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Consulting Engineers Limited

**Northacre Renewable Energy Limited**

# Northacre Facility

R1 Technical Note

# 1 Introduction

Northacre Renewable Energy Limited (NRE) is developing a scheme for the Northacre Facility (the 'Facility') to incinerate incoming residual waste fuel. The Facility will be located at Stephenson Road, Westbury, Wiltshire.

The Facility will process approximately 243,000 tonnes per annum (at the design capacity of 30.9 tph with an NCV of 10.5MJ/kg with an assumed availability of 7,860 hours).

NRE is applying for planning permission and an Environmental Permit (EP) for the Facility. This technical note has been developed to demonstrate that the design of the Facility achieves the R1 criteria and can be classified as a recovery operation in accordance with the requirements of the Waste Framework Directive (WFD).

# 2 Background

## 2.1 Waste Framework Directive

In accordance with the WFD, incineration facilities which process non-hazardous residual waste can be regarded as "Recovery" operations if the energy efficiency of the plant is greater than 0.65 (for plants permitted after January 2009). This is referred to as achieving "R1 status". In the UK, R1 status can only be formally granted by the relevant Competent Authority (for the Facility this will be the Environment Agency) when the facility has been in operation for more than 12 months. Plants which do not meet the energy efficiency criterion are classed as "Disposal" operations and therefore are considered as being equivalent to landfill in terms of the waste hierarchy.

The European Commission has published guidance titled '*Guidelines on the Interpretation of the R1 Energy Efficiency Formulae for Incineration Facilities Dedicated to the Processing of Municipal Solid Waste According to Annex II of Directive 2008/98/EC on Waste*'. Within the European Commission guidance the formula to calculate the efficiency of a facility is explained as follows:

$$\text{Energy Efficiency} = \frac{\left(E_p-\left(E_f+E_i\right)\right)}{\left(0.97\times\left(E_w+E_f\right)\right)}$$

where:

- $E_p$ means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2.6 and heat produced for commercial use multiplied by 1.1 (units of GJ/yr)
- $E_f$ means annual energy input to the system from fuels contributing to the production of steam (units of GJ/yr)

- $E_w$ means annual energy contained in the treated waste calculated using the lower calorific value of the waste (units of GJ/yr)
- Ei means annual energy imported excluding Ew and Ef (units of GJ/yr)
- 0.97 is a factor accounting for energy losses due to bottom ash and radiation.

## 2.2 R1 Approval

As the Competent Authority for granting R1 status in England, the Environment Agency (EA) has developed a three stage approval system:

1. Design stage approval;
2. Commissioning approval; and
3. Operational approval, referred to as 'Full R1 approval'.

To achieve any level of 'R1 approval', the Operator is required to submit an R1 application to the EA which demonstrates that the Facility has achieved the minimum R1 value of 0.65. The R1 application is subsequently audited by the EA to determine whether the Facility has achieved the R1 status and written confirmation of achieving the relevant approval is granted by the EA. The EA has developed an R1 application spreadsheet to assist Operators with the development for applications for R1 approval.

'Design Stage approval' is granted prior to commissioning of a Facility, and can demonstrate that the proposed design will achieve the R1 criteria if the plant is designed, commissioned and operated as the criteria assumed within the R1 application.

'Commissioning Stage approval' uses data collected during the commissioning process to demonstrate that the 'as built' Facility achieved the R1 criteria during the commissioning period.

A Facility can only be classified as having 'full' R1 approval when operational data for a period of 1 year, or more, shows that the Facility has achieved the relevant efficiency requirements of the R1 criteria. Having obtained Full R1 approval from the operational data, records are required to be submitted to the EA, on an annual basis, to demonstrate that the Facility has continued to operate at the same level of efficiency. If the operational data shows that the Facility is not achieving R1 status at the end of the year, the Operator can ask for more time to take action to fix the problem. However, R1 status will be withdrawn by the EA if the Facility cannot meet the minimum requirements the following year.

