BWSC

Guide

Reduce the Environmental Impacts of Your Diesel Power Plant

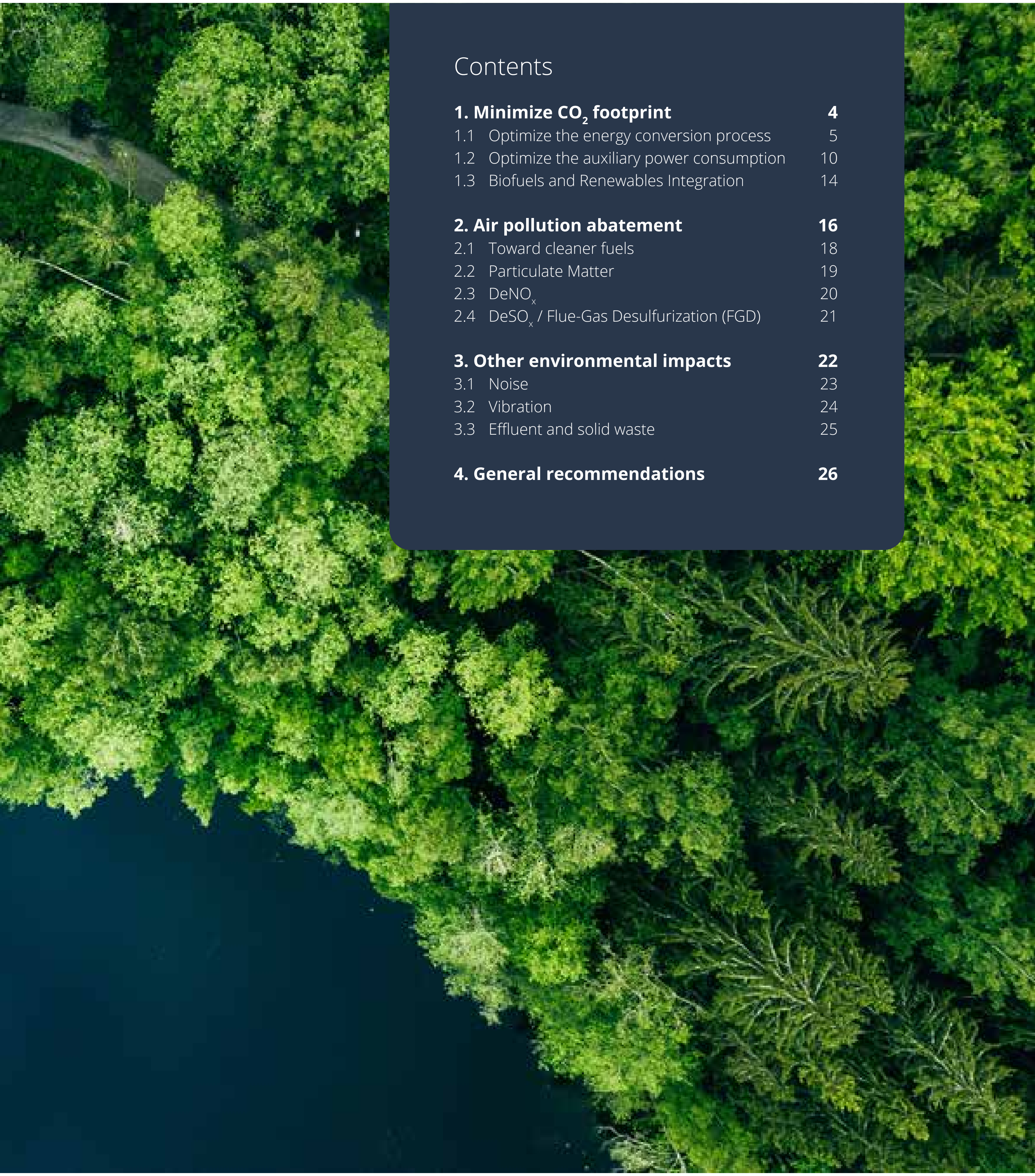
Together we can contribute to a greener future

We all have a role to play in taking care of the environment, especially within the energy industry.

We will guide you through the different solutions available for lowering emissions and improving plant efficiency.

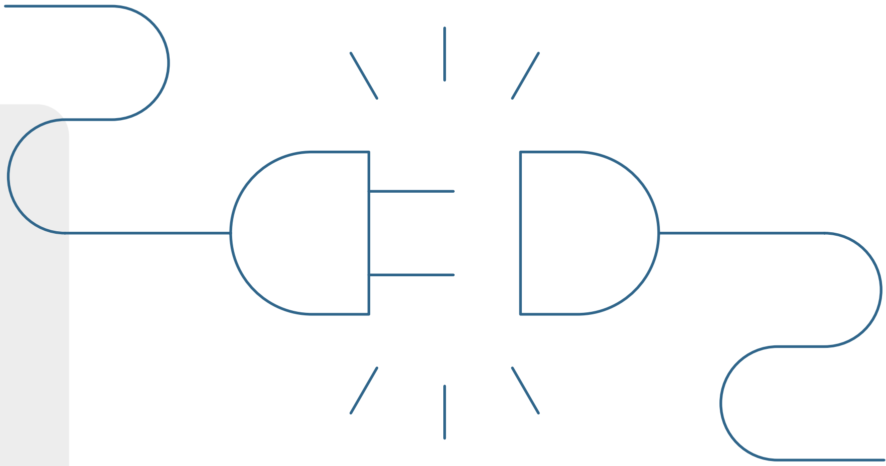
All solutions can be tailor-made to balance needs and technology preference with budgets and boundary conditions.

Ever better energy



Contents

Minimize CO_2 footprint



1.1 Optimize the energy conversion process

There are several available technologies that use the waste heat from the primary power generation process to generate additional electricity or other useful products.

Power production is inherently associated with significant heat losses, either lost with exhaust gasses or in cooling systems.

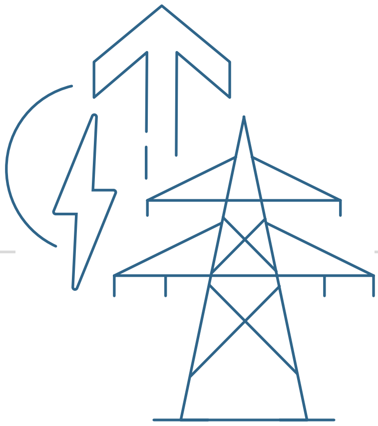
Recovering this waste heat makes it possible to produce electricity, heat, and even cooling for the plant's own consumption or for utilities, municipalities, and various businesses in the area.

On the following pages you will find our selection of the well-proven technologies BWSC master from engineering to procurement of equipment and installation at your facility.

Combined cycle

Steam cycle

You can utilize the waste heat produced from a primary electricity generation process to power a second power generation process, thus achieving dual electricity production from a single fuel.

