Advanced biomass fuels and products

---- where value is recovered from every co-product of the biomass conversion processes

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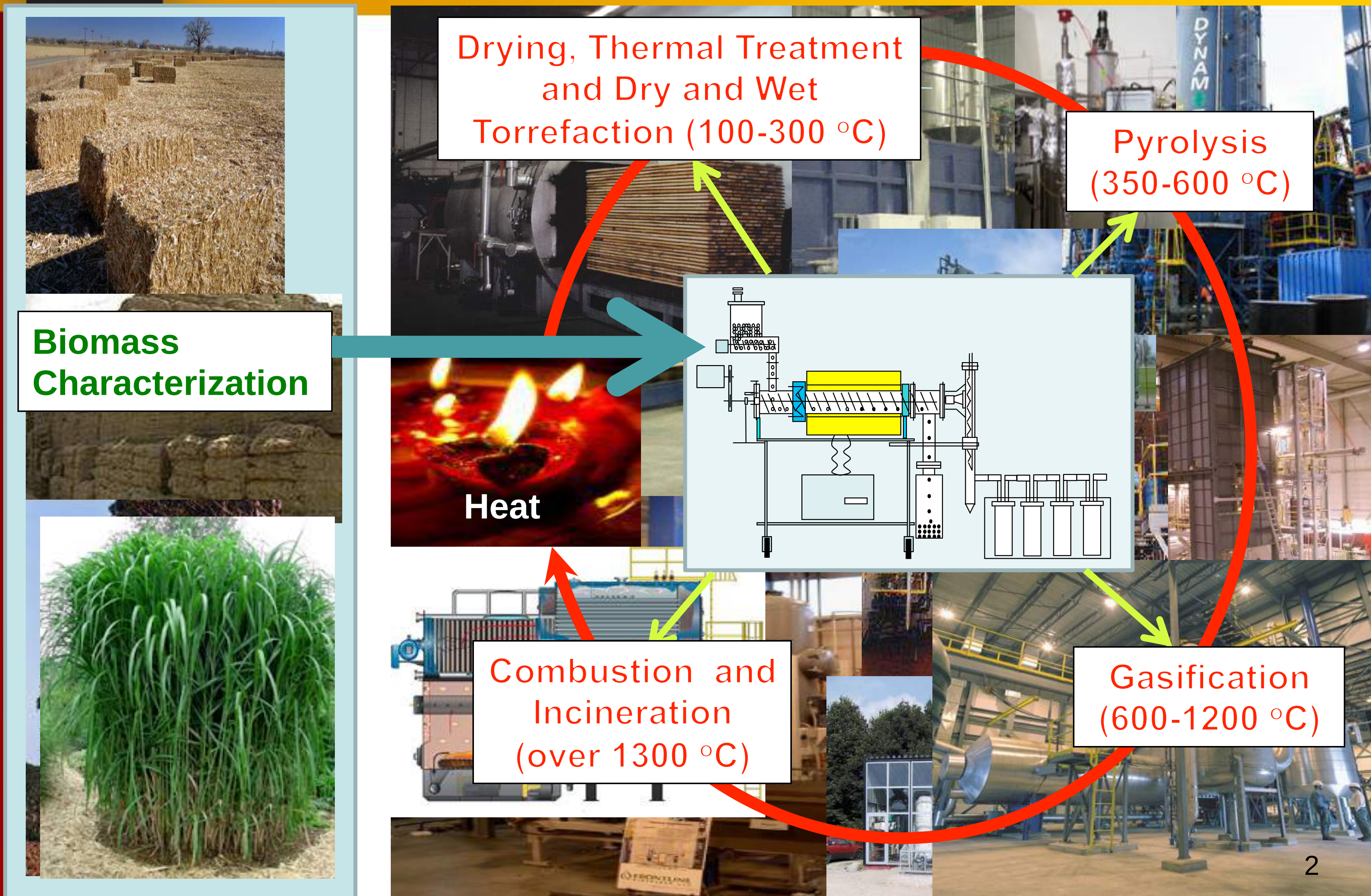
Ag Biomass Day March 27, 2015

Biomass Thermo-chemical Conversion Technologies of Interest



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Bio-Renewable Innovation Lab at Guelph

INTRODUCTION

- Bio-Renewable Innovation Lab (BRIL) at Guelph is built and located in the Thornbrough Building of University of Guelph.
- BRIL composed of two parts: research pilot plant and analytical laboratory.

Research Pilot Plant

The pilot plant involves research facilities such as supercritical, chemical looping, multi-stage, and circulating fluidized bed reactors, which have helped our group achieving research in three different areas of biomass conversion.

1) Feedstocks pre-processing

Ultrasonic equipment

Pelletization

2) Thermochemical conversion processes

Hydrothermal procesing

Moving bed reactor

Chemical Looping Gasifier

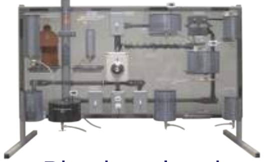
Supercritical flow reactor

Multi-Stage downdraft Gasifier

Two-Stage Gasifier-combustor

3) Bio-chemical conversion processes

Bio-syngas Fermentation



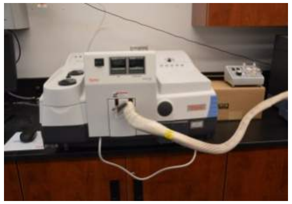
Bioethanol and biodiesel facility

Analytical Laboratory

Scientific analytical instruments for both qualification and quantification analyses.

Elemental Analyzer (C, H, N, S, O)

GC-FID/TCD



FTIR

DSC-TGA

Bomb Calorimeter

Planetary Ball Mill (Grinder)

