Portland energy recovery facility

CHP heat plan (including R1)

September 2020

Powerfuel Portland Ltd

ERF Portland

Heat Report

267701-00/Heat Plan

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Executive Summary

Arup has been appointed by Powerfuel Portland to evaluate the potential for heat export to support the planning application for the above project. This document is intended to present the design intent, potential consumers locations and the impact on electrical generation and the energy efficiency status of the Energy Recovery Facility (ERF).

The ERF will be capable of exporting around 15.2 MWe with an average throughput of 22.8 t/hr under no heat export conditions. Under average and peak heat export conditions, the electricity generation sacrifice has been calculated to be approximately 0.4 MWe and 1.6 MWe respectively.

Potential heat consumers have been identified and their demand profiles along with peak and average loads have been estimated via a desktop study. These consumers are an adult prison, a Young Offenders Institute (YOI), a sports centre, a hospital and a new housing development. Whilst contact has yet to be made with all potential sites, Powerfuel Portland is currently in contact with the Ministry of Justice (MOJ) concerning supplying the adult prison and the YOI on the isle. It is expected that the peak demand of all these consumers is approximately 11 MWth and an average demand of approximately 2.6 MWth.

The ERF's energy efficiency metrics in the form of Combined Heat and Power Quality Insurance (CHPQA) Quality Index (QI) metrics and R1 efficiency figures have been calculated to be: 57.1/60.4 and 0.68/0.71 (no/with average heat export), respectively. This means that the ERF does not currently meet the CHPQA standard of a "good quality plant" but is R1 compliant which is understood to be a requirement stated within the Engineering, Procurement and Construction (EPC) contract.

Upon proceeding with a more detailed design, the following should be considered:

- The supply to Her Majesty's Prison (HMP) The Verne and/or HMP YOI Portland must consider the additional project management/planning that may be required to build on routes to prisons, e.g. reducing obstructions for prisoner transport.
- Optimisation of the full design would have to be undertaken later when the project has progressed further.

1 Introduction

1.1 Background

Powerfuel Portland is currently designing an Energy Recovery Facility (ERF) on the Isle of Portland, UK. Alongside the generation of electricity, it is possible to export the waste heat generated to local consumers that include: Her Majesty's Prison (HMP) The Verne, HMP Young Offenders Institute (YOI) and other large consumers.

As such, the objectives of this report are to:

1. Identify potential heat consumers to connect to the heat network
2. Undertake a heat study to determine the yearly customer consumption and peak demand(s)
3. Calculate the electricity export sacrifice for connecting to these consumers
4. Determine if the ERF meets the Combined Heat and Power Quality Assurance (CHPQA) and R1 standards

The structure of this report is:

- Site context – an understanding of the site itself along with recent and current developments undertaken within its bounds
- The facility – a high level approach to how the energy conversion process is envisaged to operate, as well as detailing the potential District Heating Network (DHN) supply and export characteristics
- Heat demand investigation – A high level approach to identify potential consumers for heat export as well as the magnitude of the expected heat demand and profile characteristics
- Project economics – A high level approach to identify the current financial situation regarding external funding
- Energy efficiency measures – Two calculations to determine if the ERF should be considered a "good quality plant" and/or if it is R1 compliant

2 Site Context

A figure of the site is shown below:

Figure 1: Site plan with application boundary

2.1 Site location

The site is in the northeast of the Isle of Portland, a peninsula island on the Dorset coast, within Portland Port approximately 600m east of the villages of Fortuneswell and Castletown. The site is roughly 600m from HMP The Verne and 2km from HMP YOI. Note that these distances are as the crow flies.

The planning application area covers 6.29 hectares where the main development site is 2.14 hectares.

2.2 Surrounding area

The main development site is bounded to the east by overland fuel pipelines which supply marine fuel from Portland Bunkers fuel storage area in the nearby cliffs. Beyond the pipelines is the shingle shoreline of Balaclava Bay, which extends south from the Portland Harbour breakwaters.

To the southwest is Incline Road, a private road actively used by port traffic, and a former railway embankment. To the south west of the railway embankment is a steeply rising cliff supporting grassland, scrub and woodland habitat.

