Pyrolysis of Agricultural and Forestry Residues into Bio-oil

ENGINEERING CONFERENCES INTERNATIONAL 2009,
Bioenergy II: Fuels and Chemicals from Renewable Resources

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Outline

- Motivation
- Approach
- Experimental Set Up
- Experimental Results
- Conclusions

Motivation -1

- Global Warming.
- Depleting Conventional Fossil Fuel Reserves.

Demand for renewable energy.

Demand for proper disposal of agricultural and forestry residues.

Utilization of Agricultural and Forestry Residues as Energy Resources

Motivation -2

Wine Grape

Wine

Grape Skins and Seeds

12.2 million tonnes worldwide

Corn

Bio ethanol

Dried Distiller's Grains

3.5 million tonnes in North America

Sugarcane

Sugarcane Juice

Sugarcane Bagasse

500 million tonnes worldwide

Forest Resources

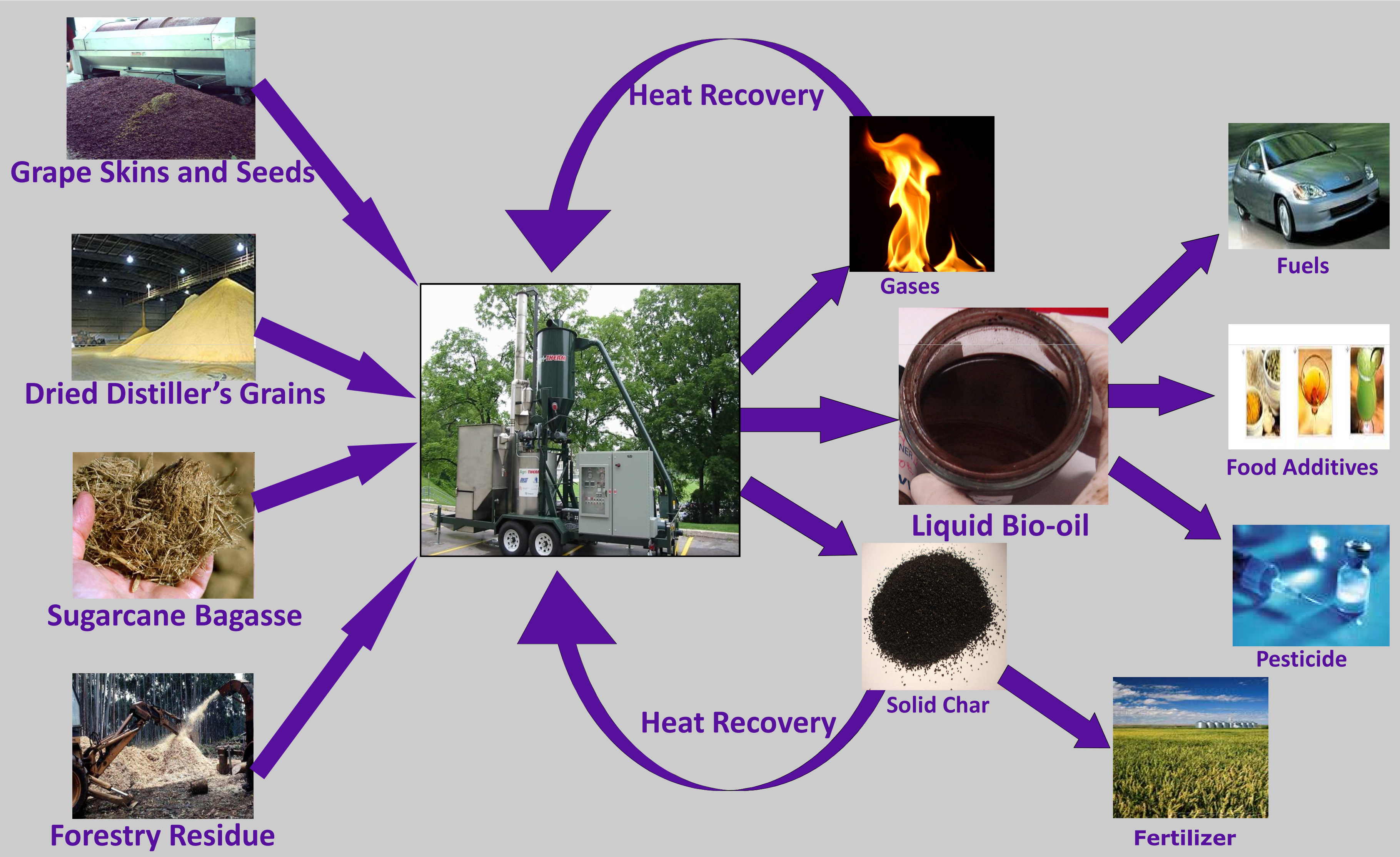
Pulp and Paper

Forestry Residue

280 million tonnes worldwide

One Possible Solution

- Conversion of Agricultural and Forestry Residues into Bio-Oil via **Fast Pyrolysis.**



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Experimental Set Up

Pilot Plant Reactor

Fluidized bed:

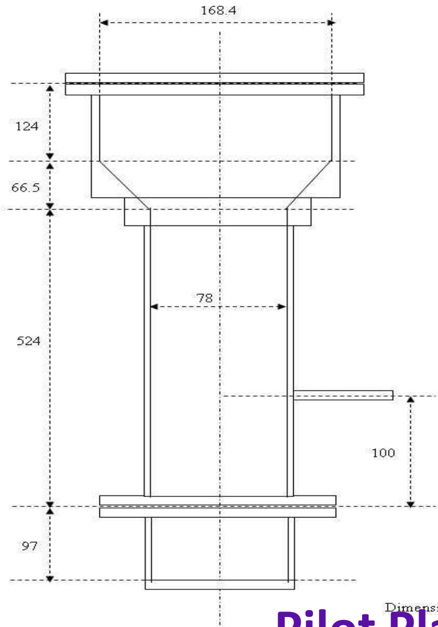
- 7.8 cm diameter
- 0.5 m high.

Equipped with removable freeboard sections.

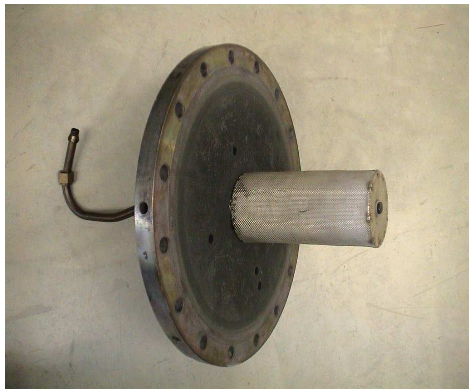
- Residence Time Range: 1 to 30 seconds.

Intense heat transfer & mixing

Operating Temperature Range: Up to 700 ° C.