To know more

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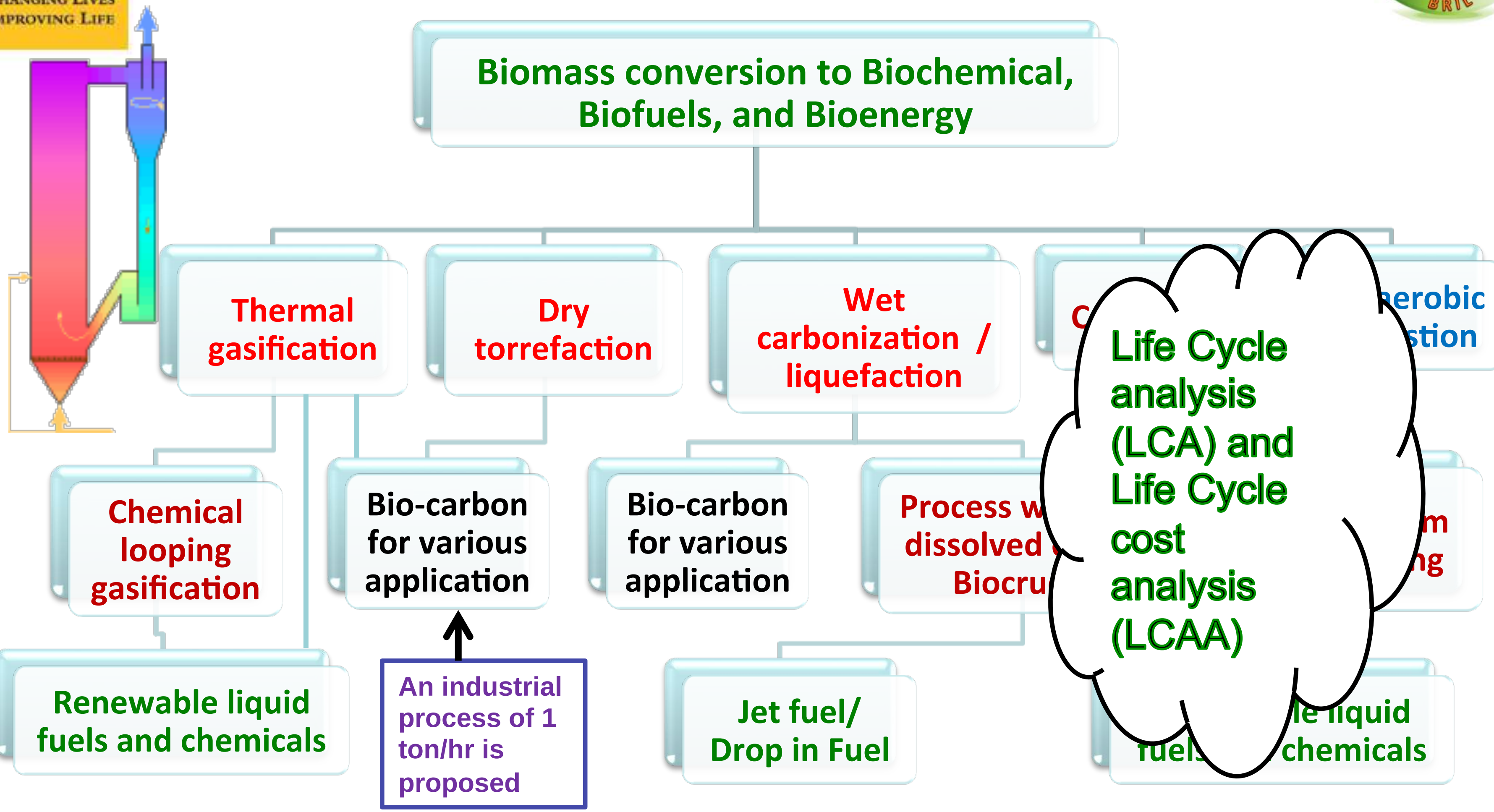
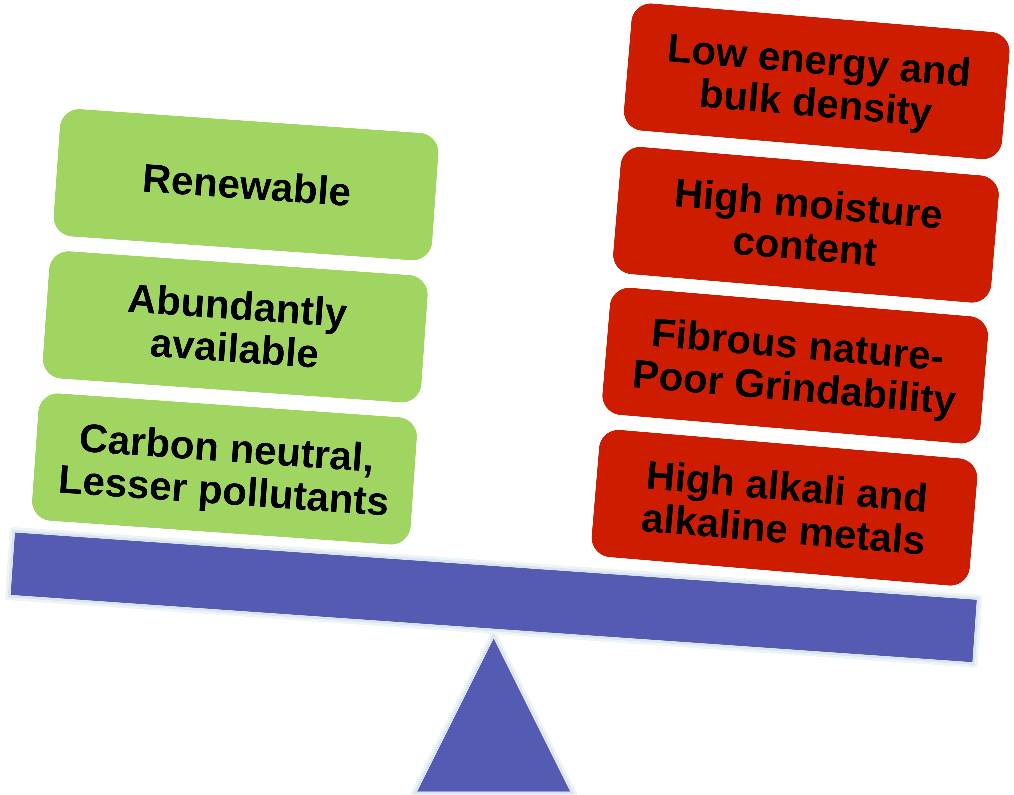
Biomass Conversion Research Program at BRIL



Funding agency: NSERC, OMAF & MRA, MITACS, Industry, Ontario ministry of environment, CFI, MRI

Pros and Cons of Biomass



“Therefore, biomass is not regarded as an Ideal fuel for energy conversion and hence needs to be pre-processed or pre-treated”

Pre-treatment of biomass research at Bio-renewable Innovation Lab

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Research Questions?

- Can we produce biocarbon/bioblack from this low quality biomass with similar properties to that of coal (low alkali metals, higher HHV, and higher grindability)?
- Will there be any by-product? What can we do to have a value added product?

Methods investigated to produce biocabon

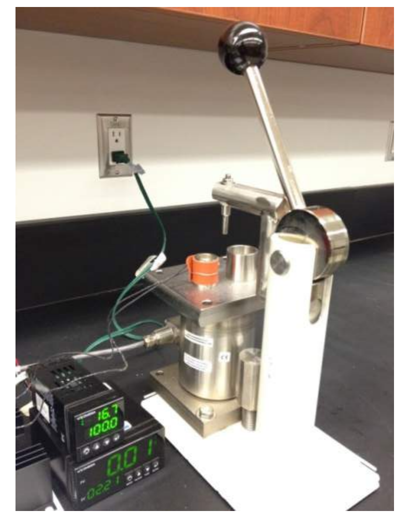
- Slow Pyrolysis (torrefaction/carbonization)
- Hydrothermal carbonization (HTC)
- Hybrid HTC and slow pyrolysis

Custom build Macro TGA (a tubular reactor for slow pyrolysis (200-800 C)

Hydrothermal reactor

Pressure: ~ (1.2-5 MPa)

Temperature: 190-260°C



Pelletization

Pressure: ~ 9 MPa

Temperature: 100°C

Torrefaction: a mild pyrolysis process

(Conventional/Dry Method)

- Typically, biomass is heated in the temperature range of 200-300°C, with residence of 30min to couple of hours under reduced levels of oxygen and atmospheric pressure.

Raw Biomass

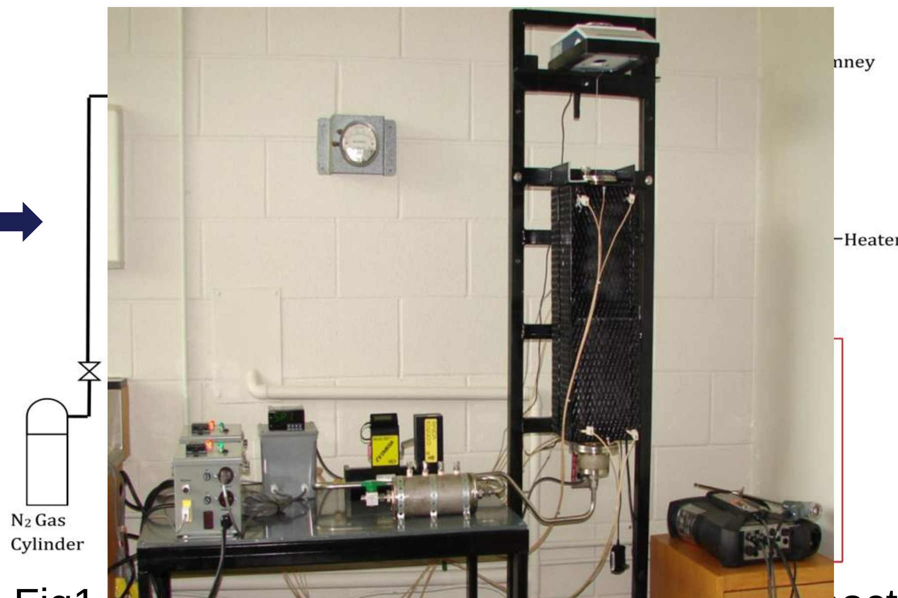


Fig1. Schematic Diagram of Torrefaction Reactor

Torrefied Biomass

- Does Torrefaction converts biomass to an ideal fuel?

Hydrothermal Carbonisation (HTC)

(A Comparatively New Method)

- Biomass is submerged in water and is heated to elevated temperatures (180-260°C) in a confined system, for reaction time of 5mins to couple of hours. Reaction pressure is not controlled and is autogenic with the corresponding temperature of water.