# 3 R1 Application

An 'R1 Application' for Design Stage approval has been developed and is intended to be submitted to the EA in support of the EP application for the Facility. The R1 application is based on the relevant design parameters for the Facility as will be presented within the planning and EP applications; waste processing capacity; and electricity consumption. The design parameters and completed R1 application form are presented in Appendix A.

As shown in the R1 application, the R1 efficiency of the Facility has been calculated as **0.90**.

# 4 Conclusions

The Facility has been assessed in accordance with the EA's R1 application process. As demonstrated within this Technical Note, the R1 efficiency of the Facility has been calculated as 0.90. Therefore, this technical note demonstrates that the design of the Facility will achieve the R1 status and would be classified as a recovery operation under the terms of the WFD.

Furthermore, NRE will be submitting the application presented with this Technical Note to the EA for Design Stage R1 approval in support of the EP application for the Facility.

Yours sincerely

FICHTNER Consulting Engineers Limited

**James Sturman**
Lead Environmental Consultant

**Nigel Garrod**
Principal Consultant

# A R1 Application

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **PROFORMA FOR DETERMINING ENERGY EFFICIENCY USING R1** | | | | | | | | |
| 2 | **Site name, address and grid reference** | Northacre Energy Recovery Facility | **EPR Permit reference (if known)** | | | | | | |
| 3 | **Operator name** | Northacre Renewable Energy | **Application fee (£)** | | 2000 | | | | |
| 4 | **Details of who to contact if we have any queries regarding this form** | James Sturman<br>jamessturman@fichtner.co.uk<br>07889 364179 | | | | | | | |
| 5 | **What data has been used in the application? →** | | Design data | | | | | | |
| 6 | Indicative R1 factor (subject to confirmation) | 0.90 | Quantity in reporting year | Units | $U_c$ | Properties (Average over reporting year) | Units | Note which parameters that have been estimated | Reference to Supporting information |
| 7 | Climate change correction factor (optional) | | | | | | | | |
| 8 | R1 after CCF adjustment | | | | | | | | |
| 9 | 1. Gross electricity meter (Electricity produced at turbine) | | 225304.96 | MWh | | | | | See Application Suppor |
| 10 | 2. Electricity exported - Net input/output meter | | 201901.36 | MWh | | | | | See Application Suppor |
| 11 | 3. Electricity imported - Net input/output meter | | 190.08 | MWh | | | | | See Application Suppor |
| 12 | 4. Other fuel inputs | | | | | | | | |
| 13 | | 4.1 Light fuel oil | 309,850 | litres | | 0.85 | kg/l | | See Application |
| 14 | | | | | | 42860 | kJ/kg | | Supporting Information |
| 15 | | 4.2 Natural gas | | $Nm^3$ | | 34200 | $kJ/Nm^3$ | | |
| 16 | | | | | | | | | |
