Intended for
Infinite Renewables Group Limited

Date
July 2021

Project Number
1620009679

INFINITE RENEWABLES GROUP LIMITED

ENVIRONMENTAL PERMIT APPLICATION- ROYAL MINT CHP

RAMBOLL

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1. INTRODUCTION

This document has been prepared to support Infinite Renewables Group Limited (“IRGL”) with the application for a bespoke Directly Associated Activity (DAA) Installation Environmental Permit (“EP” or “the permit”) for the operation of a Combined Heat and Power (“CHP”) plant at The Royal Mint site in Llantrisant, Pontyclun, CF72 8YT (“the site”).

1.1 Background

IRGL proposes to install and operate a CHP plant at the Royal Mint site in Llantrisant, South Wales, under a contract to supply electricity to the existing permitted Royal Mint Installation (Permit number EPR/KP3135KV). The CHP requires a DAA Installation permit, as it is identified as a Directly Associated Activity to the Royal Mint Installation, and is also classed as a Medium Combustion Plant and Specified Generator activity. The plant will be permitted with IRGL as the Operator.

An initial screening exercise using the Environment Agency Specified Generator Screening Tool (Air Quality Modelling and Assessment Unit (AQMAU) Specified Generator Tranche B Screening Tool, Version 2.2) resulted in the determination that a complex bespoke environmental permit is required by IRGL as the operator. The unit will require an Environmental Permit as both a Medium Combustion Plant (MCP) and a Specified Generator (SG) in accordance with Schedule 25 of the Environmental Permitting Regulations 2016 (as amended), and the application approach to be taken was discussed and verified with Natural Resources Wales (NRW) (Appendix 1).

2. NON-TECHNICAL SUMMARY

It is proposed that a CHP plant with a rated thermal input of 4.3 MWth is installed in an area of land owned by The Royal Mint adjacent to the north west of the existing Royal Mint Installation in Llantrisant, South Wales, to be operated by IRGL. The site plan is included in Appendix 2.

The unit is intended to produce electricity, under contract, for the sole use of The Royal Mint, at the adjacent Installation. Natural gas shall be provided to IRGL by The Royal Mint. The system will also supply Low Temperature Hot Water (LTHW) for use within the Installation.

The ECOMAX® 20 natural gas cogeneration module has an electrical power output of 2,001 kW, and shall be operational for up to 8760 hours annually. The CHP is required to be permitted as a Medium Combustion Plant and a Specified Generator. It will be fired on natural gas and have a 13 m high stack. The technical specification for the unit is included in Appendix 3.

The proposed unit complies with the Best Available Techniques – Associated Emission Levels (BAT-AELs) for gas-fired engines (see Section 7- 'Application of BAT').

Rhos Tonyrefail Site of Special Scientific (SSSI) is located approximately 100 m north of the proposed stack location. Due to the ecological sensitivity of area, the application would normally be considered a Complex Bespoke Environmental Permit for Medium Combustion Plant, and the application has been structured to address this, including the use of dispersion modelling to determine the impact upon the SSSI.

IRGL has an environmental management system which will incorporate the maintenance of the combustion unit, along with monitoring of emissions of oxides of nitrogen (NOx) on a 3-yearly basis.

3. ENVIRONMENTAL MANAGEMENT SYSTEM

IRGL operates an Environmental Management System (EMS) which identifies the potential risks to the environment as a result of its activity, and ensures that controls are in place to eliminate or minimise these risks.

The EMS includes an Environmental Policy (Appendix 4), signed by the company Director, which highlights specific environmental commitments made by IRGL. Additionally, IRGL has identified, within the policy document, the aspects of its operation of the CHP at The Royal Mint that have the potential to have an impact on the environment. The procedures in place to control these impacts incorporate existing Royal Mint and AB Energy (UK) Ltd environmental control measures, and include maintenance schedules, staff training, and emergency response plans.

The EMS also includes systems for recording and responding to any complaints that may be received, or incidents, should they occur.

4. ENVIRONMENTAL RISK ASSESSMENT

The source-pathway-receptor concept has been used to assess the environmental risk related to the operation of a CHP plant by IRGL at The Royal Mint site, and is based on Natural Resources Wales' EPR H1 Guidance.

The potential sources (environmental risks) of pollution have been identified and screened for their significance, and the potential pathways and receptors are identified.

The following potential risks have been considered:

- any discharge (e.g. sewage or trade effluent to surface water or groundwater);
- accidents;
- odour;
- noise and vibration;
- uncontrolled and unintended ('fugitive') emissions (for which risks include dust, litter, pests; and pollutants that shouldn't be in the discharge); and
- visible emissions (e.g. smoke or visible plumes).

Table 4.1 below shows the consideration of each of these risks to the environment. Where a risk has been considered to not be applicable in terms of its potential impact on the environment a justification has been provided for why the risk is 'screened out'.

The risks which have been identified as applicable have been included in the risk assessment in Table 4.4.

Table 4.1: Screening of Environmental Risks

Environmental Risk	Applicability	Justification
Controlled discharges to surface waters	Not Applicable	There are no controlled discharges to surface water from the Facility. This risk has not been considered for further assessment.
Controlled discharges to Groundwater	Not Applicable	There are no controlled discharges to groundwater from the Facility. This risk has not been considered for further assessment.
Accidents	Applicable	Plant or Equipment Failure: The failure of plant or equipment may result in an incident occurring which could potentially impact on the environment. Materials Handling: Raw materials and wastes will be handled during maintenance of the plant. There is the potential for accidents (e.g. spills, leaks etc.) to occur during use of these materials. Vandalism: The Facility is located in a relatively remote rural area and may be a target for vandalism and theft. Operator Error: Whilst the majority of the processing plant is automated, the potential for operator error cannot be ruled out.
Odour	Applicable	There will be no operations at the site which have the potential to release odour. This risk has not been considered for further assessment.

Environmental Risk	Applicability	Justification
Noise & Vibration	Applicable	Operation, or breakdown, of the CHP has the potential to produce noise.
Visual Impact	Not Applicable	The CHP is to be positioned in a disused carpark, which is surrounded on four sides by trees and vegetation, and on the fourth side by The Royal Mint Installation. Visible emissions from the plant are limited to the permitted release from one stack. These emissions are not considered to be significant in terms of visual impact. Visual impact has not been considered to be significant and has not been included for further assessment.
Fugitive Emissions to air and water	Not Applicable	Surface Water: There is no storage of potentially polluting substances on site that could result in spills or releases to water. Storm water discharges: The site covers a small area, and there will be no storage of potentially polluting substances at the location. Dust: The planned operations to not give arise to the potential for the generation of dust.
Controlled releases to air	Applicable	Air emissions comprise combustion products from the CHP plant.
Global Warming Potential	Applicable	Direct greenhouse gas emissions arise from the burning of gas by the CHP. Indirect emissions arise through the supply and maintenance processes.
Facility Waste	Applicable	Hazardous and non-hazardous wastes are produced at the Facility as a result of the production processes, maintenance and administrative functions.

A receptor is defined as something that could be adversely affected by a pollutant. Based on the risks identified in Table 4.1, the following relevant receptors have been identified:

Atmosphere:

Air emissions comprise combustion products from the CHP plant; Located across the entirety of the site and in the immediate vicinity of the site.

Designated Ecological Sites:

There are three designated Sites of Special Scientific Interest (SSSIs) located within a 5 km radius of the site. The nearest is the Rhos Tonyrefail SSSI, located from approximately 100 m north of the proposed stack location. Llantrisant Common and Pastures SSSI is located from approximately 0.75 km south east, and Nant Gelliwion Woodland SSSI from approximately 4 km north east. All three sites have been designated for biological interest.

Human Occupation:

Facility workers and visitors are present at the Royal Mint Installation adjacent to the east, and at the factory located from approximately 90 m south. Additionally, a public footpath passes the eastern site boundary.

The risk assessment provides a simple representation of the hypothesised relationships between contaminants, pathways and receptors. This allows the identification of potential contamination

linkages and, therefore, an interpretation of the potential for pollution to occur at the Facility or within the vicinity of the site as a result of the activities at the Facility.

The potential for pollution to occur at the site is determined by assessing the likelihood of an identified receptor being exposed to pollution emanating from a source at the Facility and the resultant consequences of any such exposure. In determining the likelihood and the consequence of a pollution exposure the risk management techniques which are used at the Facility, and the effect on any such exposure are considered. Where the risk management techniques are considered to have a mitigating impact, the resultant overall likelihood of the pollution exposure occurring and its consequences on a receptor are lowered.

Within the risk assessment, each hypothesised relationship between contaminants, pathways and receptors is assessed to determine the likelihood of the receptor being exposed to pollution and the consequences of exposure using the rankings listed in the tables below.

Table 4.2: Likelihood Rankings

Very Low	Low	Medium	High
Exposure to pollution is considered to be *highly unlikely*.	Exposure is considered to be *unlikely*.	Exposure is considered to be *likely*.	Exposure is considered to be *highly likely* to occur.

Table 4.3: Consequence Rankings

Very Low	Low	Medium	High
No impact or imperceptible impact on the receptor.	Low level impact easily and quickly mitigated or may not require any intervention to rectify any impact.	Moderate impact which will not be rectified without some mitigation / intervention.	High impact requiring significant intervention / mitigation and may have caused irreparable damage to the receptor.

4.1 Assessment of Risk

Following the determination of the likelihood and consequence rankings for the hypothesised relationships developed using the source-pathway-receptor concept, the matrix in the table below is used to determine the overall risk of the pollution exposure occurring. This matrix has then been used to assess the level of risk to the environment from the operation of the proposed CHP, as presented in Table 4.4.

Table 4.3 Risk Matrix

		Likelihood			
		Very Low	Low	Medium	High
Consequence	High	Low	Medium	High	High
	Medium	Low	Medium	Medium	High
	Low	Low	Low	Medium	Medium
	Very Low	Very Low	Low	Low	Low

Table 4.4: Environmental Risk Assessment

	Source-Pathway-Receptor Hypothetical Model			*Risk Management Techniques*	*Assessing the Risk*		
	Source of Pollution	Receptor	Pathway		Likelihood of Exposure	Consequence of Exposure	Overall Risk
NOISE AND VIBRATION	*Noise and vibration:* arising from the operation the plant	*Humans including:* Facility workers/visitors; workers on adjacent premises; local residents; intermittent presence on pedestrian routes / roadways surrounding the site; SSSI	Through the air and ground vibration	• The engine of the CHP includes an exhaust gas silencer, designed to comply with the required residual noise level. • The design of the CHP includes Rockwool panels covered by perforated steel sheets to form the walls and ceiling of the ECOMAX® housing unit. This noise dampening insulation is specifically designed to achieve the required residual noise level. The technical specification for the unit is provided in Appendix 3. • The plant is to be maintained in accordance with manufacturers' specifications and managed through a Planned Preventative Maintenance schedule to minimise excessive noise from poor performance, as detailed in the AB Preventative and Corrective Maintenance	Low	Low	Low

				Plan Service Offer (Appendix 6). • The CHP is to located in a relatively remote location. The nearest sensitive human receptors are located at least 80 m from the plant, beyond a copse. Rhos Tonyrefail Site of Special Scientific (SSSI) is located approximately 100 m north of the proposed stack location.			
	Noise and Vibration: arising from the breakdown of plant equipment			• All plant is maintained periodically in accordance with manufacturers' specifications to minimise excessive noise from poor performance.	Low	Low	Low
ACCIDENTS	*Accident:* Spillage of maintenance oils during maintenance procedures	Ground, surface water	Over site surfaces	• There is to be no bulk storage of any substance at the site. • The CHP container works as a tank and completely contains the fluids present in the engine. The CHP housing is designed to provide secondary containment in the event of an oil or coolant leak. There are minimum pressure switches that block the motor and fluid circulation when activated for any reason.	Low	Low	Low

	Accidents (Fire): Fire and arson attacks	Ground, surface water, atmosphere	Over site surfaces	• The plant has an *Emergencies and Fire Detection Safety System* which comprises safety devices and functions that are automatically enabled (sensors) or on request (emergency and fire buttons), in order to reduce risk in emergency situations and/or in the event of fire.	Low	Low	Low
CONTROLLED RELEASES TO AIR	*Controlled Releases to Air:* CHP Stack Emissions	Atmosphere; humans including: Facility workers/visitors; workers on adjacent premises; local residents; intermittent presence on pedestrian routes / roadways surrounding the site; SSSI	Through the air	• Catalyst system applied to flue gas to abate carbon monoxide and unburnt hydrocarbons • NO_X emissions from the plant are guaranteed to be <95 mg/Nm^3 (see technical specification, Appendix 5). • Emissions from the CHP are to be permitted and monitored as required by the permit. • The CHP is to be maintained under contract by AB Energy (UK) Ltd to ensure effective operation. • An Air Quality Assessment (see Appendix 7) carried out to determine the impact of emissions on local sensitive receptors concluded that it was considered that impacts on	High	Low	Medium

				all receptors identified would likely be insignificant.			
GLOBAL WARMING POTENTIAL	*Global Warming Potential:* Combustion of natural gas within CHP unit resulting in direct emissions of greenhouse gasses	*Atmosphere*	Through the air	• The CHP to be installed is a modern unit with optimum efficiency.	Medium	Very Low	Low
WASTES	*Wastes:* Wastes arising from maintenance activities, including waste oils, containers and spark plugs	Ground, surface water	Over site and surrounding surfaces	• Wastes only generated during maintenance activities – to be removed by contractor on completion of scheduled maintenance	Low	Low	Low

The above risk assessment has demonstrated that, with the appropriate management controls in place, the environmental risks identified are acceptable, i.e. low to medium. The risks identified in relation to emissions to air are assessed quantitatively with the detailed report provided in Appendix 7.

5. RESOURCE EFFICIENCY

5.1 Raw Materials

The only raw materials to be consumed during the operation of the CHP will be the combustion of natural gas, and the oils and spark plugs to be used for maintenance of the plant, at intervals specified by the manufacturer to maintain optimum operating efficiency. The intervals for replacement of consumable parts are specified in the *AB Preventative and Corrective Maintenance Plan* (Appendix 6).

5.2 Waste

The plant will produce a limited annual amount of waste from consumables discarded from air and oil filter changes, and spark plugs. According to the maintenance schedule (Appendix 6), the former should be replaced every 3,000 h, oil filters every 1,500 h and spark plugs every 1,500 h. The expected production of solid waste is less than 1 tonne a year, and will be disposed of by the maintenance contractor.

5.3 Energy Efficiency

The CHP unit is to be installed to improve energy efficiency at the adjacent Royal Mint Installation, delivering both electricity and hot water for use at the installation. A modern, energy efficient piece of equipment has been selected, which will be maintained and serviced under a contract with AB Energy (UK) Ltd (Appendix 6), and in accordance with the manufacturer, to optimise the efficiency and lifetime of the plant. Additionally, the CHP is to be operated continuously, and so will be running at maximum efficiency.

6. MONITORING

Emissions from the CHP stack will be monitored in accordance with conditions of the environmental permit. Emissions of oxides of nitrogen (NOx) will be monitored at a minimum of a 3-yearly basis to meet the requirements of the Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants (Medium Combustion Plant Directive) and to ensure compliance with the Best Available Techniques – Associated Emission Levels (BAT-AELs) for gas-fired engines.

Two standardised nozzles will be mounted on the exhaust gas line to allow for monitoring of emissions to air.

Monitoring methods shall be undertaken by MCERTS-certified methods and contractors. It is proposed that the monitoring comply with the requirements of “Monitoring stack emissions: low risk MCPs and specified generators” guidance as set out on GOV.uk, as the monitoring will be required for gas concentrations only.

7. APPLICATION OF BAT

The following section of this report sets out a summary of Best Available Techniques applicable to the operation of medium combustion plant as a Directly Associated Activity to a Part A(1) installation.

7.1 Emission Limit Values

The emission limit values for new medium combustion plant are set out in Annex II, Part 2 of Directive (EU) 2015/2193.

There is only one relevant emission limit value for the CHP (natural gas engine) set out under Directive (EU) 2015/2193, which relates to NO_X and is set at 95 mg/Nm^3 at a temperature of 273,15 K, a pressure of 101,3 kPa and after correction for the water vapour content of the waste gases and at a standardised O_2 content of 15% for medium combustion plant (engines).

According to the manufacturer's specification the emissions of NO_x from the boilers are guaranteed to below the 95 mg/Nm^3 limit.

7.2 BAT for Steam Systems

The following BAT has been identified as relevant to the proposed combustion activities from the Energy Efficiency BRef.

Operating and Control

BAT is to use operating procedures and controls (including sequential controls for more than one steam generator) and install flue-gas isolation dampers.

Not applicable- Dampers are only present for a boiler; the exhaust gas will go straight from the engine to the chimney via the (LTHW system) to be released to air.

Generation

BAT is to Preheat feedwater by using waste heat (e.g. from a process), economisers using combustion air, deaerated feedwater to heat condensate, and condensing the steam used for stripping and heating the feed water to the deaerator via a heat exchanger.

Not applicable – heat from the generation process shall be used in the LTHW system as part of the CHP process, optimising the use of waste heat.

BAT is to prevent and remove scale deposits on heat transfer surfaces.

No scale deposits are expected in the solution. The water used in the engine circuit is pre-treated. Water shall only be used in the circuit connected to the heat exchanger if it meets the required quality.

BAT is to minimise boiler blowdown by improving water treatment. Install automatic total dissolved solids control.

No blowdown is required on the primary circuit.

BAT is to optimise deaerator vent rate.

Not applicable - Steam generation/Deareator not present in the solution required.

BAT is to minimise boiler short cycling losses.

Not applicable.

BAT is to carry out boiler/CHP maintenance.

The CHP will undergo a series of pre-commissioning and commissioning safety and operational checks. Following commissioning, plant will be maintained on a preventative maintenance schedule in accordance with the manufacturer's recommendations.

Distribution

BAT is to isolate steam from unused lines.

Not applicable.

BAT is to insulate LTHW and condensate return pipes (ensuring that LTHW system piping, valves, fittings and vessels are well insulated).

The LTHW system, including the LTHW generator, will be insulated so far as practicable.

BAT is to implement a control and repair programme for steam traps.

Not applicable.

Recovery

BAT is to collect and return condensate to the boiler for re-use.

Not applicable- no condensate is generated as the system provides LTHW, not steam.

BAT for Electric Motor Driven Sub-Systems

The following BAT has been identified as relevant to the proposed combustion activities from the Energy Efficiency BRef.

System Installation

BAT is to optimise electric motors.

Electric motors will be used in the feedwater supply systems for the LTHW system. Where appropriate these will be variable speed drive pumps or controlled by the master sequence control panel to ensure that they are only operational for the shortest duration required.

APPENDIX 1
CORRESPONDENCE WITH NRW

From: Kemp, Andi <Andi.Kemp@cyfoethnaturiolcymru.gov.uk>
Sent: 19 August 2020 14:13
To: Richard Wood <RAWOOD@ramboll.com>; Lucy Cleverley <lcleverley@ramboll.com>; Martyn Grant <Martyn.Grant@royalmint.com>
Subject: CHP Unit

Good morning,

I have further conversations with my Technical Specialist and Combustion Sector lead and felt I needed to feedback some additional information, with regard to the intended CHP application and associated impact on TRM permit.

While nothing fundamental has changed in terms of how many permits, variations and SCR, the application should be:

- For an installation DAA permit not explicitly for an MCPD – standalone MCPs would be the threshold sized combustion units on non EPR sites (hospitals etc.) or on below threshold EPR sites (smaller breweries etc.); for combustion units on installations, we have DAA installation permit – probably with similar or more stringent BAT conditions
- This means Chapter II of IED and BAT would apply – BAT doesn't apply to MCPs
- MCPs have minimum standards, but BAT may require more, e.g. additional NOx reduction
- Habitats will still be dealt with, essentially applying the screening distance and simple / complex scenarios you would apply for an MCP
- According to RGN2 App. 1 & 2, an MCP type unit, with a technical connection (and other limb tests) to an existing STU installation, means the MCP becomes part of the installation and so not an MCP permit
- So there will be a "green" site boundary around the CHP permit footprint and an SCR for that and TRM "green" permit boundary stays the same, but the wider "red" installation boundary line, extends to encompass the CHP
- Both permits will have the relevant conditions in or varied in to account for technical connections, notifications and other aspects when you have two permits for one installation and a relationship and connection to each other – this should be no more than a minor technical variation for TRM, possibly an administrative one

Regards,

Andi Kemp BSc MRSC
Uwch-Swyddog Rheoliad Diwydiant / Senior Officer – Industry Regulation

Rheoliad Diwydiant De Canolog / South Central Industry Regulation

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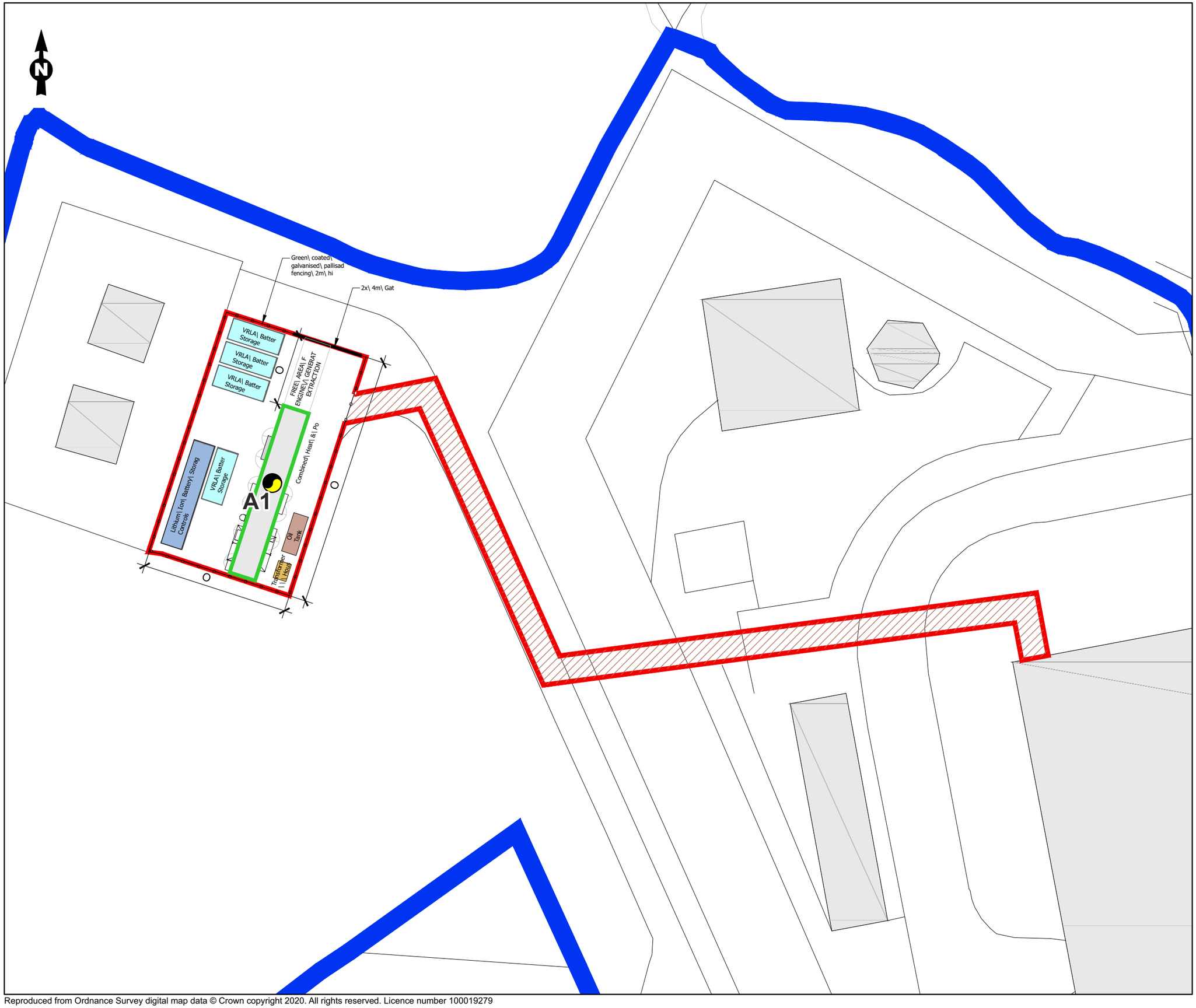
Ein diben yw sicrhau bod adnoddau naturiol Cymru yn cael eu cynnal, eu gwella a'u defnyddio yn gynaliadwy, yn awr ac yn y dyfodol.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, enhanced and used, now and in the future.

APPENDIX 2
SITE PLAN



Legend

- IRGL Operational Area
- Land with Applicants Ownership
- CHP Activity Boundary
- A1 Air Emission Point

Figure Title
CHP Activity Boundary

Project Name
IRGL CHP at The Royal Mint

Project Number	Figure No.
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Scale	**Issue**
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Client
Infinite Renewables

RAMBOLL

APPENDIX 3
TECHNICAL SPECIFICATION- ECOMAX 20

ROYAL MINT

ECOMAX® 20
NATURAL GAS

TECHNICAL DESCRIPTION OF ECOMAX® 20 NATURAL GAS MODULAR OUTDOOR SOLUTION FOR:

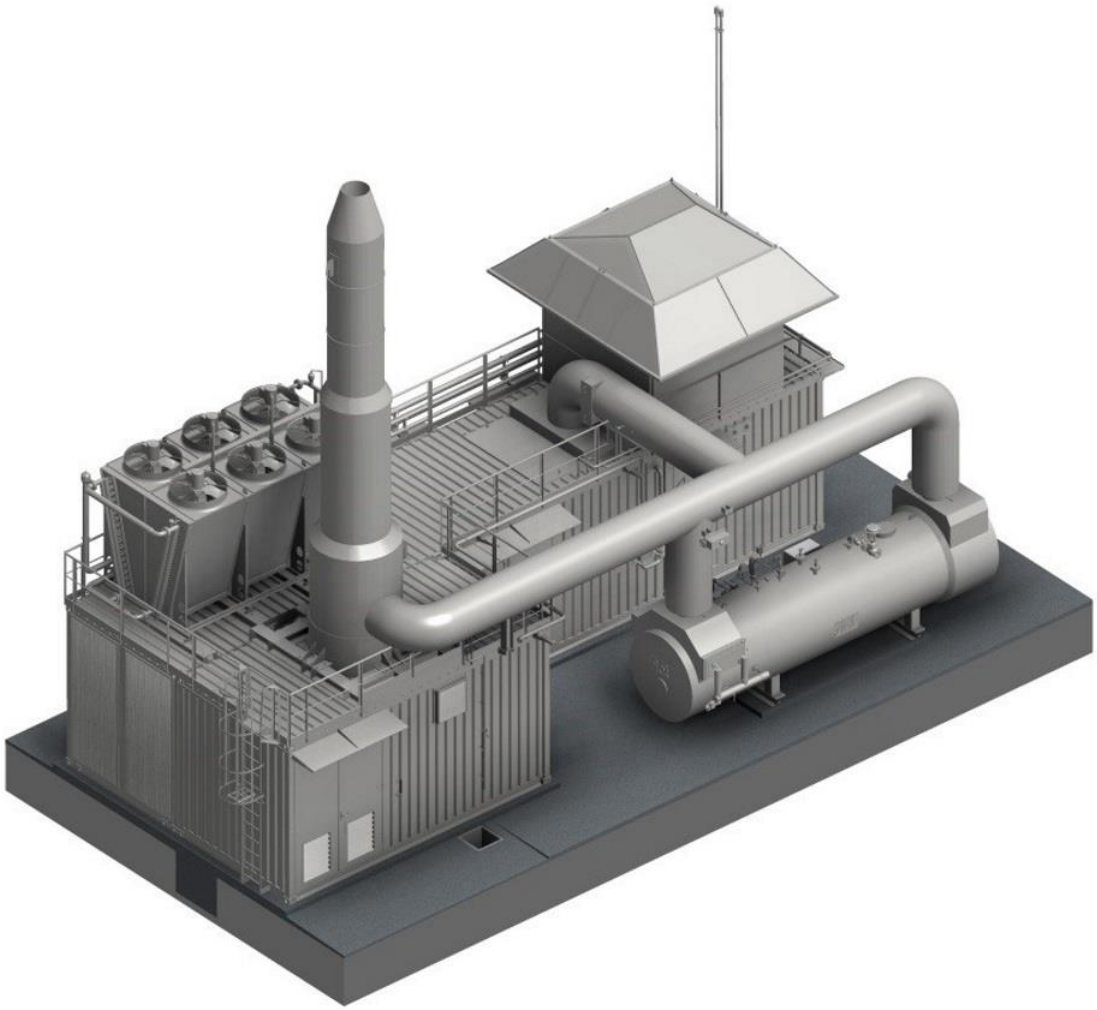
ROYAL MINT

Offer: QUO-07412-T3C2T0
Rev. 0.0

ECOMAX® 20 NATURAL GAS

Thirty years of experience go into every AB engineering decision for the ECOMAX® product line, making it a world leader in the field of distributed generation. A compact and modular design, high energy efficiency, and high system reliability are key advantages of ECOMAX® systems.

This technical description describes the ECOMAX® 20 Natural gas cogeneration module with an electrical power output of 2.001 kW, complete with balance of plant equipment and auxiliary systems, outlined by the conditions in the Commercial Offer (included in this document).



1 STANDARD REFERENCE CONDITIONS

Outdoor temperature	25 °C
Design pressure	1 bar or 100 m a.s.l.
Relative humidity	30 %
Maximum operating external temperature	35 °C
Minimum operating external temperature	-15 °C

2 PERFORMANCE

The engine is subject to derating depending on temperature according to the manufacturer's specifications:

Electrical output (gross of auxiliary)	2.001 kW
Residual noise level in free field without acoustic reflex (according to the standard reference conditions)	65 dB(A) @ 10 m
Island mode operation	Not available
B.O. Start mode operation	Not available

3 EXHAUST EMISSIONS

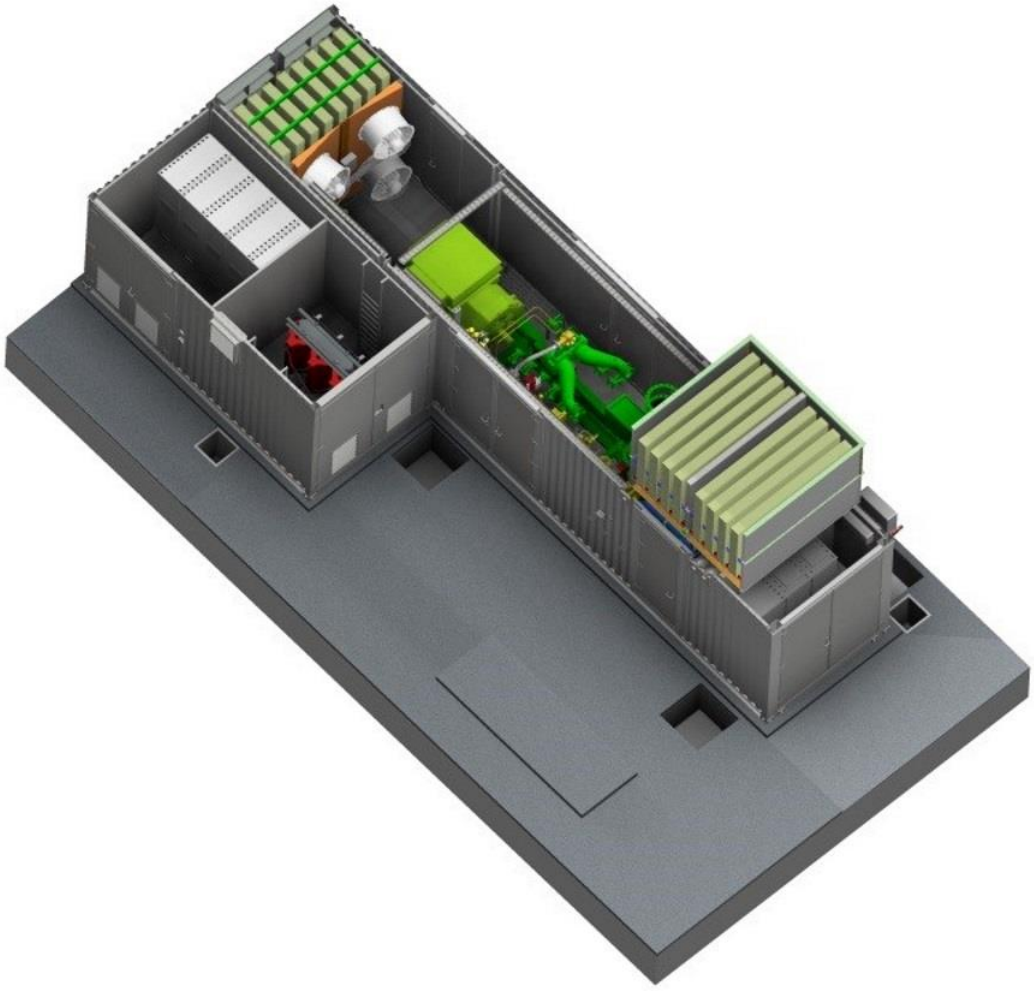
Atmospheric emissions of co-generator are:

NOx (reported at 5% O_2)	250 mg/Nm³
CO (reported at 5% O_2)	300 mg/Nm³
Exhaust stack height (measured from ground level)	13 m

4 ECOMAX® MODULE

EFFICIENCY AND RELIABILITY

In order to achieve the best possible return on investment, a cogeneration plant has to reliably perform at maximum efficiency. While focusing on high quality and cost-effective technologies, AB is able to offer project-specific innovative solutions to meet the customer's needs. The choices made during the design process are able to prevent performance issues and reduce equipment downtime, therefore also reducing the need for maintenance. AB applies this attention to technical detail to the entire CHP plant, including the purpose-built enclosure, the manufacturing process, equipment and component selection, and other plant design details. The end result is a state of the art cogeneration plant that delivers maximum performance and reliability.



4.1 GALVANIZED CARBON STEEL CASING

The cogeneration system is housed in purpose-built enclosures which are designed for outdoor installation. The enclosures are made of carbon steel and equipped with a high strength frame to support the generator set. Among the main construction characteristics are:

- walls and a roof made with externally galvanized corrugated metal layers;
- corner lifting points for crane use;
- doors throughout the plant to enable easy access for maintenance operations;
- manufacturing according to a high precision AB engineering and production process.

4.2 NOISE INSULATION

Rock wool panels covered by perforated steel sheets form the walls and ceiling of the ECOMAX® housing unit. This noise dampening insulation is specifically designed to achieve the required residual noise level.

4.3 VENTILATION SYSTEM

The superior quality of ECOMAX® systems is also reflected in the ventilation system, which is designed in order to ensure the performance of the engine and its continuous operation throughout a wide range of ambient conditions.

Inlet air system, equipped with:

- galvanized steel, weatherproof louvres;
- replaceable air filters;
- sound insulating baffles;
- VFD controlled blade fans.

Outlet air systems, equipped with:

- galvanized steel, weatherproof louvres;
- modulating air dampers;
- sound insulating baffles.

4.4 PAINTWORK

The external paint guarantees a high standard of durability and resistance to extreme weather conditions for the ECOMAX® module. The design has been laboratory tested and has proven to be resistant to salt spray corrosion (ISO 9227) for a duration greater than 1,000 hours. The painting process for external components includes the following:

- surface preparation and washing;
- a primer coating suitable for galvanized surfaces;
- a rustproof epoxy layer;
- two polyurethane enamel layers, RAL 7035.

Visible internal surfaces are painted with a primer layer and a polyurethane enamel layer on visible parts, RAL color 7035.

4.5 MAIN THERMAL CIRCUITS

To ensure the reliability and functionality of the thermal recovery and dissipation circuits, AB uses carefully dimensioned, seamless steel piping. This applies to the following connecting piping:

- connection piping on jacket water circuit up to plate heat exchanger and up to edge package flanges;
- connection piping on jacket water circuit up to its own emergency dry cooler;
- connection piping on after cooler circuit up to its own emergency dry cooler;

4.6 PLATE HEAT EXCHANGER

A decoupling plate heat exchanger is placed on the module's hot water recovery circuit (HT). The technical characteristics are to be decided during the executive design.

4.7 THERMAL INSULATION

To support superior performance, avoid spills, and protect operators from potential accidents, the supply will include the realization of the thermal insulation. The insulation density and thickness, as well as the outer surface coating, are to be defined according to the specific configuration of the plant and to the type of circuit to be insulated. Insulation for the following components is included:

- thermal recovery circuits (hot water and steam);
- the exhaust gas piping;
- the oxidation catalyst.

4.8 COMPONENT DOCKING

In order to ensure a robust and long-lasting assembly, all components placed on the roof of the ECOMAX® are held in place by galvanized steel support structures. These supports are prefabricated at the AB factory.

4.9 EXHAUST GAS PIPING

The ECOMAX® is supplied with piping to connect the engine to the installed exhaust system components. This exhaust gas piping is sized to accommodate the exhaust gas flow rate and pressure losses. Expansion joints which are necessary to absorb thermal expansion caused by high temperatures, or other factors, are included. A sampling point and condensate drain system are also provided. The exhaust gas piping terminates at the exhaust stack, with an outlet height as indicated in the exhaust parameters (section 3).

4.10 EXHAUST GAS SILENCER

To reduce the acoustic emissions of the engine, it is supply and installed on exhaust gas circuit, a top quality exhaust gas silencer, made of stainless steel welded cylinders and shell, designed to comply with the required residual noise level.

PRACTICALITY AND SAFETY

The ECOMAX® product line has taken engineered CHP systems to the next level. It reduces the footprint needed while housing all internal components in a manner which facilitates maintenance activities thanks to amply dimensioned doors placed on the enclosure. AB has given special attention to safety and security as well; each ECOMAX® contains proven and reliable devices and systems that guarantee safe operation in all working conditions.

4.11 MODULE-INTEGRATED SAFETY

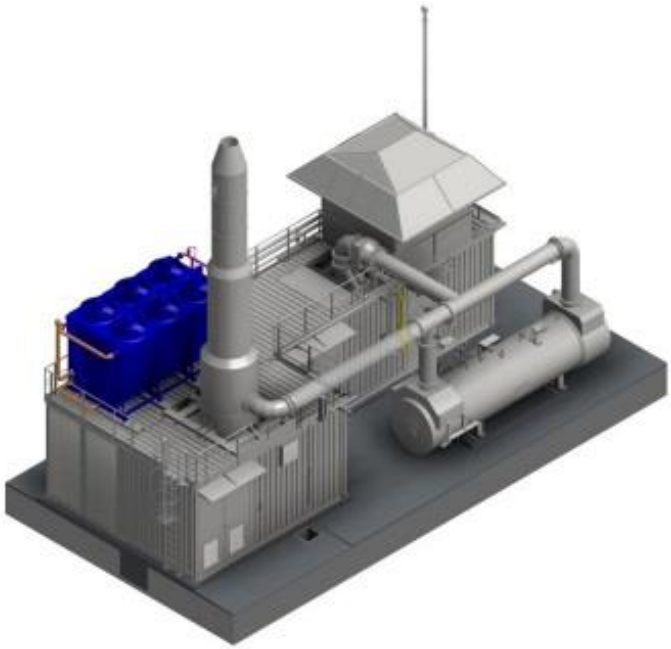
The enclosure's constructive characteristics include a series of solutions to protect the plant's personnel. These features include a galvanized steel railing along the perimeter of the roof, a caged ladder for roof access, and a floor designed to hold accidental oil spillage.

4.12 SMOKE AND GAS DETECTION SYSTEM

The module is equipped with smoke and gas detectors, installed inside the ECOMAX® module. The system consists spot-type smoke sensors, one gas sensor inside the engine room near the gas train, and an electronic detection and alarm unit. The smoke and gas detection system is only for engine use.

4.13 EMERGENCY DRY COOLER

An emergency dry cooler will be installed on the roof of the unit. The exact technical specifications of this component will be determined during the executive design phase to ensure optimal performance.



4.14 ANTI-EXPLOSION SERVO ACTUATED VALVE

To ensure maximum security, AB provides nr. 02 automatic detection valve on the gas train, certified according to ATEX regulations.

4.15 NATURAL GAS COMPRESSION SYSTEM

The natural gas supply available has a pressure minor than the pressure required to feed the engine's pre-chambers. So we provide nr. 01 natural gas compression system to feed the engine pre-chambers, sized only for pre-chambers feeding purpose. Features:

Compression system, oil-free type, explosion-proof for area 2 class 2 G and temperature class T4, ATEX certified, designed for dry natural gas compression.

The system is manufactured according to EC directives, according to standard EN 1012-1 and VDE and 97 / 23 EG - 98 / 37 / EG - 89 / 336 / EG - 87 / 404 / EG - 73 / 23 / EG, also in compliance with DIN EN and ATEX.

Technical data will be set out on executive design. Suitable soundproof housing for the compression system is included, designed to achieve the required residual noise level. Necessary electrical connection included.

CONTROL AND MANAGEMENT

To ensure complete, precise, and continuous management and control of the plant and all its performance parameters, AB Engineering has designed an integrated system, which can be used remotely, that allows for the monitoring of elements essential to operations. All components on the command and control system are directly installed by AB technicians and are part of the commitment to quality which distinguishes ECOMAX® systems from the rest of the market. The control panels, placed in a specially designed, air-conditioned room inside the module, provide a responsive and user-friendly interface for the service staff.

4.16 UNIT CONTROL PANEL

The automatic auxiliary control system, developed by AB, manages the ECOMAX® unit's basic functions and its interface with the main power grid. The system acquires all analogue and digital signals coming from the engine and is responsible for the control and management of the plant auxiliaries. Signals relating to the principal safety systems are controlled by hardwired logic.

The system acquires measurements from the ECOMAX® unit directly. The main parameters which are made available and processed by our monitoring system are the following:

- generator circuit breaker status;
- engine cooling water temperature and pressure;
- lube oil temperature and pressure;
- exhaust gas average temperature inside cylinders;
- return water temperature;
- exhaust gas temperature from each cylinder;
- number of starts;
- mixture intercooler temperature;
- engine and generator rpm;
- generator power factor;
- generator frequency;
- average generator current;
- average generator line voltage and line to neutral voltage;
- active, reactive and apparent generator power;

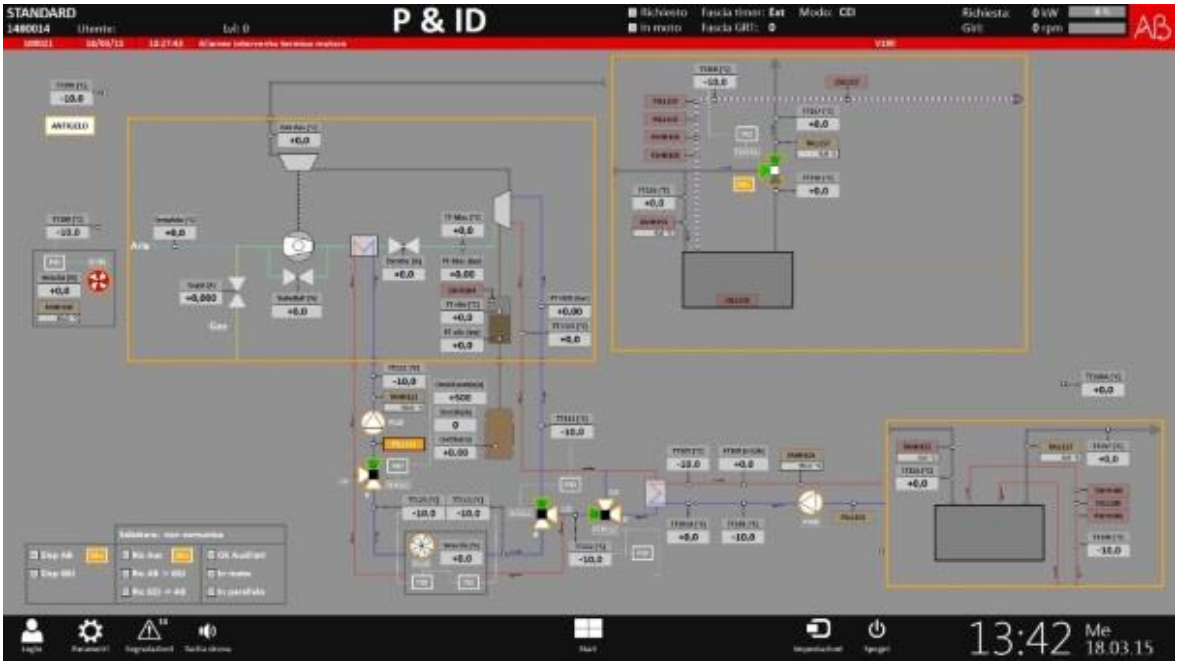
The above parameters will be processed, recorded, and displayed by the monitoring system. Through the monitoring PC, it will be possible to set operating parameters and to acquire data to be displayed. The panel will be equipped with variable speed drive units to control the fans for both the ventilation and the dry coolers. The system will also be fitted with electronic synchronization equipment, in order to automatically enter parallel operation with the electrical grid.

Supply and installation of nr.01 gateway, for the communication between Ecomax® and the plant network, is included.

4.17 SCADA SUPERVISION SYSTEM

The architecture in the automation system found in the ECOMAX® has been designed to ensure the integration of components and the security of performance. During the development of the SCADA system, it has been a fundamental consideration to provide the following:

- easy control and adjustment operations;
- clear and simple reading of alarms;
- separation of circuit equipment and different systems to prevent operating and/or reading errors;
- easy interventions for maintenance and component replacement.



The electric network monitoring system will also perform the following functions:

- local and remote command management;
- functional calculations;
- regulation of operational parameters;
- electrical network monitoring;
- automatic diagnosis of system data.

4.17.1 Supervision

The plant supervision system is based on the Siemens WinCC SCADA software, a platform with which AB Impianti has extensive experience in automation applications. This choice is derived from the adoption of Windows as the standard for automation systems and the need to use a Windows compatible platform; it has enabled AB to provide effective technical support, both on-site and remotely.

The design of the automation system monitoring the ECOMAX® ensures that all components are integrated and safely operating in unison. The supervision system is designed considering the following fundamental functions:

- display of plant performance;
- execution of operator commands;
- clear and simple reading of alarms;
- display of data trends.

The software system will provide all functions in a simple and continuous format for the operator. The software has been designed in a way to guarantee a high level of reliability and availability. The system is flexible to allow for expansions and future updates. It is possible to connect to the system through the internet for remote monitoring, using security provided by a firewall.

4.17.2 Graphics Pages

Care is given to the design of the graphics pages so that data and information is presented in a clear and logical manner to the operator. Each page will consist of a graphical window showing a P&ID or single line diagram to represent the specific mechanical or electrical system. An overview page is included to provide a summary of the entire cogeneration system. Each metric will have a historical graph which will allow for the review of past and present performance. The detailed pages for each subsystem will display metrics for individual pieces of equipment, including the desired setpoint, the actual operating point, and any present alarm or shutdown conditions. An alarm log will be available to give a visual record of past alarm and shutdown conditions with a date and time stamp. Alarm and shutdown conditions will be prominently displayed and will remain active until acknowledged by the operator.

