PLANTS

Modern equipment is more energy-efficient, which means that modernisation reduces fuel consumption and thereby lowers fuel costs. The scope of solutions can be adapted to each customer case – it may include the replacement of a single part or a complete modernisation of the entire installation. Customer needs are determined together with an audit carried out by energy efficiency experts.

Technological solutions that improve energy efficiency also include conversions, in which the power plant's equipment is converted to run on gas or multiple fuels instead of oil. Gas conversions and larger upgrade projects can be carried out in place of a major overhaul, minimising the required downtime and saving in costs.

Different solutions are best suited to different phases of the engine or power plant lifecycle. If the engines are old and worn, it is often more cost-efficient to replace them with newer ones than to overhaul the old engines. A less aged engine may still be in good shape and benefit more from a smaller project, involving replacement of individual parts.

Power plant lifecycle upgrade

In a lifecycle upgrade project, equipment in a power plant is upgraded to meet its original running parameters. The operation of a newly built power plant can differ greatly from that of an older plant. Running hours are reduced as the plant ages, and changes in load are likely as well. If maintenance has been lax, the equipment may not be in the condition to perform adequately to produce the agreed output. In a lifecycle upgrade, the condition of the power plant is analysed and actions are suggested to correct excessive de-rating, in order to restore its operating efficiency to its original state or beyond.

Case: Limbe Power Plant

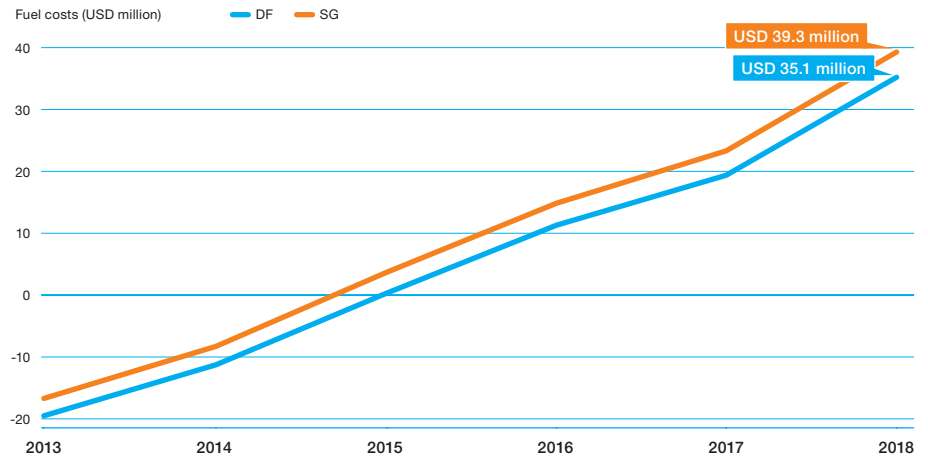
Rehabilitation project restores original capacity

Eneo Cameroon's Limbe power plant could generate only about 40% of the installed total capacity of 80MW. Wärtsilä's solution was a complete rehabilitation; a total overhaul of four Wärtsilä 18V46 engines and five alternators. The overhaul covered all critical auxiliaries, including the replacement and upgrade of radiator systems, as well as other auxiliaries.

In addition to recovering original capacity, the rehabilitation resulted in savings through reduced fuel and lube oil consumption as well reduced air emissions.

Feasibility calculation: gas conversion

The owner of a 85 megawatt HFO power plant could potentially achieve fuel savings of 33 MEUR over a period of five years by converting the plant's five Wärtsilä 18V46 engines to use gas as fuel. The payback time of the power plant gas conversion alone would in this case be around two years.



Source: Wärtsilä

Power plant profile

Five Wärtsilä 18V46 HFO engines
85 MW
7200 running hours / year
8000 kJ/kWh energy consumption
Solution
Conversion at 30000 r/h
Conversion to DF or SG
Fuel prices
HFO 450 USD / ton
LFO 680 USD / ton
Natural gas 10 USD / mmbtu

Gas conversion

In order to maximise fuel efficiency, conversions of existing engines for gas operation are increasingly being looked into. Natural gas is the most efficiently burning fossil fuel, and converting an existing engine to operate on gas can offer significant benefits both economically and environmentally. Natural gas is attractively priced, and its emissions are lower. An oil-powered power plant can be converted to run entirely on gas (spark ignited), or on both oil and gas (dual fuel), which is a valid option if gas supply is uncertain. A gas-diesel option, mainly used by oil fields, is the third alternative.

