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Biochar: Production, Characterization and Applications

Proceedings

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Pyrolysis of residues from well-established biochemical processes for the production of biochar

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Pyrolysis of Sewage Sludge for the Production of Biochar

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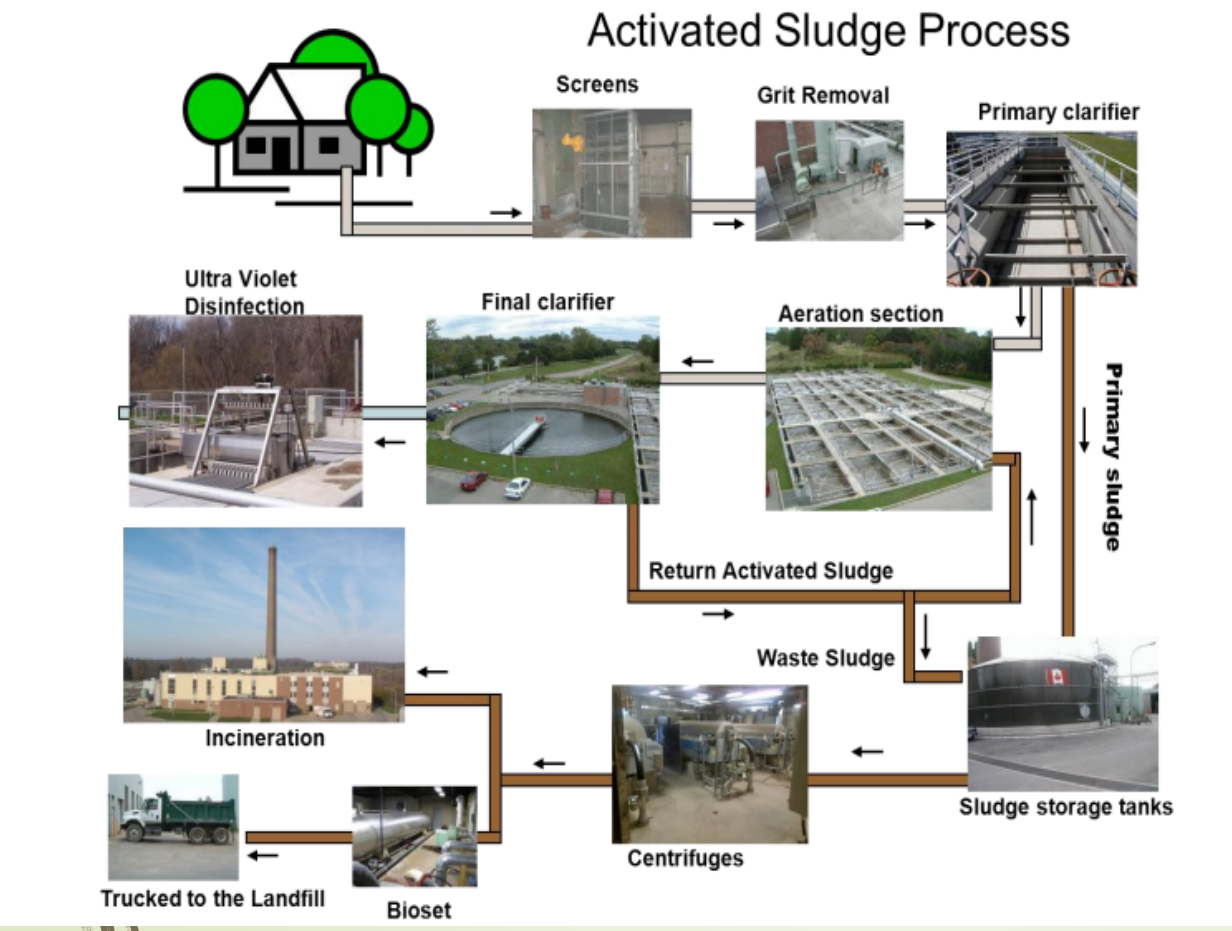
Overview

- Background and Objectives
- Feedstock Characterisation
- Overview of Reactors
- Pyrolysis results and product characterisation
- Energy Balance of Process
- Ongoing and Future Work
- Conclusions

Motivation and Background

- The disposal and treatment of sewage sludge is a problem faced by every modern city
- Global estimates for sewage sludge production are over 50 Million Tonnes of dry solids per year
- Current Technologies for sludge disposal are:
  - Landfilling
  - Soil application for agriculture
  - Anaerobic digestion
  - Incineration

Current Sludge Production and Treatment in London, Ontario



- 60% Primary Sludge
- 40% Waste Activated Sludge
- Thickening with polymer addition
- Dewatered using centrifuge to 72% moisture
- Produced 16,000 dry tonnes in 2015

Source: City of London, Environmental & Engineering Services, Wastewater Treatment Operations Division

Pyrolysis as an Alternative

Incineration

- **Pros:**
  - Process can run autogenously
  - Destruction of pathogens and odours
  - High reduction in waste volume
- **Cons:**
  - Negative public perception
  - Highest GHG emissions
  - Heavy metals concentrated in ash
  - High disposal costs of ash ($70/ton)

Pyrolysis

- Goals of pyrolysis:
  - Thermally self sustainable process (production of energy)
  - Destruction of pathogens and odours
  - Reduction of GHG emissions (Carbon Sequestration)
  - Stabilisation of heavy metals in char
  - Create zero waste solution