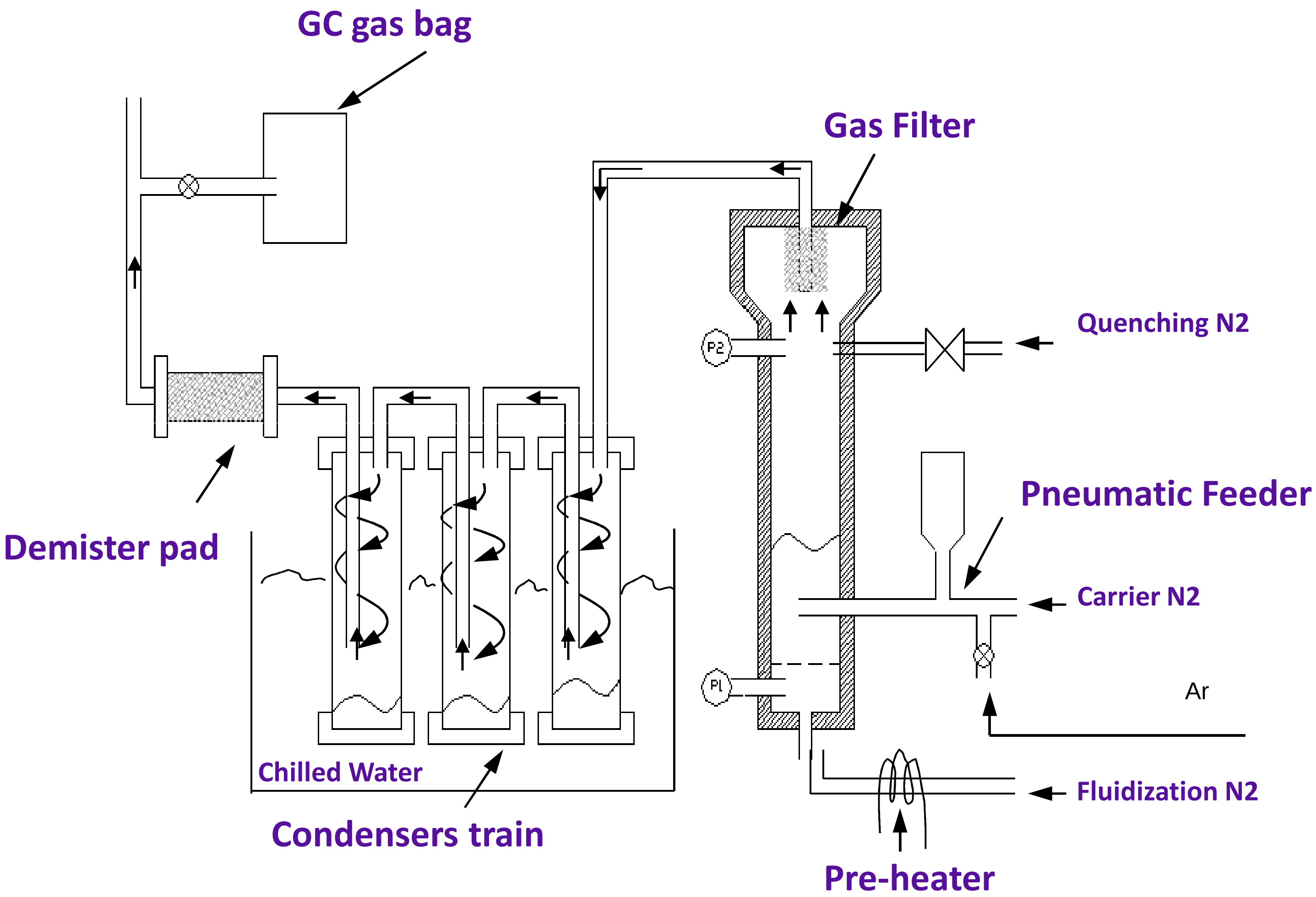
Pilot Plant Reactor



Pilot Plant Reactor Top

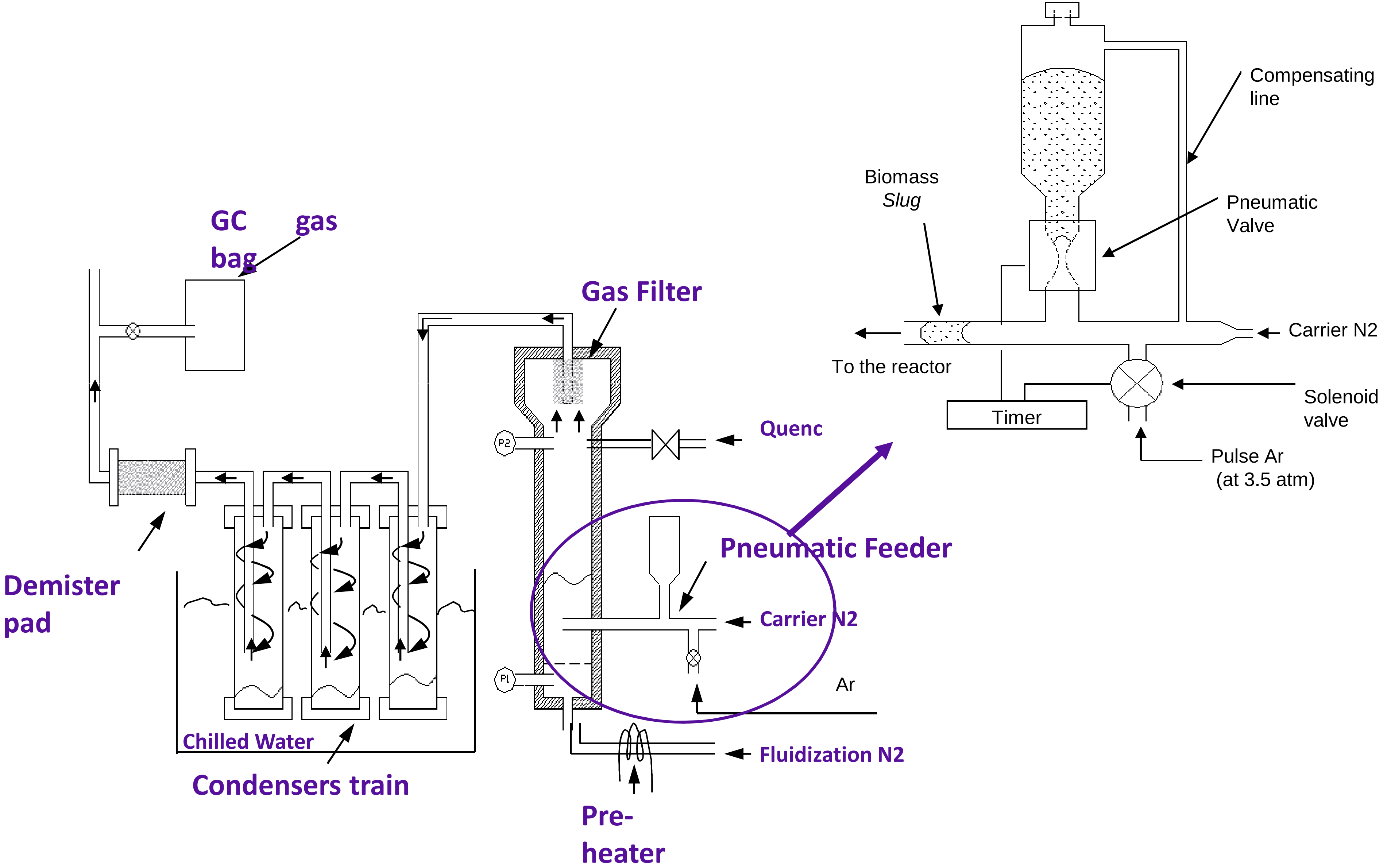
Experimental Set Up

ICFAR Pilot Plant

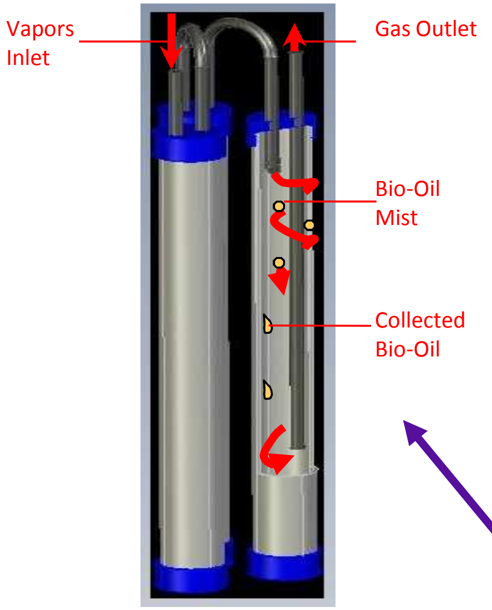


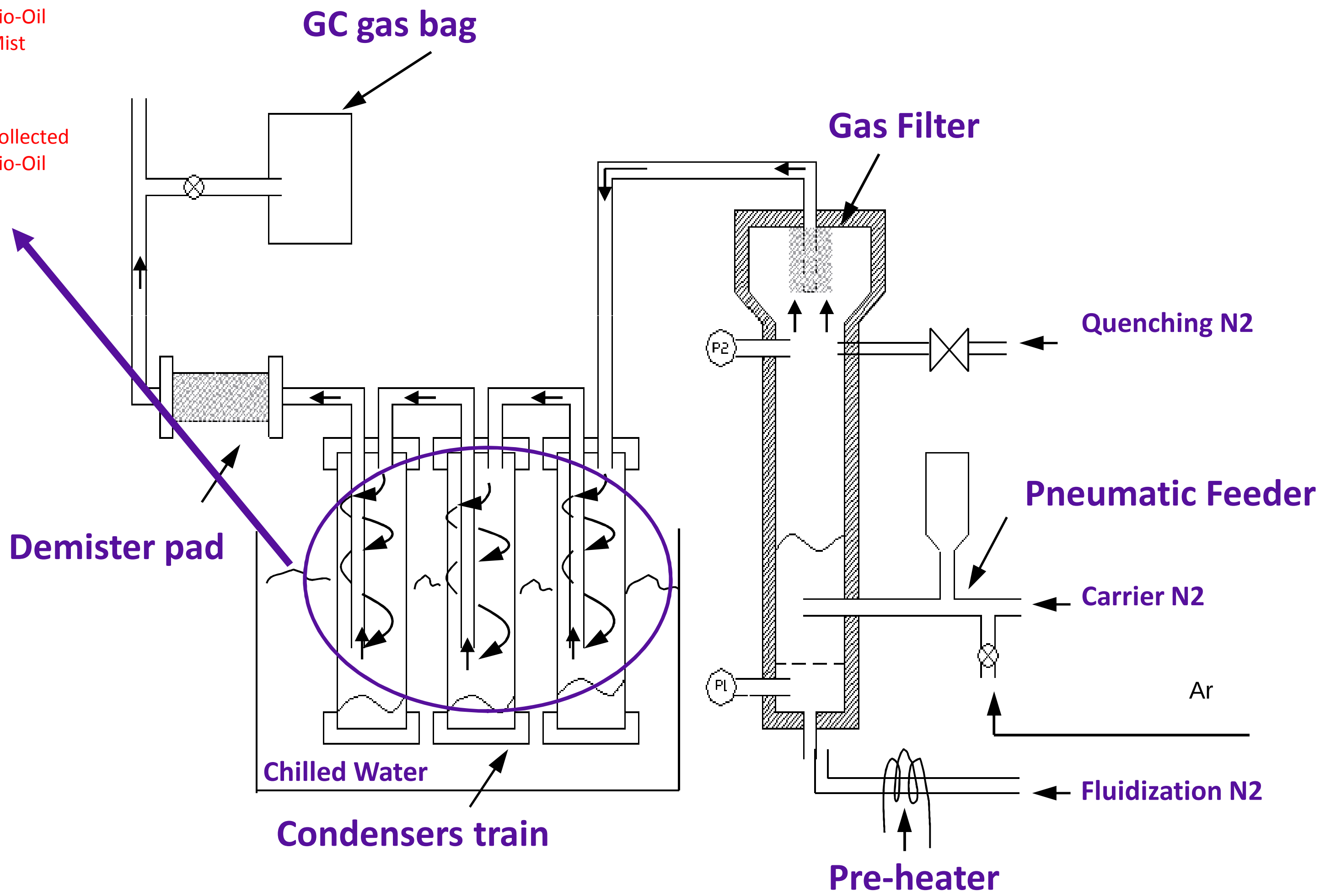
Experimental Set Up

ICFAR Pilot Plant



Experimental Set Up





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- Motivation
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- **Experimental Results**
  - **Product Yields (Mass Balance)**
  - **Thermal Sustainability (Heat Balance)**
  - **Liquid Bio-Oil Product**
- Conclusion

