UNITED KINGDOM WITHOUT INCINERATION NETWORK

Application by Peel Environmental for Off Eakring Road, Bilsthorpe

PINS Ref:	*APP/L3055/V/14/3001886*
Application No:	*ES/2950*

UKWIN Technical Note on Applicant R1 Calculations

"Development of the Bilsthorpe Energy Centre to manage unprocessed and pre-treated waste materials through the construction and operation of a plasma gasification facility, materials recovery facility and energy generation infrastructure together with supporting infrastructure"

13th October 2015

Introduction

1. Further to UKWIN's Rebuttal Submission, UKWIN provides this Technical Note which focuses on some of the shortcomings in the Applicant's R1 calculations and provides examples to illustrate how the proposed Bilsthorpe gasification facility could operate below the 0.65 R1 threshold.

2. This technical note therefore supports UKWIN's contention that the proposed Bilsthorpe gasification facility should be treated as a D10 (Disposal) facility for planning purposes due to the failure of the Applicant to demonstrate that it would operate as R1 (Recovery).

3. This submission was produced by UKWIN's Technical Adviser, Tim Hill BSc, C.Eng., M.I.Mech.E., a graduate of Bristol University.

Summary

4. In relation to the Applicant's R1 calculations, as set out in the Third Regulation 22 Submission [CD75], documents APP-SMO -1 and associated appendices [APP-SMO-2], this Technical Note demonstrates that:

    - The Applicant has significantly erred with Scenario 7; and
    - The effect(s) on R1 of operating the Bilsthorpe plasma gasification facility with waste of a calorific value of 10.5Mj/kg (rather than 12.581Mj/kg) have been underestimated by the Applicant because of unsupported and flawed assumption that the efficiency will remain constant; and
    - With the lower calorific value, R1 would be only 0.6357 (assuming other assumptions made by the Applicant are correct and adopting reasonable assumptions for illustrative purposes), defining the facility as Disposal; and
    - When the calorific value of the waste feedstock falls to 11.8Mj/kg, R1 would fall below 0.65.

5. Key to UKWIN's technical submission is the energy balance applicable to the generator sets proposed by the Applicant and the implications of a reduction in the energy flow.

6. *Energy in syngas = Energy delivered as electricity + Energy dissipated by the generator sets as heat.*

7. For the purposes of demonstrating the implications of the UKWIN's assessment of the Applicant's design details, UKWIN has made certain assumptions (explained below) and points out that Caterpillar, the generator set supplier, ought to have, but does not appear to have, been consulted as to the efficiency and R1 implications of using feedstock with a net calorific value lower than the design calorific value of 12.581Mj/kg.

8. The spreadsheet included as an Annex to this Technical Note demonstrates the implications of using waste of calorific value (CV) 10.5Mj/kg rather than the design calorific value of 12.581Mj/kg, and also of residual MSW of 9.5Mj/kg.

9. Sheet 1 shows UKWIN's R1 calculations for the Applicant's Scenario 7 and for MSW.

10. Sheet 2 shows, with aid of bar charts, the basis on which UKWIN argues that reduced waste calorific value leads to reduced efficiency.

The Rationale

11. The quoted efficiency of a generator set (i.e. an internal combustion engine driving a generator) normally reflects the ratio of the rate at which an engine delivers useful electrical energy to the rate at which it takes energy in the fuel that it uses.

12. The incoming fuel energy to an engine is converted into heat energy and mechanical energy.

13. The mechanical energy produced in the engine has not only to meet the user requirement for electrical energy, but also to overcome the internal mechanical losses.

14. These losses result in particular from friction, and 'pumping' losses associated with the movement of the pistons, and there are usually other internal power requirements such as oil and cooling water pumps, and in the case of generator sets as proposed at Bilsthorpe, the small friction losses within the generators.

15. The energy absorbed in overcoming these losses is dissipated as heat.

16. So, for the generator sets at Bilsthorpe:

- *Incoming energy in the fuel = Electrical energy delivered to the user + energy lost as heat + internal losses.*

- *Internal losses = energy lost in friction in the engine and the generator + energy lost in pumping + energy consumed by oil and cooling water pumps.*

  These internal loses are taken from the engine generator set in the form of heat energy.