4.17.3 PROFINET/Profibus network

The Profinet network will connect control systems, group management, the auxiliary PLC, and other necessary components using the Profibus protocol. The communications system will allow net information checks where alteration to information in transit should be avoided.

4.18 GENERATOR BREAKER PANEL

The generator breaker panel will be placed next to the engine control panel and, contain the generator circuit breaker with electronic protection, opening and closing coils, an under voltage coil, and a motor to the charge the dosing springs. Connections between the generator and the generator breaker panel are provided.

4.19 OPERATION AND MAINTENANCE MANUAL

The operation and maintenance manual is intended to provide guidelines for basic maintenance procedures for the ECOMAX®. The manual is divided into chapters, each having a different topic. It gives information on the operation and maintenance of the product over the lifetime of the system, while considering the following:

- the proper application of standards,
- efficacy in communicating content according to the need, the sector of operation, and operator qualification.

5 ECOMAX® ACCESSORIES

ENVIRONMENTALLY FRIENDLY TECHNOLOGY

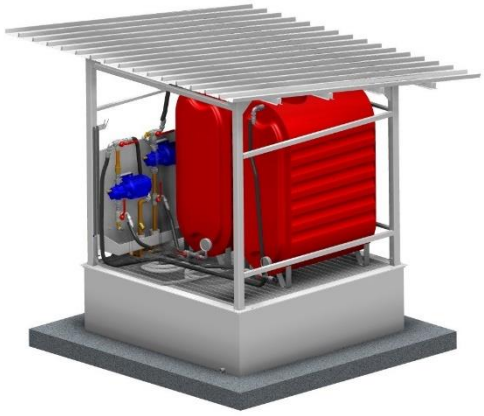
Cogeneration is globally recognized as an application that can contribute significantly to reducing emissions into the atmosphere through energy efficiency and a reduction in overall energy consumption. AB's attention to this aspect has always been a driving factor in its mission and it is what its plant design, scrupulously oriented towards maximizing energy efficiency and minimizing emissions, is derived from. When it comes to pollution reduction, ECOMAX® systems make use of a range of technologies to meet relevant regulations.

5.1 OXIDATION CATALYST

The oxidation catalyst is designed according to the engine data in order to reduce emissions to the indicated levels. The oxidation catalyst housing is made of stainless steel, complete with a removable panel for cartridge changes. Inspection points are available to measure the pressure drop.

5.2 LUBE OIL SYSTEM ON SKID

To ensure continuity of service, ECOMAX® is complete of an automatic refilling oil system, consisting of nr. 02 storage tanks (fresh oil and waste oil) made by galvanized steel, both with a capacity of 1.100 liters, complete with instrumentation, valves, pumps, oil loading and unloading, and connecting pipes to the engine. Skid housing with protective hood and grill decking made by painted steel profiles. Steel painted tank for any leakage of oil, situated below.



MEASURE TECHNOLOGIES

5.3 NATURAL GAS FLOW METER

This measurement system, installed on the natural gas supply system, features the following:

- a volumetric flow meter, complete with transmitter;
- an electronic volume corrector, able to automatically correct the measured volume of gas to the volume at given reference conditions (Sm3/h) by using measured values of pressure and temperature acquired by the built-in sensors, complete with factory inspection certificate.

5.4 HOT WATER CIRCUIT FLOW METER

This measurement system, installed on the hot water circuit, features the following:

- a magnetic flow meter, complete with transmitter and LCD display;
- a pair of temperature sensors with respective thermowells;
- a thermal energy calculator, with a display for visualization of energy consumption, instantaneous measurements, and error messages.

5.5 HOT WATER DISSIPATION CIRCUITS FLOW METER

These two measurement systems, installed on the dissipation circuit on (HT + LT), feature the following:

- a magnetic flow meter, complete with transmitter and LCD display;
- a pair of temperature sensors with respective thermowells;
- a thermal energy calculator, with a display for visualization of energy consumption, instantaneous measurements, and error messages.

7 SERVICES

7.1 ON SITE TRANSPORT

As per the Supply Offer.

7.2 ON SITE UNLOADING

As per the Supply Offer.

7.3 ON SITE ASSEMBLY

As per the Supply Offer.

7.4 COMMISSIONING

The plant's commissioning phase is a time of critical importance, in which ECOMAX®'s performance is proved and the warranty period of the system is initiated. The system test is carried out as soon as verification of all subcomponents is complete and connections of power and control systems are energized. ECOMAX® commissioning is carried out in two stages:

- "cold tests" in order to test plant signals by simulating manual and automatic performance of each device; and
- "hot tests," during which electrical parallel operation, engine carburation, and thermal exchanges with user are carried out.

During this commissioning phase AB technicians perform final adjustments and train customer personnel.

After the completion of the tests, AB technicians will perform the Site Acceptance Test (SAT) according to the Tenders Technical Specification.

The first filling of the glycol solution (water + ethylene glycol) is included only for the ECOMAX® closed circuits and the battery acid.

7.5 ENGINEERING AND DOCUMENTATION

Engineering includes a project of study and development, as well as executive drawings according to current legislation. At work completion, the following documentation will be issued:

- as-built layout (civil works, cable trail, and grounding system);
- as-built P&ID;
- technical documents for installed components;
- final technical reports;
- CE declaration of conformity;
- area classification according EN 60079-10.

8 SUPPLY LIMITS

8.1 AB SUPPLY LIMITS

Feeding gas for ECOMAX®:	Flange available on Ecomax® package;
Dissipation circuit (HT+LT):	All included.
Hot water:	Flanges available on Ecomax® package;
Exhaust gas:	All included, stack height as specified.
Compressed air:	Excluded.
Lube oil system:	Lube oil skid 1000 + 1000 l, first filling excluded.
Draining circuits:	On the outside of the ECOMAX® package.
Civil works:	Not included;
LV power connections:	Limits at generator breaker panel;
LV auxiliaries power supply	Excluded, limits at unit control panel.
Grid isolation system:	Included as described above.
Grounding system:	The system design for the foundation and equipotential connections inside the ECOMAX® unit is included; the supply and installation of components (flexible wire rope, pegs, etc.) is excluded and is the responsibility of the building contractor.

NOTE

The information provided in this document reflects a standard Ecomax® system and is provided only as an example. It is not definitive and is subject to change during the detailed design phase. The inspiring philosophy, however, will not change. It remains focused on optimizing the manufacturing, implementation, and operation of a superior system by implementing all measures and technical decisions deemed to be the most suitable during the detailed design phase.

AB - SCOPE OF WORK

ROYAL MINT

Offer: QUO-07412-T3C2T0

Rev.1.0

1 ECOMAX® 20 NATURAL GAS CONFIGURATION

Code	Description	Included	Not included
1.1	Noise insulated, weatherproof engine enclosure for outdoor installation. Sound pressure level as indicated in the reference conditions (measured in a free field environment without acoustic reflection).	√	
1.2	Internal and external protective coating on the ECOMAX®.	√	
1.3	Doors fitted with handles, locks, and door stops.	√	
1.4	Forced draught ventilation system, complete with variable-frequency drive (VFD) regulation.	√	
1.5	Motor operated air outlet louver dampers.	√	
1.6	Air intake filter.	√	
1.7	Insect screen on air intake and outlet system.	√	
1.8	ECOMAX® plant operation and maintenance manual.	√	
1.9	ECOMAX® as-built documentation.	√	
1.13	Inlet air preheating system for a minimum ambient temperature of -25 °C.		X
1.14	Inlet air preheating system for a minimum ambient temperature of -40 °C.		X

2 GENSET AND MECHANICAL COMPONENTS, PRE-INSTALLED AT AB FACILITIES

Code	Description	Included	Not included
2.1	Spark-ignition gas engine JENBACHER JGS 612 J02.	√	
2.2	Three-phase generator STAMFORD LVSI 804 W 690V.	√	
2.3	Engine control panel.	√	
2.4	Preassembled fuel gas train.	√	
2.5	Preassembled pre-chamber gas train.	√	
2.6	Gas pipework to the engine inside the ECOMAX® engine room.	√	
2.8	Starting batteries and charging rectifier.	√	
2.9	Preassembled pipework on the high temperature (HT) engine cooling system inside the ECOMAX®.	√	
2.10	Water circulation pump and three-way control valve mounted on the HT engine cooling system.	√	
2.11	Expansion tank on the HT engine cooling system.	√	
2.12	Hot water flow meter (HT+LT circuit).	√	
2.19	Preassembled pipework on the low temperature (LT) engine cooling system (2nd stage intercooler circuit).	√	
2.20	Water circulation pump and three-way control valve mounted on the LT engine cooling system (2nd stage intercooler circuit).	√	
2.21	Expansion tank on the LT engine cooling system.	√	
2.22	Automatic daily lube oil make-up system, installed inside the ECOMAX® engine room with a fresh oil daily tank. Oil excluded.		X

2.23	Automatic lube oil filling system, installed inside the ECOMAX® (capacity 1.000 + 1.000 l). Oil excluded.		X
2.26	Lube oil flow meter.		X

3 ELECTRICAL AND CONTROL COMPONENTS, PRE-INSTALLED AT AB FACILITIES

Code	Description	Included	Not included
3.1	ECOMAX® plant control panel (for auxiliary systems).	√	
3.2	Generator breaker panel for coupling of the module to the grid.	√	
3.3	Electrical preheating system.	√	
3.4	Parasitic load measurement system to measure tax-exempt electricity production.	√	
3.5	Siemens PROFINET bus communication system.	√	
3.6	Equipment to automatically synchronize the module with the grid.	√	
3.7	Siemens WinCC SCADA system to provide remote control of equipment.	√	
3.8	Graphic display of operation data as a diagram for easy analysis and management of the ECOMAX® plant.	√	
3.9	A personal computer with monitor, keyboard, and mouse.	√	
3.10	Single-phase UPS system that provides emergency power to the PC for process monitoring.	√	
3.11	Firebox for ECOMAX® remote management (ADSL).	√	
3.13	Alarm phone dialer.	√	
3.14	Profibus or Modbus connection.	√	
3.15	Electrical connections inside the ECOMAX®.	√	
3.16	Lighting system and emergency lighting system inside the ECOMAX®.	√	

3.17	Smoke and gas detection system installed inside the ECOMAX®, complete with alarm unit.	√	
3.18	Emergency stop buttons used to quickly stop the ECOMAX® plant.	√	
3.20	System and devices for the management and control of the exhaust heat recovery steam generator (HRSG).		X
3.22	Epoxy resin step-up transformer.		X
3.23	Equipotential connections inside the ECOMAX®.	√	

4 EQUIPMENT AND AUXILIARIES TO BE INSTALLED ON-SITE

Code	Description	Included	Not included
4.1	Air conditioning unit for the ECOMAX® control room.	√	
4.2	Galvanized safety fence on the ECOMAX® roof to protect all personnel who have access to it.	√	
4.3	Galvanized ladders with safety cages for safe access to the ECOMAX® roof.	√	
4.4	Shelter device above each door for protection against atmospheric agents.	√	
4.5	Dry cooler with variable-frequency drive (VFD) regulation.	√	
4.6	Cooling water pipes in prefabricated spools with bolts and gaskets.	√	
4.7	Heat recovery pipes in prefabricated spools with bolts and gaskets.	√	
4.8	Insulation for water pipe spools.	√	
4.9	Automatic lube oil filling system, skid mounted and designed for outdoor installation (capacity 1.000 + 1.000 l). Oil excluded.	√	
4.10	Automatic lube oil filling system, skid mounted and designed for outdoor installation with a minimum ambient temperature of -25 °C (capacity 1.000 + 1.000 l). Oil excluded.		X
4.11	Fuel gas flow meter with spool.	√	
4.12	Nr. 1 gas servo valves for emergency shutoff.	√	
4.17	Exhaust gas piping made of stainless steel, complete with supports, expansion joints, and emission monitoring ports.	√	
4.18	Insulation for the exhaust gas piping.	√	

4.20	Insulation for the exhaust gas silencer.	√	
4.19	Exhaust gas silencer.	√	
4.21	Exhaust gas stack.	√	
4.22	Insulation for the exhaust stack.	√	
4.24	Condensate drainage system. Terminal point at the condensate drain on the ECOMAX® plant.	√	
4.25	Oxidation catalyst.	√	
4.26	Selective catalytic reduction (SCR) exhaust gas treatment system, using urea.		X
4.31	Natural gas compressor for prechambers.	√	
4.39	QMT12 - MV coupling panel.		X
4.40	QMT11 – MV cogeneration protection panel		X
4.47	Plate heat exchanger on hot water circuit.	√	
4.49	Grounding system		X
4.50	Low voltage power connections		X
4.51	Medium voltage connections		X
4.52	Electrical connection agreement with the DNO		X
4.53	District Network Opeartor (DNO) grid connection works		X
4.55	CT's/VT's and transducer installed at site incomer with control cabling back to the CHP control panel for Export Control		X
4.56	Power system stabiliser		X
4.57	Ring main unit		X
4.58	Pipework pressure testing		X

5 ON SITE WORKS.

Code	Description	Included	Not included
5.1	On-site assembly, to be performed by skilled AB technicians.	√	
5.2	Commissioning.	√	
5.3	Contract crane and Offload and position of the container on concrete basement.	√	
5.4	Assistance at the unloading and positioning of the ECOMAX® unit on the base.	√	
5.5	Civil works		X
5.6	Site preparation, excavation and backfilling		X
5.7	Ground investigation survey		X
5.8	Compound services		X
5.9	Site office cabin		X
5.10	Site welfare facilities		X
5.11	Open and covered storage at site as necessary		X
5.12	Skip hire and waste disposal		X
5.13	Temporary Site security fencing		X
5.14	Surface and foul water drainage		X
5.15	Communication of other third-party requirements		X
5.16	Dryer integration works		X
5.17	Earth mat and bonding of equipment to earth mat		X
5.18	Export control metering + control cabling back to CHP control panel		X

5.19	Providing access to the Site to allow construction and operation of the Plant in		X
5.20	Access road		X

6 SURVEY, APPLICATIONS, PERMITS AND REPORTING.

Code	Description	Included	Not included
6.1	Discharge of planning conditions		X
6.2	Negotiating or obtaining wayleaves, easement		X
6.3	Emissions dispersion modelling (if required)		X
6.4	Environmental permit		X
6.5	Back ground noise study		X
6.6	Ecology studies		X
6.7	Grid connection application and consent		X
6.8	Harmonic study (if required)		X
6.9	CHPQA monthly (if required)		X
6.10	P28 study (if required)		X
6.11	Transient stability study		X
6.12	Sewer connection application and consent		X
6.13	Flood risk assessments		X
6.14	Drainage survey		X
6.15	Radar scan to detect buried services		X
6.16	Soil resistivity study for earthing design		X
6.17	Grid code simulation studies		X
6.18	Any permits/licences required by the Environment Agency for the operation of the facility		X

7 SITE MANAGEMENT.

Code	Description	Included	Not included
7.1	Principal Contractor role		X
7.2	Principal Designer role		X
7.3	Site Manager for duration of installation works		X

JENBACHER

02/2020

Technical Description

Genset

JGS 612 GS-N.L

dyn. GC Profile 1 (150ms/30%)

Royal

Electrical output 2001 kW el.

Emission values

NOx < 250 mg/Nm³ (5% O2) | < 95 mg/Nm³ (15% O2)

JENBACHER

0.01 Technical Data (at genset)

			100%	75%	50%
Power input	[2]	kW	4.535	3.478	2.421
Gas volume	*)	Nm³/h	477	366	255
Mechanical output	[1]	kW	2.058	1.544	1.029
Electrical output	[4]	kW el.	2.001	1.498	990
Heat to be dissipated (calculated with Glykol 30%)	**[5]**				
~ Intercooler 1st stage (Engine jacket water cooling circuit)	[9]	kW	573	327	135
~ Intercooler 2nd stage (Low temperature circuit)		kW	173	112	74
~ Lube oil (Engine jacket water cooling circuit)		kW	205	184	156
~ Jacket water		kW	317	280	235
~ Surface heat	ca. [7]	kW	158	~	~
Spec. fuel consumption of engine electric	[2]	kWh/kWel.h	2,27	2,32	2,45
Spec. fuel consumption of engine	[2]	kWh/kWh	2,20	2,25	2,35
Lube oil consumption	ca. [3]	kg/h	0,41	~	~
Electrical efficiency			44,1%	43,1%	40,9%
Fuel gas LHV		kWh/Nm³	9,5		

*) approximate value for pipework dimensioning
[_] Explanations: see 0.10 - Technical parameters

All heat data is based on standard conditions according to attachment 0.10. Deviations from the standard conditions can result in a change of values within the heat balance, and must be taken into consideration in the layout of the cooling circuit/equipment (intercooler; emergency cooling; ...). In the specifications in addition to the general tolerance of ±8 % on the thermal output a further reserve of +5 % is recommended for the dimensioning of the cooling requirements.

Main dimensions and weights (at genset)

Length	mm	~ 7.600
Width	mm	~ 2.200
Height	mm	~ 2.800
Weight empty	kg	~ 24.000
Weight filled	kg	~ 25.000

Connections

Jacket water inlet and outlet	DN/PN	100/10
Exhaust gas outlet [C]	DN/PN	500/10
Fuel Gas (at genset) [D]	DN/PN	100/10
Water drain ISO 228	G	½"
Condensate drain	mm	~
Safety valve - jacket water ISO 228 [G]	DN/PN	2x1½"/2,5
Lube oil replenishing (pipe) [I]	mm	28
Lube oil drain (pipe) [J]	mm	28
Jacket water - filling (flex pipe) [L]	mm	13
Intercooler water-Inlet/Outlet 1st stage	DN/PN	100/10
Intercooler water-Inlet/Outlet 2nd stage [M/N]	DN/PN	65/10

Output / fuel consumption

ISO standard fuel stop power ICFN	kW	2.058
Mean effe. press. at stand. power and nom. speed	bar	22,00
Fuel gas type		Natural gas
Based on methane number | Min. methane number	MZ	90 | 80 d)
Compression ratio	Epsilon	12
Min. fuel gas pressure for the pre chamber	bar	4,39
Min./Max. fuel gas pressure at inlet to gas train	bar	4,2 - 8 c)
Max. rate of gas pressure fluctuation	mbar/sec	10
Maximum Intercooler 2nd stage inlet water temperature	°C	45
Spec. fuel consumption of engine	kWh/kWh	2,20
Specific lube oil consumption	g/kWh	0,20
Max. Oil temperature	°C	80
Jacket-water temperature max.	°C	95
Filling capacity lube oil (refill)	lit	~ 549

c) Lower gas pressures upon inquiry
d) based on methane number calculation software AVL 3.2 (calculated without N2 and CO2)

0.02 Technical data of engine

Manufacturer		JENBACHER
Engine type		J 612 GS-J02
Working principle		4-Stroke
Configuration		V 60°
No. of cylinders		12
Bore	mm	190
Stroke	mm	220
Piston displacement	lit	74,85
Nominal speed	rpm	1.500
Mean piston speed	m/s	11,00
Length	mm	4.246
Width	mm	1.886
Height	mm	2.503
Weight dry	kg	9.500
Weight filled	kg	10.300
Moment of inertia	kgm²	56,67
Direction of rotation (from flywheel view)		left
Radio interference level to VDE 0875		N
Starter motor output	kW	13
Starter motor voltage	V	24

Thermal energy balance

Power input	kW	4.535
Intercooler	kW	746
Lube oil	kW	205
Jacket water	kW	317
Exhaust gas cooled to 180 °C	kW	584
Exhaust gas cooled to 100 °C	kW	867
Surface heat	kW	84

Exhaust gas data

Exhaust gas temperature at full load [8]	°C	341
Exhaust gas temperature at bmep= 16,5 [bar]	°C	~ 391
Exhaust gas temperature at bmep= 11 [bar]	°C	~ 439
Exhaust gas mass flow rate, wet	kg/h	11.881
Exhaust gas mass flow rate, dry	kg/h	11.175
Exhaust gas volume, wet	Nm³/h	9.390
Exhaust gas volume, dry	Nm³/h	8.512
Max.admissible exhaust back pressure after y-pipe	mbar	50

Combustion air data

Combustion air mass flow rate	kg/h	11.567
Combustion air volume	Nm³/h	8.951
Max. admissible pressure drop at air-intake filter	mbar	10

Sound pressure level

Aggregate a)		dB(A) re 20µPa	100
31,5	Hz	dB	90
63	Hz	dB	88
125	Hz	dB	100
250	Hz	dB	95
500	Hz	dB	94
1000	Hz	dB	93
2000	Hz	dB	91
4000	Hz	dB	91
8000	Hz	dB	94
Exhaust gas b)		dB(A) re 20µPa	116
31,5	Hz	dB	104
63	Hz	dB	121
125	Hz	dB	124
250	Hz	dB	116
500	Hz	dB	111
1000	Hz	dB	110
2000	Hz	dB	108
4000	Hz	dB	104
8000	Hz	dB	86

Sound power level

Aggregate	dB(A) re 1pW	122
Measurement surface	m²	142
Exhaust gas	dB(A) re 1pW	124
Measurement surface	m²	6,28

a) average sound pressure level on measurement surface in a distance of 1m (converted to free field) according to DIN 45635, precision class 3.
b) average sound pressure level on measurement surface in a distance of 1m according to DIN 45635, precision class 2.
The spectra are valid for aggregates up to bmep=20 bar. (for higher bmep add safety margin of 1dB to all values per increase of 1 bar pressure).
Engine tolerance ± 3 dB

0.03 Technical data of generator

Manufacturer		AVK e)
Type		DIG 130 k/4 e)
Type rating	kVA	2.800
Driving power	kW	2.058
Ratings at p.f. = 1,0	kW	2.001
Ratings at p.f. = 0,8	kW	1.984
Rated output at p.f. = 0,8	kVA	2.480
Rated reactive power at p.f. = 0,8	kVar	1.488
Rated current at p.f. = 0,8	A	130
Frequency	Hz	50
Voltage	kV	11
Speed	rpm	1.500
Permissible overspeed	rpm	1.800
Power factor (lagging - leading)		0,8 - 0,95
Efficiency at p.f. = 1,0		97,2%
Efficiency at p.f. = 0,8		96,4%
Moment of inertia	kgm²	110,00
Mass	kg	7.500
Radio interference level to EN 55011 Class A (EN 61000-6-4)		N
Cable outlet		left
Ik'' Initial symmetrical short-circuit current	kA	0,82
Is Peak current	kA	2,09
Insulation class		F
Temperature (rise at driving power)		F
Maximum ambient temperature	°C	40

Reactance and time constants (saturated) at rated output

xd direct axis synchronous reactance	p.u.	1,870
xd' direct axis transient reactance	p.u.	0,254
xd'' direct axis sub transient reactance	p.u.	0,157
x2 negative sequence reactance	p.u.	0,165
Td'' sub transient reactance time constant	ms	15
Ta Time constant direct-current	ms	70
Tdo' open circuit field time constant	s	3,20

e) JENBACHER reserves the right to change the generator supplier and the generator type. The contractual data of the generator may thereby change slightly. The contractual produced electrical power will not change.

JENBACHER

connection variant 1K

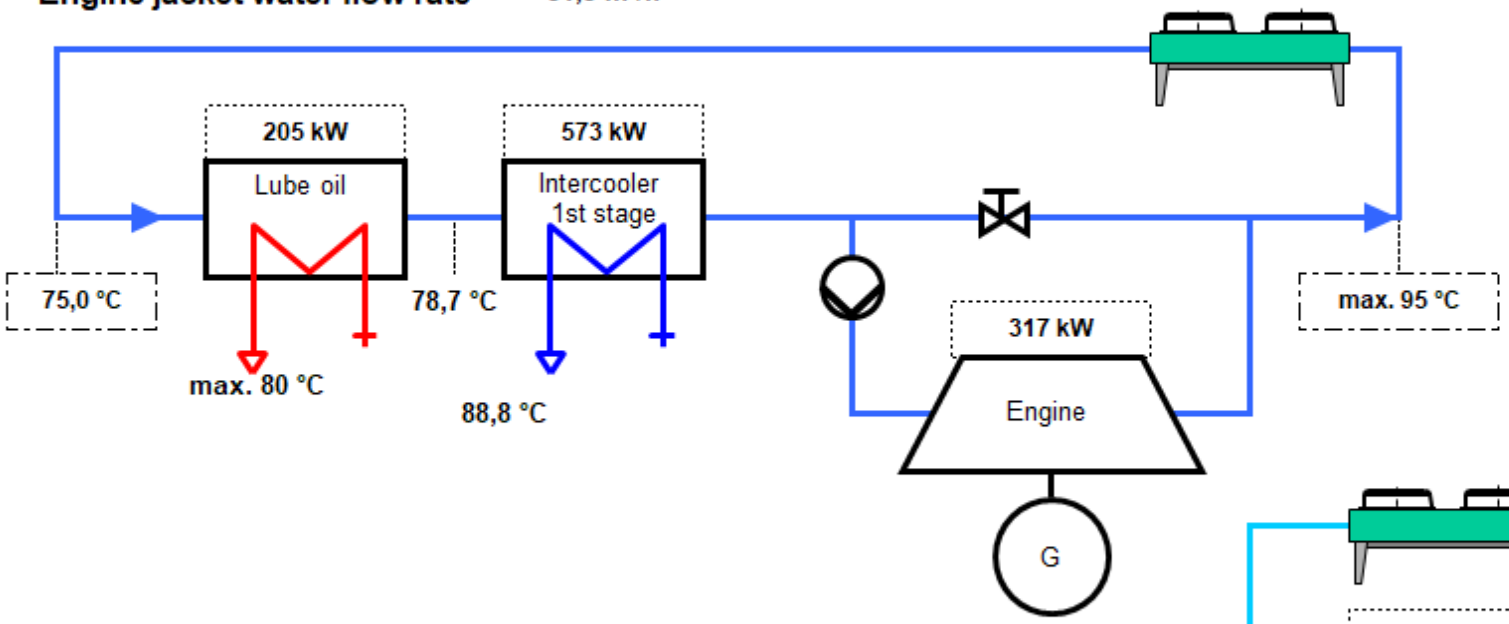
J 612 GS-J02

Engine jacket water cooling circuit (calculated with Glykol 30%)

Heat to be dissipated = 1.095 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Engine jacket water flow rate = 51,5 m³/h

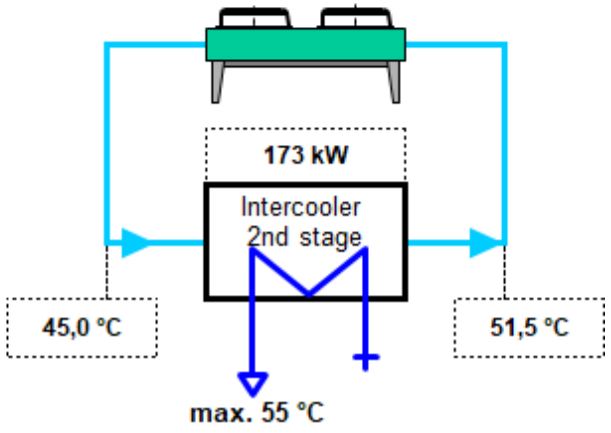


Low temperature circuit (calculated with Glykol 30%)

Heat to be dissipated = 173 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Cooling water flow rate = 25,0 m³/h



0.05 Cooling water circuit

Oil - heat (Engine jacket water cooling circuit)

Nominal output	kW	205
Max. Oil temperature	°C	80
Loss of nominal pressure of engine jacket water	bar	0,40
Safety valve - max press. set point	bar	3,50

Engine jacket water - heat (Engine jacket water cooling circuit)

Nominal output	kW	317
Max. engine jacket water temperature (outlet engine)	°C	95
Engine jacket water flow rate	m³/h	51,5
Safety valve - max press. set point	bar	3,50

Mixture Intercooler (1st stage) (Engine jacket water cooling circuit)

Nominal output	kW	573
Max. inlet cooling water temp. (intercooler)	°C	78,7
Nominal pressure of cooling water / (max. operating pressure)	PN	10
Loss of nominal pressure of engine jacket water	bar	0,25
Safety valve - max press. set point	bar	3,50

Mixture Intercooler (2nd stage) (Low temperature circuit)

Nominal output	kW	173
Max. inlet cooling water temp. (intercooler)	°C	45
Aftercooler water flow rate	m³/h	25,0
Nominal pressure of cooling water / (max. operating pressure)	PN	10
Intercooler water pressure drop	bar	0,25
Safety valve - max press. set point	bar	3,50

The final pressure drop will be given after final order clarification and must be taken from the P&ID order documentation.

0.10 Technical parameters

All data in the technical specification are based on engine full load (unless stated otherwise) at specified temperatures and the methane number and subject to technical development and modifications.

All pressure indications are to be measured and read with pressure gauges (psi.g.).

(1) At nominal speed and standard reference conditions ICFN according to DIN-ISO 3046 and DIN 6271, respectively
(2) According to DIN-ISO 3046 and DIN 6271, respectively, with a tolerance of +**5** %.
Efficiency performance is based on a new unit (immediately upon commissioning).Effects of degradation during normal operation can be mitigated through regular service and maintenance work.

(3) Average value between oil change intervals according to maintenance schedule, without oil change amount
(4) At p. f. = 1.0 according to VDE 0530 REM / IEC 34.1 with relative tolerances, all direct driven pumps are included
(5) Total output with a tolerance of ±8 %
(6) According to above parameters (1) through (5)
(7) Only valid for engine and generator; module and peripheral equipment not considered (at p. f. = 0,8), (guiding value)
(8) Exhaust temperature with a tolerance of ±8 %
(9) Intercooler heat on:
*** standard conditions** - If the turbocharger design is done for air intake temperature > 30°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 25°C. Deviations between 25 – 30°C will be covered with the standard tolerance.
*** Hot Country application (V1xx)** - If the turbocharger design is done for air intake temperature > 40°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 35°C. Deviations between 35 – 40°C will be covered with the standard tolerance.

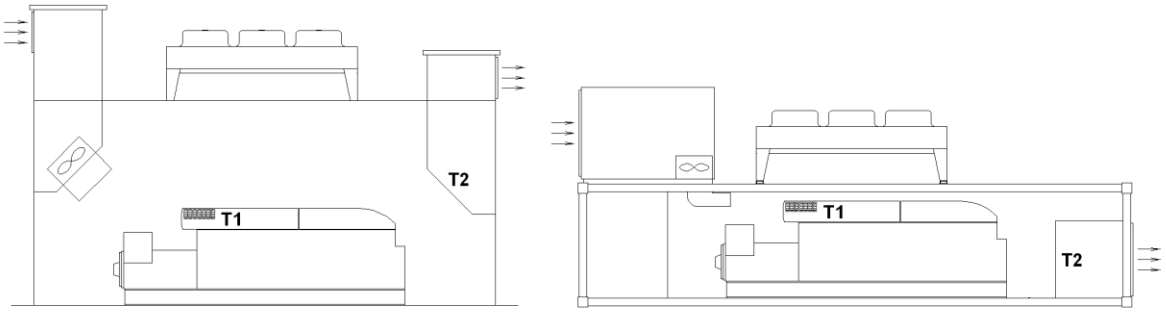
Radio interference level
The ignition system of the gas engines complies the radio interference levels of CISPR 12 and EN 55011 class B, (30-75 MHz, 75-400 MHz, 400-1000 MHz) and (30-230 MHz, 230-1000 MHz), respectively.

Definition of output
- ISO-ICFN continuous rated power:
  Net break power that the engine manufacturer declares an engine is capable of delivering continuously, at stated speed, between the normal maintenance intervals and overhauls as required by the manufacturer. Power determined under the operating conditions of the manufacturer's test bench and adjusted to the standard reference conditions.
  - Standard reference conditions:

Barometric pressure:	1000 mbar (14.5 psi) or 100 m (328 ft) above sea level
Air temperature:	25°C (77°F) or 298 K
Relative humidity:	30 %

- Volume values at standard conditions (fuel gas, combustion air, exhaust gas)
  Pressure: 1013 mbar (14.7 psi)
  Temperature: 0°C (32°F) or 273 K

Output adjustment for turbo charged engines
Standard rating of the engines is for an installation at an altitude ≤ **500 m** and combustion air temperature ≤ **30 °C** (T1)
Engine room outlet temperature: **50°C** (T2) -> engine stop



The minimum recommended air change ratio (C) must be observed to maintain the required air quality and prevent unwanted gas accumulations (refer to Section ⇨ Potentially explosive Atmospheres as per TA1100-0110). The calculation of the minimum air change rate is based on the formula below and is Cmin= $50h^{-1}$ for all JENBACHER modules.

If the actual methane number is lower than the specified, the knock control responds. First the ignition timing is changed at full rated power. Secondly the rated power is reduced. These functions are carried out by the engine management system.
Exceedance of the voltage and frequency limits for generators according to IEC 60034-1 Zone A will lead to a derate in output.

Parameters for the operation of JENBACHER gas engines
The genset fulfils the limits for mechanical vibrations according to ISO 8528-9.
The following forms an integral part of a contract and must be strictly observed: **TA 1000-0004, TA 1100 0110, TA 1100-0111**, and **TA 1100-0112.**
Transport by rail should be avoided. See **TA 1000-0046** for further details

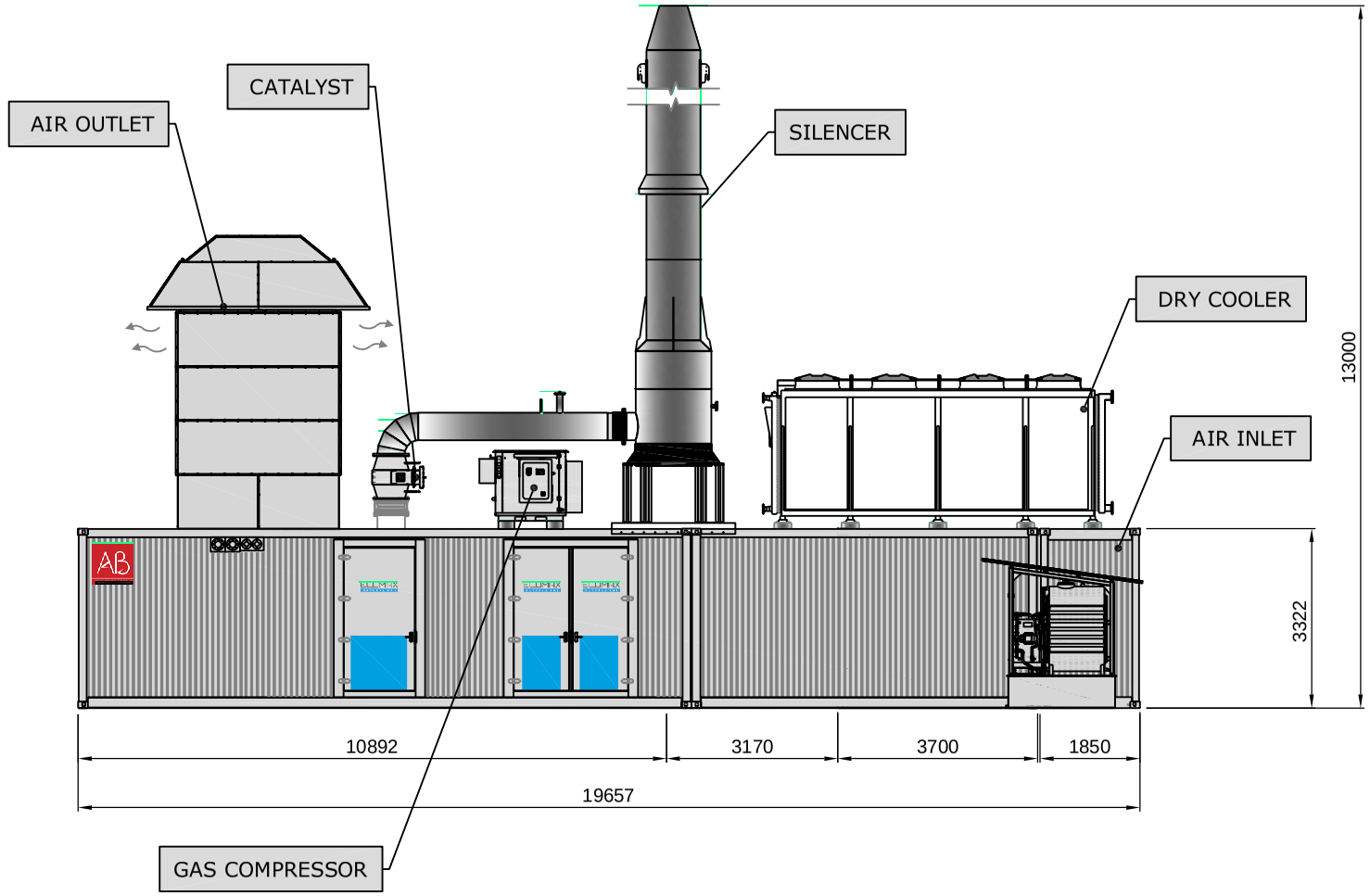
Failure to adhere to the requirements of the above-mentioned TA documents can lead to engine damage and may result in loss of warranty coverage.

Parameters for the operation of control unit and the electrical equipment
Relative humidity 50% by maximum temperature of 40°C.
Altitude up to 2000m above the sea level.

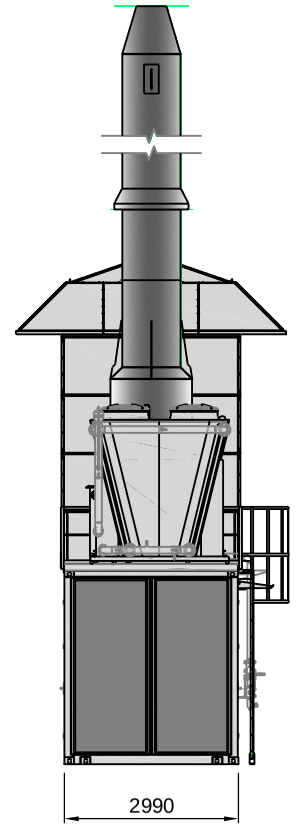
0.20 Mode of Operation

Grid Parallel Mode
The genset is running in parallel to the utility. The unit load can be adjusted via its power control set point or designated option.
Procedure in the event of mains failure:
When the mains monitor relay (protective relay ANSI No. 27, 59, 81, 78- provided either by JENBACHER or the customer) is activated due to a mains failure, the engine is isolated from the mains by opening the generator breaker. The module is shut down without any cool-down run.
Island operation is not available in this case!
The module can be restarted following the restoration of mains power after a 5-minute mains stabilization period.

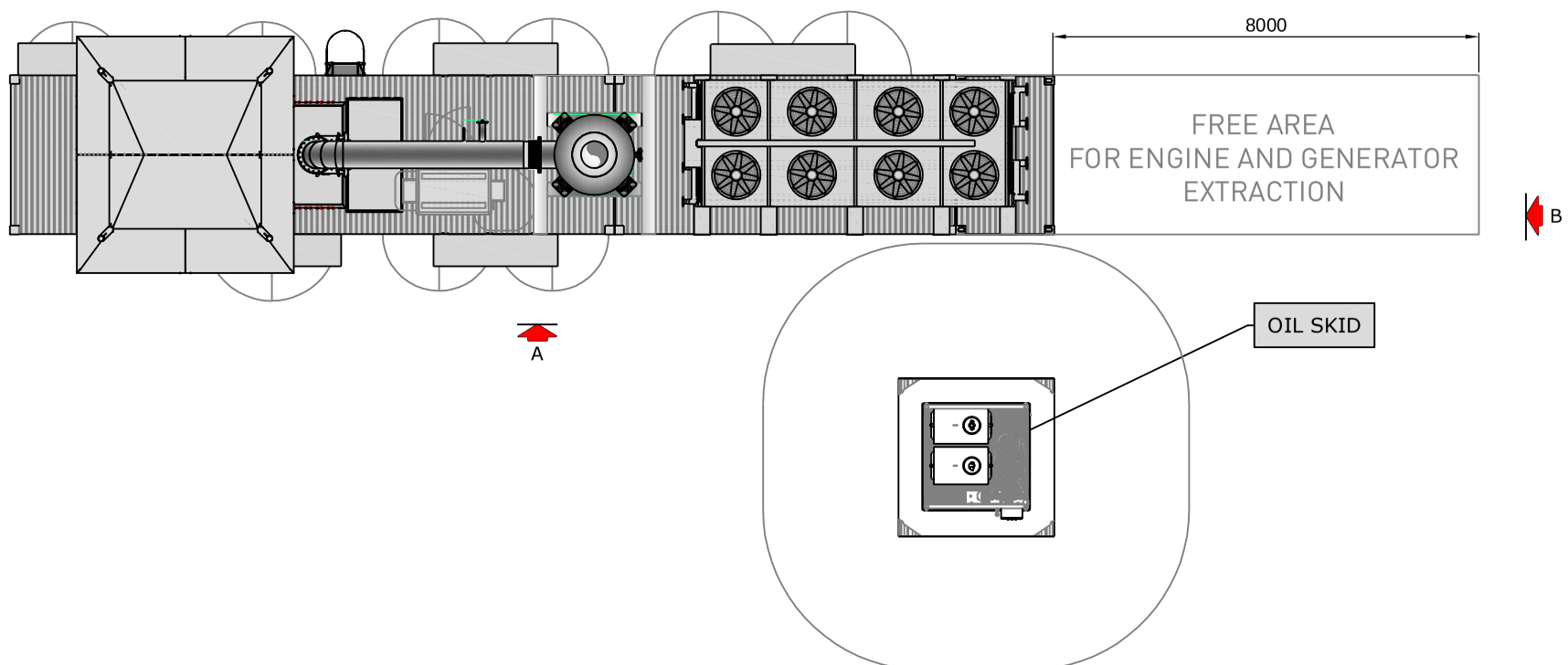
VIEV FROM A



VIEV FROM B



TOP VIEW



Rev.	Date / Data	Issue / Oggetto revisione	Dr.n/Dis.	Contr.	Appr.
0.1	09/03/20	First Issue	G.Merlo	A.Davì	M.Gentili

www.gruppoab.com

Customer/Committente: Royal Mint

Final Client/Cliente Finale:

Drawing/Disegno: Ecomax Layout

Installation Site/Sito installazione: United Kingdom

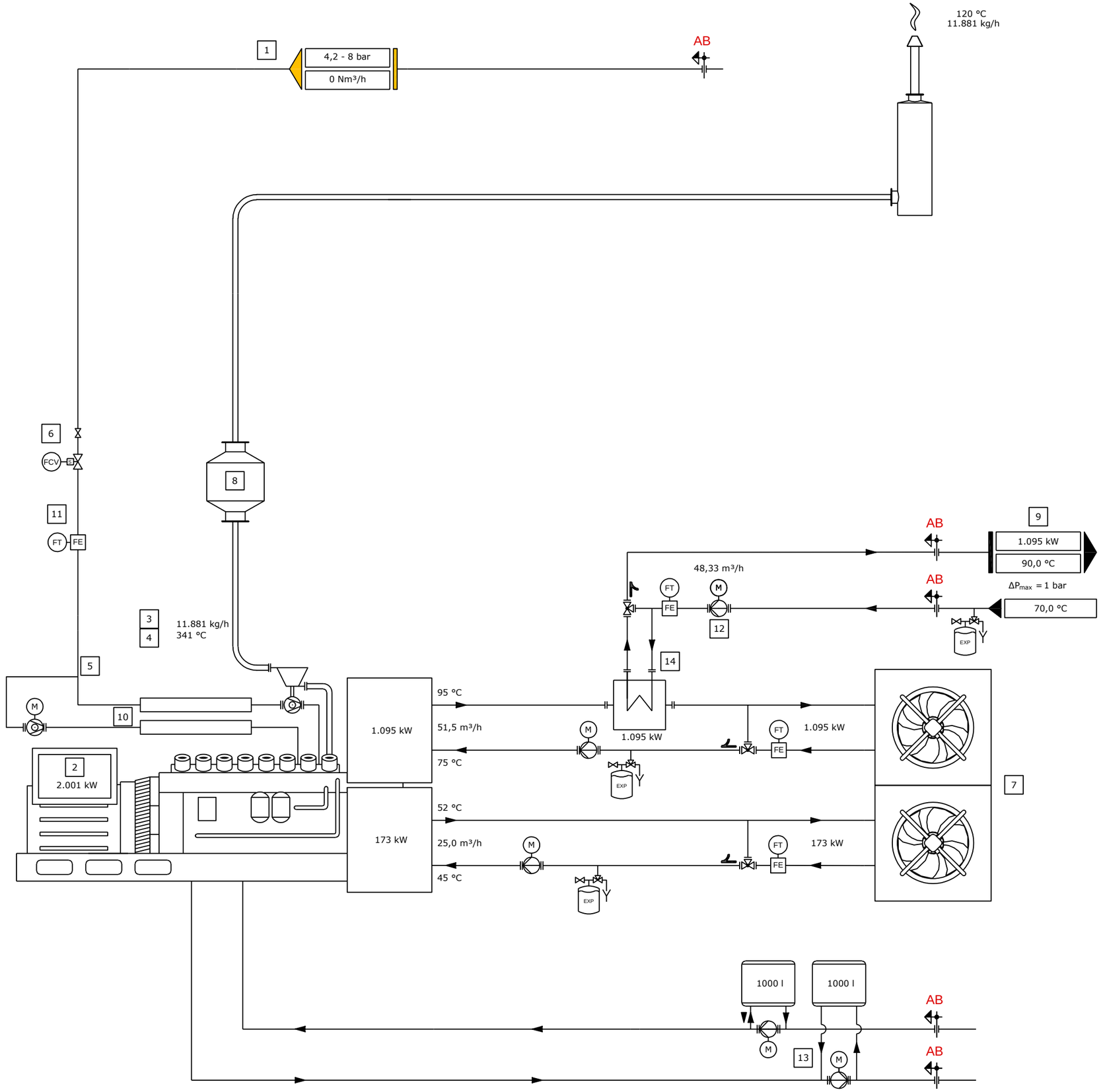
Offer Number/Numero Offerta: QUO-07412-T3C2T0

ECOMAX® 20 NATURAL GAS

Project/Progetto: PRJ-4102

Scale/Scala: A3

AB IMPIANTI S.r.l.
ISO9001 Cert. nº 50-100-10939 Rev.3
ISO3834-2 Cert. nº 523-090-2012
EN 1090-1 Cert. nº 0948-CPR-0176



LEGEND

1 -Natural gas
2 -Electrical power
3 -Exhaust gas flow
4 -Exhaust gas temperature
5 -Gas train
6 -Cut-off valve
7 -Drycooler
8 -Catalyst
9 -Hot water
10 -Prechamber gas train
11 -Flow meter
12 -Customer side pump
13 -Internal oil system
14 -Plate heat exchanger

PRELIMINARY

Rev.	Date	Description	Drawn	Checked	Approved
0.1	09/03/20	Revisione generale	G.Merlo	A.Davì	M.Gentili

www.gruppoab.com

Customer: Royal Mint

Final Purchaser:

Drawing: Flow diagram Hot water

Installation Country: United Kingdom

Offer Number: QUO-07412-T3C2T0

Model: ECOMAX® 20 NATURAL GAS

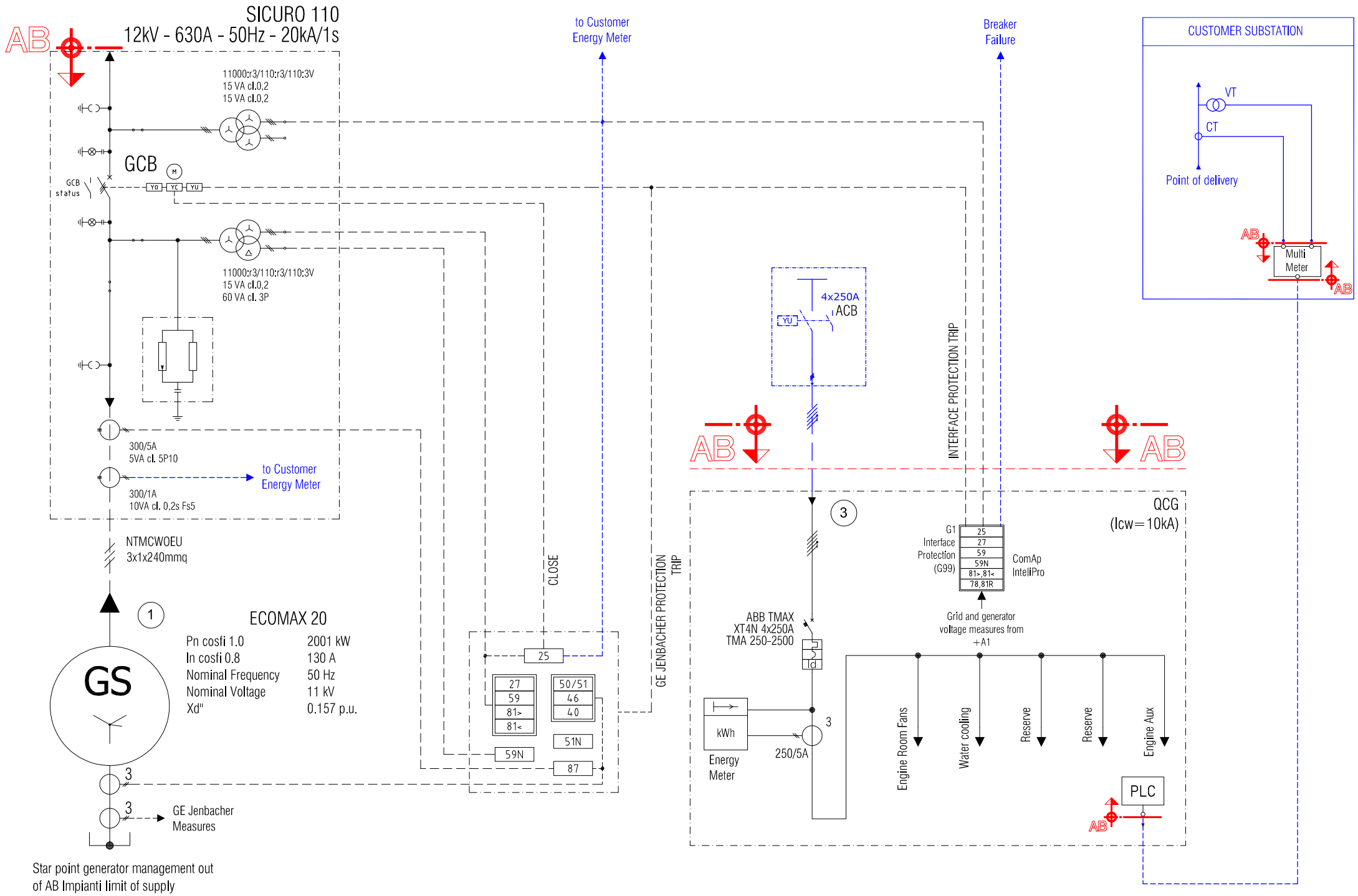
Scale: ---

Format: A3

Project Number: PRJ-4102

AB Impianti S.r.l.
ISO9001 Cert. n° 50-100-10939 Rev. 3
ISO3834-2 Cert. n° 523-090-2012

(R)ED 1.5.2.1



25 -Synchronizing device;
27 -Undervoltage protection;
50 -Instantaneous overcurrent protection;
50N - Instantaneous homopolar overcurrent relay;
51 -a.c. time overcurrent relay;
51N -a.c. time homopolar overcurrent relay;
59 -Overvoltage relay;
59N -Homopolar overvoltage relay;
67N -Earth fault directional protection;
81 -Frequency relay;
YU -Undervoltage release coil;
YO -Release coil;
YC -Closing coil;
M -Geared motor for closing springs charging;
PG -General protection;
DG -General device;
PI -Interface protection;
DDI -Interface device;
DDG -Generator device;
DBO -Island/BO Start device;
DDR -DDI opening failure device;
CT -Current transformer;
HCT -Toroidal current transformer;
VT -Voltage transformer;
AB scope of supply;
Components provided by AB;
Existing components and/or provided by Customer;
Optional components.