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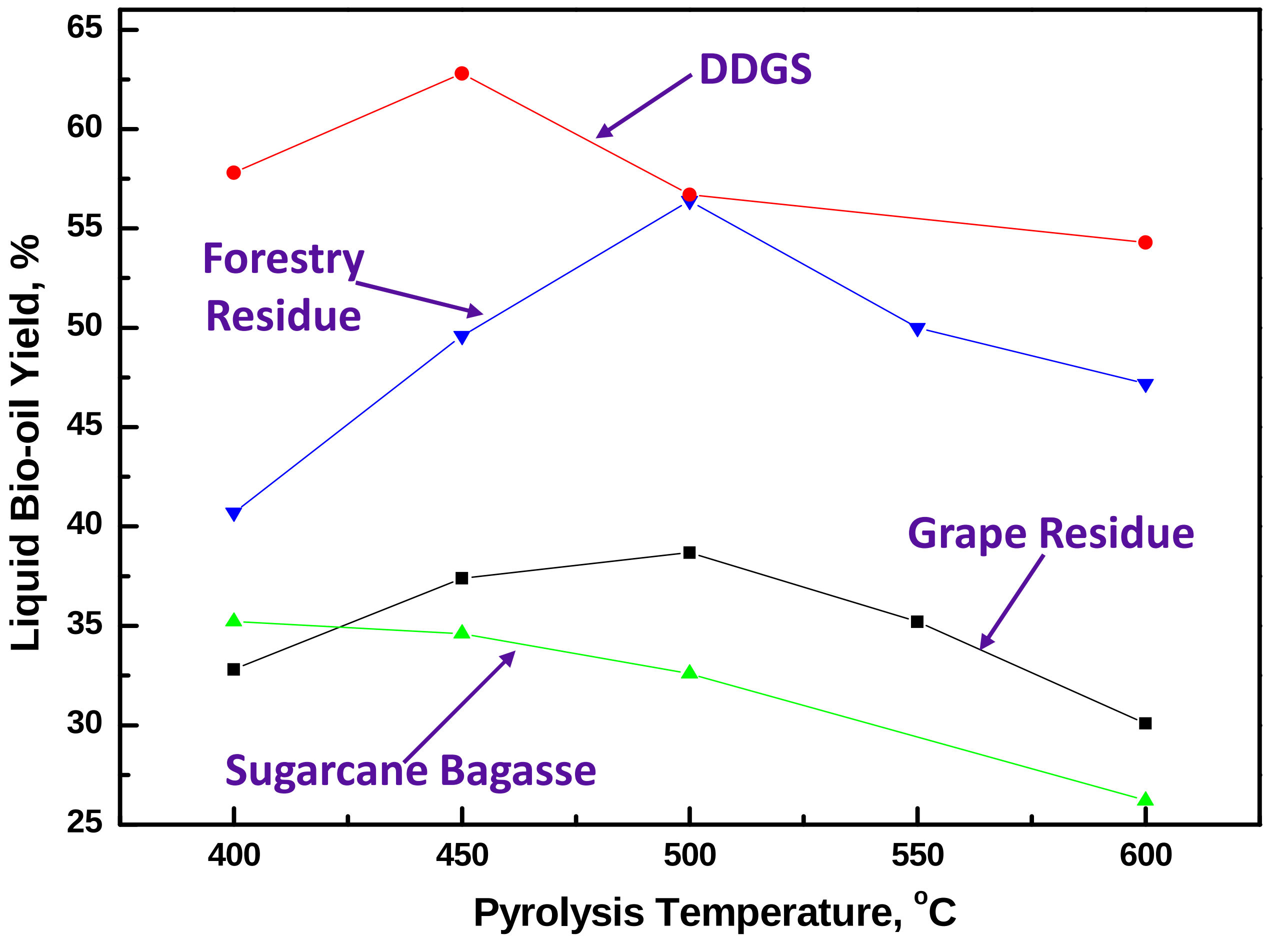
Experimental Results