| 17 | | 4.3 LPG | | $Nm^3$ | | | $kg/Nm^3$ | | |
| 18 | | | | | | | kJ/kg | | |
| 19 | | 4.4 Other fuels similar to light fuel oil | | litres | | | kg/l | | |
| 20 | | | | | | | kJ/kg | | |
| 21 | 5. Primary combustion air (as supplied to furnace) | | 759950431 | $m^3$ | | 1.287283698 | $kg/Nm^3$ | | |
| 22 | | | | | | 120 | °C | | See Application |
| 23 | | | | | | 95.95 | kJ/kg | | Supporting Information |
| 24 | 6. Secondary combustion air (as supplied to furnace) | | 236836631 | $m^3$ | | 1.287283698 | $kg/Nm^3$ | | |
| 25 | | | | | | 120 | °C | | See Application |
| 26 | | | | | | 95.95 | kJ/kg | | Supporting Information |
| 27 | 7. Recycled flue gas (as supplied to furnace) | | | $m^3$ | | | $kg/Nm^3$ | | |
| 28 | | | | | | | °C | | |
| 29 | | | | | | 0 | kJ/kg | | |
| 30 | 8. Heat exported outside R1 boundary | | | | | | | | |
| 31 | | 8.1 steam exported | | tonnes | | | °C | | |
| 32 | | | | | | | kPa | | |
| 33 | | | | | | | kJ/kg | | |
| 34 | | condensate returned | | tonnes | | | °C | | |
| 35 | | | | | | | kPa | | |
| 36 | | | | | | | kJ/kg | | |
| 37 | | 8.2 hot water exported | | tonnes | | | °C | | |
| 38 | | | | | | | kPa | | |
| 39 | | | | | | | kJ/kg | | |
| 40 | | hot water returned | | tonnes | | | °C | | |
| 41 | | | | | | | kPa | | |
| 42 | | | | | | | kJ/kg | | |
| 43 | | | | | | | | | |
| 44 | 9. Internal steam use | | | | | | | | |
| 45 | | 9.1 for soot blowing (no backflow) | | tonnes | | | °C | | |
| 46 | | | | | | | kPa | | |
| 47 | | | | | | | kJ/kg | | |
| 48 | | 9.2 for steam driven devices | | tonnes | | | °C | | |
| 49 | | | | | | | kPa | | |
| 50 | | | | | | | kJ/kg | | |
| 51 | | backflow as steam | | tonnes | | | °C | | |
| 52 | | | | | | | kPa | | |
| 53 | | | | | | | kJ/kg | | |
| 54 | | 9.3 for trace heating | | tonnes | | | °C | | |
| 55 | | | | | | | kPa | | |
| 56 | | | | | | | kJ/kg | | |
| 57 | | backflow as condensate | | tonnes | | | °C | | |
| 58 | | | | | | | kPa | | |
| 59 | | | | | | | kJ/kg | | |
| 60 | | 9.4 for re-heating flue gas | | tonnes | | | °C | | |
| 61 | | | | | | | kPa | | |
| 62 | | | | | | | kJ/kg | | |
| 63 | | backflow as condensate | | tonnes | | | °C | | |
| 64 | | | | | | | kPa | | |
| 65 | | | | | | | kJ/kg | | |
| 66 | | 9.5 for concentration processes | | tonnes | | | °C | | |
| 67 | | | | | | | kPa | | |
| 68 | | | | | | | kJ/kg | | |
| 69 | | backflow as condensate | | tonnes | | | °C | | |
| 70 | | | | | | | kPa | | |
| 71 | | | | | | | kJ/kg | | |
| 72 | | 9.6 for building, equipment, tank heating | | tonnes | | | °C | | |
| 73 | | | | | | | kPa | | |
| 74 | | | | | | | kJ/kg | | |
| 75 | | backflow as condensate | | tonnes | | | °C | | |
| 76 | | | | | | | kPa | | |
| 77 | | | | | | | kJ/kg | | |
| 78 | | 9.7 for deaeration and demineralisation | | tonnes | | | °C | | |
| 79 | | | | | | | kPa | | |
| 80 | | | | | | | kJ/kg | | |