GCB: Generator Circuit Breaker
ACB: Auxiliary Circuit Breaker

Rev.	Date / Data	Issue / Oggetto revisione	Dr.n/Dis.	Contr.	Appr.
5					
4					
3					
2					
1					
0	01/08/2019	First issue	M.Gentili	M.Magarini	A.Baronchelli

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Customer / Committente:
ROYAL MINT

Final Client / Cliente Finale:

Drawing Title / Oggetto disegno:
Single line diagram
cogeneration plant

Installation Site / Sito installazione:
United Kingdom

Drawing / Disegno:
QUO-07412

ECOMAX® 20 NGS

Scale / Scala:
/

Format / Formato:
A3

File:
QUO-07412 REV 0.0.dwg

Order / Commessa:
PRJ-4102

AB IMPIANTI S.r.l.
ISO9001 Cert. n° 50-100-10929 Rev.3
ISO3834-2 Cert. n° 520-090-2012
EN 1090-1 Cert. n° 0948-CPR-0176

GE Power & Water

TA 1000-0300

Fuel gas and combustion air requirements

Technical Instruction

3249203123166202384227561345153625 41

Tekniske anvisninger

Technical instruction

Technische Richtlijnen

技术指导

Indicazioni tecniche

Технические инструкции

Τεχνικές οδηγίες

Achenseestr. 1-3
A-6200 Jenbach, Austria
www.gejenbacher.com

GE imagination at work

The target recipients of this document are:

Prospective Customers, Customers, Distribution Partners, Service Partners, Commissioning Partners, Subsidiaries/ Branches, Location Jenbach

NOTE

Observance of the conditions of this Technical Instruction and performance of the activities described therein is the basis of safe and efficient plant operation.

Non-observance of the conditions of this Technical Instruction and/or non-performance of the prescribed activities or any departure from the prescribed activities may result in the loss of guarantee rights.

The activities and conditions defined in this Technical Instruction shall be performed and/or observed by the plant operator. This shall not apply if this Technical Instruction is expressly allocated to the area of responsibility of GE Jenbacher or a contractual agreement between the operator and GE Jenbacherprovides for a different arrangement.

1 Scope

This Technical Instruction (TI) applies to GE Jenbacher engines that are designed to be used with gaseous fuels.

2 Purpose

The purpose of this Technical Instruction is to illustrate the requirements and the limits that apply to the use of fuel gas in combustion engines. Specifically, these relate to the limit values and requirements placed on the gas composition, the trace substances and impurities, and the oil, condensate and particles that the mixture may contain. In addition, the requirements on the combustion air are also described.

3 General

GE Jenbacher engine systems make use of a broad range of gaseous fuels as fuel gas. In contrast to petrol and diesel fuels, gaseous fuels generally do not have to comply with strict specifications or classifications. Nevertheless, special requirements and defined limit levels are imposed on fuel gas. In principle, all gaseous fuels that can be used in combustion engines can be classified as "fuel gases".

The physical and chemical characteristics of gaseous fuels can vary enormously. However, from the point of view of construction and operating processes, the engines are designed to function within a very strict range of characteristics and are often very sensitive to changes to these characteristics.

The engine system is optimally matched to the contractually defined fuel-gas composition for which it was sold, and no major changes may be made to this.

The fuel gas is mixed with the combustion air to produce a usable mixture and conveyed to the engine for combustion. Impurities as well as combustion air can be aspirated into the engine. If the fuel gas or combustion air does not comply with the requirements, this can have adverse effects on engine operation. This can result in situations where the safety of the plant and its operation cannot be guaranteed.

Lubricating oil can lose its corrosion protection properties as a result of impurities in both the fuel gas and the combustion air. The results of regular lubricating oil analyses indicate whether there are any impurities in the mixture. Refer to the following Technical Instructions as well:

- TI 1000-0099B: Limit values for used oil in GE Jenbacher gas engines
- TI 1000-0099C Procedure for testing the oil service life specific to the plant
- TI 1000-0112 Taking lubricating oil samples / lubricating oil sampling protocol
- TI 1000-1109: Lubricating oil for type 2, 3, 4 and 6 GE Jenbacher engines
- TI 1000-1108: Lubricating oils for type 9 engines

⚠ ATTENTION

Environment, health & safety

Fuel gases and their production, and the use of fuel gases in engines, can result in exposure to substances which are dangerous or harmful to the environment and human health. Before dealing with fuel gases, deposits and condensates, we therefore have to pay attention to relevant health and safety instructions and take precautionary measures.

4 Gas types

The fuel gases used in GE Jenbacher gas engines can be divided into the main categories listed below. GE Jenbacher gas engines are not confined to these main categories. Solutions for other gas types can be developed in conjunction with GE Jenbacher.

Natural gas

Natural gas is characterised by its high methane (CH_4) content and is very pure. Its methane content is between 65 and 100% by volume.

Associated petroleum gas

This class of fuel gas is characterized by a medium to high methane content. Its methane concentration can be anywhere between 35 and 90% by volume . Of the other constituents, nitrogen (N_2) or carbon dioxide (CO_2) can occur in high concentrations of up to 45% by volume, and a higher proportion of higher-value hydrocarbons can also occur.

Biogas, sludge gas, landfill gas

These fuel gases are produced by the conversion of liquid or solid organic substances by micro-organisms. Like associated petroleum gas, they are characterised by a medium to high methane content and the constituents N_2 and CO_2. However, as this gas emanates from highly heterogeneous substances, special care must be taken with regard to trace substances and impurities.

Mine gas

This fuel gas is recovered from mines and is characterised by very wide fluctuations in its methane content, which can lie between 25 and 95 vol%. Of the other constituents, N_2 can be present in a concentration of up to 65% by volume, CO_2 up to 15% by volume or oxygen (O_2) up to 15% by volume. This gas is frequently associated with a certain amount of dust loading, which necessitates a pre-separation stage.

Gases from thermal gasification processes

These gases are produced through the targeted gasification of biomass (e.g. wood), waste material, coal, etc., and typically exhibit high levels of hydrogen (H_2) and carbon monoxide (CO). As this gas emanates from highly heterogeneous substances, special care must be taken with regard to trace elements and accompanying substances. This type of gas is also referred to as synthesis gas.

Process gases

Process gases arise in the steel industry and are hence also referred to as steel gas. These gases fall into the following main groups:

Gas description	Main components	Origin
Coke-oven gas	$H_2/CH_4/N_2/CO$	Coking process
Blast furnace gas	$N_2/CO/CO_2/H_2$	Process gas from steel production
Converter gas	$CO/N_2/CO_2/H_2$	Process gas produced during the manufacture of steel, e.g. LD gas (Linz-Donawitz process)

Liquid gas, propane gas

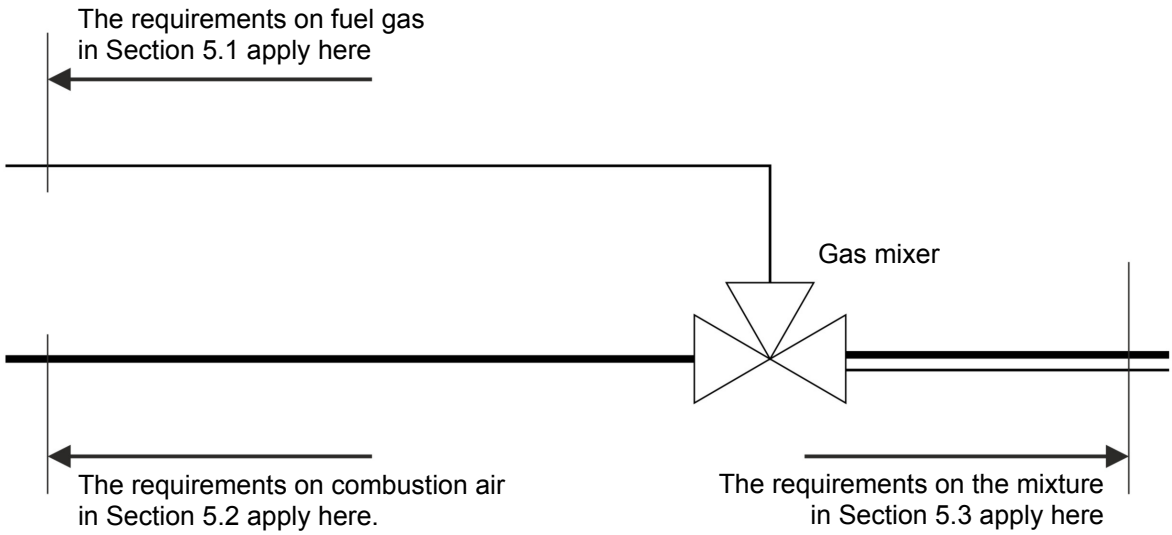
The most distinctive feature of liquid gases is that they are transported and stored in a liquid state. They are then evaporated before being used.

Liquid natural gas (LNG) consists initially of natural gas, which is liquefied by cooling it to -161°C. However, "fractionation" can occur during the evaporation process, resulting in possible deviations and fluctuations in the gas composition, such as an increase in the concentration of longer-chain hydrocarbons.

Propane gas is already in a liquid state under relatively low pressures and normal temperatures. Its main constituent is propane (C_3H_8), which is present in concentrations of 60 to 100 vol%. It may also contain high concentrations of butane (C_4H_{10} - up to 10% by volume), ethane (C_2H_6 - up to 20% by volume) or methane (up to 40% by volume). Propane HD-5 contains more than 90% propane and less than 5% propene (C_3H_6), and less than 5% of other hydrocarbons.

5 Requirements and limit values

The requirements and limits set out in this Technical Instruction for the fuel gas and combustion air apply to GE Jenbacher engines and plants. This ensures that the mixture aspirated by the engine meets the engine's requirements and does not cause any damage. Any ingress of unwanted substances into the engine should always be avoided in principle. The following diagram illustrates the relationship between the requirements on the fuel gas, the combustion air and the mixture.



5.1 Fuel gas requirements and limits

To guarantee trouble-free engine operation and the specified maintenance intervals, the specified fuel gas requirements must be permanently maintained at the GE Jenbacher interface. A summary of the requirements and limit values, together with any other special requirements, can be found in the Appendix.

GE Jenbacher cannot honour warranty claims relating to problems caused by exceeding one or more of the limit values specified in this Technical Instruction.

Physical fuel gas properties, main components and thermodynamic requirements

The main components determine the relevant fuel gas characteristics for physical engine operation (e.g. calorific value, combustion air ratio, combustion temperature, laminar flame propagation speed, ignition limits, knock resistance). They are normally expressed as a % by volume and must be specified in the form of a comprehensive gas analysis (see Appendix: Check list for fuel gas quality information).

Apart from a number of limiting conditions relating to the data sheet, the technical specifications also contain the fuel gas type.

In cases where the available fuel gas does not conform to what is stated in the standard product range, a special - client-specific - solution can be arranged, taking into account all technical and efficiency-related options.

It is normal for the composition of some gas types to vary substantially. In Leanox-controlled engine operation (under load), these fluctuations can to a large extent be compensated for by the engine management system. In order to guarantee a satisfactory starting behaviour, however, a certain fluctuation range is necessary and the engine management must be provided with usable information (e.g.: calorific value, CH_4 content) on the current gas quality.

Physical characteristics, main components and thermodynamic requirements

Description	Characteristic	Limitation	Unit	Note
Gas pressure	Fluctuation	≤ 10	mbar/s	
Gas temperature	Min. Max.	10 40	°C °C	Higher temperatures should be checked in all cases!
Relative gas humidity	Max.	80	% rel.	Must be guaranteed at any temperature and supply pressure! [1)]
	Max.	50	% rel.	When using a GE Jenbacher active carbon filter at the intake of the active carbon system. Higher temperatures should be checked in all cases!
Lower calorific value	Fluctuation	≤ 4	%/min	
Methane number	Speed of change	≤ 10	MN/min	According to standard calculation method (AVL)
Hydrogen H_2	Speed of change	≤ 4	vol%/min	Especially in the case of process gases
Ignitability		The gas must not be ignitable. Take note of statutory regulations and limit levels!		

[1)] If a prechamber gas compressor is used for the prechamber gas system or if the plant is located in a tropical zone, the limit values set out in Section 5.3 apply.

5.2 Requirements and limits for the combustion air

The combustion air for GE engine plants is generally aspirated from the immediate vicinity of the plant. Ambient air when dry consists of the following gaseous constituents:

Constituent	% by volume
Nitrogen N_2	78.08
Oxygen O_2	20.95
Argon Ar	0.93
Carbon dioxide CO_2	0.04

The reference points are the standard conditions for temperature and pressure (STP), with a temperature of 273.15 K and a pressure of 101.3 kPa.

Ambient air also includes trace gases such as neon, helium and krypton.

Air always includes a proportion of water vapour as well. This depends greatly on local ambient conditions and is also aspirated into the engine.

The following measures must be observed, depending on the humidity content of the combustion air:

Humidity content in gH2O/kgAir	Effect
≤ 15	No condensate formation and therefore no influence on engine operation expected

Humidity content in gH2O/kgAir	Effect
> 15	Check the reduction diagram

The following requirements and limits are placed on the combustion air:

Requirements and limits for the combustion air

Description	Characteristic	Limitation	Unit	Note
Temperature				See TI 1100-0110
Particles Total particle content		≤ 0.1	mg/Nm³	Type 2 to 6: Purity class G3 as per EN779 J920: purity class M6 as per EN779 (previously F6) A filter in the combustion air intake protects the system against particles. The value specified is the design basis for the air filter [1)]
Highly-flammable components				Safety limits must not be exceeded. If the combustion air is not free of highly-flammable components, its usability must be agreed with GEJ.
Acid-forming and base-forming constituents				Must not enter the engine

[1)] If the filter service life stated in the maintenance plan is not reached or if the filter service life turns out to be unacceptable, the customer must take measures to improve it.

If the ambient air contains impurities (such as sulphur compounds, oil vapours, other gaseous constituents, etc.) its usability must be checked.

Care must be taken to ensure that the location where the combustion air is aspirated is not subject to any microclimate, such as warm humid zones in greenhouse applications. It must also be ensured that emissions from a wide variety of sources such as industrial air outlets, emissions from biogenous processes or solvents cannot enter the engine intake air and therefore cannot have any effect on engine operation. GEJ engine plants require a special air intake system which is described in the following Technical Instruction together with further boundary conditions:

- TI 1100-0110: Boundary conditions for GE Jenbacher gas engines

⚠ ATTENTION

Draught effect

When the engine is at rest, note that depending on the design of the intake system and the chimney draught effect, air may be permanently drawn through the engine. This means that the engine is exposed to ambient air even when shut down, which can result in damage if the air quality is poor.

5.3 Requirements and limits for the mixture

GE Jenbacher engines and plants must be protected generally against the ingress of unwanted substances into the mixture via both the fuel gas and the combustion air.

Limit values for trace substances and impurities, oil, condensate and particles

Trace substances and impurities usually enter the gas during the gas formation process, but can also come from the ambient air. They are usually impurities in the ppm range. The effects of trace substances and impurities do not become noticeable until the engine has been in operation for a certain time (cumulative effect). The same applies to oil, condensate and particles. As these effects are predominantly harmful, both the fuel gases and the ambient air should be as free as possible of trace substances and impurities. If the impurity content in the fuel gas is very high, suitable fuel gas cleaning may, under certain circumstances, be the best method of ensuring economic utilisation of the fuel gas.

To determine the suitability of a fuel gas for use in combustion engines, comprehensive knowledge of the gas analysis is required. Field experience shows that even results that were obtained under the same operating conditions can vary substantially. The effect of trace elements can therefore only be predicted to a certain extent, as very complex interrelations and cause/effect relations are often involved. In principle, the effects of trace elements are proportional to the quantity fed into the engine while it was operating. When using a fuel gas with a high calorific value, the gas flow to the engine is smaller compared with a gas with a low calorific value. As a result, the amount of trace substances introduced into the engine - and therefore their effect - differs even if there are identical concentrations of trace substances in the fuel gas. In order to be able to compare various gases, the trace substance concentration values must be related to a certain fuel gas energy amount (the fuel gas output required to generate a certain engine output is very similar for all gas types).

GE Jenbacher has therefore set the energy content of one standard cubic metre of methane as: 10 kWh (rounded off).

The combustion air requirement also depends on the fuel gas and its calorific value. This results in a specific fuel gas to air mixture ratio for the gas types, which can be seen in the Appendix.

Additional trace elements or impurities not explicitly mentioned or limited in this Technical Instruction can change the properties of the fuel gas. GE Jenbacher does not accept responsibility for reduced output, reduced efficiency, reduced availability or possible engine damage resulting from such additional trace substances or impurities. In such cases GE Jenbacher is also relieved of any and all warranty obligations.

Limit levels for trace substances and impurities [1)]

Description	Characteristic	Limitation	Unit	Note
Total sulphur	S	≤ 700	mg/10 kWh	Check the effect on the oil service life [2)]
		≤ 1200	mg/10 kWh	With limited warranty [3)]
Halogen compounds	Total Cl + 2 x F	≤ 100	mg/10 kWh	Check part-load operation [4)]
		≤ 400	mg/10 kWh	With limited warranty [3)]
Ammonia	NH_3	≤ 50	mg/10 kWh	Higher NH_3 values in the fuel gas may result in the NOx values for the engine exhaust gas stated in the specification being exceeded.
VOSC as total silicon	Total silicon as Si_{OL} (silicon operational limit value)	≤ 0.02		The operational value of silicon Si_O to be determined exactly by means of an oil analysis [5)]
Highly flammable components	Acetylene (C_2H_2)	≤ 0.02	vol%	These substances can cause uncontrolled spontaneous combustion in the system!
	Carbonyl sulphide (COS)	≤ 0.02	vol%	

[1)] The limit values quoted in the following sections apply if GE Jenbacher fuel gas or exhaust gas treatment systems are being used, or if engines are being used with a pre-chamber gas system, or if the system is installed in tropical zone countries.

[2] The oil service life is noticeably reduced above a total sulphur content of approx. 50 mg/10 kWh and/or a total halogen content of approx. 20 mg/10 kWh (refer to TI 1000-0099 B and C). If desulphurisation units are being used, note that extremely high concentrations of sulphur can enter and damage the engine very quickly when a fault occurs in such units.

This category also includes the limit values for hydrofluoric acid (HF) and hydrochloric acid (HCl). Please also refer to the sample calculation for converter gas in the appendix.

[3] Assuming a service life reduction of all engine and plant components that come into contact with the fuel gas, engine oil or exhaust gas and an increase in maintenance activities, the limits can be increased. In order to achieve a satisfactory minimum oil service life (approx. 500 Oh) a suitably large additional lubricating oil tank must be fitted, as designed by GE Jenbacher.

[4] For installations using heat recovery, care must be taken to ensure that the acid dew point in the heat recovery boiler - taking partial load operation into account - does not fall below its minimum value.

[5] When a fuel gas with traces of volatile oxidisable silicon compounds is used, it is not possible to specify a limit level in the fuel gas due to severe fluctuations and the difficulty of performing an analysis. The operational value Si_O, determined on the basis of two analyses, is the determining value for the amount of silicon fed to the engine. This must not exceed the operational limit value Si_{OL}. The calculation method is explained in the appendix.

Limit levels for oil, condensate and particles

Description	Characteristic	Limitation	Unit	Note
Particles		A filter in the gas train protects the system against particles. The filter in the gas train is not used as a work filter [6]		
Total oil content		≤ 0.2	mg/10 kWh	
Tar	CxHyRz	No tar in the intake system		Where gases (particularly wood gas) contain tar, the gas train must be fitted with a trace heating system and thermal insulation! [7]
Condensate or sublimate		No condensate and no sublimation of water or tars in components that come into contact with gas and/or mixture! [8]		

[6] If the filter service life as stated in the maintenance plan is not achieved or the filter service life is found to be unacceptable or the operation of the gas train is compromised, measures must be taken by the customer to improve the situation.

If a work filter is necessary, it must have a filtration efficiency of at least 99.99% with particle diameters greater than 3 µm.

[7] In mixtures or gases in which the hydrocarbons form solid, liquid or highly viscous products when the mixture or gas cools to below the dew point, the condensation or sublimation products are described as tar. This affects all hydrocarbons ($C_xH_yR_z$) with 6 or more carbon atoms and a molar mass (M) ≥ benzene (78.11 g/mol) with every possible substitution group (R_z).

When condensing out, tars can cause problems in the gas or mixture-side intake tract.

If tars condense or sublimate in components that are in contact with the gas or mixture, some of the problems that may arise are as follows:

- Clogging of fittings (filters, pressure regulators, solenoid valves, etc.) in the gas train
- Clogging of the gas mixer and compressor impeller on the exhaust gas turbocharger
- Clogging of the intercooler

When gases containing tar are mixed with cold combustion air, the mixture temperature must not fall below the tar dew point. In such situations, the tar dew point of the fuel gas must be correspondingly lower in order to prevent the tar condensing and/or sublimating in components that are in contact with the gas or mixture!

⚠ ATTENTION

Condensed and/or sublimated tars

Condensed and/or sublimated tars can result in a reduced service life for components, increased maintenance costs and limited engine operation as well as compromising the safety of the gas train!

[8] Condensate or sublimate in the area where gas and air are mixed (gas mixer) can sometimes also be caused by combustion air which is too cold. In this case, the problem can be remedied if the customer takes measures to preheat the combustion air, such as recirculating the room ventilation!

The absolute quantity of elements which have entered the engine is decisive when analysing the trace element content. The limit levels will be valid, assuming that the combustion air is free from impurities.

By accepting a service life reduction of all engine and system components that come into contact with the fuel gas, engine oil or exhaust gas and an increase in maintenance activities, the limits can be increased in consultation with GE Jenbacher. Moreover, additional measures, such as the design and attachment by GE Jenbacher of a supplementary lubricating oil reservoir, can help increase the minimum service life of the oil.

Additional requirements when GE Jenbacher fuel gas or exhaust gas treatment systems are used

GE Jenbacher supplies a range of designs of bespoke treatment systems which it has developed for fuel gas and exhaust gas in engine systems. In the case of engine systems that use this type of treatment system, the additional requirements for the system as a whole are as shown in the table below.

Description	Characteristic	Limitation	Unit	Note
Total sulphur	S	≤ 500 ≤ 200 ≤ 20	mg/10 kWh mg/10 kWh mg/10 kWh	When GEJ activated carbon system used When GEJ CO catalytic converter used [9] When GEJ formaldehyde catalytic converter used [9]
Halogen compounds	Total Cl + 2 x F	≤ 200 ≤ 200 ≤ 20	mg/10 kWh mg/10 kWh mg/10 kWh	When GEJ activated carbon system used When GEJ ClAir system used When GEJ CO catalytic converter or GEJ formaldehyde catalytic converter used
VOSC as total silicon	Total silicon as Si_{OL}	≤ 0.0005		When GEJ CO catalytic converter or GEJ formaldehyde catalytic converter used
Total trace substances when catalytic converter is used	The metals and heavy metals listed as examples have the effect of deactivating the catalytic converter. This reduces its service life accordingly.			
	▪ Sulphur, phosphorus, lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chromium, etc.			
	▪ The warranty will cease to apply if the cumulative volume of these elements exceeds 350g/Nm^3 of the honeycomb catalytic converter. The evidence will be provided by quantitative analysis of a used sample. The exhaust gas must, in all cases, be free of silicon compounds, such as siloxanes.			

[9] SO_2 is converted to SO_3 in the catalytic converter. As condensate forms, sulphurous or sulphuric acid is produced. Consequently, heat recovery boilers, catalytic converters and exhaust gas systems for exhaust gas temperatures < 180°C are covered by a limited warranty in the event of damage.

Additional requirements for engines with a pre-chamber gas system

The following additional limit values for the fuel gas apply to engines with a prechamber gas system.

Description	Characteristic	Limitation	Unit	Note
Total sulphur	S	≤ 200	mg/10 kWh	

Engines equipped with a pre-chamber gas system require fuel gas at a higher pressure. Changes in pressure level could result in the condensation and sublimation of trace substances in the fuel gas. If a compressor is used to increase the pressure level, the additional requirements for the compressor will apply as follows:

Additional requirements on the fuel gas when using a prechamber gas compressor for the prechamber system

Description	Characteristic	Limitation	Unit	Note
Gas temperature at prechamber gas compressor inlet	Min. Max.	10 40	°C °C	Higher temperatures should be checked in all cases! If the engine room temperature is below 30°C, trace heating and insulation of the entire gas train can be carried out to reliably avoid condensation and sublimation.
Relative gas humidity at the prechamber gas compressor intake	Max.	15	% rel.	No condensate in the gas train up to the pre-chamber gas valve!

Additional requirements on the fuel gas for applications using mine gas in tropical zone countries

Special requirements exist for mine gas applications in tropical zone countries located between latitudes 30° north and 30° south. Areas affected include Central America (including Mexico), South America (with the exception of Uruguay, Argentina and Chile), Africa, the Arabian Peninsula (including Israel), the Indian subcontinent (Pakistan, Bangladesh, India, Sri Lanka), the whole of South-East Asia (including China), Australia (north of 30° latitude) and Oceania. To prevent condensation in the components conveying fuel gas and the mixture, the following requirements apply in these countries to the operation of GE Jenbacher engine systems with mine gas.

Additional requirements in tropical zone countries located between latitudes 30° north and 30° south

Description	Characteristic	Limitation	Unit	Note
Relative gas humidity of coal mine gas	Max.	50	% rel.	No condensate in the gas train up to the gas mixer!

Requirements on the freedom from condensate of the fuel gas - air - mixture.

In addition to water vapour, many types of gas also contain other condensable substances that demand special attention. Condensation processes can adversely affect engine operation. This is particularly true in the case of gases from gasification processes, which, depending on the process and the gas treatment system, may contain condensable organic components such as tar and water-soluble naphthalene, not to mention many others. This can have potentially negative consequences, especially for the components conveying the fuel gas.

NOTE

Danger of engine damage

Experience shows that an insufficiently dry gas initially mostly causes malfunctions in the valves, devices and piping outside the engine itself. If the cause is not rectified, however, damage to the engine cannot be ruled out.

Malfunctions that occur because the fuel gases supplied are insufficiently free from condensate are not covered by our warranty. This warranty exclusion does not apply if the contractual scope of supply of GE Jenbacher expressly includes a specific fuel gas drier.

Additional information relating to freedom from condensate can be found in the Appendix.

6 Appendix

6.1 Overview of the fuel gas requirements and limits

Physical characteristics, main components and thermodynamic requirements

Description	Characteristic	Limitation	Unit	Note
Gas pressure	Fluctuation	≤ 10	mbar/s	
Gas temperature	Min. Max.	10 40	°C °C	Higher temperatures should be checked in all cases!
Relative gas humidity	Max.	80	%	Must be guaranteed at any temperature and supply pressure!
Lower calorific value	Fluctuation	≤ 4	%/min	
Methane number	Speed of change	≤ 10	MN/min	According to standard calculation method (AVL)
Hydrogen H_2	Speed of change	≤ 4	vol%/min	Especially in the case of process gases
Ignitability		The gas must not be ignitable. Take note of statutory regulations and limit levels!		

6.2 Overview of the requirements and limits for the combustion air

Description	Characteristic	Limitation	Unit	Note
Temperature				See TI 1100-0110
Particles Total particle content		≤ 0.1	mg/Nm³	Purity class G3 as per EN779 A filter in the combustion air intake protects the system against particles. The value specified is the design basis for the air filter
Highly-flammable components				Safety limits must not be exceeded. If the combustion air is not free of highly-flammable components, its usability must be agreed with GEJ.
Acid-forming and base-forming constituents				Must not enter the engine

The table shown only represents an extract. Details can be found in the individual sections.

6.3 Overview of the requirements and limits for the mixture

Description	Characteristic	Limitation	Unit	Note
Limit levels for trace substances and impurities				
Total sulphur	S	≤ 700 ≤ 1200	mg/10kWh mg/10kWh	Note effect on oil service life With limited warranty
Halogen compounds	Total Cl + 2 x F	≤ 100 ≤ 400	mg/10 kWh mg/10 kWh	Note partial load operation With limited warranty

Description	Characteristic	Limitation	Unit	Note
Ammonia	NH_3	≤ 50	mg/10 kWh	Higher NH_3 values in the fuel gas may result in the NOx values for the engine exhaust gas stated in the specification being exceeded.
VOSC as total silicon	Total silicon as Si_{OL} (silicon operational limit value)	≤ 0.02		Operational value of silicon Si_O to be determined exactly by means of oil analysis
Highly flammable components	Acetylene (C_2H_2) Carbonyl sulphide (COS)	≤ 0.02 ≤ 0.02	vol% vol%	These substances can cause uncontrolled spontaneous combustion in the system!
Limit levels for oil, condensate and particles				
Particles		-		A filter in the gas train protects the system against particles. The filter in the gas train is not used as a work filter
Total oil content		≤ 0.2	mg/10 kWh	
Tar	CxHyRz	No tar in components that are in contact with the gas or mixture		Where gases (particularly wood gas) contain tar, the gas train must be fitted with a trace heating system and thermal insulation!
Condensate or sublimate		-		No condensate and no sublimation of water or tars in components that come into contact with gas and/or mixture!
Additional requirements when GE Jenbacher fuel gas or exhaust gas treatment systems are used				
Total sulphur	S	≤ 500 ≤ 200 ≤ 20	mg/10 kWh mg/10 kWh mg/10 kWh	When GEJ activated carbon system When GEJ CO catalytic converter used When GEJ formaldehyde catalytic converter used
Halogen compounds	Total Cl + 2 x F	≤ 200 ≤ 200 ≤ 20	mg/10 kWh mg/10 kWh mg/10 kWh	When GEJ activated carbon system used When GEJ ClAir system used When GEJ CO catalytic converter or GEJ formaldehyde catalytic converter used
VOSC as total silicon	Total silicon as Si_{OL}	≤ 0.0005		When GEJ CO catalytic converter or GEJ formaldehyde catalytic converter used
Total trace substances when catalytic converter is used	The metals and heavy metals listed as examples have the effect of deactivating the catalytic converter. This reduces its service life accordingly. • Sulphur, phosphorus, lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chromium, etc. • The warranty will cease to apply if the cumulative volume of these elements exceeds 350g/m³ of catalytic converter. The evidence will be provided by quantitative analysis of a used sample. The exhaust gas must, in all cases, be free of silicon compounds, such as siloxanes.			
Additional requirements on the fuel gas for engines with a prechamber system				
Total sulphur	S	≤ 200	mg/10 kWh	
Additional requirements on the fuel gas when using a prechamber gas compressor for the prechamber system				

Description	Characteristic	Limitation	Unit	Note
Gas temperature at the intake of the prechamber gas compressor	Min. Max.	10 40	°C °C	Higher temperatures should be checked in all cases! If the engine room temperature is below 30°C, trace heating and insulation of the entire gas train can be carried out to reliably avoid condensation and sublimation.
Relative gas humidity at the prechamber gas compressor intake	Max.	15	% rel.	No condensate in the gas train up to the pre-chamber gas valve!
Additional fuel gas requirements for mine gas in tropical zone countries between latitudes 30° north and 30° south This additional requirement for mine gas applications typically applies to the countries of Central America (incl. Mexico), South America (with the exception of Uruguay, Argentina and Chile), Africa, the Arabian peninsula (incl. Israel), the Indian subcontinent (Pakistan, Bangladesh, India, Sri Lanka), the whole of South-East Asia (incl. China), Australia (north of 30° latitude) and Oceania.				
Relative gas humidity of coal mine gas	Max.	50	% rel.	No condensate in the gas train up to the gas mixer!

The table shown only represents an extract. Details can be found in the individual sections.

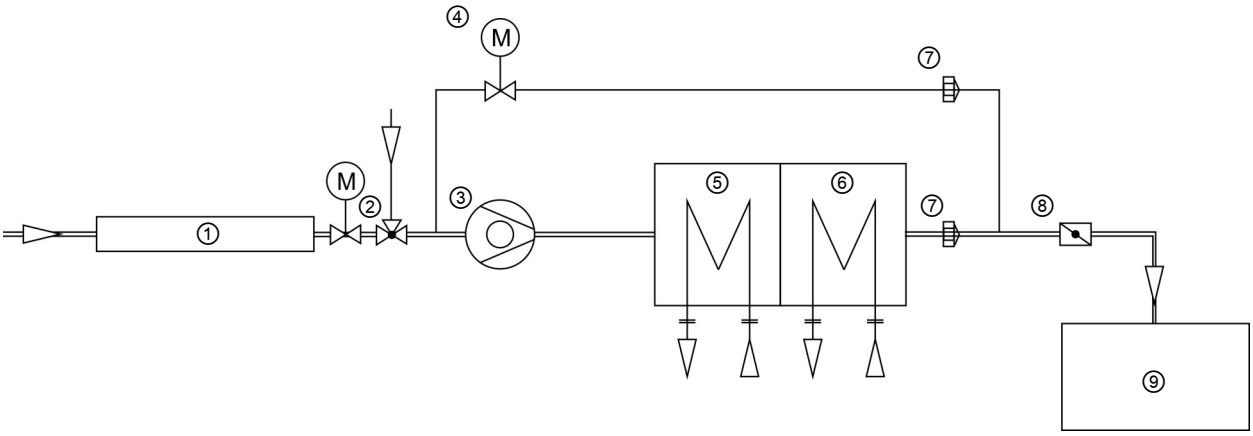
6.4 Explanation of freedom from condensate

To adhere to this TI, no condensate should form in any components conveying fuel gas or the mixture. Should condensation nevertheless occur, the following explanations may prove helpful.

The most common types of condensate formation

Gas	Condensate structure	Most common consequences for engines
Biogas, sewage gas and landfill gas	Acidic water, also as an emulsion with the lubricating oil in the gas compressor	Corrosion (→ wear)
		TAN concentration or pH reduction in lubricating oil
		Carbon deposited on valves, piston ring grooves and slots
Associated petroleum gas	Higher hydrocarbon compounds in liquid form	Film of lubricating oil washed off (seizing)
		Knocking combustion
		Edges burnt off
	Higher hydrocarbon compounds in liquid form and/or crude oil	Carbon deposits on: valves, piston ring grooves and slots
Liquid gas, propane gas	Liquid propane/butane	Film of lubricating oil washed off (seizing)
		Knocking combustion
		Edges burnt off
Gas from gasification processes, process gases	Same as all other gases	Same as all other gases

Influence on engine operation



Component	Effect	Solution	Detection
No. ① Gas train	Fouling of the gas filter, swelling of diaphragms, deposits of condensate or sublimate	Clean or replace affected parts as per maintenance instruction	Visual inspection after 10,000 operating hours (Oh) or in the event of a fault
No. ② Gas mixer	No known consequences		
No. ③ Turbocharger	Deposits on compressor wheel or diffuser	Clean as per maintenance schedule after 10,000 Oh or as required	Difficulty reaching full load / power reduction
No. ④ Turbocharger bypass valve	Clogged by tar deposits; in worst case, failure of the valve	Clean using solvent. Can be cleaned at the same time as the intercooler (10,000 Oh)	Visual inspection after 10,000 Oh or in the event of a fault
No. ⑤ Intercooler 1st stage	No known consequences		
No. ⑥ Intercooler 2nd stage	Clogged with tar deposits and condensate; possible power reduction as a result of increasing pressure loss	Clean with intercooler cleaning device	Large fall in pressure can be equalised to a certain extent using turbocharger reserves; indication: increase in boost pressure
No. ⑦ Flame trap	Clogged by tar deposits; possible power reduction	Mechanical cleaning. Can be cleaned at the same time as the intercooler (10,000 Oh)	Large fall in pressure can be equalised to a certain extent using turbocharger reserves; indication: increase in boost pressure Component temperature greater than e.g. intercooler temperature (~80-90°C)

Component	Effect	Solution	Detection
No. ⑧ Throttle valve	Clogged by tar deposits; in worst case, failure of the throttle valve	Clean using solvent. Can be cleaned at the same time as the intercooler (10,000 Oh)	Visual inspection after 10,000 Oh or in the event of a fault
No. ⑨ Engine	-	-	-

How to avoid malfunctions resulting from condensate in the fuel gas

- In general, the technical project execution department at GE Jenbacher should be contacted if condensation occurs.
- Condensation of the vapour by cooling and/or expansion.
- Mechanical separation (e.g. cyclone or separation filter) and by gas-tight discharge of the condensate.
- The fuel gas line leading to the engine must be designed not to allow the gas to continue to cool down (and also not to be expanded by resistance or downstream pressure reducers). If necessary, the fuel gas line must be insulated or provided with a trace heating system.
- In spite of the freedom from condensate found at the condensate test points, a certain amount of condensate can find its way into the engine. It is therefore very important to ensure that the condensate is as free from acid-forming components as possible. To verify this, the pH-value of the aqueous extract taken from the condensate separators must be checked. The stronger the acid, the more powerful the adverse effect is, even with condensate quantities that can hardly be verified.

⚠ ATTENTION

Skin hazards from chemical substances! Corrosive condensate

The safety instructions must be observed when draining condensate from the gas system. Wear acid-resistant gloves when handling condensate.

6.5 Check list for fuel gas quality information

General information

Name of the project or the plant	
Location (country and/or city) of the plant	
Name of the contact person	
Telephone number	
Origin of the gas	
Gas type classification: Natural gas (**NG**) Associated petroleum gas (**APG**) Biogas, sewage gas, landfill gas (**BG**) Mine gas (**CMG**) Gases from gasification processes (**GG**) Process gases (**PG**) Liquid gas, propane gas (**LG**)	

Physical properties

Gas pressure (from – to)	-	mbar(o)
Gas temperature (from – to)	-	°C
Gas relative humidity (from – to)	-	%
Atmospheric pressure (from – to)	-	mbar

Main components	**Relevant for the following gas types ***							**% by vol.**	**Measurement method**
	NG	**APG**	**BG**	**CMG**	**GG**	**PG**	**LG**		
Methane CH_4	X	X	X	X	X	X	X		
Ethane C_2H_6	X	X					X		
Propane C_3H_8	X	X			X		X		
Butane C_4H_{10}	X	X					X		
Pentane C_5H_{12}	X	X					X		
Hexane C_6H_{14}	X	X					X		
Carbon monoxide CO			X		X	X			
Hydrogen H_2					X	X			
Carbon dioxide CO_2		X	X	X	X	X			
Nitrogen N_2		X	X	X	X	X			
Oxygen O_2			X	X	X	X			
Miscellaneous	X	X	X	X	X	X	X		

Trace elements and accompanying substances	**Relevant for the following gas types ***							**Qty.**	**mg/10 kWh**	**Measurement method**
	NG	**APG**	**BG**	**CMG**	**GG**	**PG**	**LG**			
Ammonia NH_3			X		X	X				
Total chlorine			X		X	X				

Trace elements and accompanying substances		Relevant for the following gas types *							Qty.	mg/10 kWh	Measurement method
Total fluoride				X		X	X				
Prussic acid HCN						X					
Hydrogen sulphide H_2S			X	X		X	X				
Total organosilicon compounds				X							
Total sulphur			X	X		X	X				
Acetylene C_2H_2						X	X				
Carbonyl sulphide COS						X	X				
Tar	Benzene					X	X				
	Naphthalene					X	X				
	Tar dew point					X	X		Temperature	°C	
Miscellaneous		X	X	X	X	X	X	X			

Particles										
< 3 µm				X	X	X				
> 3 µm				X	X	X				
Miscellaneous	X	X	X	X	X	X	X			

* The individual positions are relevant if this component is (or can be) present in the gas. Positions allocated to a gas type are marked "X" and are required in each case.

Other information:

GE Jenbacher recommends that you only use analysis institutes with which it is familiar.

6.6 Organosilicon compounds in biogas, sewage gas and landfill gas

Organosilicon compounds

Organosilicon compounds are found in fuel gases from landfills, water purification plants and biogas installations (depending on the source of the biomass). When using these fuel gases in combustion engines, silicon oxide is produced (quartz particles), which may result in increased maintenance of the machinery and, in certain cases, in the deactivation of an exhaust gas catalytic converter.

Siloxanes, silanes and silanoles all belong to the organosilicon compound group. Siloxanes are increasingly used in cosmetics, detergents and as anti-foaming agents in industry. The other substances enter the fuel gas primarily as siloxane decomposition products. These are combustible and very volatile substances that originate from watery systems (sewage, fermenters, landfill leach water).

An assessment of the levels of organosilicon compounds in fuel gas should be carried out in the following applications:

- Gases from landfills
- Gases from sewage plants that mainly process domestic waste water
- Gases from biogas installations, depending on the origin of the biomass
- Gases from landfills where intermediate products from silicon chemical processes or other silicon-containing products are dumped, and gases from sewage plants into which silicon-containing effluent is discharged

While the tried and tested GE Jenbacher renewable active carbon system effectively removes these organosilicon compounds from sewage gas and biogas, any decision to use this cleaning technique for landfill gas should be taken on a case-by-case basis.

Determining levels of organosilicon compounds

The total of the organosilicon compounds contained in the fuel gas is used to calculate the total silicon atoms contained in the fuel gas in [mg/Nm³]. Given the the methane value, this value can be converted into the content of silicon atoms from organosilicon compounds in [mg/10 kWh].

Particularly in the case of fuel gases from landfill sites, GE Jenbacher's advice is to analyse the organosilicon compounds in the preparatory project phase in order to estimate the expected level of maintenance operations. The analysis results also provide GE Jenbacher with a framework on which to base its advice for the best gas-cleaning method, taking into account feasibility and efficiency aspects.

The sampling and analysis of organosilicon compounds in the typically occurring concentrations do not reflect the generally accepted state-of-the-art. GE Jenbacher offers its customers a tried and tested analysis technique which the company has developed itself. The sampling should only be performed by trained specialist GE Jenbacher staff.

During operation, the silicon load is determined from the silicon content of the oil. Strict maintenance of this limit value forms the basis for the validity of a service contract. This limit value does not indicate the current silicon load value, but shows the amount of silicon accumulated during the period between two oil analyses.