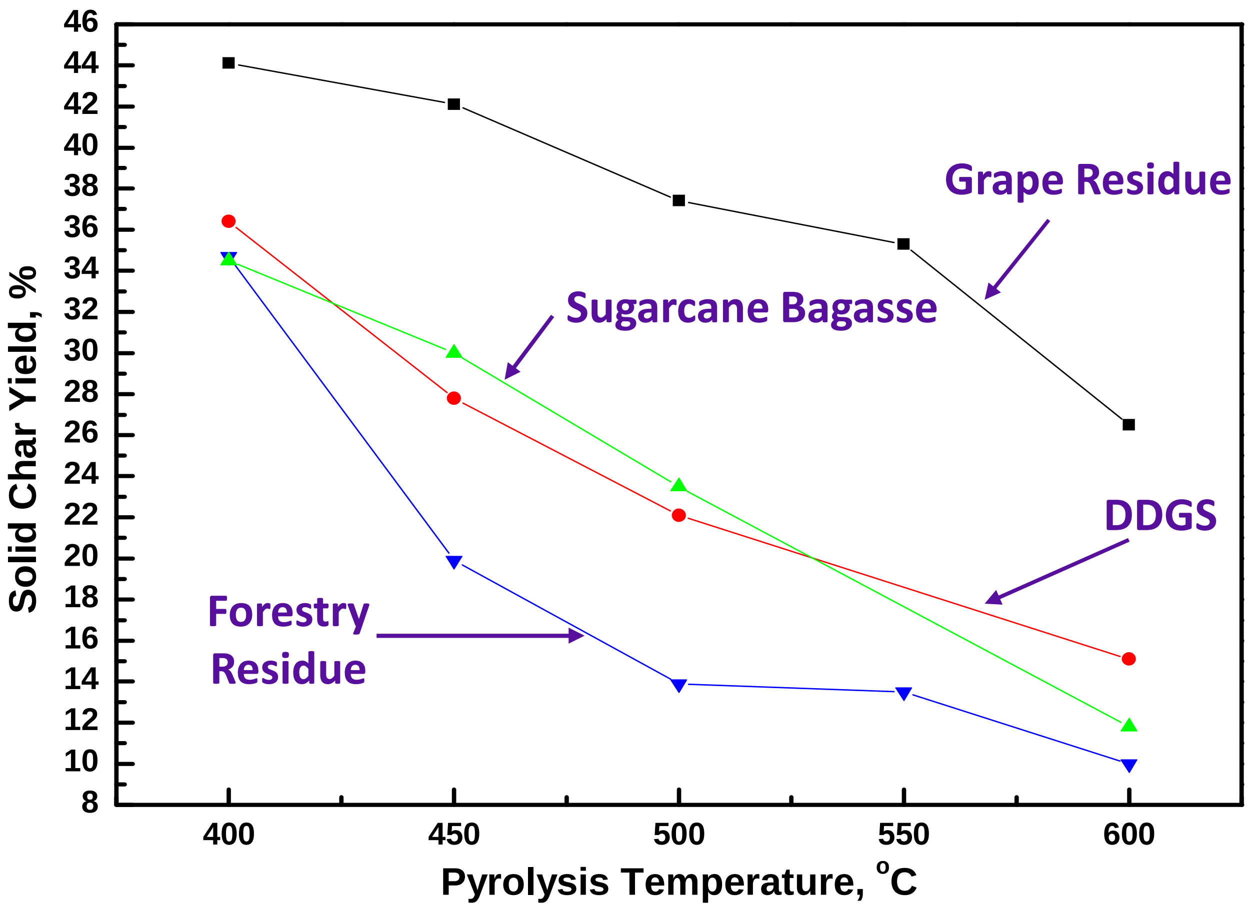
Product Yields: Liquid

Liquid Bio-oil Yields of Different Biomass Resources
Residence Time: 5 seconds



Experimental Results
Product Yields: Biochar

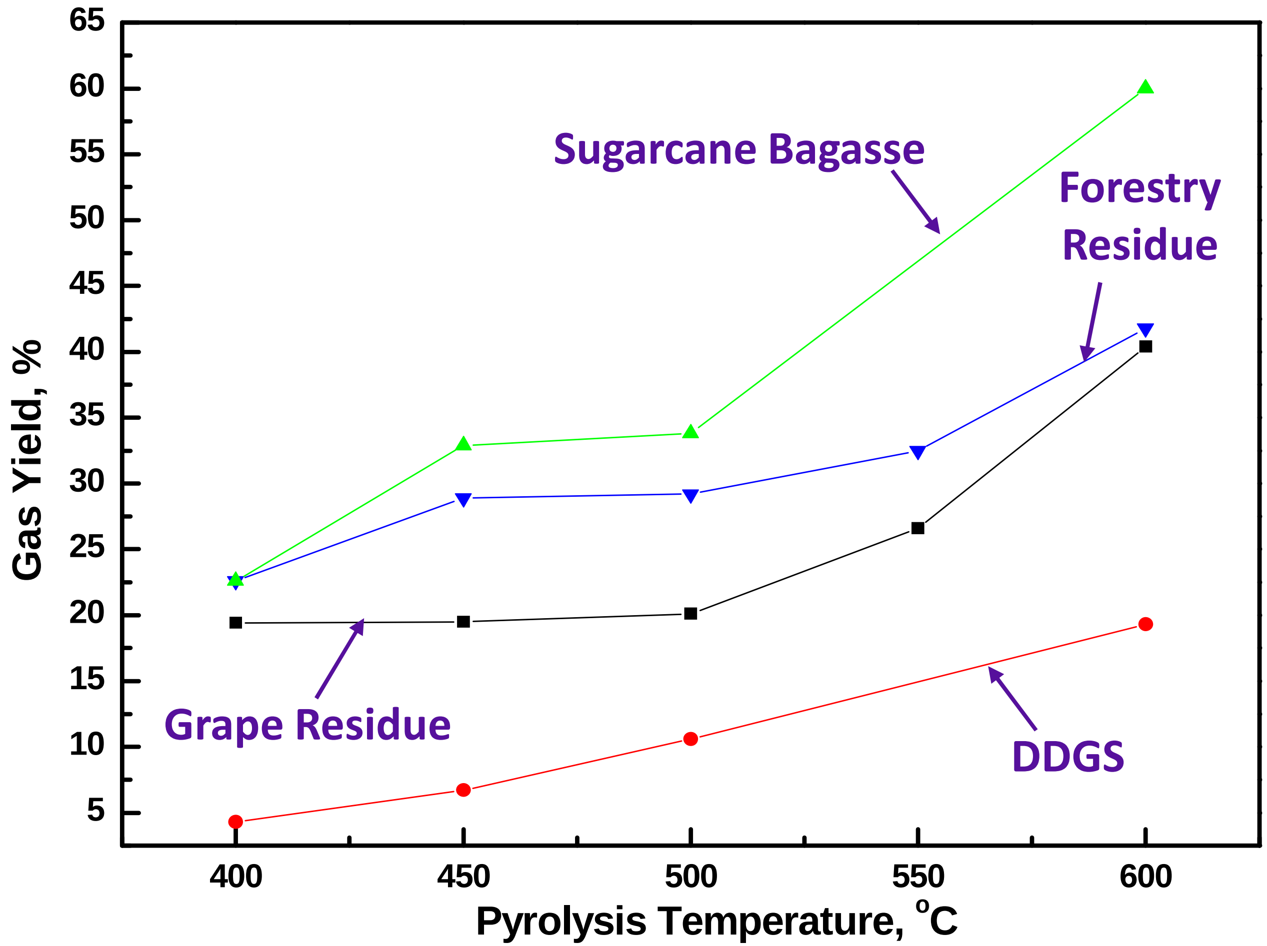
Solid Biochar Yields of Different Biomass Resources
Residence Time: 5 seconds



Experimental Results

Product Yields: Gases

Gas Yields of Different Biomass Resources
Residence Time: 5 seconds



Experimental Results

Thermal Sustainability (Heat Balance)

Heat Measurements