Existing operational port development lies to the north and northwest of the site.

As the site lies within the port, it is not publicly accessible. Vehicular access is from the west through the main Portland harbour complex.

2.3 Site characteristics

The main development site is roughly triangular and is currently vacant. All previous buildings have been demolished.

The groundcover is predominantly hardstanding associated with former roads/buildings and there are some areas of rough gravel cover.

A weighbridge is present in the western corner of the site, it is understood that the weighbridge will be retained within the proposed development.

An electricity substation is located outside the site, adjacent to the northern site boundary.

The northern boundary of the site is formed by a retaining structure increasing in height to the east. Towards the east the retaining wall has arched structures behind which voids may remain.

3 Description of the Technology and Heat Network

3.1 The facility

The ERF will be capable of exporting around 15.2 MWe with an average throughput of 22.8 t/hr. It is also envisaged that the site will be capable of exporting heat to nearby consumers of around 11 MWth. The combustion fuel, which is a Refuse Derived Fuel (RDF) typically has a net calorific value of 11 MJ/kg.

The subsequent sections detail the ERFs envisaged operation in a step-by-step fashion.

3.1.1 Combustion process

1. A crane grab will transfer the waste from the bunker into a hopper to feed the combustion chamber. The chamber will use a moving grate to agitate the fuel bed and promote good burnout of the waste, ensuring a uniform heat release.
2. Primary combustion air will be drawn from the waste reception area and fed into the combustion chamber beneath the grate. This will maintain negative pressure in the waste reception area.
3. Secondary combustion air will be injected into the flame body above the grate to facilitate the combustion of waste on the grate.
4. In the flue, above the combustion zone, ammonia will be injected to react with oxides of nitrogen (NOx) formed in the combustion process. The ammonia will reduce the concentration of NOx in the flue gas to achieve required emission limits.
5. The combustion chamber will be provided with auxiliary burners. These are used during start-up to ensure the combustion chamber temperature reaches the required 850°C, prior to feeding of waste into the combustion chamber.
6. Interlocks will prevent the charging of waste until the temperature within the combustion chamber has reached 850°C. During normal operation, the burners are not used unless the temperature falls below 850°C. The auxiliary burners will typically operate for up to 16 hours during a start-up event and up to two hours during a shut-down. The auxiliary burners will use fuel oil.
7. Bottom ash will fall from the end of the grate into a discharger, comprising a water bath. The water will act as an ash quench and make it possible to remove cooled bottom ash without dust generation. The ash will then be transferred to a dedicated Incinerator Bottom Ash (IBA) storage area.

3.1.2 Energy recovery

1. Heat will be recovered from the flue gases by means of a water tube boiler integral with the furnace.
2. The heat will be transferred through a series of heat exchangers and the hot gases from the furnace will first pass through evaporators that raise the steam, which then passes into the boiler.
3. Superheated steam will be supplied to a high efficiency turbine that, through a connecting shaft, will turn a generator to produce electricity. To generate the pressure-drop necessary to drive the turbine, the steam will be condensed back to water. The majority will be condensed in the air-cooled condenser following the turbine at a pressure well below atmospheric.

3.1.2.1 Potential heat recovery/export

There will be the opportunity for steam and / or low temperature hot water to be recovered for delivery to an off-site DHN, when available. The space and necessary valves to enable connection to make the heat available will be included within the plant. However, the DHN itself is not part of this application.

3.2 Flue Gas Treatment

3.2.1 Particulates/Pollutants

1. Flue gases generated from the combustion process will be cleaned before being released into the atmosphere to the appropriate standards required to protect human health and the environment.
2. The flue gas treatment systems will be designed to comply with the requirements of the Waste Incineration Best Available Techniques reference document (BREF).
3. The abatement of NOx will be achieved by careful control of combustion air and a NOx abatement system. NOx will be formed in the boiler at high temperature from nitrogen in the waste and in the combustion air. The NOx abatement system will use a NOx reagent (ammonia), which will be injected into the flue gas stream to minimise emissions of nitrogen dioxide (NO2).
4. The acid gas abatement system will use lime as a reagent to reduce concentrations of acid gases, such as sulphur oxides (SOx) and hydrogen chloride (HCl), in the flue gas stream.