Requirements for sampling and the selection of the sampling location

Identifying the organosilicon compounds in fuel gas is always a reflection of the current situation at the time the sample was taken. Sample taking can only yield suitable results if the fuel gas source to be sampled meets the following criteria:

1. The sample location must be a part of the gas line with a constant gas flow and must be **free of condensate**. Up or downward pipe sections are well suited for this purpose. In case of horizontal pipe sections, the sample location must branch off upward, otherwise condensate will collect in the branches. This also falsifies the sample if the condensate has been drained off and the gas is visually dry.

2. The fuel gas supply must have been up and running without interruption for at least three (3) hours. The gas volume flow must be at least 75% of the operational gas flow that would be needed at full-load condition of the projected gas engine installation. With gas lines having a reduced flow during sampling, there is the risk of a faulty measurement when trace components condense on cold surfaces and/or when organosilicon compounds are absorbed into other condensed trace components.
3. The sampling location should preferably be in the pressurised part of the fuel gas line upstream of the projected engine is reached. However, sample taking in negative pressure lines is also possible.
4. During this period, landfill gas installations require the suction pressure to be approximately the same as the suction pressure during the projected full-load operation. Landfills which produce no gas flows in the volumes required for the projected engine operation cannot be sampled satisfactorily. In the case of landfills, suitable samples can only be taken in a gas collecting line. Sample taking from individual sources will not yield results that can be used as described in this Technical Instruction.
5. In order to achieve a fuel gas trace element load that is as constant as possible, none of the settings of the operational gas installation should be modified during sample taking.

6.7 Note about the mixture

Polluted combustion air may be used in individual cases provided that the pollutants it contains are not already present in the fuel gas in the maximum permitted concentration. Note here that the mixture ratio is dependent on the fuel gas composition and determines the specific combustion air requirement. The mixture ratio is roughly 4 for gases originating from gasification processes, and this means that the fuel gas must be mixed with approximately 4 times its volume of combustion air. The figure for this ratio for natural gas or propane is more than 20. The Table below shows approximate mixture ratios for individual gas types.

Fuel gas	**Mixture ratio of combustion air to fuel gas (approximate, depends on the project)**
Natural gas (NG)	22
Associated petroleum gas (APG)	13
Biogas, sludge gas, landfill gas (BG)	8
Coal mine gas (CMG)	10
Gases from gasification processes (GG)	4
Process gases (PG)	8
Liquid gas, propane gas (LG)	24

This shows that the ingress of harmful substances via the combustion air (with the same concentrations as in the fuel gas) can lead to significantly more severe damage to the engine.

This means that the sulphur limit of 700 mg/10 kWh applicable to fuel gas can be converted to the combustion air using the mixture ratio. For example, a sulphur limit of 88 mg/Nm³ for the combustion air can be calculated for an engine running on biogas, provided that the fuel gas is totally free of sulphur! The mixture ratio contains the conversion of [mg/10 kWh] in [mg/Nm³].

The following Appendix shows a calculation example for a plant with polluted fuel gas and polluted combustion air.

6.8 Sample calculations

Sample calculation trace substance concentration SC

$$SC = \frac{\text{Measured concentration [mg/Nm}^3\text{]}}{\text{Calorific value [kWh/Nm}^3\text{]}} \times 10$$

Concentrations are frequently indicated in volume-related quantities e.g. ppm (parts per million), which must be converted in an intermediate step to mg/Nm3 using the density under normal conditions: i.e.

$$SC' \text{ [mg/Nm}^3\text{]} = \text{Measured concentration [ppm]} \times \text{element density [kg/Nm}^3\text{]}$$

Remark: expressing the quantity as ppm (= 10^{-6}) and conversion from kg to mg (10^{+6}) cancel each other out.

Calculation example for biogas

CO_2	40%
CH_4	60%
H_2S	260 ppm (at normal density condition = 1.52 kg/Nm^3)
Lower calorific value	6 kWh/Nm3 (= 60% of 100% CH4 = 10 kWh/Nm^3)

Step 1: conversion of measured value in ppm to mg/Nm^3, referred to H_2S

SC'_1 [mg/Nm^3]= 260 [ppm] x 1.52 [kg/Nm^3] $\qquad$ SC'_1= 395 mg/Nm^3

Step 2: conversion of the value in relation to H_2S to the limited sulphur value in mg/Nm^3

$$SC' \text{ [mg/Nm}^3\text{]} = \frac{\text{Sulphur molar mass}}{\text{Molar mass of } H_2S} \times SC'_1 \qquad SC' \text{ [mg/Nm}^3\text{]} = \frac{32}{34} \times 395 \text{ [mg/Nm}^3\text{]}$$

SC'= 372 mg/Nm^3

Step 3: conversion of measured value in mg/Nm^3 to comparison value (mg/10 kWh).

$$SC = \frac{372 \text{ [mg/Nm}^3\text{]}}{6 \text{ [kWh/Nm}^3\text{]}} \times 10 \Rightarrow SC = 620 \text{ mg/10 kWh} \quad \text{actual value}$$

Without catalytic converter ⇨ SC_L= 700 mg/10 kWh $\qquad$ $SC < SC_L$ ⇨ OK

In principle, this sample calculation also applies to all limit values expressed as mg/10 kWh.

Calculation example for a plant with polluted fuel gas and polluted combustion air

The combustion air for the biogas plant in the above example contains sulphur dioxide (SO_2) in a concentration of 12 mg/Nm³.

Step 1: conversion of the value referred to SO_2S to the limited sulphur value in mg/Nm³

$$SC'' \text{ [mg/Nm}^3\text{]} = \frac{\text{Sulphur molar mass}}{\text{SO}_2\text{ molar mass}} \times SC''_1 \qquad SC'' \text{ [mg/Nm}^3\text{]} = \frac{32}{64} \times 12 \text{ [mg/Nm}^3\text{]}$$

$$SC'' = 6 \text{ mg/Nm}^3$$

Step 2: calculation of the additional sulphur ingress via the combustion air

For biogas, the mixture ratio of combustion air to fuel gas is 8. The mixture ratio contains the conversion of [mg/Nm³] in [mg/10 kWh].

SC_{air} [mg/Nm³] = SC'' x mixture ratio SC_{air} = 6 [mg/Nm³] x 8 [mg/10 kWh] / [mg/Nm³]

SC_{air} = 48 mg/10 kWh

Step 3: calculation of the total sulphur ingress

$SC_{tot} = SC + SC_{air}$ SC_{tot} = 620 [mg/10 kWh] + 48 [mg/10 kWh]

SC_{tot} = 668 mg/10 kWh

$SC_{tot} < SC_L$ ⇨ OK

Sample calculation for converter gas

Main gas components	Value	Unit
Acetylene C_2H_2	< 0.1	% vol.
Higher-value HC (> C_5H_{12})	< 0.2	% vol.
CO	67.75	% vol.
N_2	13.21	% vol.
CO_2	16.22	% vol.
H_2O	2.52	% vol.
Trace substances and impurities	**Value**	**Unit**
H_2S	80	ppm
HF	7.1	mg/10 kWh
HCl	4.0	mg/10 kWh
Gas characteristics	**Value**	**Unit**
Lower calorific value	2.38	kWh/Nm³

Hydrofluoric and hydrochloric acid

Step 1: calculation of the total quantity of chlorine

$$Cl \text{ [mg/10 kWh]} = \frac{\text{Chlorine molar mass}}{\text{HCl molar mass}} \times Cl' \qquad Cl \text{ [mg/10 kWh]} = \frac{35.4}{36.4} \times 4 \text{ [10 mg/kWh]}$$

$$Cl = 3.9 \text{ [mg/10 kWh]}$$

Step 2: calculation of the total quantity of fluoride

$$F\ [mg/10\ kWh] = \frac{\text{Fluorine molar mass}}{\text{HF molar mass}} \times F'$$

$$F\ [mg/10\ kWh] = \frac{19}{20} \times 7.1\ [10\ mg/kWh]$$

$$F = 6.7\ [mg/10\ kWh]$$

Step 3: calculation of the total quantity of halogens

$$Hal\ [mg/10\ kWh] = Cl + 2 \times F$$

$$Hal\ [mg/10\ kWh] = 3.9\ [mg/10\ kWh] + 2 \times 6.7\ [mg/10\ kWh]$$

$$Hal = 17.3\ [mg/10\ kWh]$$

Step 4: comparison of actual and setpoint value

Without catalytic converter ➔ Hal_L = 100 mg/10 kWh

$Hal < Hal_L$ ➔ OK

In principle, these sample calculations apply to all limit values indicated in mg/10 kWh.

Sample calculation of silicon operational value Si_o

Determined using two oil analyses:

Δ Si $_{\text{content in engine oil}}$: the increase of the Si content in the engine oil in ppm between two analyses, and

Δ oil service life: the operating time in hours between the two oil analyses.

$$Si_{\text{operational value}}\ [Si_O] = \frac{\Delta Si_{\text{content in engine oil}}\ [ppm] \times \text{total operating oil volume (l)}}{\text{Average engine power output [kW]} \times \Delta \text{ oil service life (h)}} \times 1.1$$

The total operating oil volume equals the oil volume in the oil pan plus the oil volume of any additional oil tanks, if installed.

Refilling volume is definitely excluded.

Sample calculation

Increase in the Si content of the engine oil between two oil samples	40 ppm
Total operating oil volume	500 l
Engine power output	2000 kW
Operational oil life between the analyses	600 h

$$Si_O = \frac{40\ ppm \times 500\ l}{2000\ kW \times 600\ h} \times 1.1$$

Si_O=0.018 actual value
Si_{OL}=0.02 $Si_O < Si_{OL}$ ⇨ OK

7 Revision code

Revision history

Index	Date	Description / Revision summary	Expert *Checked by:*
8	30.11.2015	Ergänzung „Klassifizierung – Potenzieller Kunde“ / Additional „Classification - Prospective Customers“	**Bilek** *Kelly*
		Geringfügige Änderungen (Formatierung, Terminologie, Übersetzung)/ Minor Changes (formatting, terminology, translation)	**Provin** *Nübling*
		Ergänzung Verbrennungsluft und Gemisch / Extension for intake air and mixture	**Provin** *Nübling,Wall*
7	30.04.2015	Implementierung TA 1000-0301, TA 1000-0302, TA 1400-0091 und Umbenennung Treibgasanforderungen/ Implementation TA 1000-0301, TA 1000-0302, TA 1400-0091 and renaming Fuel gas requirements	**Provin** *Nübling, Wall*
6	06.11.2014	Hinweis zur Einhaltung der Bedingungen / Information on observing the conditions	**Bilek** *Lippert*
5	06.12.2013	Verbesserte Erläuterung der Ölfüllmenge / Improved explanation of the oil capacity	**Kecht** *Wall*
4	06.09.2012	Ergänzung rechtlicher Hinweis/ legal notice added	**Provin** *Spieker*
3	13.09.2011	Grenzwerte für Staub geändert / Limit values regarding dust changed	**Provin** *Ast*
2	17.06.2010	Fußnoten geändert / footnotes changed	**Provin** *Hillen*
1	26.05.2010	Umstellung auf CMS / Change to **C**ontent **M**anagement **S**ystem ersetzt / replaced Index: **z**	**Schartner** *Giese*

1. HEAT EXCHANGER WATER SPECIFICATIONS

1.1 CHEMICAL PRESCRIPTIONS

One of the main causes that produce defects in heaters is the improper and inadequate treatment of water. Due to the great variety of particular problem is that are presented regarding the analysis of the available waters and different locations for installation, it is not possible nor practical to suggest a general system of water treatment for heat exchangers. Therefore we suggest:

- Consult a specialized technician in water treatment for heat exchangers.
- Systematically perform water analysis (see Table C and Table. D).
- Comply with technician indications to maintain the analysis values within the limits indicated.

For feed water and boiler water, we indicate:

Table 1 – Feed water for steam boiler and hot water boilers

Parameter	Unit	Feed water for steam boilers		Make-up water for hot water boilers
Operating pressure	bar	>0,5 – 20	>20	Total range
Appearance	-	Clear, free from suspended solids.		
Direct conductivity at 25 °C [1]	µS/cm	Not specified, only guide values relevant for boiler water (see Table 2)		
pH value at 25 °C	-	>9,2 [b)]	>9,2 [b)]	>7,0
Total hardness (Ca + Mg)	mmol/l	<0,01 [c)]	<0,01	<0,05
Iron (Fe) concentration	mg/l	<0,3	<0,1	<0,2
Copper (Cu) concentration	mg/l	<0,05	<0,03	<0,1
Silica (SiO_2) concentration	mg/l	Not specified, only guide values relevant for boiler water (see Table 2)		
Oxygen (O_2) concentration	mg/l	<0,05 [d)]	<0,02	
Oil/grease concentration	mg/l	<1	<1	<1
Organic substances (as TOC) concentration	-	See footnote e).		

a) With copper alloys in the system the pH shall be maintained in the range 8,7 to 9,2.

b) With softened water pH value >7,0 the pH value of boiler water according to table B should be considered.

c) At operating pressure <1 bar total hardness max 0,05 mmol/l shall be acceptable.

d) Instead of observing this value at intermittent operation or operation without deaerator if film forming agents and/or excess of oxygen scavanger shall be used.

e) Organic substances are generally a mixture of several different compounds. The composition of such mixtures and the behavior of their individual components under the conditions of boiler operations are difficult to predict. Organic substances may be decomposed to form carbonic acid or other acid decomposition products which increase the acid conductivity and cause corrosion or deposits. They also may lead to foaming and/or priming which shall be kept as low as possible.

Table 2 – Boiler water for steam boilers and hot water boilers

Parameter	Unit	Boiler water for steam boilers using			Boiler water for hot water boilers
		Feeding water direct conductivity >30 µS/cm		Feeding water direct conductivity ≤30 µS/cm	
Operating pressure	bar	0,5 – 20	>20	>0,5	total range
Appearance	-	clear, no stable foam.			
Direct conductivity at 25 °C [1]	µS/cm	<6.000 a)	See Fig. 1 a)	<1500	<1500
pH value at 25 °C	-	10,5 - 12	10,5 – 11,8	10,0 – 11,0 b-c)	9,0 – 11,5 d)
Composite alkalinity	mmol/l	1 – 15 a)	1 – 10 a)	0,1 – 1 c)	<5
Silica (SiO_2) concentration	mg/l	Pressure dependent, according to Fig. 2			
Phosphate (PO_4)	mg/l	10 - 30	10 - 30	6 – 15	
Organic substances	-	See footnote f).			

a) As a rule for good working performances and/or with super heater consider 50% of the indicated upper value as maximum value.

b) Basic pH adjustment by injecting Na_3PO_4 additional NaOH injection only the pH value is <10.

c) If the acid conductivity of th boiler feed water is <0,2 µS/cm and its Na + K concentration is <0,010 mg/l, phosphate injection is not necessary. Under the conditions AVT (all volatile treatment, feed water pH ≥9,2 and boiler water pH ≥8,0) can be applied in this case the acid conductivity of the boiler water is <5 µS/cm.

d) If non-ferrous materials are present in the system, e.g. aluminium, they may require lower pH value and direct conductivity, however, the protection of the boiler has priority.

e) If coordinated phosphate treatment is used, considering all other values higher PO_4 concentration are acceptable.

f) See note e) in table A.

Table 3 – Analysis frequency for feed water

Parameter	Unit	Frequency
pH value at 25 °C	-	72 h
Total hardness (Ca + Mg)	mmol/l	72 h
Iron (Fe) concentration	mg/l	monthly
Copper (Cu) concentration	comg/l	monthly
Oxygen (O_2) concentration	mg/l	72 h
Direct conductivity at 25 °C	µS/cm	72 h
Silica (SiO_2) concentration	mg/l	monthly

Table 4 – Analysis for boiler water

Parameter	Unit	Frequency
pH value at 25 °C	-	72 h
Composite alkalinity	mmol/l	72 h
Direct conductivity at 25 °C	µS/cm	72 h
Phosphate (PO_4)	mg/l	monthly
Silica (SiO_2) concentration	mg/l	monthly

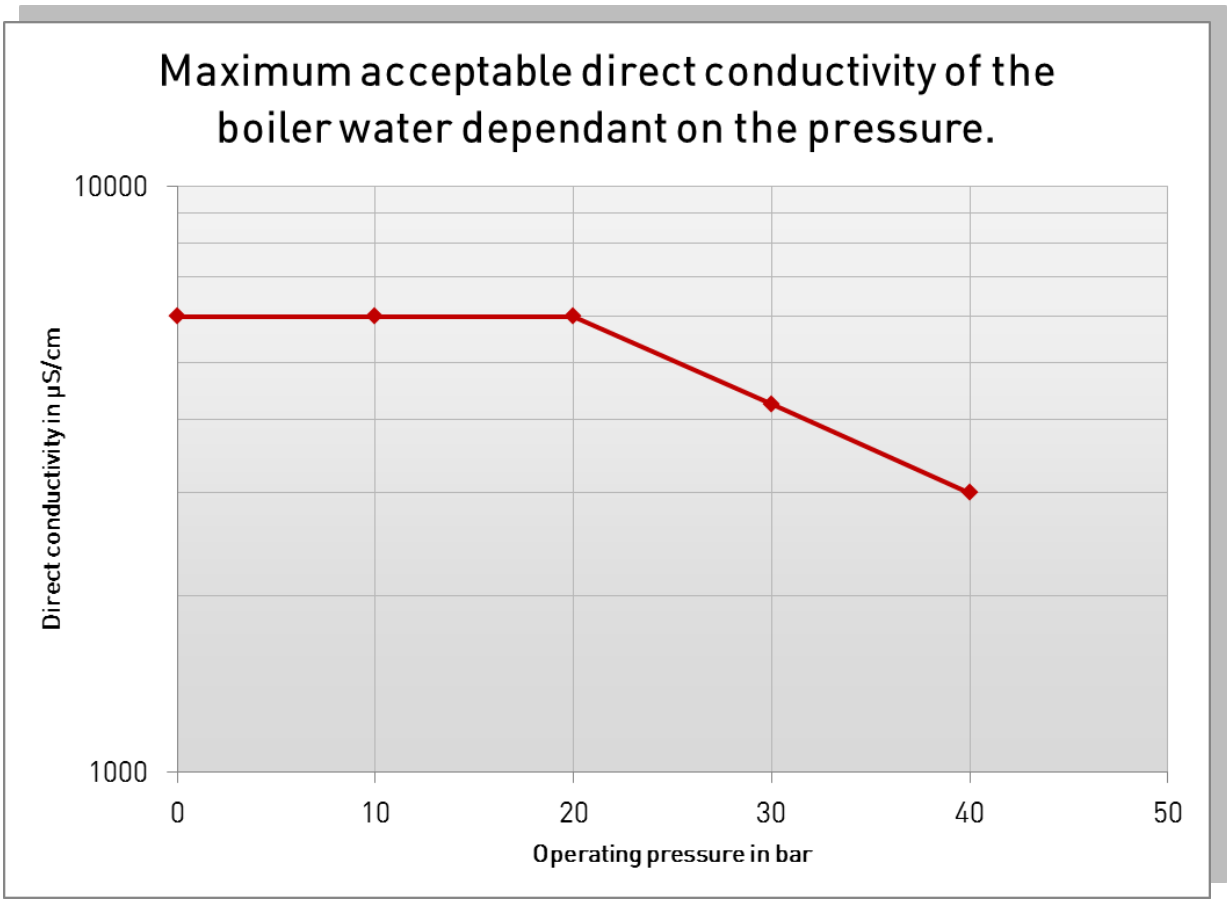


Figure 1

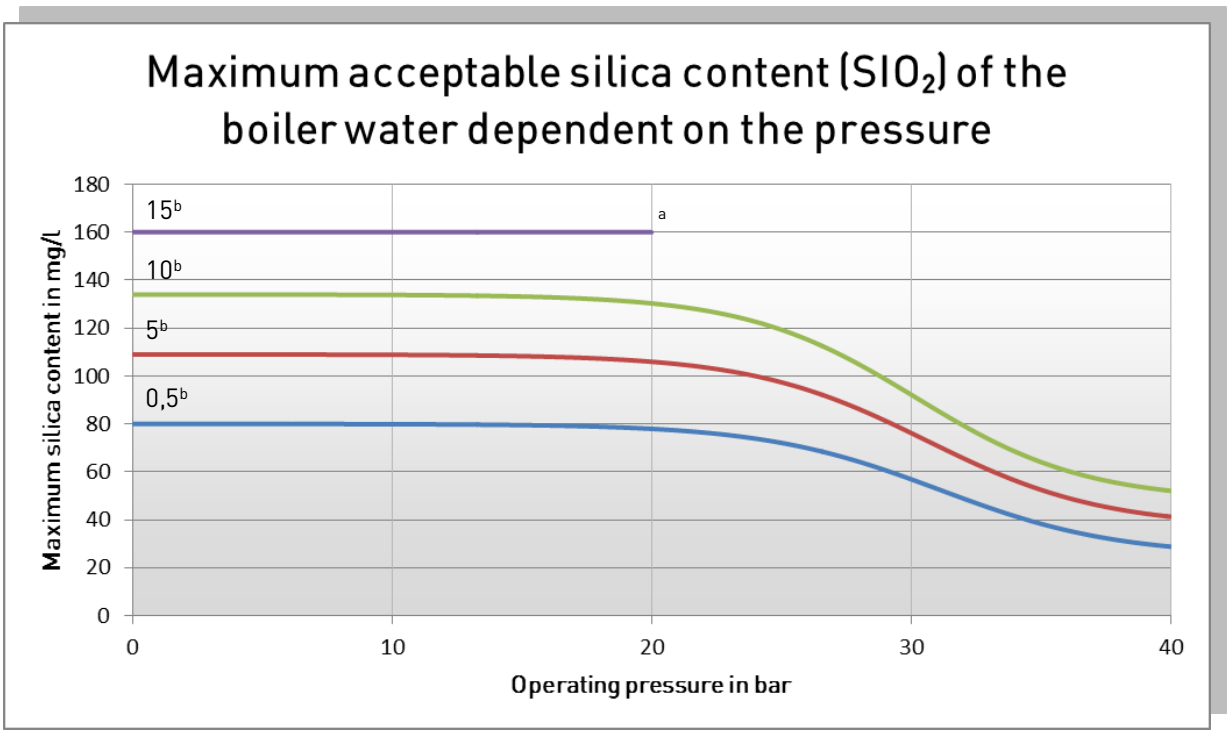


Figure 2

Note:

a – such level of alkalinity is not allowed >20bar

b – Mmol/l alkalinity

Data: 06/12/2018 Rev.: 1

Periodic checks of the boiler feed water is recommended as fouling can cause reduced performance and void the warranty.
In the event that the steam generators are fed with condensation in addition to pure and ultra-pure demineralized water, fixed alkalis-based products are prohibited. Volatile alkalis and coordinated phosphate use is allowed.

1.2 TUBED EXCHANGER DISCHARGE

In operational working conditions, the conferment of condensations going out from the exchanger and exhaust stack are expected, in the collection network, in which are currently conferred also heater condensations present in the existing central heater. The reach is about one litter during transitory phases (starting-turning off). The reach of these waters are not constant during operation and vary depending on functioning modalities of the plant.

2. SPECIFICATIONS FOR HOT WATER CIRCUIT (without glycol)

Components	Unit	Circuit limit
pH (25°C)	-	9 – 10,5
Conductivity	µs / cm	5 – 500
Turbidity	NTU	<5
M Alkalinity	ppm	<500
Chlorides (CI)	ppm	<30
Silica (SiO2)	ppm	<50
Total hardness	ppm	<5
Iron (Fe)	ppm	<0,5
Copper (Cu)	ppm	0
Ammonium ion NH4+	ppm	<0,5
Sulphates (SO_4)	ppm	<50
Oil and grease	ppm	<1
Suspended solids / sedimentable	ppm	Missing
Oxidisability	Mg/lO2	<10
NOTE: if you use glycol (min. 30%) with softened or demineralised water , you can ignore the table above.		

3. SPECIFICATIONS FOR CHILLED WATER CIRCUIT (without glycol)

Components	Unit	Circuit limit
pH (25°C)	-	7-8
Conductivity	µs / cm	5 – 500
Turbidity	NTU	<10
M Alkalinity	ppm	<500
Chlorides (CI)	ppm	<100
Silica (SiO2)	ppm	<50
Total hardness	ppm	<100
Iron (Fe)	ppm	<0,5
Copper (Cu)	ppm	<0,1
Ammonium ion NH4+	ppm	<0,5
Sulphates (SO_4)	ppm	<100
Oil and grease	ppm	<1
Suspended solids / sedimentable	ppm	Missing
Oxidability	Mg/lO2	<10
NOTE: if you use glycol (min. 30%) with softened or demineralised water , you can ignore the table above.		

4. COOLING TOWER WATER SPECIFICATIONS

Components	Unit	Circuit limit
pH (25°C)	-	7,5 - 9
Conductivity	µs / cm	50 - 1200
Turbidity	NTU	<10
M Alkalinity	ppm	75 - 500
Chlorides (Cl)	ppm	<200
Silica (SiO2)	ppm	<50
Total hardness	ppm	50 - 200
Calcium hardness	ppm	<150
Iron (Fe)	ppm	<0,5
Copper (Cu)	ppm	<0,3
Ammonium ion NH4+	ppm	<1
Sulphates (SO_4)	ppm	<200
Oil and grease	ppm	<1
Suspended solids	ppm	<25
Stability index	-	5 - 7
Local bacterial load	cfu / ml	< 10000

ATTENTION: the values refer to the water in the tower circuit
A technical assessment of the available feeding water, of treatments and of the required concentration factor should be carried out in order to define the parameter limits.

ATTENTION: In compliance with the abovementioned limits, the use of a suitable dosing system for non-persistent chemicals in the tower circuit is also recommended to prevent fouling (including biological fouling), corrosion and algae formation.

5. ENGINE SPECIFICATIONS

TA GE Jenbacher	Technical instruction
TA_1000_1109	Lubricating oil for type 2, 3, 4 and 6 GE Jenbacher engines.
TA_1100_0110	Boundary conditions for GEJ gas engines.
TA_1100_0111	Operation and maintenance.
TA_1100_0112	Installation.
TA_1000_0200	Characteristics required for closed loop water cooling.
TA_2108_0031	Generality of the island operation.
NOTE: The following manufacturer technical instructions are available on request.	

GENERAL TERMS AND CONDITIONS FOR SALE OF EQUIPMENT

Edition 03/2018

These General Terms and Conditions for Sale of Equipment (the "**Terms and Conditions**") together with the Supply Offer and all other attachments to the Supply Offer constitute the entire Agreement between AB Energy (UK) Ltd (the "**Supplier**") and the Customer (the "**Parties**" and each of them a "**Party**"). Acceptance of the Supply Offer is expressly subject to acceptance of these Terms and Conditions, and the Supplier shall not be bound, and hereby expressly objects to, any terms or conditions proposed by the Customer that are additional or different from these Terms and Conditions. Capitalized terms in any document constituting the Agreement, including those within these Terms and Conditions and within the Supply Offer, shall have the meaning as from time to time stated within these documents.

1. Equipment and Works

1.1 The Supplier, also through one or more of its Affiliates, shall perform all activities related to the Equipment including the construction, delivery, assembly, Commissioning and Final Test (the "**Works**") according to the sectors best quality standards, in compliance with the AB – Scope of Work, Technical Description and other attachments of the Supply Offer. The Supplier shall not be responsible for the accuracy of specifications, drawings and other data and/or information provided by the Customer, the Customer's employees, or the Customer's agents. For the purpose of the Agreement, "**Affiliate**" means a corporation, company, or other entity which is, now or hereafter, directly or indirectly, owned or controlled by, owning or controlling, or under common control with the Supplier.

1.2 Without prejudice to what is stated under section 1.7 below, the Supplier reserves the right to modify the AB – Scope of Work, the Technical Description and all other attachments of the Supply Offer to comply with legal requirements and to the extent that such modifications will not result in a deterioration of the quality and usability of the Equipment.

1.3 The obtainment of all Permits, as well as the performance of the Civil Works (as defined below), the operation of the Equipment, and all other activities not expressly included in the Agreement as under the Supplier's responsibility, are excluded from the Supplier's Works and, therefore, under the sole responsibility of the Customer. For the purpose of the Agreement, "**Permits**" means any permits, licenses or similar authorizations to be obtained by the Customer, necessary for the execution of the Works and required under any national, secondary, and local legislations, laws, and regulations, including amendments thereto and interpretations thereof by court decisions or administrative orders which are necessary for the design, construction, development, operation, and connection of the Equipment to the national electric grid (including any land rights).

1.4 The delivery of the Equipment and, in general, the performance of the Works, shall be carried out by the Supplier pursuant to the Project Schedule indicated in the Supply Offer. The Project Schedule shall be binding on the Supplier only upon the condition that the Customer is fully and correctly compliant with all of its obligations as indicated in the Agreement, including, by way of example, payments according to the milestones set forth under the Supply Offer. In case of any delay by the Customer in fulfilling its obligations, the Supplier shall have the right, without prejudice to any other remedy indicated in the Agreement, to modify the terms and conditions of the Supply Offer and, in general, of the Agreement including, by way of example, the Price, the payment terms and the Project Schedule.

1.5 Partial delivery of Equipment, with corresponding partial acceptance and partial invoicing, shall be permitted under the Agreement.

1.6 In case the delivery of the Equipment cannot occur at the agreed written date for any reason not related to the Supplier, starting after the 7th day of delay the Customer shall pay to the Supplier an amount equal to Euro 400.00 per each CHP unit per every day of delay for storage costs without prejudice to any other remedy indicated in the Agreement. Payment shall be made by bank transfer within 10 days from the issuance of the relevant invoice by the Supplier, before and as a condition for the delivery.

1.7 If additional works in relation to the Equipment and/or Works originally set forth in the Agreement are required (the "**Additional Works**"): (A) by the Customer in writing; and/or (B) due to changes of the Applicable Law and regulations, the Supplier shall send to the Customer an offer stating the Additional Works, related price and time needed to carry out such new activities (the "**Offer for Additional Works**"). Consequently: (i) Price adjustments shall be made by including the price for the Additional Works, and (ii) the Supplier shall be entitled to receive an extension of the Project Schedule. The Supplier shall start any Additional Works indicated in this section 1.7 only after having received the Offer for Additional Works duly signed by the Customer and provided that the Customer has fully and correctly paid the portion of the Price and any amount due to the Supplier before the beginning of the Additional Works. To the purpose of the Agreement, "**Applicable Law**" means all laws, statutes, codes, acts, ordinances, orders, judgments, decrees, injunctions, rules, regulations, directions, and requirements, including the technical and safety standards and regulations, of all governmental, regional, municipal and any other authorities enforceable on the date of the Supply Offer signature applicable to the Equipment, the Works, the Site and to the Agreement.

1.8 The progress of the Works shall be certified by the following works reports: (i) Notice of Goods Ready to Ship, sent by the Supplier upon the completion of the works in factory stating that the Equipment is ready for the delivery; (ii) Delivery on Site Report, issued by the Supplier upon the arrival of the Equipment on Site; (iii) Assembly Completion Report (*not applicable in case the installation works shall be performed by the Customer*), issued by the Supplier upon the completion of the installation Works on Site; (iv) Commissioning Reservation Notice, sent by the Customer at least 4 (four) weeks in advance in order to obtain the availability of the Supplier for the performance of the Commissioning (as defined below) indicating a date when it has to start; and (v) Final Test and Approval Report, issued by the Supplier and signed by the Customer upon the positive outcome of the Final Test (as defined below), stating the correct functionality of the Equipment in conformity with Technical Description and its acceptance.

2. Prices and Terms of Payment

2.1 The Price shall be paid by Customer at invoice date according to the milestones set forth in the Supply Offer, and all payments shall be made to the Supplier by wire transfer. The Customer shall not have any right to set-off, compensate or make any deduction (e.g. deduction of withholding taxes) from any such payment for any reason whatsoever. The obligation of Customer to make any payment pursuant to the Agreement shall be absolute notwithstanding any claim that Customer may assert against Supplier or any of its Affiliates.

2.2 Without prejudice to any other rights the Supplier may have, on any amounts due to Supplier by Customer that is not paid when due, interest shall accrue on the unpaid principal amount of such obligation beginning on the day immediately following the date on which such payment became due at the annual rate eight percentage points (8%) above the discount rate of the 6 month European Interbank Offered Rate (EURIBOR) as quoted by Reuters at 11:00 a.m. Brussels time on the banking day before the start of the relevant interest period or the higher maximum interest allowed under the Governing Law as defined in these Terms and Conditions, during the period in which payment is in arrears. The Supplier shall be entitled to such payment without formal notice.

3. Retention of Title and Passing of Risk

3.1 Title to or in any part of the Equipment and of the Works shall pass to Customer upon the receipt by the Supplier of the full payment of the Price. Customer shall take all the necessary steps under local law to make this retention of title clause known to, and valid and enforceable against, any third parties. During the whole retention of title period the Customer shall, at its costs and expenses, maintain the Equipment in its possession in perfect repair status, purchasing all necessary insurance for its protection (covering, amongst others, theft, total loss, fire, water and other risks), and undertake all measures necessary to ensure that the Supplier's title is not prejudiced.

3.2 The risk of damage to or loss of the Equipment and ancillary components shall pass to the Customer according to the Incoterms ® 2010 agreed in the Supply Offer.

4. Warranty

4.1 The Supplier warrants that the Works and Equipment shall have a clear title and be free and clear from any encumbrances, and shall be free from defects in material and workmanship ("**Defect/s**") for a period of (i) twelve (12) months from the completion of the Commissioning (as defined below) or (ii) eighteen (18) months from the Notice of Goods Ready to Ship issued by the Supplier, whichever comes earlier (hereinafter referred to as the "**Warranty Period**" and this warranty hereinafter referred to as "**Warranty**").

4.2 The Supplier warrants that it shall perform all necessary activities to remove and/or correct Defects, provided that, within 10 days of occurrence of a Defect during the Warranty Period: (i) Customer gives notice of any such Defects, (ii) Customer makes the Site and the Equipment available promptly for Supplier to correct any such Defects, whenever possible, and (iii) in any case, any request to repair Defect has been notified to Supplier, in writing, before the expiration of the Warranty Period.

4.3 For any Equipment's components or spare parts repaired or replaced at the discretion of the Supplier under this Warranty, the Warranty Period for Works and such spare parts supplied shall be renewed for a further period equal to 12 (twelve) months from the replacement or repair, provided that the Warranty for this replaced material shall in no case exceed 6 (six) months from the expiration of the original Warranty Period.

4.4 The Warranty under this section 4 shall not apply in the following events: (i) normal wear and tear on parts whose normal life expectancy is less than the Warranty Period; (ii) improper use and operation, negligence or other inappropriate application and/or interventions by the Customer and/or third parties not authorized by the Supplier (by way of example, but not limited to, in case of repeated ignition attempts of the engine without having been instructed by the Supplier); (iii) type, quality and quantity of fluids (e.g. fuel, water, oil, gas/biogas, etc.) not in conformity with the technical instructions of the engine manufacturer and of the Supplier; (iv) detrimental air inlet conditions or erosion, corrosion or material deposits from fluids; (v) occurrence of an Event of Force Majeure; and (vi) impossibility to operate the data retrieval system as indicated under section 10.4 below. The Customer acknowledges and agrees that in case of any modifications and/or alterations made by the Customer or any third party without the prior written consent of the Supplier, the Warranty granted according to this section shall automatically expire.

4.5 It is further agreed and understood between the Parties that the following items and/or services are not covered by this Warranty: (a) service supplies such as coolant, oil and any component not reusable due to needed warranty repairs; (b) all elastic, rubber, and wear materials, all types of filters (air, gas, oil, etc.), spark plugs, all parts of the ignition system (spark plug cables, etc.), batteries, any component that the Customer tries to repair directly (c) labor costs to perform the interventions; and (d) rigging costs to gain access to the Site and/or replace the Equipment. The Equipment components or spare parts required to remove and/or correct the Defects under this Warranty shall be delivered Ex Works (Incoterms ® 2010) AB Impianti S.r.l., Via Agnelli, 9 – 25034 Orzinuovi (BS), Italy.

4.6 The Supplier may require that the defective component be returned to the Supplier's factory or other designated location for inspection and/or failure analysis. In such event, the Supplier will provide the Customer a return authorization within 120 days from the notice of the Defect sent by the Customer, and the Customer shall, at its sole cost and expense, return the defective component to the Supplier as directed on the return authorization. If the defective component is not received by the Supplier within 30 days after the return authorization is provided to Customer, the Customer will be invoiced for the component or spare part repaired or replaced under this Warranty at full price, unless the Customer entered into a service contract including corrective maintenance on the Equipment with the Supplier or with any Affiliate of the Supplier.

4.7 The preceding paragraphs of this section 4 set forth the sole and exclusive remedies for all claims based on failure or Defects of the Equipment and Works provided under the Agreement, whether the failure or Defect arises before, during or after the Warranty Period, for damages of any kind, including direct damages or indirect costs, loss of profit, loss of business, indirect, consequential, exemplary or punitive damages and whether a claim, however instituted, is based on contract, indemnity, warranty, tort (including negligence), strict liability or

otherwise. The foregoing warranties are exclusive and are in lieu of all other warranties and guarantees whether written, oral, implied or statutory. The Supplier makes no other warranties, whether express, implied or statutory, including the warranty of merchantability or fitness for a particular use or purpose with respect to the Equipment or works, except as provided in these terms and conditions and in the warranty material delivered to Customer, the receipt of which Customer acknowledges by accepting delivery of the Equipment.

5. Commissioning, Final Test and Acceptance

5.1 Once the installation Works are completed, the Supplier shall carry out all the activities concerning the so called "cold tests" aimed at verifying, amongst others, the alarm chain when the engine is off, and the "hot test" to verify the functionality of the Equipment when the engine is on (the "**Commissioning**"), subject to the following conditions: (i) the Supplier has received the Commissioning Reservation Notice according to the terms and conditions set forth under section 1.8 above; (ii) availability of the gas/biogas and all other needed fluids to perform the Commissioning in conformity with the technical instructions of the engine manufacturer and of the Supplier; (iii) the Customer has timely and correctly performed any preparatory or required activity including the interconnections to the national electric grid and; (iv) the Customer has performed any and all obligations under its competence until this moment, including the payment of the portion of the Price due and outstanding under the Agreement.

5.2 In case for causes not attributable to the Supplier (e.g. failure to send the Commissioning Reservation Notice, no availability of the gas and/or biogas in quantity and quality indicated in the Agreement, and/or not availability of the electricity, and/or not completion of the interconnection activities, etc.) the Commissioning cannot be carried out by the Supplier within (i) 30 days from the completion of the installation Works, if such works shall be carried out by the Supplier or (ii) within 60 days from the arrival on Site of the main components of the Equipment on Site in case the installation works shall be performed by the Customer, the following shall apply: (a) the remaining portion of the Price, if any, shall be immediately due to the Supplier; (b) the Warranty Period as set forth under section 4.1 shall start; (c) the Customer shall pay all costs and expenses incurred by the Supplier to attend the new Commissioning (e.g. travel, accommodation, etc.) which shall be performed at the date agreed provided that the issuance of the Commissioning Reservation Notice has been received by the Supplier at least 4 (four) weeks in advance.

5.3 Upon completion of all Commissioning activities, the Supplier shall convene the Customer, communicating the date of the performance of all tests aimed at verifying the compliance of the Equipment with the Technical Description (the "**Final Test**") for the final acceptance of the Equipment.

5.4 The Works and the Equipment shall be immediately accepted by the Customer at the positive outcome of the Final Test, upon confirmation of the Equipment's conformity to the Technical Description. In such a case, the Parties shall sign the Final Test and Approval Report within maximum 1 day from the completion of the Final Test, and any portion of the Price, if any, shall be immediately due to the Supplier.

5.5 The Equipment and the Works shall be deemed automatically accepted and therefore the Final Test positively executed, the risk of damage or loss of the Equipment transferred (if not already occurred) and any portion of the Price, if any, shall be immediately due to the Supplier, in the following cases: (i) the Equipment and the Works meet the Technical Description during the Final Test and within 1 day the Customer does not sign the Final Test and Approval Report; and/or (ii) if the Final Test cannot be carried out within 10 days from the invitation sent by the Supplier, for causes not attributable to the Supplier (e.g. the Customer does not attend the Final Test, and/or not availability of the gas and/or biogas, and/or of the electricity); and/or (iii) if the Equipment runs for 2 consecutive days from the beginning of the Final Test without the Customer officially raising in writing any objection nor notifying any Punch List Works (as defined below) to the Supplier. In all of these cases, the Supplier shall (a) issue to the Customer a certificate stating that the Equipment has been deemed accepted by the Customer according to this section, and (b) reserve the right to switch off the engine(s) should the Customer not pay within 1 day the remaining portion of the Price.

5.6 If during the Final Test, the Customer discovers any defects or deficiencies that do not compromise the safe operation or use of the Equipment in accordance with the provisions provided for in these Terms and Conditions and Applicable Law, then the Customer is not entitled to refuse signing the Final Test and Approval Report, provided that the Parties have previously agreed to perform the necessary works still missing (the "**Punch List Works**"). In such a case, the Parties shall sign the Final Test and Approval Report and then decide the time for the completion of the Punch List Works which, in any case, shall not be less than 120 days from the date of issuance of the Final Test and Approval Report.

6. Force Majeure

6.1 Except for payments due to Supplier, if by any reason of any Event of Force Majeure either of the Parties to this Agreement shall be delayed in, or prevented from, performing any of its duties or obligations under this Agreement then the affected Party's performance shall be excused and the time for performance shall be extended for the period of delay or inability to perform due to such occurrence and such delay or non-performance shall not be deemed to be a breach of this Agreement and no loss or damage shall be claimed by either of the Parties hereto from the other by reason thereof.

6.2 In the case of such an Event of Force Majeure, the prevented Party shall notify the other Party by the most expedient means available (express mail being acceptable in any event) without any delay, and within 15 days thereafter provide detailed information of the events and explain the reason for its inability to perform or delay in the performance of all or part of the Agreement.

6.3 To the purpose of the Agreement, "**Event of Force Majeure**" means any event which is beyond the reasonable control of a Party or its subcontractors, which could not have been prevented by good industry practice and which results in a Party being unable to perform or being delayed in performing in whole or in part its obligations under the Agreement, and it shall include but not be limited to earthquake, typhoon, adverse weather conditions (e.g. heavy rain and/or snow and/or wind, critical temperature, etc.), epidemics, fire, flood, casualty, lockout, strike, labor disputes, unavoidable accident, breakdown of equipment, any disruption to manufacturing and/or delivery

services of Supplier, Supplier's Affiliates or authorized suppliers or their suppliers, subcontractors and/or agents, act of war, act of the public enemy, act of terrorism, national calamity or riot, any cause or event arising out of or attributable to war, or any other unforeseen event the happening and consequences of which are reasonably unavoidable.

7. Customer's Obligations

7.1 The Customer shall perform all obligations under the Agreement according to the terms and conditions set forth in the same Agreement, being understood that shall fall under Customer's responsibility also the activities and supplies performed by third parties directly and/or indirectly related to it. The Customer shall pay to the Supplier the higher costs incurred by the latter deriving from the non-fulfilment or breach of the Agreement's provisions which are attributable to the Customer and/or to third parties related to it.

7.2 Without prejudice to what stated under previous article 7.1, Customer's duties and obligations under the Agreement shall include the following:

a) Correctly and timely (i.e. completed at least 2 months before the arrival on Site of the main components of the Equipment) carry out the building works concerning the realization of the platform over which shall be installed the Equipment, according to the building directions, sizing and loading information given by the Supplier (the "**Civil Works**"), as well as any other activity to be performed at the Site (including, amongst others, the interconnections to the national electric grid);

b) upon the Supplier's request, make appropriate areas for the storage of the materials available to the Supplier, and take care of the surveillance of such areas, as well as custody of the Equipment and materials (also through adequate dedicated insurance policies, the evidence of which shall be given to the Supplier);

c) obtain and keep in force for the entire duration of the Agreement, all Permits and authorizations related to the Site and necessary to assembly and operate the Equipment (dealing with any Governmental Authority in charge), including but not limited to any health and safety rules or occupational rules falling under the Applicable Law or State program related, or environmental requirements;

d) ensure to the Supplier and its subcontractors free access at the Site and at the area where the Equipment is going to be located and the corresponding entry routes;

e) timely and correctly comply with payment terms as set forth in the Supply Offer and pay any sum due in accordance with the Agreement;

f) provide the Supplier, free of charge, with internet line at Site (including the internet connection to the Equipment 24 hours per day for 7 days of the week, for the Supplier's remote monitoring), as well as with fuel gas in quantity and quality compliant with the "TA 1000-0300 Fuel Gas Quality" issued by the engine's manufacturer, electrical power, water, fluids such as oil, glycol, urea, battery acid, gear box oil, and drinkable water required by Supplier's or subcontractor's workers, needed during the execution of the Works, etc., and everything necessary to let the Supplier perform the Works (including Commissioning and Final Test activities);

g) provide the Site free from any hazardous material and/or hazardous waste, and take care of waste disposal at Site;

h) carry out all other necessary activities not included in the Supplier's Works.

8. Health and Safety

8.1 Before starting the Works at Site, Supplier will provide Customer with its health and safety policy and Customer shall inform Supplier if such policy is compliant with any health (including environmental), safety, and security procedure, requirements, and measures at Site, or environmental requirements according to the Applicable Law to be followed by the Supplier during the Works. In doing so, therefore, Customer shall inform Supplier on its safety practices, proper and safe handling of hazardous substances and protection of Supplier's personnel from exposure thereto. If, in Supplier's opinion, the safe execution of the Works is, or is apt to be, imperiled by local conditions at Site, Supplier shall be entitled to remove some or all of its personnel from the Site and/or suspend performances of all or any part of the Works and/or evacuate its personnel, without being considered in delay in the Project Schedule for this reason. Customer shall assist the Supplier in said evacuation.

8.2 The operation of the Equipment at the Site is under the responsibility of Customer. If Customer requires or permits Supplier's personnel to operate the Equipment at the Site, Customer shall indemnify and hold the Supplier, its Affiliates, employees and agents, harmless from expense and liability (including legal fees) incurred by or imposed upon Supplier, its employees, agents and/or Affiliates, arising from injury (including death), or property damage resulting from the operation and management of the Equipment by Supplier's personnel.

9. Liability of Supplier

9.1 The Supplier is liable (i) for the Equipment construction, installation (if applicable) and Commissioning in compliance with the Technical Description; (ii) to comply, also with reference to its staff and subcontractors, with the safety and environment regulations in force at the Site; and (iii) to perform all activities as set forth in the Supply Offer, in these Terms and Conditions, and in the Technical Description.

