

**Institute for Chemicals and Fuels
from Alternative Resources**

The University of Western Ontario



Meat and Bone Meal Pyrolysis Study in a Laboratory-Scale Bubbling Fluidized Bed Reactor

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Outline

- MOTIVATION
- PYROLYSIS PROCESS FOR MBM RESIDUES
- RESULTS
 - Yields
 - Product Properties
 - Effect of CO₂ on Product Quality/Yields
 - Heat of Pyrolysis/Total Reaction Energy
 - Energy Balance/Sustainability
- CONCLUSIONS/FUTURE WORK

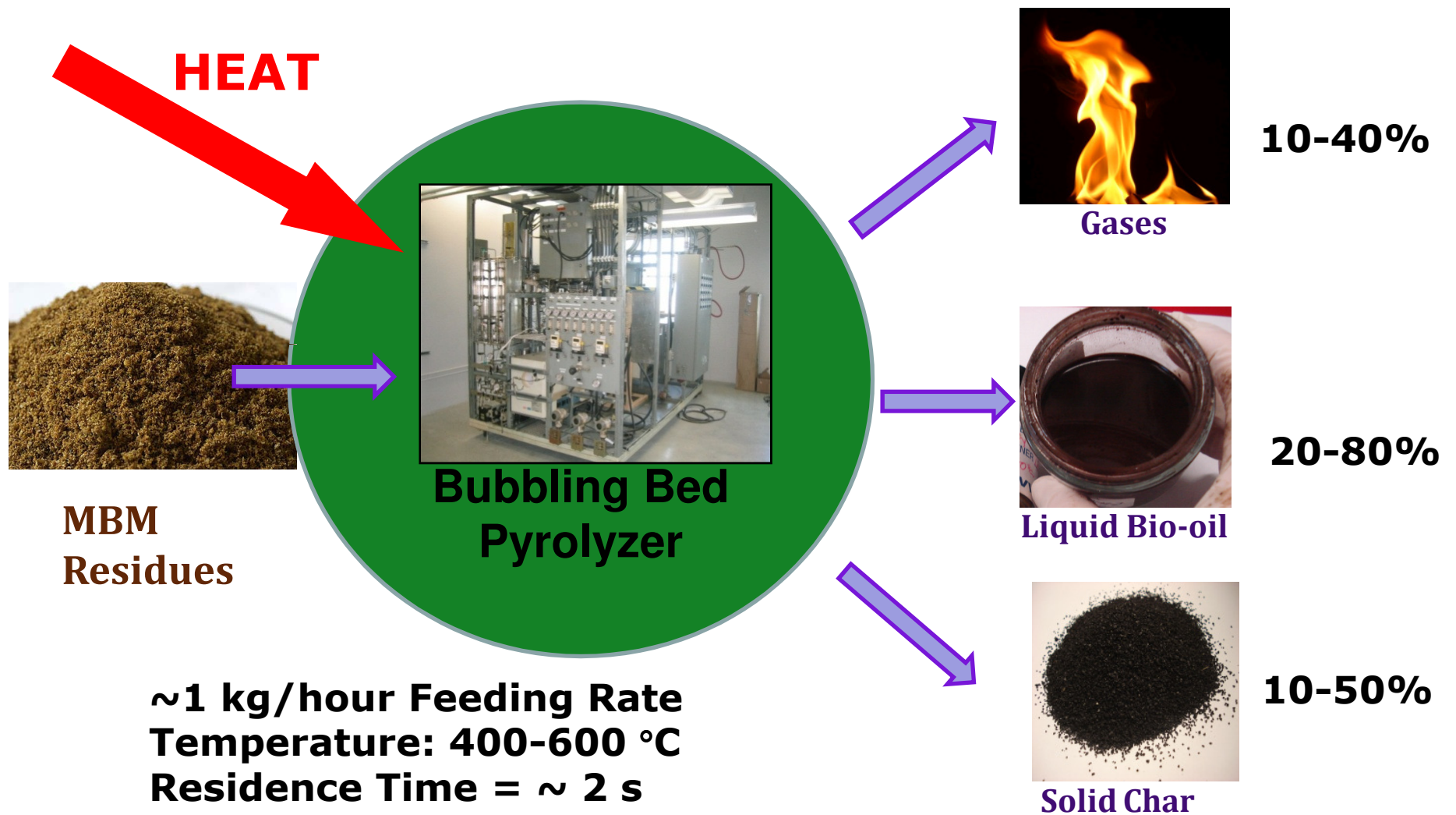
Meat and Bone Meal (MBM)

Meat & Bone Meal Specifications		
Thorndale Farm Pork Supply		
Specifications:		
Moisture	wt%	6.0%
Ash	wt%	26.4%
Volatiles	wt%	26.6%
Fixed Carbon	wt%	41.0%
Protein	wt%	55.0%
Fat	wt%	12.0%
Calcium	wt%	8.0%
Phosphorus	wt%	4.0%
Elemental Analysis:		
Nitrogen	wt%	8.7%
Carbon	wt%	42.6%
Hydrogen	wt%	6.3%
Oxygen	wt%	16.0%
Heating Values:		
HHV	J/g	17,751
LHV	J/g	16,384

