Waste Heat and Carbon Dioxide Utilization at Robbins Community Power

Robbins Community Power

Plant Overview

- Refitting former waste to energy plant to clean burning wood biomass plant
- 50 MW output

Team Problem

Problem:

- 40% of wood chips utilized inefficiently
- Plant generates waste heat and carbon dioxide

Solution:

- Turn small wood chips into useful products
- Capture waste heat for productive uses
- Remove carbon dioxide from flue gas

Objectives

- **Examine** the feasibility of using the heat and CO_2 from the plant
- **Quantify** heat to be captured with heat exchanger
- **Determine** the requirements and market for wood byproducts
- **Analyze** cost-benefit of the various processes

Group Structure

IPRO 347

Waste Heat and Carbon Dioxide Utilization at Robbins Community

Thermodynamic Sub Team

Liam Mulcahy
Kunle Apampa
Kevin Abankwa
Kamaldeen Olorunoje
Pierre –Paul Amegasse

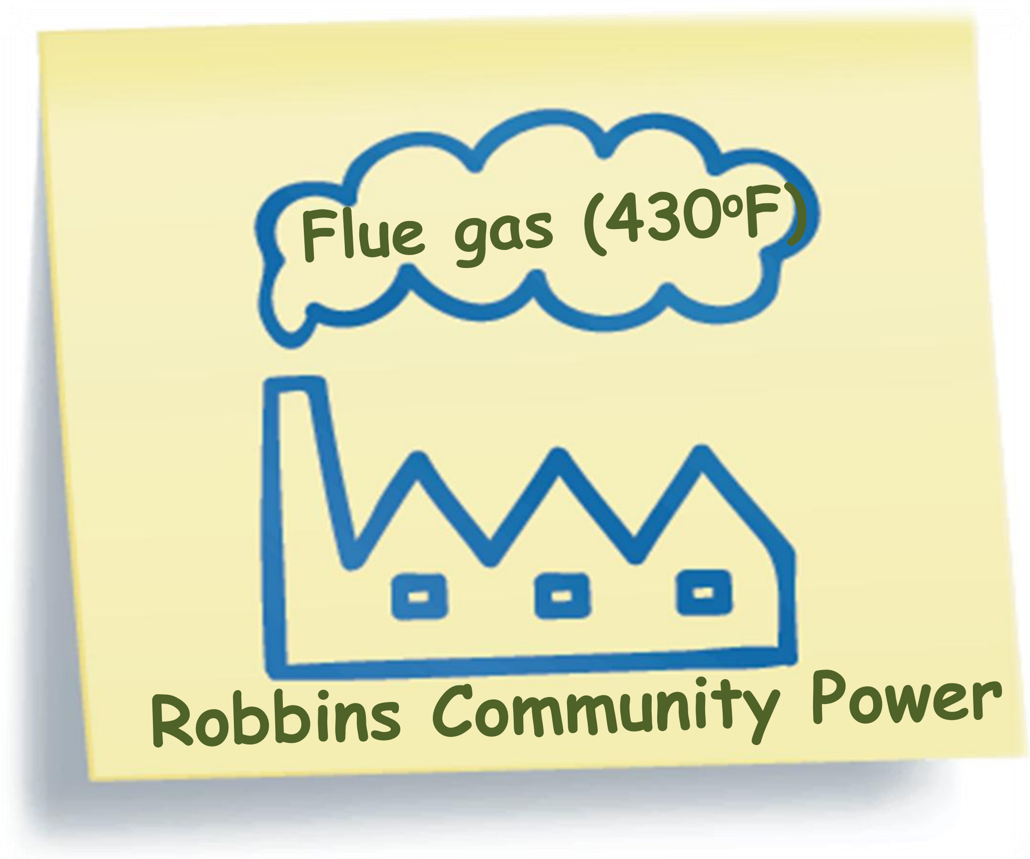
Bio-Char/Pelletizer Sub Team

Young Jung
BoKyeong Park
Suliman Ibrahim
Kolade Adebowale
Alhassan Abdalmohsen

Greenhouse Sub Team

Emily Kunkel
Daniel Drecoll

Heat Exchanger



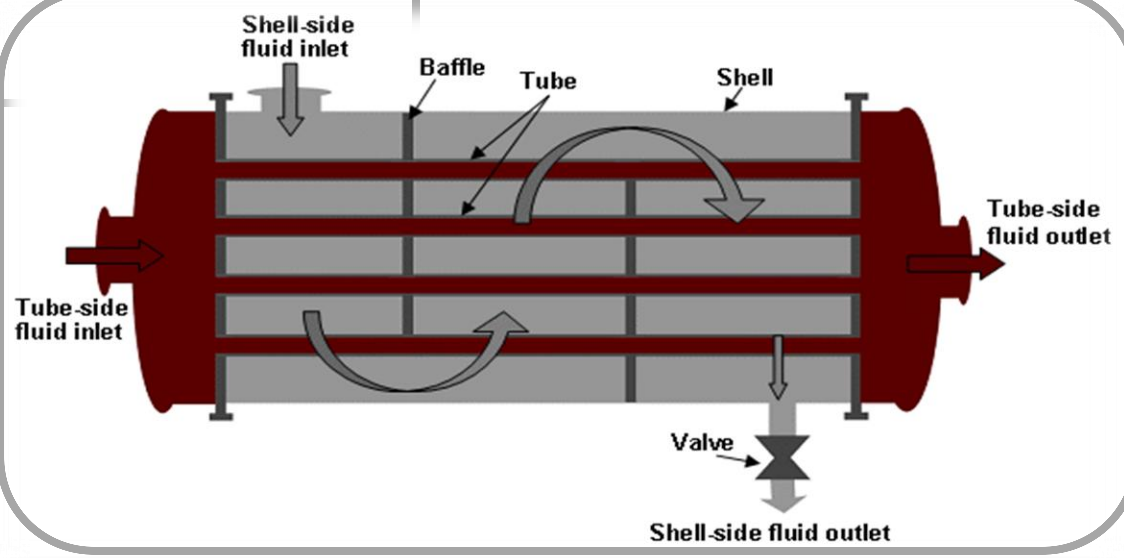
Purpose

- The plant produces waste in the form of high temperature flue gas and find a way to extract the heat from the flue gas and use it elsewhere.
- Produce steam or hot water as options.

Heat Exchanger

Process

- Heat extraction needs a heat exchanger
- Transfer of heat depends on
  - Temperature
  - Pressure



Heat Exchanger Option

- Shell and fin tube heat exchanger
  - Hot water production
- Plate and frame heat exchanger
  - Preheat ambient air
- Additional heater provides low/high pressure steam

Heat Exchanger

The “2” Components

Components	Mass flow rate (lb/hr)	T (in) (^{0}F)	T (out) (^{0}F)
Flue gas	565,644.4	429.8	199.4
Water	456,356.9	81.3	212