9.2 Any other or further claims, rights and remedies of the Customer against the Supplier that are not expressly stipulated in these Terms and Conditions shall be excluded, irrespective of the legal theory they are based on (e.g. in contract or tort or under warranty). In particular, the Supplier shall in no event be liable for special, incidental, indirect and/or consequential damages, loss of profit, loss of use, business interruption, loss of interest, capital cost, increased operating cost, loss of information and data and damages also based on claims by other contractual partners of the Customer. Supplier shall not be liable for any amounts otherwise covered by applicable insurance proceeds payable to Customer.

9.3 Any and all damages caused by Force Majeure as well as by the Customer or any third person are excluded from the Supplier's liability.

9.4 Any and all physical damages to goods and property of the Customer and/or its subcontractors' and/or sub-suppliers' and/or any third party caused by the Supplier, shall be paid by the same Supplier within the limits of the amounts paid by the insurance company of the Supplier and in any case limited to the lesser of:

a) the actual direct costs incurred by the Customer in repairing the property damage, to be substantiated to the reasonable satisfaction of Supplier;

b) the amount of the Customer's property damage insurance deductible applicable to such loss; and

c) Five Hundred Thousand Euro (EUR 500,000.00) per event,

and shall be further limited to Two Million Euro (EUR 2,000,000.00) in the maximum aggregate.

9.5 Notwithstanding anything to the contrary contained in the Agreement, in no event shall the Supplier's total aggregate liability under any theory of recovery (including reimbursement of costs incurred by the Customer), exceed 10% (ten percent) of the price, whether arising by way of indemnity, in contract, in tort (including negligence) or otherwise, under or in connection with the Agreement.

9.6 The limitations of liability set forth in the Agreement shall not apply in case of mandatory liability by law or in case of willful misconduct or gross negligence of the Supplier.

9.7 Any limitations of liability set forth in the Agreement shall also apply for the benefit of the Supplier's Affiliates, subcontractors, employees, directors or agents.

9.8 Any and all liability of the Supplier under the Agreement shall cease with the expiry of the Warranty Period.

10. Intellectual Property and Proprietary Technology

10.1 The Supplier is the sole owner of any intellectual proprietary rights, trade-secrets, know-how and technology (the "**Supplier's Right/s**) incorporated into the Equipment and Works. The Agreement cannot be construed as granting to the Customer and/or to the end user (if any) any express or implied title, right and interest over the Supplier's Rights.

10.2 Save as may be strictly necessary for the operation and maintenance of the Equipment, the Customer shall not be entitled to copy, alter, modify, reverse engineer, or attempt to derive the composition or underlying information, of the Equipment, the Supplier's Rights or any of their parts.

10.3 In the event a third party asserts legitimate claims against the Customer because of an infringement of a third party's intellectual property right related to the Equipment and/or used by the Customer in conformity with the Agreement, the Customer shall immediately notify the Supplier in writing of such claims, being understood that upon the receipt of such notice, the Supplier is given sole control of the defense and the sole right to compromise and settle such claims.

10.4 The Customer, also on behalf of the end user, if any, shall grant to the Supplier, its Affiliates and/or suppliers, with a non-exclusive, sublicensable, royalty-free worldwide license to access, collect, operate, store, and use, through a data retrieval system, all data and information, including operating data, concerning and/or generated by the Equipment ("**Data**").

11. Assignment and Subcontract

11.1 The Customer shall not be entitled to assign the Agreement or Supplier's Rights as a whole, or as individual rights or obligations thereof, to any third parties without the Supplier's prior written approval.

11.2 By executing the Supply Offer, Customer authorizes Supplier to assign the whole Agreement or a part of it, and/or to subcontract the Works to any of its Affiliates.

12. Confidentiality and Non-use Obligations

12.1 Customer shall keep confidential and secure all Confidential Information including, without limitation, the Supplier Rights belonging or relating to Supplier or its Affiliates. To the purpose of the Agreement, "**Confidential Information**" means any and all information, data, notes, records, agreements, documents, in any form, disclosed by the Supplier to the Customer or, in any case, obtained by the Customer and related to the performance of the Works including, without limitation, all technical, commercial and contractual documentation related to the Works and Equipment and their object, as well as every document of a commercial nature or any financial data, data related to prices and know-how, forms, industrial processes, records, photographs, drawings, contractual conditions, prices, software, clients, programs and models and all other intellectual property belonging to the Supplier or, in any case, referring to the Supplier.

12.2 The Customer shall not: (a) make any use of the Confidential Information other than what is strictly necessary to perform its obligations under the Agreement; and (b) disclose the Confidential Information to any third parties (including competitors), or permit or encourage the use of such Confidential Information by any third party.

12.3 Customer shall, at Supplier's written request or on termination of the Agreement for any reason, immediately return to Supplier all copies and other records of such Confidential Information and destroy any records that cannot be returned and confirm such destruction in writing to the Supplier.

12.4 The Customer's confidentiality obligation under this section 12 shall survive the expiration or termination of the Agreement for a period of 5 (five) years.

13. Suspension

13.1 The Supplier shall be entitled to suspend the performance of the Works until Customer becomes current on its contractual obligations, if: (a) without prejudice to what stated under section 2.2, the Customer is in delay with any payment for more than 10 days; (b) the Supplier has serious grounds to believe that, due to reasons that occurred after the signature of the Supply Offer, payments will not be effected timely or in full, unless the

Customer provides sufficient securities acceptable for the Supplier; (c) the Supplier finds hazardous substances and materials at Site or the Site is non-compliant with any health and safety local regulation or State occupational health and safety regulations or any environmental laws and regulations, real estate or other regulatory issues under the Applicable Law; (d) the Customer fails to perform one or more of its obligations under the Agreement; or (e) delivery of the Equipment and/or completion of the Works is prevented by temporary suspension of import/export licenses or other legal restrictions for more than 6 months.

13.2 In the event the Supplier suspends any part of the Works and/or in case the Customer at its discretion decides to suspend the Agreement, without prejudice to the Supplier's right to keep the portion of the Price already paid by the Customer: (i) the Customer shall pay to the Supplier the portion of the Price due for the Works already performed until the date of the suspension (including that portion of the Price related to any components and materials ordered even if not delivered), and (ii) the Customer shall pay to the Supplier all additional costs and expenses incurred as a result of such suspension (e.g. payments to subcontractors, cost of waiting time, demobilization and remobilization, legal fees, collection costs and court costs, damages suffered, etc.), and (iii) such a suspension shall result in an adjustment of the Project Schedule as communicated by the Supplier.

14. Indemnification

Customer shall indemnify and hold the Supplier and its Affiliates harmless from and against any loss or expense by reason of physical damage to the property of third parties or bodily injury, including death, of persons to the extent such damage or injury results directly from a breach of the Agreement, or the negligence of Customer or any of its agents and subcontractors. In case of installation works performed by the Customer, the Customer shall indemnify and hold the Supplier and its Affiliates harmless from and against any claim, proceeding, action, fine, loss, cost and damages arising out of or relating to such installation works, and the Customer shall compensate the Supplier for all losses and expenses resulting thereof.

15. Termination

15.1 Either Party shall be entitled to terminate the Agreement by written notice: (i) if the other Party becomes insolvent or has bankruptcy, composition or reorganization proceedings or any other insolvency proceedings opened against it by a court or another public authority, has an order entered against it either appointing a receiver or trustee or issuing a levy or attachment against a substantial portion of its assets, without this order being vacated, set aside or stayed within 45 days from the date of entry, voluntarily files a petition under the bankruptcy or equivalent insolvency law, consents to or applies for reorganization under bankruptcy or insolvency law or makes an assignment for the benefit of its creditors; and/or (ii) if a Force Majeure Event occurs and its effect continues for a period exceeding 120 days.

15.2 Without prejudice to the Supplier's rights under sections 2.2 and 13 of these Terms and Conditions, if the Customer fails to make any payment due under the Agreement, the Supplier will promptly notify the Customer thereof granting 30 days to remedy such default. If upon expiration of the remedy period, the Customer has not made the payment the Supplier shall be entitled to terminate the Agreement by written notice with immediate effect.

15.3 Supplier shall be entitled to terminate the Agreement in case of Works stoppage for over 60 days due to causes not attributable to the same Supplier.

15.4 In any event of termination of the Agreement and/or in any case of its cancellation after the signature of the Supply Offer (including the cases of withdrawal of the Customer), without prejudice to the Supplier's right to keep the portion of the Price already paid by the Customer, the following shall apply: (i) the Customer shall pay the remaining portion of the Price related to the Works already performed until the termination and all additional costs and expenses incurred as a result of such termination (e.g. any components and materials ordered even if not delivered, payments to subcontractors, cost of waiting time, demobilization and remobilization, legal fees, collection costs and court costs, damages suffered, etc.); (ii) once received said payment, the Supplier shall transfer to the Customer the title of the Works and Equipment in proportion to the amount of the Price paid, as well as all documents related to the Equipment and prepared by the Supplier and its subcontractors; (iii) the Supplier and/or the Customer, depending on who is attributable the termination, shall remove all materials and components from the Site, including any debris and waste generated during the Works.

16. Governing Law and Jurisdiction

16.1 The Agreement shall be governed and interpreted under the laws of Italy, without regard to conflict of laws principles or any choice of law rules that would cause the application of laws of any other jurisdiction.

16.2 All disputes arising in connection with the Agreement shall be settled, if possible, by negotiation between the Parties. If the matter is not resolved by such negotiations within 30 days, the dispute shall be submitted to the exclusive Court of Milan (Italy).

17. Export Regulations

17.1 The Supplier's obligation to fulfil the Agreement is subject to the provision that the fulfilment is not prevented by any impediments arising out of national and international foreign trade and customs requirements or any embargos or other sanctions. If the Customer transfers Works and/or Equipment or parts of them delivered or performed by Supplier to a third party, the Customer shall comply with all applicable national and international re- export control regulations.

17.2 Prior to any transfer of Works and/or Equipment provided by the Supplier to a third party the Customer shall in particular guarantee that: (a) there will be no infringement of an embargo imposed by the European Union and/or by the United States of America and/or by the United Nations, also considering the limitations of domestic business and prohibitions of by-passing; (b) the Works and/or Equipment are not intended for use in connection with armaments, nuclear technology or weapons, if and to the extent such use is subject to prohibition or authorization, unless required authorization is provided; (c) the regulations of all applicable sanctioned party lists

of the European Union and the United States of America concerning the trading with entities, persons and organizations listed therein are considered.

17.3 The Customer shall indemnify and hold the Supplier and its Affiliates harmless from and against any claim, proceeding, action, fine, loss, cost and damages arising out of or relating to any noncompliance with export control regulations by the Customer, and the Customer shall compensate the Supplier for all losses and expenses resulting thereof, unless such noncompliance was not caused by fault of the Customer.

18. Miscellaneous

18.1 Any communication requested or consented in relation to the Agreement must be made in writing and shall be sent to addresses indicated in the Supply Offer.

18.2 The commencement of the Supplier's performance of the Works set forth in the Agreement is subject to the final positive outcome of the compliance check made by the Supplier and its major components' manufacturers, concerning, amongst others, their internal policy and procedures such as "know your customer" process, and/or ethical and geopolitical compliance (the "**Compliance Check**"). Should the Compliance Check not be positive, the Supplier shall timely inform the Customer and it shall take, at its discretion, the necessary steps to proceed with the transaction. In case for some reasons the Supplier shall not succeed in this within seven months, the Agreement shall terminate and therefore, with reference to the Parties' liabilities, it is considered as if it had never been stipulated.

18.3 Customer and Supplier are each independent of the other and are not joint ventures, partners, agents, nor representatives of each other, and have no legal relationship other than as contracting Parties to the Agreement. Nothing herein shall be construed to create the relationship of employer and employee, principal and agent, partnership or joint venture, or any other fiduciary relationship among the Parties.

18.4 No modification, amendment, rescission, waiver or other change shall be binding on a Party unless agreed in writing by that Party. The Agreement represents the entire agreement between the Parties. Any oral or written representation, warranty, course of dealing or trade usage not contained or referenced herein shall not be binding on either Party. Each Party agrees that it has not relied on, or been induced by, any representations of the other Party not contained in the Agreement.

18.5 No delay on the part of any Party in the exercise of any right or remedy shall operate as a waiver thereof, and no single or partial exercise by any Party of any right or remedy shall preclude other or further exercise thereof or the exercise of any other right or remedy.

18.6 Whenever possible, each provision of these Terms and Conditions and of the Supply Offer shall be construed and interpreted in such a manner as to be effective and valid under Applicable Law, but if any provision of the Terms and Conditions and/or of the Supply Offer or the application thereof to any Party or circumstance shall be prohibited by or invalid under Applicable Law, such provision shall be ineffective to the extent of such prohibition without invalidating the remainder of such provision or any other provision of these Terms and Conditions and/or of the Supply Offer or the application of such provision to other parties or circumstances.

18.7 The Customer hereby authorizes the Supplier and/or any of its Affiliates to include the Customer's and Equipment's data in any advertising, promotional or public relations materials issued or created by Supplier and/or any of its Affiliates for marketing purposes. The Supplier and/or any of its Affiliates may reproduce Customer's trademarks in any such advertising, promotional or public relations materials without consideration.

18.8 The Supplier and/or any of its Affiliates may organize visits to the Equipment upon prior agreement with the Customer.

SUPPLY OFFER

AB ENERGY (UK) LTD
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EC3V 9DF London (UK)
T. +39 030 94 00 100
VAT: GB 185213904
e-mail: gary.collins@gruppoab.com

FOR

INFINITE RENEWABLES GROUP LIMITED

Number 1 Waterton,
Bridgend, Wales
CF31 3PH
T: +44 (0)1656 644 477
VAT registration no. 242362136
(the "**Customer**")

Site of installation: The Royal Mint, Llantrisant, Pontyclun, CF72 8YT, United Kingdom (to be confirmed)

Date: 16/04/2020
Our Offer No. QUO-07412-T3C2T0

1. SCOPE

This supply offer (the "**Supply Offer**") issued by AB Energy UK. ("**AB**"), includes the engineering, designing, supply, installation, Commissioning and Final Test of one Ecomax 20 NGS (the "**Equipment**"), as better described in the table attached to this Supply Offer (the "**AB – Scope of Work**") and in the AB technical specifications (the "**Technical Description**").

The Equipment shall be installed at The Royal Mint, Llantrisant Pontyclun, CF72 8YT, United Kingdom (the "**Site**").

The supply of the Equipment shall be carried out by AB pursuant to the "**Agreement**", which includes the following documents: (i) this Supply Offer, (ii) the AB – Scope of Work, (iii) the AB General Terms and Conditions for Sale of Equipment (the "**Terms and Conditions**"), (iv) the Technical Description, and (v) all other attachments of this Supply Offer.

2. PRICE

The total price that the Customer shall pay to AB for the Equipment is equal to fixed price **GBP 853,600.00 + VAT** (if applicable) (the "**Price**"), calculated considering an exchange rate EUR/GBP of 0.88.

The Price includes all goods and services as specified in the Agreement, under the conditions mentioned therein, including all activities related to the Commissioning for a number of days, trips and personnel as indicated in the AB – Scope of Work or in the Technical Description.

The Price does not include (i) any taxes (including withholding taxes, if any), duties and any other fee applicable in the Country of the Customer and/or of the Site, and (ii) any costs relating to bank guarantees and/or costs for insurance coverage, if any.

3. PAYMENT TERMS

Payment Milestone	Percentage of Price	Payment Term	Payment Method
M1	20%	Down-payment within and not later than 5 days from the signature of this Supply Offer.	Bank transfer, invoice date
M2	30%	Upon receipt of the Notice of Goods Ready to Ship.	Bank transfer, invoice date
M3	30%	At the issue of the Assembly Completion Report and, in any case, within 60 days from the Notice of Goods Ready to Ship, whichever comes earlier.	Bank transfer, invoice date
M4	20%	Upon the signature of Final Test and Approval Report and, in any case, within 90 days from the Notice of Goods Ready to Ship, whichever comes earlier.	Bank transfer, invoice date

To guarantee the delivery on Site of Equipment, AB shall provide the Customer with an irrevocable on first demand bank guarantee/stand-by letter of credit issued by a leading bank, for an amount equal to M1 (the "**Advance Payment Bond**"). The validity of the Advance Payment Bond shall start upon the receipt of the payment of M1 by AB and shall expire at the delivery on Site of the Equipment.

To guarantee the correct and full payment of the Price, the Customer shall provide AB, upon receipt of the Notice of Goods Ready to Ship and in any case as a condition for the delivery of the same Equipment, with an irrevocable on first demand bank guarantee/stand-by letter of credit acceptable for AB, for an amount equal to the remaining payment milestones due after the shipment (the "**Payment Security**"). The validity of the Payment Security shall start upon receipt of the Notice of Goods Ready to Ship and in any case before the shipment of the Equipment and shall expire upon the receipt by AB of the full and correct payment of the Price.

All payments shall be made by the Customer in GBP at the bank account details stated in the relevant invoice.

4. DELIVERY TERMS (INCOTERMS ® 2020)

DUP at The Royal Mint, Llantrisant, Pontyclun, CF72 8YT, United Kingdom.

Also for the application of article 5 and 12, the Customer acknowledges that Equipment will be manufactured and shipped from Italy.

5. PROJECT SCHEDULE

AB shall perform the activities set forth in the Agreement according to the following project schedule (the "**Project Schedule**"):

Activity	Term
Delivery DUP	Within 7 months from the receipt of M1 by AB
Assembly Completion	Within 30 days from the arrival of the main components of the Equipment on Site
Beginning of Commissioning	After the signature of the Assembly Completion Report but, in any case, not earlier than 4 weeks from the AB receipt of the Commissioning Reservation Notice sent by Customer
Final Test	Within 4 weeks from the completion of the Commissioning

It is agreed and understood between AB and the Customer that the Project Schedule above indicated is binding on AB only upon the condition that the Customer is fully, timely and correctly compliant with all of its obligations indicated in the Agreement, including the payment of the Price pursuant to the payment terms indicated under section 3 above.

In case of any delay by the Customer in fulfilling its obligations, AB shall have the right, without prejudice to any other remedy indicated in the Agreement, to modify the terms and conditions of this Supply Offer including, by way of example, the Price, the payment terms and the Project Schedule.

The Parties expressly acknowledge that, at the time of the conclusion of this Contract, the COVID19 pandemic event is ongoing at worldwide level ("**Pandemic**") and that the Italian Government as well as the Government of the other states interested by the Pandemic have issued, and may issue in the future, orders that provide for the shutdown of industries, productions, services and activities, inclusive of worksite activities, and/or impose restrictions to the possibility for goods and people to move and travel ("**Orders**").

Therefore, in consideration of the objective impossibility for the Parties to predict: (i) the duration of the Pandemic and of the Orders, and (ii) the actual impact of the Pandemic and of the Orders on the industrial activities of AB and of AB suppliers, the Client acknowledge to AB the right to obtain a prorogation of the terms of the Project Schedule above, and of the Price or other terms of this Contract, being understood that AB shall undertake any reasonable action directed to avoid or to minimize any changes to the Contract.

6. WARRANTY

AB warrants that the components and the whole Equipment have been manufactured pursuant to the Technical Description and with the sector best quality standards, as better specified in the Terms and Conditions.

AB warrants the Works and Equipment for a period of 12 months from the completion of the Commissioning, or 18 months from the Notice of Goods Ready to Ship, whichever event comes earlier, as better defined in the Terms and Conditions.

7. STAFF TRAINING

This Supply Offer also includes staff training to the personnel indicated by the Customer (two employees) which shall be in charge for the operation of the Equipment, for a training period of 2 days during the Commissioning.

8. VALIDITY

This Supply Offer will be valid for a period of 7 days from the date of issuance.

9. EXCLUSIONS

This Supply Offer does not include the supply of items and components which are not mentioned in the AB – Scope of Work and in the Technical Description.

10. VARIATIONS REQUIRED BY THE CUSTOMER

Any variation to the Works described in the Agreement and required by the Customer after the signature of this Supply Offer, could imply modifications of the Price and/or of the Project Schedule and/or of other provisions of this Supply Offer, as better specified in the Terms and Conditions.

11. CONFIDENTIALITY

The provisions of this Supply Offer and, in general, of the Agreement, including drawings, technical documentation, Price and any other information exchanged, are to be considered strictly confidential between AB and the Customer. The Customer, therefore, undertakes not to disclose such information to any third party without AB's prior written consent. The Customer's confidentiality obligation under this Supply Offer shall survive the expiration of the validity of this Supply Offer for a period of 5 (five) years, everything as better specified under the Terms and Conditions.

12. MATERIAL ADVERSE CHANGE

This Supply Offer has been prepared and issued considering the legal and international framework at the date of its issuance.

Notably, it is acknowledged that:

1) the United Kingdom of Great Britain and Northern Ireland is not a member of the European Union and a transition period is ongoing;
2) upon the expiry of the current transition period, the commercial, economic and trade rules applicable to the relationship between United Kingdom of Great Britain and Northern Ireland and the European Union may change as well as those, among the others, related to the merchantability of the Equipment and to the performance of services in the United Kingdom of Great Britain and Northern Ireland ("Brexit Effects").

Should (i) any Brexit Effect and/or (ii) any other event connected in anyhow to the expiry of the current transition period which might affect the performance of any activity under this Supply Offer occur in the period between the signature and the performance of any activity under this Supply Offer, the Parties will agree to enter into an amendment to the Agreement in order to acknowledge and address such changes, being understood that the Customer will bear the possible extra costs (if any) and the possible consequences of a delay in the performance of the Agreement.

13. ENTIRE AGREEMENT

The term "**Agreement**" means the entire contractual documentation entered into between AB and the Customer which includes the documents listed here below in order of priority.

Any reference to the Agreement shall mean this Supply Offer, the AB – Scope of Work, the Terms and Conditions, the Technical Description and all other documents listed below, which are incorporated by reference in this Supply Offer.

In case of any discrepancy between the documents from (i) to (x) mentioned below in order of priority, the document with the higher priority shall prevail:

(i) This Supply Offer;
(ii) AB – Scope of Work;
(iii) Terms and Conditions;
(iv) Technical Description;
(v) Engine Data Sheet;
(vi) Layout Ecomax;
(vii) Functional Diagram;
(viii) Singe Line Diagram;
(ix) TA 1000-0300 Fuel gas quality;
(x) Technical Instructions AB.

This Supply Offer and all other documents mentioned above under the section named "Entire Agreement" may be executed in any number of counterparts and may be delivered originally, or by email communication in Portable Document Format ("PDF") and each such original or PDF copy, when so executed and delivered shall be deemed to be an original and all of which taken together shall constitute one and the same document.

AB Energy (UK) Ltd

_____

[signature]

I have authority to bind the Company

Name: _____

Title: _____

Date: _____

By signing this Supply Offer, the Customer unconditionally declares to have entirely received, acknowledged and accepted this Supply Offer and all other documents mentioned under the section named "Entire Agreement" above, and agrees to be bound by them.

Infinite Renewables Group Limited

_____

[signature]

I have authority to bind the Company

Name: _____

Title: _____

Date: _____

Pursuant to articles 1341 e 1342 of the Italian Civil Code, the Customer hereby confirms to have acknowledged and specifically approved the following sections of the General Terms and Conditions for Sale of Equipment (*Ed.03/2018*): 1 (Equipment and Works), 3 (Retention of Title and Passing of Risk), 4 (Warranty), 5.2 (failure to perform the Commissioning), 5.5 (deemed acceptance of the Equipment), 5.6 (Punch List Works), 7 (Customer's Obligations), 9 (Liability of Supplier), 11 (Assignment and Subcontract), 13 (Suspension), 14 (Indemnification), 15 (Termination), 16 (Governing law and Jurisdiction).

Infinite Renewables Group Limited

_____

[signature]

I have authority to bind the Company

Name: _____

Title: _____

Date: _____

AB Energy (UK) Ltd

_____

[signature]

I have authority to bind the Company

Name: _____

Title: _____

Date: _____

APPENDIX 4
ENVIRONMENTAL POLICY

Infinite Renewables Group Ltd: ENVIRONMENTAL MANAGEMENT PROCEDURES

SAFE AND EFFICIENT OPERATION OF COMBUSTION EQUIPMENT

Combined Heat and Power (CHP) Scheme: The Royal Mint, Llantrisant, S Wales

Infinite Renewables Group Ltd (IRG), as Operator, is responsible for the safe, efficient operation and maintenance of the Combined Heat and Power (CHP) unit sited at The Royal Mint.

A service contract is held by IRG with the CHP manufacturer, AB Energy, for the supply and installation of the CHP equipment and for its safe and efficient operation and maintenance. AB Energy have a Preventive and Corrective Maintenance Plan for the supplied CHP model (Ecomax Innio Jenbacher Model J 612 GS-N.L) which shall be adopted as part of the Operation and Maintenance contract in meeting the requirements of the Environmental Permit.

IRG shall manage the contract with AB Energy in accordance with its contractual and regulatory obligations.

IRG will conduct regular inspections at the site installation in collaboration with the site operation management at The Royal Mint, to ensure any issues will be mitigated and/or dealt with promptly and to maintain the efficiency and safety of the plant.

The Royal Mint has operational management procedures in place to ensure the safe operation of all equipment on its site at Llantrisant. These procedures will be incorporated into the operational management responsibilities held by IRG for the safe and efficient operation of the CHP unit.

1. Environmental Impacts Plan and Controls

- Key legislation in respect of the operation of the combined heat and power unit falls within the Environmental Protection Act 1990 – Integrated Pollution Control & Integrated Air Pollution Control.
- IRG's responsibility is to operate and maintain the combined heat and power equipment safely and efficiently to minimise the impact to the environment.
- The CHP equipment registers a low-medium impact on the local environment based on the gas emissions to air under normal or abnormal operation.
- Energy usage consists of gas consumption to generate electricity with the biproduct of heat supporting the site's process heat requirements.
- Environmental waste disposal measures and procedures are employed for the oil changes to the machinery during scheduled maintenance of the equipment.
- Noise nuisance has been classified as low impact with the operation of the equipment producing low level localised noise.

2. Accident / Pollution Incident Management Plan

- The Site Plan showing the CHP location at The Royal Mint site is detailed in Appendix A.

- Key Site and Emergency Contacts are displayed on site and held by IRG, AB Energy and The Royal Mint, to ensure a prompt and clear communication protocol in the event of a pollution incident or accident.
- Emergency Procedures and Instructions are also displayed on site and held by IRG, AB Energy and The Royal Mint, to ensure correct and immediate on-site response to an accident/pollution incident.
- Lists of Substances and their Storage Facilities are held by The Royal Mint in accordance with the Control of Substances Hazardous to Health (COSHH) Regulations. Storage Facilities are listed within the site's building inventory. No substances e.g., oil will be stored at the CHP Site and all substances essential for maintenance activities shall be transported to site safely during scheduled maintenance visits.
- Preventing Accidents; In the unlikely event a spillage shall occur, the CHP housing container is designed to capture any oil and/or coolant spillage, acting as a failsafe to minimise risk to the environment.

3. Maintenance Checklist and maintenance record

- Maintenance checklists and records will be maintained by AB Energy for both scheduled and unscheduled maintenance, as required within the AB Energy operation and maintenance contract. All maintenance checklists and records are to be circulated to IRG for verification as part of the maintenance management procedure.

4. Training Checklist

- A Training Checklist will be maintained to ensure all personnel responsible for maintenance or inspections of the CHP unit shall have the appropriate health and safety training and competency in their work responsibilities.

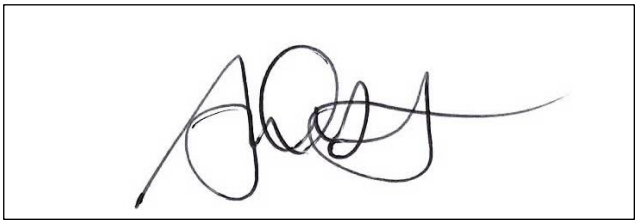
5. Complaints

- All complaints shall be directed to IRG and shall be dealt with fairly and with full consideration to all parties as part of the management procedure.

6. Accident and Incident recording form

- An Accident and Incident recording form shall be maintained as part of The Royal Mint's and IRG's standard management procedures, to properly record any incidents or accidents that may be associated with the CHP's operation.

Signed by Andrew Crossman, IRG Director



Date: -
15th January 2021

INFINITE RENEWABLES GROUP LIMITED, Number 1 Waterton Park, Bridgend, South Wales, CF31 3PH. VAT/Registration Number: 24236213

APPENDIX 5
AB ENERGY TECHNICAL SPECIFICATION

JENBACHER

Technical Description

Genset

JGS 612 GS-N.L

dyn. GC Profile 2 (150ms/5%)

AB ENERGY 612 - 62

Electrical output 2000 kW el.

Emission values

NOx < 250 mg/Nm³ (5% O2) | < 95 mg/Nm³ (15% O2)

JENBACHER

0.01 Technical Data (at genset)

			100%	75%	min.
Power input	[2]	kW	4.534	3.477	2.421
Gas volume	*)	Nm³/h	477	366	255
Mechanical output	[1]	kW	2.057	1.544	1.029
Electrical output	[4]	kW el.	2.000	1.497	990
Heat to be dissipated (calculated with Glykol 30%)	**[5]**				
~ Intercooler 1st stage (Engine jacket water cooling circuit)	[9]	kW	572		
~ Intercooler 2nd stage (Low temperature circuit)		kW	173		
~ Lube oil (Engine jacket water cooling circuit)		kW	205		
~ Jacket water		kW	317		
~ Surface heat	ca. [7]	kW	158		
Spec. fuel consumption of engine electric	[2]	kWh/kWel.h	2,27	2,32	2,45
Spec. fuel consumption of engine	[2]	kWh/kWh	2,20	2,25	2,35
Lube oil consumption	ca. [3]	kg/h	0,41	~	~
Electrical efficiency			44,1%	43,1%	40,9%
Fuel gas LHV		kWh/Nm³	9,5		

*) approximate value for pipework dimensioning
[_] Explanations: see 0.10 - Technical parameters

All heat data is based on standard conditions according to attachment 0.10. Deviations from the standard conditions can result in a change of values within the heat balance, and must be taken into consideration in the layout of the cooling circuit/equipment (intercooler; emergency cooling; ...). In the specifications in addition to the general tolerance of ±8 % on the thermal output a further reserve of +5 % is recommended for the dimensioning of the cooling requirements.

Main dimensions and weights (at genset)

Length	mm	~ 7.600
Width	mm	~ 2.200
Height	mm	~ 2.800
Weight empty	kg	~ 24.000
Weight filled	kg	~ 25.000

Connections

Jacket water inlet and outlet	DN/PN	100/10
Exhaust gas outlet [C]	DN/PN	500/10
Fuel Gas (at genset) [D]	DN/PN	100/10
Water drain ISO 228	G	½"
Condensate drain	mm	~
Safety valve - jacket water ISO 228 [G]	DN/PN	2x1½"/2,5
Lube oil replenishing (pipe) [I]	mm	28
Lube oil drain (pipe) [J]	mm	28
Jacket water - filling (flex pipe) [L]	mm	13
Intercooler water-Inlet/Outlet 1st stage	DN/PN	100/10
Intercooler water-Inlet/Outlet 2nd stage [M/N]	DN/PN	65/10

Output / fuel consumption

ISO standard fuel stop power ICFN	kW	2.057
Mean effe. press. at stand. power and nom. speed	bar	21,99
Fuel gas type		Natural gas
Based on methane number | Min. methane number	MZ	90 | 80 d)
Compression ratio	Epsilon	12
Min. fuel gas pressure for the pre chamber	bar	4,39
Min./Max. fuel gas pressure at inlet to gas train	mbar	120 - 450 c)
Max. rate of gas pressure fluctuation	mbar/sec	10
Maximum Intercooler 2nd stage inlet water temperature	°C	45
Spec. fuel consumption of engine	kWh/kWh	2,20
Specific lube oil consumption	g/kWh	0,20
Max. Oil temperature	°C	80
Jacket-water temperature max.	°C	95
Filling capacity lube oil (refill)	lit	~ 549

c) Lower gas pressures upon inquiry
d) based on methane number calculation software AVL 3.2 (calculated without N2 and CO2)

0.02 Technical data of engine

Manufacturer		JENBACHER
Engine type		J 612 GS-J02
Working principle		4-Stroke
Configuration		V 60°
No. of cylinders		12
Bore	mm	190
Stroke	mm	220
Piston displacement	lit	74,85
Nominal speed	rpm	1.500
Mean piston speed	m/s	11,00
Length	mm	4.246
Width	mm	1.886
Height	mm	2.503
Weight dry	kg	9.500
Weight filled	kg	10.300
Moment of inertia	kgm²	56,67
Direction of rotation (from flywheel view)		left
Radio interference level to VDE 0875		N
Starter motor output	kW	13
Starter motor voltage	V	24

Thermal energy balance

Power input	kW	4.534
Intercooler	kW	745
Lube oil	kW	205
Jacket water	kW	317
Exhaust gas cooled to 180 °C	kW	584
Exhaust gas cooled to 100 °C	kW	867
Surface heat	kW	84

Exhaust gas data

Exhaust gas temperature at full load	[8]	°C	341
Exhaust gas temperature at bmep= 16,5 [bar]		°C	~ 391
Exhaust gas temperature at bmep= 11 [bar]		°C	~ 439
Exhaust gas mass flow rate, wet		kg/h	11.877
Exhaust gas mass flow rate, dry		kg/h	11.171
Exhaust gas volume, wet		Nm³/h	9.387
Exhaust gas volume, dry		Nm³/h	8.509
Max.admissible exhaust back pressure after y-pipe		mbar	50

Combustion air data

Combustion air mass flow rate	kg/h	11.563
Combustion air volume	Nm³/h	8.948
Max. admissible pressure drop at air-intake filter	mbar	10

basis for exhaust gas data: natural gas: 100% CH4; biogas 65% CH4, 35% CO2

Sound pressure level

Aggregate a)		dB(A) re 20µPa	100
31,5	Hz	dB	90
63	Hz	dB	88
125	Hz	dB	100
250	Hz	dB	95
500	Hz	dB	94
1000	Hz	dB	93
2000	Hz	dB	91
4000	Hz	dB	91
8000	Hz	dB	94
Exhaust gas b)		dB(A) re 20µPa	116
31,5	Hz	dB	104
63	Hz	dB	121
125	Hz	dB	124
250	Hz	dB	116
500	Hz	dB	111
1000	Hz	dB	110
2000	Hz	dB	108
4000	Hz	dB	104
8000	Hz	dB	86

Sound power level

Aggregate	dB(A) re 1pW	122
Measurement surface	m²	142
Exhaust gas	dB(A) re 1pW	124
Measurement surface	m²	6,28

a) average sound pressure level on measurement surface in a distance of 1m (converted to free field) according to DIN 45635, precision class 3.
b) average sound pressure level on measurement surface in a distance of 1m according to DIN 45635, precision class 2.
The spectra are valid for aggregates up to bmep=20 bar. (for higher bmep add safety margin of 1dB to all values per increase of 1 bar pressure).
Engine tolerance ± 3 dB

0.03 Technical data of generator

Manufacturer		AVK(-0,925cap) e)
Type		DIG 130 k/4 e)
Type rating	kVA	2.800
Driving power	kW	2.057
Ratings at p.f. = 1,0	kW	2.000
Ratings at p.f. = 0,8	kW	1.983
Rated output at p.f. = 0,8	kVA	2.479
Rated reactive power at p.f. = 0,8	kVar	1.488
Rated current at p.f. = 0,8	A	130
Frequency	Hz	50
Voltage	kV	11
Speed	rpm	1.500
Permissible overspeed	rpm	1.800
Power factor (lagging - leading) (UN)		0,8 - 0,95
Efficiency at p.f. = 1,0		97,2%
Efficiency at p.f. = 0,8		96,4%
Moment of inertia	kgm²	110,00
Mass	kg	7.500
Radio interference level to EN 55011 Class A (EN 61000-6-4)		N
Cable outlet		left
Ik'' Initial symmetrical short-circuit current	kA	0,82
Is Peak current	kA	2,09
Insulation class		F
Temperature (rise at driving power)		F
Maximum ambient temperature	°C	40

Reactance and time constants (saturated) at rated output

xd direct axis synchronous reactance	p.u.	1,869
xd' direct axis transient reactance	p.u.	0,254
xd'' direct axis sub transient reactance	p.u.	0,157
x2 negative sequence reactance	p.u.	0,165
Td'' sub transient reactance time constant	ms	20
Ta Time constant direct-current	ms	70
Tdo' open circuit field time constant	s	3,20

e) JENBACHER reserves the right to change the generator supplier and the generator type. The contractual data of the generator may thereby change slightly. The contractual produced electrical power will not change.

JENBACHER

connection variant 1K

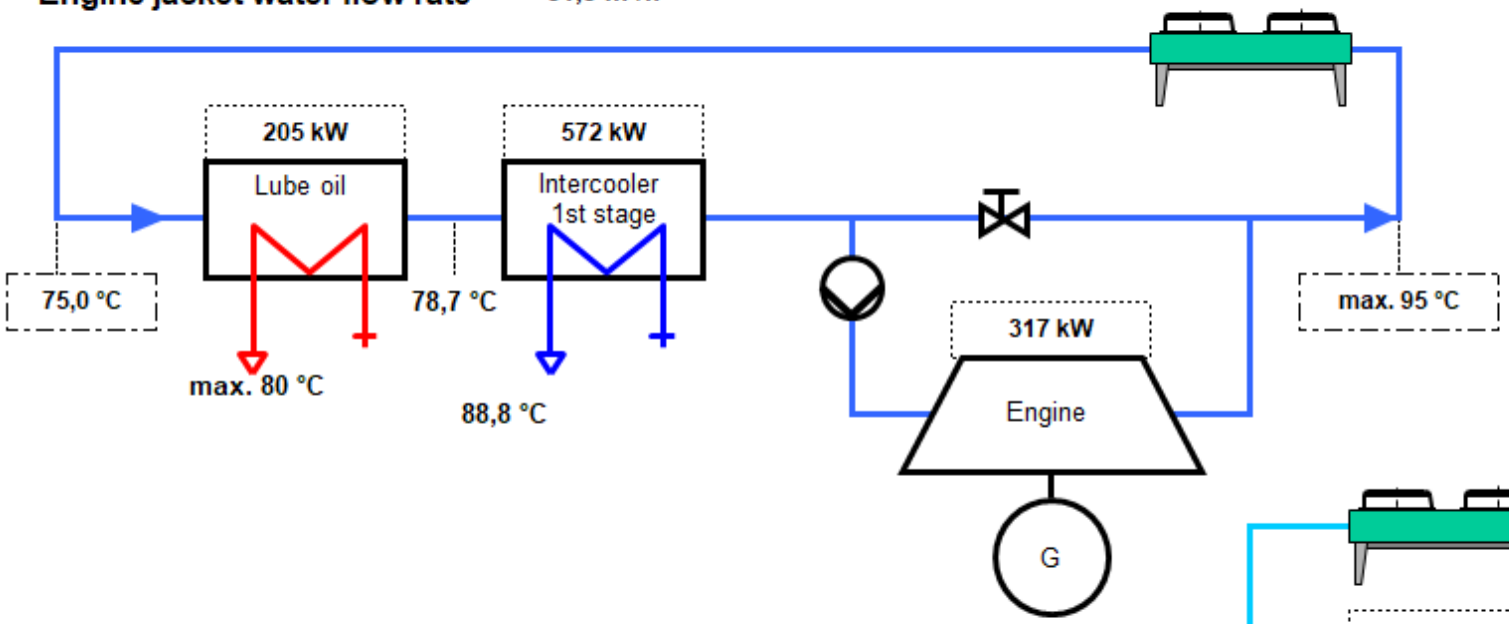
J 612 GS-J02

Engine jacket water cooling circuit (calculated with Glykol 30%)

Heat to be dissipated = 1.094 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Engine jacket water flow rate = 51,5 m³/h

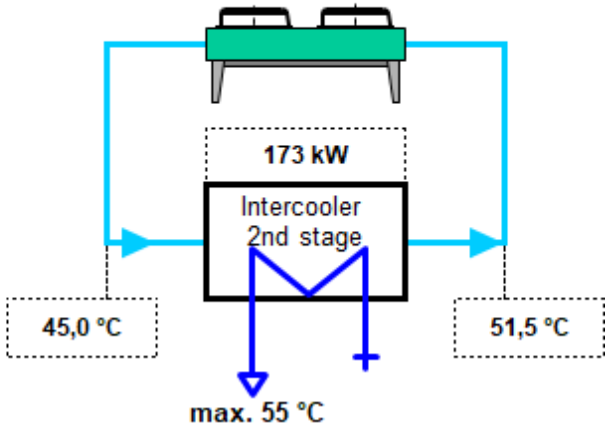


Low temperature circuit (calculated with Glykol 30%)

Heat to be dissipated = 173 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Cooling water flow rate = 25,0 m³/h



0.05 Cooling water circuit

Oil - heat (Engine jacket water cooling circuit)

Nominal output	kW	205
Max. Oil temperature	°C	80
Loss of nominal pressure of engine jacket water	bar	0,40
Safety valve - max press. set point	bar	3,50

Engine jacket water - heat (Engine jacket water cooling circuit)

Nominal output	kW	317
Max. engine jacket water temperature (outlet engine)	°C	95
Engine jacket water flow rate	m³/h	51,5
Safety valve - max press. set point	bar	3,50

Mixture Intercooler (1st stage) (Engine jacket water cooling circuit)

Nominal output	kW	572
Max. inlet cooling water temp. (intercooler)	°C	78,7
Nominal pressure of cooling water / (max. operating pressure)	PN	10
Loss of nominal pressure of engine jacket water	bar	0,25
Safety valve - max press. set point	bar	3,50

Mixture Intercooler (2nd stage) (Low temperature circuit)

Nominal output	kW	173
Max. inlet cooling water temp. (intercooler)	°C	45
Aftercooler water flow rate	m³/h	25,0
Nominal pressure of cooling water / (max. operating pressure)	PN	10
Intercooler water pressure drop	bar	0,25
Safety valve - max press. set point	bar	3,50

The final pressure drop will be given after final order clarification and must be taken from the P&ID order documentation.

0.10 Technical parameters

All data in the technical specification are based on engine full load (unless stated otherwise) at specified temperatures and the methane number and subject to technical development and modifications.

All pressure indications are to be measured and read with pressure gauges (psi.g.).

[1] At nominal speed and standard reference conditions ICFN according to ISO 3046-1, respectively
[2] According to ISO 3046-1, respectively, with a tolerance of +**5** %.
Efficiency performance is based on a new unit (immediately upon commissioning).Effects of degradation during normal operation can be mitigated through regular service and maintenance work.

[3] Average value between oil change intervals according to maintenance schedule, without oil change amount
[4] At p. f. = 1.0 according to VDE 0530 REM / IEC 34.1 with relative tolerances, all direct driven pumps are included
[5] Total output with a tolerance of ±8 %
[6] According to above parameters [1] through [5]
[7] As a guiding value at p.f. 0.8 and only valid for (engine, generator, TCM). Other peripheral equipment is not considered.
[8] Exhaust temperature with a tolerance of ±8 %
[9] Intercooler heat on:
*** standard conditions** - If the turbocharger design is done for air intake temperature > 30°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 25°C. Deviations between 25 – 30°C will be covered with the standard tolerance.
*** Hot Country application (V1xx)** - If the turbocharger design is done for air intake temperature > 40°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 35°C. Deviations between 35 – 40°C will be covered with the standard tolerance.

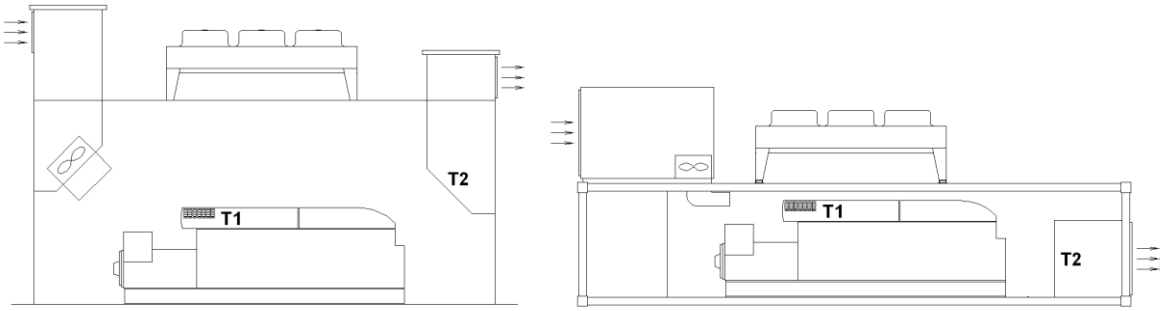
Radio interference level
The ignition system of the gas engines complies the radio interference levels of CISPR 12 and EN 55011 class B, (30-75 MHz, 75-400 MHz, 400-1000 MHz) and (30-230 MHz, 230-1000 MHz), respectively.

Definition of output
- ISO-ICFN continuous rated power:
  Net break power that the engine manufacturer declares an engine is capable of delivering continuously, at stated speed, between the normal maintenance intervals and overhauls as required by the manufacturer. Power determined under the operating conditions of the manufacturer's test bench and adjusted to the standard reference conditions.
  - Standard reference conditions:

Barometric pressure:	1000 mbar (14.5 psi) or 100 m (328 ft) above sea level
Air temperature:	25°C (77°F) or 298 K
Relative humidity:	30 %

- Volume values at standard conditions (fuel gas, combustion air, exhaust gas)
  Pressure: 1013 mbar (14.7 psi)
  Temperature: 0°C (32°F) or 273 K

Output adjustment for turbo charged engines
Standard rating of the engines is for an installation at an altitude ≤ **500 m** and combustion air temperature ≤ **30 °C** (T1)
Engine room outlet temperature: **50°C** (T2) -> engine stop



The minimum recommended air change ratio (C) must be observed to maintain the required air quality and prevent unwanted gas accumulations (refer to Section ⇨ Potentially explosive Atmospheres as per TA1100-0110). The calculation of the minimum air change rate is based on the formula below and is Cmin= $50h^{-1}$ for all JENBACHER modules.

If the actual methane number is lower than the specified, the knock control responds. First the ignition timing is changed at full rated power. Secondly the rated power is reduced. These functions are carried out by the engine management system.
Exceedance of the voltage and frequency limits for generators according to IEC 60034-1 Zone A will lead to a derate in output.

Parameters for the operation of JENBACHER gas engines
The genset fulfils the limits for mechanical vibrations according to ISO 8528-9.
The following forms an integral part of a contract and must be strictly observed: **TA 1000-0004, TA 1100 0110, TA 1100-0111**, and **TA 1100-0112.**
Transport by rail should be avoided. See **TA 1000-0046** for further details

Failure to adhere to the requirements of the above-mentioned TA documents can lead to engine damage and may result in loss of warranty coverage.

Parameters for the operation of control unit and the electrical equipment
Relative humidity 50% by maximum temperature of 40°C.
Altitude up to 2000m above the sea level.