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 81 | | backflow as condensate | | tonnes | | | °C | | |
| 82 | | | | | | | kPa | | |
| 83 | | | | | | | kJ/kg | | |
| 84 | | | | tonnes | | | °C | | |
| 85 | | | | | | | kPa | | |
| 86 | | | | | | | kJ/kg | | |
| 87 | | backflow as condensate | | tonnes | | | °C | | |
| 88 | | | | | | | kPa | | |
| 89 | | | | | | | kJ/kg | | |
| 90 | | | | tonnes | | | °C | | |
| 91 | | | | | | | kPa | | |
| 92 | | | | | | | kJ/kg | | |
| 93 | | backflow as condensate | | tonnes | | | °C | | |
| 94 | | | | | | | kPa | | |
| 95 | | | | | | | kJ/kg | | |
| 96 | 10. Use of condensing energy from steam in flue gas | | | GJ | | | | | |
| 97 | 11. Superheated steam at boiler outlet | | 897563.52 | tonnes | | 430 | °C | | |
| 98 | | | | | | 7647 | kPa | | See Application |
| 99 | | | | | | 3228 | kJ/kg | | Supporting Information |
| 100 | 12. Boiler feedwater | | 906641.28 | tonnes | | 141.8 | °C | | |
| 101 | | | | | | 8238 | kPa | | See Application |
| 102 | | | | | | 602.1 | kJ/kg | | Supporting Information |
| 103 | 13. Boiler Efficiency (Design) | | 94% | ± | 1.5% | | | | See Application Suppor |
| 104 | **Instructions for completing this spreadsheet** | | | | | | | | |
| 105 | 1. | Ensure that you have completed the first three rows of the application form | | | | | | | |
| 106 | 2. | This form should be accompanied by supporting information for the figures quoted. Where this information is in the permit application, reference to the relevant sections of the application can be made. | | | | | | | |
| 107 | | A Sankey diagram (or equivalent) reflecting the boundaries of the installation used as well as any references to physical properties is the absolute minimum that should be provided for an application based on design information | | | | | | | |
| 108 | 3. | We have colour coded the cells in this spreadsheet to assist you in completing this form, an explanation of the colour codes is provided below. The colour will disappear when data has been entered. | | | | | | | |
| 109 | | Blue cells require data that is essential for the R1 calculation, where information on uncertainty of the data is available it would be useful (but not mandatory) for this to be included for these parameters. | | | | | | | |
| 110 | | Beige Cells indicate that any data entered will be used in the R1 calculation. They have been used where there is a choice of inputs but not all plants will have data for all the input options. | | | | | | | |
| 111 | | Where you are entering data into beige cells you need to make sure that you enter data into all the beige cells associated with the input as they are all needed for carrying out the calculation. | | | | | | | |
| 112 | | Yellow cells have been used to provide flexibility to include fuels or energy uses not identified elsewhere. Supporting information to explain why the standard fields were not appropriate or adequate will need to be provided where these cells are used. | | | | | | | |
| 113 | | Data entered in uncoloured cells are not used when calculating the R1 energy efficiency factor but can be completed to provide a more complete data set. | | | | | | | |
| 114 | | Data in the purple cell for the CCF factor is optional. If used the way it was calculated must be explained in supporting information | | | | | | | |
| 115 | 4. | Ensure the temperatures entered into cells F19 and F22 (and F25) are the actual temperatures of the heated air in $^{o}$C. | | | | | | | |
| 116 | | The spreadsheet uses these values to calculate the specific enthalpy associated with heating the air from ambient 25 $^{o}$C in cells F20 and F23 (and F26). | | | | | | | |
| 117 | 5. | Densities used in cells F18 and F21 (and F24) should be at the temperatures at which the flows quoted in C18 and C21 (and C24) are reported. | | | | | | | |
| 118 | | The spreadsheet multiplies these pairs of entries to generate a mass of air. | | | | | | | |
| 119 | 6. | If you believe that any of the information that you have submitted in this application form is commercially confidential please identify the confidential information and the grounds on which you believe it to be confidential in your covering letter | | | | | | | |
| 120 | LIT 5753 | | | | | | | | |
| 121 | EAD/0812/xls/v3 | | | | | | | | |

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# Northacre Facility

R1 Application Supporting Information

## 1 Design Data

The following data on the Northacre Facility (the Facility) has been assumed for the purposes of the R1 application.