3.2.2 Absorption/Filtering

1. Powdered Activated Carbon (PAC) will be used as an adsorbent to remove volatile metals, dioxins and furans. Both PAC and lime will be held in dedicated storage silos and injected into the flue gas stream.

2. The flue gases containing the reagents will pass through a reaction chamber and into a bag filter arrangement, where reaction products and unreacted solids will be removed from the flue gases.
3. The residue, referred to as Air Pollution Control Residue (APCr), will accumulate on the outside of the filter bags. The filter bags will be periodically cleaned by a reverse jet of air displacing the filtered residue into chutes beneath.
4. The APCr collected by the bag filters will be held in a silo, from where it will be recycled back into the flue gas stream at the top of the reaction chamber. As fresh reagents are added, an equivalent concentration of residues collected from the bag filters will be removed.
5. The cleaned gas will be monitored for pollutants and discharged to atmosphere via the flue stack.

3.3 Heat Supply Specification

It is currently envisaged that the DHN system will use a water flow temperature from the ERF of around 80 ^{o}C and an envisaged return temperature will be around 55 ^{o}C. The exact volumes of heat and supply/return temperatures are to be confirmed but indicative figures have been presented within this report.

3.4 Heat Export Specification

The ERF will be designed with a steam turbine that can generate both electrical power and supplying heat via an extraction point to potential heat consumers. At day one the ERF will be designed to operate in a power only mode, and as such steam turbine operation has been optimised for this mode in accordance with Combined Heat and Power (CHP)-ready guidelines, but it is envisaged that a DHN will be connected as soon as reasonably practicable.

The amount of heat required to be extracted from the turbine is in the region of 11MWth which will be used in the DHN. Spatial allowances have been made within the buildings envelope to house all required equipment.

4 Heat Demand Investigation

4.1 Consumer data

Nearby potential heat consumers were identified as shown in Table 1. These were chosen based upon the utility of the consumer as well as the geographical footprint.

Table 1: Possible consumers

Consumer	Annual Consumption (MWh/Annum)
Osprey Leisure Centre	2,486
Portland Hospital	254
HMP The Verne	6,966
Comer Homes	3,445
HMP YOI Portland	7,149

It is currently understood that Powerfuel Portland has been in consultation with Ministry of Justice (MOJ) who have expressed interest in connecting to the ERF should a DHN become available, regarding heat provision to both HMP The Verne and the YOI.

4.2 Network consumers and capacity

For simplicity, the consumers were given individual designations as shown by Table 2.

