P2P Ltd: Waste to Hydrogen

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P2P Energy Ltd.
Paper to Power

SCHULICH School of Engineering
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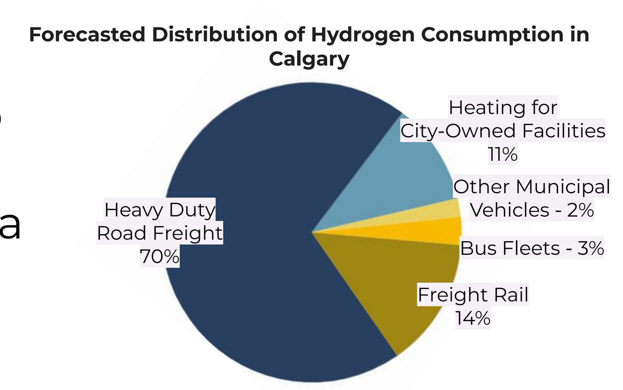
Introduction

Problem to be addressed

Population growth drives **increased** human activity and **solid waste production**. ➡Industries are shifting focus to produce **sustainable energy** from solid waste.
Hydrogen emerges as a promising **alternative energy carrier** for clean and sustainable solutions.

Motivation

Calgary's hydrogen demand projected to reach **5,043 tonnes/day**, offering a **$4.6 billion** market opportunity.



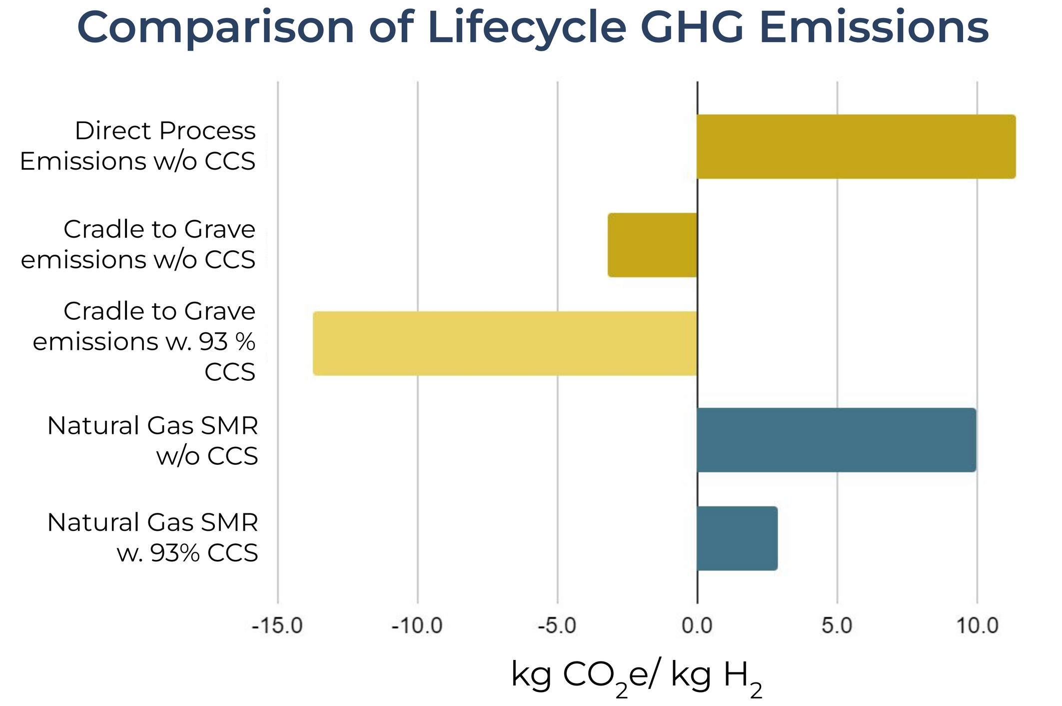
Goal

Develop a gasification plant to generate **15 tonnes/day of pure hydrogen (99.99%)** while diverting landfill waste through use of paper waste feedstock; and minimizing GHG emissions through CCS and use of biomass feed.

