Design of a Molten Carbonate Fuel Cell Power Plant for a Delhi landfill

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BACKGROUND

Methane's contribution to GHG emissions:

- Global average - 15%
- **India - 29%**

Methane emissions from waste:

- Global average - 3%
- **India - 6%**

Fire at the Okhla landfill

- Delhi ranks 9th in the world and 1st in India in terms of air pollution
- Global Warming potential of methane is 28 to 36 times that of carbon dioxide
- Delhi's landfills collectively produce around 40 million kg of methane a year
- MCFCs offer a cleaner solution to generate power from landfill gas

LANDFILL GAS PRETREATMENT

LFG Pre-treatment Process

Reduce hydrogen sulfide content to less than 5000 ppbv using two iron oxide beds

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Convert trace organic sulfur and organic halogens to hydrogen sulfide and hydrogen halides by reaction with hydrogen over a hydrogenation catalyst.

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Capture of residual hydrogen halides by reaction with potassium carbonate

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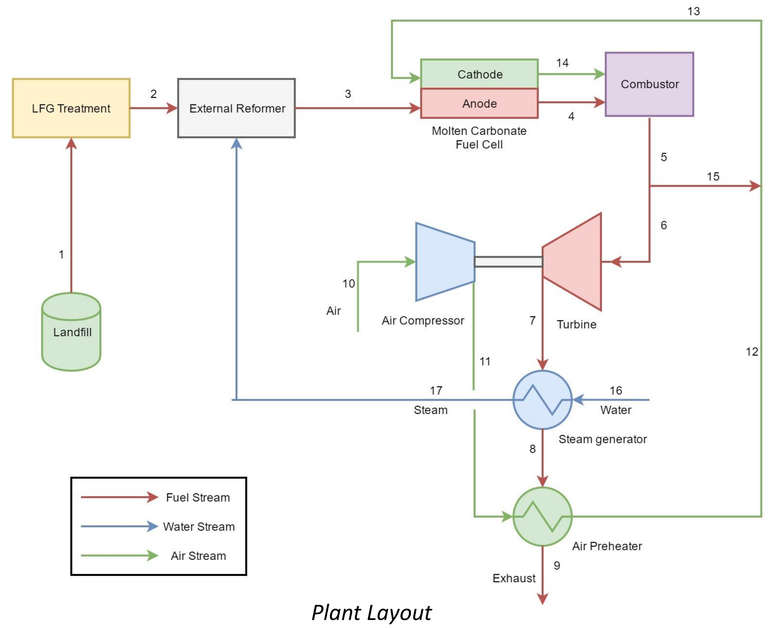
Capture of residual hydrogen sulfide by reaction with zinc oxide

Landfill Gas Composition Before and After Treatment

Component	Raw Landfill Gas, % vol	Cleaned Landfill Gas, % vol
Methane	49.27	43.37
Carbon Dioxide	45.40	44.89
Nitrogen	3.5	3.2
Oxygen	0.55	0.18
Ammonia	0.55	0.55
NMOCs	0.03	<100 ppbv
Sulphides	0.5	<100 ppbv
Hydrogen	0.1	7.7
Carbon Monoxide	0.1	0.1

PLANT LAYOUT



Plant Layout

- Excess fuel and air from MCFC sent to combustor
- Turbine extracts additional work to drive compressor
- Heat from exhaust gases used to generate steam for the reformer as well as preheat the air

FUEL CELL DESIGN

Fuel Cell Reaction:

Anode: $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$

Cathode: $CO_2 + 1/2O_2 + 2e^- \rightarrow CO_3^{2-}$

Overall: $1/2O_2 + H_2 \rightarrow H_2O$

Operating Point:

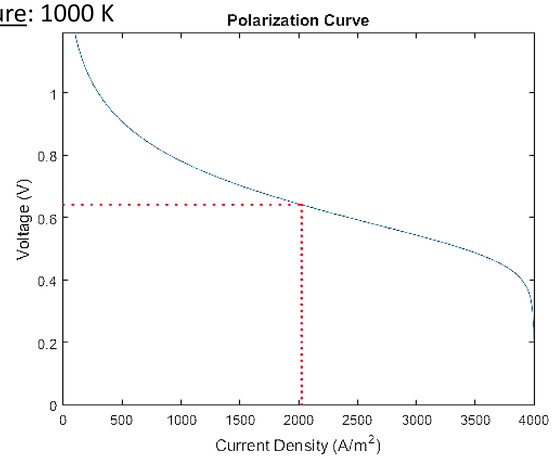
Voltage: 0.6404 V

Current Density: 2028 A/m^2

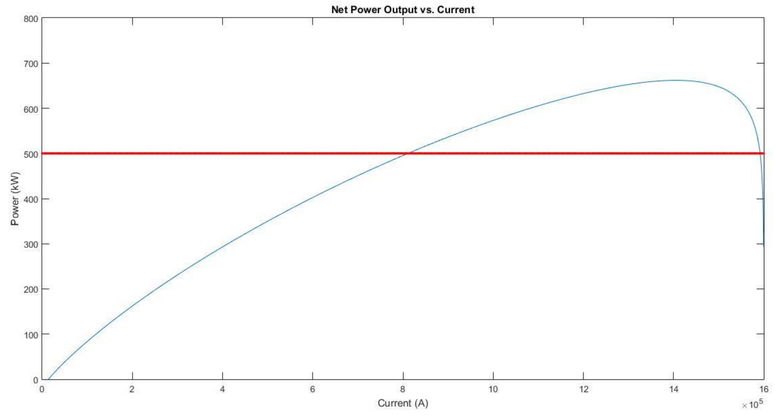
Temperature: 1000 K

Fuel Cell Parameters

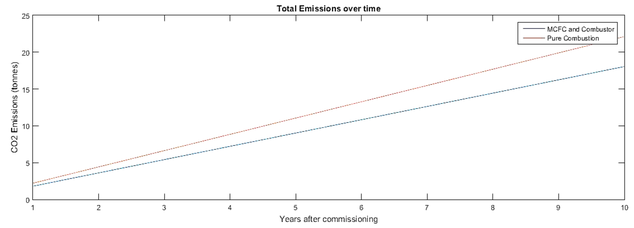
Electrolyte Conductivity	2,400 S/m
Electrolyte Thickness	0.001 m
Limiting Current Density	4000 A/m^2
Exchange Current Density	100 A/m^2



RESULTS



- Based on the desired power output of 500 kW, operating point of 2028 A/m2 and a fuel cell stack area of 400 m^2 are chosen
- Based on the heating requirement of steam generator fuel utilization rate of 85% in the fuel cell was chosen
- The result is a voltage efficiency of 52.1 %



- Recirculation of CO_2 causes reduction in overall emissions
- This amounts to 0.41 million kg of annual reduction in CO_2 emission

CONCLUSIONS

- Based on a 10 year lifetime and a 7% discount rate, a levelized cost of electricity using major equipment was found to be 0.0702 $/kWhr
- Development of electrolytes with higher conductivities can greatly improve fuel cell performance
- Reduction in capital costs with increased incorporation can make MCFCs more economically viable

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