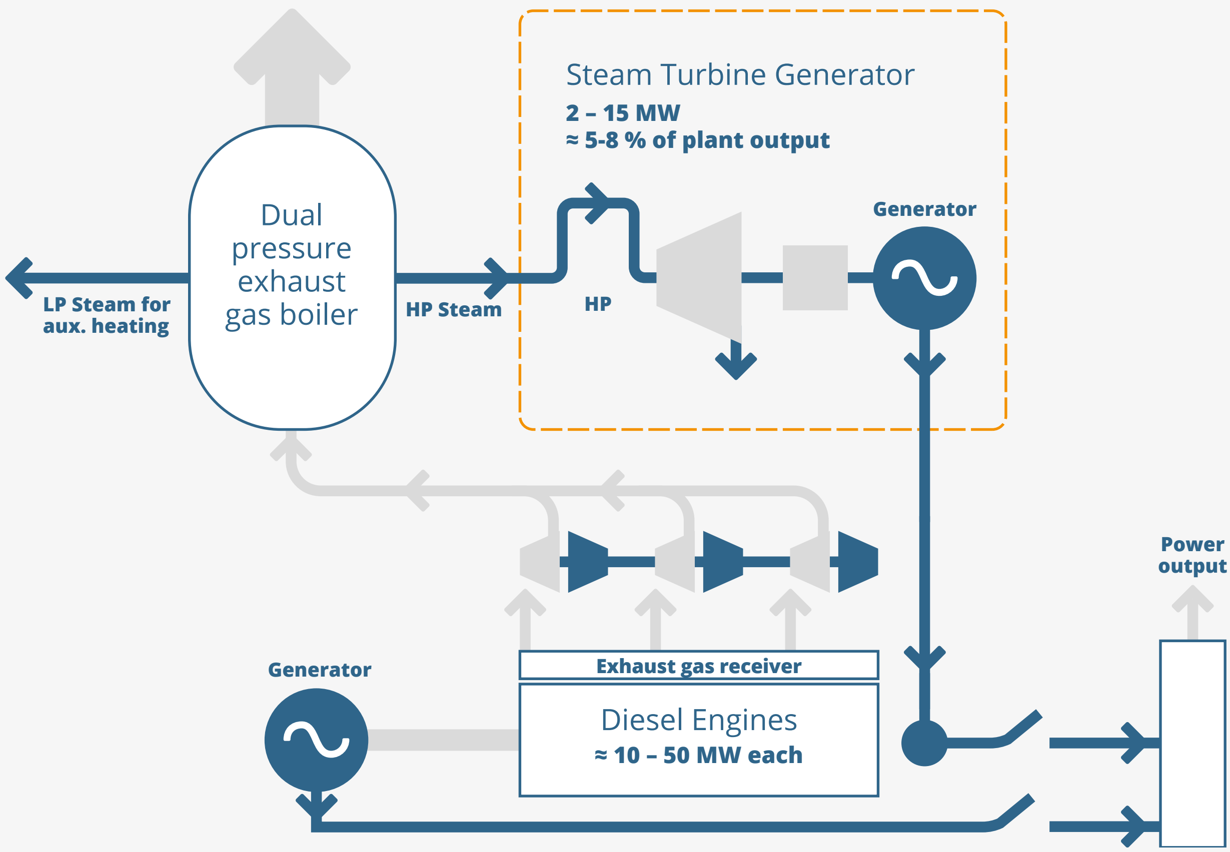


Typically,

5-8 % extra electricity,

depending on engine and plant type, can be generated without additional fuel consumption.

EXAMPLE OF CO-GENERATION/COMBINED CYCLE CONCEPT



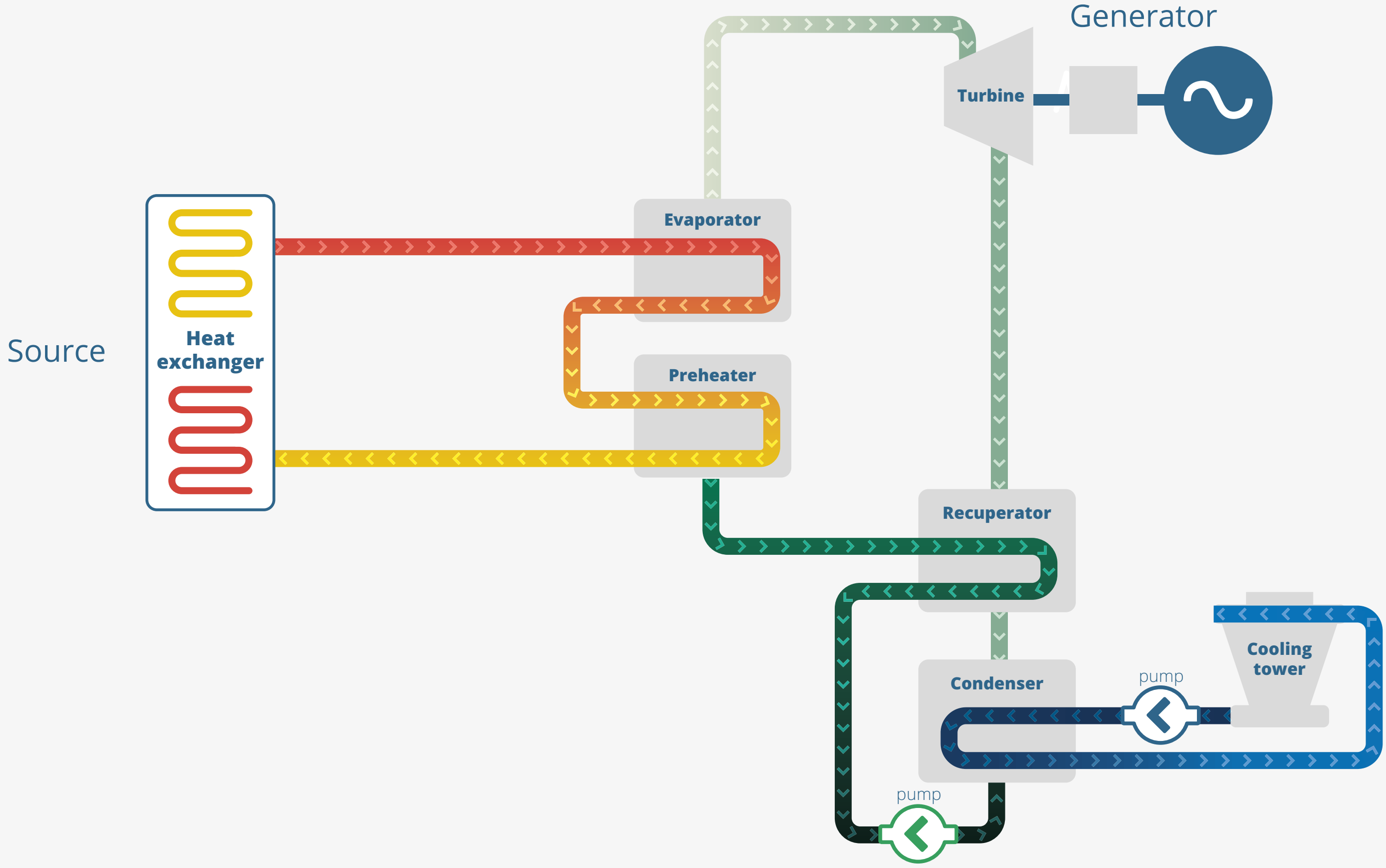
Organic Rankine Cycle (ORC)
An ORC system is used in a closed thermodynamic cycle used to produce power from low to medium-high temperature heat sources ranging from 80 to 400°C and for small-medium applications at any temperature level. The process is similar to a steam/water cycle but operating with an organic media with higher density.

Efficiency is usually slightly lower than for a steam/water cycle but

cost-efficient and simple

for small-scale applications and without make-up water preparation.

