

## 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 <sup>-1</sup> K <sup>-1</sup>		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: <a href="http://www.wbuf.noaa.gov/tempfc.htm">http://www.wbuf.noaa.gov/tempfc.htm</a>
Flue gas (Ts)	202	396	328	<a href="http://www.epa.gov/ttn/naaqs/ozone/areas/plant/nc/pl37048x.htm">http://www.epa.gov/ttn/naaqs/ozone/areas/plant/nc/pl37048x.htm</a>
	232	450	382	<a href="http://www.epa.gov/ttn/naaqs/ozone/areas/plant/fl/pl17034x.htm">http://www.epa.gov/ttn/naaqs/ozone/areas/plant/fl/pl17034x.htm</a>
	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 <sub>2</sub> (%)	2.73	
A2	0. 63	
B	0. 011	
qA (%)	17. 37	
Efficiency (%)	82. 63	
Efficiency adopted in the assessment (%)	80	

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

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

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

$$\text{Efficiency} = 100 - qA$$

Where: qA = flue loss  
 Ts = flue temperature  
 Ta = supply air temperature  
 O<sub>2</sub> = 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>

---

### 3. NO<sub>x</sub> Emission Rate

Power Input =	2425.15 MJ/hr	1kJ = 0.000278kWh 1MJ = 0.278kWh ( <a href="http://www.volker-quaschnig.de/datserv/faktoren/index_e.html">http://www.volker-quaschnig.de/datserv/faktoren/index_e.html</a> ) as advised by Towngas via email on 20 April 2009
=	674.19 kWh/hr	
NO <sub>x</sub> emission rate =	220 mg/kWh	
=	0.22 g/kWh	
NO <sub>x</sub> Emission Rate of Each Boiler =	0.04 g/s	

#### 4. Indicative Estimation of Efflux Velocity of the Towngas Boiler

##### Part a - Required Towngas

Towngas heat value<sup>a</sup> = 17.27 MJ/m<sup>3</sup>  
Power input = 2425.15 MJ/hr (Hyder calculations refer)  
Required Towngas = 140.43 m<sup>3</sup>/hr

##### Part b - Number of Moles of the Components in Towngas

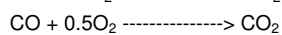
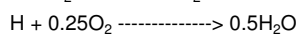
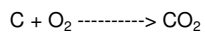
At 20°C and 1atm, the volume of a gas is 24.056 L/mol<sup>b</sup>

Composition of Towngas by volume<sup>c</sup>

Hydergen (H <sub>2</sub> ) =	49%	=	68808.54 L/hr	=	2860.35 mol/hr
Methane (CH <sub>4</sub> ) =	28.5%	=	40021.29 L/hr	=	1663.67 mol/hr
Carbon dioxide (CO <sub>2</sub> ) =	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<sub>2</sub> and H<sub>2</sub>O



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

$$n_C = 1663.67 \text{ mol/hr}$$

$$n_H = 12375.38 \text{ mol/hr}$$

$$n_{CO} = 175.12 \text{ mol/hr}$$

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

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

$$= 4932.64 \text{ mol/hr}$$

Required fraction of excess air<sup>d</sup> = 15%

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

$$= 27012.08 \text{ mol/hr}$$

At 20°C and a relative humidity of 50%, water content (X) in air<sup>b</sup>

$$= 0.0116 \text{ mol/mol dry air}$$

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

$$= 27325.42 \text{ mol/hr}$$

##### Part d - Flue Gas

$$n_{CO_2} (\text{CO}_2 \text{ from combustion \& Towngas}) = n_C + n_{CO_2} \text{ of Towngas} = 2801.97 \text{ mol/hr}$$

$$n_{H_2O} (\text{H}_2\text{O} \text{ from combustion \& ambient air}) = n_H \text{ of Towngas} / 2 = 6501.03 \text{ mol/hr}$$

$$n_{N_2} (\text{N}_2 \text{ from ambient air}) = n_{\text{dry air}} \times 79\% = 21339.54 \text{ mol/hr}$$

$$n_{O_2} (\text{remaining O}_2 \text{ after combustion}) = \text{Fraction of Excess Air} \times n_{\text{stoich}} = 739.90 \text{ mol/hr}$$

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

Total volume of flue gas = 754.94 m<sup>3</sup>/hr under 20°C

$$\text{Flue gas temperature}^e = 202 \text{ }^\circ\text{C}$$

$$= 475 \text{ K}$$

$$\text{Ambient Temperature} = 20 \text{ }^\circ\text{C}$$

$$= 293 \text{ K}$$

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

$$\text{volumetric flow at } 475\text{K}^f = 1223.87 \text{ m}^3/\text{hr}$$

$$= 0.34 \text{ m}^3/\text{s}$$

$$\text{diameter of stack} = 0.2 \text{ m}$$

$$\text{stack area} = 0.03 \text{ m}^2$$

$$\text{Efflux Velocity} = 11 \text{ m/s}$$

**Therefore, assuming efflux velocity of 6m/s is a conservative approach and 6m/s was adopted for assessing the NO<sub>2</sub> emission impact.**

##### Part e - Reference:

- <http://www.towngas.com/files/Tai%20Po%20Plant%20Leaflet.pdf>
- Noel de Nevers: The Air Pollution Control Engineering, 2nd ed., McGraw-Hill, 2000
- as advised by Towngas via email on 20 April 2009
- <http://www.tsi.com/documents/CA-basic-2980175b.pdf>
- <http://www.epa.gov/ttn/naaqs/ozone/areas/plant/nc/pl37048x.htm> refers
- Combined Gas Law,  $V_1P_1/T_1 = V_2P_2/T_2$

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 <sub>x</sub> 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:

- NO<sub>x</sub> 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