Water

+

Biomass

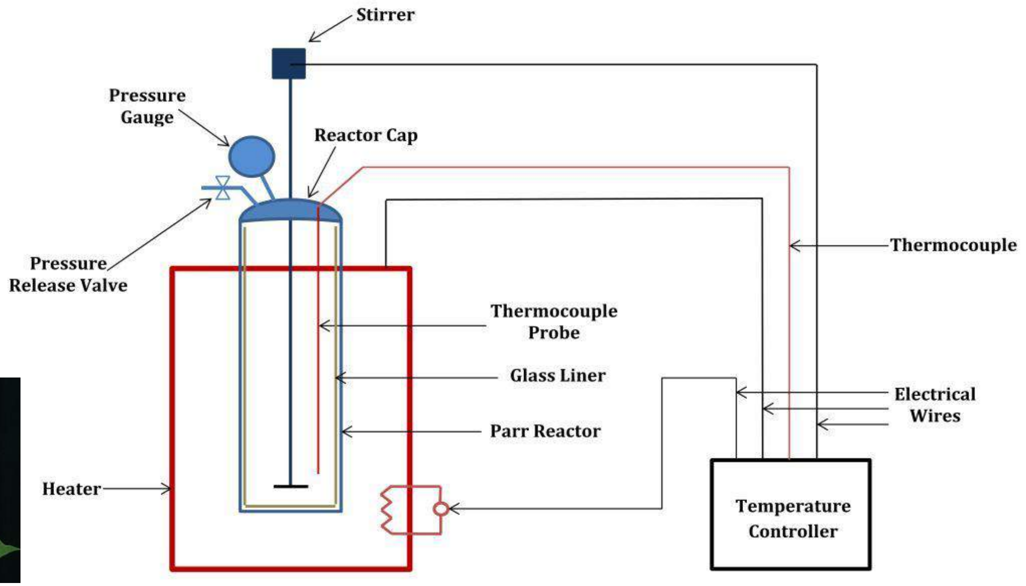
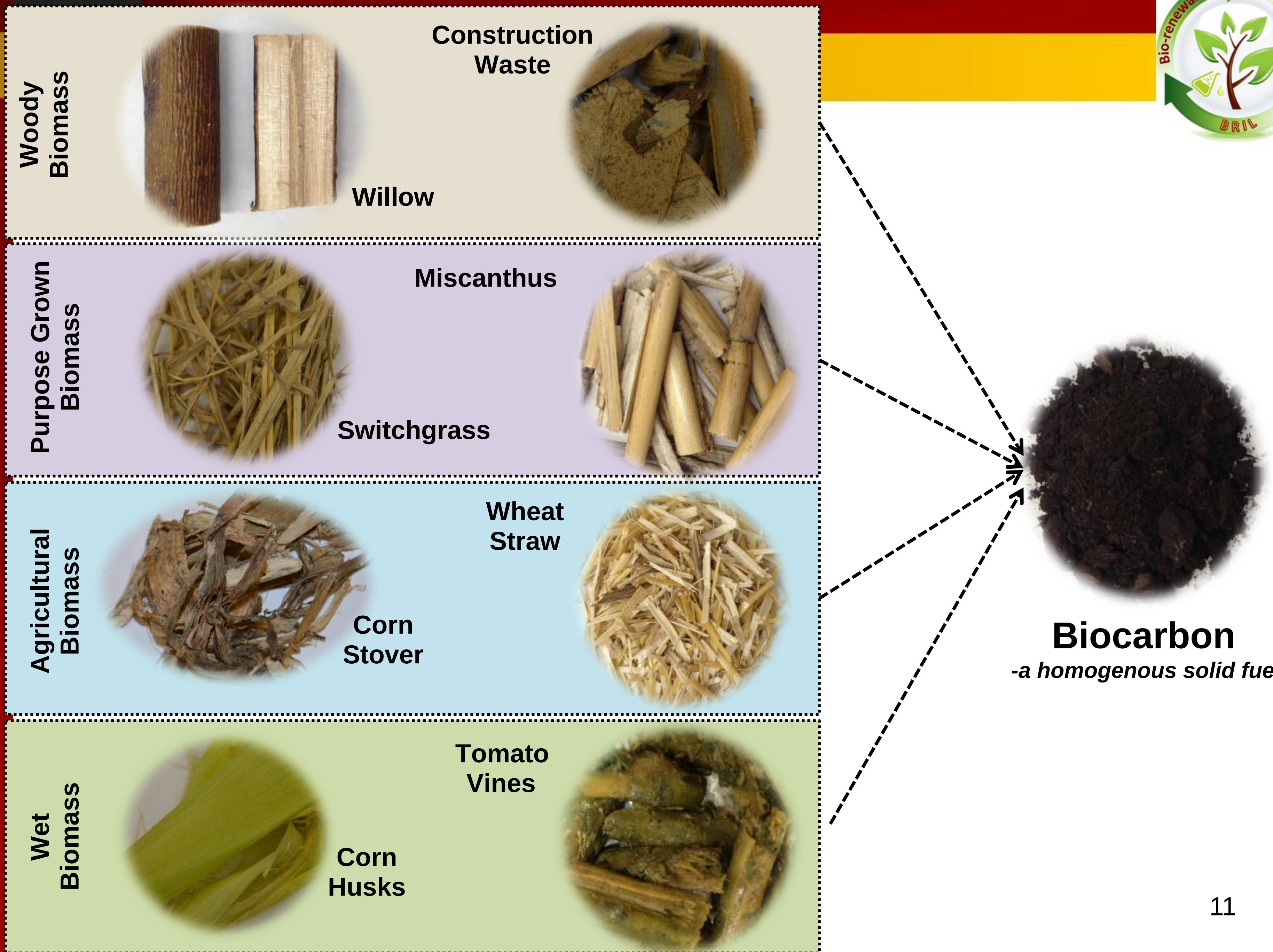
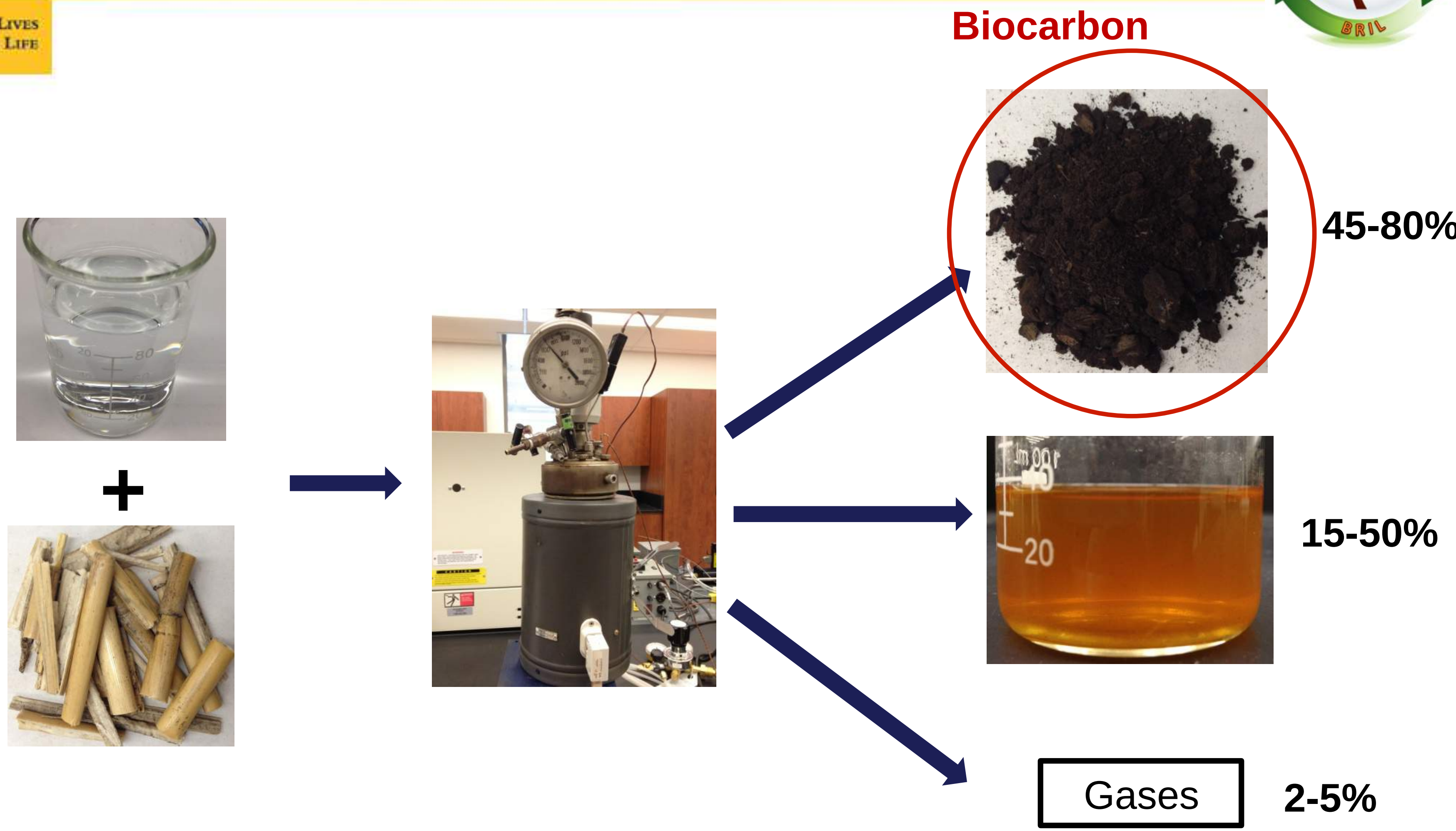