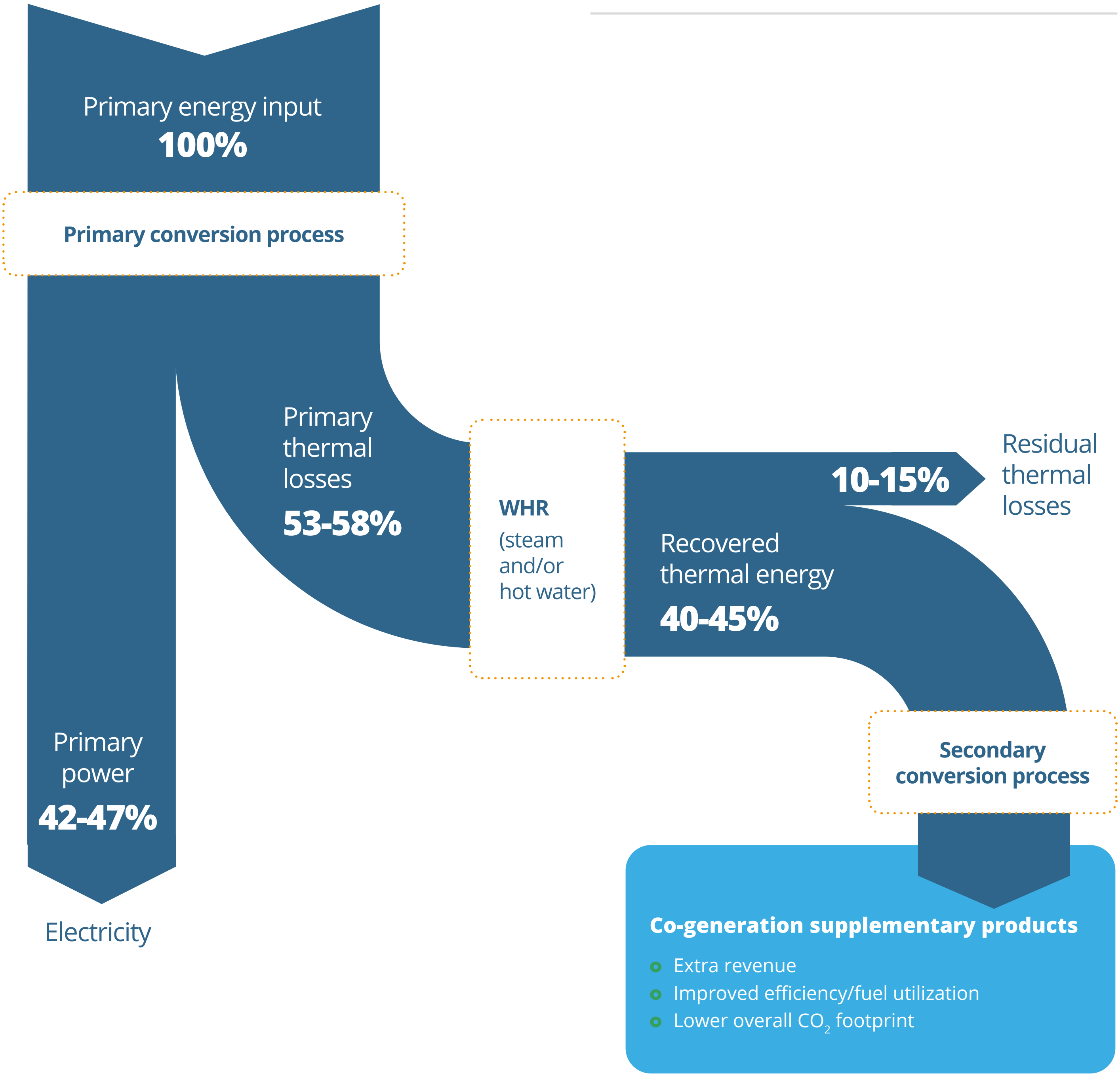
ORGANIC RANKINE CYCLE



Cogeneration

Combined cycle generation of electricity is a versatile energy product but with limited primary energy conversion efficiency, typically up to 50%. If residual heat can be used for other energy purposes the total energy efficiency can approach 100% and a significant reduction in overall primary energy consumption can be achieved compared to separate production.

Waste Heat Recovery (WHR) can reduce carbon emissions by up to 50%



Combined Heat & Power (CHP)

CHF plants typically use cogeneration of heat in the form of hot water, which is distributed by district heating networks to residential housing, or steam and/or hot water for use in nearby industrial processes.

The heat extraction systems are arranged to suit local heat demand and quality requirements and to maximize efficiency, thus reducing overall CO_2 emissions.

Combined Cooling & Power (CCP)

In some cases, CPP can be considered as a co-generation product where the heat produced is being used to generate chilled water for air conditioning or industrial cooling, which also reduces the peak power consumption in the area by substituting traditional power driven refrigiration.

Tri-generation

In some cases, one can combine both CHP and CCP coming into a tri-generation concept.

Potential offtakers for both heat and cooling are many:

- Cold stores
- Office complexes
- Shopping malls
- Hotels
- Airports
- Hospitals
- Refineries
- Destilleries
- Breweries
- Residential complexes

Desalination for public or industrial use

For communities with scarce drinking water resources, combining power and freshwater generation is becoming increasingly attractive. The waste heat from power generation is used to evaporate sea water or saline water in vacuum distillation units thereby extracting potable fresh water, leaving salts in a brine fraction.

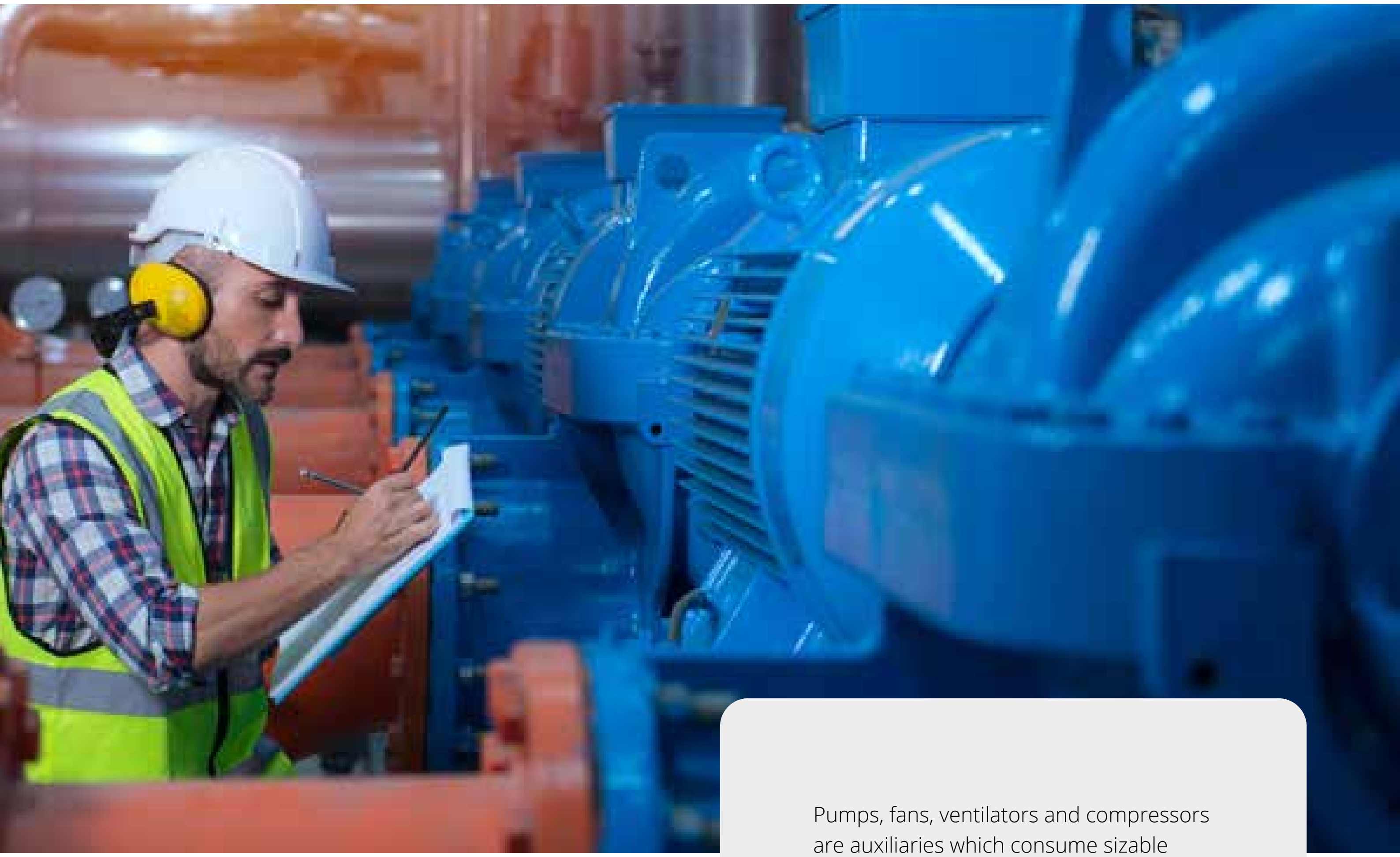
By using multiple stage distillation technology, the waste heat can be used repeatedly in sequential stages to yield substantial amounts of fresh water, before dissipating.