Exchangeable heat between flue gas and water is about **59 MMBTU/hr**

Flue gas in → Shell and tube Heat Exchanger → Flue gas out

Water out ← Shell and tube Heat Exchanger ← Water in

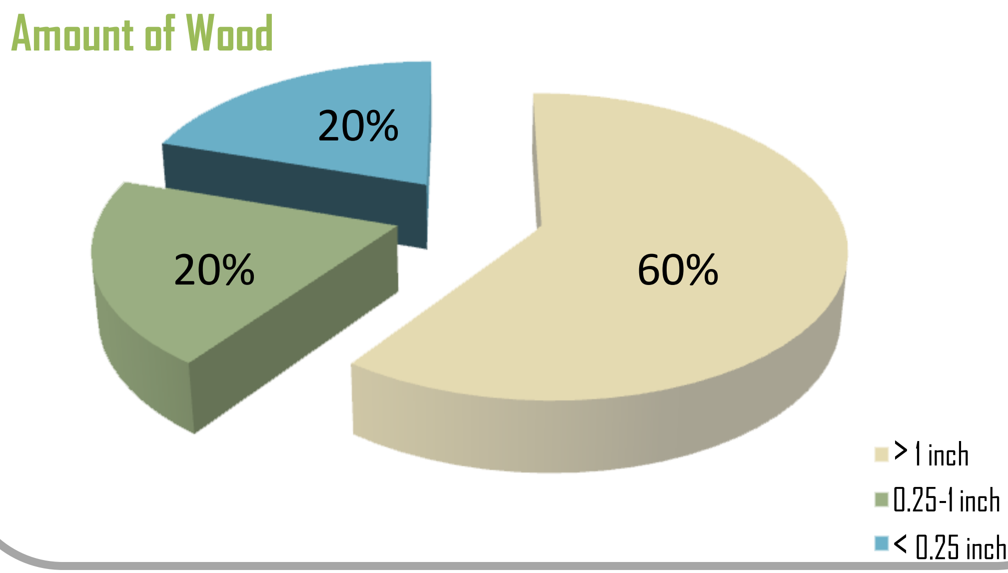
Heat Exchanger

Results and Economics

- Shell and Tube heat exchanger is ideal.
- Flue gas output is at a low temperature and well enriched with quality CO_2 for greenhouse.
- Our clients invests $ 1.31 million into building heat exchanger.
- Based on 0.3 cents/lb of steam, company can produce $1,359/hr
- Ability to use steam for space heating or industrial process heat

Resulting in $1.1 million in revenue per year

Bio-Char

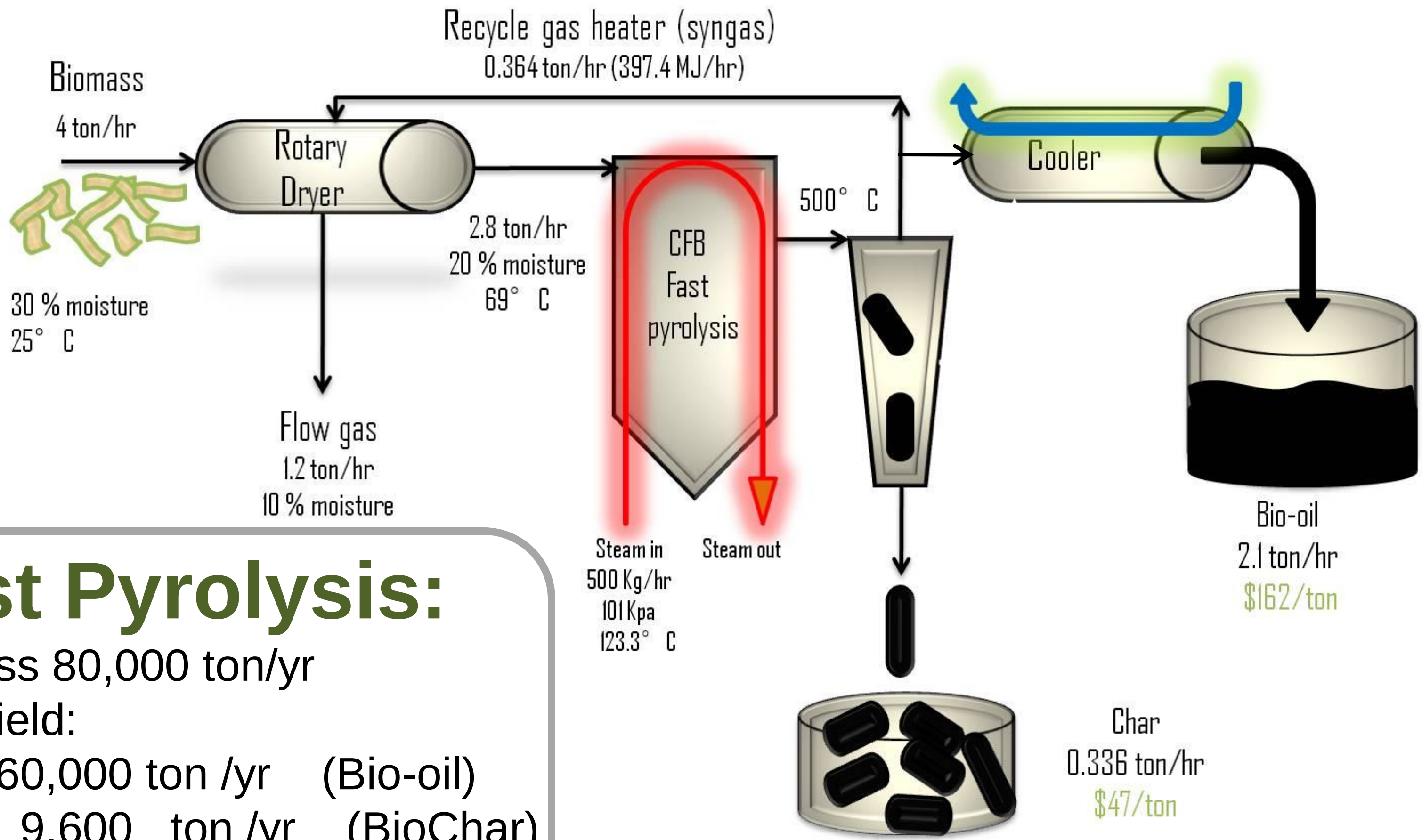



Bio-Oil


Bio-char


Pellets

Bio-Char



Fast Pyrolysis:

Process 80,000 ton/yr

Yield:

- 60,000 ton /yr (Bio-oil)
- 9,600 ton /yr (BioChar)
- 10,400 ton /yr (Syngas)

Bio-Char

	Annualized Cost ($MM)	Capital Cost ($MM)	Revenue ($MM)
Cost of feed ($)	1.44		
Cost of dryer ($)		0.3	
Cost of steam ($)	0.08		
Cost of storage (bio-oil and bio-char) ($)		1.5	
Labor and Maintenance ($)	0.43		
Reactor cost ($)		6.0	
Miscellaneous cost ($)	0.15		
Transportation cost ($)	1.30		
Value of Bio-oil ($)			9.7
Value of Bio-char ($)			0.4
Loan Repayment	1.2		1.2
Yearly Cost			3.4
Net ($)	4.6	7.8	5.5

Bio-Char

Pelletizer Process

Bio-Char

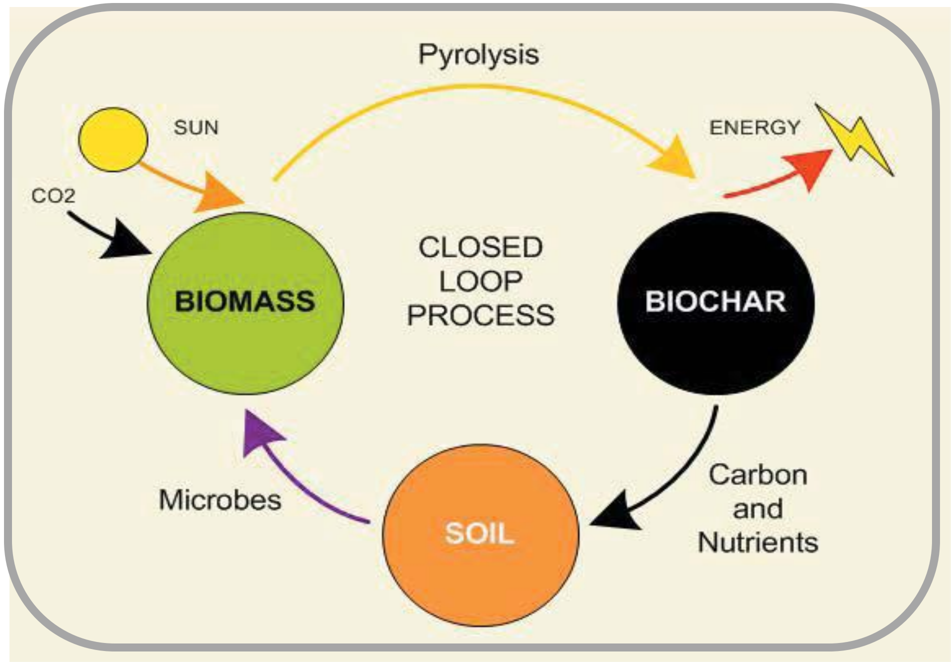
Total cost and profit

Production (ton/ hours)	**Start Cost** (USD) (x 10^6)	**Operating Cost** (USD) (x 10^6)	**Total Pellet Sales** (USD) (x 10^6)	**Total Shipping Cost** (USD) (x 10^6)	**Number of pellets produced** (tons) (x 10^6)	**Energy** (kWh) (x 10^6)	**Profit** (USD) (x 10^6)
5	1.66	0.425	6.90	2.83	0.025	113.25	**1.98**
10	3.32	0.700	13.80	5.66	0.050	226.50	**4.12**
15	4.98	0.825	20.70	8.49	0.075	339.75	**6.40**

Bio-Char

Benefits

- Environmental Sustainability
  - Reduced greenhouse gas emissions
  - Improved air and water quality
- Zero Waste/Low Energy Process
- Job creation and economic growth