• Heat of Pyrolysis	=	Heaters Power consumption during the pyrolysis test	-	Power consumption before the start of the feed
• Lower Heating Value (LHV) of the Feedstocks and Liquids Products	=	Higher Heating Value (HHV)	-	Water vapor in the combustion gases

• Lower Heating Value (LHV) of the product gases

estimated from the product gases composition and the lower calorific value of each gas.

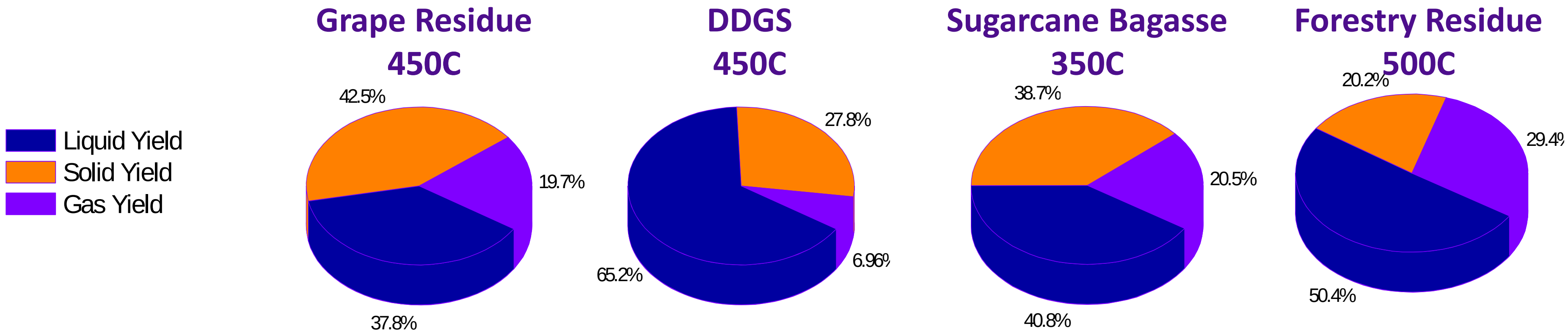
Thermal Sustainability

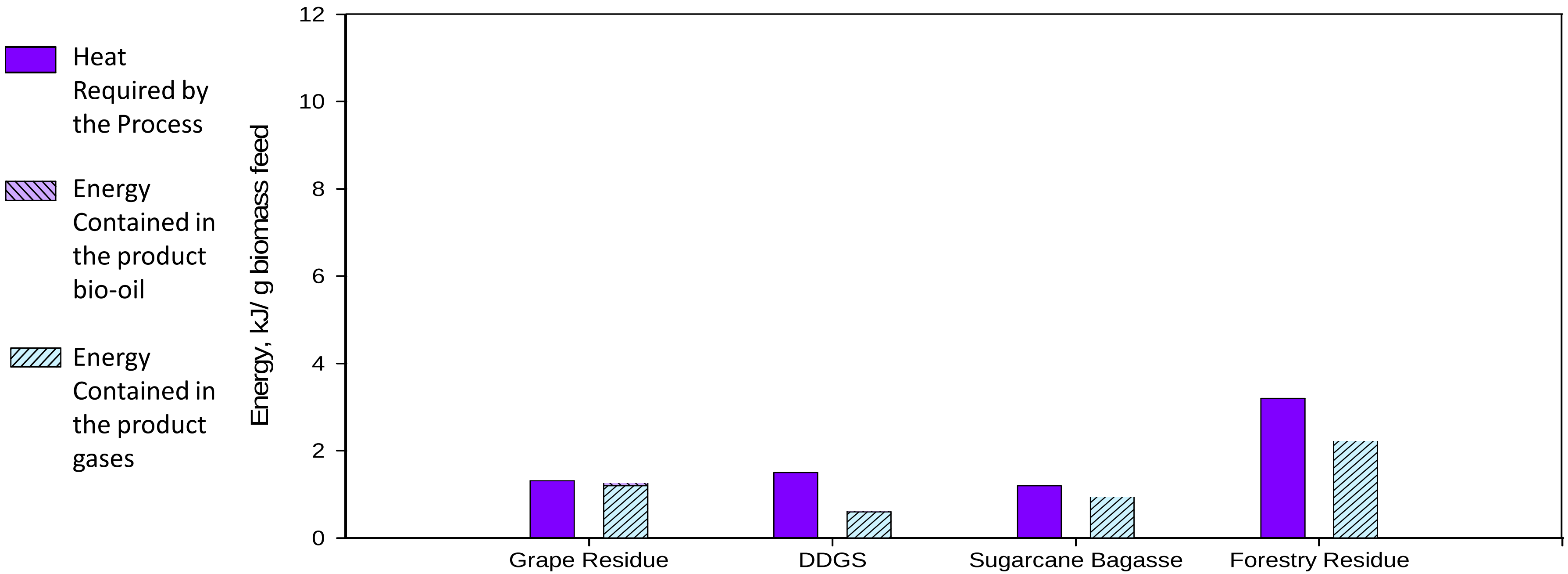
Heat of Pyrolysis	**vs.**	**Product Gases LHV** **Product Bio-oil LHV**