Since desalination otherwise requires either heat generated from primary energy or the use of electricity, cogeneration of power and water lead to improved overall energy efficiency.

Selected reference
Revithoussa, Greece, 2013

BWSC delivered an industrial CHP power plant based on gas engines.

The heat recovery system will be used for the evaporation process of LNG being landed by ship as well as for power supply to the Revithoussa Island and export of excess power to the public electric company grid system on the mainland.



1.2 Optimize the auxiliary power consumption

In thermal power plants a part of the power generated by the plants is being consumed by different auxiliaries.

Pumps, fans, ventilators and compressors are auxiliaries which consume sizable amounts of power produced by thermal power plants. However, there are also many other equipment and systems which can be checked for optimisation.

The following recommendations provide guidance but are not the complete list of areas that can be improved. We recommend making a complete assessment of the auxiliary power consumption to best tackle those issues.

The power consumption by these auxiliaries can be unnecessarily high in case of inefficient operation/maintenance or poor design of the equipment and systems.

Here are

7 ways

to reduce auxiliary power consumption

1. **Avoid oversizing**
   At specification, limit adding safety margins to ensure that the actual operation is close to BEP (Best Efficiency Point).

2. **Impeller trimming**
   If a pump is oversized, trimming the impeller is a more cost-effective and energy-efficient way of reducing the pressure and flow than using throttling.

3. **Install variable frequency drives**
   Reduce energy use of oversized pumps, fans, radiators, or engine hall ventilation fans to achieve the actual capacity required.

4. **Parallel pumping systems**
   When maximum conditions are a lot higher than standard operating demands, install a smaller, second pump to relieve the larger pump from operating far below its capacity and away from its BEP.

5. **Limit pipework pressure loss**
   Reduce pressure loss by minimising bends, optimising pipe diameter/length and installing low-pressure drop valves.

6. **Eliminate unnecessary use**
   Implement control systems to shut down pumps when not required.

7. **Maintenance**
   E.g. replace worn wear rings to reduce leakage inefficiencies.

Further ideas to reduce auxiliary power consumption

Compressors

- Eliminate pressurised air leaks to avoid unnecessary compressor power consumption

Lighting systems

- Switch to LED light sources – Compared to HP sodium vapour lamps, LED lights use 80% less power and last 10 times longer
- Install timer, dimmer relays and/or motion sensors on lighting to ensure lights are only used when needed

Air conditioning (A/C) systems

- Optimise A/C distribution system by checking pipe insulation and buildings insulation
- Install timers on A/C in offices to save energy at night and on weekends

Cooling systems

- Keep radiator coolers clean by installing semi-automatic cleaning devices. This increases heat transfer capacity and fans can save energy. Better cooling can also save fuel consumption on engines.

Up-to-date control system

- An up-to-date control system is an important precondition to monitor, optimize, control, and safeguard the plant against cyber attacks and optimize the potential of other equipment.

By using only the amount of energy required to do the job,

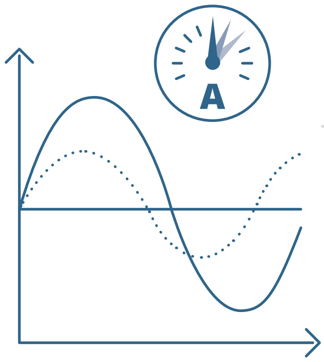
you can save up to 50% energy

Power Factor Correction (PFC) and reduction of harmonic disturbances
It reduces the load and losses in the entire power generation, transmission and distribution system, thereby increasing overall energy efficiency.

When unnecessary losses in cables and components are reduced, the remaining life will increase and the probability of failure and system instability will decrease.

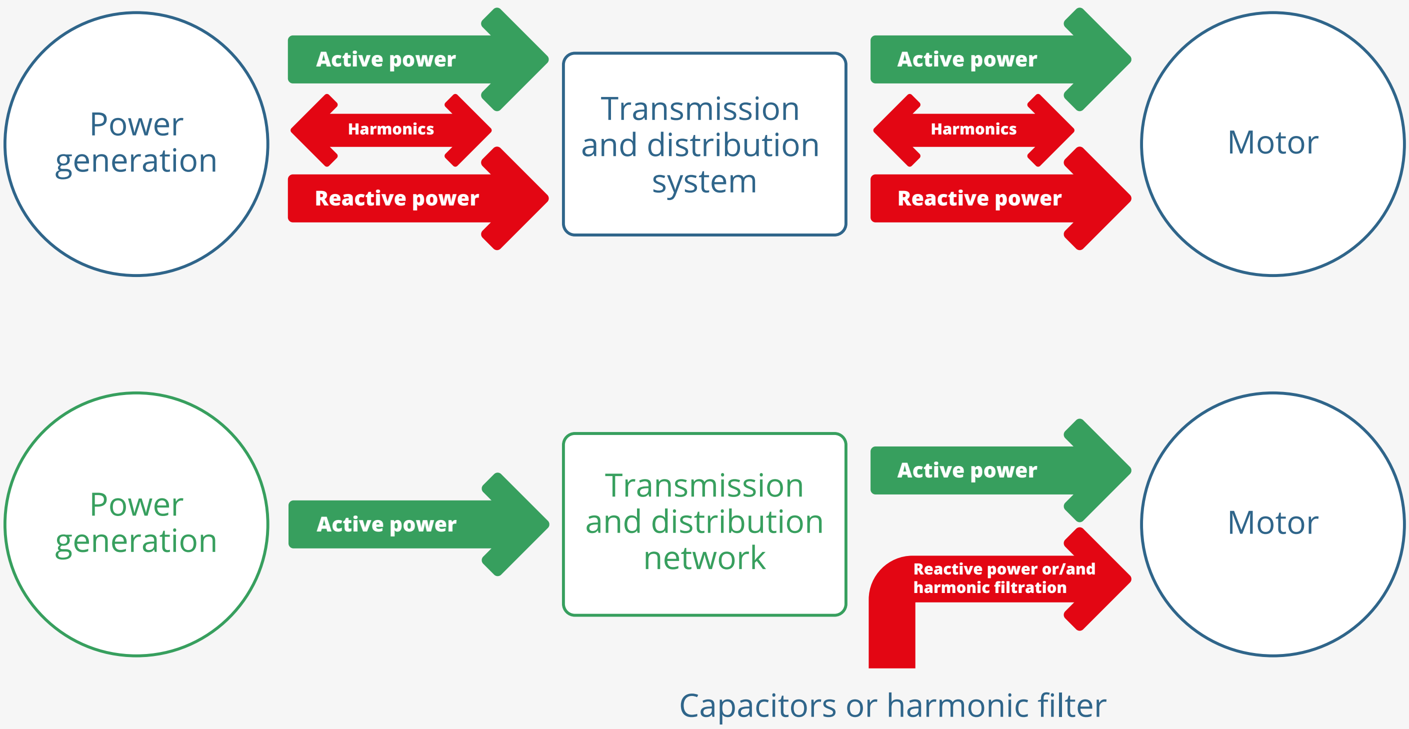
PFC is achieved via the connection of capacitors which produce reactive power absorbed by electromagnetic loads such as electric motors. The entire power supply system will be relieved of unnecessary transport of reactive power.