The most convenient time for carrying out a gas conversion is to do it instead of a major engine overhaul. The needed modifications are to the engines, electrical & automation systems, and the mechanical auxiliary systems. Maintenance of gas engines differs from that of oil engines, which means that new service capabilities may be needed to keep the new equipment in optimal condition.

Combined cycle upgrade

By implementing a combined cycle upgrade concept, heavy industries with large amounts of waste heat can achieve high power efficiency while lowering the emissions per MWe produced. This solution is well suited to base load power plants in which high electrical efficiency is required. It allows more power to be produced with the same amount of fuel, by applying waste heat recovery steam generators connected to common steam turbine generator sets. The boost in energy output can be as much as 10%, with no increase in fuel consumption.

Case: Delimara Power Plant 3

Gas conversion reduces power plant emission levels

Shanghai Electric Power, one of the major listed companies of China Power Investment Corporation, reduced both electricity production costs and emission levels at their Delimara 3 Power Plant in Malta. Eight Wärtsilä HFO-fuelled engines were converted to run on natural gas including installation of the new UNIC C3 engine control system.

The conversion led to lower heat rate for the engines, increased efficiency, higher power output capacity, and lower emissions, in other words, reduced operational costs.

— Two years of operation has established a 5g/kWh improvement for each engine, which enabled savings of about USD 400,000 in 2016.

Engine performance optimisation

Engine performance upgrades are often based on the latest, state-of-the-art turbocharger with improved efficiency. Higher pressure ratio capability combined with optimum engine settings such as advanced valve timing, improves engine efficiency, while the optimised combustion reduces exhaust gas emissions. The benefits of the efficiency improvements are considerable. For example for Wärtsilä 46 engines fuel consumption reduction up to 4 percent can be achieved compared to existing operation mode. This has an obvious positive impact on operational costs. The certainty and reliability of operations is also improved. For Wärtsilä 34SG engine's power output can be increased by up to 20% within the alternator limit, while improving engine efficiency by up to 0,7%. The components that are affected or to be upgraded depend on the configuration, operation requirements, ambient conditions, etc. Combining engine performance optimisation with a major service interval is most cost efficient.

Case Enercal

Performance optimisation upgrade

New Caledonian public utility company ENERCAL wanted to optimise the operational cost and performance of their Nepoui power plant. The solution was a Wärtsilä 46 Performance optimisation, consisting of engine tuning by means of a camshaft modification to Miller timing and an upgrade to ABB-TPL76C turbochargers.

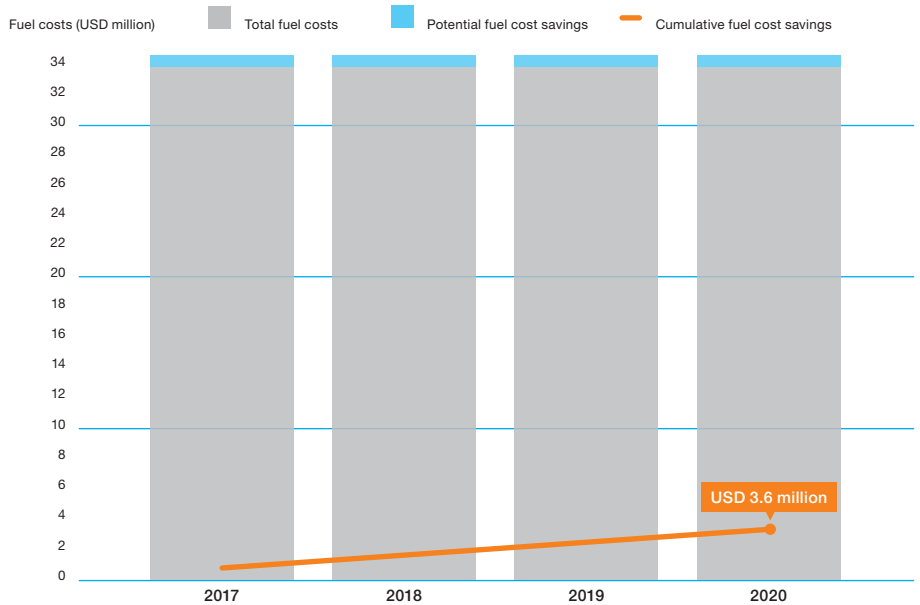
Before the performance optimisation, the specific consumption of the power plant was about 218g/kWh with a utilisation rate of 52%, totalling the average annual consumption of fuel to about 55,000 tons/year. In 2014, the price of the fuel amounted to approximately 73% of the global plant operational costs.