0.20 Mode of Operation

Grid Parallel Mode
The genset is running in parallel to the utility. The unit load can be adjusted via its power control set point or designated option.
Procedure in the event of mains failure:
When the mains monitor relay (protective relay ANSI No. 27, 59, 81, 78- provided either by JENBACHER or the customer) is activated due to a mains failure, the engine is isolated from the mains by opening the generator breaker. The module is shut down without any cool-down run.
Island operation is not available in this case!
The module can be restarted following the restoration of mains power after a 5-minute mains stabilization period.

APPENDIX 6
AB ENERGY PPM SCHEDULE

SERVICE OFFER

AB PREVENTIVE AND CORRECTIVE MAINTENANCE PLAN

AB ENERGY (UK) LTD

Lower Ground Floor – One George Yard
EC3V 9DF London (UK)
VAT Number: GB 185213904

FOR

INFINITE RENEWABLES GROUP LIMITED

Number 1 Waterton, Bridgend Wales CF31 3PH

VAT/Registration Number: 242362136.

(the "**Customer**")

Our Offer n. 2020.0055_ENU_REV1

Date: 16/04/2020

1. SCOPE OF THE PLAN

1.1 Scope of the Plan

With reference to your inquiry, AB Service S.r.l. (hereinafter "**AB**" or the "**Contractor**") is pleased to provide this service offer based on the AB Preventive and Corrective Maintenance Plan (the "**Service Offer**"), to be performed on the following Covered Unit:

- **Ecomax Model:** 1 x Ecomax 20 Ngs
- **Engine Model:** 1 x Innio Jenbacher Model J 612 GS-N.L
- **Site:** United Kingdom

The scope of the Service Offer includes the following services and activities:

a) Preventive Maintenance for the Covered Unit
b) Minor Overhaul (scheduled at 30,000 OPH)
c) Corrective Maintenance
d) Oil Supply
e) Assistance and Technical Support
f) Remote Monitoring
g) Guaranteed Intervention Time
h) Training
i) Availability Guarantee
j) Performance Guarantee

a) Preventive Maintenance for the Covered Unit

The Contractor will perform all Preventive Maintenance, including parts, labor, and travel, as recommended in the Preventive Maintenance calendars by GE Jenbacher for the Engine, AB for the ECOMAX, and the other OEMs for each of their respective components. This maintenance will follow 2,000 operating hours service intervals within 0-59,999 engine operating hours. The 10,000 operating hour Preventive Maintenance intervals shall be performed at the following service intervals:

- Minor Overhaul at 30,000 OHP;
- Cylinder head overhaul at 30,000 OPH;
- Generator maintenance at 30,000 OPH;
- Turbocharger inspection every 10,000 OPH;
- Turbocharger standard overhaul every 20,000 OPH;
- Supply of nr. 39 complete spark plugs sets, each one supplied every 1,500 OPH;
- All re-fills or topping of fluids needed during Preventive Maintenance (oil, glycol, etc.) are excluded from the above scope.

Please note that all the OPH above are intended to be approximate; the exact amount of OPH will be agreed upon between the Customer and the Contractor.

Any Preventive Maintenance activities which are additional to the ones prescribed by the OEM in its Preventive Maintenance schedule will be considered as Corrective Maintenance activities and will be applied against the corrective caps (see after).

b) Minor Overhaul (scheduled at 30,000 OPH)

The Contractor will supply all parts, labor, and travel to perform a minor overhaul; pricing includes shipping costs for all parts.

c) Corrective Maintenance

The Contractor will supply the parts and labor required to repair or replace parts or components of the Covered Unit that have failed.

The Service Offer includes an annual as well as a total contract coverage price cap. If the annual coverage cap is not reached during the referring year, the remaining value cannot be transferred to subsequent years. Once having reached the maximum amount per year, or upon reaching the contract coverage cap, incremental spare parts and labor will be supplied and invoiced according to Schedule C of this Service Offer.

- Annual Coverage Cap: £ 33.163,00 (based on 8,000 OPH per year)
- Contract Coverage Cap: £ 218.875,00

All the above prices are quantified based on an exchange rate EUR/GBP at 0,85.

Final prices will be reviewed and fixed in consideration at the exchange rate at the moment of the eventual award of the project (or in an immediate previous time).

d) Oil Supply

The Contractor will supply fresh oil and filters to the Customer for engine oil consumption and oil change requirements; pricing for oil is based on 2000 OPH change intervals. The Customer must take oil samples as specified by the Contractor, but not more frequently than every 250 OPH during roughly the first 1000 OPH and every 400 OPH afterwards.

e) Assistance and Technical Support

This refers to the assistance given to Customer personnel in charge of the operation of the Covered Unit ("**Operation**"), provided through remote support or phone support during the operation or breakdown of the Covered Unit.

AB will grant continuous availability to the Customer's personnel who are in charge of the Operation, during 24 hours/day, 7 days/week, 365 days per year. Such support will be supplied through telephone assistance or remote control.

f) Remote Monitoring

Under the Service Offer, the plant (i.e. the Engine, the ECOMAX, and the BoP) can be remotely accessed and monitored 24/7 in the AB Control Room; the Control Room can monitor performance and operational data, provide remote technical support, and is run by highly qualified personnel.

g) Guaranteed Intervention Time

By signing this offer, the Customer will become a preferred AB customer and will take priority over other customers who have not entered into a long term service agreement with AB Service. Therefore, AB is committed to your successful operation and will respond as quickly as possible to any "engine down" situations, with technicians on-site within 24 hours, in the event of a Failure.

Please note that interventions at Site will be considered as Corrective Maintenance to be applied against the Annual Coverage Cap and the Contract Coverage Cap as described under letter c) above, and based on Schedule C of this Service Offer

h) Training

AB will provide basic operational training to the Customer in order to perform the basic operations required by OEMs and which are not included in the Preventive Maintenance calendars (i.e. daily checks, etc.).

i) Availability Guarantee

Provided the Engine is remotely connected to AB's monitoring center, and that AB performs all Corrective Maintenance activities, AB provides to the Customer an availability guarantee of the Covered Unit equal to 95% (the "**Availability Guarantee**"), calculated according to the Availability Guarantee Calculation as defined in the Service Terms and Conditions, and subject to section 5.1 (m) of the Service Terms and Conditions.

For every 1% of down time below the Availability Guarantee, AB shall pay to the Customer, as liquidated damages and not as a penalty, an amount equal to 1% of the annual billing of the Agreement (the "**Availability Liquidated Damages**")

The Availability Liquidated Damages shall be in lieu of all actual damages and shall be the Customer's sole and exclusive remedy in case of failure of the Covered Unit to meet the Availability Guarantee.

It is agreed and understood that the Availability Liquidated Damages shall in no case exceed the amount equal to 10% of the annual billing.

For every 1% up to the Availability Guarantee the Contractor will receive a bonus, which corresponds to 1% of the annual billing of the contract. This award is limited to 5% of the annual billing for the relevant Engine per year.

The Parties agree that: (i) every month the Parties will share the "Monthly Performance Report" of the Covered Unit. It will be filed by Contractor and approved by the Customer; and (ii) the value of the Availability Liquidated Damages within a solar year from the 1st of January to the 31st of December will be defined, formalized, and paid within the end of January of the following year.

j) Performance Guarantee

During the first four years of the Agreement, in case that the Customer notices that the electrical efficiency of any of the Equipment being part of the Covered Unit is lower than the electrical efficiency recorded at the time of the acceptance of the Equipment, the Customer may require the execution of an electrical performance test.

The performance test values of reference will be the electrical efficiency recorded at the time of the acceptance of the Equipment, corrected by the application of: (i) the tolerance limits indicated in the engine data sheet; and (ii) the derating curve here attached as Schedule E ("**Performance Guarantee**") .

If the performance test returns an electrical efficiency value which is higher than the Performance Guarantee, then the Customer shall reimburse the costs for the performance test.

If the performance test returns an electrical efficiency value which is lower than the Performance Guarantee, AB shall cure the deficiency within the next 30 days ("**Correction Period**").

Should AB fail to cure the deficiency within the Correction Period, than AB shall pay as liquidated damage, and not as a penalty, an amount equal to 50% of the difference between the extra cost for the additional natural gas consumed by the Equipment starting from the end of the Correction Period up to the day when the Equipment electrical efficiency value is fixed in accordance with the Performance Guarantee ("**Performance Liquidated Damages**").

It is agreed and understood that the Performance Liquidated Damages shall in no case exceed the amount equal to 30% of the Contract Price paid by the Customer in the previous calendar year.

The Availability Liquidated Damages and the Performance Liquidated Damages can be cumulative and, in any case, the total amount of the penalties can't exceed the 30% of the Contract Price paid by the Customer in the previous calendar year.

To guarantee, if this is the case, the proper payment of the Performance Liquidated Damages and the Availability Liquidated Damages, AB shall provide to the Customer an irrevocable first demand bank guarantee for an amount equal to the 10% of the Contract annual invoice (the "**Performance Bond**"). The Performance Bond shall become effective as of the effective date of the Contract and shall expire two years thereafter. The Customer shall refund to AB the cost for the Performance Bond upon AB's issuance of dedicated invoice alongside the evidence of such cost; payment term will be invoice date.

1.2 Major Overhaul (scheduled after 59,999 OPH)

The Contractor will supply a long block overhaul, alternator refurbishment, and associated labor, subject to the following:

- Pricing includes engine (long block, see annex) and generator overhaul;
- Pricing is exclusive of crane supply and operation, all freight, customs, duties, and taxes.

The Major Overhaul is an Additional Service; the Customer will choose, at a future date, whether to perform it or not. By signing this offer the Customer is not bound to buy the Major Overhaul. The cost of the Major Overhaul is not included in the hourly rate and has to be paid separately, should the Customer ask for it to be performed.

1.3 Exclusions

The AB Preventive and Corrective Maintenance Plan shall not include the activities set forth under article 3.6 of the Service Terms and Conditions; in addition to those activities, this offer also shall not include:

- BOP (Balance of Plant) maintenance;
- All Corrective Maintenance activities, after either of the caps has been reached;
- Any un-planned Corrective Maintenance which is required due to the Customer's or any third parties' negligence, incorrect operation, or failure to comply with the user and OEM maintenance manuals, technical instructions, OEM gas requirements, or work instructions;
- Catalytic converter and biogas filter supply;
- Supply of spark plugs more than the number 39 sets included;
- Any import/export customs duty or local tax;
- The Major Overhaul;
- Periodic verification of the emissions of the Covered Unit requested by the relevant authorities;
- Anything that is not explicitly mentioned in the Preventive Maintenance calendars or is not explicitly mentioned in this Service Offer.

1.4 Customer Obligations

The Customer will:

- perform the Operation inclusive but not limited to:

- get in contact with the Contractor in case of Failure/Fault and perform first interventions, first checks, and alarm resets as instructed during the Training;
- carry out and record the operation, inspection, and maintenance works according to the operation log and maintenance schedules as required by the OEMs;
- operate the steam boiler as required by the relevant authorities;
- ensure the daily oil tank is filled and perform oil sampling;

- meet the gas quality as per Innio Jenbacher instruction TA 1000-0300 ;

1.5 General Terms and Conditions

The AB Preventive and Corrective Maintenance Plan shall be performed pursuant to this Service Offer and to the AB General Terms and Conditions of Service (the "**Service Terms and Conditions**"), which are incorporated hereto by reference.

2 TERM

The AB Preventive and Corrective Maintenance Plan will start at 0 OPH and shall expire at 59,999 OPH, or after 10 years, whichever comes first (the "**Term**"). Minimum engine OPH per year are 8,000 OPH.

3 PRICE

3.1 Contract Price

The price for the AB Preventive and Corrective Maintenance Plan set forth in this Service Offer to be paid by the Customer during the Term is equal to

£ 13,65 (thirteen / 65) + VAT/Taxes (if applicable) (the "**Contract Price**")

per each OPH of each Engine as resulting from the Engine's counter, including Minor Overhaul costs.

The Contract Price shall be adjusted according to the Service Terms and Conditions.

3.2 Additional Services

The price for the Major Overhaul is equal to:

£ 268.600,00 (two hundred sixty eight thousand six hundred/00) + VAT/Taxes (if applicable)

The Major Overhaul maintenance intervention is excluded from the present Service Offer. It can be requested by the Customer at least 6 months before its execution and it shall be regulated by a separate agreement between the Parties. The price of the Major Overhaul shall be adjusted according to the Service Terms and Conditions.

All the above prices are quantified based on an exchange rate EUR/GBP at 0,88. Final prices will be reviewed and fixed in consideration at the exchange rate at the moment of the eventual award of the project (or in an immediate previous time).

4 PAYMENT TERMS

The Customer shall pay AB the Contract Price calculated on a monthly basis and billed monthly by AB. Payment shall be within 30 days from the invoice date and paid by wire transfer or cheque.

The Parties hereby agree that the Contract Price and all other prices set forth in this Service Offer will be annually adjusted as indicated in the Service Terms and Conditions.

5 VALIDITY

This Service Offer will be valid for a period of 30 days from the date of its issuance, or until the signature of the same by both Parties, whichever event comes first.

6 CONFIDENTIALITY

Terms and conditions of this Service Offer, including all drawings, technical documentation, Contract Price and all other prices, and any other information exchanged between AB and the Customer, in general are to be considered strictly confidential between AB and the Customer. The Customer, therefore, undertakes not to communicate them to third parties without AB's previous written consent. The Customer's confidentiality obligations under this Service Offer shall survive the expiration of the validity of this Service Offer for a period of 5 (five) years.

7 ENTIRE AGREEMENT

The following documents shall constitute the entire Agreement entered into between the Parties. Any reference to the Agreement shall mean this Service Offer, the Service Terms and Conditions, and the Schedules as listed below, which are incorporated by reference into this Service Offer.

The documents (i) through (iii) below are listed in order of priority. In case of any discrepancy, the document with the higher priority shall prevail

(i) THIS SERVICE OFFER

(ii) SCHEDULE A SERVICE TERMS AND CONDITIONS

(iii) SCHEDULE B MAINTENANCE CALENDAR(S)

(iv) SCHEDULE C TIME AND MATERIAL RATES

(v) SCHEDULE E PERFORMANCE DERATING CURVE

AB Energy (UK), Ltd

_____

[signature]

Name: _____

Role: _____

Date: _____

By way of acknowledgment and acceptance by the Customer of this Service Offer, the Service Terms and Conditions, and Schedules attached hereto

Infine Renewables Group Limited

_____

[signature]

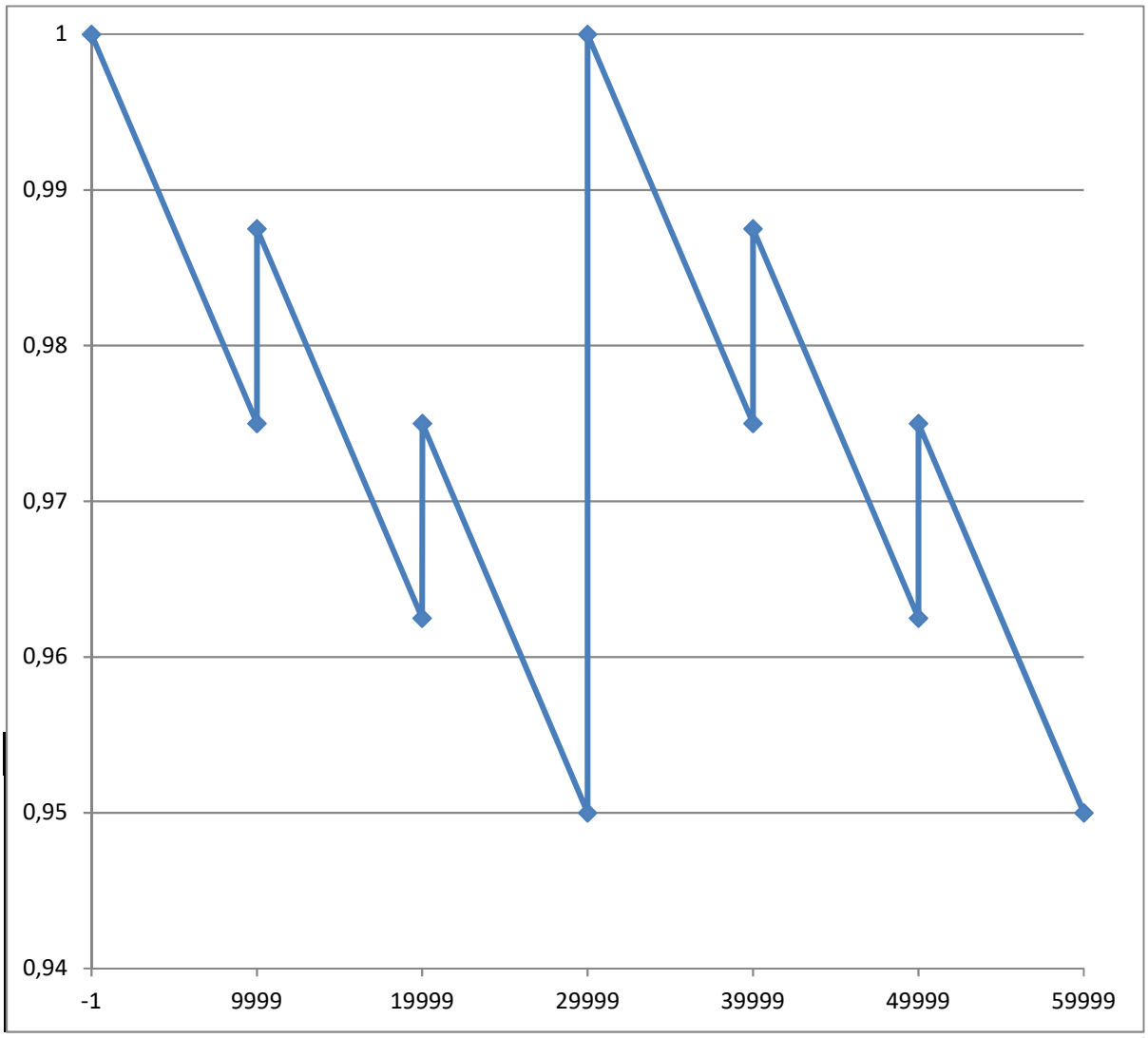
Name: _____

Role: _____

Date: _____

Performance Curve

The following graph illustrates the trend of the electrical efficiency estimated as a function of the endothermic engine's operating hours and planned maintenance activities.
The factor shown in the graph must be applied to the nominal electrical efficiency following the tolerances according to ISO/DIN standards as per engine specification.



GENERAL TERMS AND CONDITIONS OF SERVICE

Version 02/2017

1. Parties; Agreement

AB Energy (UK) Ltd, is referred to as the "**Contractor**" or "**AB**" and the person or company accepting the Service Offer (as hereinafter defined) issued by the Contractor is referred to as the "**Customer**". These service standard terms and conditions (these "**Terms and Conditions**"), together with our Service Offer (as hereinafter defined), constitute the Agreement (as hereinafter defined) between the Contractor and the Customer. Acceptance of the Contractor's Service Offer (as hereinafter defined) is expressly subject to acceptance of these Terms and Conditions, and the Contractor shall not be bound, and hereby expressly objects to, any terms or conditions proposed by the Customer that are additional or different from these Terms and Conditions.

No order request forms or any other documents shall modify these Terms and Conditions, unless such document (a) is made in writing, (b) expressly states that it is an amendment or waiver of these Terms and Conditions, specifically indicating which provisions are being amended or waived, and (c) is signed by an agent or representative of the Contractor who has been granted written authority to amend or waive these Terms and Conditions. Any order to perform Services (as hereinafter defined), and the Contractor's performance of Services (as hereinafter defined), shall constitute the Customer's acceptance of these Terms and Conditions.

Unless explicitly indicated otherwise, advertising prospectuses and catalogues shall not be binding.

2. Definitions and Contractual Documents

2.1 "**Affiliates**" means, in relation to each Party, a corporation, company or other entity, now or hereafter, directly or indirectly, owned or controlled by, or owning or controlling, or under common control with one of the Parties, but such corporation, company or other entity shall be deemed to be an Affiliate only so long as such ownership or control exists. For purposes of this definition "control" of a corporation, company or other entity shall mean to have, directly or indirectly, the power to direct or cause the direction of the management and policies of a corporation, company or other entity, through the ownership of voting securities providing for the right to elect or appoint, directly or indirectly, the majority of the board of directors, or a similar managing authority.

2.2 "**Agreement**" means the Service Offer accepted by the Customer, subject to and incorporating these Terms and Conditions, and all the Schedules attached to the Service Offer.

2.3 "**Applicable Law**" means all laws, statutes, codes, acts, ordinances, orders, judgments, decrees, injunctions, rules, regulations, directions, and requirements, including the technical and safety standards and regulations, of all governmental, regional, municipal and any other authorities enforceable on the date of the Service Offer signature applicable to the Services, to the Covered Unit(s) and to the Site.

2.4 "**Availability Guarantee Calculation**" means the following formula to perform the calculation of the Availability Guarantee (as defined in the Service Offer):

$$A = \frac{T_{act}}{\left(T_{std} - T_{prv} - T_{ofs}\right)} * 100$$

Where

T_{act} = actual operating hours of the engine, as measured by the hour counter

T_{std} = 8760hours

T_{prv} = hours of Preventive Maintenance

T_{ofs} = hours of stops out of the scope of the Contractor's responsibility, for example, are planned stops at the Customer's discretion, improper operation by the Customer, etc.

2.5 "**BoP**" means the balance of plant machinery and accessories supplied by the Contractor or one of its Affiliates, and installed outside and not pertaining to the Ecomax, as better described in the Service Offer.

2.6 "**Contractor Taxes**" means any and all corporate and individual taxes that are measured by net income or profit imposed by any governmental authority of any country on the Contractor, its employees or subcontractors, due in connection with the performance of, or payment for, the Services.

2.7 "**Contract Price**" means the price for the Services as set out in the Service Offer.

2.8 "**Corrective Maintenance**" means the maintenance needed to fix Failures (events which shut down the Engine) and Faults (events which not shut down the Engine).

2.9 "**Covered Unit(s)**" means the scope as better identified under section 1 of the Service Offer, upon which the Contractor shall perform the Services.

2.10 "**Customer Taxes**" means any and all government, federal, state, municipal or local taxes, duties, fees, or other charges of any nature (including, but not limited to, sales taxes, ad valorem consumption, excise, franchise, gross receipts, import, export, license, property, sales, stamp, storage, transfer, turnover, use or value-added taxes, and any and all items of withholding, deficiency, penalty, addition to tax, interest, or assessment related thereto), other than Contractor Taxes.

2.11 "**Ecomax**" means the container supplied by the Contractor or one of its Affiliates including the Engine(s) and the auxiliary devices (e. g.: ventilation and dissipation systems) as identified in the Service Offer and in the Technical Documentation.

2.12 "**Effective Date**" means the date in which the

Customer has accepted the Service Offer, in writing.

2.13 "**Engine(s)**" means the main components comprising a gen set: reciprocating gas engine, generator and engine control cabinets, excluding all the connections (pipes and cables).

2.14 "**Extra Services**" means any goods or services that the Contractor provides or performs which are not included in the definition of Services, to be approved in writing by the Customer. Any Extra Services not included in the Contract Price shall be subject to additional charges at applicable billing rates for materials and labour, and shall be invoiced separately by the Contractor to the Customer. Additionally, Extra Services shall include, by way of example, any Services that are necessary as a result of and in connection with misuse, vandalism, improper or insufficient maintenance at the fault of the Customer or a third party, excessive heat, electrical supply fluctuations, storms, fires, floods, riots, retrieval/replacement of the Covered Unit(s), or any parts thereof which may be required as a consequence of such events, or any other cause beyond the Contractor's control shall qualify as Extra Services. Unless otherwise accepted by the Contractor, the execution of tests, additions, alterations, or modifications to the Covered Unit(s) as may be required by the Customer or any third parties, or pursuant to government or local authorities, to the extent that such tests, additions, alterations, or modifications are not necessary to abide by mandatory rules and regulations, shall also qualify as Extra Services. The Customer shall pay the Contractor for Extra Services at the Time and Material Rates and according to the payment terms specified in the Agreement.

2.15 "**Facility**" means the power generation plant, station or power generation section of the premises where the Covered Unit(s) is/are located, as identified in the Service Offer and identified in the Schedule attached to the Service Offer, where applicable.

2.16 "**Hazardous Materials**" means toxic substances, hazardous substances or hazardous wastes, or in any case any substances, materials, or emissions, that are regulated pursuant to any laws, statutes, ordinances or regulations promulgated by any national, federal, state, provincial, or local governmental authority where the Site is located.

2.17 "**Insolvent**" means a person or entity (a) which has generally ceased to pay debts in the ordinary course of business other than as a result of bona fide dispute; or (b) is unable to pay debts as they become due; or (c) qualifies as "insolvent" within the meaning of applicable bankruptcy law.

2.18 "**Major Overhaul**" means the maintenance activities on the Engine, not included in the Contract Price, which may be carried out by the Contractor at the OPH suggested by the OEM maintenance schedule (+/- 8%), if specifically requested by the Customer.

2.19 "**Minor Overhaul**" means the maintenance activities on the Engine to be carried out by the Contractor at the OPH suggested by the OEM maintenance schedule (+/- 12%) if specified in the Service Offer.

2.20 "**Monitoring & Performance System**" (e.g. the AB protocol system) means a system or systems which may be used by the Contractor, continuously or from time to time, to monitor the Facility equipment and/or to provide performance information and support, generally consisting of hardware, software, and a connection to a source of technical oversight or review.

2.21 "**OEM**" means the Original Equipment Manufacturer.

2.22 "**OEM Manuals**" mean all manuals, booklets and instruction sheets related to the Covered Unit and its Operation, delivered by the Contractor to the Customer.

2.23 "**Operation**" means the operation and management of the Covered Unit, to be performed by the Customer's personnel, or professionals, who have been specifically trained by the Contractor, including, by way of example, daily checks, small maintenance and first interventions in case of alarm or breakdown, troubleshooting, all other simple activities and the elimination of insignificant leaks. The Operation has to be conducted in strict adherence to the OEM Manuals.

2.24 "**OPH**" means the operation hours of the Engine(s).

2.25 "**Parties**" means jointly the Contractor and the Customer and, each of them, is a "Party".

2.26 "**Parts**" means all new, repaired or refurbished parts, materials, components and other goods furnished by the Contractor, or its subcontractors or suppliers, in connection with the performance of Services.

2.27 "**Preventive Maintenance**" means the preventive maintenance on the Engine to be carried out by the Contractor approximately every 2,000 OPH. In the case of the AB Protection Plan, the Contractor may adjust the Preventive Maintenance scheme, at its discretion, in order to optimize the functioning of the Engine.

2.28 "**Schedules**" means the technical schedules eventually attached to the Service Offer accepted by the Customer.

2.29 "**Services**" means the Preventive Maintenance and/or the Corrective Maintenance and/or all other services, including all equipment and materials in connection thereto, to be provided by the Contractor as set out in the Service Offer. Services shall not include any amendments to the Services, equipment or materials after the date of the Service Offer, unless the Contractor has expressly accepted to include such amendments to the services, equipment or materials, in the definition of Services.

2.30 "**Service Offer**" means the Contractor's offer and attached Schedules incorporating, by reference, these Terms and Conditions.

2.31 "**Site**" means the premises where the Facility is located, and where the Covered Unit object of the Service has been delivered, as agreed in the Service Offer.

2.32 "**Supply Contract**" means the contract entered into between the Customer and the Contractor (or one

of its Affiliates), according to which the Customer has acquired the Covered Unit.

2.33 "**Technical Documentation**" means all documents delivered with the Covered Unit(s) according to the Supply Contract.

2.34 "**Term**" has the meaning provided in section 7.

2.35 "**Time and Material Rates**" means the rates set out in the Schedules attached to the Service Offer, where applicable.

3. Scope of the Services; Delivery Limitation

3.1 The Contractor shall perform the Services as set out in the Service Offer, and/or any amendments to the Services or any Extra Services, accepted, in writing, by the Contractor.

3.2 If the lube oil is provided by the Contractor as specified in the Service Offer, the former shall strictly meet the requirements for Engine lubrication oil or the oil change parameters of the OEM.

3.3 The Services shall include a training period of two days for no more than three employees of the Customer for the purpose of the Operation.

3.4 The Contractor shall provide the Customer with (i) "Standard Assistance and Technical Support," aimed at assisting the Customer's personnel dedicated to the Operation, through remote support or phone support with availability during office hours and/or intervention on the Site within 24/36 hours (as defined in the Service Offer) starting from the receipt of the Claim Notice (as defined in section 4.1.6) sent by the Customer; or (ii) "Full Assistance and Technical Support," providing assistance to the Customer's personnel dedicated to the Operation through remote support or phone support with continuous availability 24 hours/day for 7 days/week for all the days of the year (or leap year) and/or intervention on the Site, depending on what is indicated in the Service Offer.

3.5 Preventive Maintenance interventions will be scheduled by the Contractor, in accordance with the Customer.

3.6 Unless differently specified in the Service Offer, the following shall not be included in the Services:

a) Supply, delivery, and transport of commodities and goods including, without limitation, fuel gas and urea, for which the Customer shall be responsible to provide.

b) Storage and disposal of commodities and goods, including without limitation, lubrication oils, flushing compounds, battery acids, antifreeze compounds, and cleaning materials. The Customer shall be responsible for providing storage and disposal for these items.

c) Disposal and management of any and all waste fluids and Hazardous Materials in compliance with the Applicable Law.

d) Additional expenditures due to any shut-down of the Engine(s) for more than 3 continuous months (e.g. preservation and storage services).

e) Third party services and machines (such as the operation of cranes, lifting operations, construction activities, hydraulic modifications, etc.), required in connection with the replacement of a Covered Unit or any related equipment or materials.

f) Services and any activity necessary after any intervention on the Covered Unit performed by the Customer or third parties, which were not previously authorized by AB in written form.

g) Any activities that are needed as a result of improper use of, and/or improper operations and tasks performed on, the Covered Unit(s) which are executed by the Customer, and/or third parties, which were not previously authorized by the Contractor in writing, as well as in the case of any use of the Covered Unit that is not compliant with the Contractor's instructions and/or with the Technical Documentation.

h) Supply of fuel gas, water, electricity and other utilities necessary for the functionality of the Covered Unit(s) and/or maintenance.

i) Un-planned maintenance due to force majeure such as flooding, fire, corrosion, etc.

j) Maintenance on any components which are not a part of the Covered Unit.

k) Any other activities not included in the Agreement.

3.7 The Contractor shall not be liable for delays in delivery or failure to deliver Services due to causes beyond its reasonable control, including, but not limited to, acts of God, the Customer's actions, acts of military or civil authorities, fires, strikes, floods, epidemics, war, riots, delays in transportation, or any of the above circumstances causing an inability to obtain the necessary permits, labour, material, components, or manufacturing facilities. In the event of any such delay, the date of delivery, or date to provide the Services shall be extended for a period equal to the time lost by reason of such delay.

4. Claim Management Procedure

4.1 In the case of a Failure or a Fault, the following procedure shall apply:

4.1.1 The Customer shall promptly contact the Contractor, describing the issue and the circumstances under which it appeared;

4.1.2 The Contractor shall open a "ticket" to record the Customer's assistance request (the "**Ticket for Assistance**"), and qualify, at its discretion and based on the information provided by the Customer, the problem as a Failure or Fault;

4.1.3 The Parties shall try to fix the Fault or Failure through remote assistance;

4.1.4 In case the Fault or Failure is fixed, the Contractor shall close the ticket and give evidence to the Customer. It is understood that should the Contractor not receive objections raised by Customer within the following 24 hours, the support shall be deemed accepted.

4.1.5 In case the Parties are not able to fix the Fault or Failure remotely, the following shall apply: (i) in the case that the issue is qualified as Fault, the Contractor shall fix it no later than during the next Preventive Maintenance intervention; (ii) in case the event is qualified as Failure, the Contractor shall send its technicians on Site, within the intervention time defined in the Service Offer, subject to the procedure explained in the following sections.

4.1.6 In the case that activities are to be carried out according to section 4.1.5 (ii), the Customer shall notify the Contractor by sending a written claim (the "**Claim Notice**") to the address indicated by the Contractor, according to the terms and conditions set forth below. It is agreed and understood between the Parties that should the Contractor not receive the Claim Notice within 12 hours from the opening of the Ticket for Assistance, the Contractor shall close the Ticket for Assistance and, as a consequence, the Contractor shall not be under the obligation to intervene on Site to fix the Failure.

4.1.7 The Claim Notice shall include the following information:

a) The name of the person producing the Claim Notice, who has to be authorized to act in the name and on behalf of the Customer;

b) The date of the Failure detection;

c) A short description of the Failure and of the circumstances under which it appeared, including the essential parameters of the Covered Unit;

d) A list of affected components of the Covered Unit;

e) An indication if the Customer carried out any action upon the detection of the Failure and, if so, details of the activities performed in this respect.

4.1.8 The Claim Notice has to be in English.

4.1.9 Any Claim Notice sent by the Customer not in conformity with the previous indications of this section 4, shall be deemed as not received by the Contractor. In this case the Contractor, where possible, shall inform the Customer in order to allow the latter to correct the Claim Notice.

4.1.10 The Contractor guarantees that, once it has received the correct Claim Notice in compliance with this section 4, (i) it shall confirm the receipt of the Claim Notice, and (ii) it shall send the technicians on Site, within the intervention time defined in the Service Offer.

5. Customer Undertakings

The obligations of the Customer include the following:

a) Operation of the Covered Unit, without prejudice to the technical support performed by the Contractor, or the warranty obligations.

b) The Customer, either directly or indirectly acting through third parties, shall not make any alterations, modifications or changes to the Covered Unit(s), without the prior written consent of the Contractor and/or, if need be, compensating the Contractor for any Extra Services associated with such alterations, modifications or changes.

c) The Customer shall maintain safe working conditions at the Facility, including, but not limited to, implementing appropriate procedures regarding all Hazardous Materials, compliance with all applicable rules and regulations, confined space entry regulations, and power systems. The Customer shall timely notify the Contractor, in writing, of any health (including environmental), safety, and security procedures, requirements, and measures to be followed by the Contractor during the Services. The Contractor reserves the right to evacuate the premises where the Facility is located, or to have the Contractor's employees and agents evacuated, and to suspend the Services in the event that, in its sole discretion, it shall deem that the environment in which the Services should be performed is not a safe environment.

d) The Customer shall, at its own costs and risk, take all necessary measures which may be needed in order to allow the Contractor to perform the Services without interruption. Therefore, any scaffold, ground, foundation and mortise work and so forth to be carried out in order to prepare the Site shall be timely completed before the Services are commenced. The Contractor is only obliged to provide the tools required for assembly.

e) The Customer shall acquire any authorization related to the management of hazardous waste applicable to the Services and the Facility and maintain such requirements.

f) Upon request from the Contractor, the Customer shall promptly provide the Contractor with the fuel gas analysis, which shall be carried out by the Customer at its expenses. The fuel must meet OEM specifications as set out in the Service Offer. The Contractor shall not be liable for any damages of any kind resulting from unacceptable gas quality or nonconformity to OEM specifications.

g) The Customer shall provide, free of charge, (i) a secured room suitable for storage at the Site and (ii) material-handling equipment, for the Contractor's use to store and move supplies in connection with the Services.

h) The Customer shall dispose of and manage any and all waste material and Hazardous Materials (if any) produced in connection with the installation and Services in strict compliance with the Applicable Law.

i) The Customer shall provide all consumables such as oil and glycol.

j) If necessary, the Customer shall make any modifications to the Facility's operations which are necessary to minimize physical harm to people and damage to the Facility in the event of an emergency. Any other modifications require written approval by the Contractor's Service Manager.

k) The Customer shall allow the Contractor to carry out the Preventive Maintenance, without interference,

during the working hours from 7.30 a.m. to 6.00 p.m., from Monday to Friday with exclusion of the national holidays. Any Preventive Maintenance Services included in the Contract Price, but provided outside of normal working hours shall be considered Extra Services and will be compensated by paying the difference between normal working hour fees and standard overtime fees, as well as other costs associated with working outside normal working hours.

l) If the lube oil is provided by the Customer (as specified in the Service Offer), the former shall strictly meet the requirements for Engine lubrication oil or the oil change parameters as per the list of oils suggested by the Engine manufacturer set forth in the OEM manuals. The Customer shall perform oil changes with a frequency such that its chemical and physical properties are always in accordance with the Contractor's requirements. The Customer shall provide: necessary quantities of lube oil for oil changes and the top ups, the lube oil pan(s), lube oil sampling, sending of samples to the laboratory, and lube oil analysis (to be provided to the Contractor as soon as available).

m) The Customer shall be responsible for (i) the fluid quality and quantity (such as cooling water, make-up water, anti-freezing compounds and anti-corrosion compounds, etc.), (ii) fuel gas quality and pressure, and (iii) meeting the requirements for engine lubrication oil and oil changes, according to the OEM manuals and the Technical Documentation. In case the Customer does not meet the quality requirements, any cost associated with the resulting corrective maintenance will be reimbursed to the Contractor, who will also no longer be liable for any loss of availability in that period.

n) The Customer agrees also to provide the Contractor's employees, free of charge, with the use of all utilities (electricity, drinking water, etc.) at the Site.

o) The Customer shall install and maintain a dedicated static IP address with a high speed internet connection with a minimum upload speed of 128kb/s, a data volume minimum of 3GB, open selected ports, and forwarding to the Contractor's connection to permit the Contractor to have immediate and uninterrupted remote access in accordance with the Contractor's instructions; the cost of the internet connection shall be borne by Customer.

p) The Customer shall accept the presence of online monitoring systems that allows the Contractor to take off-site readings of the status of the OPH and certain performance relevant measurements. The Contractor has the right to take on-site readings in order to perform the Services as well as possible in the interest of the Customer, and for accounting purposes, or to ask for written records of the operating hours and performance. The Monitoring & Performance System is enabled by the presence of the online monitoring systems.

q) The Customer agrees that without the Contractor's written consent, at all times while the Customer is employing the services of the Contractor and for twelve (12) months after termination of this Agreement, the Customer will not, directly or indirectly, whether individually or as an officer, director, employee, consultant, partner, stockholder, individual proprietor, joint venture, investor, lender, consultant or any other capacity whatsoever: solicit, divert hire, retain (including as a consultant) or encourage any employee or contractor of the Contractor to leave employment, or a contract with, the Contractor, or hire or retain (including as a consultant) any former employee of the Contractor who has left employment, or a contract, with the Contractor within twelve (12) months prior to such hiring or retention.

r) The Customer agrees to stop the machinery, and especially the reciprocating Engine, whenever necessary to allow the performance of the Services.

s) The Customer agrees to promptly make payments of the Contract Price as required by this Agreement.

t) The Customer needs to provide on-site support at the Facility to assist the Contractor with remote support diagnosis, as required to help identify technical issues.

u) The Customer agrees to provide, maintain, and pay for an adequate insurance policy to cover any damage, even towards third parties, due to the Covered Unit(s) and its(their) operation, including fire or explosion. The Customer shall provide proof of such insurance upon the Contractor's request.

v) The Customer agrees it shall be the sole party responsible for complying with any applicable workplace health and safety legislation in respect of the Services at Site and shall keep the Contractor fully indemnified against any and all liabilities thereto.

6. Contract Price

6.1 The Contract Price to be paid by the Customer to the Contractor for the performance of Services is set out in the Service Offer, and shall be net of any applicable Customer's Taxes, including sales taxes (if any), and is based on easy Site accessibility and Engine installation on the ground floor.

6.2 The Customer shall pay the Contract Price calculated on a monthly basis and billed monthly by the Contractor no later than five (5) days after receipt of the relevant invoice.

6.3 If, during the Term of the Agreement, any new legislation, taxes or regulations are established that cause an increase in fees or charges in connection with the Services set forth in the Agreement, then the Customer shall bear such increase.

6.4 The payment of the Contract Price shall be made by wire transfer to the bank account specified in the invoice, or by check.

6.5 The lower of 8% and the maximum interest rate provided by the governing law defined in section 14 will be charged on amounts not paid when due and shall be payable by the Customer.

6.6 The obligation of the Customer to make any payment pursuant to the Agreement shall be absolute notwithstanding any claim that the Customer may

assert against the Contractor or any of its Affiliates. The Customer shall not have any right to postpone, compensate, or make any deduction from any such payment for any reason whatsoever. The Customer may not undertake any action towards the Contractor before having totally paid all due amounts.

6.7 The Customer agrees that the Services qualify as services or materials on which a claim for a lien, with respect to the construction lien, mechanic's lien, or builder's lien, may arise pursuant to the applicable lien legislation should the Contractor opt to pursue such a lien for monies owed to it, and further, the Customer waives any defence associated with the non-applicability of such lien legislation to the Services.

6.8 If the Customer defaults in making any of the payments associated with the Agreement, the Customer agrees to pay, in addition to any defaulted amount, all of the Contractor's legal fees, collection costs and court costs in connection herewith. The Contractor reserves the right to disclose any relevant credit information when requested.

6.9 If the Customer is in breach of any payment terms or any other Customer obligations under the Agreement, the Contractor shall be entitled to suspend the Services until the Customer has fulfilled all previous contractual obligations, or to terminate the Agreement for a breach after providing the Customer with a reasonable grace period, and to assert damages, as the case may be.

7. Term of Agreement

7.1 This Agreement shall become effective upon the Effective Date and shall continue until the end of the Term stated in the Service Offer, unless terminated earlier in accordance with its terms.

7.2 In the case of the AB Protection Plan,with the exception of the AB Protection Plan for low running hour applications, both Parties understand by signing this Agreement that the prices quoted are based on an expected minimum 3,500 OPH per year completed by each Engine during the Term of this Agreement. If the annual OPH fall short for any reason, by more than twenty percent (20%), the Customer shall pay for a minimum of 2,800 OPH for that year. If applicable, an adjustment will be calculated to be paid within January of the next year.

8. Termination for breach of the Agreement

8.1 Either Party may terminate this Agreement if the other Party (i) becomes Insolvent or (ii) commits a material breach of this Agreement and fails to cure the breach within thirty (30) days of written notice of such breach from the other Party, or if it is not possible to cure such a breach within thirty (30) days of such notice.

8.2 Without prejudice to the Contractor's right to suspend the Service according to section 13 of these Terms and Conditions, the Contractor may terminate the Agreement with immediate effect if the Customer has delayed the payment of at least two invoices issued by the Contractor during the Term, regardless of the invoice's amounts.

8.3 In any case of termination the Customer shall pay the Contractor any and all amounts due and outstanding pursuant to the Agreement, including amounts due for Services performed, or portion thereof, and Parts supplied/ordered prior to the effective date of such termination.

8.4 The Parties agree that if the Customer terminates the Agreement at its discretion before the expiration of the Term, in addition to what is stated under section 8.3, the Customer shall pay to the Contractor a fee (the "**Termination Fee**") calculated per Engine at one third of the residual value of the Agreement (the hourly rate times the remaining number of OPH up to the end of the Term).

8.5 The termination has to be communicated by the Customer with 90 days' prior notice, and it shall be considered effective upon the payment of the Termination Fee (calculated and paid at the end of the notice period), in addition to the portion of the Contract Price for the Service performed until the effectiveness of the termination. The "remaining OPH" mentioned to compute the Termination Fee are the OPH as measured at the end of the 90 days' notice.

8.6 If a Minor Overhaul is to be performed during the notice period, the Termination Fee has to be paid in advance, before the Contractor performs the Minor Overhaul.

9. Warranty

9.1 Subject to the limitations in the Agreement, the Contractor warrants that all Services performed during the Term of this Agreement shall be performed in a competent, diligent manner, in accordance with generally accepted engineering standards, using reasonable care and skills consistent with those generally and ordinarily exercised by professionals under similar conditions.

9.2 Any claim related to the performance of Services must be notified to the Contractor within 10 days from the discovery of any faults or defects related to such Service.

9.3 In the case that the AB Protection Plan is offered to the Customer as per the Service Offer, the Contractor shall replace the damaged, defective or inefficient parts of the Covered Unit with proper spare parts which are similar in technology and quality. This section shall not apply in case of AB Protection Plan for low running hour applications.

9.4 In case of an AB Protection Plan for low running hour applications is offered as well as in case of any other kind of Service different from the AB Protection Plan (as indicated in the Service Offer), the activities set forth under previous section 9.3 shall be considered as Extra Services and, therefore, if requested by the Customer, they shall be paid by the Customer separately.

9.5 It is agreed and understood between the Parties that all substituted parts and components removed from the Covered Unit during the performance of the Services, shall automatically pass to the Contractor's ownership without any kind of formalities.

9.6 The spare parts installed as a consequence of the substitution and/or repair activities, set forth previously under sections 9.3 and 9.4, shall be guaranteed for a period of 12 months from their installation, except for the following items, which are not covered by the warranty of this section 9:

a) All elastic and rubber wear materials;

b) All types of filters (air, gas, oil, etc.);

c) Spark plugs;

d) All parts of the ignition system (spark plug cables, etc.);

e) Batteries;

f) All other components that the Customer tries to repair directly.

9.7 Contractor hereby disclaims any implied warranties, warranty of merchantability and fitness for particular purpose in relation to the Services.

10. Assignment of Services

10.1 The Contractor shall have the right to transfer, assign, or subcontract in whole or in part, by way of assignment or novation, its rights and/or obligations under the Agreement to one of its Affiliates without prior written consent from the Customer.

10.2 Except as otherwise provided herein, neither Party may transfer or assign, in whole or in part, any of its rights or obligations under this Agreement without the express written consent of the other Party, such consent not to be unreasonably withheld. Any transfer or assignment, or attempted transfer or assignment, in contravention of this Agreement, whether by operation of law or otherwise, shall be null and void.

10.3 Nothing in this section shall restrict the Contractor from subcontracting portions of the Services, provided that the Contractor shall remain responsible to the Customer for the performance of the subcontracted scope.

11. Indemnification

Customer shall indemnify and hold the Contractor and its Affiliates harmless from and against any loss or expense by reason of physical damage to the property of third parties or bodily injury, including death, of persons to the extent such damage or injury results directly from a breach of the Agreement, or the negligence of Customer or any of its agents and contractors, including but not limited to Customer or any of its employees or any third parties not abiding to OEM Manuals' prescriptions.

12. Amendments

Each Party may, from time to time, propose changes in the scope of Parts and/or Services to be provided by the Contractor under the Agreement. Such changes will be subject to the mutual agreement of the Parties. The Contractor will advise the Customer if any proposed change will result in Extra Services, or have any other cost or performance impact. The Contractor shall not be obligated to proceed with any change to the scope of the Services and/or Parts until and unless the Parties have agreed upon its scope and signed a written amendment to the Agreement.

13. Contractor's Suspension Right

In addition to other rights the Contractor may have, if the Customer fails to make payments as required by this Agreement, becomes generally unable to pay its debts when they become due, or sustains a material deterioration of its financial condition, the Contractor may suspend performance and delivery of the Services and/or of the Parts and/or thereafter require full or partial payment in advance. Any cost incurred by the Contractor in accordance with such suspension (including storage costs) shall be payable by the Customer upon submission of the Contractor's invoices, and all related risks and responsibilities for the Operation of the Covered Unit(s) will exclusively be borne by the Customer.