Fig2. Schematic Diagram of HTC reactor

HTC Biomass


Woody Biomass
Willow
Construction Waste
Purpose Grown Biomass
Switchgrass
Miscanthus
Agricultural Biomass
Corn Stover
Wheat Straw
Wet Biomass
Corn Husks
Tomato Vines
Biocarbon
-a homogenous solid fuel

HTC Product Streams



The distributions & properties of products strongly depends on reaction conditions!

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Effect of Pre-treatment on Polymeric Composition

Pre-treatment	Material (Miscanthus)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Extractives (%)	Ash (%)
HTC	Raw	36.30	38.80	11.50	12.60	0.80
	190C-5min	5.77	56.94	15.61	21.14	0.54
	225C-5min	5.11	53.38	17.75	23.08	0.68
	260C-5min	0.97	27.50	30.57	39.99	0.97
Torrefaction	260C-30min	21.46	36.21	41.31	6.20	1.02

Raw HTC-190C HTC-225C HTC-260C Torrefaction-260C

Grinded

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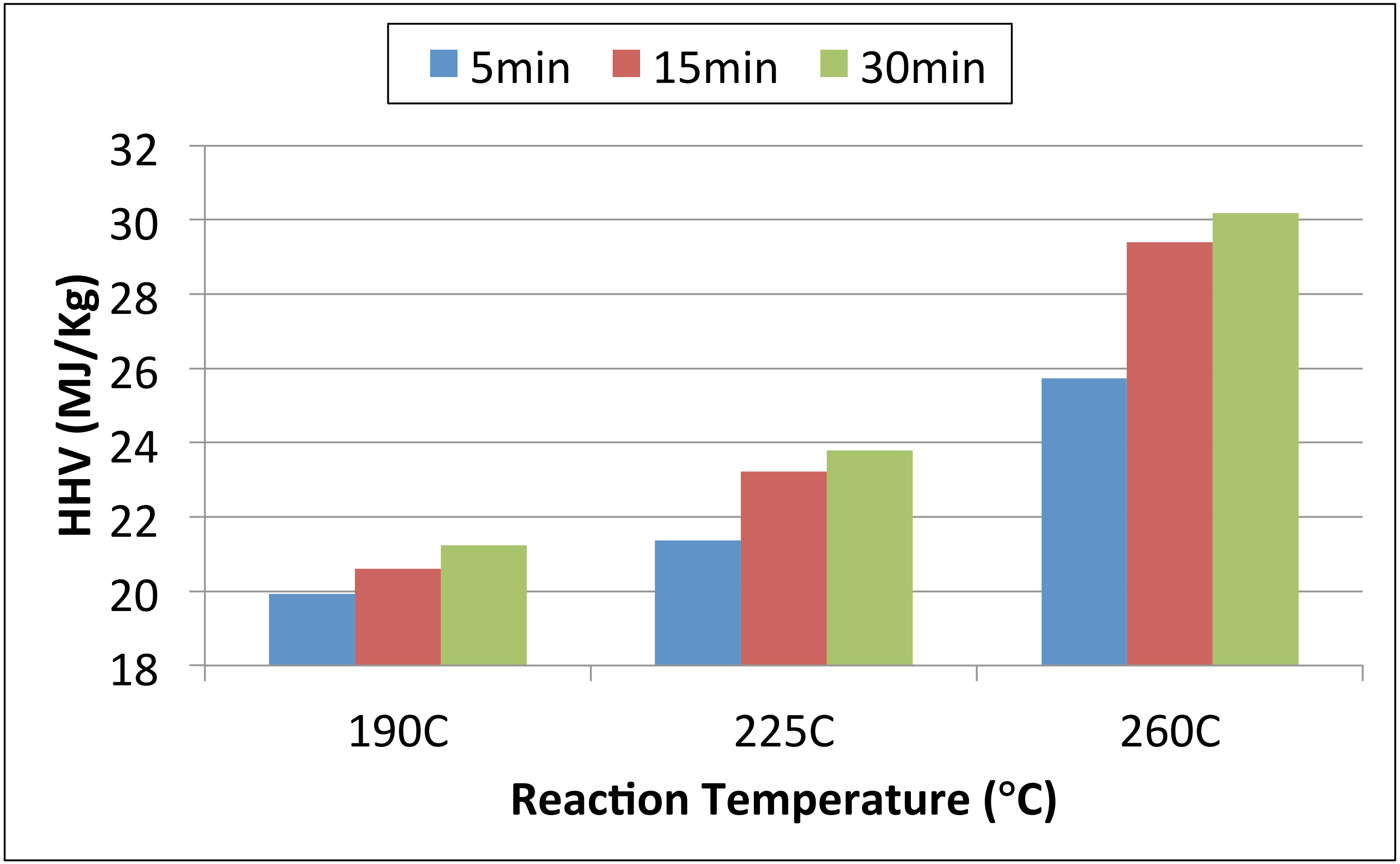
Effect of HTC on Higher Heating Value (HHV)



