1. Calculation of Required Power Input of the Towngas Boiler

2900	poultry/hr	max bird slaughtering rate
1450	poultry/hr	max bird slaughtering rate per stall
8	L/poultry	Section 5.6.37 of EIA report refers
1000	g/L	density of water
60	final water temperature, degC	Table 3-4 of EIA report refers
20	initial water temperature, degC	assumed average water temperature
4.1813	$J\ g^{-1}\ K^{-1}$	specific heat capacity of water
Power output of the boiler:	$\Delta Q = mc\Delta T$	(8 x 1450) x (4.1813 x 1000) x (60 - 20) / 1000000
ie.	1940.12 MJ/hr	
Power input:	2425.15 MJ/hr	assume 80% efficiency

2. Checking of the Assumed Boiler Efficiency

	degC	degF	Difference (Ts-Ta) (F)	
Combustion (ambient) air (Ta)	20	68	N/A	conversion: http://www.wbuf.noaa.gov/tempfc.htm
Flue gas (Ts)	202	396	328	http://www.epa.gov/ttn/naaqs/ozone/areas/plant/nc/pl37048x.htm
	232	450	382	http://www.epa.gov/ttn/naaqs/ozone/areas//plant/fl/pl17034x.htm
	214	417	349	ditto

Assumptions: for the worst-case scenario, the maximum difference (Ts - Ta) of 382 F, and lowest Ts of 202 C were adopted in the assessment

Ts-Ta (F)	382	
Excess air (%)	15	p.10 of Combustion Analysis Basis - An Overview of Measurements, Methods and Calculations Used in Combustion Analysis, TSI
O_2 (%)	2.73	
A2	0.63	
B	0.011	
qA (%)	17.37	
Efficiency (%)	82.63	
Efficiency adopted in the assessment (%)	80	

$$\%\,\text{Excess Air} = \frac{\%O_2\ measured}{20.9 - \%O_2\ measured} \times 100$$

The Siegert formula is widely used in Europe to determine flue losses (qA) and efficiency.

$$qA = (Ts - Ta) \times \left(\frac{A2}{(21 - O_2)} + B \right)$$

$$Efficiency = 100 - qA$$

Where: *qA* = flue loss
Ts = flue temperature
Ta = supply air temperature
O_2 = measured volumetric oxygen concentration expressed as a percent
A2, B = fuel dependent constants

The constants *A2* and *B* are derived from the fuel composition. In Germany, the following values are prescribed for some common fuels:

Fuel Type	A2	B
Natural gas	.66	.009
Fuel oil	.68	.007
Town gas	.63	.011
Coking oven gas	.60	.011
LPG (propane)	.63	.008

http://www.tsi.com/documents/CA-basic-2980175b.pdf

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3. NO_x Emission Rate

Power Input =	2425.15	MJ/hr	1kJ = 0.000278kWh
=	674.19	kWh/hr	1MJ = 0.278kWh (http://www.volker-quaschning.de/datserv/faktoren/index_e.html)
NO_x emission rate =	220	mg/kWh	as advised by Towngas via email on 20 April 2009
=	0.22	g/kWh	
NO_x Emission Rate of Each Boiler =	0.04	g/s	

4. Indicative Estimation of Efflux Velocity of the Towngas Boiler

Part a - Required Towngas

Towgas heat value[a] =	17.27	MJ/m^3
Power input =	2425.15	MJ/hr (Hyder calculations refer)
Required Towngas =	140.43	m^3/hr

Part b - Number of Moles of the Components in Towngas

At 20C and 1atm, the volume of a gas is 24.056 L/mol[b]

Composition of Towngas by volume[c]

Hydergen (H_2) =	49%	=	68808.54 L/hr	=	2860.35 mol/hr
Methane (CH_4) =	28.5%	=	40021.29 L/hr	=	1663.67 mol/hr
Carbon dioxide (CO_2) =	19.5%	=	27382.99 L/hr	=	1138.30 mol/hr
Carbon monoxide (CO) =	3%	=	4212.77 L/hr	=	175.12 mol/hr

Part c - Required Airflow for Combustion

After complete combustion, the flue gas will only contain CO_2 and H_2O

$C + O_2$ ----------> CO_2

$H + 0.25O_2$ --------------> $0.5H_2O$

$CO + 0.5O_2$ ---------------> CO_2

Number of mole (n) of each molecule in Towngas:

n_C = 1663.67 mol/hr

n_H = 12375.38 mol/hr

n_{CO} = 175.12 mol/hr

Required stoichiometric oxygen (n_{stoich}) for complete combustion

= $n_C + n_H/4 + n_{CO}/2$

= 4932.64 mol/hr

Required fraction of excess air[d] = 15%

$n_{dry\ air}$ = n_{stoich} (1 + excess air)/21%

= 27012.08 mol/hr

At 20°C and a relative humidity of 50%, water content (X) in air[b]

= 0.0116 mol/mol dry air

n_{air} = $n_{dry\ air}$ x (1 + X)

= 27325.42 mol/hr

Part d - Flue Gas

n_{CO_2} (CO_2 from combustion & Towngas) =	n_C + n_{CO_2} of Towngas =	2801.97 mol/hr
n_{H_2O} (H_2O from combustion & ambient air) =	n_H of Towngas / 2 =	6501.03 mol/hr
n_{N_2} (N_2 from ambient air) =	$n_{dry\ air}$ x 79% =	21339.54 mol/hr
n_{O_2} (remaining O_2 after combustion) =	Fraction of Excess Air x n_{stoich}	739.90 mol/hr

$n_{flue\ gas}$ = 31382.44 mol/hr

Total volume of flue gas = 754.94 m^3/hr under 20°C

Flue gas temperature[e] =	202	°C
=	475	K
Ambient Temperature =	20	°C
=	293	K

Assume gas pressure at 20°C (or 293K) = that at 475K

volumetric flow at 475K[f] =	1223.87	m^3/hr
=	0.34	m^3/s
diameter of stack =	0.2	m
stack area =	0.03	m^2
Efflux Velocity =	11	m/s

Therefore, assuming efflux velocity of 6m/s is a conservative approach and 6m/s was. adopted for assessing the NO_2 emission impact.

Part e - Reference:

a. http://www.towngas.com/files/Tai%20Po%20Plant%20Leaflet.pdf
b. Noel de Nevers: The Air Pollution Control Engineering, 2nd ed., McGraw-Hill, 2000
c. as advised by Towngas via email on 20 April 2009
d. http://www.tsi.com/documents/CA-basic-2980175b.pdf
e. http://www.epa.gov/ttn/naaqs/ozone/areas/plant/nc/pl37048x.htm refers
f. Combined Gas Law, V1P1/T1 = V2P2/T2)

5. Other Chimneys Identified within 500m from the Site

Coordinate		Height above ground, m	Elevation, mPD	Diameter, mm	Exit Temperature, C	Fuel Consumption Rate, (L/hr)	NO_x Emission Rate, g/s
X	Y						
830910	842390	13.0	7.0	280	400	35.0	0.0233
830911	842389	13.0	7.0	280	400	18.0	0.0120
830911	842380	15.6	6.4	355	400	228.0	0.1520
830911	842380	15.6	6.4	355	400	142.0	0.0947

Note:

1. NO_x emission rate (Table 1.3-1 of USEPA AP-42 Section 1.3 (version 9/98) refers) =

= 20 lb/1000 gal

= 2.4 kg/1000L

= 2.4 g/L