Passive and active harmonic filters are able to correct the sinusoidal voltage and current curves, reducing the losses in the entire power supply system and loads. Depending on the size, an active harmonic filter can function both as a reduction of harmonic disturbances and as a power factor corrector (PFC) at the same time.



PFC or harmonic filters aim to improve the power factor and voltage quality and thus
power quality.

EXAMPLE OF POWER FACTOR CORRECTION



1.3 Biofuels and Renewables Integration

Biofuels

All of the above-mentioned initiatives aim at improving energy usage/increase efficiency, which is beneficial for the CO_2 footprint and environment regardless of fuel type.

The best way to reduce the CO_2 footprint of your facility drastically would be to switch from conventional fossil fuel to a renewable liquid fuel.

There are already bio-oil available on the market which can be utilized without major adaptation.

It can be produced from straight vegetable oil, animal oil/fats, tallow, and waste cooking oil.

Further renewable fuels are expected to become commercially available in quantity, such as Green Hydrogen, Green Methanol, Green Ammonia. Those fuels might require considerable adaptation of the facility and engine conversion kits are under development.

Renewables Integration

Hybrid power plants are another important option to secure future proof energy systems to deliver efficient, low carbon, reliable, and affordable power.

Integration of solar panels (PV) and/or wind turbines to your facility can substitute a significant part of the engines fuel consumption and thus lower CO2 emissions, while still securing reliable supply and grid stability from the engine units.

Including also a Battery Energy Storage System (BESS) can be efficient to:

- Equalize gap between renewable energy availability and power demand
- Allow for a larger and more economical renewable facility achieving higher average annual power supply share
- Optimize thermal power operating pattern in transition periods to increase generating efficiency
- Contribute to grid stability by damping transient power supply/demand imbalances
- Provide short term back up power/supply reliability

EXAMPLES OF RENEWABLE INTEGRATION SCENARIOS

Thermal power only

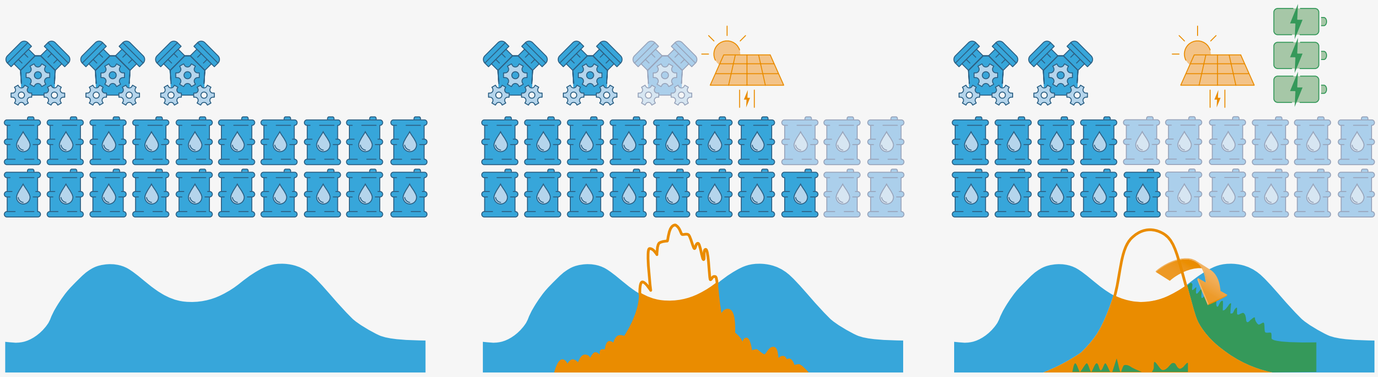
- No fluctuation
  Reliable energy 24/7/365
- Fuel prices vary
  High operation cost
  CO_2 footprint higher than alternative

Thermal power + PV

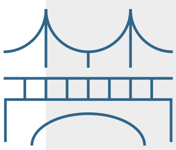
- Low Levelized Cost of Energy (LOCE)
  Fuel savings
  Proven technology
- Solar not continuous during the year
  Fluctuation during the day
  Engine as spinning reserve

Thermal power + PV + BESS

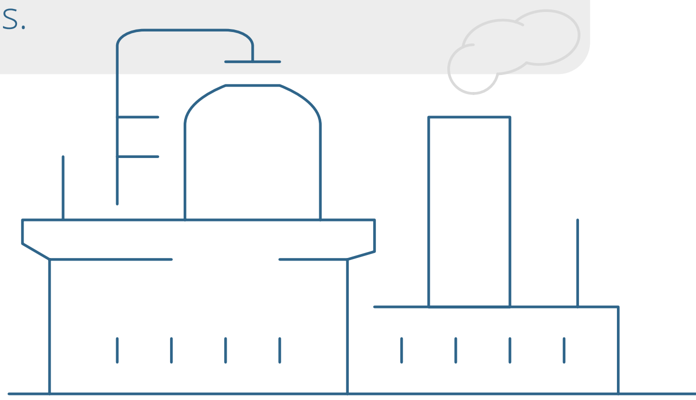
- Adding BESS increases stability
  Fuel savings
  Less fluctuation
  High flexibility in power supply
  Higher fuel savings in the evening
  Ancillary services
  No engine as spinning reserve
  Low CO_2 footprint
  Lower LCOE



Bridging fuel: Natural Gas



While awaiting a larger availability of biofuels, a useful alternative as a bridging fuel is natural gas, which will lower the CO_2 emissions by about 30% compared to fossil fuel oils.



It will also have a significant effect on reducing pollutant emissions which will be elaborated on later.

Many liquid-fueled engines can be rebuilt to Dual Fuel (DF) engines or pure gas engines, but off course also gas supply logistics need to be considered and can be significant.
DF configuration can be useful for reliability reasons if sufficient and continuous gas delivery are not entirely dependable.

2 Air pollution abatement

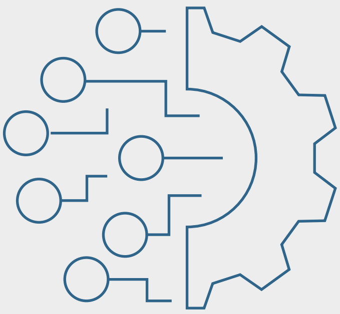
Pollutants such as nitrogen oxide (NO_x), sulphur oxide (SO_x), and particulate matter (PM) emitted by power plants may affect health and cause environmental issues.

Reducing the environmental impacts and pollution of power plants is at the heart of BWSC's activities to provide "Ever better energy".