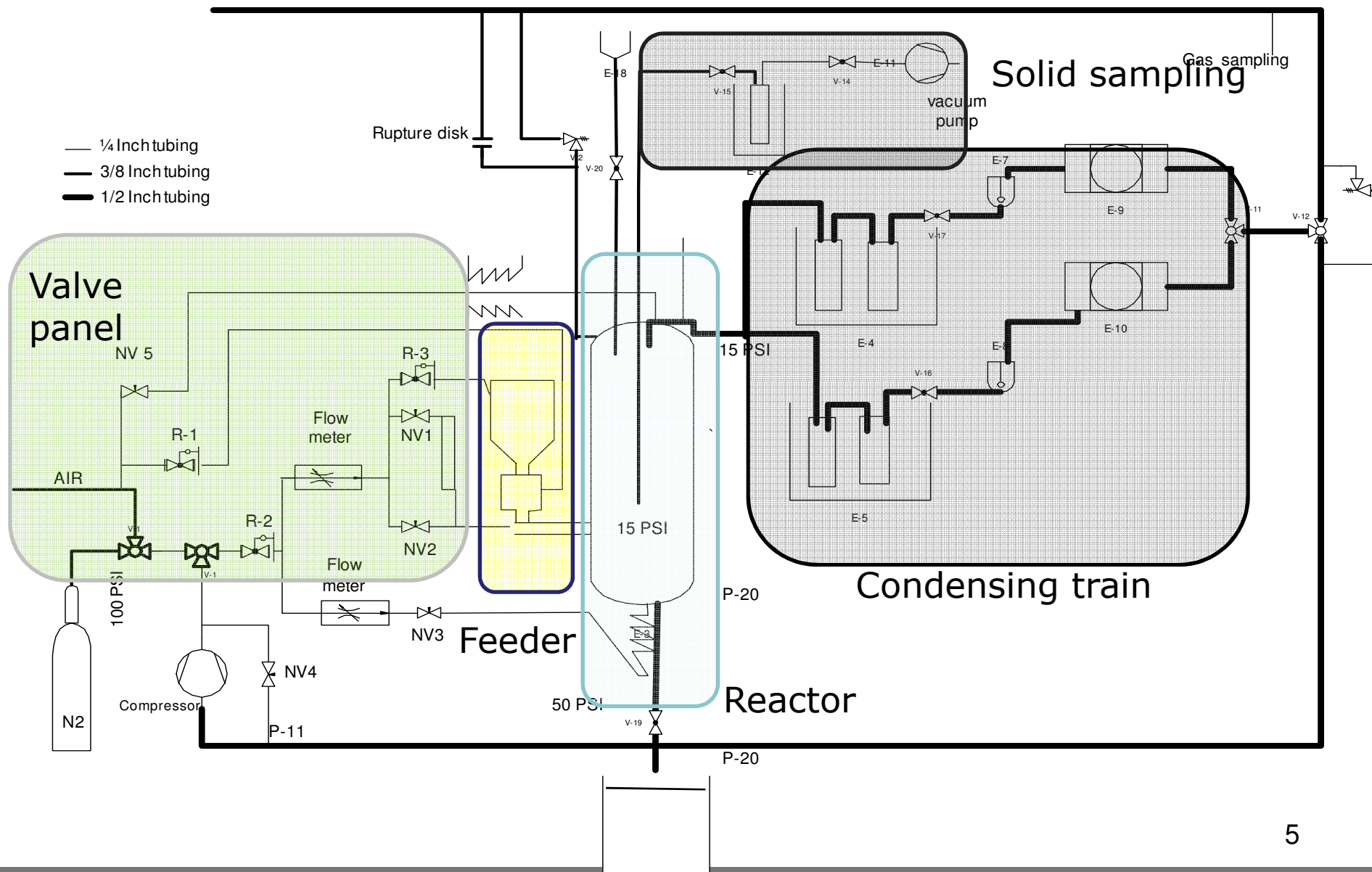


- Problematic residue due to Bovine Spongiform Encephalopathy (BSE)
- Extremely temperature sensitive and cohesive ($dp_{sm} = 30\mu\text{m}$, Hausner Ratio > 1.3)
- High ash content
- Millions of tons produced world-wide

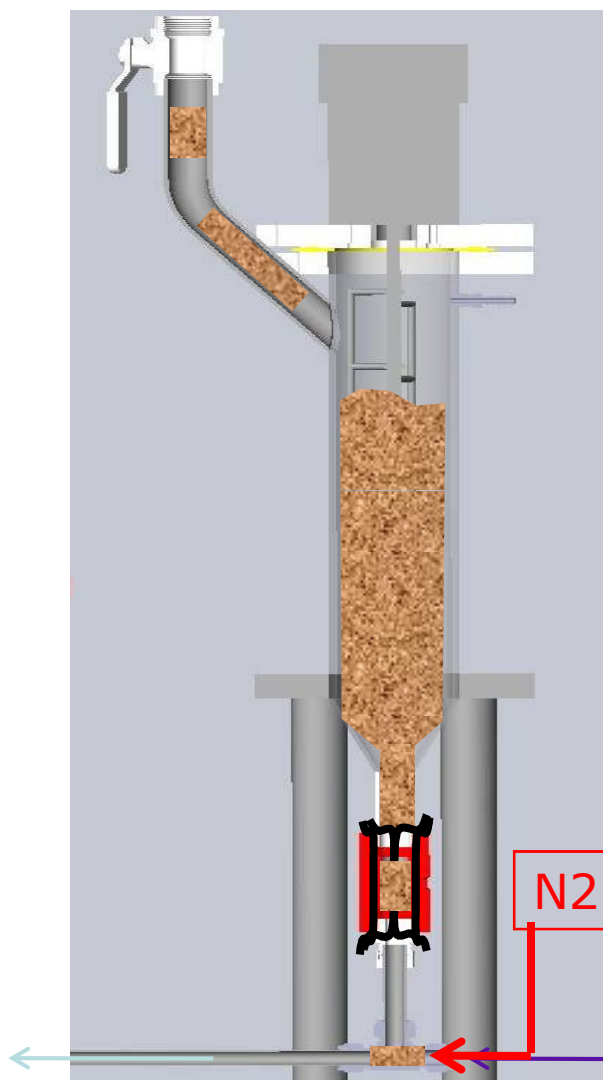
Pyrolysis Process



Experimental Setup



Experimental Setup



- MBM highly cohesive ($HR > 1.3$) and temperature sensitive (due to fat content)

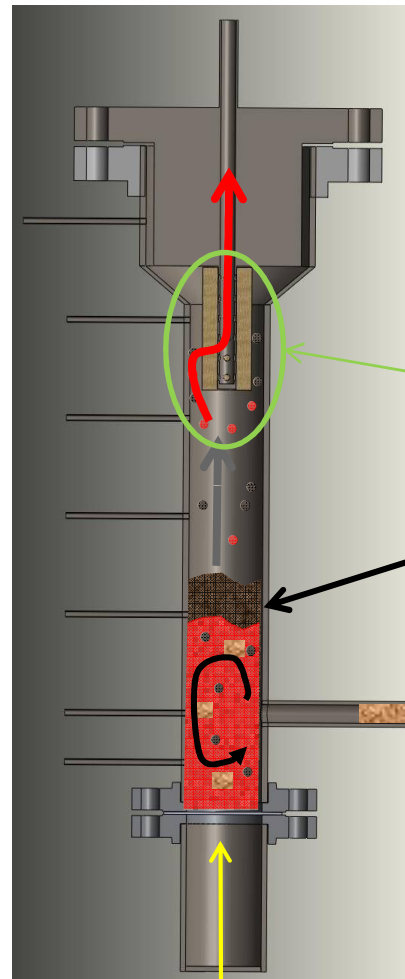
- Conventional feeders plug, MBM begins to react and melt in hot feeding tubes. Considered effectively impossible to feed!

- ICFAR Intermittent Slug Feeder successfully feeds MBM at a relatively constant feeding rate (~ 0.25 g/s)