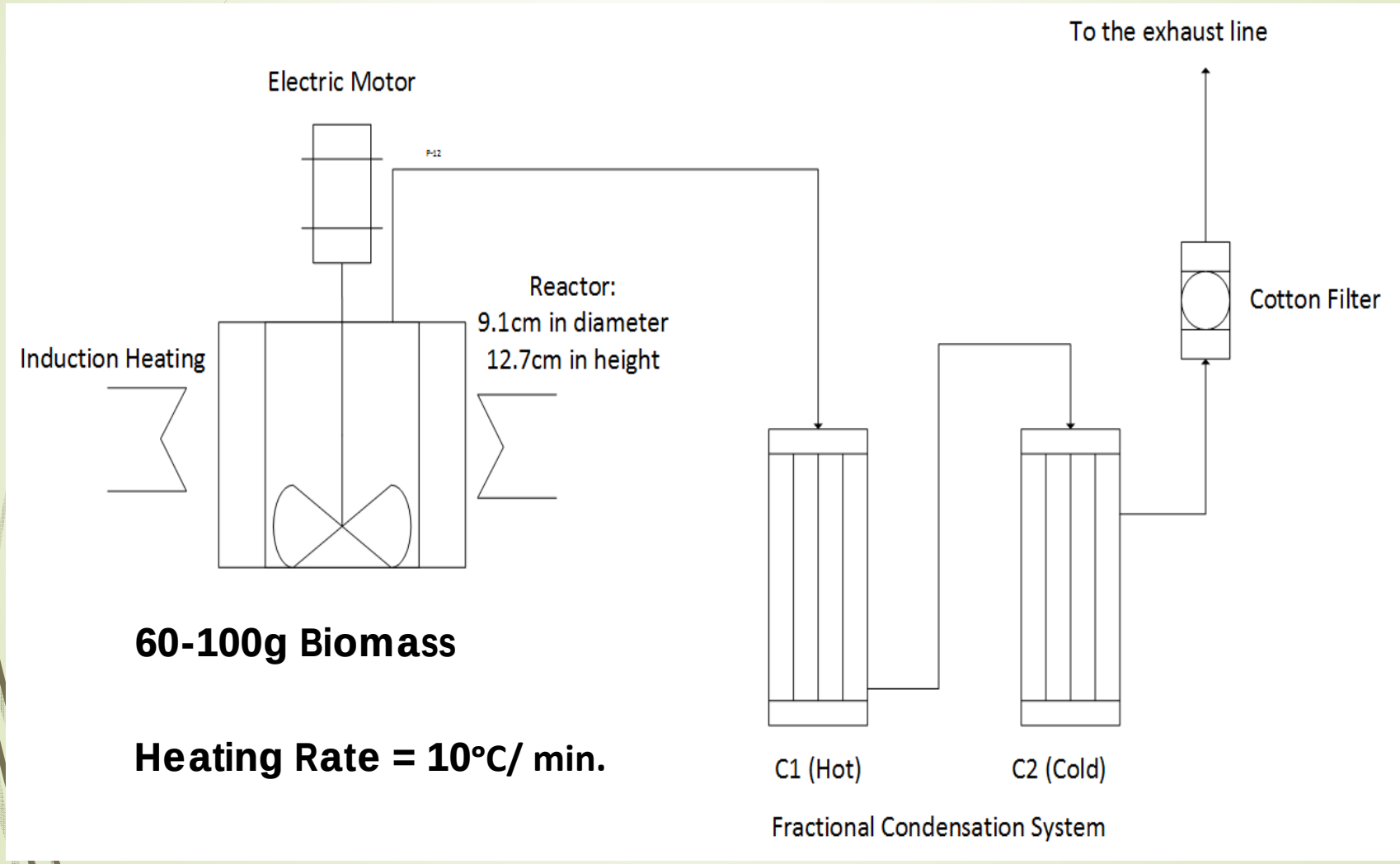
Dried Sewage Sludge Analysis

HHV (MJ/kg)	14.1
Ash Content (wt% d.b.)	16%
Elemental Composition (wt% d.b.)	
C	38.3
H	5.0
N	3.4
S	0
O	37.3

Dried Sludge ICP Analysis

Restricted Metal Analysis	(mg/kg d.b.)
As	<1.25
Cd	0.49
Co	<0.125
Cr	2
Cu	350
Mo	2
Ni	10
Pb	45
Se	<1.25
Zn	443
Other Metal Analysis	**(mg/kg d.b.)**
K	2,300
P	16,500
Fe	49,800

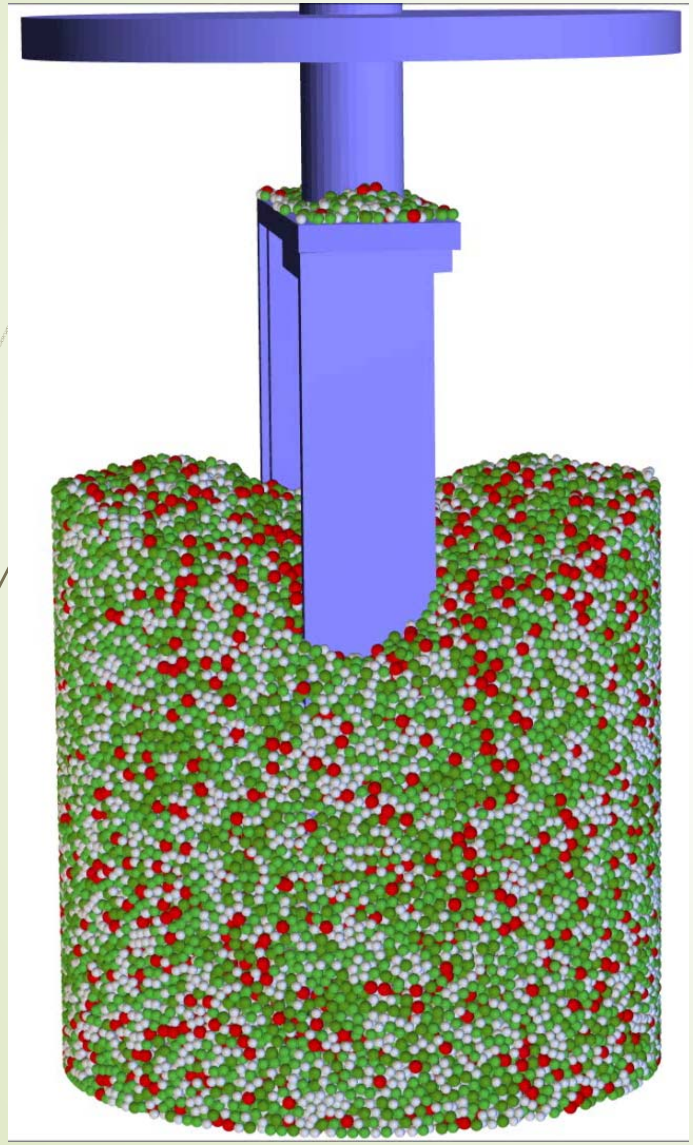
Sow Pyrolysis Mechanically Fluidized Reactor (MFR)



60-100g Biomass

Heating Rate = 10°C/ min.