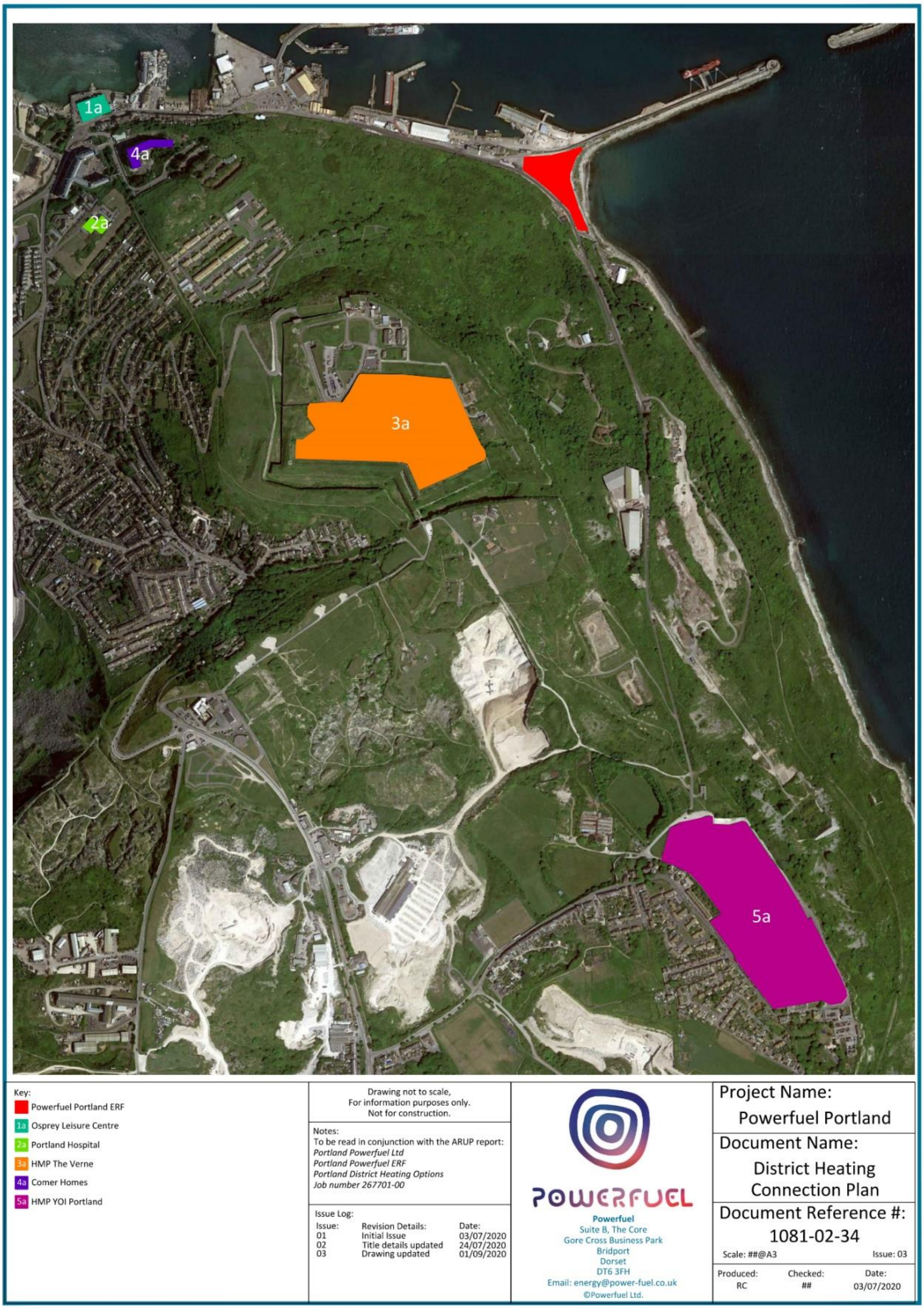
Table 2: Consumer designations

Consumer	Designation
Osprey Leisure Centre	1a
Portland Hospital	2a
HMP The Verne	3a
Comer Homes	4a
HMP YOI Portland	5a

4.2.1 Consumer locations

A map showing the potential DHN connections is shown below:

Figure 2: DHN potential consumer map



4.2.2 Heat demand profile

The combined demand where all possible consumers are supplied was found to be approximately 11 MWth and an average demand of 2.6 MWth.

As most of the heat demand uses a “residential” heat profile, the peak demand times are roughly when most occupants wake up and return from work; 06:00 and 18:00 respectively.

4.3 Backup Heat Source

The ERF has been designed to achieve an availability of 8,000 hrs/annum (91.32%) which means the backup heat source will be required to service the DHN.

The exact arrangement for these backup heat sources is still to be confirmed during detailed design but could consist of a permanently installed gas boiler which will be available to supply the network during periods where the ERF is unavailable.

5 Project Economics

5.1 Financial support

External financial support for the project is still being investigated. Powerfuel Portland are currently looking to work with a leading DHN provider to develop the possibility of district heating on the Isle of Portland. Powerfuel Portland and their partners are aware of Heat Networks Investment Project (HNIP) funding availability and if appropriate will prepare an application as this will improve the project's economic viability.

5.2 Additional considerations

The following must be considered:

- The supply to HMP The Verne and/or HMP YOI Portland must consider the additional project management/planning that may be required to build on routes to prisons, e.g. reducing obstructions for prisoner transport.
- Optimisation of the full design would have to be undertaken later when the project has progressed further.