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Experimental Setup



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

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

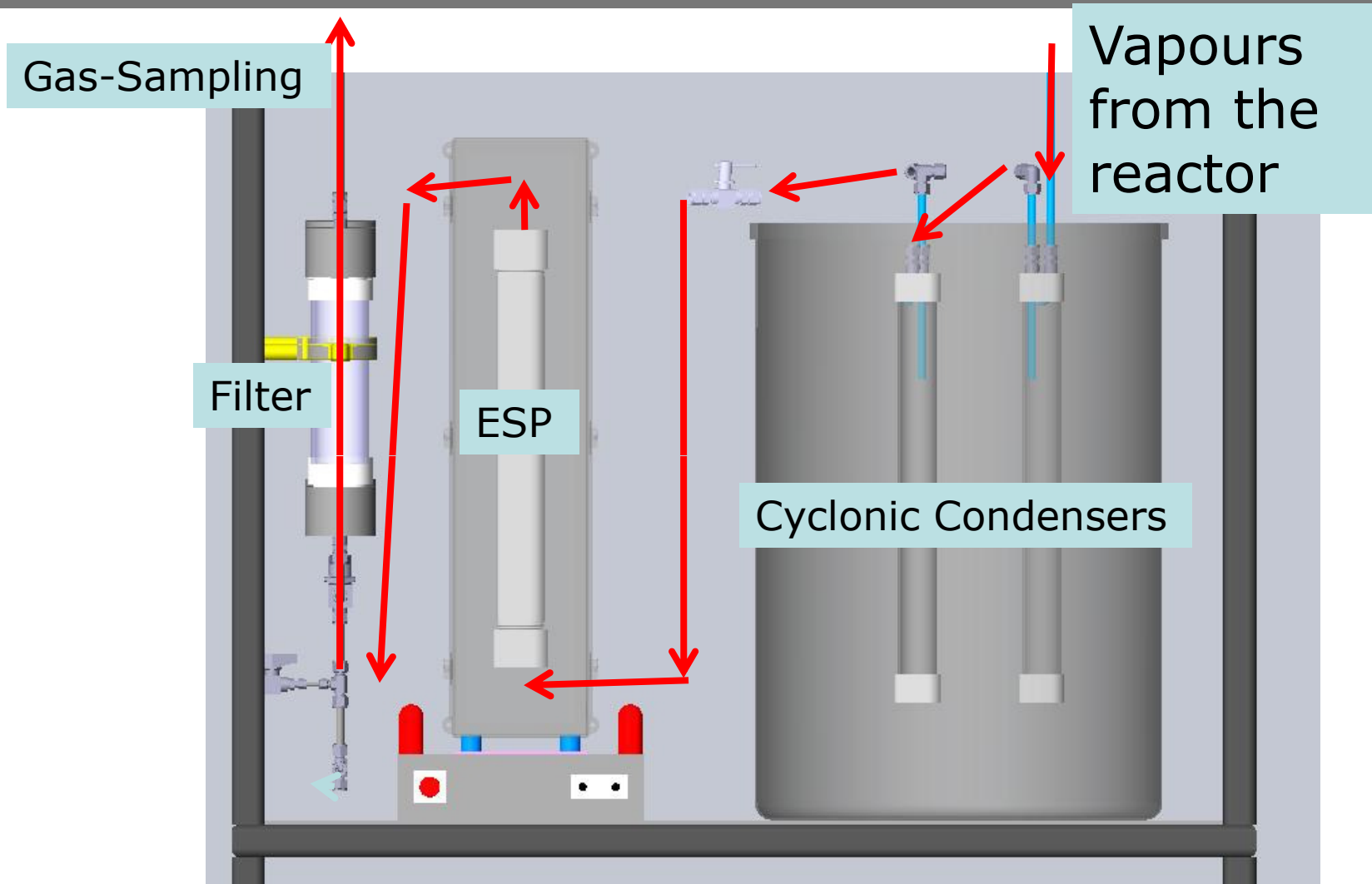
3) The char stays in the bed.

1) The biomass is injected into the bed.

2) It mixes with the hot sand and reacts.