Greenhouse

Purpose

- Bypassing the use of the 300ft tall smokestack

Problem

- Reduce CO_2 and excess heat in flue gas

Greenhouse

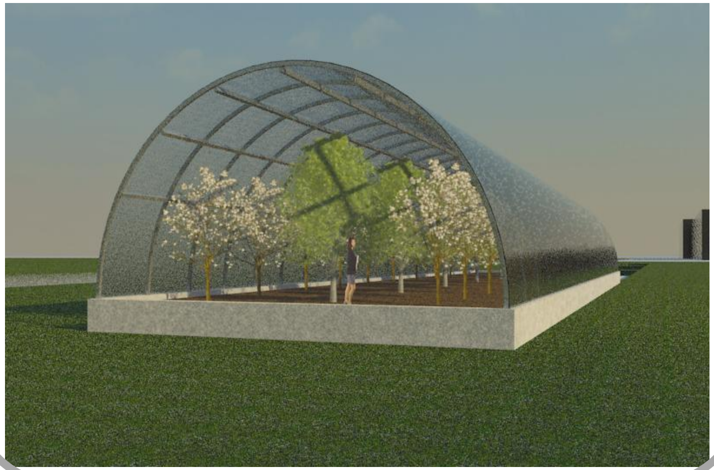
Utilizes .25-.9MMBTU/hr of waste heat to retain ideal temperature
Plant generates enough heat for 30 acres of greenhouses

Trees

- Absorb 2 lbs/year of carbon dioxide at 0-3 in DBH
- Tree nursery to replace trees killed by diseased

Crops

- Absorb 3-8 lbs/year of CO_2 per square meter
- Greenhouses provide jobs and healthy food for community residents

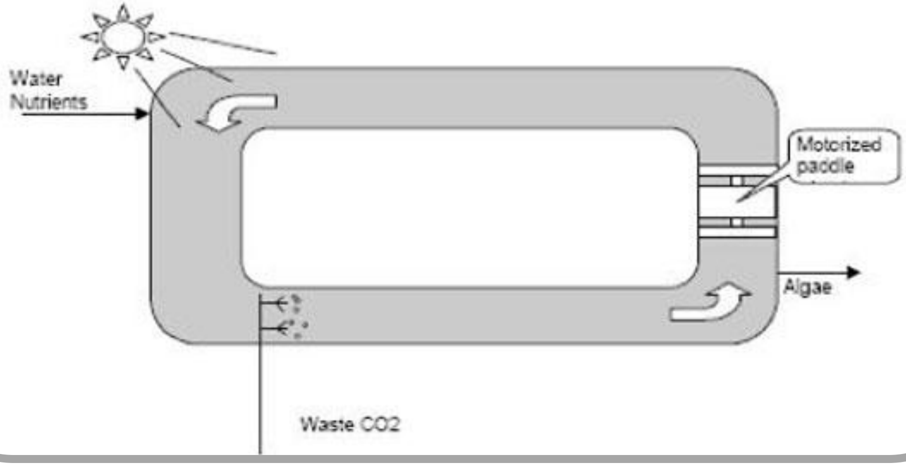


Greenhouse

Algae Production

Utilizes carbon dioxide more efficiently than other plants.
The oil in the biomass can be extracted and made into 2000 gallons of biodiesel per acre of algae.

Raceway Pond



Bioreactor

Economic Feasibility

- Costs:
  - Initial construction of 20 structures/ponds $1,200,000
  - Cost per year for initial construction $ 190,000/year
  - Annual lease of the Cal-Sag property ` $ 200,000/year
  - Costs to grow algae $ 10,000/year
- Revenue
  - Sales of algae oil $ 30,000/year
  - Lease of heated greenhouses $1,300,000/year

  - Total Net Revenue $ 930,000/year

Community Benefits

- Growth of replacement trees
- Reduction of carbon dioxide and heat in the environment
- Jobs in the community

Conclusion

- Reduce CO_2 and waste heat
- Minimize wood waste
- Develop valuable byproducts
- Increase revenue for the plant
- Create jobs in the surrounding communities

Questions?

Range Calculations

U (BTU/ft-hr-°F)	Inner Area (ft^2)	Outer Area (ft^2)	Fixed Head C_{BM} ($)
10	43,610	52,819	5,816,715
50	8,189	9,909	1,111,576

- Recommended option,
  - C_B = $72,940
  - C_P = $396,996
  - C_{BM} = $1,310,088