Safety and Environment

Risks	Mitigations
1 Gasifier fouling, slagging and corrosion	1 Pretreatment to remove alkalis and sulfur
2 Over/ under pressurization (air ingress + gas release)	2 Pressure relief valves and air monitoring
3 Hydrogen embrittlement	3 Special storage tank lining materials

Comparison of Lifecycle GHG Emissions



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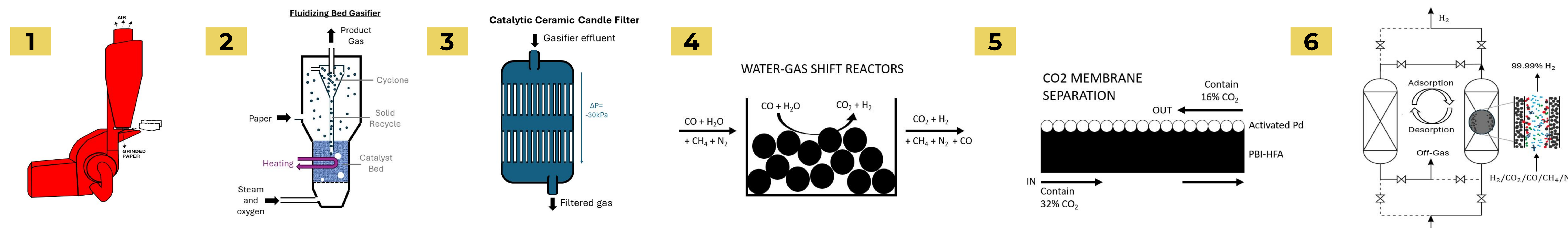
Our Designed Process



1 Grinder

Feed rate: 180 tonnes/day
Paper particle size: 150 µm
Equipment: Hammer mill grinder
Input: Air (0.453 kg/s)
Grinder Size: 0.69 m x 0.56 m
Cyclone Size: 0.33 m x 1.50 m

3 Ceramic Ash Filter

Operation: Removes ash in the product stream
Operating Conditions: 900°C
Catalyst: Nickel catalyst layer promotes tar reforming
Inputs: Activated carbon upstream removes remaining chlorine

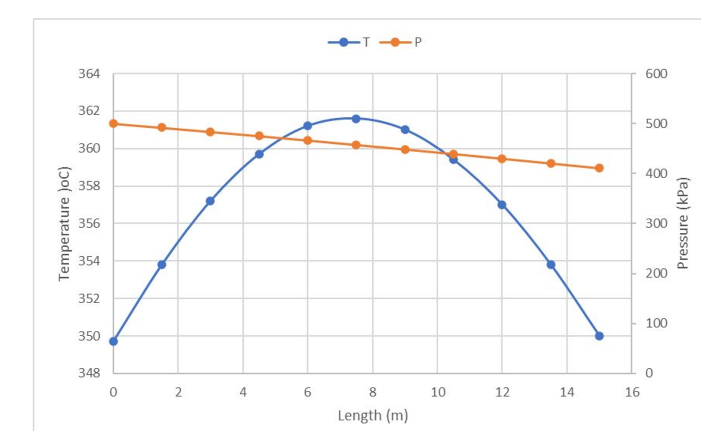
2 Fluidized Bed Gasifier

Operation: Partially combusts paper in a gasification reaction to produce H2 and CO rich gas
Operating Conditions: 900°C and 10 MPa
Yield: 0.05 kg H_2/kg paper and 0.52 kg CO/kg paper
Byproducts: Slag and nitrogen-rich ash