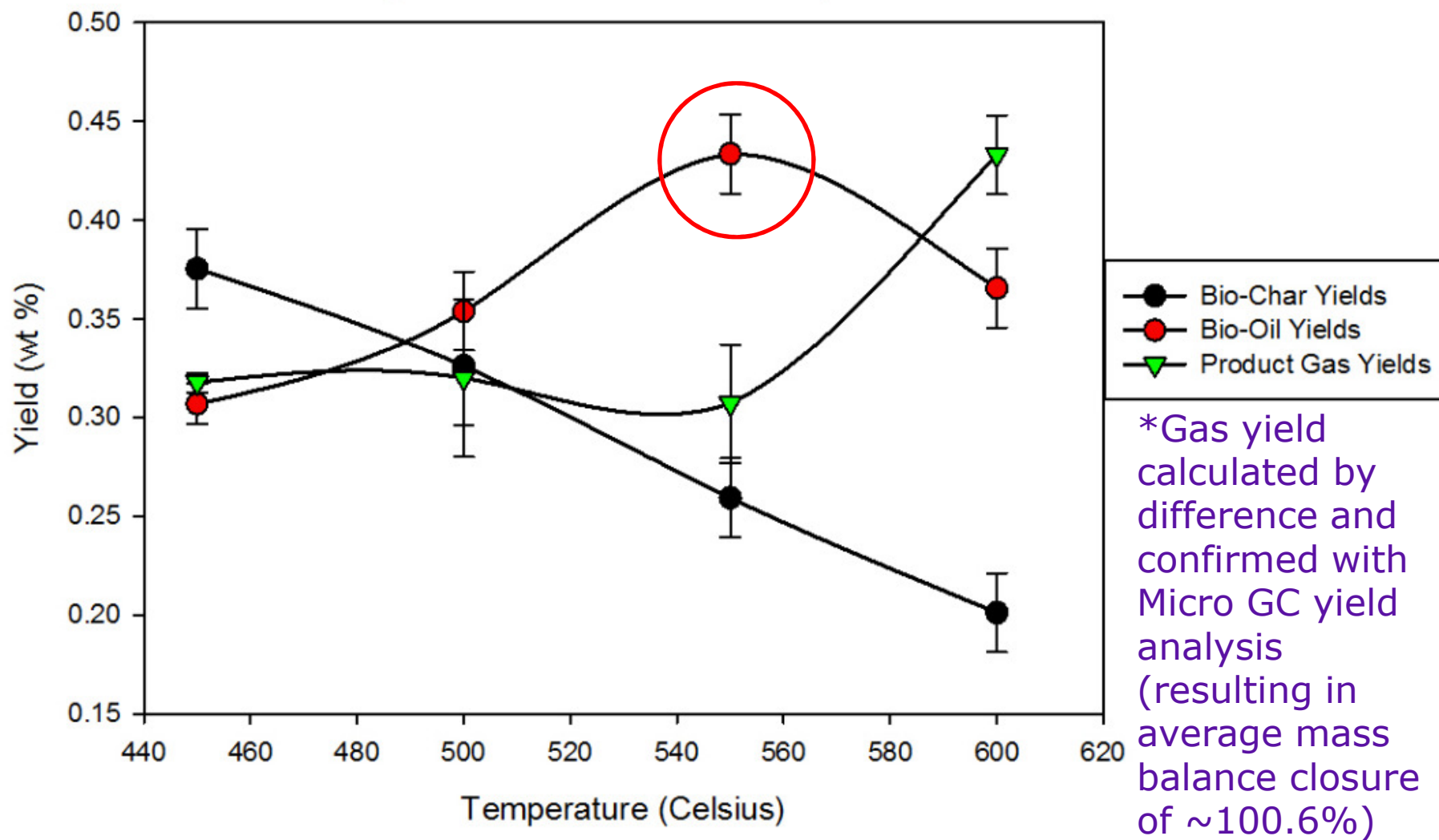
N2 for Fluidization

Experimental Setup



Results - Yields

Average Product Yields vs. Temperature



Results – Bio-Oil Properties

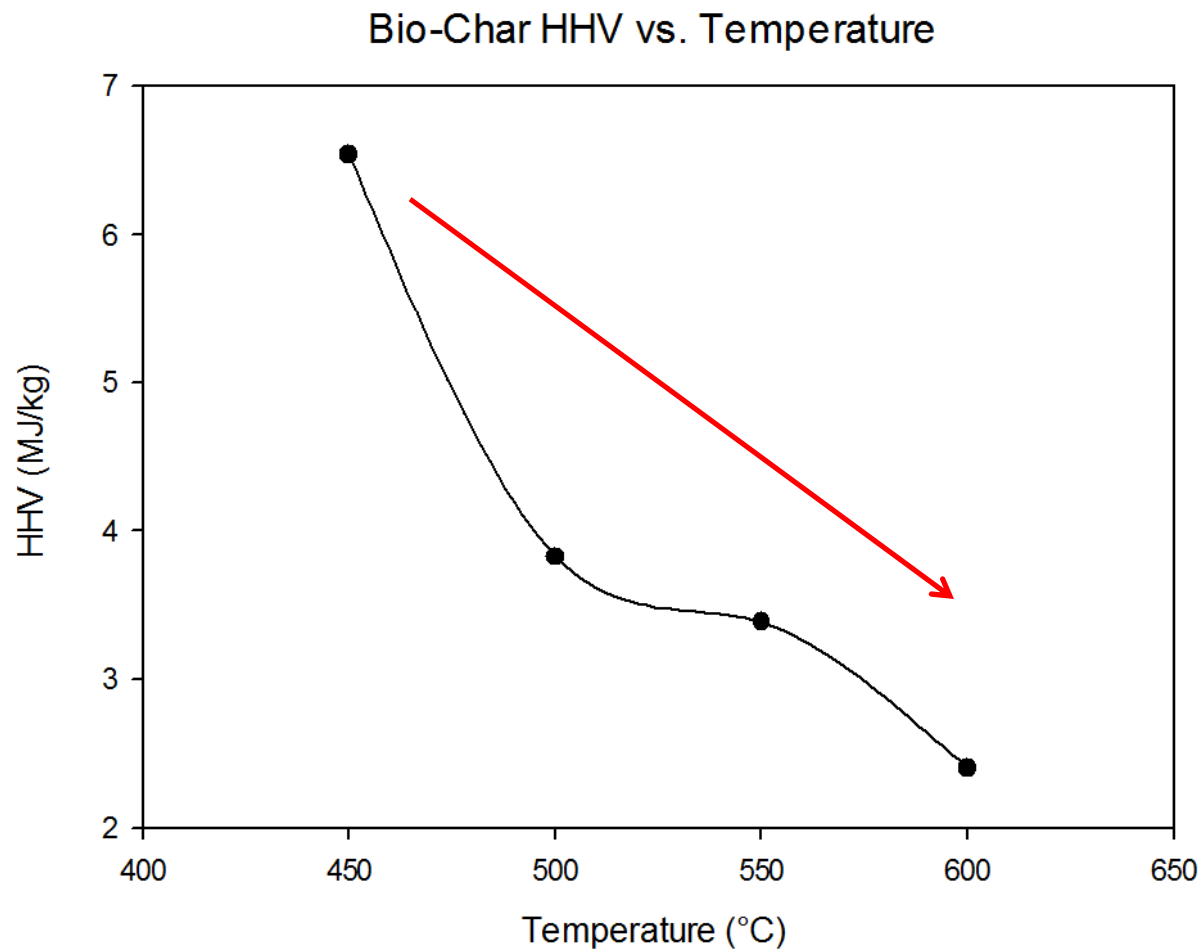
- Single-phase, homogeneous bio-oil produced
- All conditions resulted in basic bio-oils (pH 9.1-9.5)

Average MBM Bio-Oil Properties				
Reaction Temp (°C)	450	500	550	600
HHV (MJ/kg)	29.1	30.1	31.5	23.7