How The MFR Works

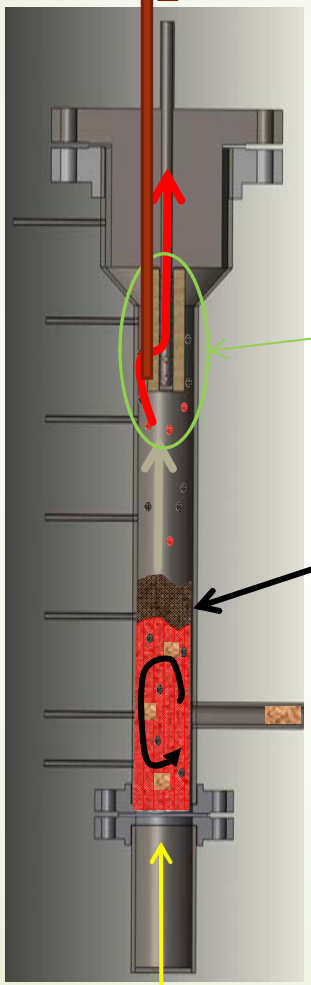


- Vertical arm mixer intimately mixes the bed
- Mechanical mixing and propagation of pyrolysis vapours equal or more effective than traditional gas fluidisation

Fast Pyrolysis Reactor

Char Periodically Elutriated

To Condensers



5) Bio-oil vapours and permanent gases leave the reactor toward condensers.

4) A hot filter traps the small fraction of fine particles elutriated from the bed, avoiding contamination of the bio-oil.

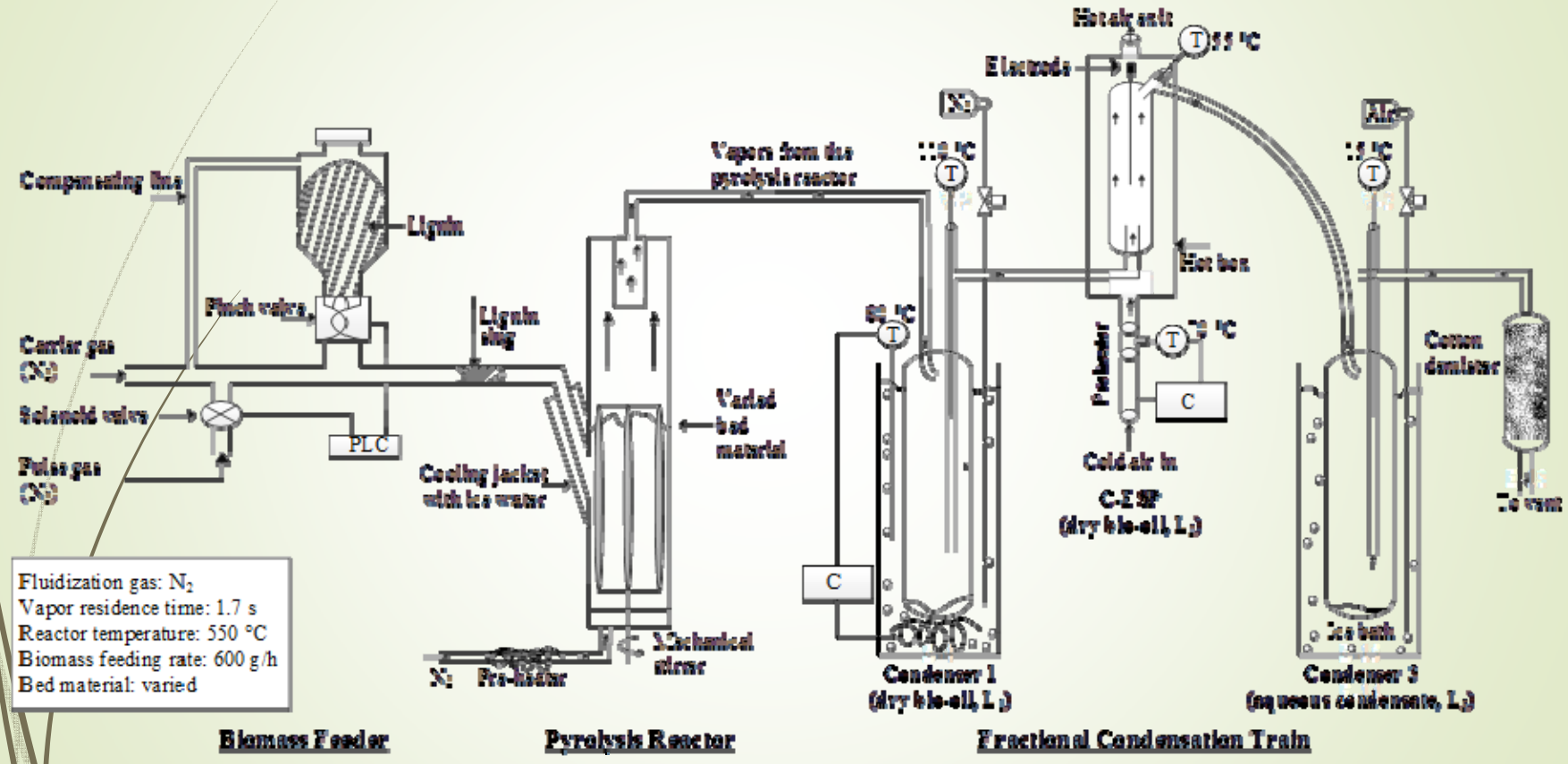
3) The char stays in the bed.

2) It mixes with the hot sand and reacts.