| Description | Value | Units |
|---|---|---|
| Lines | 1 | line |
| Operational hours | 7880 | hours/year |
| Non-operational Hours | 880 | hours/year |
| Waste consumption (nominal design capacity) | 30,863 | kg/hour |
| Waste LHV | 10,500 | kJ/kg |
| Gross power generation | 28.6 | $MW_e$ |
| Parasitic load | 2.97 | $MW_e$ |
| Auxiliary fuel consumed annual | 263,373 | Kg/y |
| Auxiliary fuel LHV | 42,860 | kJ/kg |
| Auxiliary fuel density | 0.850 | kg/l |
| Start up electricity | 47.52 | MWh |
| Number of start ups per year | 4 | |
| Start up time | 16 | hrs |
| Annual time for start ups | 64 | hrs/y |
| Primary air flow | 96,440 | $Nm^3/hr$ |
| Primary air temperature | 120 | $^oC$ |
| Primary air density | 1.29 | $kg/m^3$ |
| Primary air enthalpy | 95.95 | kJ/kg |
| Secondary air flow | 30,055 | $Nm^3/hr$ |
| Secondary air temperature | 120 | $^oC$ |
| Secondary air density | 1.29 | $kg/m^3$ |

| Description | Value | Units |
|---|---|---|
| Secondary air enthalpy | 95.95 | kJ/kg |
| Main steam produced by boiler at 100% MCR | 113.90 | tonnes/hour |
| Main steam temperature | 430 | $^{o}$C |
| Main steam enthalpy | 3,228 | kJ/kg |
| Boiler feedwater flowrate | 115.06 | tonnes/hour |
| Boiler feedwater enthalpy | 602 | kJ/kg |
| Boiler design efficiency | 93.58 | % |

# 2 Assumptions

The following assumptions on the design and performance of the Facility have been used for the purposes of this R1 application. These assumptions are based on the available design assumptions. Where applicable, conservative assumptions on operational parameters based on our experience of similar facilities have been made.

- The availability of the Facility will be 7,880 hours/year.
- The auxiliary fuel will be low sulphur fuel oil. No other auxiliary fuels will be combusted in the Facility.
- The parasitic load will be 2.97 MW.
- There will be 4 start ups / shutdowns per year.
- Despite aspirations from the applicant, there is assumed to be no heat export from the Facility since no formal heat supply agreements are currently in place with heat users. Therefore, the Facility is assumed to be operating in fully condensing mode. This approach represents a conservative position with regards to energy efficiency, which will improve when heat export is realised.
- There will be no internal heat use within the Facility.

# 3 Calculations

## 3.1 Gross Electricity

The gross electrical generation of the Facility has been calculated as follows:

Total gross electrical generation = Gross power generation ($MW_e$) x Annual operating hours
= 28.6 ($MW_e$) x 7,880 (hours)
= 225,368 MWh

## 3.2 Electricity Exported

The electricity exported from the ERF was calculated as follows:

Electricity exported = (Gross power generation – Parasitic power) ($MW_e$) x Operating time (hours)

= (28.592 ($MW_e$) – 2.97 ($MW_e$)) x 7,880 (hours)

= 201,901 MWh

## 3.3 Electricity Imported

The only electricity imported to the site should be during start-ups before the plant is able to export power. The electricity imported into the ERF has been calculated as follows:

Total electricity import = Hours spent during start up x Parasitic load during start-up
= 64 hours of start-ups x 2.97 MW

= 190.08 MWh

## 3.4 Fuel Oil

Fuel oil is consumed by all burners during start-ups and discontinuously by the top burner during nominal operation to prevent the temperature falling below 850°C. For the purpose of this calculation, the discontinuous operation is ignored. The fuel oil consumed on the ERF has been calculated as follows.