Installation and commissioning of the Wärtsilä 46 Performance optimisation took place during a scheduled major engine overhaul, which minimised the overall downtime.

Two years of operation has established a 5g/kWh improvement for each engine, which enabled savings of about USD 400,000 in 2016.

Example: Performance optimisation for Wärtsilä 46 engine

A performance upgrade with a new turbocharger model and Miller valve timing



SFOC reduction 4g/kWh resulting fuel consumption savings of 1863.2 t/year

Source: Wärtsilä

The installation is a base load plant with four Wärtsilä46 Power plant engines. Each engine accumulates approximately 6,850 running hours per year. The given actual SFOC situation with the engine before the upgrade is 205 g/kWh. Each engine has a nominal output of 17,000 kW. HFO oil price used in the calculation is 362 USD/ton. The performance upgrade is evaluated to generate 4g/kWh savings.

Case: Tyr Energy Inc., Plains End

Pre-chamber upgrade

Tyr Energy is an investor and developer of North American independent power projects (IPPs). Its Plains End power plant provides peak load, standby and emergency operating modes in the Colorado area.

Upgrading Plains End II, the world's largest natural gas-fired peaking power plant with reciprocating engines, to Wärtsilä's 0.9% pre-chamber provided extra room for improved efficiency and stable emissions.

In Wärtsilä 34SG engines, for example, pre-chambers are now an effective tool for optimising combustion dynamics, which can be seen in improved engine performance and a better balance between the heat rate and NOx emissions.

Wärtsilä energy efficiency offering

- Guaranteed asset performance - a lifecycle solution with performance guarantees
- Power plant lifecycle upgrade
- Power plant gas conversions
- Power plant combined cycle upgrade
- Engine and turbocharger upgrades

Summary and future outlook

As power plants and their equipment age, their efficiency often declines, leading to reduced output and increased fuel consumption – and thereby weaker profitability. However, the energy efficiency of power plants can be improved with various methods, from the replacement of a single part to a full-scale plant lifecycle upgrade project. The choice of the best way to proceed depends on a careful analysis of the plant's operating profile, original design parameters, the actual condition of the equipment and production requirements. The best solution is tailored to the customer's needs.

Lifecycle solutions provide continuity and maintain the energy efficiency and performance of the power plant. In a long-term partnership, the installation's energy consumption levels are continuously monitored and as new energy efficiency-enhancing innovations emerge, they can be applied to further improve performance.

Data intelligence will bring new means to improve the energy efficiency of power plants and grids. The amount of data that can be gathered and analysed keeps growing, and in the future, may enable completely new data-based business models.

Consumers are showing increasing interest in producing their own energy with, for example, rooftop solar panels. Any surplus could be sold back to the grid. As this trend gains momentum, energy industry players must rethink their business models to adjust to the change.

New trends are re-shaping the energy industry and the role of energy efficiency is likely to keep growing. An investment in energy efficiency creates significant commercial, operational and environmental benefits. It decreases fuel costs, increases the efficiency of operations, can lengthen the lifecycle of the plant and reduces emissions. It is also a way of future-proofing operations and increasing brand value.

Wärtsilä Services in brief

Wärtsilä Services provides high-quality lifecycle services that enhance customers' business. Its broad range of services supports both shipping and power generation companies, whenever and wherever needed. Solutions range from spare parts and basic support to ensuring the maximised lifetime, increased efficiency and guaranteed performance of the customer's equipment or installation – in a safe, reliable, and environmentally sustainable way.

<http://www.wartsila.com/services>

wartsila.com/services

© 2017 Wärtsilä Corporation – All rights reserved.

No part of this publication may be reproduced or copied in any form or by any means (electronic, mechanical, graphic, photocopying, recording, taping or other information retrieval systems) without the prior written permission of the copyright holder. Neither Wärtsilä Finland Oy, nor any other Wärtsilä Group Company, makes any representation or warranty (express or implied) in this publication and neither Wärtsilä Finland Oy, nor any other Wärtsilä Group Company, assumes any responsibility for the correctness, errors or omissions of information contained herein. Information in this publication is subject to change without notice.

No liability, whether direct, indirect, special, incidental or consequential, is assumed with respect to the information contained herein. This publication is intended for information purposes only.