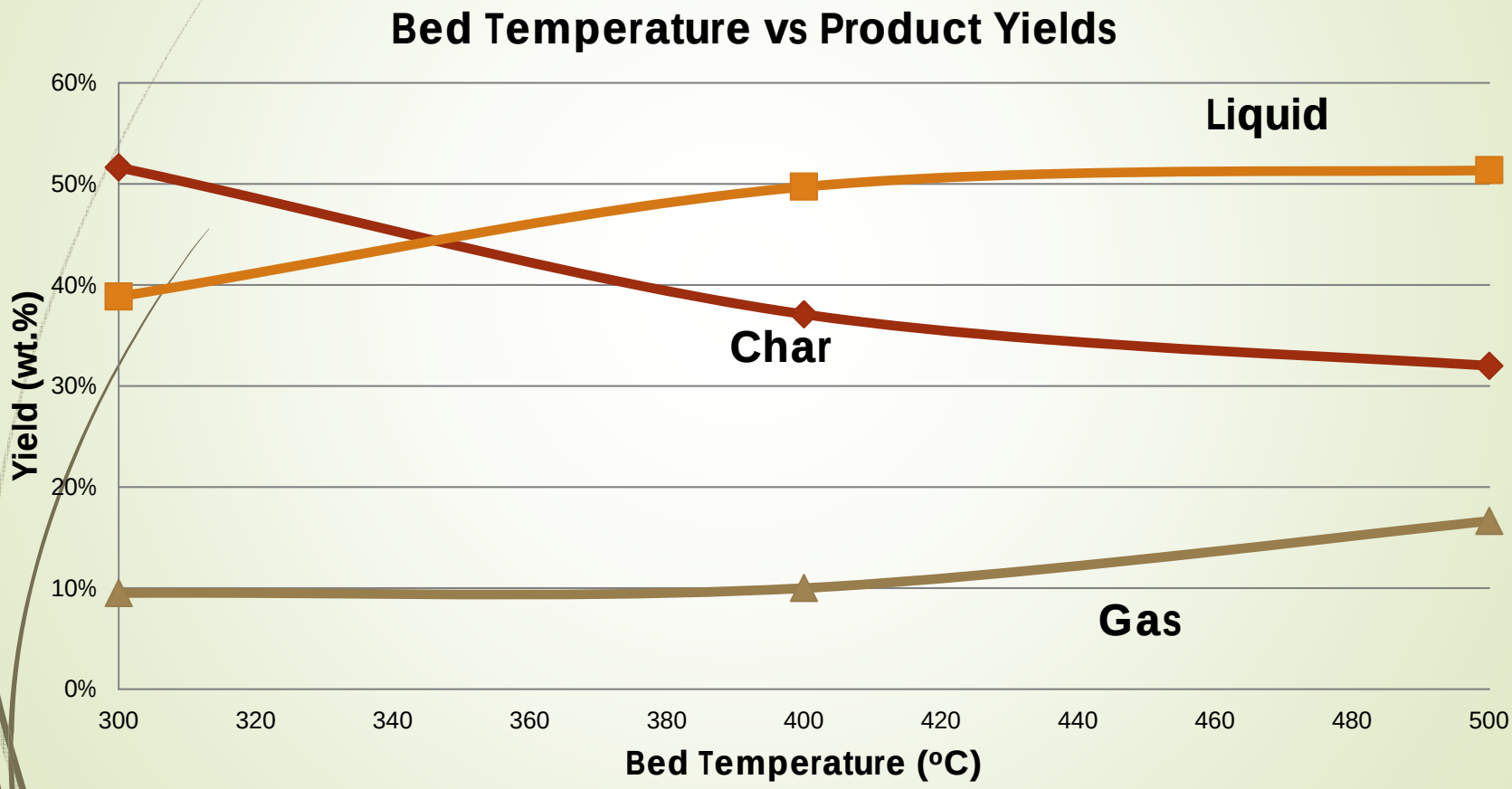
1) The biomass is injected into the bed.

