UPCYCLING OF BIOWASTES FOR ENERGY AND MATERIALS: A CIRCULAR ECONOMY APPROACH

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BRIL-OMAFRA KTT Workshop March 22, 2024, Guelph, ON

Bio-Renewable Innovation Lab (BRIL)

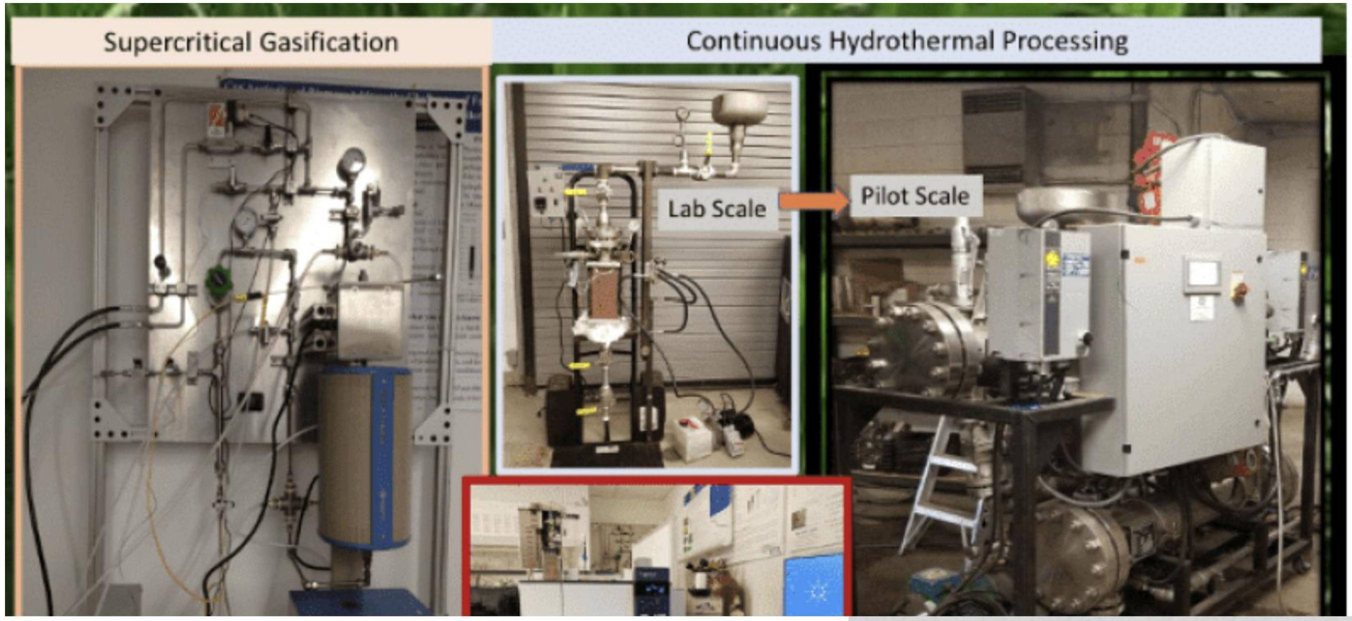
BRIL is a multidisciplinary research facility initiated in 2014

Mission: To conduct research and develop innovative technology solutions to help circular economy for long-term sustainability.

Research Focus: Valorisation of various organic wastes to promote sustainability through circular economy concept

Other Activities:

- Knowledge Translation and Transfer (KTT)
  - Webinars
  - Workshop
- HQP Training
  - Undergrad, Graduate,
  - Post doctoral
- Research Capacity Building



Process Technologies	Analytical Capabilities
Thermochemical	Py- GC/MS
Hydrothermal	HP – TGA, TGA – FTIR
Supercritical	Surface and pore Characterization
Modeling & Scaling-up	Catalysis and Kinetics Studies

Bio-Renewable Innovation Lab (BRIL) at Guelph

- 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 processing

Moving bed reactor

Chemical Looping Gasifier

3) Bio-chemical conversion processes

Bio-syngas Fermentation

Bioethanol and biodiesel facility

Supercritical flow reactor

Multi-Stage Gasifier

Two-Stage Gasifier-combustor

PY-Pyrolyzer with GCMS

Analytical Laboratory

Scientific analytical instruments for both qualification and quantification analyses.