- *Electrical energy delivered to the user = Total mechanical energy developed in the engine minus energy absorbed by Internal Losses*

- *Efficiency = Electrical Energy delivered divided by Incoming energy in the fuel*

17. These internal losses vary with the rotational speed of the engine, but for a given rotational speed are effectively independent of the incoming energy in the fuel and the power delivered to the user.

18. It follows that, whilst the output of the generator sets, at a particular rotational speed, can vary according to the energy in the fuel, the internal losses at that speed remain broadly constant.

19. It further follows that the greater the energy value in the fuel, the smaller the proportion of its energy that will be absorbed in the internal losses and vice versa.

20. Thus, the lower CV in the Applicant's Scenario 7 will bring with it a lower efficiency figure. This lower efficiency figure has not been taken into account by the Applicant in their Scenario 7 calculations, and thus they have significantly overestimated the R1 factor for their Scenario 7.

Assumptions

21. It should be noted that UKWIN has, for these illustrative purposes, assumed that:

- The reduction in calorific value does not affect the proportions of fuel energy converted to heat and to mechanical energy;
- The total mechanical energy developed within the engine falls in proportion to the fall in fuel calorific value;
- The internal engine losses referred to above equate to 5% of the gross mechanical power developed (i.e. electrical power + internal losses);
- The efficiency quoted in Caterpillar's 26th February 2015 letter relates to the Applicant's net syngas calorific value of 8.633 MJ/m^3. This is not made clear in the letter.

  Note: Without explicit confirmation from Caterpillar that their calculations are based on this calorific value for the syngas it cannot be ruled out that Caterpillar assumed a higher calorific value when providing their efficiency calculation, e.g. based on the Heat Load assumption (set out in Paragraph 2.5.16 of APP-SMO-1) that the waste would have a calorific value of 14.46 MJ/kg rather than 12.581 MJ/kg prior to being converted into syngas. If a higher calorific value was assumed by Caterpillar then all of the Applicant's R1 calculations have overestimated the R1 value to a greater degree than is assumed in this Technical Note.
- The calorific value of the syngas will fall in proportion to the fall in the calorific value of the waste; and
- The quoted calorific value of the syngas (8.633 MJ/m3) is derived from waste with a calorific value of 12.581 Mj/kg.

Implications for the Bilsthorpe proposals

22. In the case of the plasma gasification facility proposed for Bilsthorpe, the generator set supplier, Caterpillar, has confirmed that the generator set full load output capability to be expected (1833KW), given the syngas calorific value (energy) specified by the Applicant, and the generator set efficiency to be expected (39.5% representing the ratio electrical power produced / energy in the fuel consumed). This is at a rotational speed understood to be 1800RPM.

23. It is understood from the Applicant's documentation that the syngas calorific value specified by the applicant is 8.633 MJ/m3 and that this value is based on the assumption of waste with a calorific value of 12.581 Mj/kg.

24. In the event of the fuel calorific value falling below the Applicant's 12.581 Mj/kg figure, the internal losses will remain effectively constant, but the energy left for driving the generators will fall to an extent greater than the fall in fuel calorific value. In other words, the efficiency will fall below 39.5%.

25. Whilst the Applicant has included a 'low calorific value' Scenario 7 in their R1 sensitivity analysis table [APP-SMO-2], there is no evidence that Caterpillar have been asked to state (or have stated) the extent to which this should have reflected a decline in efficiency.

26. It seems reasonable to assume that Caterpillar have not confirmed the Applicant's various assumptions, because if they had then the Applicant would have provided evidence of this to support their application.

27. This lack of confirmation should reduce the weight given to the Applicant's R1 claims that rely on assumptions where the Applicant has provided no evidence that the assumptions they have used have been confirmed by Caterpillar.