14. Governing Law

This Agreement shall be governed and interpreted under the English law, without regard to conflict of laws, principles, or any choice of law that would cause the application of laws of any other jurisdiction.

15. Confidentiality; Proprietary Information

15.1 The Customer shall keep confidential and secure all confidential information (including, without limitation, pricing and other terms relating to the Services) belonging or relating to the Contractor or its Affiliates, or to the business of the Contractor or its Affiliates, which the Customer receives or of which it becomes aware, and shall not use such information except to perform its obligations under the Agreement. The Customer shall, at the Contractor's written request or on termination of the Agreement for any reason, immediately return to the Contractor all copies and other records of such confidential information and destroy any records that cannot be returned and confirm such destruction in writing to the Contractor. The Customer shall disclose confidential information of the Contractor only to those of its officers, employees, agents and contractors to whom, and to the extent to which, such disclosure is necessary for the performance of its obligations under the Agreement, and shall ensure that such employees, agents and contractors are made aware of, and observe the obligations in, this section 15, and shall require them to enter into written undertakings in such terms as the Contractor may from time to time require or approve. The Customer shall immediately notify the Contractor of any breach of this section 15 or such undertaking.

15.2 The Parties acknowledge that the Contractor and its Affiliates have developed and will continue to develop valuable proprietary information, including, but not limited to, software source codes, processes, plans, devices, research and development results, proprietary design, any know-how, processes and methods related to the performance of the Services including the management and scheduling of the interventions, internal financial information, client lists, marketing and communication information, and marketing strategies

(the "**Proprietary Information**") and have devoted significant time, effort and money into identifying and attracting new clients and expanding into new markets. In addition, the Parties acknowledge that the reputation of the Contractor and its Affiliates for quality products and services has earned the Contractor and its Affiliates valuable goodwill and that the Contractor's and its Affiliates' high quality sales, marketing and operations personnel are a significant factor in the success of the Contractor and its Affiliates. The Parties hereto agree that during the Term of the Agreement and for an indefinite period thereafter, the Customer shall not (a) use, other than within the scope of the Agreement, or (b) disclose to any third parties any trade secret or other Proprietary Information relating to the business or affairs or products of, or services provided by, the Contractor or any person or entity having dealings therewith, or permit or encourage the use of such trade secrets or other Proprietary Information by another, or (c) use or disclose any Proprietary Information, including but not limited to the Contractor's and its Affiliates' customer lists, customer information, or customer preferences constituting a trade secret, or solicit the Contractor's and its Affiliates' customers, other than within the scope of the Agreement. For the purpose of this section 15.2, a "customer" of the Contractor or of its Affiliates shall mean and refer to (i) each person or entity who has received services or purchased products from the Contractor or its Affiliates during the Term, and (ii) each person or entity solicited by the Contractor or its Affiliates to receive services or purchase products during the Term.

16. Insurance

16.1 The Contractor shall provide, maintain, and pay for the following insurance coverage in connection with the Services:

a) coverage of the Contractor's liability against the risk of physical loss or damage to the Customer's and/or third parties' properties as per section 17.4, as well as;

b) coverage of the Contractor's liability towards its employees and/or its sub-contractors in case of death and/or injury and/or mental injury as a result of an accident or illness which occurs during the course of the performance of the Services;

with a maximum limit of liability equal to Euro 1.000.000,00 per event and Euro 2.000.000,00 in aggregate.

16.2 The Contractor shall provide proof of such insurance upon the Customer's request.

17. Limitation of Liability

17.1 The Contractor shall not be liable for the performance of the Covered Unit(s) due to causes beyond its reasonable control, including but not limited to acts of God, the Customer's actions, acts of military or civil authorities, fires, strikes, flood, epidemic, war, riot, delays in transportation or inability to obtain necessary permits, labour, material, components, or manufacturing facilities. In the event of any such delay, the date of delivery, or date to provide services shall be extended for a period equal to the time lost by reason of such delay.

17.2 Any other or further claims, rights and remedies of the Customer against the Contractor that are not expressly stipulated in these Terms and Conditions shall be excluded, irrespective of the legal theory on which they are based on (e.g. in contract or tort or under warranty). In particular, the Contractor shall in no event be liable for indirect and/or consequential damages, loss of profit, loss of use, business interruption, loss of interest, loss of information and data and damages also based on claims by other contractual partners of the Customer. The Contractor shall not be liable for any amounts which are otherwise covered by applicable insurance proceeds payable to the Customer.

17.3 Any and all damages caused by Force Majeure as well as by the Customer or any third person are excluded from the Contractor's liability.

17.4 Any and all physical damages to goods and property of the Customer and/or its subcontractors' and/or sub-suppliers' and/or any third party, shall be paid by the Contractor within the limits of the amounts payable by the insurance policies of the Contractor, which shall be limited on a per event basis to the lesser of:

a) the actual direct costs incurred by the Customer in repairing the property damage, to be substantiated to the reasonable satisfaction of the Contractor;

b) the amount of the Customer's property damage insurance deductible applicable to such loss; and

c) five hundred thousand Euro (Euro 500.000,00) per event,

and shall be further limited to two million Euro (Euro 2.000.000,00) in the aggregate.

17.5 Notwithstanding anything to the contrary contained in the Agreement, in no event shall the Contractor's total aggregate liability under any theory of recovery (including reimbursement of costs incurred by the Customer), exceed 10% (ten percent) of the annual Contract Price, whether arising by way of indemnity, in contract, in tort (including negligence) or otherwise, under or in connection with the Agreement.

17.6 The limitations of liability set forth in the Agreement shall not apply in case of mandatory liability by law or in case of wilful misconduct or gross negligence of the Contractor.

17.7 Any limitations of liability set forth in the Agreement shall also apply for the benefit of the Contractor's subcontractors, employees, directors or agents.

17.8 The Customer shall ensure that any liability of the Contractor towards contractual partners and Affiliates of the Customer shall not exceed the limitations of liabilities agreed between the Customer and the Contractor in these Terms and Conditions. The Customer shall indemnify the Contractor for any exceeding claims of such a contractual partner.

18. Dispute Resolution

All disputes arising in connection with the Agreement shall be settled, if possible, by negotiation between the Parties. If the matter is not resolved by such negotiations within 30 days, all disputes under this Agreement shall be exclusively and finally settled by the Court of London (UK).

19. Miscellaneous

19.1 The Customer and Contractor are each independent of the other and are not joint ventures, partners, agents, nor representatives of each other, and have no legal relationship other than as contracting parties to the Agreement. Nothing herein shall be construed to create the relationship of employer and employee, principal and agent, partnership or joint venture, or any other fiduciary relationship among the Parties.

19.2 Except as provided in the section entitled "Limitations of Liability", the provisions of the Agreement are for the benefit of the Parties hereto and not for any other or third party.

19.3 No modification, amendment, rescission, waiver or other change shall be binding on a Party unless agreed in writing by that Party. The Agreement represents the entire agreement between the Parties. Any oral or written representation, warranty, course of dealing or trade usage not contained or referenced herein shall not be binding on either Party. Each Party agrees that it has not relied on, or been induced by, any representations of the other Party not contained in the Agreement.

19.4 No delay on the part of any Party in the exercise of any right or remedy shall operate as a waiver thereof, and no single or partial exercise by any Party of any right or remedy shall preclude other or further exercise thereof or the exercise of any other right or remedy.

19.5 Whenever possible, each provision of the Agreement shall be construed and interpreted in such a manner as to be effective and valid under governing law indicated in section 14, but if any provision of the Agreement or the application thereof to any Party or circumstance shall be prohibited by or invalid under governing law indicated in section 14, such provision shall be ineffective to the extent of such prohibition without invalidating the remainder of such provision or any other provision of this Agreement or the application of such provision to other parties or circumstances.

19.6 The language of these Terms and Conditions and any other document to be provided by the Contractor under the Agreement shall be English.

19.7 The Customer represents the sole owner of the Covered Unit(s), Facility and Site. In the event that there is an additional or different customer of all or any portion of the Covered Unit(s), Facility, or Site, in addition to any other rights of the Contractor, the Customer shall indemnify and hold the Contractor and its Affiliates harmless from any and all claims, suits, losses and expenses (including legal fees) brought against or incurred by the Contractor and its Affiliates by, or on account of, any such additional or different customer.

19.8 This Agreement may be signed in counterparts with the same effect as if all signing Parties had signed the same document. All counterparts shall be construed together and constitute one and the same contract.

20. Price Adjustment

20.1 The annual Contract Price set forth under section 3.1 of the Service Offer shall be adjusted upward (the "**Price Adjustment**") beginning on January 1 of the first calendar year of the Term, and on January 1 of each year thereafter during the Term, on a cumulative annual basis.

20.2 If the lube oil is included in the Contract Price, the Price Adjustment shall be calculated in accordance with the formula described hereinafter, by an amount determined in accordance with the definitions and formulas described in this section:

$$P = P0 * \left(\frac{L1}{L0}0.25 + \frac{M1}{M0}0.65 + \frac{N1}{N0}0.10\right)$$

20.3 In case the lube oil price is not included in the Contract Price, the Price Adjustment shall be calculated according to the following formula:

$$P = P0 * \left(\frac{L1}{L0}0.25 + \frac{M1}{M0}0.75\right)$$

20.4 In case the lube oil price is quoted separately, in addition to the Price Adjustment of the Contract Price that shall be calculated pursuant to the formula set forth under section 20.3 above, the lube oil price shall be annually increased according to the following formula:

$$P = P0 * \left(\frac{N1}{N0}\right)$$

In the formulas above indicated:

P = price for the subsequent year.

P0 = for the first year, P0 corresponds to prices defined in the Service Offer; for the subsequent years P0 will be equal to the value of P of the previous year.

L = harmonized indices of consumer prices or Eurostat Index for labour of the Contractor's Affiliate performing the Services.

M = indices of the German Statistical Federal Authority for "combustion engines and turbines"; no. GP-2811, price indices for industrial products.

N = Eurostat - Harmonized Index of Consumer Prices (HICP) for fuels and lubricants.

As subscript, the meaning is as follows:

	1st year	Following years
0	First available value, after Agreement	Value with subscript 1 of the

	signature	previous year
1	Value on 1st January of the coming year	

20.5 The price for the Additional Services set forth under section 3.2 of the Service Offer, if any, shall be adjusted every January 1st during the Term according to the AB price list.

20.6 The price (P) of the applicable payments shall equal the greater of the starting price (PO) or the result from the calculation in accordance with the above formula.

20.7 In the event that the specified indices are discontinued, or the basis of their calculation is modified, equivalent indices shall be substituted by mutual agreement between the Parties.

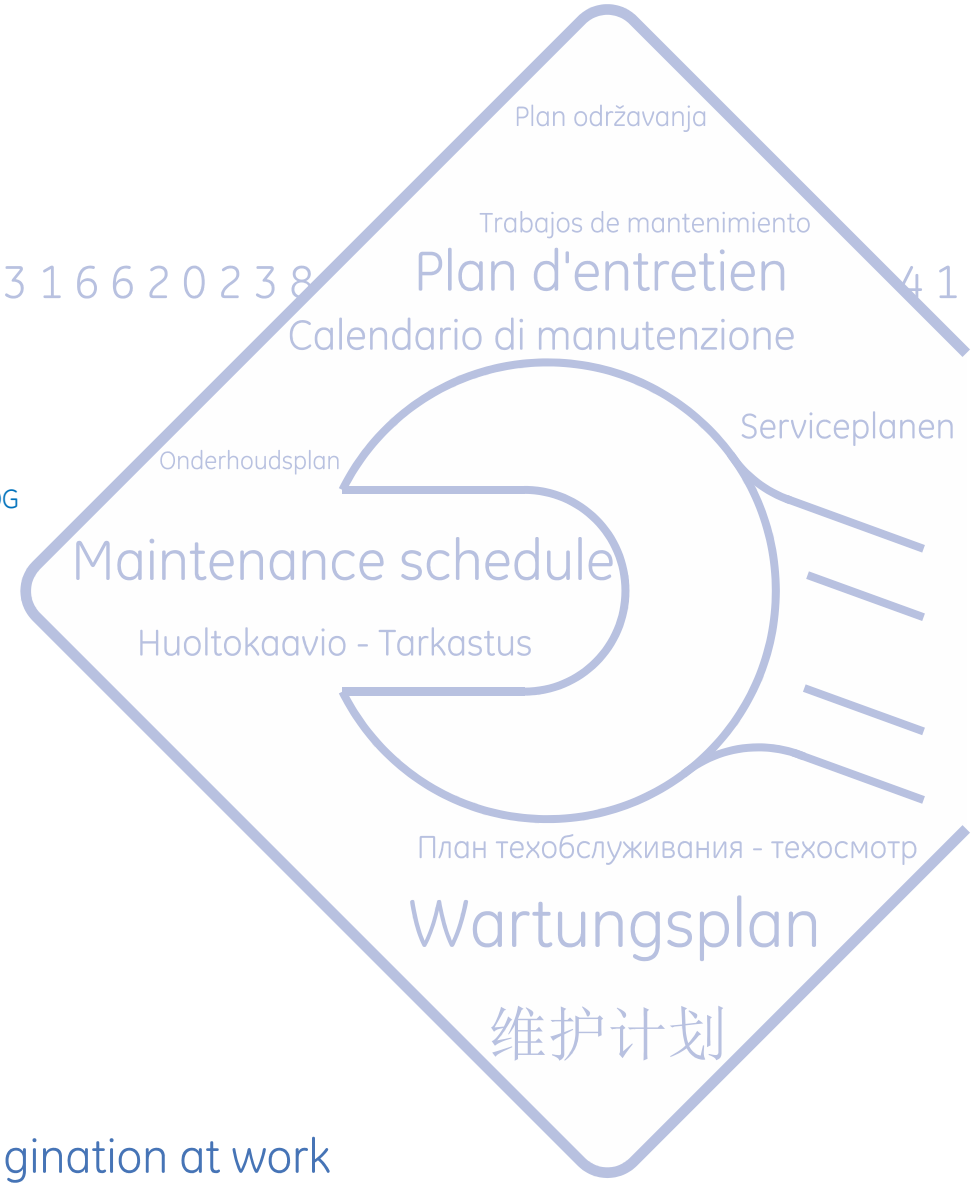
20.8 The Contractor will indicate the Price Adjustment amount as a separate item on the first invoice submitted after January 1 of the applicable calendar year or claim for payment submitted under the Agreement.

21. Currency Fluctuation Adjustment

The Contract Price set forth in the Service Offer is expressed in British Pound and is based on the exchange rate EUR/£ applicable at the date of signature of the Service Offer ("Base Exchange Rate"). If during the Term the monthly average exchange rate next preceding the invoice date ("Average Exchange Rate") deviates by up to 40% (exclusive) from the Base Exchange Rate, any cost related to the currency fluctuation shall be incurred by the Contractor. Any deviation in the Average Exchange Rate exceeding 40% (inclusive) from the Base Exchange Rate shall result in an extra cost equal to 10% to be added on top of the Contract Price, after the application of the yearly Price Adjustment according to the formula set forth under section 20.1, and it shall be invoiced by the Contractor and paid by the Customer in the same invoice issued for the monthly Services performed. For the purposes of this section, the Average Exchange Rate shall be the average monthly exchange rate published by the -- on the last Friday of each month.

GE Power

Standard Maintenance schedule A Type 6



Achenseestr. 1-3
A-6200 Jenbach, Austria
www.gejenbacher.com

GE imagination at work

Maintenance instruction highlighted in green

The maintenance instructions highlighted in green in the maintenance schedule are plant-specific and are incorporated into the customer-specific maintenance schedule according to engine type and version.

Maintenance instruction highlighted in yellow

The maintenance work highlighted in yellow in the maintenance plan only applies for the J612 with mean effective pressure ≥22 bar.

Maintenance instruction highlighted in blue

The maintenance work highlighted in blue in the maintenance plan only applies to engines with gearboxes.

Interval	Number/Section	Inspection work	Note
Daily	I 9003 0	Daily inspection	Visual inspection of the module to be carried out daily
Daily	I 8030 0	Grid Code	Inspection by grid code on the DIANE
Daily	IW 0511 M6	Crankcase ventilation	Inspection
Daily	IW 0513 M6	Crankcase ventilation	Inspection
Daily	IW 8040 A6	Intake air filter (ROLF) - engine	If the underpressure displayed exceeds 2.5 Pa, the filter cartridges should be replaced (but after 2,000 operating hours at the latest)
Daily	IW 8041 A6	Intake air filter - engine	If the manometer at the pocket filter indicates an underpressure of > 10 mbar (1,000 Pa), you must replace the filter cloths (but after 2,000 operating hours at the latest)
Daily	IW 8047 A0	Surge suppressor	Visual inspection of the overvoltage suppressors
Daily	IW 8048 A0	Surge suppressor	Visual inspection of the overvoltage suppressors
Daily	W 8038 M6	Oil filter cartridge - engine	Replace the oil filter cartridge if the differential oil pressure warning appears on the DIA.NE.
Daily	----	Operational data log	Daily record of the operational data
Daily	----	Generator	Record bearing temperature
			Visual Inspection

Interval	Number/Section	Inspection work	Note
Weekly < 250 Oh	IW 0309 M0	Ignition voltage check / spark plugs	The result of the ignition voltage check to be carried out weekly serves as the indicator for the actual service life of the spark plugs
Weekly	IW 8071 A0	Gearbox	Inspect oil level
The first time after 75 Oh	IW 0101 M6 TA 1000-0099A TA 1000-0099B TA 1000-0099C	Lubricating oil	Depending on the fuel gas class according to TA 1000-1109, the first engine lubricating oil analyses can also be carried out at a later stage according to TA 1000-0099C.
	TA 1100-1109	The results from the engine lubricating oil analyses dictate the actual measuring intervals and oil change periods.	
At every oil change	W 8038 M6	Oil filter cartridge - engine	After 4,000 operating hours at the latest
At every oil change	W 8038 M6	Oil filter cartridge - engine	After 6,000 operating hours at the latest
When differential pressure warning displayed on the DIA.NE	W 8038 M6	Oil filter cartridge - engine	After 6,000 operating hours at the latest
Once a month	TA 1000-0050	Battery	Check the acid level Check if the pole binders are properly secured
Six-monthly	W 8048 A4	Humidity sensor - intake air	At an air humidity of: > 90 % rH -> calibration
Annually			Between 80 and 90% rH -> calibration
Every 2 years			Up to 80% rH -> calibration
Once a year	---	Control cabinet cooling device	Check for dirt and clean using compressed air, if necessary
Once a year or in accordance with official regulations	----	Safety valve	Check for function
Once a year or in accordance with official regulations	---	Gas and smoke alarm installation	Check (comply with official regulations)
2,000 Oh **Heat exchanger >100°C Water temperature ➔ in acc. with official regulations**	I 0103 6	Exhaust gas/water heat exchanger	In many countries, heat exchangers with a water temperature >100°C are classified as installations requiring special monitoring. Before commissioning - and subsequently at regular intervals - these installations are legally subjected to inspections by certified inspection agencies (e.g. operational safety regulations, steam boiler regulations, etc.).
According to W 8080 A0	W 8080 A0 TA 1000-0200	Cooling water	Concentration check / cooling water replacement

Interval	Number/Section	Inspection work	Note
2,000 Oh **at least 4 times a year**	IW 8090 A0	Condensate drain line in the fuel gas system (if part of scope of supply) Automatic condensate removal	Check for gas leaks
When required		Manual condensate drain	Condensate drain
monthly	IW 8095 A0	Exhaust gas system condensate drain line	Check exhaust gas system condensate drain line
When required			
When required	IW 8083 A6	Scavenging air fans	Condensate drain
6 months or 4,000 Oh			Check motor cooling ribs for dirt deposits
12 months or 8,000 Oh			Check the impeller blades for dirt deposits
2,000 Oh **At least every three months**	IW 8049 0	All pipes and components carrying fuel gas and mixtures	Leak test
8,000 Oh **At least once a year** **For natural gas only**	IW 8049 0	All pipes and components carrying fuel gas and mixtures	Leak test
Six-monthly	---	Exhaust gas silencer	Check the exhaust silencer and connection pieces for scaling and cracking. Leaks can be determined through a change in colour or damage of the insulation (noise) or a slight emission of soot. **Repairs may only be carried out after consulting the manufacturer!**
10,000 Oh (or 4,000 engine starts)	W 8032 M0	Starter motor	Replace
10,000 Oh (or 3,000 engine starts)	W 8054 M0	Prelubrication pump electric motor	Checking the brushes
30,000 Oh (or 4,000 engine starts)	W 8050 M6	Main crankshaft bearings/ thrust bearing	Crankshaft main bearings/thrust bearings - replace
Every 2 years	---	Battery in DIANE module	Replace
Every 2.5 years	---	Buffer battery at battery charger	Replace
---	---	Gas compressor	Service according to Manufacturer's instructions (Description / Operation: Gas compressor)
Measure the emissions as laid down by the official regulations or at least every six months	--- W 8056 M0	Emission measurement Combustion chamber cleaning	If the emission levels listed in the specification are exceeded, inspect and, if required, clean the combustion chambers.

Proper maintenance according to the maintenance schedule is a condition for the acceptance of warranty claims.

The risk assessment to be performed by the plant operator as well as the official and quasi-official safety rules and legislation may give rise to acceptance tests, inspections and maintenance operations that are not included in the maintenance schedule. The operator is responsible for implementing and enforcing these additional measures.

The maintenance intervals are based on empirical values during average types of operation while fully complying with the manufacturer's operating and maintenance instructions. In individual cases, the operating conditions and other factors relating to wear may affect the actual amount of maintenance required. The manufacturer therefore reserves the right to specify different maintenance intervals where appropriate.

After the 'overhaul' at 60,000 operating hours, the maintenance work to be carried out is repeated.

Inspection work/Maintenance instruction	Number	Operating hours																																																													
		< 100	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,000	28,000	29,000	30,000	31,000	32,000	33,000	34,000	35,000	36,000	37,000	38,000	39,000	40,000	41,000	42,000	43,000	44,000	45,000	46,000	47,000	48,000	49,000	50,000	51,000	52,000	53,000	54,000	55,000	56,000	57,000	58,000	59,000	60,000
Maintenance after initial commissioning	W 1000 6	■																																																												
Crankcase ventilation	IW 0509 M6		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Crankcase ventilation	IW 0511 M6		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Crankcase ventilation	IW 0513 M6		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Generator	W 8034 A0		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Generator	W 8035 A0		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Leanox setting	IW 8090 M6		■	■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Inspection	I 0103 6			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Intake air filter (ROLF) - engine	IW 8040 A6			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Engine intake air	IW 8041 A6			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Leak test	IW 8049 0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Gearbox	IW 8071 A0			■		■				■				■				■				■				■				■				■				■				■				■				■				■				■				■
Control rod assembly/throttle valve/actuator	W 0200 M6ef			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Ignition	W 0303 M0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Valve clearance	W 0400 M6			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Exhaust-gas turbocharger	W 8025 M0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Exhaust-gas turbocharger	W 8025 M6			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Jenbacher - switch cabinets	W 8031 A0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Generator	W 8037 A0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Cooling water system / mixture circulating water	W 8080 A0			■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■		■
Prechamber mixture formation system	IW 0500 M6					■				■				■				■				■				■				■				■				■				■				■				■				■				■				■
Flexibly-mounted coupling housing	IW 8079 A6					■				■				■				■				■				■				■				■				■				■				■				■				■				■				■
Oil filter cartridge	W 8038 M6					■				■				■				■				■				■				■				■				■				■				■				■				■				■				■
Gas train	W 8045 A0					■				■		■				■				■		■				■				■		■				■				■		■				■				■		■				■				■		■
Pre-combustion chamber/Pre-combustion chamber gas valve/Spark plug sleeve	W 0501 M6							■						■						■						■						■						■						■						■						■						■
Elastomer components	W 8034 6							■				■		■						■		■				■						■						■				■		■						■		■				■						■
Oil filter cartridge	W 8038 M6							■						■						■						■						■						■						■						■						■						■
Leak test	IW 8049 0									■								■								■								■								■								■								■				
Engine cooling water pump	W 0203 A6											■										■										■										■										■										■
Vibration damper	W 0601 M0											■										■										■										■										■										■
Exhaust gas turbocharger	W 8023 M0											■										■										■										■										■										■
Exhaust gas turbocharger	W 8026 M6											■										■										■										■										■										■
Starter motor	W 8032 M0											■										■										■										■										■										■
Cylinder head	W 8053 M6											■										■										■										■										■										■
Pre-lubrication pump	W 8054 M0											■										■										■										■										■										■
Crankshaft thrust bearing	W 8060 M6											■										■										■										■										■										■
Vibration damper	W 0601 M0																					■																				■																				■
Gas quantity controller	W 0705 M0																					■										■										■																				■
Mixture bypass valve	W 0802 M0																					■																				■																				■
Engine oil pump	W 8046 M6																															■																														■
Piston/Piston cooling	W 8047 M0																															■																														■

Inspection work/Maintenance instruction	Number	Operating hours																																																											
		< 100	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,000	28,000	29,000	30,000	31,000	32,000	33,000	34,000	35,000	36,000	37,000	38,000	39,000	40,000	41,000	42,000	43,000	44,000	45,000	46,000	47,000	48,000	49,000	50,000	51,000	52,000	53,000	54,000	55,000	56,000	57,000	58,000	59,000	60,000
Connecting rods / conrod bearings	W 8048 M0																															■																														■
Cylinder liner	W 8049 M0																															■																														■
Main crankshaft bearings/thrust bearing	W 8050 M6																															■																														■
Camshaft/valve timing gear	IW 8052 M0	if required																																																												■
Plate heat exchanger	W 8043 A0																																																													■
Revision	W 2100 M0																																																													■
Exhaust gas manifold/Insulation	W 8051 M0	in the course of the cylinder head exchange																																																												

Please note that properly carried out maintenance work is to be acknowledged by filling in the maintenance record sheet.

AB ENERGY (UK) LTD's Labor Price List

All the maintenance interventions requested and performed by the AB ENERGY (UK) LTD, will be invoiced according to the following price list valid till 31/12/2019:

Standard price for maintenance interventions executed from 7.30 am and 5.00 pm:

- Labor and travel costs	€/h 90,00 + V.A.T.
- Km reimbursement	€/h 0,70 + V.A.T.
- Exit fee	€ 200,00 + V.A.T.
- Lunch reimbursement	€ 15,00 + V.A.T.
- Dinner reimbursement	€ 25,00 + V.A.T.
- Technicians lodging costs	€ 115,00 + V.A.T.
- Flights costs	end intervention – final balance
- Necessary spare parts for the execution of the maintenance	end intervention - final balance

Extra price for maintenance interventions executed from 5.00 pm and 7.30 am:

- Labor and travel costs	€/h 110,00 + V.A.T.
- Km reimbursement	€/h 0,70 + V.A.T.
- Exit fee	€ 200,00 + V.A.T.
- Lunch reimbursement	€ 15,00 + V.A.T.
- Dinner reimbursement	€ 25,00 + V.A.T.
- Technicians lodging costs	€ 115,00 + V.A.T.
- Flights costs	end intervention – final balance
- Necessary spare parts for the execution of the maintenance	end intervention - final balance

APPENDIX 7
AIR QUALITY ASSESSMENT

On behalf of
Infinite Renewables Limited.

Intended for
Infinite Renewables Limited.

Date
August 2020

Project Number
1620009679

ROYAL MINT CHP ENGINE
AIR QUALITY MODELLING REPORT

RAMBOLL

ROYAL MINT CHP ENGINE
AIR QUALITY MODELLING REPORT

Project No.	**1620009679**
Issue No.	**P01**
Date	**30/07/2020**
Made by	**Ana Gomes**
Checked by	**Graham Harker**
Approved by	**Graham Harker**

Made by:	
Checked/Approved by:	

Version Control Log

Revision	Date	Made by	Checked by	Approved by	Description
01	10/08/2020	AG	GH	GH	First Draft Modelling Report

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EXECUTIVE SUMMARY

Ramboll UK Ltd (Ramboll) has been commissioned by Infinite Renewables Ltd to undertake air dispersion modelling in support of an Environmental Permit application incorporating the operation of a CHP engine.

This report sets out the method and results of the dispersion modelling; broadly the scope of the air quality assessment includes:

- Review of local air quality data surrounding the Site;
- Desk study of the building arrangements and locations of human and ecological receptors sensitive to a change in local air quality resulting from the boiler emissions; and
- ADMS dispersion modelling of the operational plant emissions to predict process contributions (PCs) and Predicted Environmental Concentrations (PECs) at identified sensitive receptors for comparison against relevant ambient assessment levels.

The modelling assessment has been undertaken on a conservative basis of the CHP engine operating all year round. The maximum predicted impacts for any of the five years' worth of meteorological data modelled have been reported. Overall, the predicted impacts are considered to be conservative and worst case. As the equipment is gas fired, only emissions of NO_x have been modelled as natural gas contains insignificant amounts of sulphur. The impacts of CO emissions have been screened out as insignificant using the H1 tool.

Impacts have been predicted at a number of human health and ecological receptor locations in the vicinity of the site.

With the CHP engine operational all year round, all of the PCs are either insignificant or the PECs are significantly lower than the environmental assessment levels at the human health receptor locations. The maximum predicted NO_x PCs at the designated sites are either insignificant or the PECs do not exceed the long term or short term critical levels.

Nitrogen deposition is above 1% of the grassland and woodland critical loads within the Rhos Tonyrefail SSSI parcel closest to the site, with the total PEC dominated by existing baseline deposition rates. Nitrogen deposition is above 1% of the woodland habitat critical load for an area of scrubland along the northern edge of the Llantrisant Common SSSI, but not above 1% for grassland habitats. The areas of deposition above 1% of the critical loads are approximately 1% of the areas of each SSSI.

For grassland habitats, the nitrogen acid deposition is above 1% of the critical load for approximately 30% of the Rhos Tonyrefail SSSI parcel closest to the site. The acid deposition is less than 1% of the critical load for woodland habitats.

Overall, taking into account the areas affected, it is not considered that the additional deposition will have a significant overall effect on the habitats within the Rhos Tonyrefail or Llantrisant Common SSSI.

1. INTRODUCTION

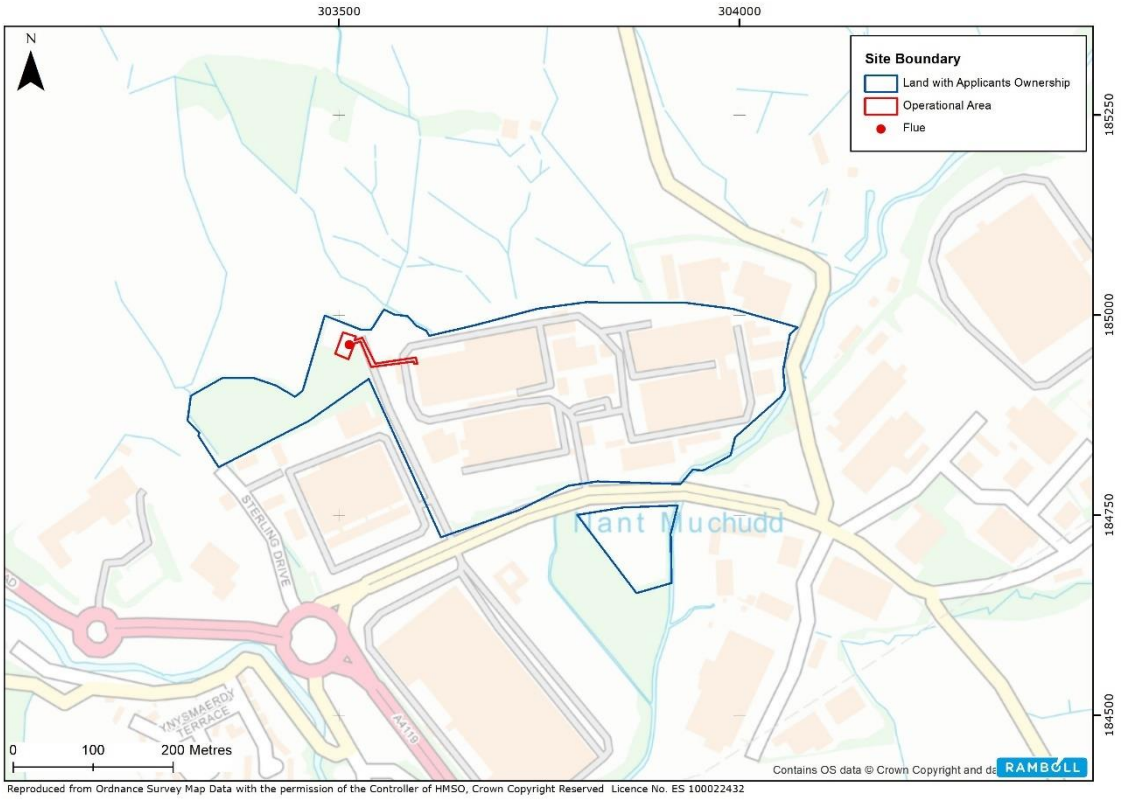
Ramboll UK Ltd (Ramboll) has been commissioned by Infinite Renewables Ltd ('the client'), to undertake air dispersion modelling in support of an Environmental Permit application at the Royal Mint site at Llantrisant Business Park.

This report sets out the method and results of the dispersion modelling used to assess the air quality impacts of the plant.

1.1 Site Description

The site lies to the north west of the Royal Mint and the site location is shown in Figure 1.1.

Figure 1.1: Site Location



The site is not located within an Air Quality Management Area (AQMA).

1.2 Scope

The permit application concerns the operation of a 2.5MWe CHP engine. permit.

As the engine is natural gas fired, the pollutants of concern are oxides of nitrogen (NO_x) and carbon monoxide (CO). Natural gas has negligible sulphur content and therefore emissions of sulphur dioxide are considered to be negligible and are not incorporated into the model. Enissions of CO have been assessed using the H1 toolkit and the impacts are negligible and have therefore been screened out of modelling.

Relevant human health receptors have been identified in the vicinity of the site and impacts have been assessed at specific receptor locations closest to the site.

Identified ecological receptors within 5km of the site are:

- Rhos Tonyrefail SSSI
- Llantrisant Common and Pastures SSSI

2. METHODOLOGY

2.1 Introduction

The scope of the assessment has been determined by consideration of the following:

- Review of local air quality data for the including Defra background maps and information on the Air Pollution Information System (APIS) website;
- Desk study of the building arrangements and locations of human and ecological receptors sensitive to a change in local air quality resulting from the boiler emissions;
- ADMS dispersion models with operational energy centre emissions to predict process contributions (PCs) and Predicted Environmental Concentrations (PECs) at identified sensitive receptors for comparison against relevant assessment levels and loads.

2.2 Air Quality Strategy Objectives

The long-term and short-term National Air Quality Objectives (NAQOs) that are applicable to this assessment are detailed below in Table 2.1.

Table 2.1: National Air Quality Objectives

Pollutant	Concentration ($\mu g/m^3$)	Averaging Period	NAQO Exceedances Allowed	Percentiles
Human Health Impacts				
Nitrogen dioxide (NO_2)	200	One hour mean	18	99.79
Nitrogen dioxide (NO_2)	40	Annual mean	-	-
Ecological receptors				
Oxides of nitrogen (NO_x)	30	Annual mean	-	-

Recent guidance produced by the Institute of Air Quality Management (IAQM)[1] provides an explanation of the reasoning behind setting of the annual mean NO_x objective for the protection of ecosystems (paragraphs D.4.8 to D.4.10):

> *'The critical level does not differentiate between the role of nitrogen deposition and NO_x in the air. It is a precautionary general threshold, not specific to a particular habitat, plant species or impact pathway, below which there is currently a high degree of confidence that no adverse effects on vegetation will arise. Long-term NO_x concentrations below the critical level are therefore desirable. Some species or habitats may not show adverse effects until higher concentrations are present.*
>
> *The long-term (annual mean) concentration of NO_x is most relevant for its impacts on vegetation, as the effects, particularly through the nitrogen deposition pathway, are additive over months and years. This is reflected in the adoption of the long-term guideline in the EU Air Quality Directive as a limit value for vegetation. However,*

[1] A guide to the assessment of air quality impacts on designated nature conservation sites, D.4.9, v1.0 June 2019

atmospheric exposure to very high concentrations of NO_x for short periods (hours/days) may also have an adverse effect under certain conditions even if the long-term concentrations are below the limit value. The WHO guidelines include a short term (24-hour average) NO_x critical level of 75µg/m³. Originally set at 200µg/m³ as a four-hour mean, the more detailed CD-ROM version of the 2000 WHO guidelines comments: "Experimental evidence exists that the CLE decreases from around 200µg/m³ to 75µg/m³ when in-combination with O_3 or SO_2 at or above their critical levels. In the knowledge that short-term episodes of elevated NO_x concentrations are generally combined with elevated concentrations of O_3 or SO_2, 75µg/m³ is proposed for the 24 h mean." Ozone and SO_2 concentrations are typically low in the UK compared to many other countries. If a regulator does require the use of the short term NO_x critical level, given the low UK SO_2 concentrations IAQM consider it is most appropriate to use 200µg/m³ as the short term critical load.

The relative importance of the long-term mean compared to the short term mean is reflected in several studies which state that the 'UNECE Working Group on Effects strongly recommended the use of the annual mean value, as the long-term effects of NO_x are thought to be more significant than the short term effects'. This IAQM guidance, therefore, recommends that only the annual mean NO_x concentration is used in assessments unless specifically required by a regulator; for instance, as part of an industrial permit application where high, short term peaks in emissions, and consequent ambient concentrations, may occur.'

In terms of the assessment of the impacts of NO_x emissions for an Environmental Permit, the assessment is required to consider both the annual mean and daily mean concentrations. As the extract from the IAQM guidance makes clear however, compliance with the annual mean critical level is the more significant of the two parameters and is likely to be highly protective of vegetation in general.

In terms of the daily mean critical level, the published Environmental Assessment Level in EA guidance[2] is 75µg/m³ and this is likely to be highly conservative in the context of UK O_3 and SO_2 concentrations, and a critical level of 200µg/m³ is likely to be more appropriate. However, in order to be conservative, the results of the dispersion modelling are compared against the lower critical level of 75µg/m³ in this assessment.

2.3 Critical Loads

2.3.1 Introduction

For the deposition of air pollutants critical loads have been set for different habitats. The Air Pollution Information System (APIS)[3] provides critical loads for nitrogen deposition (leading to eutrophication) and nitrogen acid deposition (leading to acidification) for different habitat types and specific site relevant critical loads for designated sites. For the assessment of deposition there are two deposition velocities that are used; one for 'short' habitats (i.e. grassland) and one for 'tall' habitats (i.e. woodland). The modelling has therefore considered whether both types of habitat are present.

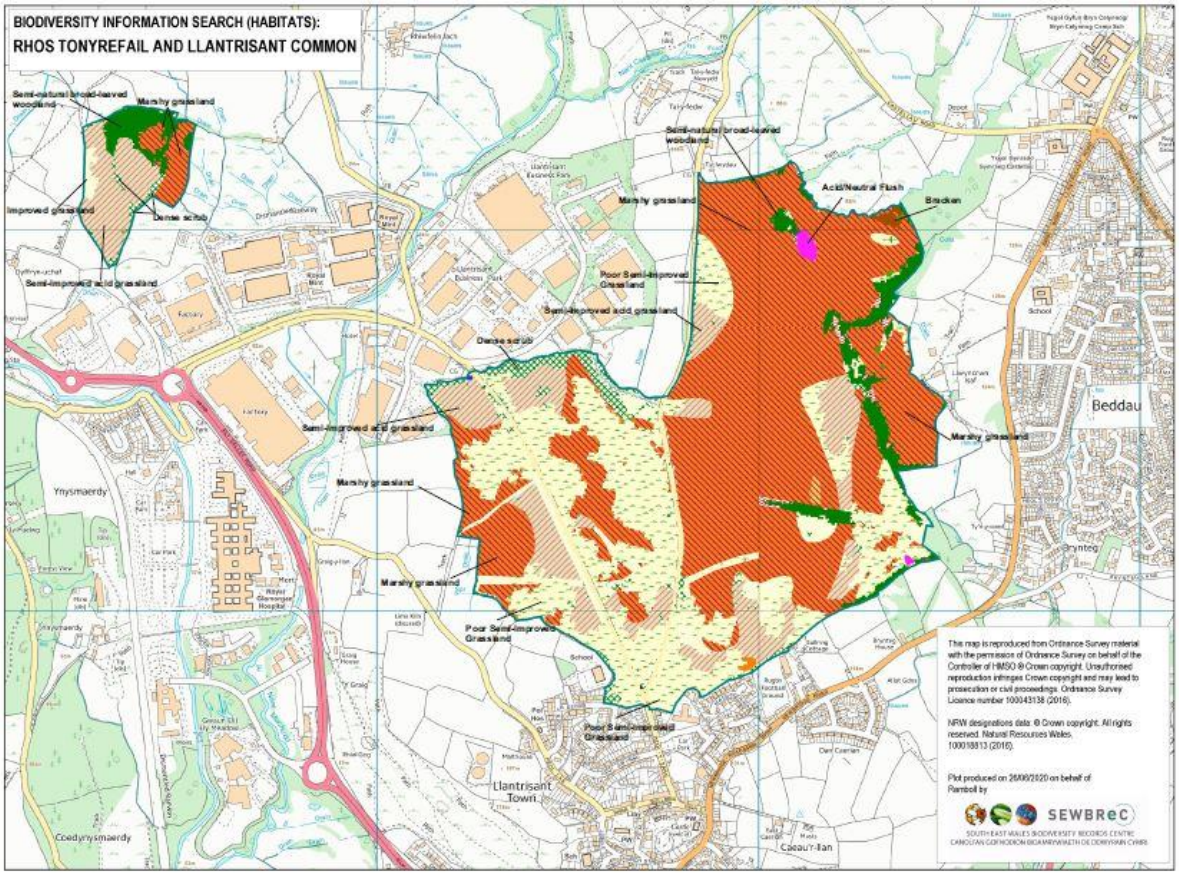
[2] https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

[3] http://www.apis.ac.uk accessed March 2020

2.3.2 Site Relevant Critical Loads for Designated Sites

An initial assessment has been undertaken for the types of habitats present at the two SSSIs in the immediate vicinity of the site which will be most impacted by emissions from the CHP engine. Figure 2.1 shows the distribution of habitats in these locations.

Figure 2.1: Habitat Distribution



For this study, the most appropriate site relevant critical loads quoted on APIS for the designated sites have been used, as shown in Table 2.2. The site relevant critical loads were the lowest for the various types of habitat shown in Figure 2.1.

Table 2.2: Site Relevant Critical Loads

Site	Habitat	N critical load (kgN/ha/yr)	Acid critical load (keq/ha/yr)		
			MinCLMinN	MinCLMaxN	MinCLMaxS
Rhos Tonyrefail SSSI	Acid grassland	8 - 15	0.366	0.660	0.240
Rhos Tonyrefail SSSI	Semi natural woodland (broadleaved mixed and yew woodland)	5 - 15	0.285	1.316	1.37
Llantrisant Common and Pastures SSSI	Acid grassland	8 - 15	0.366	0.660	0.240

Site	Habitat	N critical load (kgN/ha/yr)	Acid critical load (keq/ha/yr)		
			MinCLMinN	MinCLMaxN	MinCLMaxS
Llantrisant Common and Pastures SSSI	Semi natural woodland (broadleaved mixed and yew woodland)	5 - 15	0.285	1.316	1.37

The area of scrub shown along the southern boundary of the Rhos Tonyrefail SSSI parcel closest to the site are deciduous hedgerows which are not listed as an interest feature on APIS for the site. The area of woodland is therefore assumed to be present in the northern part of the parcel as shown in Figure 2.1.

2.4 Significance Criteria

2.4.1 Human Health Receptors

For Environmental Permitting, Natural Resources Wales currently follow guidance issued by the Environment Agency for assessing the risks of air pollution. For Environmental Permitting, the process contribution (PC) is compared against the relevant environmental standard. PCs that meet both the following criteria can be screened out from further assessment:

- the short-term PC is less than 10% of the short-term environmental standard,
- the long-term PC is less than 1% of the long-term environmental standard.

Whilst intended to apply to screening assessments and the need to undertake dispersion modelling of emissions, the above criteria are commonly applied to the consideration of the impacts from dispersion modelling. Where the PCs do not screen out, the Predicted Environmental Concentration (PEC) must also be calculated. The PEC includes the background concentration and assesses the cumulative impact in relation to the environmental standard.

The following screening criteria are then applied to the PECs:

- the short-term PC is less than 20% of the short-term environmental standards minus twice the long-term background concentration,
- the long-term PEC is less than 70% of the long-term environmental standards.

Again, whilst these are screening criteria, they are commonly applied to the consideration of the results of modelling assessments.

2.4.2 Ecological Receptors

For ecological assessments for designated sites similar criteria apply:

- the short-term PC is less than 10% of the short-term environmental standard for protected conservation areas,
- the long-term PC is less than 1% of the long-term environmental standard for protected conservation areas.

Where the above assessment criteria are not met, the long-term PEC is assessed:

- If the long-term PEC is less than 70% of the long-term environmental standard, the emissions are insignificant and dispersion modelling is not required.

If the PEC is greater than 70% of the long-term environmental standard, detailed modelling is required, but thereafter, the assessment of significance is whether or not the PEC exceeds the environmental standard.

For non-designated sites such as ancient woodlands and LWS, then consideration is only given to the PC. If concentrations meet both of the following criteria, then the impacts are considered insignificant and no further assessment is necessary:

- the short-term PC is less than 100% of the short-term environmental standard.
- the long-term PC is less than 100% of the long-term environmental standard.

The guidance simply states that if the PC exceeds the screening criteria then detailed modelling must be undertaken.

3. DISPERSION MODELLING

3.1 Introduction

Air quality impacts were modelled using the ADMS5[4] air quality dispersion model. This uses representative meteorological data for the local area and plant emissions data to predict ambient concentrations of pollutants in the vicinity of the stack. Details of the ADMS 5 model set up are provided in Appendix 1 with an overview in the following sections.

3.2 Model Set Up

3.2.1 Emission Rates and Operating Hours

For dispersion modelling purposes it is assumed that the CHP engine will be operational all year round; this will over-estimate both the long-term and short-term concentrations as the equipment cannot be operational 100% of the time due to maintenance periods.

Emission rates and volumetric flowrates have been based on data contained in the Ecomax technical data sheet[5]. The flue stack is 13m above ground level.

Table 3.1: Emission Data used in the Modelling

Equipment	Flowrate (Am^3/s)	Temp (°C)	Velocity (m/s)	Normalised Flowrate* (Nm^3/s)	NO_x	
					mg/Nm^3	g/s
Jenbacher JGS 612 GS-N.L engine	3.75	120	19.16	4.25	95	0.40

*Emissions have been normalised to 273K, dry gas and 15% oxygen.