Raw Miscanthus: 18.47MJ/kg

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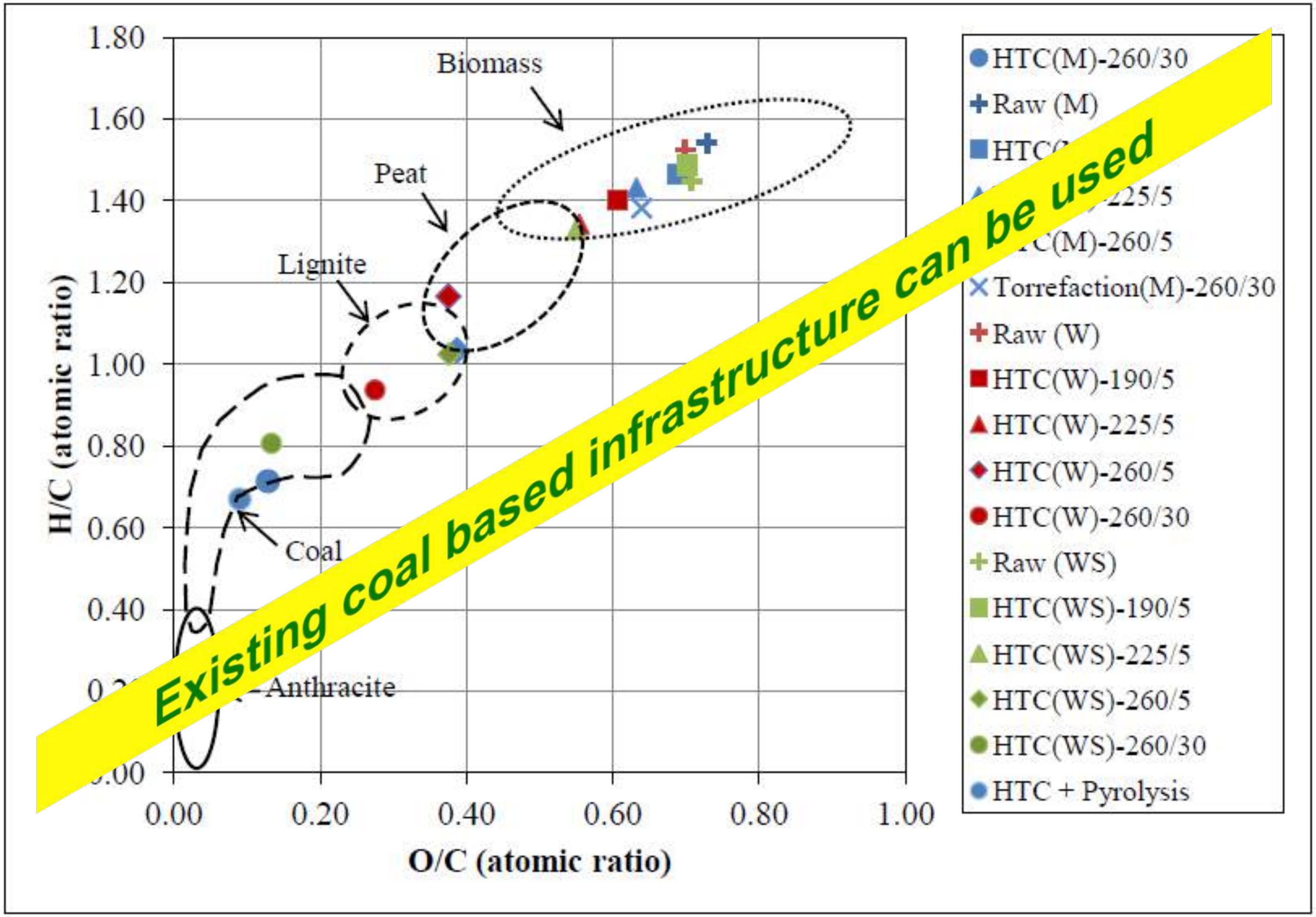
Van-krevalen diagram

(Effect on H/C-O/C Atomic Ratios)



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Effect of Pre-treatment on Alkali and Alkaline Content

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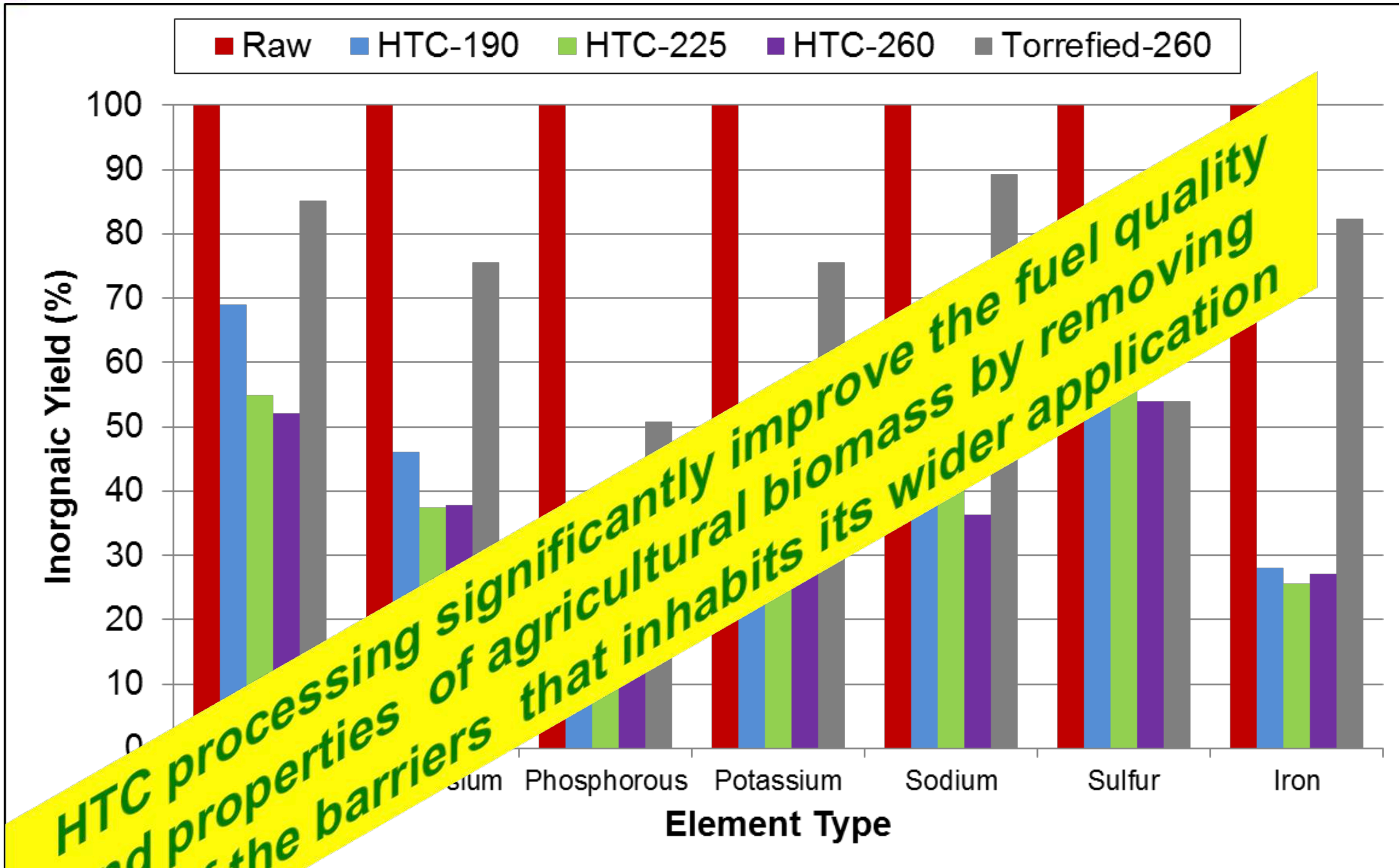

HTC processing significantly improve the fuel quality and properties of agricultural biomass by removing most of the barriers that inhabits its wider application