6 Energy Efficiency Measures

6.1 Heat and power export

The Z-ratio which is the ratio of reduction in power export for an increase in heat export can be used to calculate the effect of variations in demand.

Using CHPQA Guidance Note 28 (The Determination of Z Ratio) table GN 28-1 a Z-ratio of 7 is expected. This is assuming a steam extraction of 2 bar and a generation capacity of 18.1 MWe and a parasitic load of 2.9 MWe.

Table 3: Heat and power export scenarios

Scenario	Heat Export (MWth)	Net Power Export (MWe)
No heat export	0	15.2
Average thermal export	2.6	14.8
Maximum thermal export	11	13.6

Note that the subsequent CHPQA and R1 calculations are based on the current design information and will be updated should the information be superseded at a later stage.

6.2 CHPQA Quality Index

The CHPQA programme was initiated by the UK Government to promote energy best practice. CHPQA aims to monitor, assess and improve the quality of CHP plants in the UK. A “good quality” plant would have a Quality Index (QI) of at least 105 which should be achieved in the design, specification and approval stages. Under standard operating conditions, the threshold for a good quality CHP reduced to 100. The QI for CHP achieves is dependent on their heat efficiency and power efficiency and is determined by the following formula.

$$QI = X\eta_{power} + Y\eta_{heat}$$

Where:

η_{power} is power efficiency

η_{heat} is heat efficiency

The power and heat efficiencies are calculated by using the gross electrical output and is based upon the Gross Calorific Value (GCV) of the input fuel. The coefficients, X and Y, are defined by CHPQA based on the gross electrical capacity of the scheme and fuel/technology used.

An updated version of the CHPQA Quality Index was released in December 2018. These updates are intended to ensure Government-supported schemes are supplying significant quantities of heat and delivering intended energy savings. For the ERF, X = 220 and Y = 120.

The QI and efficiency values, where the GCV is: 11 MJ/kg, have been calculated in accordance with CHPQA methodology for various load cases and the results are presented below.

Table 4: Heat and power export scenarios (CHPQA)

Scenario	Gross power efficiency (%)	Heat efficiency (%)	Overall efficiency (%)	CHPQA QI
No heat export	25.9	0	25.9	57.1
Average heat export	25.4	3.7	29.1	60.4
Maximum thermal export	23.7	15.8	39.5	71.0

The results in the table above show that the ERF would not achieve a QI score that exceeds the "Good Quality" threshold of 105 for the average heat load exported to the DHN. Additionally, even if exporting the maximum load continuously at all operating periods, it would still be significantly below the "Good Quality" CHP threshold with a resulting QI of 71.

For reference, if we assume the same Z-ratio of seven, approximately an average 38 MWth heat export would be required to achieve the "Good Quality" CHP status which is not currently envisaged.

6.3 R1 Calculation

The current governing legislation regarding incineration operations is the European Commission Waste Framework Directive (WFD). This Directive states that if the energy efficiency of the incineration plant is above 0.65, then it can be designated as a "Recovery" operation. If the energy efficiency of the plant is below 0.65 then they are designated "Disposal" operations which would also be considered in the same hierarchy as a landfill.

The R1 energy efficiency equation used for this calculation is:

$$Efficiency\ (\%) = \frac{(E_p - (E_f + E_i))}{(0.97 * (E_w + E_f))}$$

Where:

E_p = annual energy produced as heat or electricity. It is calculated with energy in the form of electricity and then multiplied by 2.6 and heat produced for commercial use multiplied by 1.1 (units of GJ/annum)

E_i = annual energy input to the system from fuels contributing to the production of steam (units of GJ/annum)

E_w = annual energy contained in the treated waste calculated using the net calorific value of the waste (units in GJ/annum)

E_f = annual energy input to the system from fuel contributing to the production of steam (units GJ/annum)

0.97 = The factor accounting for energy losses due to bottom ash and radiation

Using the formula presented and the interpretation of the guidance as well as the anticipated design figures, we have determined that with no heat export the R1 value is 0.68 and will increase as an average heat export is applied to 0.71.

It is our understanding that a clause within the proposed Engineering, Procurement and Construction (EPC) contract contains a requirement for the ERF to be R1 compliant.