3.2.2 Meteorological Data

The modelling has used 5 years' worth of meteorological data for 2015-2019 from the Cardiff Airport meteorological station which is located approximately 18km to the south of the site. The results from the year that gave the highest predicted concentrations have been reported in the assessment.

3.2.3 Receptor Locations

Annual mean and the 99.79th percentile of one hour mean NO_2 concentrations have been predicted at human health receptor locations in the vicinity of the development. In addition, specific receptor locations were chosen within each ecological habitat to represent the closest points to the site. All concentrations were predicted at ground level. The receptor locations are specified in Table 3.2 overleaf and are shown in Figures 3.1 and 3.2.

In addition to predicting concentrations at individual receptor locations, a grid of receptors was used to provide a visual interpretation of the dispersion of emissions. The receptor grid was

[5] Technical Description of Ecomax 20 Natural Gas Modular Outdoor Solution. Offer: QUO-07412-T3C2T0

4,000 metres west to east and north to south approximately centred on the site, with a grid spacing of 40 metres.

Table 3.2: Receptor Locations

No	Name	Type	Relevant Averaging Period		Grid Reference	
			Long-term	Short Term	x	y
1	Rhos Tonyrefail SSSI	Designated Site	√	√	303315	184913
2	Rhos Tonyrefail SSSI	Designated Site	√	√	303362	185049
3	Rhos Tonyrefail SSSI	Designated Site	√	√	303410	185090
4	Rhos Tonyrefail SSSI	Designated Site	√	√	303464	185061
5	Rhos Tonyrefail SSSI	Designated Site	√	√	303630	186223
6	Rhos Tonyrefail SSSI	Designated Site	√	√	303035	186358
7	Rhos Tonyrefail SSSI	Designated Site	√	√	303368	186781
8	Llantrisant Common and Pastures SSSI	Designated Site	√	√	304128	184592
9	Llantrisant Common and Pastures SSSI	Designated Site	√	√	304840	185143
10	Adjacent business	Commercial	x	√	303532	184890
11	Adjacent business	Commercial	x	√	303593	184942
12	Residential Property	Residential	√	√	303378	184553
13	Residential Property	Residential	√	√	304063	185117

Figure 3.1: Receptor Locations – 5km

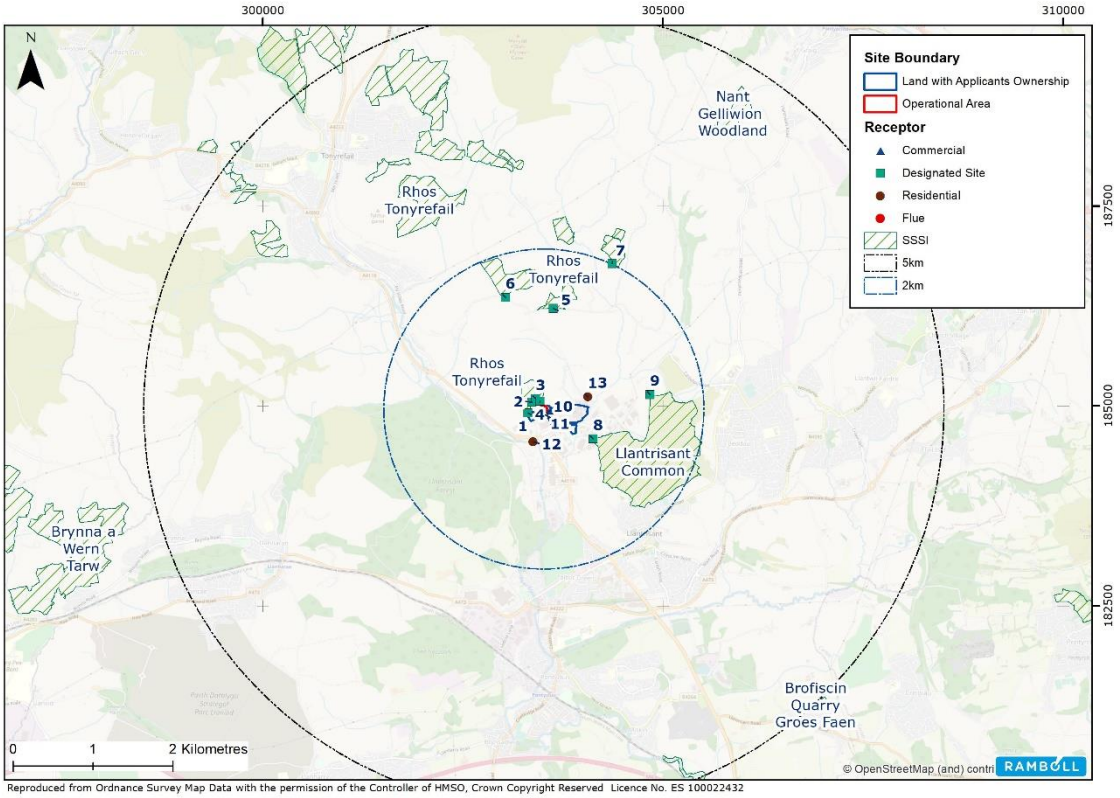
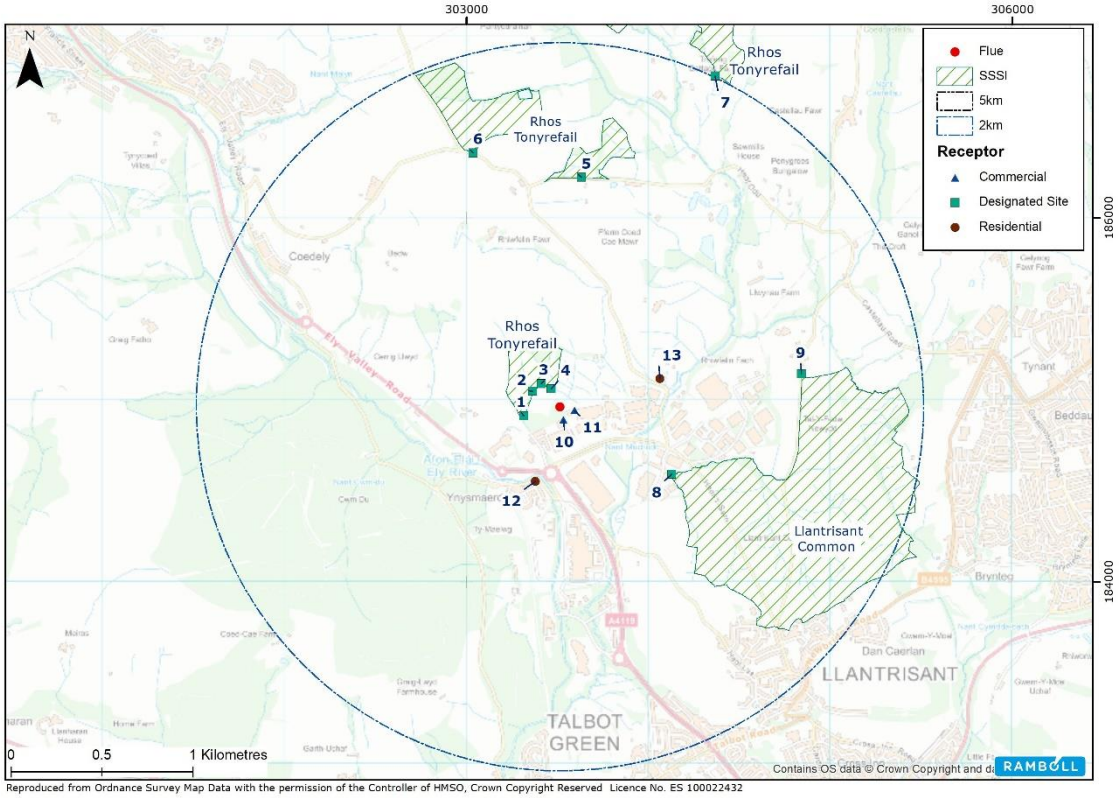


Figure 3.2: Receptor Locations – 2km



Nitrogen deposition has been calculated from the predicted annual mean NO_x concentrations by using a conversion factor of 0.7 to convert NO_x to NO_2. A deposition velocity of 1.5mm/s was used to convert NO_2 concentrations into a deposition flux for grassland habitats; and the results converted into kgN/ha/year in accordance with the AQTAG06 guidance[6].

[6] AQTAG06 Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air. 20/4/10, v10

4. BASELINE

4.1 Local Monitoring Data

A review of the Rhondda Cynon Taf County Borough Council monitoring data confirms that there are no nitrogen dioxide monitoring locations in the vicinity of the site.

4.2 Defra Background Map Data

The 2020 Defra predicted background concentrations for the grid squares covering the site and the receptor locations are shown in Table 4.1 below. These show relatively low NO_x and NO_2 concentrations as would be anticipated for the generally rural area.

Table 4.1: 2020 Background Concentrations (µg/m^3)

No	Name	NO_x	NO_2
1	Rhos Tonyrefail SSSI	16.5	-
2	Rhos Tonyrefail SSSI	9.5	-
3	Rhos Tonyrefail SSSI	9.5	-
4	Rhos Tonyrefail SSSI	9.5	-
5	Rhos Tonyrefail SSSI	8.2	-
6	Rhos Tonyrefail SSSI	8.2	-
7	Rhos Tonyrefail SSSI	8.5	-
8	Llantrisant Common and Pastures SSSI	14.0	-
9	Llantrisant Common and Pastures SSSI	10.1	-
10	Adjacent business	-	12.1
11	Adjacent business	-	12.1
12	Residential Property	-	12.1
13	Residential Property	-	7.7

The Defra background concentrations represent modelled pollutant concentrations averaged across the relevant 1km grid square. There will be locally higher concentrations where receptors are located in close proximity to locally busy roads, but this is not the case for either the ecological or human health receptor locations. The Defra background concentrations are therefore likely to be representative of the baseline concentrations in this study

To assess the short-term PEC against the short-term air quality objectives, a baseline concentration of double the annual mean has been used.

4.3 APIS Background Data

The APIS website provides estimates of background pollutant concentrations and deposition for ecological sites averaged over 5km grid squares. The background deposition data are currently 3-year averages for 2016-2018 and are shown in Table 4.2 for the designated sites. It should be

noted that the background data are not projected forward and background deposition rates are anticipated to reduce in the future due to reductions in NO_x emissions from combustion.

Table 4.2: Background Nitrogen Deposition (kgN/ha/year)

Site	Receptor	Baseline Deposition		
		Nitrogen (kgN/ha/yr)	Nitrogen acid (keqN/ha/yr)	Sulphur acid (keqS/ha/yr)
Rhos Tonyrefail SSSI – acid grassland	1	16.5	1.18	0.27
Rhos Tonyrefail SSSI – acid grassland	2-7	17.2	1.23	0.28
Rhos Tonyrefail SSSI – Broadleaved mixed and yew woodland	1	25.6	1.83	0.32
Rhos Tonyrefail SSSI - Broadleaved mixed and yew woodland	2-7	26.5	1.89	0.34
Llantrisant Common and Pastures SSSI – acid grassland	8-9	16.5	1.18	0.27
Llantrisant Common and Pastures SSSI - Broadleaved mixed and yew woodland	8-9	25.6	1.83	0.32

Based on the site relevant critical loads presented in Table 2.2, the baseline deposition exceeds the critical loads in the habitats. APIS provides a source apportionment breakdown of the baseline deposition which is shown in Figure 4.1 for nitrogen deposition at Rhos Tonyrefail. The data is based on the FRAME model using emissions data from 2012 so is not strictly comparable with the data presented in Table 4.2. However, it shows that the majority of nitrogen input is from agricultural and long range sources, which are likely to have been higher in the past than presently. The habitat is therefore likely to have been subject to nitrogen deposition above the critical load for an extended period of time, and its current condition will be reflective of that.

The APIS data also shows that the baseline deposition estimate includes a contribution from Aberthaw B power station (0.3kgN/ha/yr). The power station is now closed and therefore the contribution no longer exists, but it indicates that the baseline is likely to reduce in the future as industrial combustion and transport sources diminish, although this may not be true for agricultural sources.

Figure 4.1: Deposition Source Apportionment

Total Nitrogen deposition(Kg N/ha/yr) from combined UK sources

▬ Data Table: sources ranked by total deposition showing short/long range split, and NOy/NHx split

#	Source Name	Total Deposition (Kg N/ha/yr)	Short Range (Kg N/ha/yr)	Long Range (Kg N/ha/yr)	Reduced N (NHx)(Kg N/ha/yr)	Oxidised N (NOy) (Kg N/ha/yr)
0	Total Deposition	21.3 (100%)	9.3	12	12.5	8.9
1	Livestock	5.7 (26.92%)	2.9 (50%)	2.8 (50%)	5.7 (100%)	0 (0%)
2	Europe import	4.8 (22.45%)	0.9 (19%)	3.9 (81%)	2.5 (52%)	2.3 (48%)
3	International Shipping	1.8 (8.41%)	0.2 (10%)	1.6 (90%)	0 (0%)	1.8 (100%)
4	Road transport	1.8 (8.37%)	0.8 (48%)	0.9 (52%)	0 (0%)	1.8 (100%)
5	Non-agricultural non-abatable	1.7 (7.88%)	1.3 (75%)	0.4 (25%)	1.7 (100%)	0 (0%)
6	Other transport	1.4 (6.42%)	1 (74%)	0.4 (26%)	0 (0%)	1.4 (100%)
7	Non-agricultural abatable	0.9 (4.1%)	0.7 (78%)	0.2 (22%)	0.9 (100%)	0 (0%)
8	Fertiliser	0.8 (3.99%)	0.4 (48%)	0.4 (52%)	0.8 (100%)	0 (0%)
9	Non-agricultural waste	0.8 (3.75%)	0.6 (73%)	0.2 (27%)	0.8 (100%)	0 (0%)
10	Aberthaw B	0.3 (1.47%)	0.1 (42%)	0.2 (58%)	0 (0%)	0.3 (100%)
11	Commercial Industry and Residential Combustion	0.3 (1.18%)	0.1 (37%)	0.2 (63%)	0 (0%)	0.3 (100%)
12	Industrial Combustion	0.2 (1.05%)	0.1 (42%)	0.1 (58%)	0 (0%)	0.2 (100%)
13	Others (<1%)	0.9 (4.23%)	0.2 (22%)	0.7 (78%)	0 (0%)	0.8 (89%)

5. RESULTS

5.1 Introduction

The modelling results in this section are the highest predicted concentrations and deposition from any of the five years' worth of meteorological data modelled except where noted. They represent the CHP engine operating at its ELV all year round and are therefore conservative. The results are presented for the relevant averaging period appropriate for the receptor, i.e. the annual mean concentrations are only presented at residential receptor locations.

The results are presented for the human health and ecological receptors separately.

5.2 Human Health Impacts

The maximum predicted PCs and PECs for the five years' worth of meteorological data modelled are shown in Tables 5.1 to 5.2.

Table 5.1: Predicted Annual Mean NO_2 Concentrations

Receptor	Baseline Concentration µg/m³	PC µg/m³	PC as % of the AQAL	PEC µg/m³	PEC as a % of the AQAL
12	12.1	0.11	0.3	12.2	30.4
13	7.7	0.39	1.0	8.1	20.2

With the baseline concentration equal to the Defra background concentration, none of the PECs exceeds the air quality assessment level, with the maximum PEC only 30.4%. The Defra background concentration is likely to be representative of the baseline concentration as these receptors are located away from main roads. In any case, the PCs are insignificant in their own right.

Table 5.2: Predicted Hourly Mean 99.79th%ile NO_2 Concentrations

Receptor	PC µg/m³	PC as % of the AQAL
10	6.7	3.3
11	7.3	3.7
12	2.8	1.4
13	1.8	0.9

All of the hourly mean PCs are less than 10% of the assessment level and therefore insignificant in their own right.

5.3 Ecological Impacts

5.3.1 Designated Sites

NO_x

The maximum predicted NO_x concentrations within the habitats are shown in Tables 5.3 and 5.4. Contour plots for nitrogen deposition and acid deposition for grassland woodland habitats are contained in Appendix 2. The contour plots are derived from the maximum predicted

concentration at each of the receptor grid points for any of the five years of meteorological data modelled, i.e. they are a composite of the individually annually modelled results.

Table 5.3: Maximum Annual Mean NO_x concentrations

Site	Critical Level (µg/m³)	PC (µg/m³)	% PC of Critical Level	2020 NO_x Background (µg/m³)	PEC (µg/m³)	% PEC Critical Level
Rhos Tonyrefail - 1	30	1.49	5.0	16.5	18.0	60.1
Rhos Tonyrefail - 2	30	1.17	3.9	9.5	10.6	35.5
Rhos Tonyrefail - 3	30	0.83	2.8	9.5	10.3	34.3
Rhos Tonyrefail - 4	30	0.96	3.2	9.5	10.4	34.8
Rhos Tonyrefail - 5	30	0.11	0.4	8.2	8.3	27.8
Rhos Tonyrefail - 6	30	0.04	0.1	8.2	8.3	27.5
Rhos Tonyrefail - 7	30	0.04	0.1	8.5	8.5	28.4
Llantrisant Common - 8	30	0.42	1.4	14.0	14.4	48.1
Llantristant Common - 9	30	0.15	0.5	10.1	10.2	34.1

The maximum predicted annual mean NO_x concentrations are above 1% of the long-term critical level apart from the northern receptors in the Rhos Tonyrefail SSSI and at the north eastern Llantrisant Common receptor location. At these locations the PECs are well below the critical levels and the impacts are not significant.

Table 5.4: Maximum Daily Mean NO_x concentrations

Site	Critical Level (µg/m³)	PC (µg/m³)	% PC of Critical Level	PEC (µg/m³)	% PEC Critical Level
Rhos Tonyrefail - 1	75	12.5	16.6	45.5	60.7
Rhos Tonyrefail - 2	75	13.3	17.8	32.3	43.0
Rhos Tonyrefail - 3	75	15.0	19.9	33.9	45.2
Rhos Tonyrefail - 4	75	17.7	23.5	36.6	48.8
Rhos Tonyrefail - 5	75	2.29	3.1	18.7	25.0
Rhos Tonyrefail - 6	75	0.77	1.0	17.2	23.0
Rhos Tonyrefail - 7	75	0.43	0.6	17.4	23.2
Llantrisant Common - 8	75	2.89	3.9	30.9	41.2
Llantristant Common - 9	75	0.87	1.2	21.0	28.1

The maximum predicted daily mean NO_x concentrations are above 10% of the short-term critical level for the closest portion of Rhos Tonyrefail SSSI. The PECs do not exceed the critical level.

Nitrogen Deposition

The maximum predicted nitrogen deposition within the habitats is shown in Table 5.5 for grassland habitats and Table 5.6 for woodland habitats.

Table 5.5: Maximum Nitrogen Deposition – Grassland Habitats

Site	Critical Load (kg/ha/yr)	PC (kg/ha/yr)	% PC of Critical Load	Background (kg/ha/yr)	PEC (kg/ha/yr)	% PEC Critical Level
Rhos Tonyrefail - 1	8	0.150	**1.88**	16.5	16.65	**208**
Rhos Tonyrefail - 2	8	0.118	**1.47**	17.2	17.32	**216**
Rhos Tonyrefail - 3	8	0.084	**1.04**	17.2	17.28	**216**
Rhos Tonyrefail - 4	8	0.097	**1.21**	17.2	17.30	**216**
Rhos Tonyrefail - 5	8	0.011	0.14	17.2	17.21	215
Rhos Tonyrefail - 6	8	0.004	0.05	17.2	17.20	215
Rhos Tonyrefail - 7	8	0.004	0.05	17.2	17.20	215
Llantrisant Common - 8	8	0.042	0.53	16.5	16.54	207
Llantristant Common - 9	8	0.015	0.19	16.5	16.52	206

Table 5.6: Maximum Nitrogen Deposition – Woodland Habitats

Site	Critical Load (kg/ha/yr)	PC (kg/ha/yr)	% PC of Critical Load	Background (kg/ha/yr)	PEC (kg/ha/yr)	% PEC Critical Level
Rhos Tonyrefail - 1	5	0.300	6.00	25.6	25.90	**518**
Rhos Tonyrefail - 2	5	0.236	4.71	26.5	26.74	**535**
Rhos Tonyrefail - 3	5	0.167	3.34	26.5	26.67	**533**
Rhos Tonyrefail - 4	5	0.193	3.87	26.5	26.69	**534**
Rhos Tonyrefail - 5	5	0.022	0.44	26.5	26.52	530
Rhos Tonyrefail - 6	5	0.008	0.16	26.5	26.51	530
Rhos Tonyrefail - 7	5	0.008	0.16	26.5	26.51	530
Llantrisant Common - 8	5	0.085	**1.69**	25.6	25.68	**514**
Llantristant Common - 9	5	0.030	0.60	25.6	25.63	513

For grassland habitats, the nitrogen deposition is above 1% of the critical load (i.e. above 0.08 kgN/ha/yr) for approximately 50% of the Rhos Tonyrefail SSSI parcel closest to the site, but below 1% within Llantrisant Common. The existing baseline deposition dominates the PEC, with the PC being less than 1% of the existing baseline.

For woodlands habitats, the nitrogen deposition is above 1% of the critical load (i.e. above 0.05 kgN/ha/yr) for all of the woodland within the Rhos Tonyrefail SSSI parcel closest to the site, and for the woodland habitat along the northern edge of Llantrisant Common SSSI. The existing baseline deposition dominates the PEC, with the PC being 1.2% of the existing baseline at receptor 1 and less than 1% at the other receptor locations.

A breakdown of the areas of habitat above 1% of the critical load is provided in Table 5.7 compared to the overall areas of the SSSIs (244.7 Ha for Rhos Tonyrefail and 113.4 Ha for Llantrisant Common).

Table 5.7: Breakdown of Areas above 1% of the Critical Load

Site	Grassland Habitat		Woodland Habitat	
	Area >1% (Ha)	% of SSSI Area	Area >1% (Ha)	% of SSSI Area
Rhos Tonyrefail SSSI	4.2	1.7	3.8	1.6
Llantrisant Common SSSI	0	0	1.5	1.3

For Rhos Tonyrefail, 4.2 Ha of the grassland habitat in the parcel closest to the site exceeds 1% of the critical load, but this amounts to only 1.7% of the total area of the SSSI. All of the woodland habitat in this parcel (3.8 Ha) exceeds the critical load, but this is only 1.6% of the total SSSI area.

For Llantrisant Common, none of the grassland habitats exceed 1% of the critical load, whereas the majority (1.5 Ha) of the dense scrub in the northern part of the SSSI exceeds 1%. However, this amounts to only 1.3% of the total area of the SSSI.

Acid Deposition

The maximum predicted acid deposition within the habitats is shown in Table 5.8 for grassland habitats and Table 5.9 for woodland habitats.

Table 5.8: Maximum Nitrogen Acid Deposition – Grassland Habitats

Site	Critical Load (keq/ha/yr)	PC (keq/ha/yr)	% PC of Critical Load	Background (keq/ha/yr)	PEC (keq/ha/yr)	% PEC Critical Level
Rhos Tonyrefail - 1	0.66	0.0107	**1.62**	1.18	1.191	221
Rhos Tonyrefail - 2	0.66	0.0084	**1.28**	1.23	1.238	230
Rhos Tonyrefail - 3	0.66	0.0060	0.90	1.23	1.236	230
Rhos Tonyrefail - 4	0.66	0.0069	**1.05**	1.23	1.237	230

Site	Critical Load (keq/ha/yr)	PC (keq/ha/yr)	% PC of Critical Load	Background (keq/ha/yr)	PEC (keq/ha/yr)	% PEC Critical Level
Rhos Tonyrefail - 5	0.66	0.0008	0.12	1.23	1.231	229
Rhos Tonyrefail - 6	0.66	0.0003	0.04	1.23	1.230	229
Rhos Tonyrefail - 7	0.66	0.0003	0.04	1.23	1.230	229
Llantrisant Common - 8	0.66	0.0030	0.46	1.18	1.183	220
Llantristant Common - 9	0.66	0.0011	0.16	1.18	1.181	220

Table 5.9: Maximum Nitrogen Acid Deposition – Woodland Habitats

Site	Critical Load (keq/ha/yr)	PC (keq/ha/yr)	% PC of Critical Load	Background (keq/ha/yr)	PEC (keq/ha/yr)	% PEC Critical Level
Rhos Tonyrefail - 1	1.316	0.0214	**1.63**	1.83	1.851	165
Rhos Tonyrefail - 2	1.316	0.0168	**1.28**	1.89	1.907	171
Rhos Tonyrefail - 3	1.316	0.0119	0.91	1.89	1.902	170
Rhos Tonyrefail - 4	1.316	0.0138	**1.05**	1.89	1.904	171
Rhos Tonyrefail - 5	1.316	0.0016	0.12	1.89	1.892	170
Rhos Tonyrefail - 6	1.316	0.0006	0.04	1.89	1.891	169
Rhos Tonyrefail - 7	1.316	0.0006	0.04	1.89	1.891	169
Llantrisant Common - 8	1.316	0.0060	0.46	1.83	1.836	164
Llantristant Common - 9	1.316	0.0022	0.16	1.83	1.832	164

For grassland habitats, the nitrogen acid deposition is above 1% of the critical load (i.e. above 0.0066 keq/ha/yr) for approximately 30% of the Rhos Tonyrefail SSSI parcel closest to the site, but below 1% within Llantrisant Common. The existing baseline deposition dominates the PEC.

For woodland habitats, the nitrogen acid deposition is above 1% of the critical load (i.e. above 0.0132 keq/ha/yr) in the southern portion of the Rhos Tonyrefail SSSI parcel closest to the site, but this is outside of the area of woodland habitat. It is below 1% within Llantrisant Common. The existing baseline deposition dominates the PEC.

The increases in nitrogen acid deposition therefore only affect the Rhos Tonyrefail SSSI and are less significant than those of nitrogen deposition.

5.3.2 Uncertainty

All of the predicted impacts are presented assuming that the engine operates at full load all year road where-as in reality there will be periods of downtime for maintenance. In addition, the maximum of any of the 5 years' worth of data are presented. As an example of the range of predicted impacts for the 5 years, the annual mean NO_x concentrations at the ecological receptors are shown in Table 5.10.

Table 5.10: Range of Predicted Annual Mean NO_x concentrations (µg/m^3)

Site	2015	2016	2017	2018	2019	Average
Rhos Tonyrefail - 1	0.92	1.48	0.77	**1.49**	1.13	1.16
Rhos Tonyrefail - 2	0.92	0.83	0.94	**1.17**	1.04	0.98
Rhos Tonyrefail - 3	**0.83**	0.68	0.73	0.80	0.77	0.76
Rhos Tonyrefail - 4	**0.96**	0.71	0.78	0.81	0.78	0.81
Rhos Tonyrefail - 5	0.10	0.09	0.10	**0.11**	0.10	0.10
Rhos Tonyrefail - 6	**0.04**	0.03	0.03	0.03	0.03	0.03
Rhos Tonyrefail - 7	0.03	0.03	**0.04**	0.03	0.03	0.03
Llantrisant Common - 8	0.28	0.33	**0.42**	0.32	0.34	0.34
Llantristant Common - 9	0.13	0.13	**0.15**	0.12	0.12	0.13

The long term average impacts are approximately 80-90% of the maximum impacts for any one year depending on the location of receptor. Long term impacts associated with deposition are therefore likely to be lower than the maximum predicted impacts presented in the results tables.

5.3.3 Ecological considerations

For both habitats, the PECs for nitrogen and nitrogen acid deposition are dominated by existing baseline deposition rates which are well above the site relevant critical loads and which are likely to have been so for a significant period of time (greater than 30 years). The condition of the habitats is therefore likely to reflect the exceedances.

The additional nitrogen deposition is 1% or less of the existing baseline deposition, but above 1% of the critical loads for very small areas of the habitat. The additional contribution is within the likely range of fluctuation in baseline deposition rates. Overall therefore, it is not considered that the additional contribution will have a significant effect on the SSSIs.

6. CONCLUSIONS

An assessment of the impacts of emissions from the CHP engine at the Royal Mint has been carried out. The assessment has been undertaken assuming that the engine operates all year round at the maximum ELV for NO_x of 95mg/Nm^3. Overall, the predicted impacts are considered to be conservative and worst case.

Impacts have been predicted at a number of human health receptor locations in the vicinity of the site, both residential and office/recreational receptor locations. For the residential receptors, long-term and short-term impacts have been considered where-as for office/recreational receptors only short-term impacts have been considered.

Impacts have also been predicted at designated ecological receptor locations in the vicinity of the site.

With the CHP engine operational all year round, all of the PCs are either insignificant or the PECs are significantly lower than the environmental assessment level at the human health receptor locations. The maximum predicted NO_x PCs at the designated sites are either insignificant or the PECs do not exceed the long term or short term critical levels.

Baseline nitrogen and acid deposition rates are well above the site relevant critical loads within the Rhos Tonyrefail SSSI and Llantrisant Common SSSI primarily as a result of agricultural and long range deposition.

Nitrogen deposition is above 1% of the grassland and woodland critical loads within the Rhos Tonyrefail SSSI parcel closest to the site, with the total PEC dominated by existing baseline deposition rates. Nitrogen deposition is above 1% of the woodland habitat critical load for an area of scrubland along the northern edge of the Llantrisant Common SSSI, but not above 1% for grassland habitats. The areas of deposition above 1% of the critical loads are approximately 1% of the areas of each SSSI.

For grassland habitats, the nitrogen acid deposition is above 1% of the critical load for approximately 30% of the Rhos Tonyrefail SSSI parcel closest to the site. The acid deposition is less than 1% of the critical load for woodland habitats.

Overall, taking into account the areas affected, it is not considered that the additional deposition will have a significant overall effect on the habitats within the Rhos Tonyrefail or Llantrisant Common SSSI.

APPENDIX 1
MODELLING SET UP

Stack Emissions Modelling Input Parameters

Parameter	
Modelled Stack Location	329046.53 185545.19
Flue height (m)	13
Flue diameter (m)	0.5
Exit velocity (m/s)	19.16
Flue exit Temperature (°C)	120
Actual flue volumetric flow (Am^3/s)	3.755
Oxygen Concentration (%)	10.3
Water vapour content (%)	9.35
Normalised flue volumetric flow (Nm^3/s)	4.248
NO_x emission concentration (mg/Nm^3)	95
NO_x emission (g/s)	0.40

Emissions data based on Engine Data Sheet JGS 612 GS-N.L

Operational Hours

For modelling purposes, the equipment is assumed to be operating continuously, 24 hours every day or 8,760 hours per year. Actual operating hours will be lower due to maintenance periods.

Special Treatments

Conversion ratios of 70% and 35% have been applied for the conversion of NO_X to NO_2 for annual and hourly mean concentrations in accordance with the *EA Conversion Ratios for NO_x and NO_2*[7].

Buildings Effects

Tall buildings can have a substantial impact on the dispersion of pollutants from stacks, as a result of building downwash i.e. pollutants being drawn down in the wake of a building, giving rise to high concentrations close to the base of the buildings. ADMS5 is able to take account of this

[7] Air Quality Modelling and Assessment Unit, available at file:///Z:/Modelling%20Data/Guidance/noxno2conv2005_1233043.pdf

potential impact by the inclusion of buildings in the model. The buildings included within the modelling are provided in the table below.

Buildings

New Delete

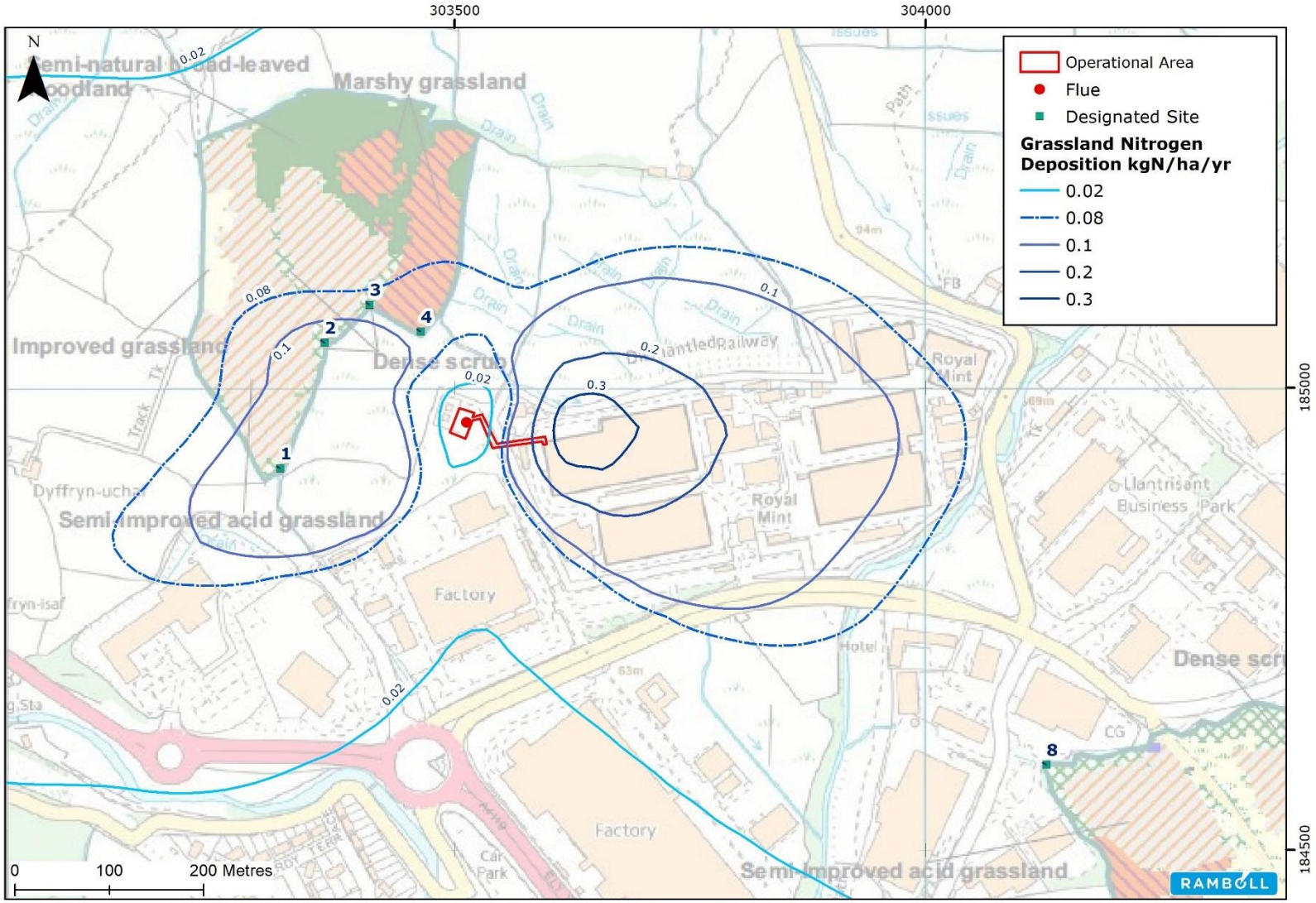
Main	Name	Shape	X (m)	Y (m)	Height (m)	Length / Diameter (m)	Width (m)	Angle (°)
✓	air outlet	Rectangular	303510.9	184955.4	9	5.6	3	16
	base	Rectangular	303512.6	184961.4	3.3	7	3	16
	cooler	Rectangular	303514.5	184968.2	6.3	7.1	3	16
	Tank1	Rectangular	303494	184980	7	7	7	16
	Tank 2	Rectangular	303491	184969	7	7	7	16
	Tank 3	Rectangular	303568	184977	7	15	15	80

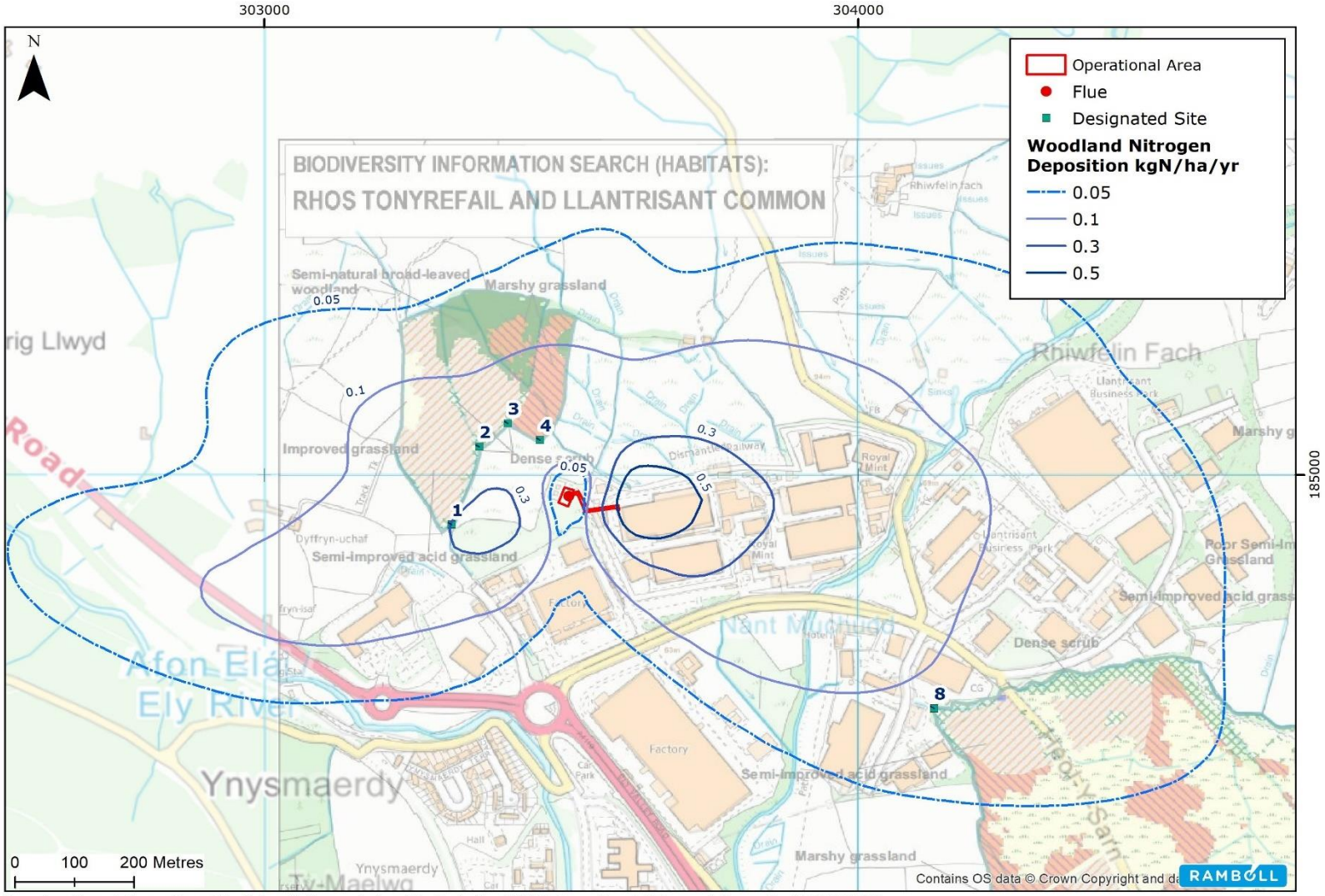
Terrain and Surface Roughness

Terrain was included in the model as the area in the immediate vicinity of the site is relatively hilly. A terrain grid receptor resolution of 256 x 256 was used.

The modelling adopts the maximum surface roughness value of 0.2m for the Site. The meteorological measurement site's surface roughness was set to the same value of the site.

APPENDIX 2
CONTOUR PLOTS





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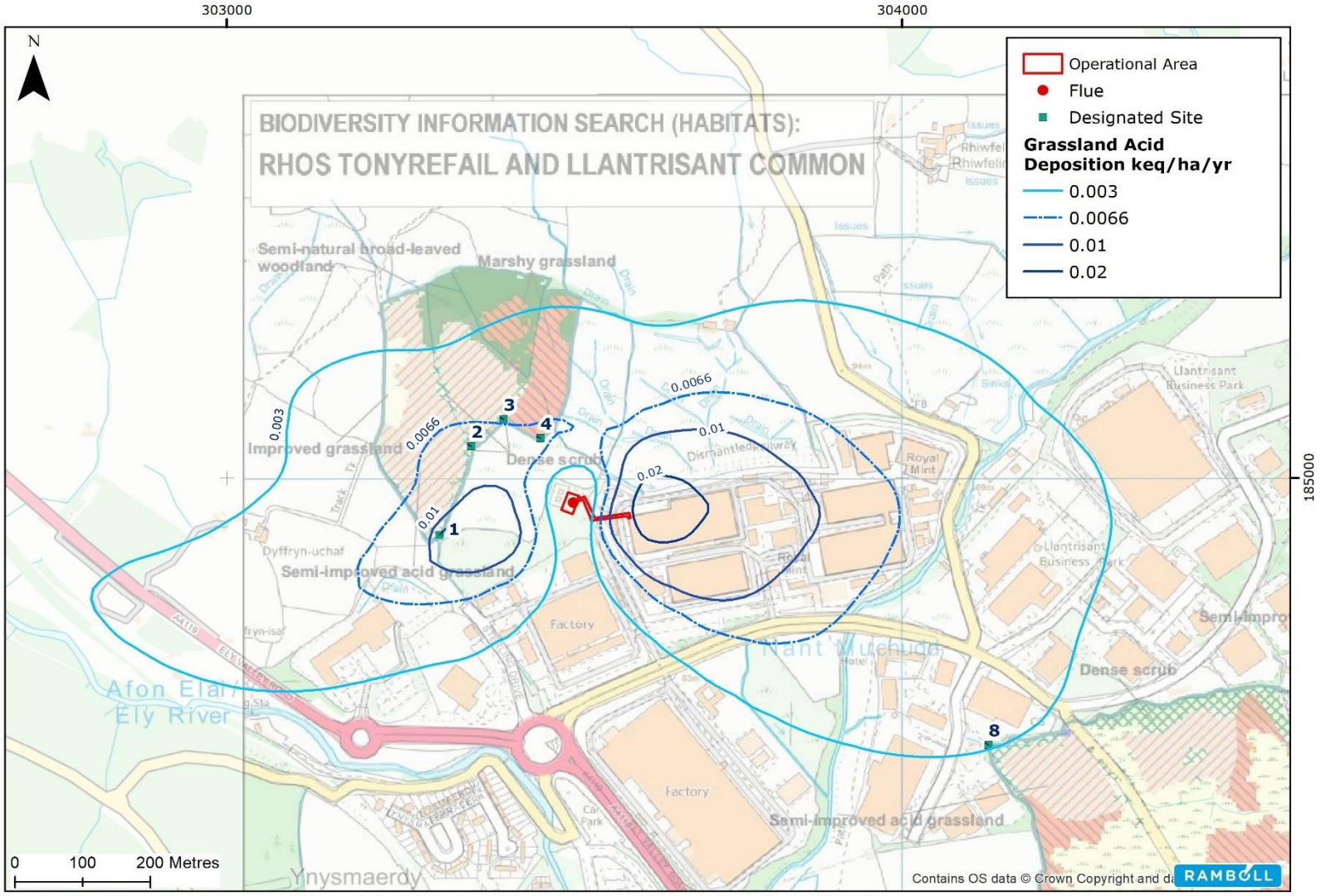

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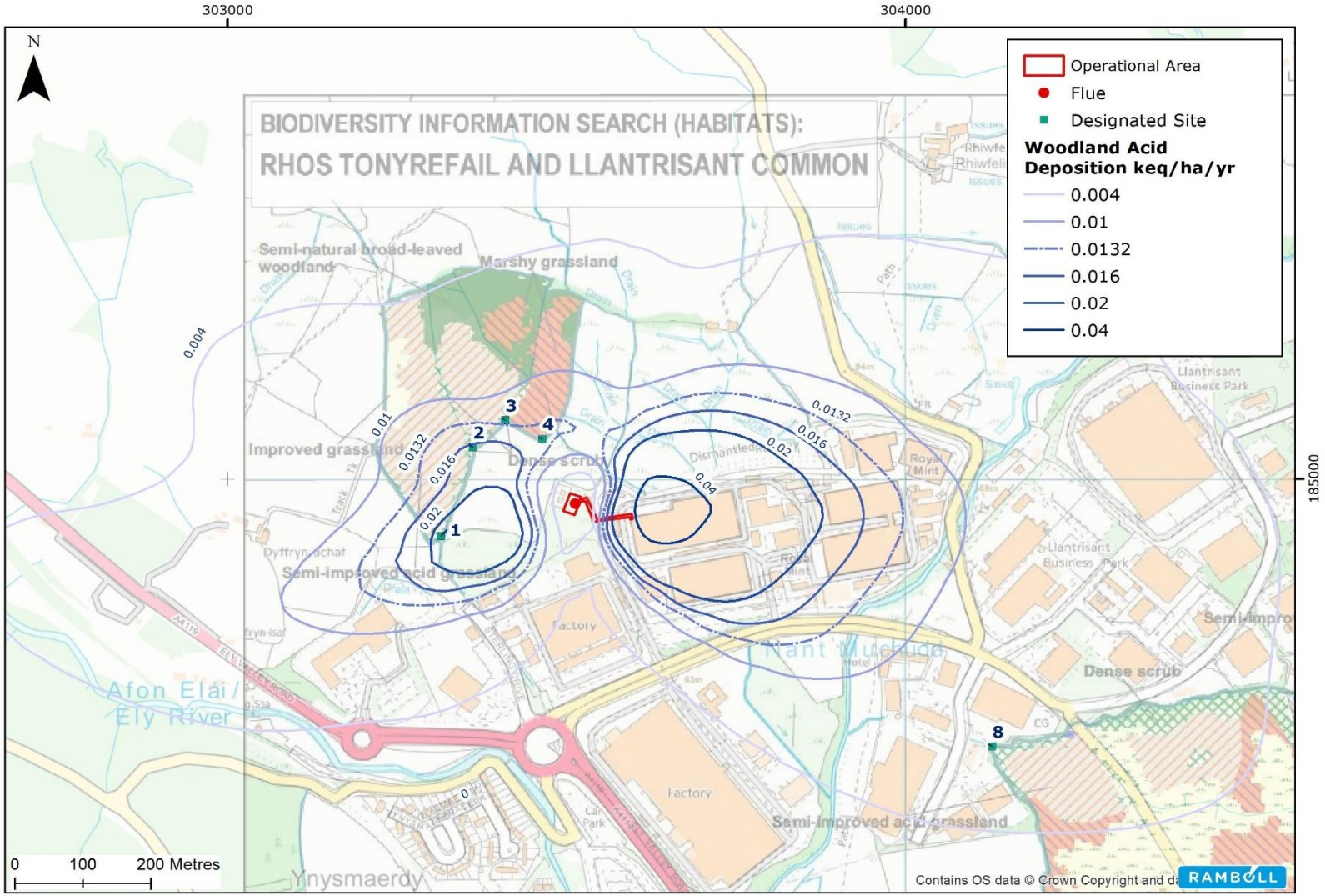

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