		Reaction	
01	Pyrolysis	$C_{19.82}H_{2\,4.52}O_{11.86} \rightarrow 5.96\,CO + 2.95\,CO_2 + 8.26\,H_2 + 1.5\,CH_4 + 0.5\,C_2H_4 + 8.41\,Char$	(ΔH = 310.01 kJ)
02	Heterogeneous	$C + O_2 \rightarrow CO_2$	(ΔH = -393.51 kJ)
		$C + H_2O \leftrightarrow CO + H_2$	(ΔH = 131.29 kJ)
		$C + CO_2 \leftrightarrow 2\,CO$	(ΔH = 172.46 kJ)
		$C + 2\,H_2 \leftrightarrow CH_4$	(ΔH = -74.87 kJ)
03	Homogeneous	$CO + 0.5\,O_2 \rightarrow CO_2$	(ΔH = -283 kJ)
		$H_2 + 0.5\,O_2 \rightarrow H_2O$	(ΔH = -241.82 kJ)
		$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$	(ΔH = -802.28 kJ)
		$C_2H_4 + 3\,O_2 \rightarrow 2\,CO_2 + 2\,H_2O$	(ΔH = -1323.13 kJ)
		$C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$	(ΔH = -2043.20 kJ)
		$CO + H_2O \rightarrow CO_2 + H_2$	(ΔH = -41.17 kJ)

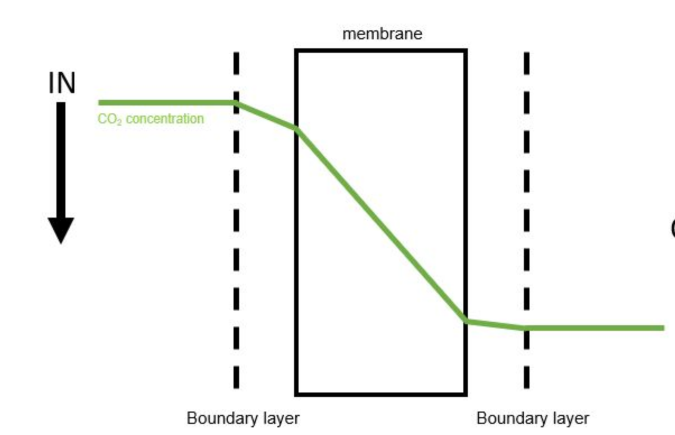
4 Water Gas Shift Reactors

Reactor Type and Size: PFR - 3 m x 10 m
Conversion: 97% CO conversion
Production: 40% hydrogen production
Catalyst: $Fe2O_3/Cr2O_3/CuO$ + $Al2O_3/ZnO/CuO$
Operating Conditions: 350°C/500 kPa and 200°C/450 kPa



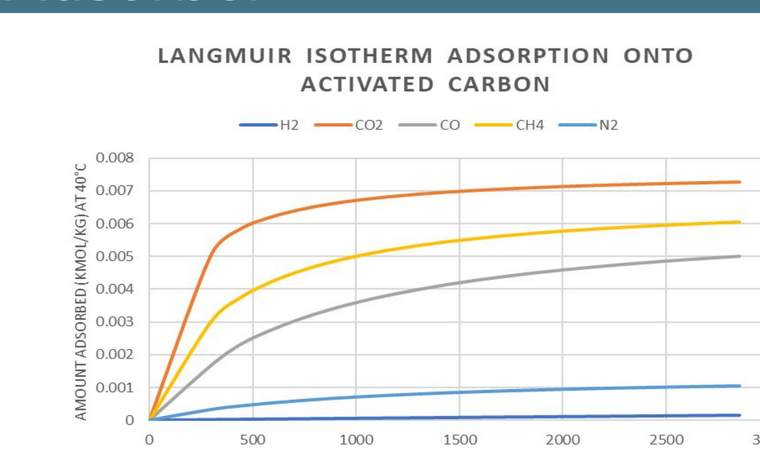
5 Pd Membrane

System: 2 membranes in series
Production: Removal of 63% of CO_2
Operating Conditions: 300 kPa (input) - 900 kPa (output)
Membrane Composite: Pd films on PBI–HFA-CO_2 plasma-treated



6 Pressure Swing Adsorber

Hydrogen purity: Upto 99.99% for fuel cells.
Adsorbent: Activated carbon captures impurities while allowing hydrogen to pass through
Operating Conditions: 40°C and 2500 kPa
Simulation Modeling: Using Symmetry to predict PSA performance under varying operating conditions.