HHV (MJ/kg) - water free	34.6	36.7	32.8	31.2
Water Content (wt%)	16%	18%	4.1%-10%	24%
pH	9.16	9.4	9.3	9.1
<i>Elemental Analysis:</i>				
Nitrogen	8%	11%	11%	11%
Carbon	56%	60%	62%	57%
Hydrogen	5%	9%	9%	8%
Oxygen	31%	20%	18%	23%



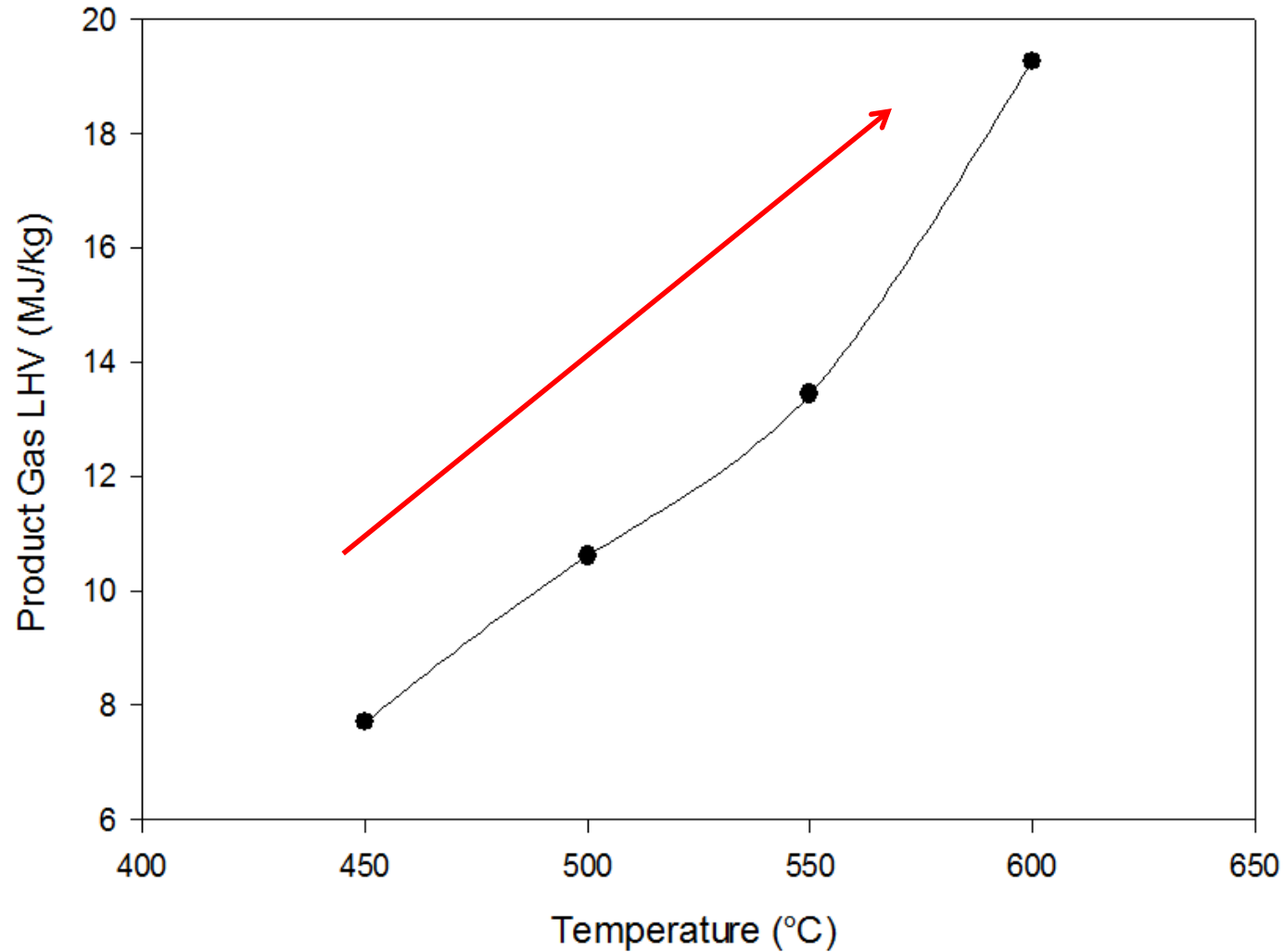
Results – Bio-Char Properties

- High ash content (>70% wt) results in low HHV
- May be tested for water retention and fertilizer properties in future work (all char samples retained)