We are going to walk you through the different options for air pollution reduction or abatement and the choice of technology for it is dependent of boundary conditions such as:

- Local regulations, World Bank, etc.
- Fuel type and composition
- Operating hours and load pattern
- Local price and availability of raw materials; water/lime/urea/etc.
- Local cost for disposal of by-products
- Engine technology (2-/4-stroke)

BWSC can advise on a choice of technology depending on the above boundary conditions.



2.1 Towards cleaner fuels

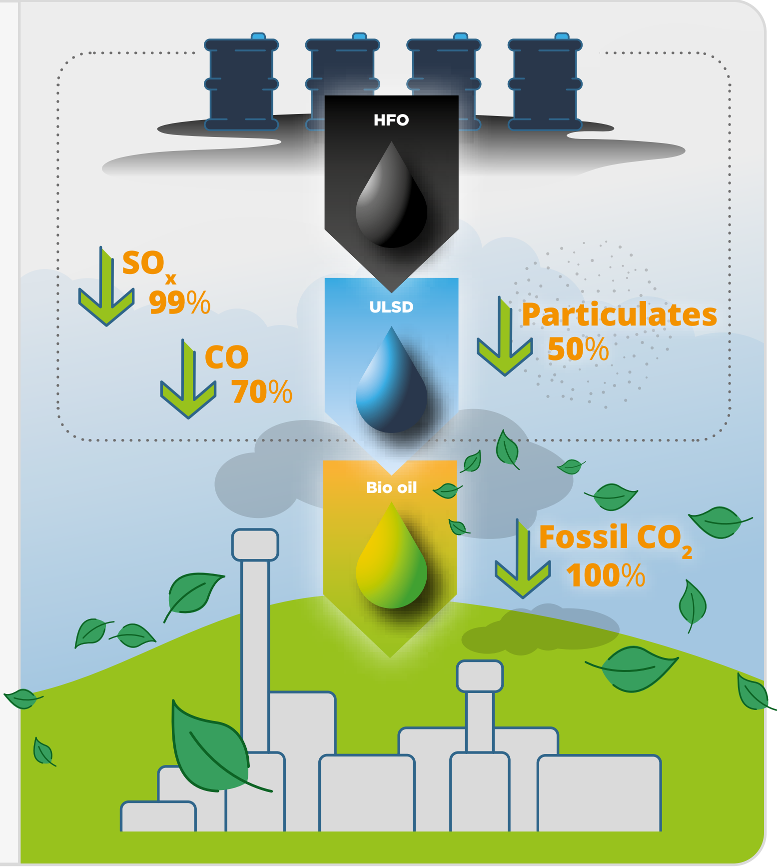
Changing the quality or type of fuel will often be the most efficient solution with the least impact on your facility and therefore is the first solution you should consider before secondary air pollution abatement.

To Ultra-Low Sulfur Diesel (ULSD)
Switching from Heavy Fuel Oil (HFO) to ULSD would make a remarkable difference in terms of SO_x and PM emissions reduction.

Selected reference
Fuel conversion
(HFO from ULSD), Guam, 2022

BWSC helped a client to convert 2-stroke generation units from Heavy Fuel Oil (HFO) to Ultra-Low Sulfur Diesel (ULSD). As soon as the project was completed, the SO_x emissions drastically decreased by at least 99%, together with particulates by approximately 50%, and CO emissions by roughly 70%. The local air quality for nearby residents and the environment significantly improved thanks to the reduction of pollution.

The project was initiated by the plant owner who implemented an environmental plan with the purpose of using cleaner fuel and complying with governmental regulations rules. This fuel conversion will also ensure the facility continues to operate in many years to come.



Natural Gas
In addition to being a cleaner fuel reducing CO_2 emissions, switching from HFO to Natural Gas reduces SO_x emissions by almost 100% and PM emissions by 80% or more depending on the fuel substituted. NO_x emissions are also improved by being reduced by more than 50%, depending on the engine technologies.

2.2 Particulate Matter (PM)

Primary measures

Preventing or limiting particle formation at combustion level:

- Engine internal measures
(injection control, valve timing , etc.)
- Fuel measures (limit S and ash contents)
- Minimize LO consumption

Secondary measures

Electrostatic Precipitators (ESP) and Bag House Filter (BHF are typically an integral part of Semi-dry or Dry $DeSO_x$ processes to remove reaction products together with combustion PM.

Electrostatic Precipitators (ESP)

An ESP can be installed to reduce PM by more than 90% if not already addressed in combination with SO_x emissions reduction with one of above solutions.

The ESP system filters fine particles from a flowing gas using electrical energy to charge particles either positively or negatively. The charged particles are then attracted to collector plates carrying the opposite charge.

The collected particles may be removed from the collector plates as dry material (dry ESPs), or they may be washed from the plates with water (wet ESPs).

Bag House Filter (BHF)

In some cases, typically in conjunction with exhaust gas cooling and/or SO_x reduction, bag house filters can be an alternative to ESP.

However, filter bags cannot withstand full exhaust gas temperature which need to be under control at all times.

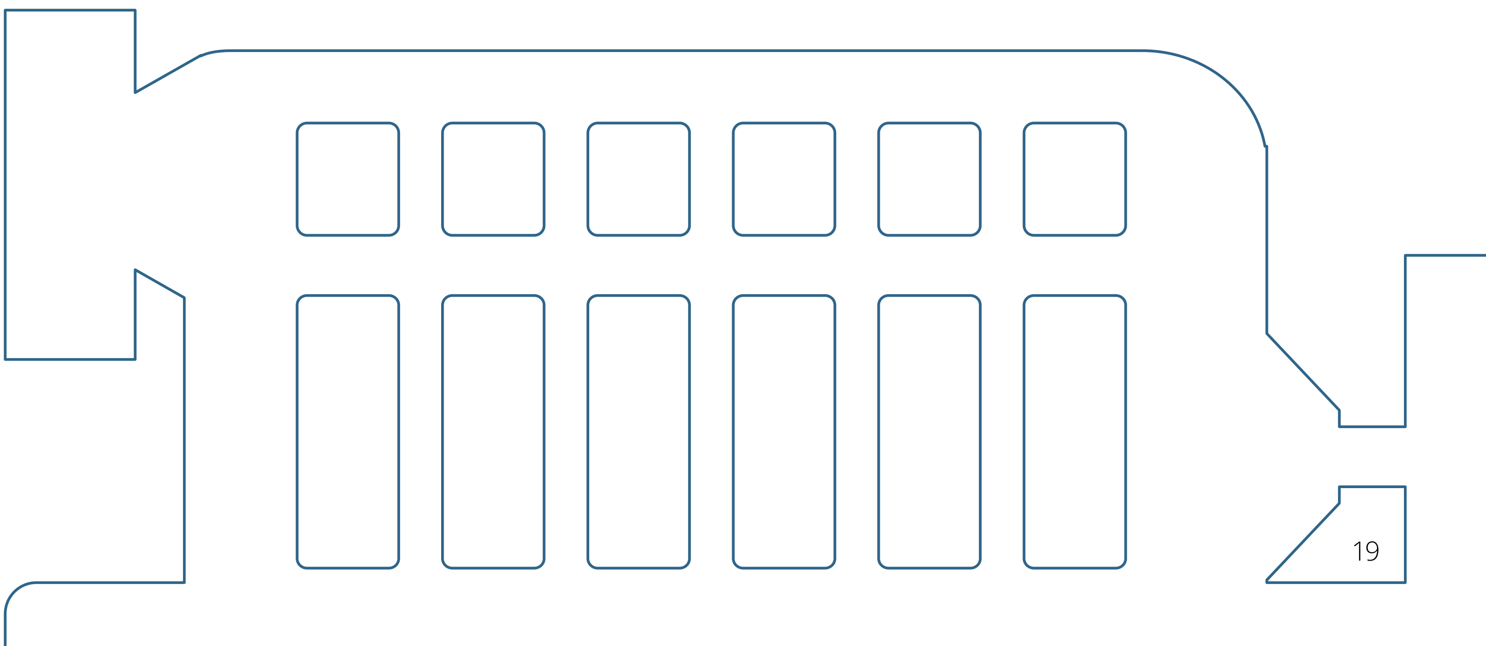
BHFs may also lead to the need of having an ID fan to overcome pressure loss, which is a major complexity.