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

GC-FID/TCD

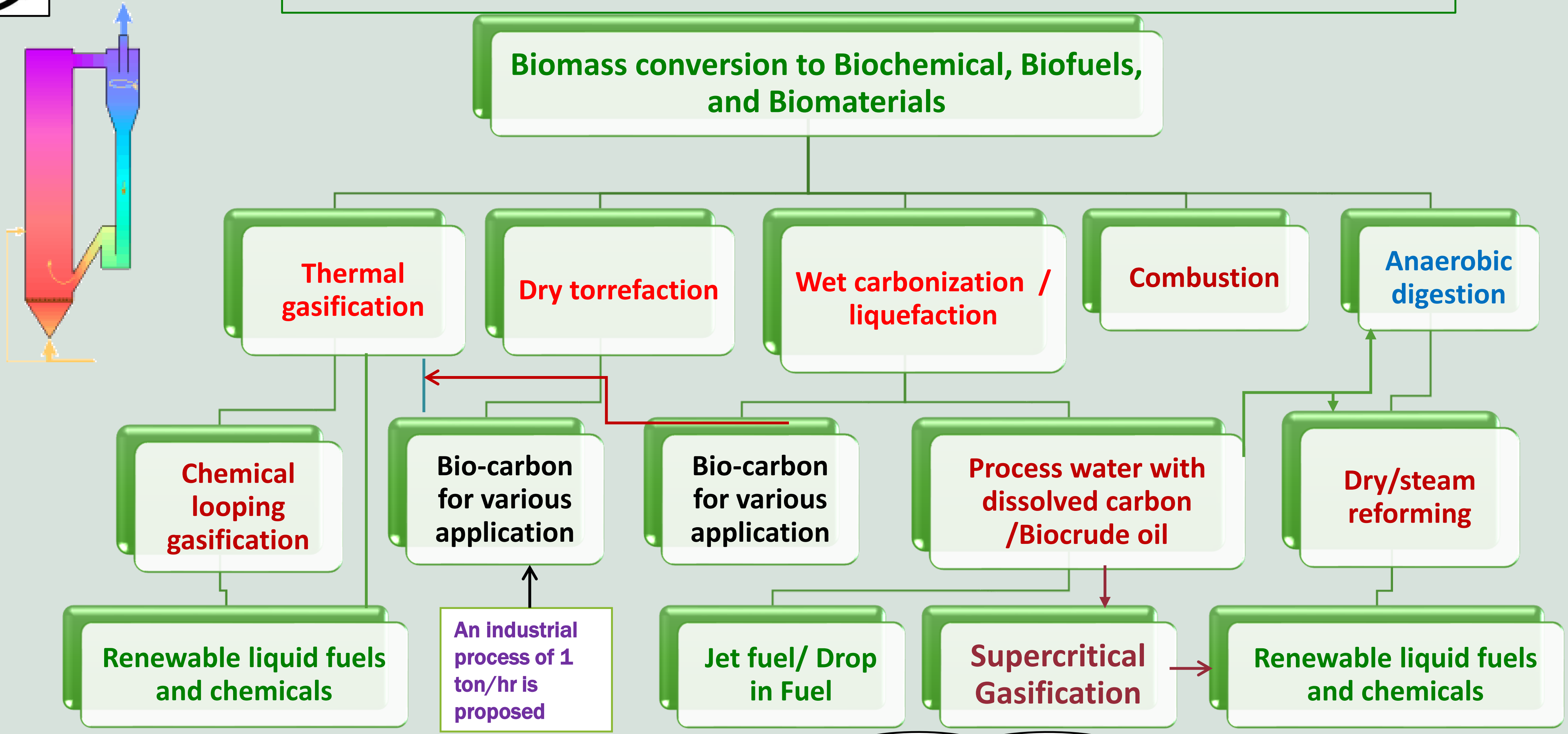
FTIR

DSC-TGA

Bomb Calorimeter

Planetary Ball Mill (Grinder)