N_2 for Fluidization

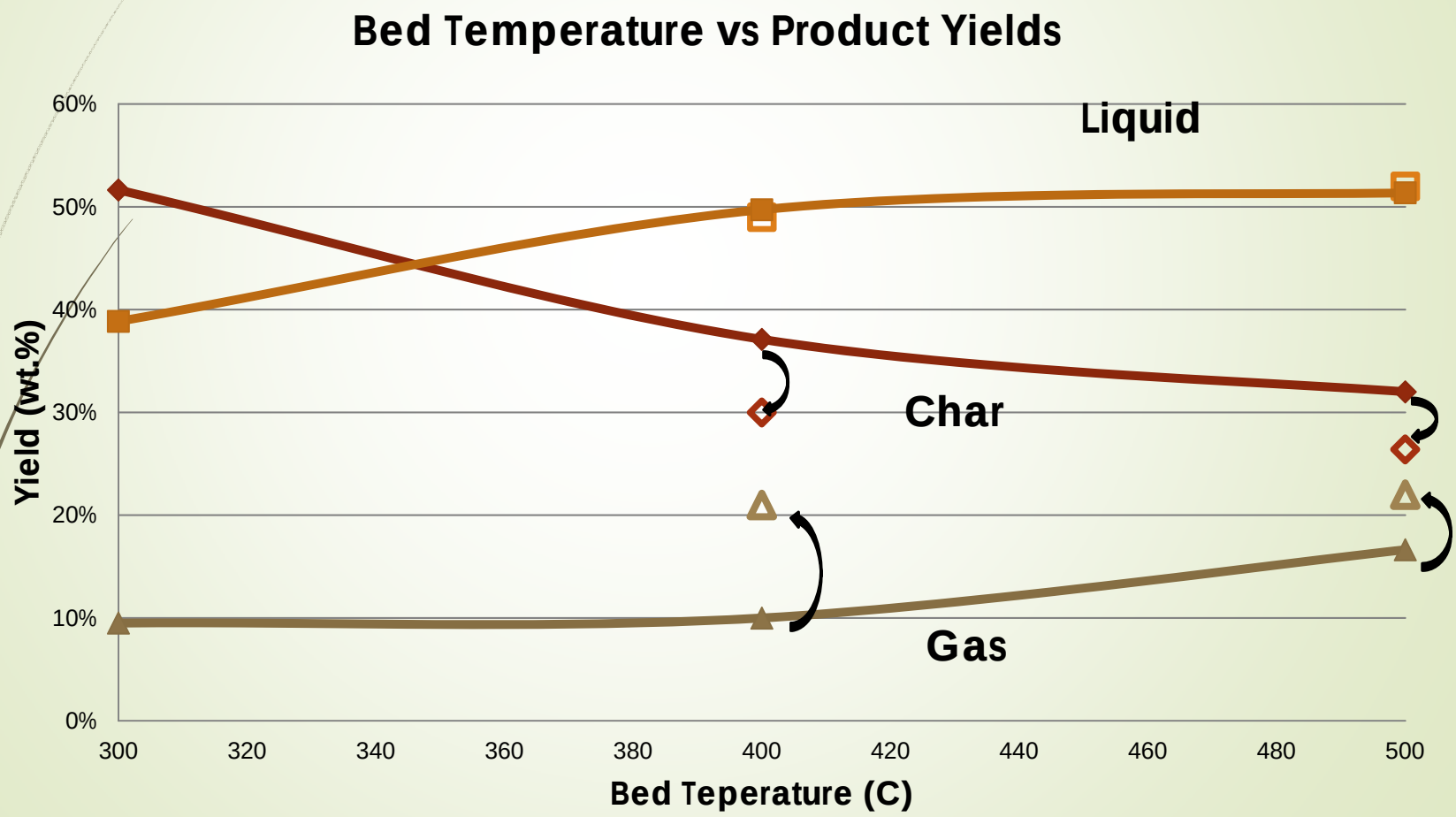
fast pyrolysis system overview



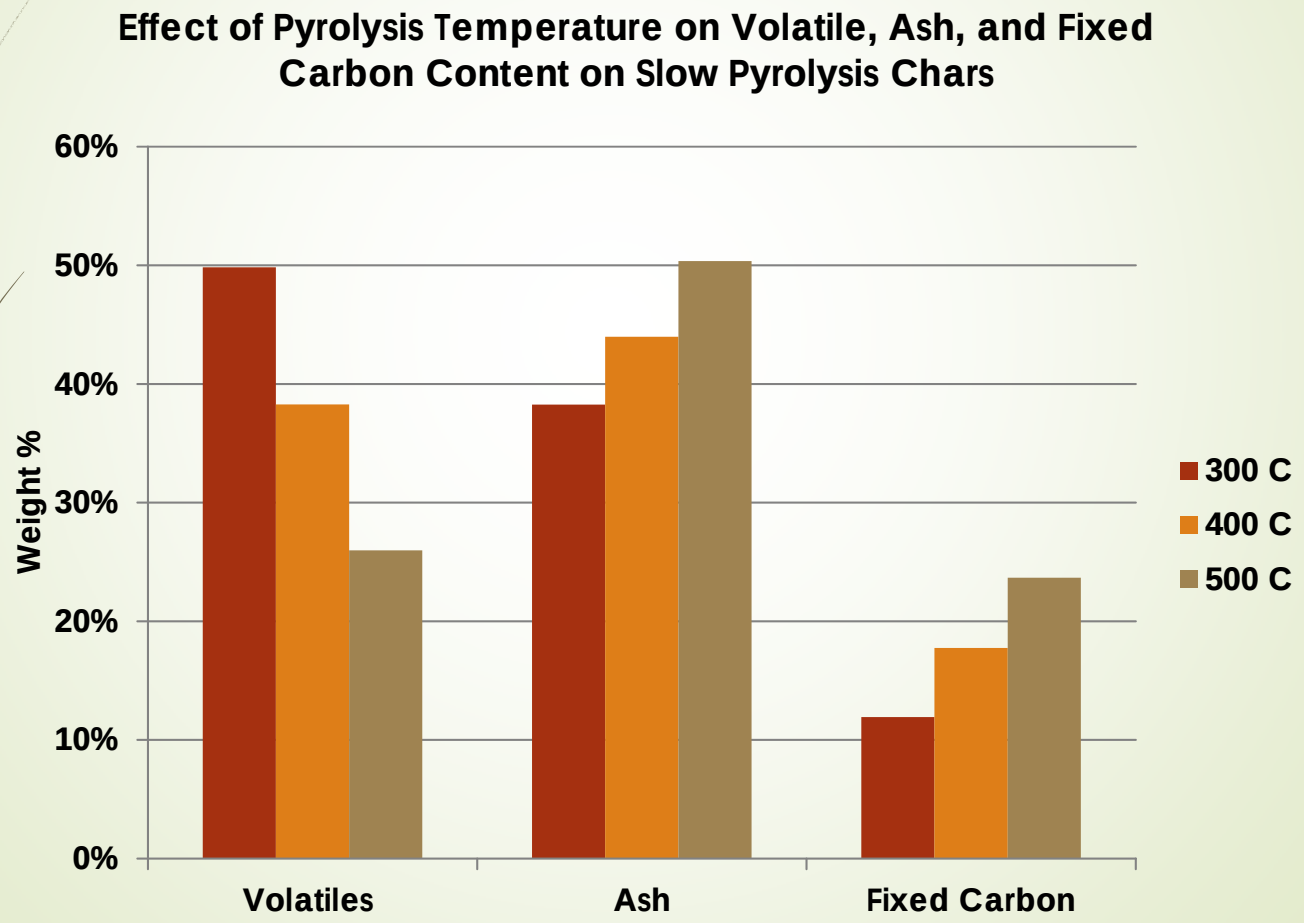
Slow Pyrolysis Yields



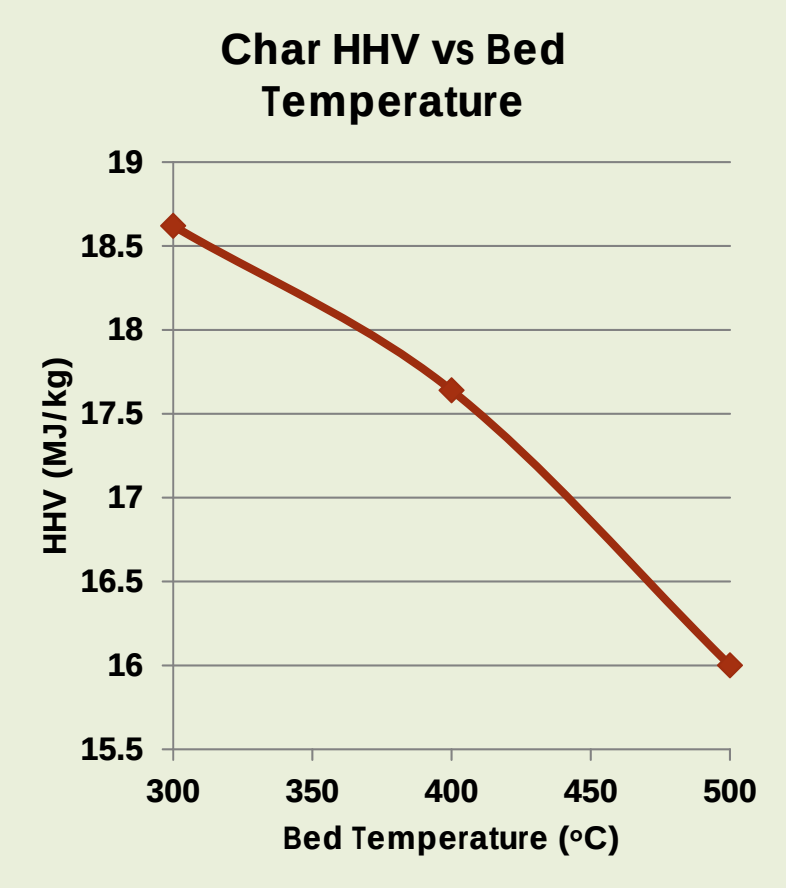
Compare With Fast Pyrolysis Yields

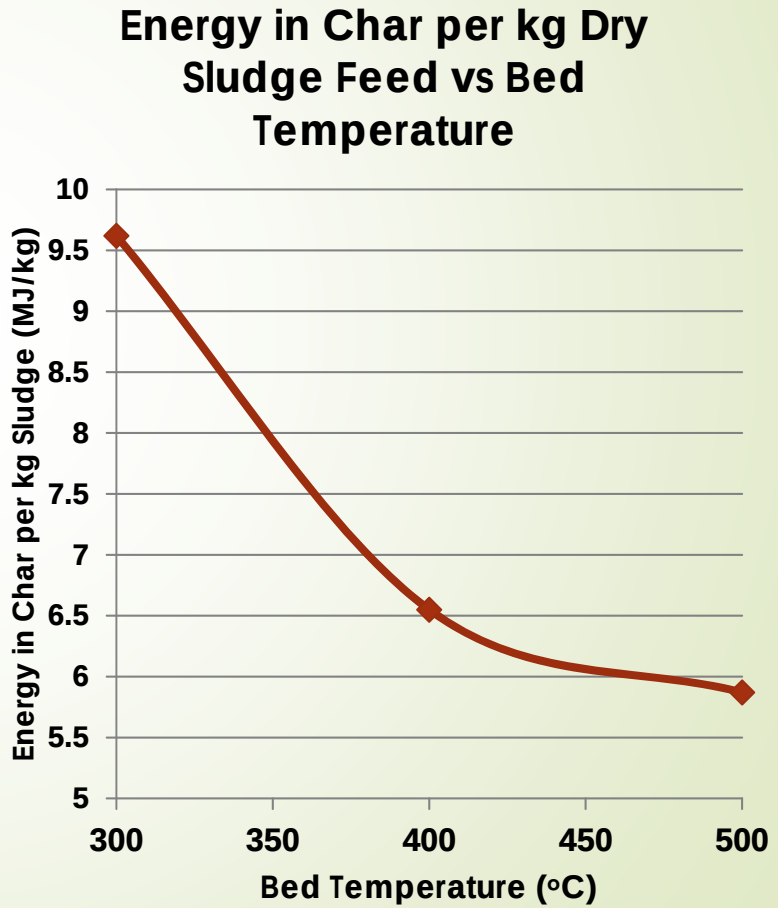


Slow Pyrolysis Char Analysis