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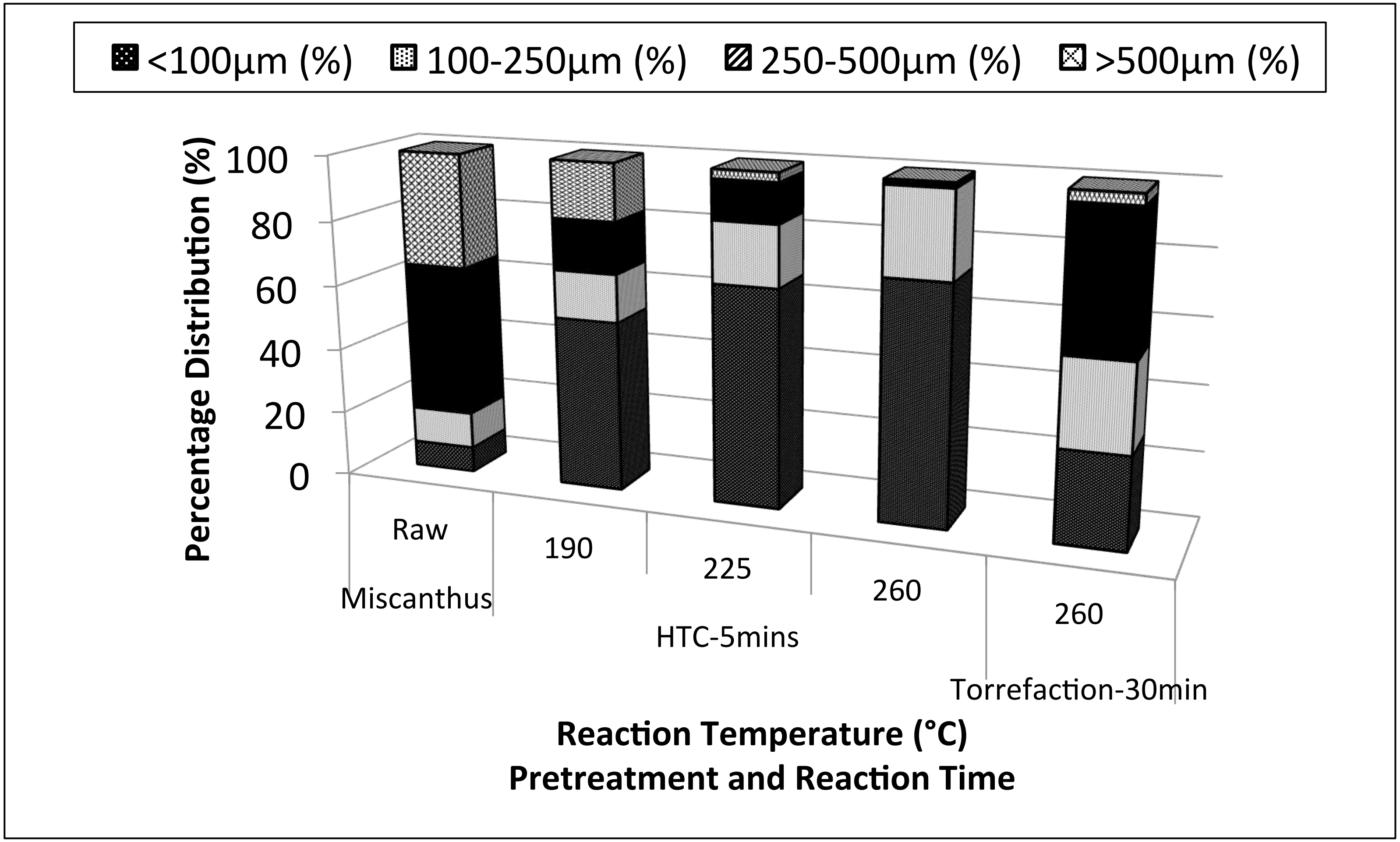
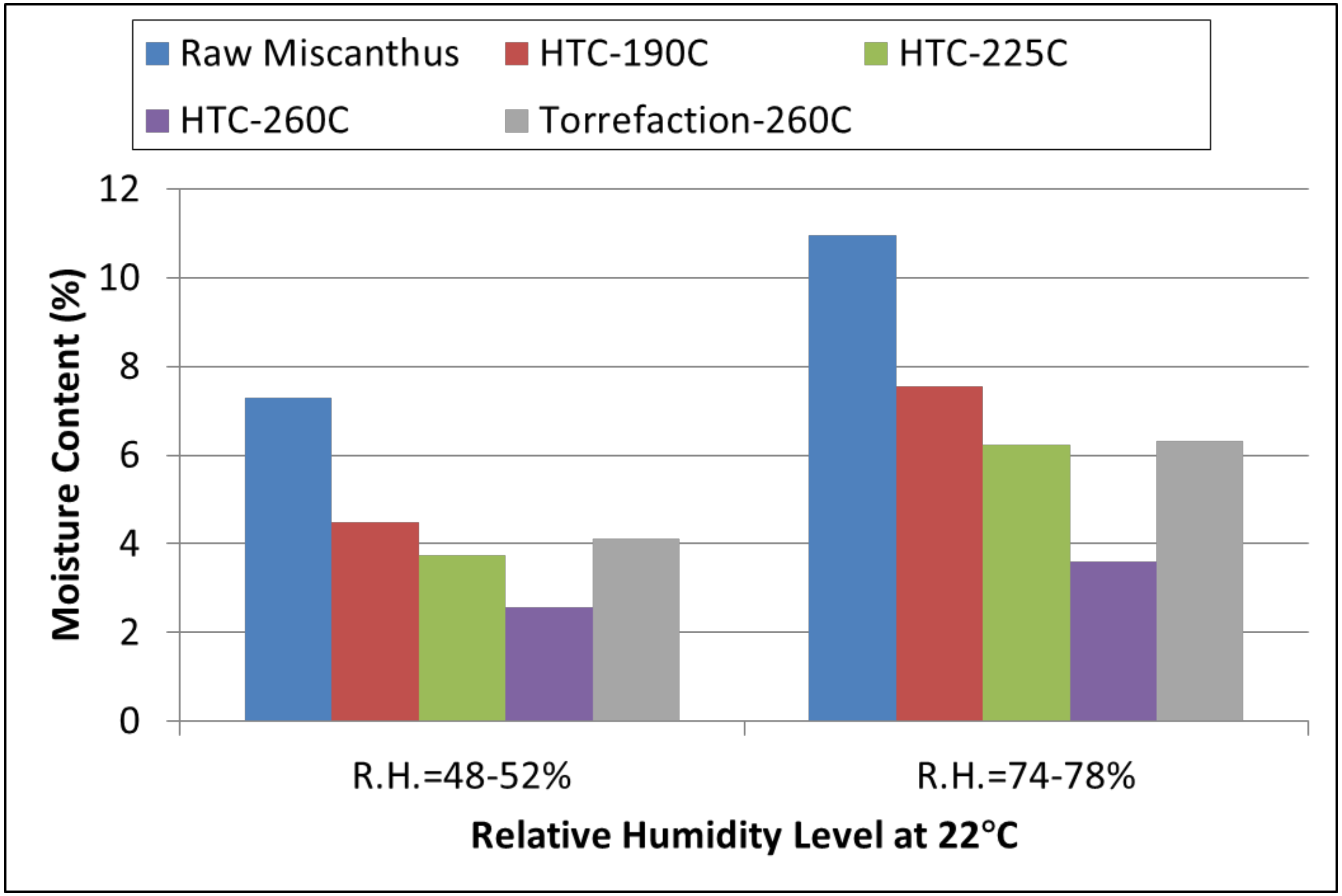
Effect of pre-treatment on Grindability