28. As noted above, the Applicant has not even provided evidence that Caterpillar has confirmed the assumed efficiency at the calorific value used in the Applicant's central scenario, and it is possible that the efficiency figure provided by Caterpillar was for a higher calorific value, e.g. the higher figure that the Applicant has assumed for their Heat Load analysis.

29. The extent of the decline in efficiency will depend on the ratio of internal losses to mechanical energy developed in the engine.

30. As noted above, the extent of the internal losses within the G3520C Engine / generator set have not been made available, but for illustrative purposes these have been assumed to represent 5% of the mechanical power developed in the engine if the generator set output is to be 1833KW as per Caterpillar's 26th February 2015 letter Ref: *Caterpillar G3520C Engine / generator set electrical conversion efficiency.*

31. The potential implications are set out in the spreadsheet included as an Annex to this Technical Note.

32. In the Applicant's Scenario 7 (which assumes a waste calorific value of 10.5Mj/kg), UKWIN suggests that R1 can be expected to fall to 0.6357, resulting in an R1 figure significantly lower than is suggested by the Applicant, and critically, an R1 figure that is below the 0.65 Threshold to qualify as Recovery.

33. The R1 figure in Scenario 7 would in practice decline more than the Applicant suggests and the performance of the installation would fall into the category of Disposal.

34. If a calorific value of 11.8Mj/kg is substituted in the spreadsheet (Sheet 1, Peel R1 Scenario 7) for 10.5Mj/kg, it will be seen that R1 falls to 0.6493, i.e. below the 0.65 R1 Threshold, demonstrating the extent to which the Applicant's claim for Recovery status of the proposed installation is a fragile one.

35. It is important to note that UKWIN's calculations make clear that a small reduction in generator efficiency results in a rapid fall in R1.

Bilsthorpe R1 Scenarios **Sheet 1**

		GENSET PERFORMANCE AND LOSSES			**GENSET PERFORMANCE**				
		Waste CV 12.581Mj/kg			**adjusted for waste CV 9.5 Mj/kg**				
		Assumes notional 5% internal losses			Assumes 5% internal losses				
A	Net gen set output	1833	KW	Peel (Third Reg 22 Submission)					
B	Gross genset output	1929.47	KW	A*100/95					
C	Losses	96.47	KW	B - A					
D	Ancilliaries	15	KW	Peel					
E	losses + Ancill	111.47	KW	C + D					
		847200.00	KWh	annually					
		3049920.00	Mj						
	Annual losses + Ancilliary	847200	KWh						
		3049920	Mj						
F	Total gross output	1944.47	KW	B + D	New total Gross output	1468.29	Kw	Including previous internal losses	
					New Net output	1356.81	KW	Excluding previous internal losses	
					per year	10311769.88	KWh		
						37122371.55	Mj		
						37122.37155	Gj		
					8 engines	296978.9724	Gj	potential net annual output	

	THIRD REGULATION 22 SUBMISSION R1 Scenario 1	
Peel	Annual energy figures	
RDF CV	12.581	Mj/kg
	3.495	KWh/kg
Ew	1,195,195	Gj
Ei	9122	Gj
Ef	113369	Gj
Energy in Syngas	954243	Gj
Engine Efficiency %	39.5	Peel (Third Reg 22 submission)
Elec Energy delivered	376,926	Gj
Ep	980007.6	
Ep-(Ef+Ei)	857516.6	
(Ew+Ef)	1,308,564	
0.97(Ew+Ef)	1269307.08	
R1	0.6756	

UKWIN MSW scenario R1	**(losses as in scenario 1)**	
	Annual energy figures	
Waste CV	9.5	Mj/Kg
	2.639	KWh/kg
Ew	902500	Gj
Ei	9122	Gj
Ef	113369	Gj
Energy in Syngas	720555.48	Gj
Engine Efficiency %	38.67	Sheet 2 K''
Elec Energy delivered	278644.19	Gj
Ep	724474.90	
Ep-(Ef+Ei)	601983.90	
(Ew+Ef)	1015869	
0.97(Ew+Ef)	985392.93	
R1	0.6109	