Experimental Results

Thermal Sustainability (Heat Balance)

Pyrolysis at the Temperature for Maximum Liquid Yield, 5s Residence Time

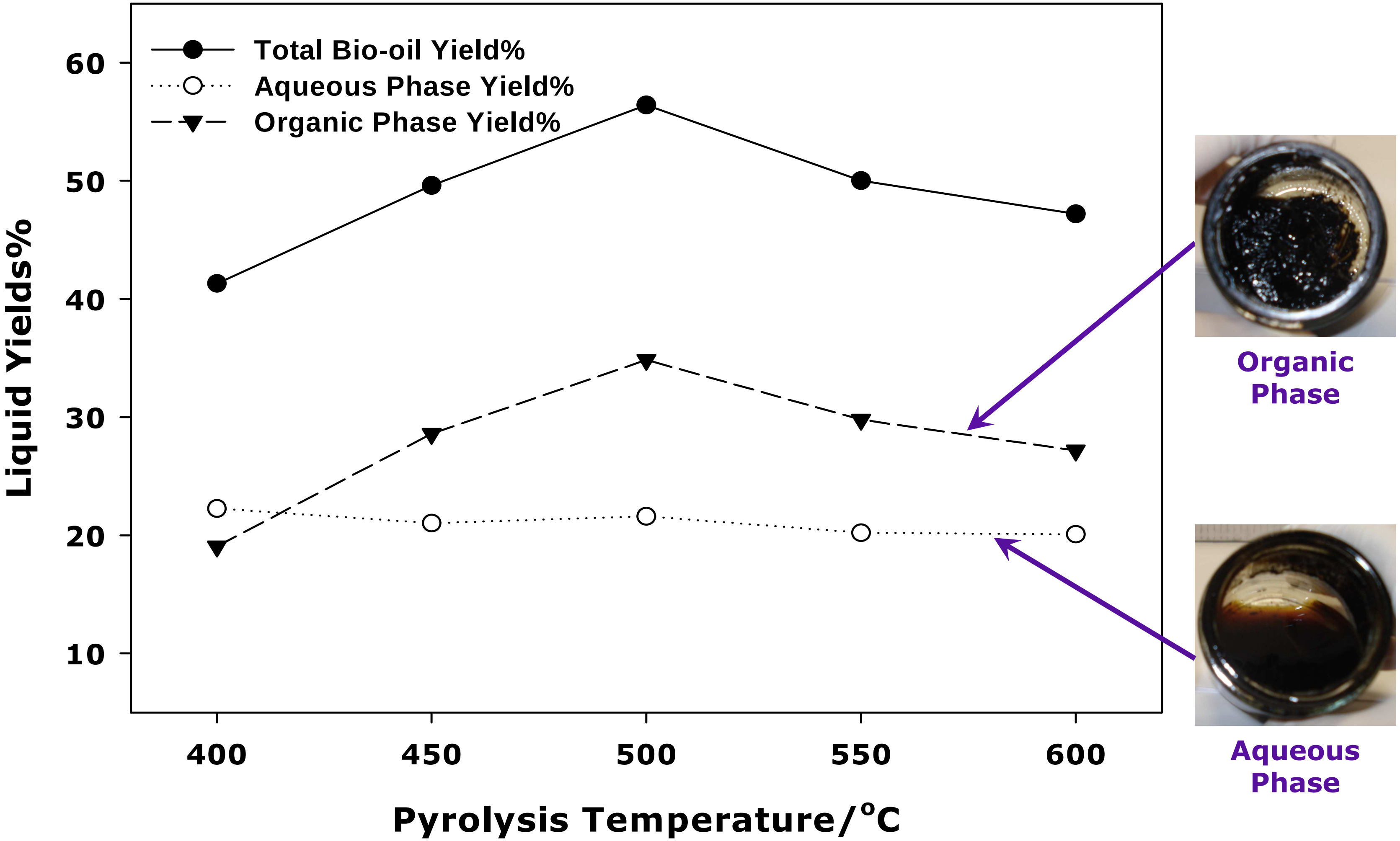




Forestry Residue Bio-oil

Bio-oil Phase Separation

Forestry Residue Pyrolysis Liquid Biooil
Aqueous Phase & Organic Phase Yields



Grape Residue Bio-oil
Aqueous Phase Environmental Analysis

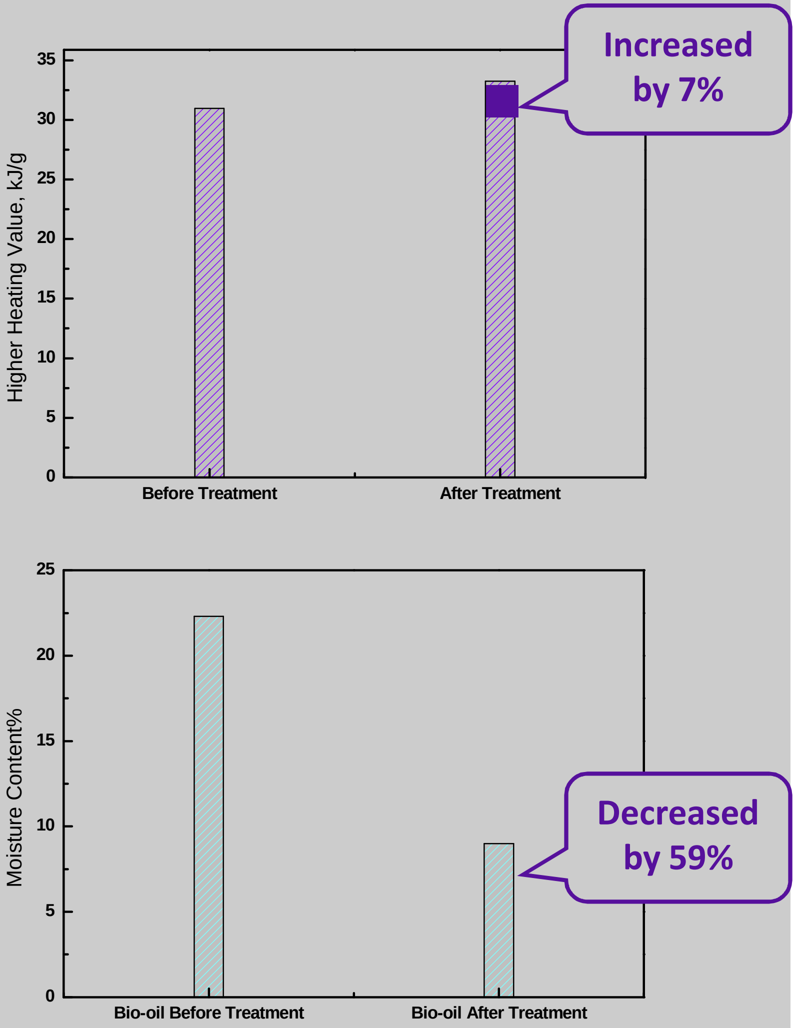
- Environmental analysis has been conducted for the distilled aqueous phase (85 C to 115 C):