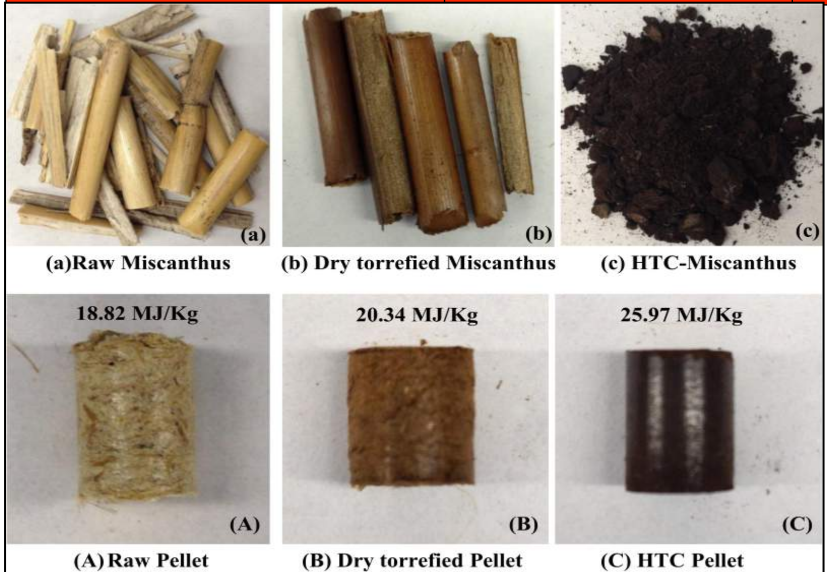


Effect of pre-treatment on Hydrophobicity

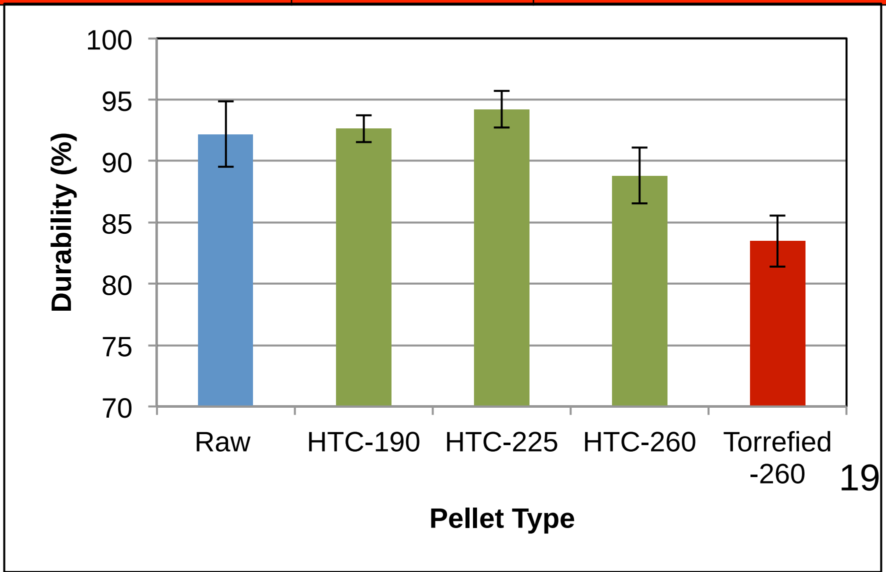


Effect on Mass and Energy Density

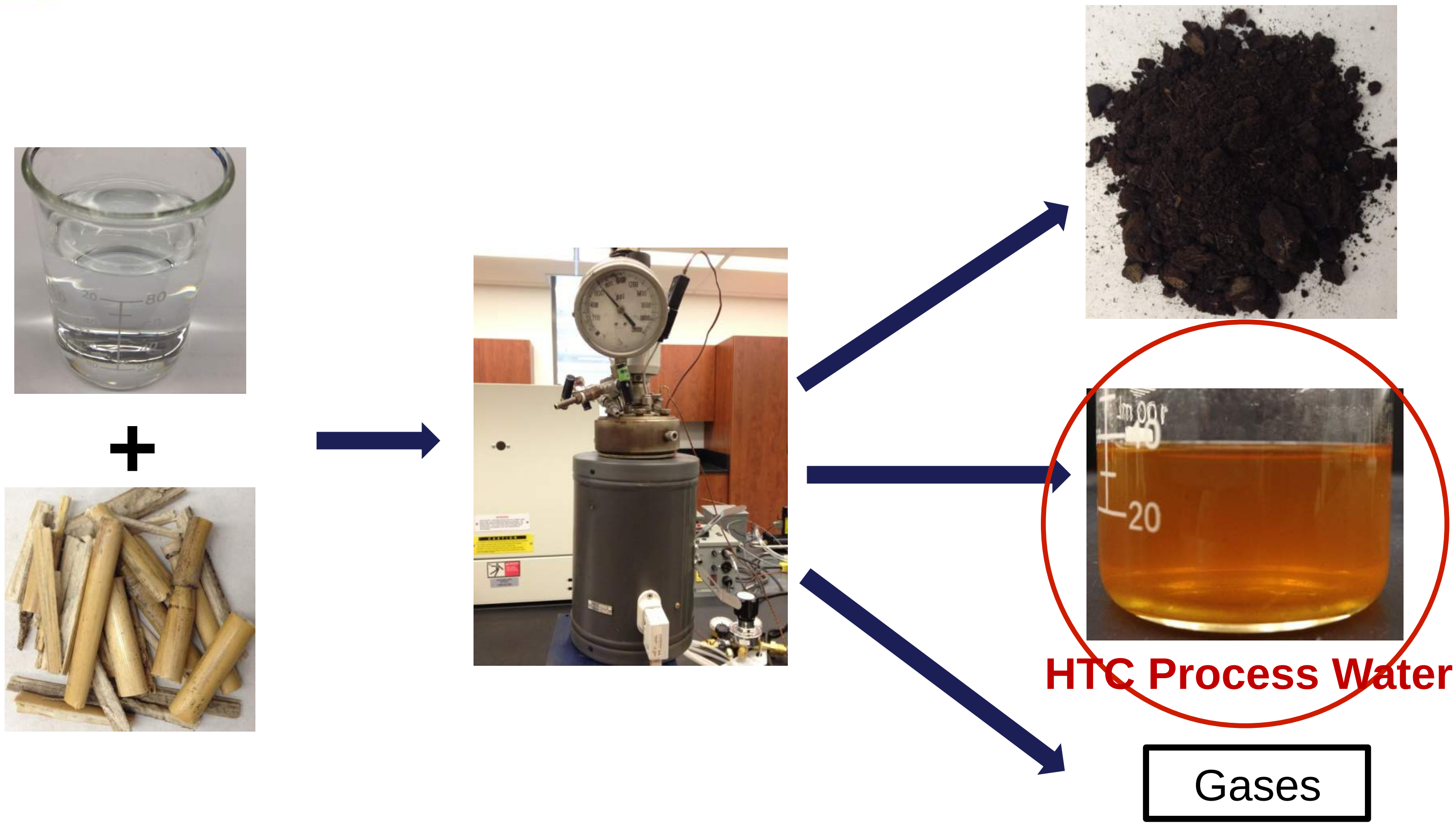
Material	Reaction Time (mins)	Mass Density (kg/m^3)	HHV (MJ/kg)	Energy Density (GJ/m^3)
Raw Biomass		321.09	18.47	5.93
Raw Pellet		834.05	18.82	15.69
HTC-190	5	886.87	20.19	17.9
HTC-225	5	959.39	21.62	20.74
HTC-260	5	1035.99	25.97	26.9
HTC-260	30	-	29.52	-
Torrefaction-260C	30	819.55	20.34	16.66



(a)Raw Miscanthus (b) Dry torrefied Miscanthus (c) HTC-Miscanthus
(A) Raw Pellet (B) Dry torrefied Pellet (C) HTC Pellet