BIOWASTE CONVERSION RESEARCH PROGRAM AT BRIL
"WASTE IS A RESOURCE-WAITING FOR AN OPPORTUNITY"



Biomass conversion to Biochemical, Biofuels, and Biomaterials

Thermal gasification

Dry torrefaction

Wet carbonization / liquefaction

Combustion

Anaerobic digestion

Chemical looping gasification

Bio-carbon for various application

Bio-carbon for various application

Process water with dissolved carbon /Biocrude oil

Dry/steam reforming

Renewable liquid fuels and chemicals

An industrial process of 1 ton/hr is proposed

Jet fuel/ Drop in Fuel

Supercritical Gasification

Renewable liquid fuels and chemicals

Life Cycle analysis (LCA) and
Life Cycle cost analysis (LCAA)

Our Ultimate Goal is to Develop

"A wide variety of renewable products including bio-carbon, renewable chemicals, bio-methane, and bio-fertilizers from a variety of **non-food sustainable agri-food wastes** feedstocks."

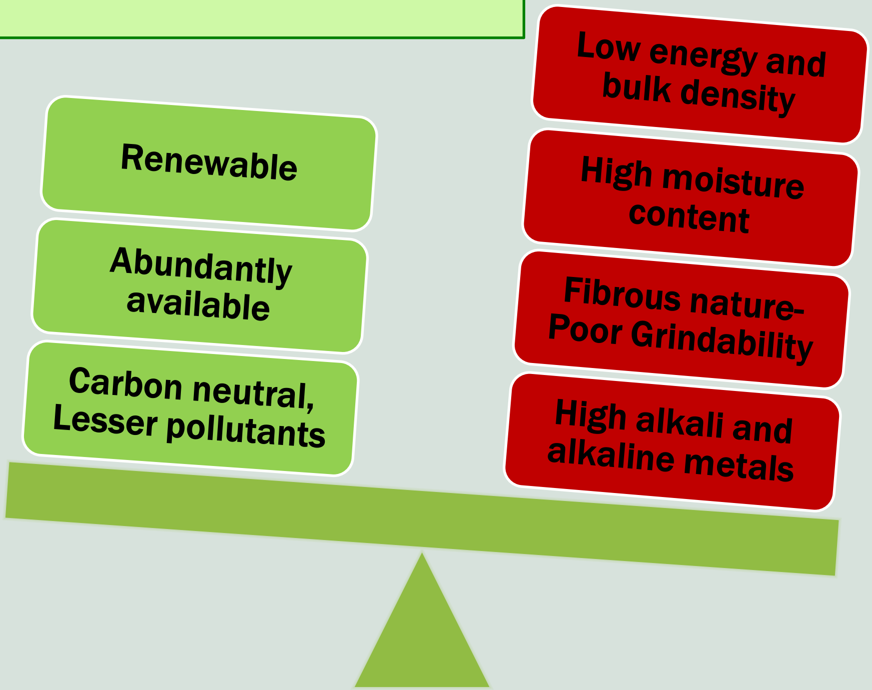
Meeting Goal by

- Valorization of agricultural and food wastes (crop residues, greenhouse, and food processing wastes) that has the potential to replaces non-renewable fossil based resources
- Developing green processes and products value chain to mitigate GHG emissions
- Strengthening sustainability and bioeconomy of Canadian agriculture and agri-food sector

RESEARCH OVERVIEW

THEME: “WASTE IS A RESOURCE - WAITING FOR AN OPPORTUNITY”

> “Agri-food wastes is not regarded as an ideal replacement for fuel and materials application”



Renewable

Abundantly available

Carbon neutral, Lesser pollutants

Low energy and bulk density

High moisture content

Fibrous nature- Poor Grindability

High alkali and alkaline metals

Hydrothermal Carbonization (HTC) processing where biomass is treated with hot compressed water instead of drying exhibits unique physicochemical properties