  Total Ammonia-N, Total BOD, COD, TKN, TOC, Phenols-4AAP, etc.

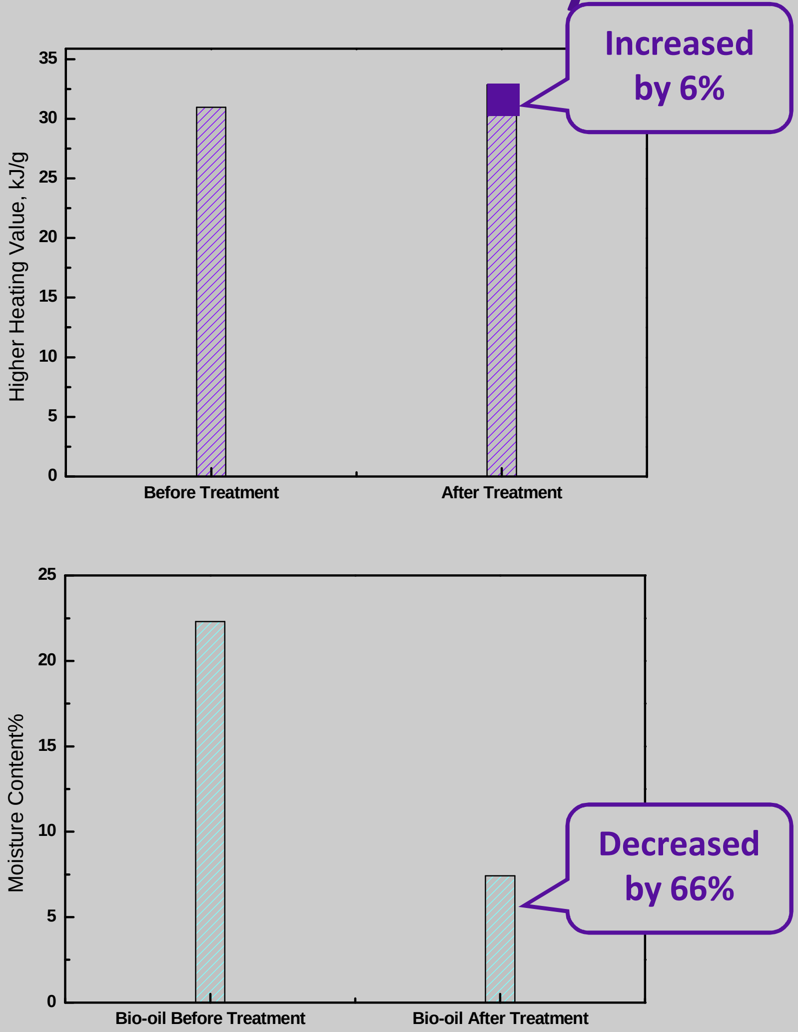
- Comparison with ”Sanitary and Combined Sewer Discharge by Law, Toronto, Canada” shows that the distilled aqueous phase needs to be treated before disposal to sewer.

Dried Distiller's Grains Bio-oil
Organic Phase Drying Agents

Molecular Sieve 4A



Sodium Sulfate Anhydrous



Conclusions

For the product yields at 5 s residence time:

Maximum liquid yield at:

- 450 ºC for grape residue and DDGS.
- 350 ºC for sugarcane bagasse.
- 500 ºC for forestry residue.

Thermal Sustainability : It can be achieved by burning all the gas products and part of the bio-oil

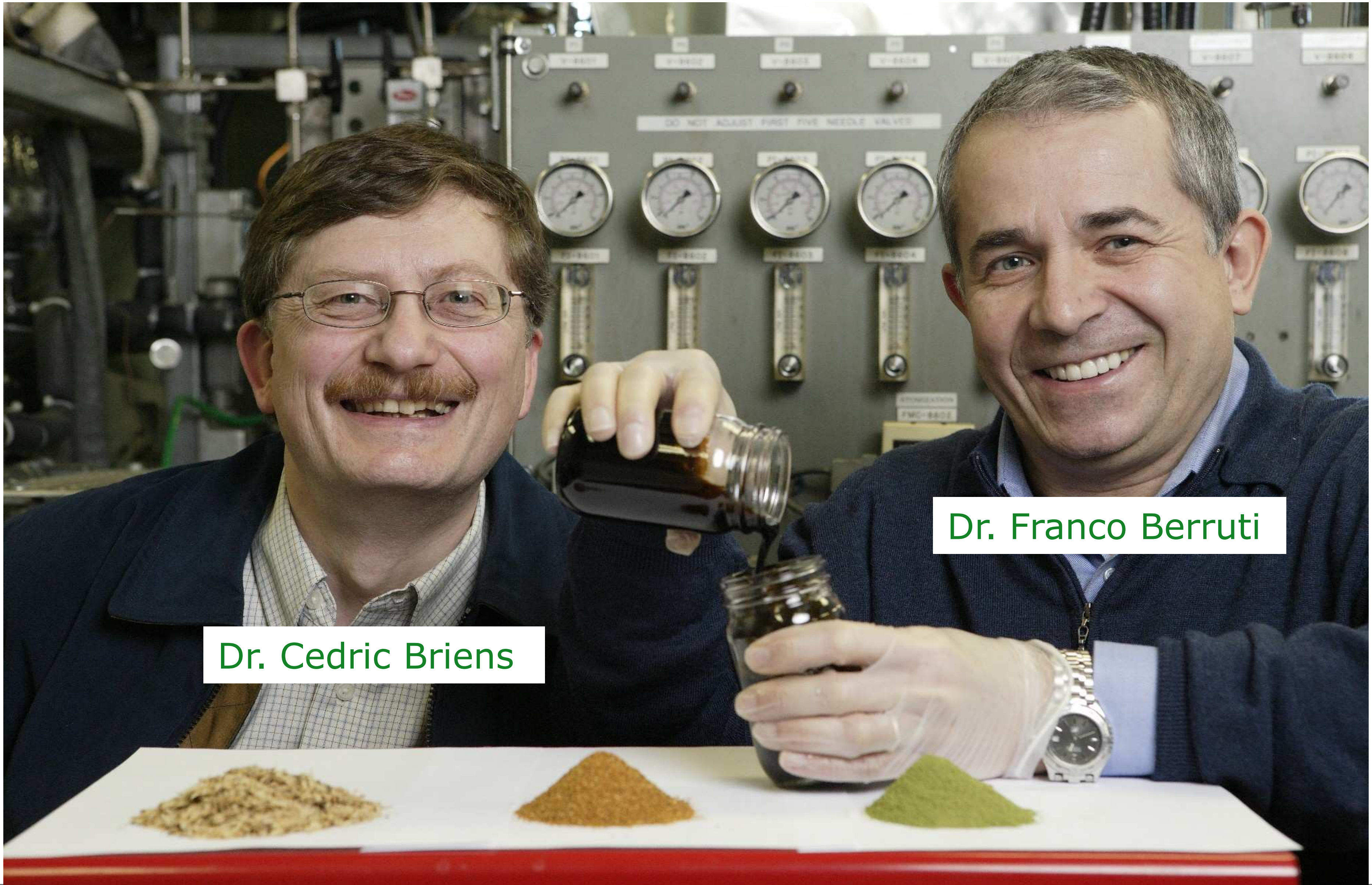
Phase separation of Bio-oil :