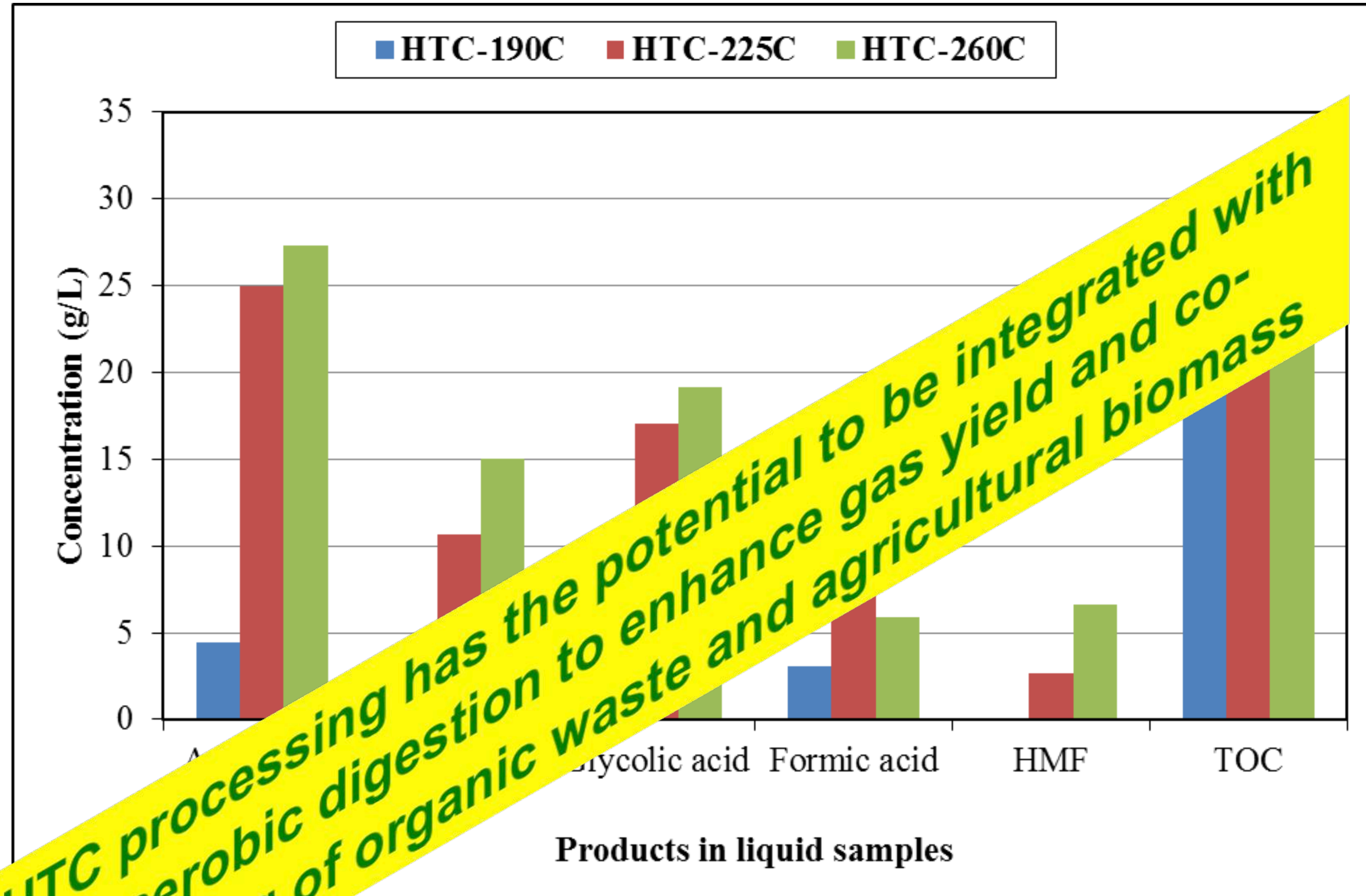


HTC Product Streams



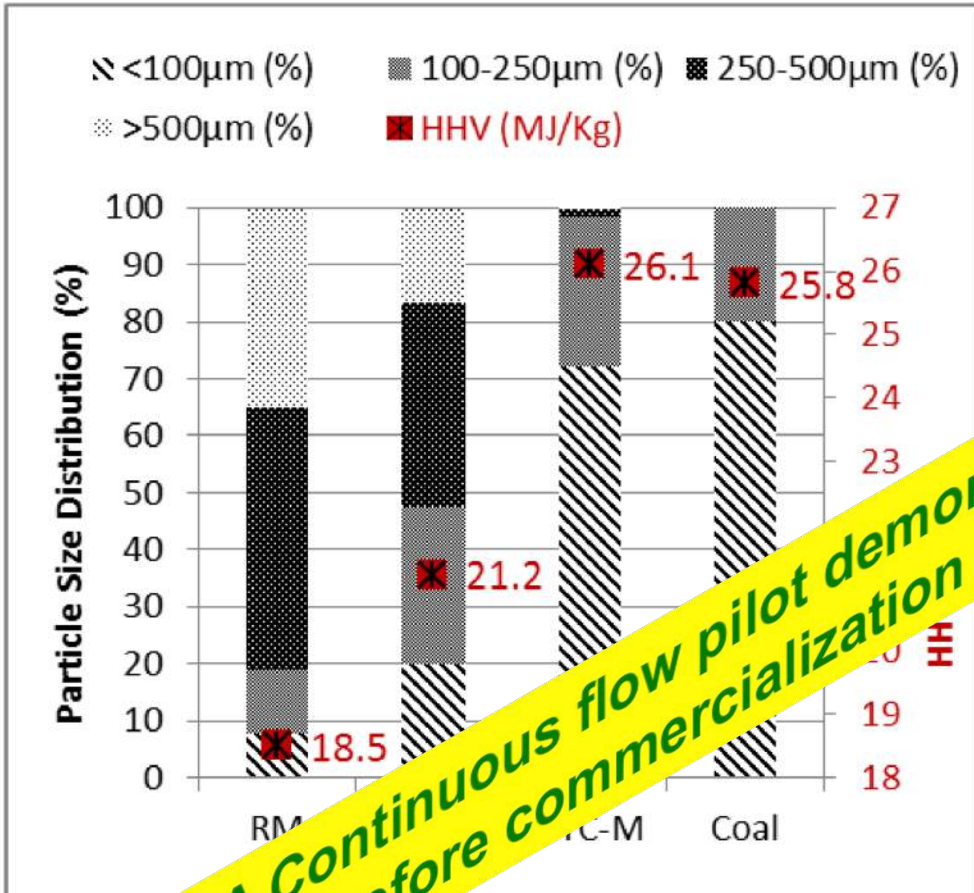
What is in HTC process water and what to do with it?

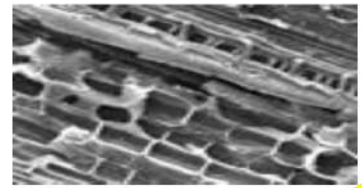
Characterization of HTC Process Water

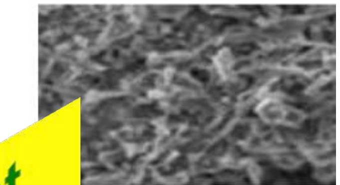


HTC processing has the potential to be integrated with anaerobic digestion to enhance gas yield and co-processing of organic waste and agricultural biomass

Take home Message

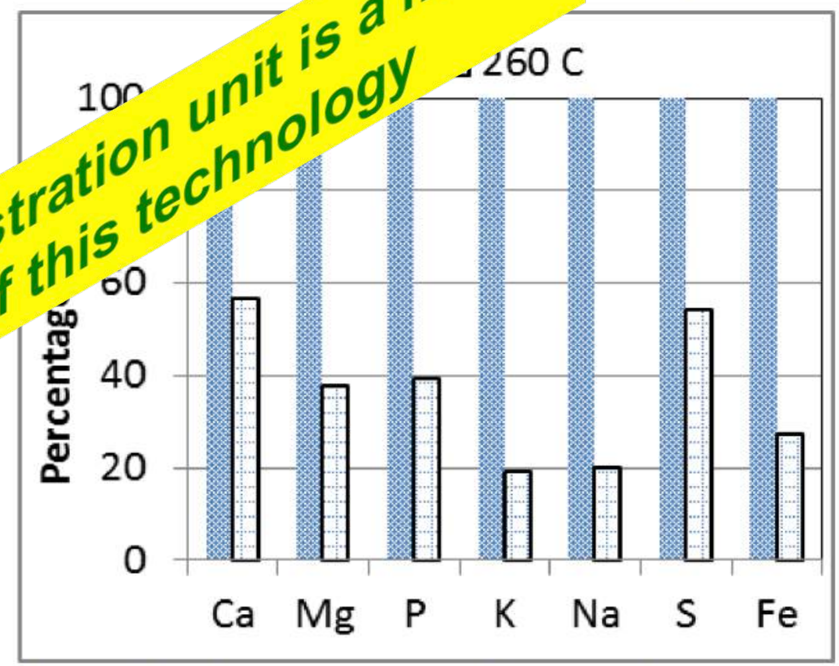






Raw: difficult to g

: Easy to grinc



A Continuous flow pilot demonstration unit is a must before commercialization of this technology

The un onality of increasing of HHV and grindability index, and reduction in alkali in biochar produced from lower value feedstock (Miscanthus) through HTC proces – **MAIN MOTIVATION** to explore resources for commercial demonstration

Economics of HTC for Ontario Grown Corn Stover

- Raw corn stover pellets cost: $6.57 CAD/GJ [1].
- Total corn residues in Ontario (2010) was 6,381,000 tonnes @ MC = 15% (d.b.) [1].
- 30% of the residue must remain on the field to ensure sustainable growth of the crop [1].
- Ontario has potential to generate a total revenue of $473 million CAD/year, through the production of corn stover pellets, based on an HHV of 18 MJ/kg (own research).
- Applying HTC to corn stover @ 260^{o}C for 15 minutes increases HHV to 26.14 MJ/kg while reducing the solid mass to 78.8% of the original mass, producing an energy yield of 1.18.
- Applying the HTC to corn stover has the potential to generate an additional $71 million CAD/year compared to raw corn stover pellets.
- Similarly, ethanol production cost would be about 0.9 $/L with a feedstock cost of 71.5 $ /tDM using syngas fermentation technique.

Ref1: Hewson D, Aung O, Albion KJ. Assessment of agricultural residuals as a biomass fuel for Ontario power generation. London (ON), The University of Western Ontario Research Park, Sarnia-Lambton Campus; 2010 Nov.

Concluding remarks

- As with every emerging technology, hydrothermal carbonization is currently hardly a competitive stand alone process on the open market.
- But if the process can be implemented in an existing infrastructure e.g. AD, compost plant, sewage plant or other businesses which are confronted with large amounts of wet organic waste, HTC can be a financially feasible process.
- HTC is a promising research and development field leading to new functional materials **(application to biomaterials, energy, carbon sequestration, waste water treatment, Metallurgy, catalyst, biorefinary, nano technology** and so on) based on renewable resources.
- The economic viability of biocarbon would improve significantly further if it becomes tradable as a carbon offset (as it is in Australia) and if Carbon Tax is applied, thereby making fossil fuels more expensive by comparison.

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Thank You!

Questions?

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