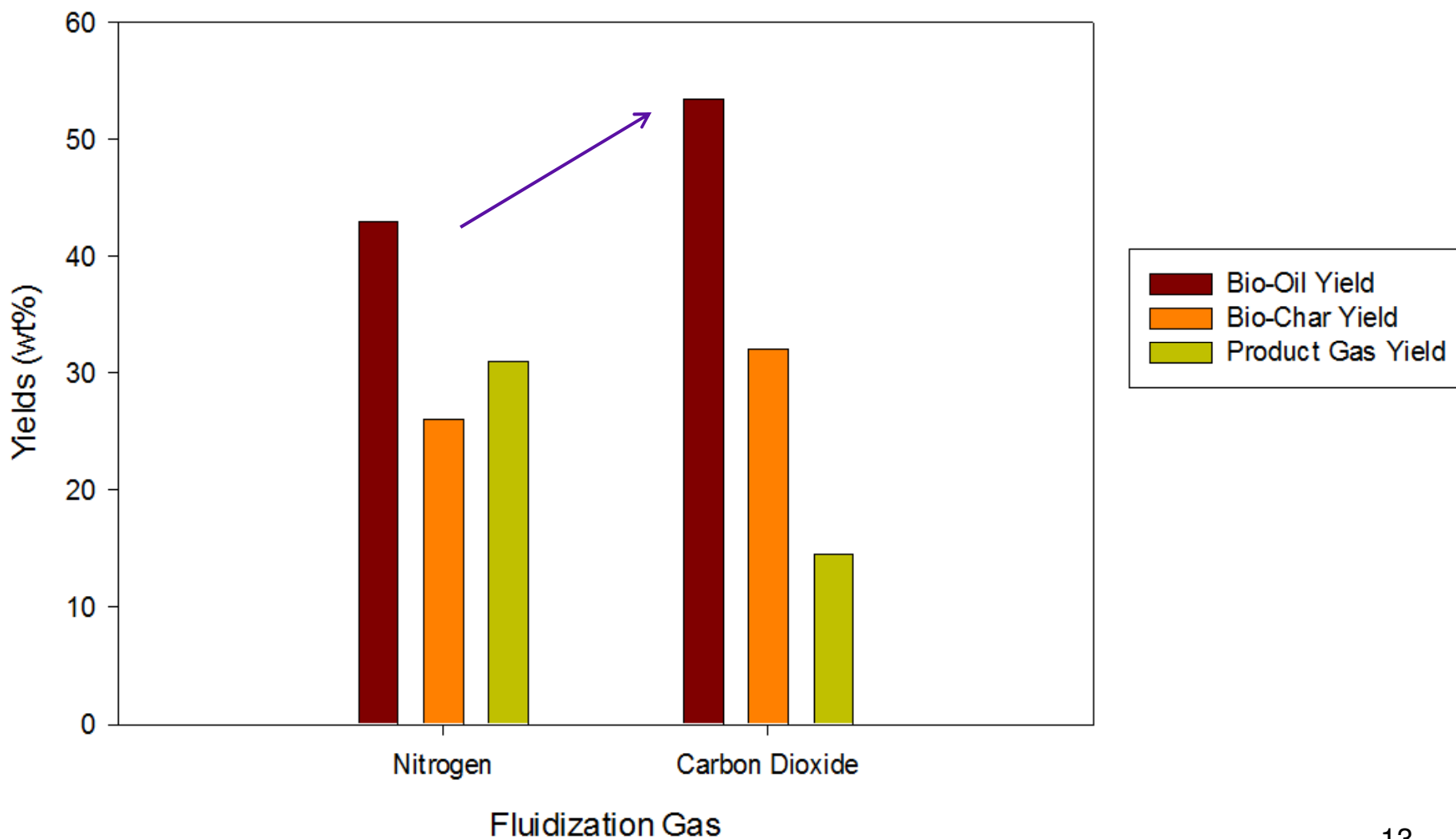
Results – Gas Micro GC Analysis

Product Gas LHV vs. Temperature



Results – Effect of CO₂

Fluidization Gas (N₂ or CO₂) vs. Product Yields



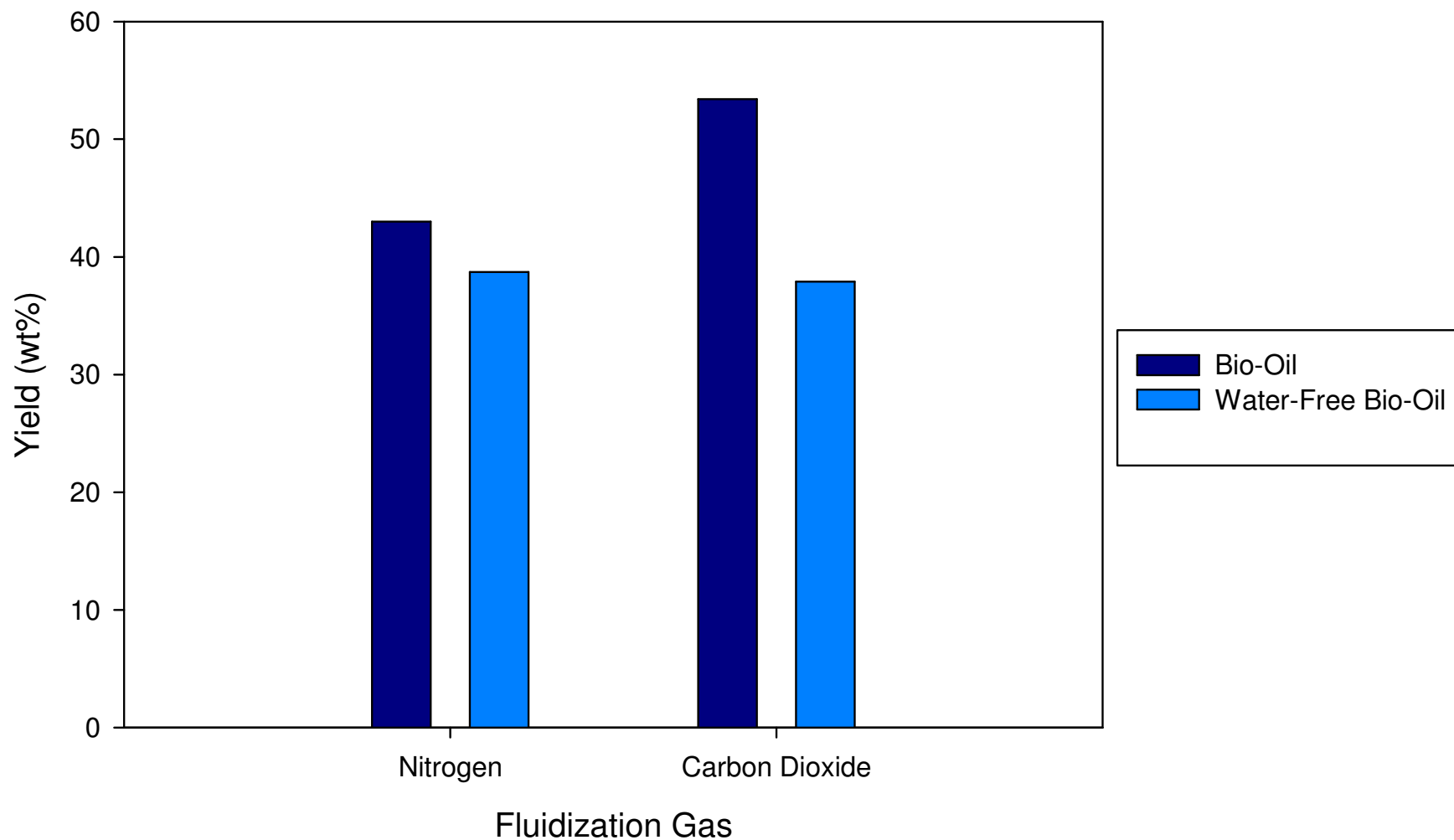
Results – Effect of CO₂

CO ₂ vs. N ₂ Bio-Oil Comparison		
Fluidization Gas	N ₂	CO ₂
Reaction Temp (°C)	550	550
HHV (MJ/kg)	31.5	19.1
HHV (MJ/kg) - water free	32.8	27.0
Water Content (wt%)	4.1%-10%	29%
pH	9.3	9.1

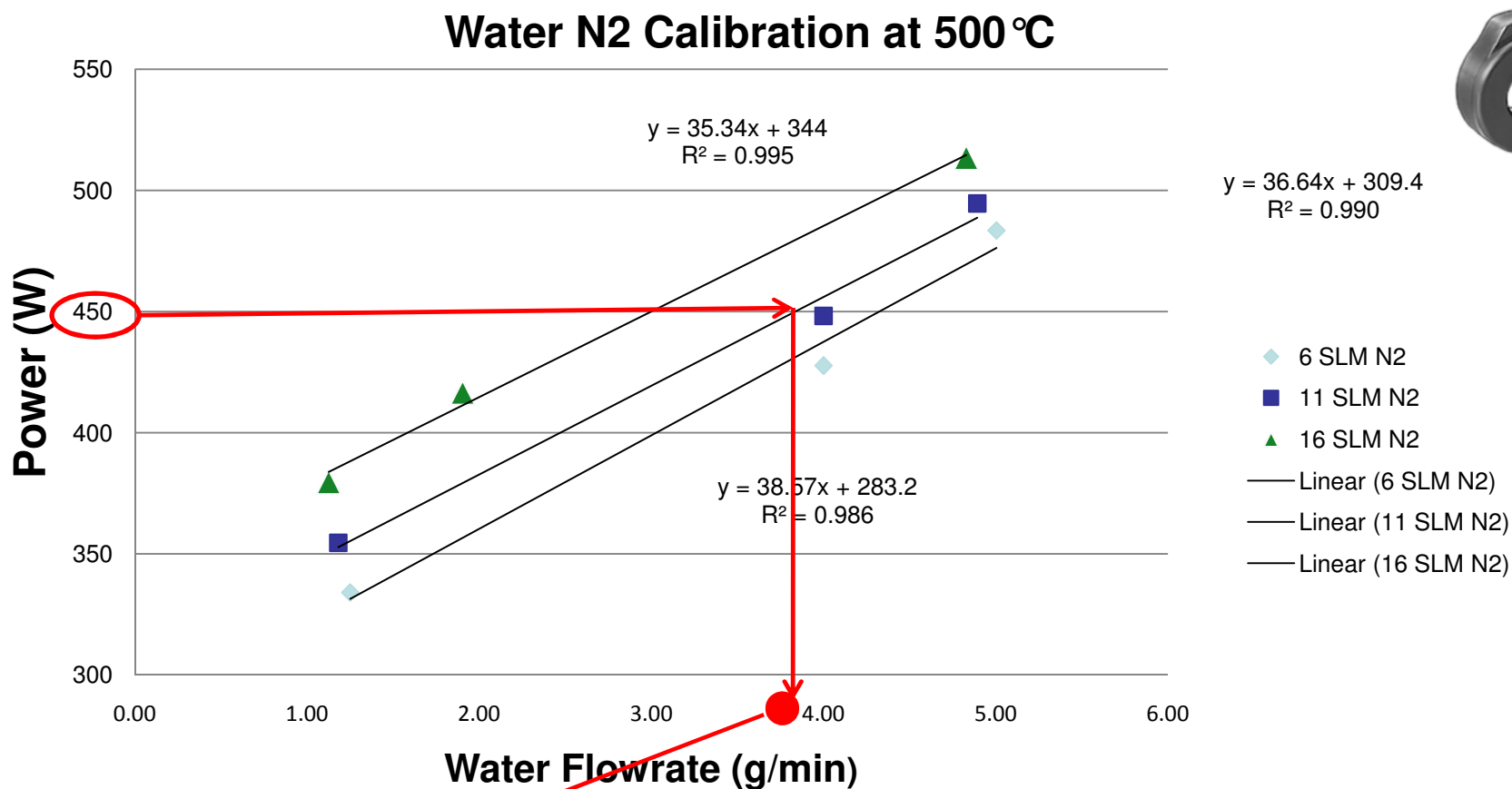
← Close Values!