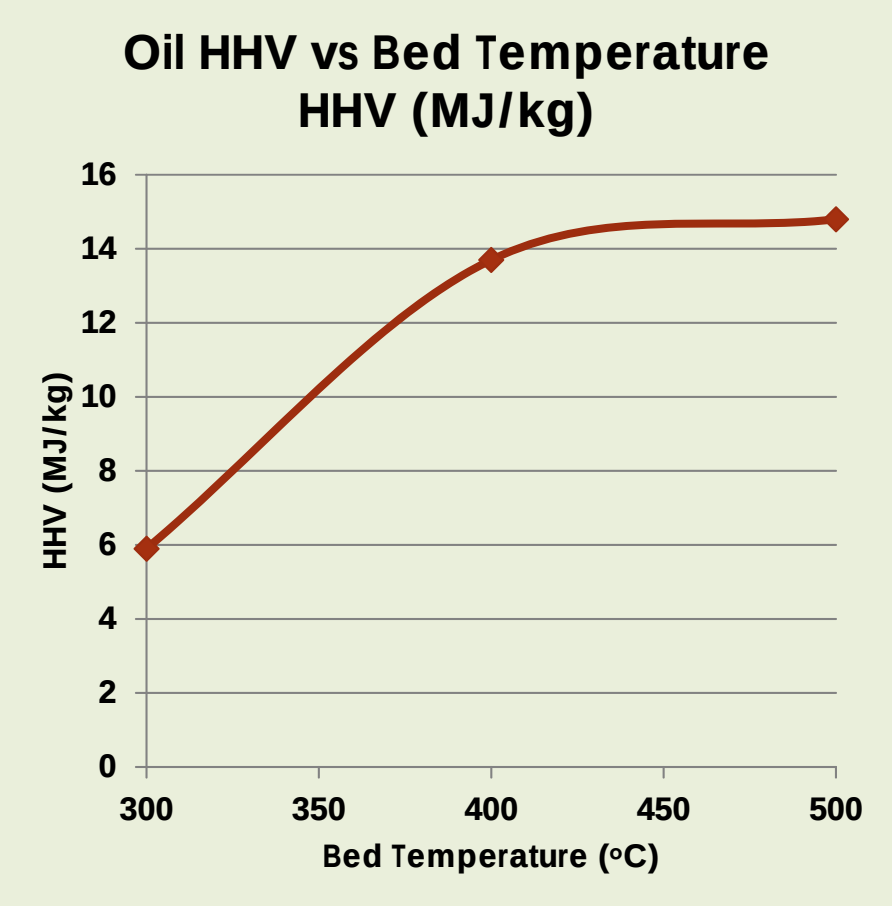


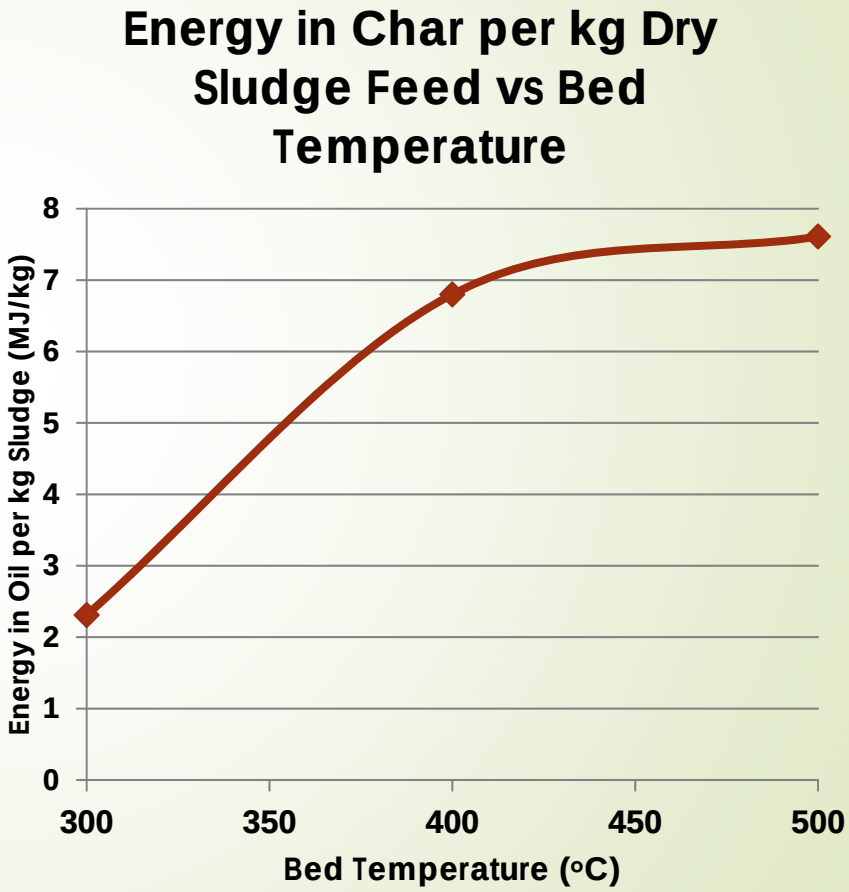
Slow Pyrolysis Char Energy Analysis



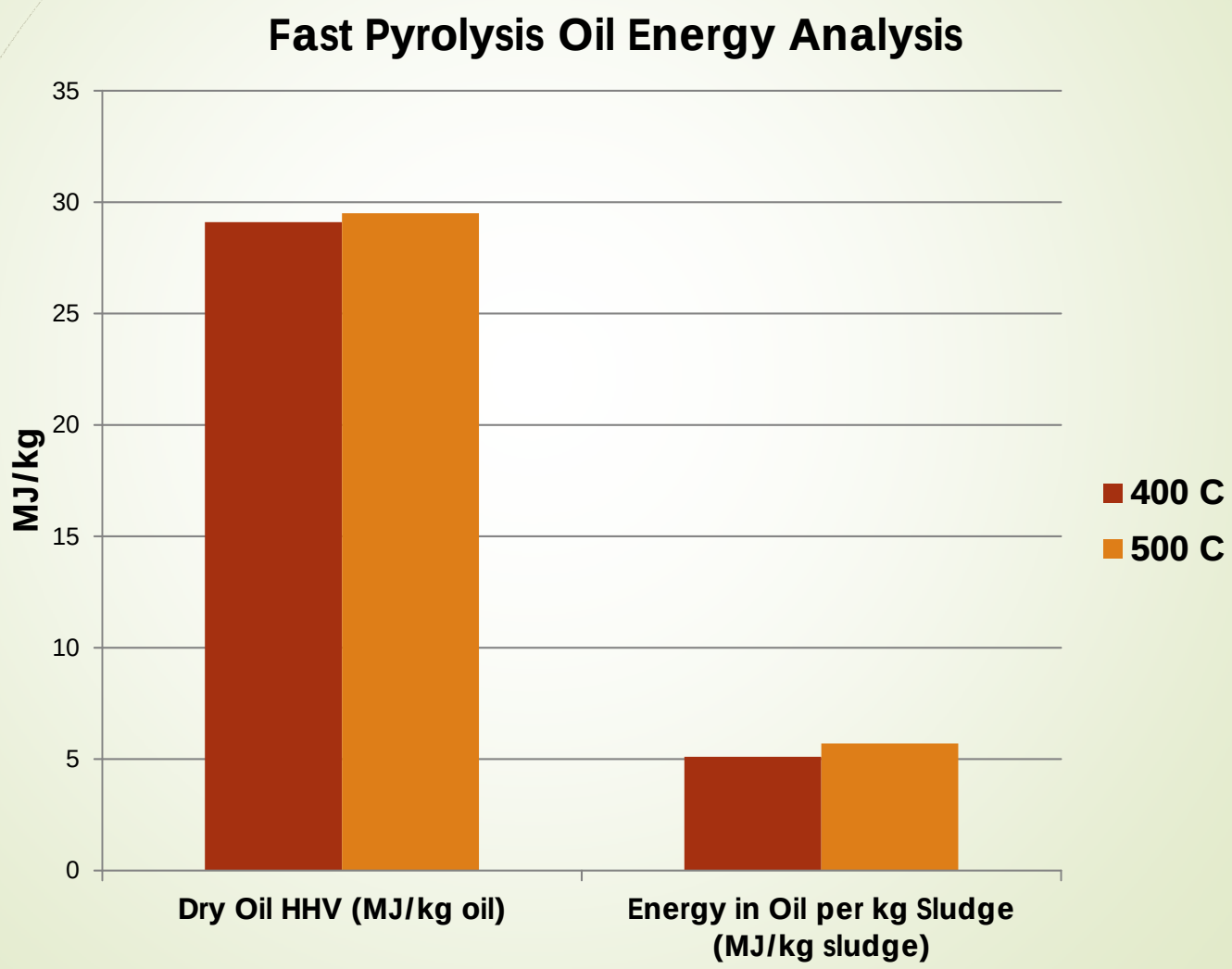


Slow Pyrolysis Oil Analysis





Fast Pyrolysis Oil Energy Analysis



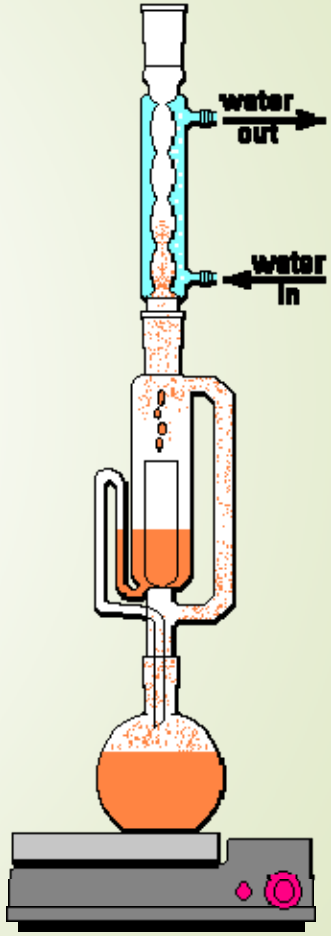
Fast Pyrolysis Gas Analysis (500°C)

Gas Component	Weight %
CO*	43.4%
C_2H_4	37.5%
CO_2	13.9%
C_3H_8	3.9%
C_4H_{10}	1.3%

Total Gas Yield	Heating Value (MJ/kg)	Energy in Gas per kg Dry Sludge (MJ/kg)
22%	24.7	5.4

Char Heavy Metals Leaching

- Leaching experiments performed using soxhlet extractor
- Water used as solvent
- Extraction temperature = 70 ^{o}C
- 72 hr extraction time