Swirl to remove heavy soot particles

In some cases, large/heavy soot particles may lead to significant local nuisance, although only constituting a limited fraction of PM emission. They are typically created from small soot particles accumulating as fouling/deposits in the exhaust pathway and then released occasionally at start or soot blowing when disturbed.

If they are larger than 50-100 micron they tend to drop out of the plume and precipitate close to the stack. Such soot particles can be very corrosive and harmful to the local ecosystems and neighboring communities.

Since they are heavy (as opposed to most combustion primary measures) they can be removed by fairly simple cyclone technology without major space requiring equipment (such as ESP or BHF). BWSC has developed a unique version of this technology utilizing the stack itself as a long low intensity axial cyclone, which can be offered where this particular problem occurs.



2.3 $DeNO_x$

Primary measures

Preventing or limiting NO_x formation at combustion level:

- Engine internal measures (injection control, valve timing, etc.
- Fuel measures (limit fuel N content, water emulsion)
- Exhaust gas recirculation (up to 50% reduction)
- Water injection or humidification of combustion air

Secondary measures

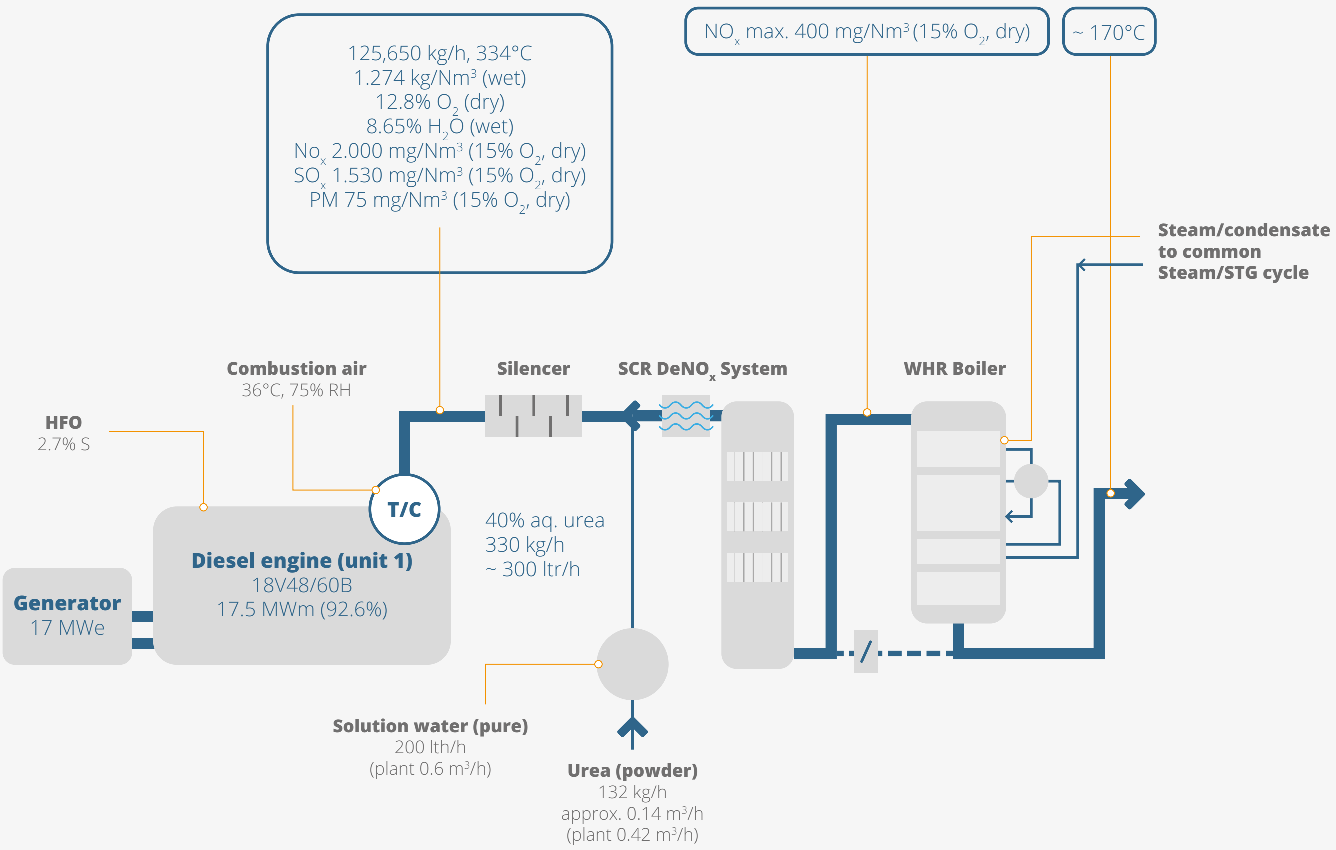
Selective Catalytic Reduction (SCR) system

A SCR system can remove up to 95% of the NO_x emissions by selectively targeting NO_x to remove it from an exhaust stream and convert it to harmless nitrogen (N_2) and water (H_2O). Ammonia or an aqueous urea solution is injected upstream the catalyst chamber through a reactant injection grid.

The SCR unit shall be located before any exhaust gas cooling as it works best at temperatures around 350°C.

This technology is well proven on diesel engines, although a bit more complicated for low speed two-stroke engines than for medium-speed four stroke engines. The systems are easy to maintain and are capable of stable operation.

BWSC TECHNOLOGY: EXAMPLE OF 4-STROKE APPLICATION



2.4 $DeSO_x$ / flue-gas desulfurization (FGD)

Primary measures

Preventing or limiting NO_x formation at combustion level:

- Limit fuel S content

Secondary measures

Capture of SO_x in exhaust gas – 3 different methods are available:

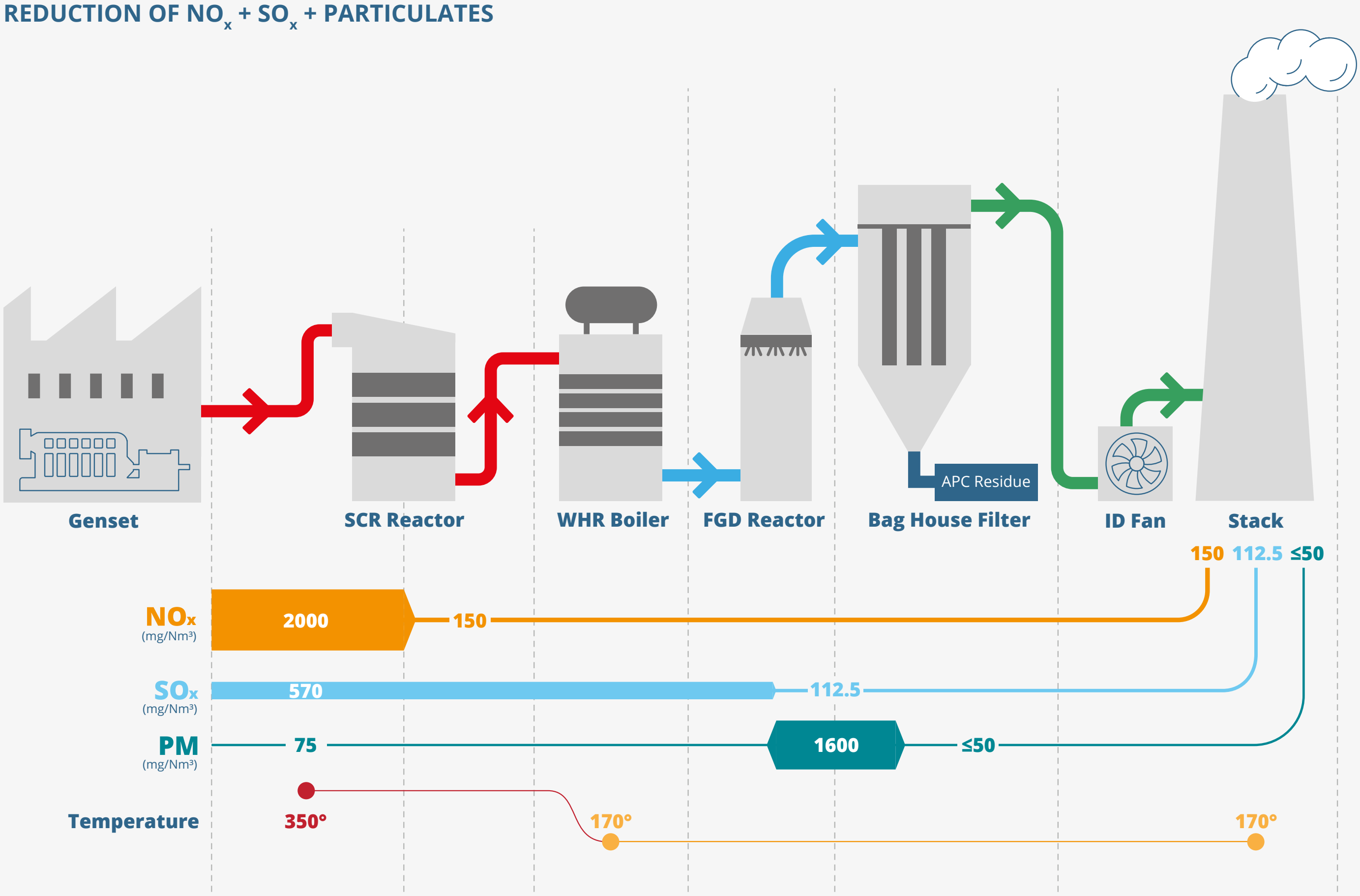
- Wet processes, using a reagent, mostly lime (CaO) or limestone ($CaCO_3$) based, but also NaOH or MgO/$Mg(OH)_2$
- Semi-dry processes. Typical reagents CaO or $Ca(OH)_2$
- Dry processes. Typical reagent Sodium-bi-Carbonate (SBC, $NaHCO_3$)

There are three types of lime that are sometimes wrongly used interchangeably.

- Limestone = $CaCO_3$, the natural mineral broken from quarries
- Activated Lime/Burned Lime or just Lime = CaO, results from heating limestone in kilns, a product from the cement industry
- Hydrated Lime/Slaked Lime = $Ca(OH)_2$, results from slaking (mixing) lime with water

When using semi-dry or dry technologies, it will be necessary to remove reaction products together with combustion soot downstream the $DeSO_x$ process with either ESP or BHF as described earlier.

REDUCTION OF NO_x + SO_x + PARTICULATES



3 Other environmental impacts

3.1 Noise

Regular exposure to high noise levels emanating from power plants affects people working in the plants as well as neighboring communities. Noise can emanate from the engines/powerhouse itself, but also from many other types of equipment and indirectly via exhaust or ventilation openings, etc.

Survey noise and investigate if major noise sources can be reduced – there may be low-hanging fruits that can be addressed with reasonable means to the satisfaction of employees and neighbors.

3.2 Vibration

In some cases, ground borne vibrations typically originating from the engine foundations constitute serious nuisances to neighbors.

Avoiding this is primarily a design issue, but various forms of vibration suppression, passive or active, can be applied on a case-by-case basis. This may involve resonance detuning, resonance tuned oscillators or driven vibration counter balancing.

3.3 Effluent and solid waste

Power plants generally produce some amount of wastewater which can be harmful to the environment.

Power plants' wastewater can be high in heavy metals, due to the process of Flue Gas Desulfurization (FGD).

Wastewater

- Monitor and potentially improve wastewater collection and treatment system
- Settling, floatation, coalescing, filtering, etc. can be necessary to achieve an acceptable effluent standard

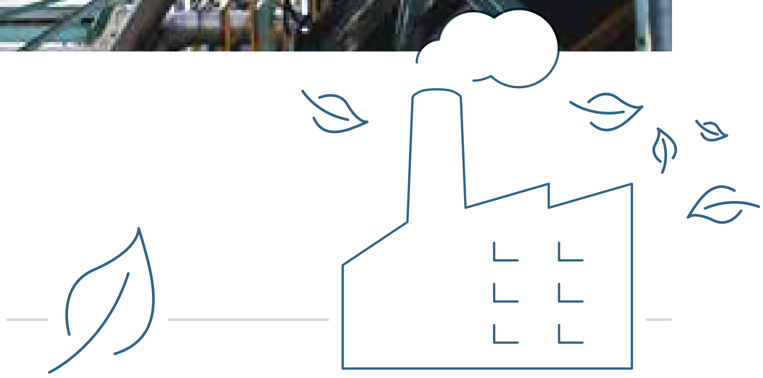
Waste oil, sludge and other hazardous wastes

Ensure a proper handling of waste oil and sludge to protect the environment

- With an on-site incineration facility
- Export to a licensed off-site waste handling utility

4 General recommendations

All the advice we provided in this guide are aimed to reduce the impacts of your facility on the surrounding environment and therefore improve the quality of relations with the neighbor communities.



A well maintained power plant minimizes its environmental impacts and contirbutes to a greener and cleaner future.

On top of that, we recommend that you

- follow the environmental rules of your area and country and always are updated on new environmental regulations coming up
- perform regular environmental surveys to follow up on environmental compliance to identify and address potential problems before they develop further
- implement a system to record and deal with potential external and internal complaints or concerns regarding the facility's nuisance

BWSC

BWSC Headquarters
Gydevang 35, 3450 Allerød, Denmark
P: +45 4814 0022 · bwsc.com

BWSC Panama
La Loceria, Arturo del Valle St,
BWSC Building, N°2, Panama City, Panama
P: +507 388 4478 · bwsc.com

BWSC North America Representation
Houston, Texas, United States
P: +1 832 709 9974 · bwsc.com

BWSC Generation Services UK Ltd.
Unit 3, The Point, Lions Way, Sleaford
Lincolnshire NG34 8GG, United Kingdom
P: +44 (0) 1529 417580 · bwsc.com

About BWSC

Headquartered near Copenhagen, Denmark, BWSC provides specialized consultancy, engineering, installation, operation and maintenance services at power plants and green energy facilities worldwide.

Forty years of experience with energy infrastructure, a diverse staff of seasoned experts, full technology independence and our big-picture approach make us uniquely able to help customers define their ambitions and reach them through expert design and continuous improvement of their facilities.

March 2023