Economic Analysis

Cost Breakdown

Capital Investment ➡	$66.4 MM
Annual Operating Expense ➡	$42.7 MM

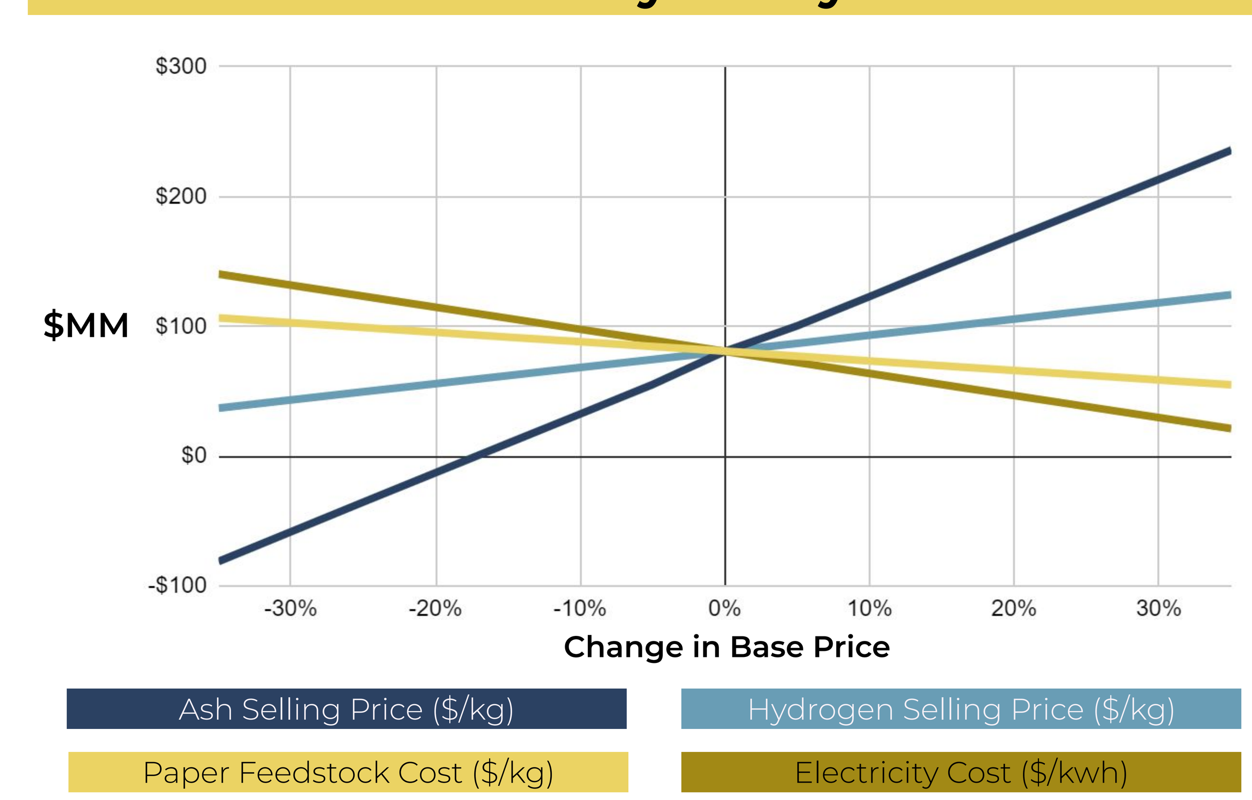
Key Financial Indicators

NPV ➡	$80.7 MM
IRR ➡	15.6 %
Payout Period ➡	7.4 yrs

Estimated hydrogen production cost ➡ $7.87 kg/ H_2

Estimated hydrogen revenue ➡ $12.3 MM /yr
@ $2.50/kg H_2 selling price
Estimated nitrogen-rich ash revenue ➡ $45.0 MM/ yr

Sensitivity Analysis



CONCLUSION

This process achieves GHG emission reduction, landfill diversion, and hydrogen production (clean fuel)

The cost of hydrogen production ($7.87/kg H_2) is quite high [compared to Steam Methane Reforming ($1.34/kg H_2)].
need reduction in electricity use/cost and "cost" of feedstock
Direct process emissions are comparable to SMR
If paper is not a true negative carbon source, and diverted methane emissions can not be counted, emissions are high

You may contact the group leader: noor.awan@ucalgary.ca for further questions. Questions will be directed to the appropriate team member.