Results – Effect of CO₂

Fluidization Gas (N₂ or CO₂) vs. Bio-Oil Yields



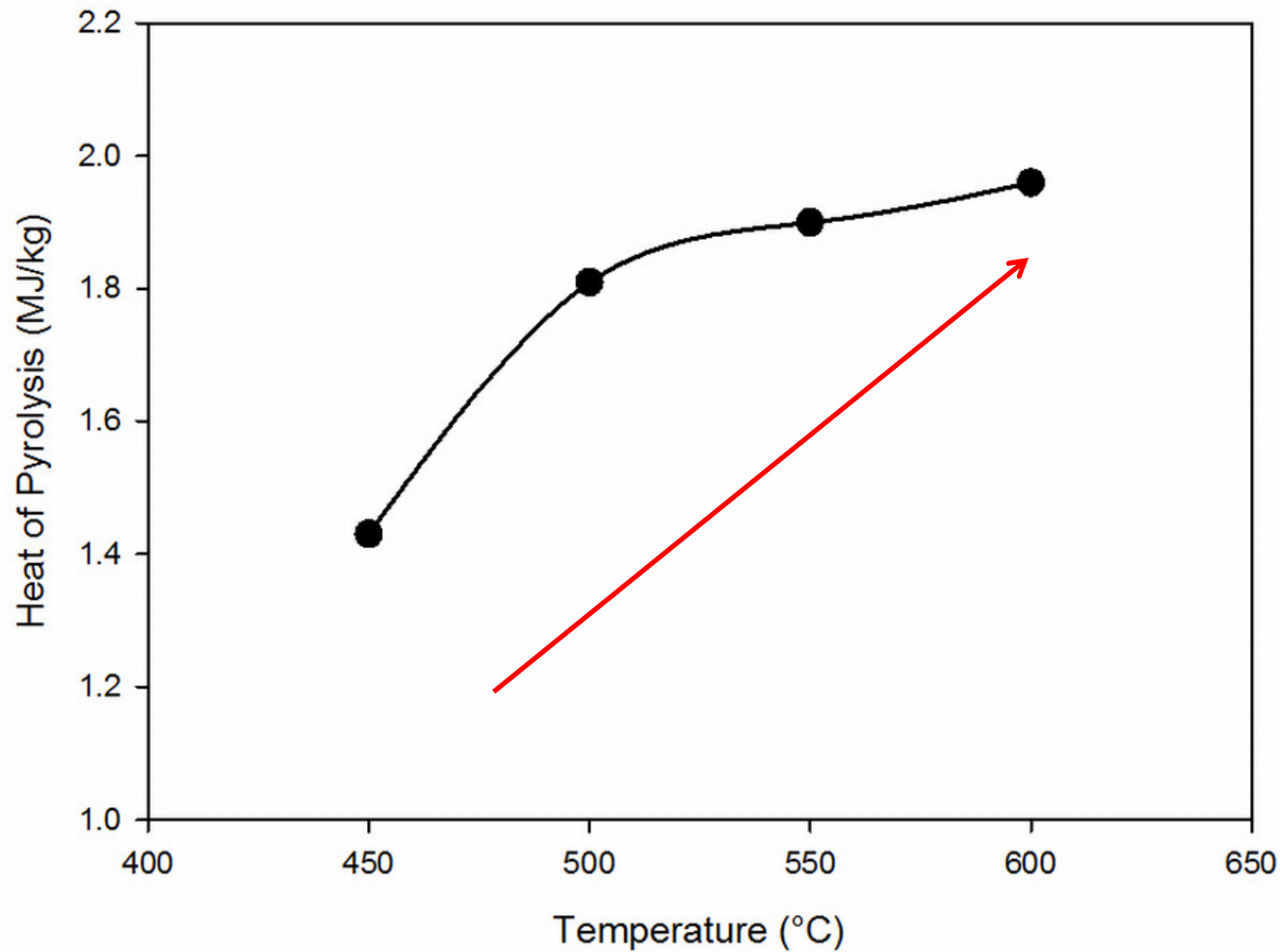
Results – Heat of Pyrolysis



3.83 g/min of water → **0.74 MJ/kg Heat of Pyrolysis**

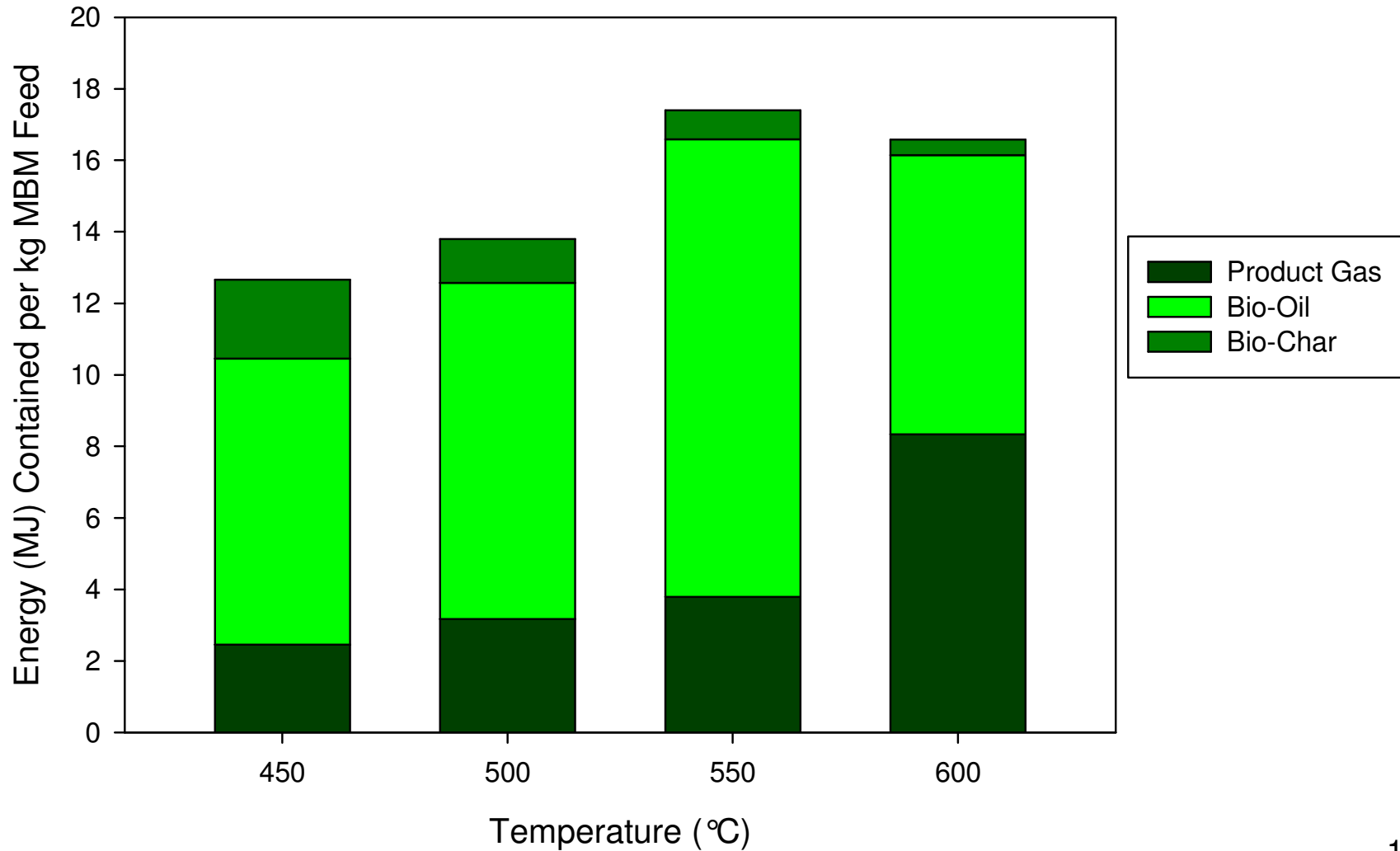
Results – Heat of Pyrolysis

Heat of Pyrolysis vs. Temperature



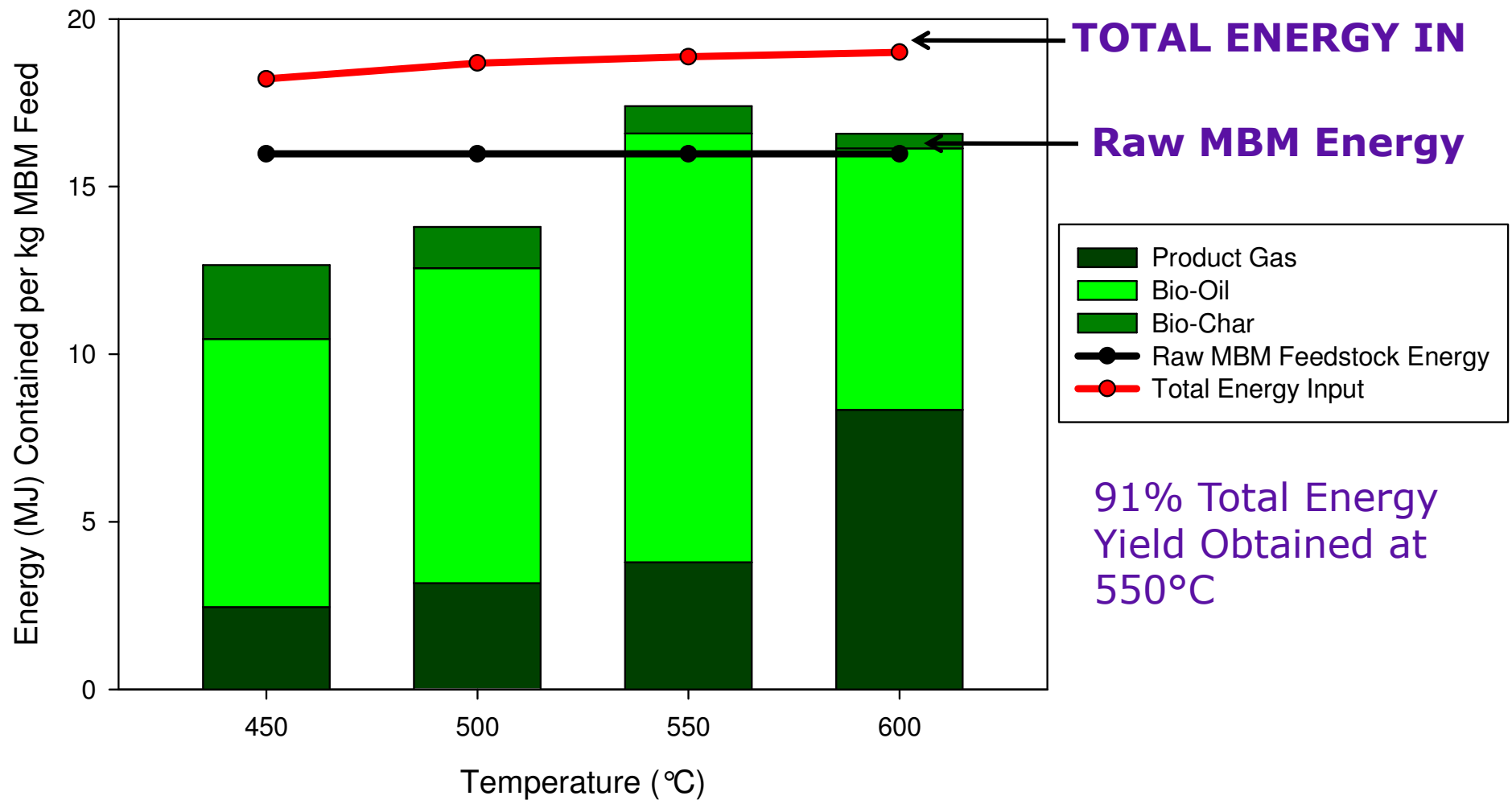
Results – Energy Balance

Energy Balance and Sustainability vs. Temperature



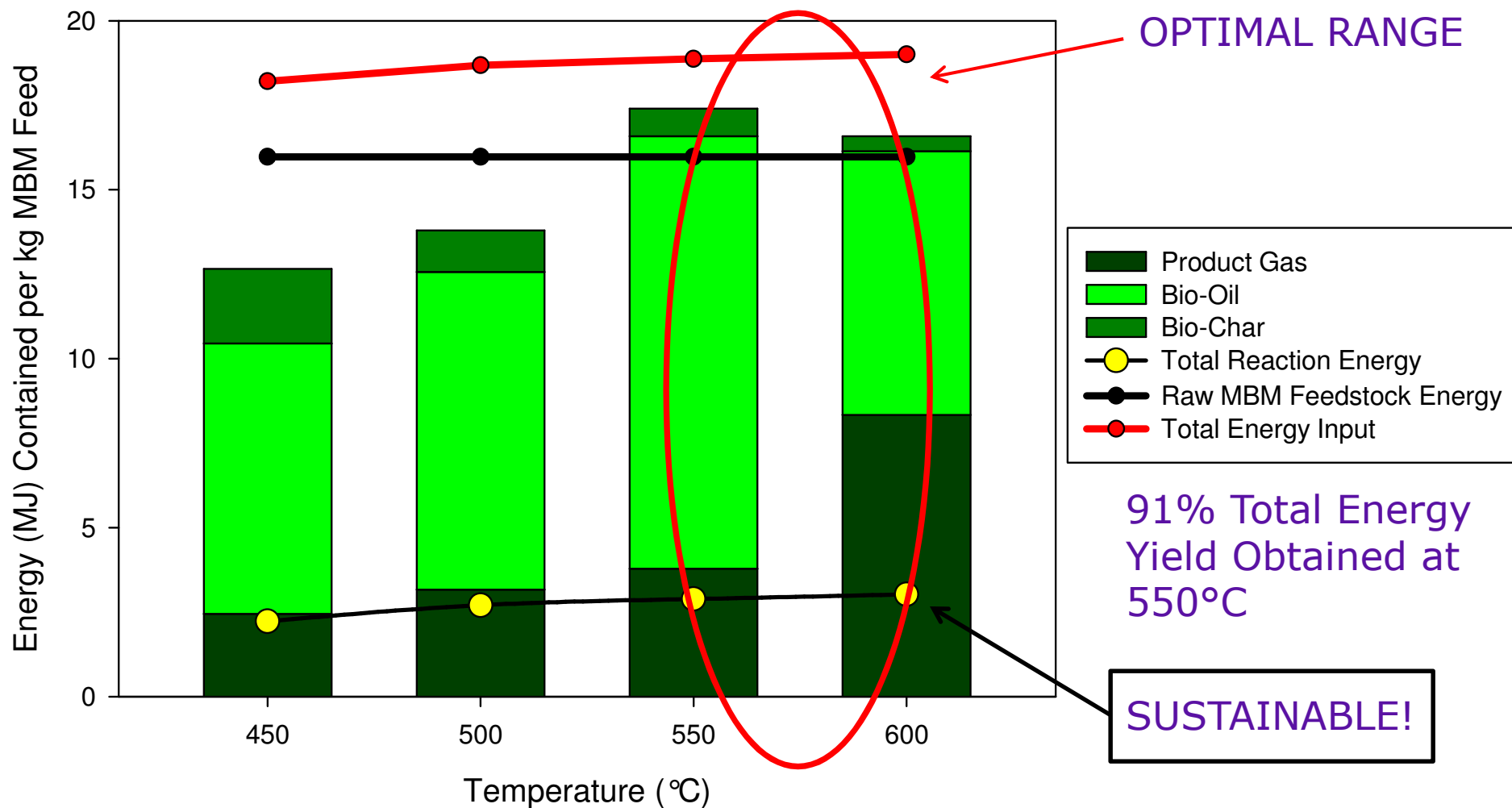
Results – Energy Balance

Energy Balance and Sustainability vs. Temperature



Results – Energy Balance

Energy Balance and Sustainability vs. Temperature



Conclusion & Future Work

- Meat and Bone Meal residues can be converted to higher value products using pyrolysis.
- The ICFAR Feeding Technology outperforms conventional feeders.
- Optimum operating conditions determined from a product quality and energy perspective: $\sim 550^{\circ}\text{C}$, ~ 2 s residence time.
- The effect of CO_2 on the product yields and quality was analyzed
 - **Future work to test with CO and H_2 fluidization gases.**
- Bio-char may be collected and sent to Agricultural and Agri-Food Canada for Fertilizer Properties and Water Retention Analysis.

THANK YOU!

THANK YOU FOR YOUR ATTENTION!

THANKS TO:

Dr. Cedric Briens

Dr. Lorenzo Ferrante

Dr. Franco Berruti



NSERC
CRSNG