- The aqueous phase of grape bio-oil needs to be treated before disposal to sewer.
- The heating value of the organic phase of DDGS bio-oil can be enhanced through the use of drying agents.

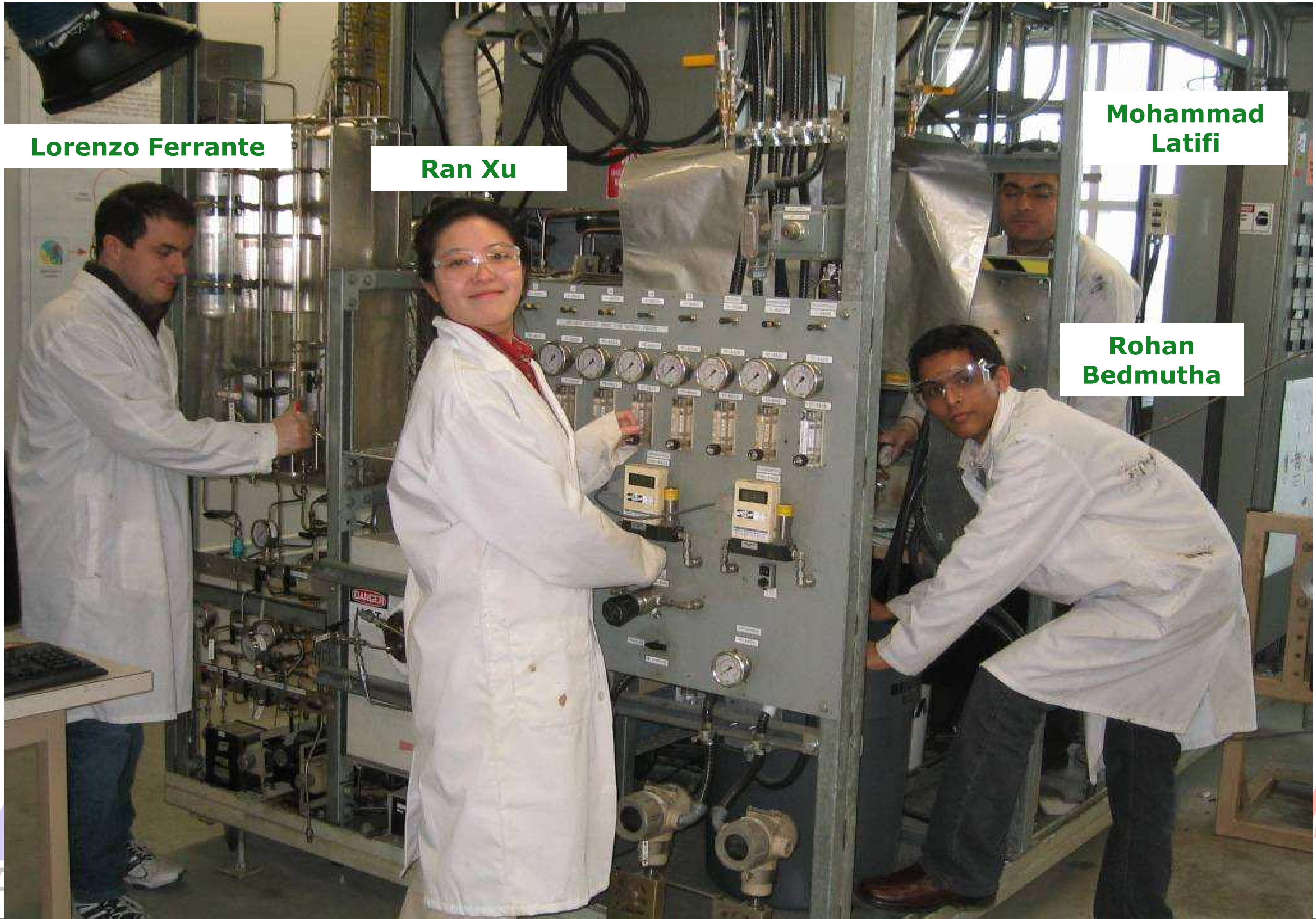
Acknowledgements

- Natural Sciences & Engineering Research Council of Canada
- Canada Foundation for Innovation
- Ontario Research Fund
- Agri-Therm
- Ontario Centers of Excellence
- Agriculture and Agri-Food Canada
- The University of Western Ontario

Our Team: Supervisors



Our Team: Lab Pilot Plant Team



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Questions?

Thank You!

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Grape Residue Bio-oil
Aqueous Phase Environmental Analysis

	Units	Distilled Aqueous Phase Grape Bio-oil	Sanitary and combined sewer discharge by Law, Toronto, Ontario[i]	RDL
Calculated Parameters				
Hardness ($CaCO_3$)	mg L_{-1}	11		1
Inorganic				
Total Ammonia-N	mg L_{-1}	10000 #	<50	300
Total BOD	mg L_{-1}	3400	<300	2
Total Chemical Oxygen Demand (COD)	mg L_{-1}	21000	<500	800
Conductivity	Umho/cm	29100		2
Total Kjeldahl Nitrogen (TKN)	mg L_{-1}	10000 #	<100	400
Total Organic Carbon (TOC)	mg L_{-1}	7010	<500	5
pH	pH	9.5	6~10.5	
Phenols-4AAP	mg L_{-1}	1080	<1.0	250
Total Phosphorus	mg L_{-1}	ND *	<10	1
Total Suspended Solids	mg L_{-1}	36	<350	10
Volatile Suspended Solids	mg L_{-1}	36	<350	10
Alkalinity (Total as $CaCO_3$)	mg L_{-1}	32700	<250	10
Nitrite (N)	mg L_{-1}	ND		1
Nitrate (N)	mg L_{-1}	ND		10
Nitrate + Nitrite	mg L_{-1}	ND		10
Petroleum Hydrocarbons				
Total Oil & Grease	mg L_{-1}	1	<150	1