Peel R1 Scenario 7	**(losses as in Scenario 1)**	
	Annual energy figures	
Waste CV	10.5	Mj/Kg
	2.917	KWh/kg
Ew	997500	Gj
Ei	9122	Gj
Ef	113369	Gj
Energy in Syngas	796403.43	Gj
Engine Efficiency %	38.99	Sheet 2 K'
Elec Energy delivered	310543.51	Gj
Ep	807413.13	
Ep-(Ef+Ei)	684922.13	
(Ew+Ef)	1110869	
0.97(Ew+Ef)	1077542.93	
R1	0.6356	

Bilsthorpe Lower CV and Gen set efficiency **Sheet 2**

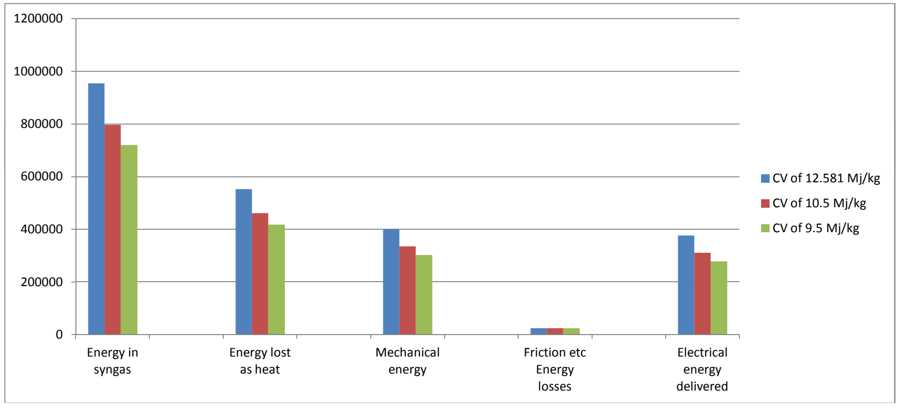
5% Internal Losses - Energy Lost				
Peel	RDF CV	12.581	Mj/kg	
A	3049.92	Gj	Friction etc Losses (per genset	UKWIN estimate
B	24399.36	Gj	Energy Lost (8 gensets)	
C	376926	Gj	Electrical Energy delivered	Peel
D	401325.36	Gj	B + C	
E	954243	Gj	energy in syngas	Peel
F	0.42057		D/E	

Lower CV: Efficiency Impact			Applicant's Scenario 7	
waste CV	10.5	Mj/kg		
G'	796403.426	Gj	E*10.5/12.581	energy in syngas
	461460.553	Gj	G' - H'	Energy lost as heat
H'	334942.873	Gj	F*G'	Mechanical Energy
	24399.36	Gj	H' - J'	Friction etc losses
J'	310543.513	Gj	H' - B	Electrical energy delivered
K'	38.993	%	J'/G'	Illustrative
				genset efficiency
				at lower CV

Lower CV : Efficiency Impact			UKWIN MSW Scenario	
MSW CV	9.5	Mj/kg		
G''	720555.48	Gj	E*9.5/12	energy in syngas
	417511.93	Gj	G'' - H''	Energy lost as heat
H''	303043.55	Gj	F*G''	Mechanical Energy
	24399.36	Gj	H''-J''	Friction etc losses
J''	278644.19	Gj	H'' - B	Electrical energy delivered
K''	38.671	%	J''/G''	Illustrative
				genset efficiency
				at lower CV

Efficiencies and R1	Data for Bar Charts			
CV	12.581	10.5	9..5	Mj/kg
Energy in syngas	954243	796403	720555.4805	Gj
Energy lost as heat	552917.64	461461	417511.9291	Gj
Mechanical energy	401325.36	334943	303043.5514	Gj
Friction etc Energy losses	24399.36	24399.4	24399.36	
Electrical energy delivered	376926	310544	278644.1914	Gj
Illustrative Gen set efficiency	0.395000016	0.38993	0.386707476	%/100
R1	0.675578521	0.63563	0.610907466	

Energy



R1 and Efficiency