Fuel oil consumed during start-ups and shutdowns = 263,373 kg/y

Total fuel oil consumed = Total fuel oil consumed ÷ Fuel oil density

= (263,373 kg/y) ÷ 0.85 kg/L

= 309,850 litres/y

## 3.5 Primary Combustion Air (Heated)

The annual heated primary combustion air flow was calculated as follows:

Primary combustion air = Primary combustion air ($Nm^3$/hour) x Operating time (hours)

= 96,440 ($Nm^3$/hour) x 7,880 (hours)

= 759,950,431 $Nm^3$

## 3.6 Secondary Combustion Air (Heated)

The annual heated secondary combustion air flow was calculated as follows:

Secondary combustion air = Secondary combustion air ($Nm^3$/hour) x Operating time (hours)

= 30,055 ($Nm^3$/hour) x 7,880 (hours)

= 236,836,631 $Nm^3$

## 3.7 Heat export outside R1 boundary

No steam is currently exported from the ERF.

## 3.8 Superheated Steam at Boiler Outlet

The annual superheated steam at the boiler outlet for the ERF was calculated as follows:

Superheated steam from boilers = Main steam flow rate (tonnes/hour) x Operating time (hours)
= 113.9 (tonnes/hour) x 7,880 (hours)
= 897,563 tonnes

## 3.9 Boiler Feedwater

The annual boiler feedwater used by the ERF was calculated as follows:

Boiler feedwater = Boiler feedwater flow rate (kg/hour) x Operating time (hours)
= 115.06 (tonnes/hour) x 7,800 (hours)
= 906,641 tonnes

# 4 Sankey Diagram

An indicative Sankey Diagram for the Northacre ERF (exporting power only) is presented below.

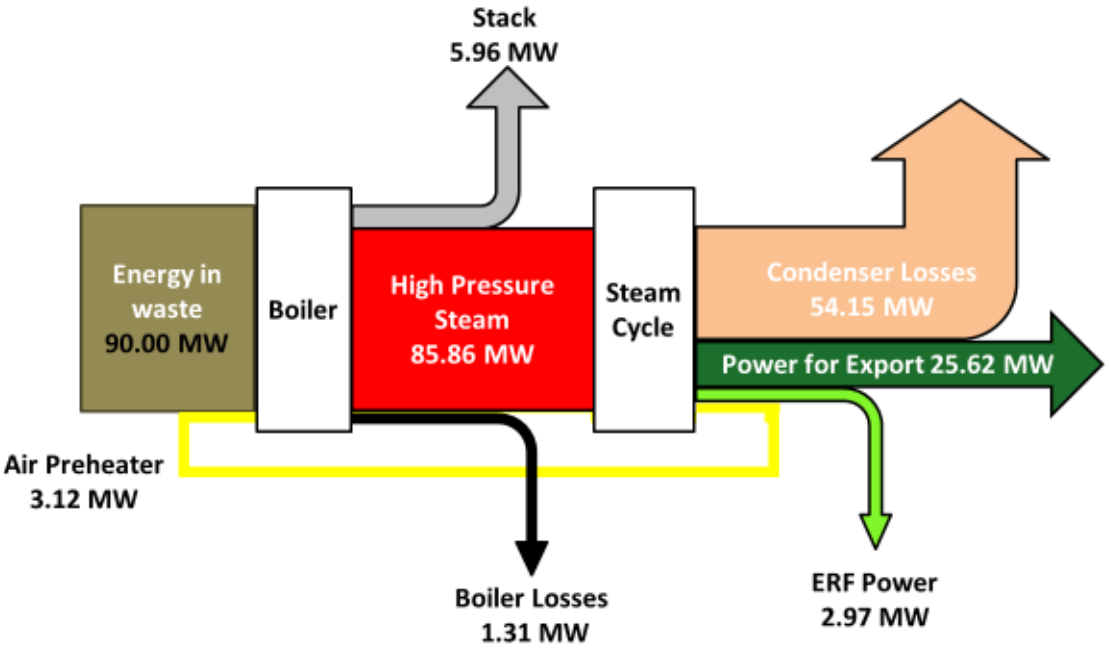


Figure 4 – ERF Indicative Sankey Diagram