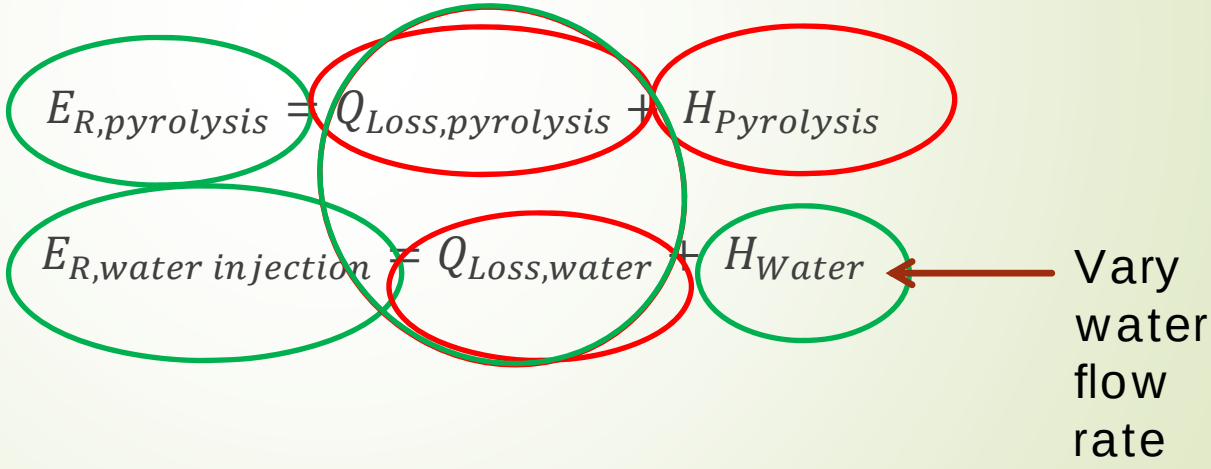


Leaching results

Restricted Metals	Slow Pyrolysis Char 500 °C	Fast Pyrolysis Char 500 °C
Cd	0%	0%
Cr	0%	0.7%
Cu	1.1%	1.5%
Ni	0%	2.4%
Pb	0%	0%
Zn	0.2%	0.4%
Other Metals		
P	0.2%	0.5%
K	29.0%	66.0%

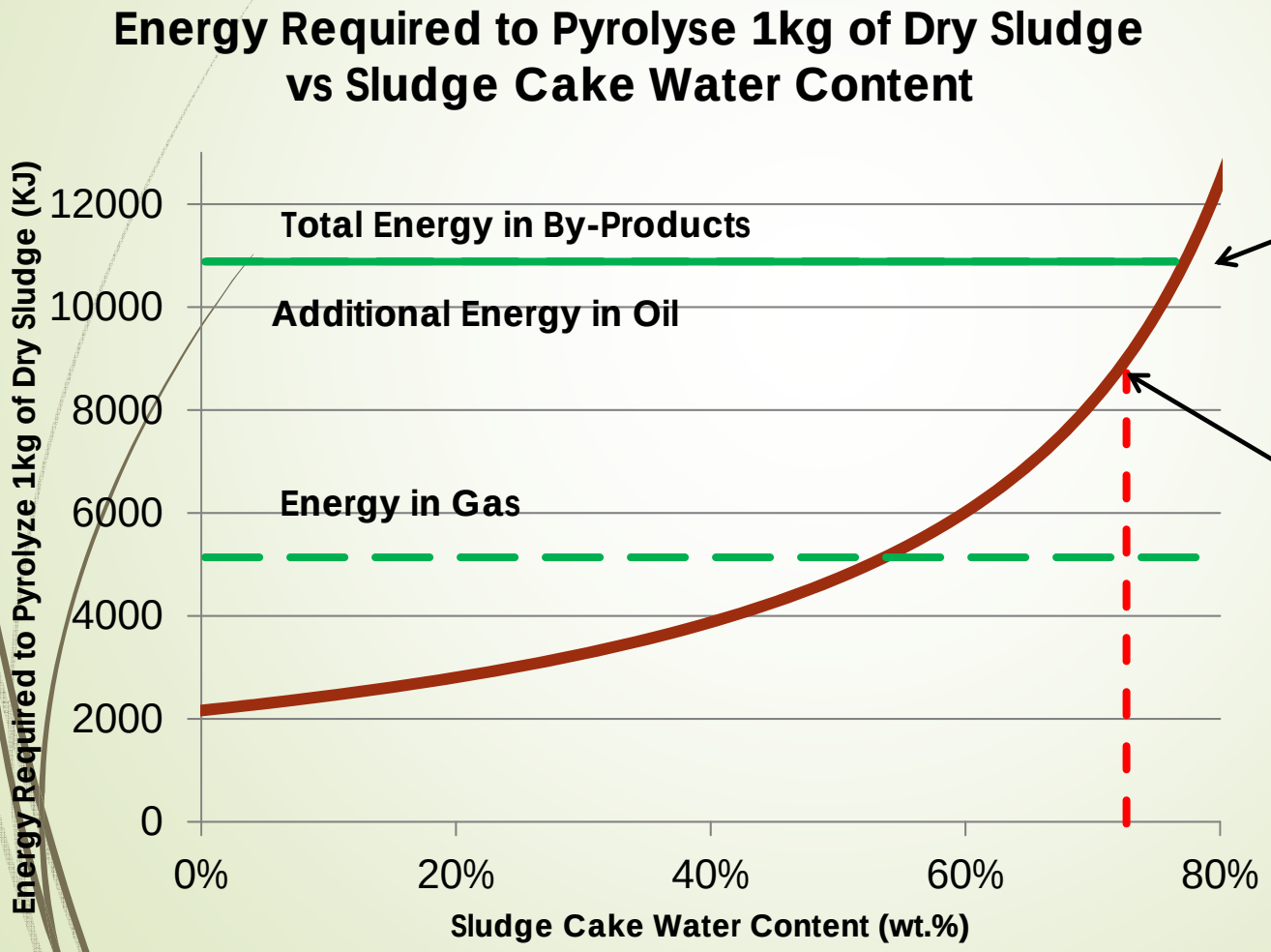
Enthalpy of Pyrolysis Method

- Enthalpy of pyrolysis was determined by analysing the power applied to heat the reactor during biomass feeding, and again while injecting a known flowrate of water
- The energy balance of the reactor can be expressed as:



$$H_{Pyrolysis} = 2.16\ MJ/kg$$

Energy Balance of Pyrolysis at 500°C



77% is the maximum moisture content that can be accommodated

Typical sludge with a moisture content of 72% is capable of thermal self sustaining pyrolysis

Ongoing and Future work

- Autothermal pyrolysis of sewage sludge
- Economic analysis of commercial scale sewage sludge pyrolysis
- Life Cycle Analysis of commercial scale sewage sludge pyrolysis
  - Global warming potential
  - Acidification potential
  - Human health effects

Conclusions

- Pyrolysis is viable as a thermally self sufficient process to transform sewage sludge into biochar
- Good recovery and stabilisation of heavy metals in the biochar.
- Likely to be economically and environmentally favourable to incineration
- Increases in dewatering efficiencies will allow for excess energy generation from products.

Acknowledgements

Questions?