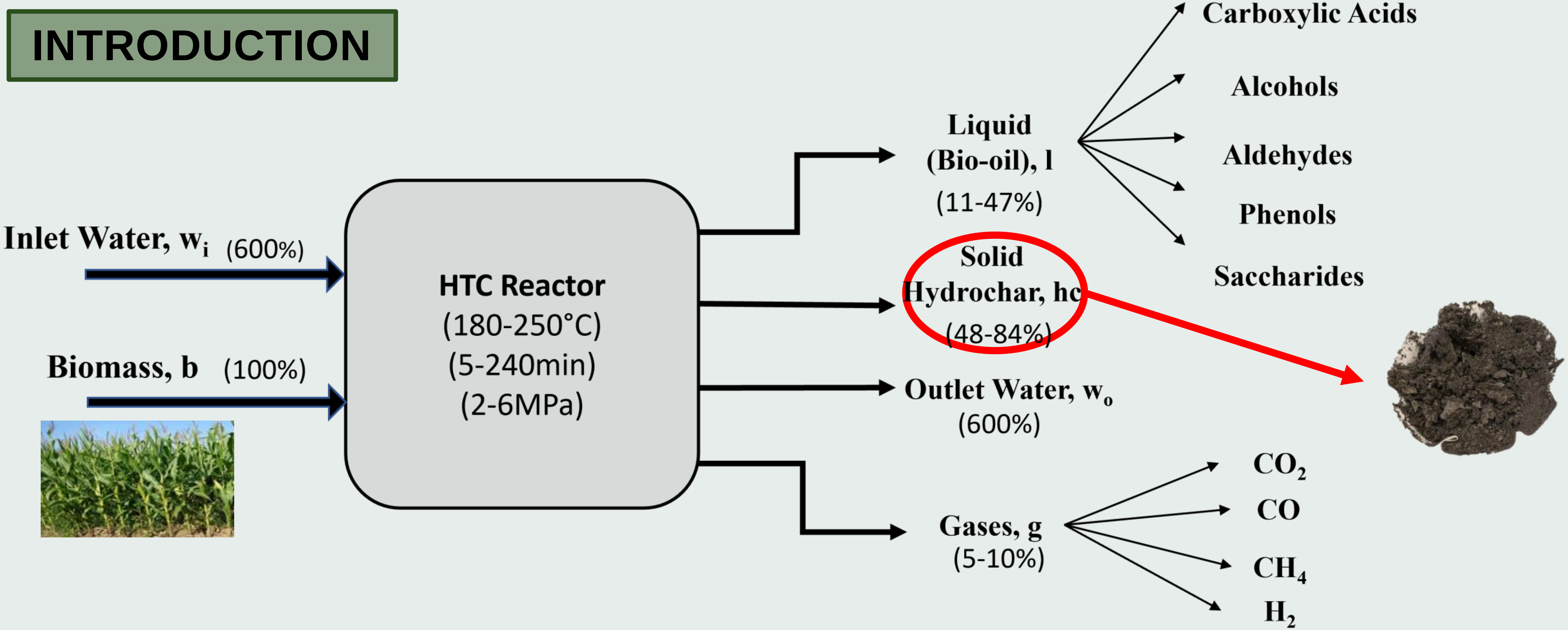
HTC products from low quality agri-food residue can be a potential newer value chain

Research Questions:

- Can we produce industrial grade biocarbon from this low quality biomass (low alkali metals, higher HHV, and higher grindability) for energy and materials applications?
- Will there be any industrial grade biochemical as a co-product from HTC Process Water (HTCPW)?

Hydrothermal Carbonization

INTRODUCTION



Inlet Water, w_i (600%)

Biomass, b (100%)

HTC Reactor
(180-250°C)
(5-240min)
(2-6MPa)

Liquid
(Bio-oil), l
(11-47%)

Carboxylic Acids
Alcohols
Aldehydes
Phenols
Saccharides

Solid
Hydrochar, hc
(48-84%)

Outlet Water, w_o
(600%)

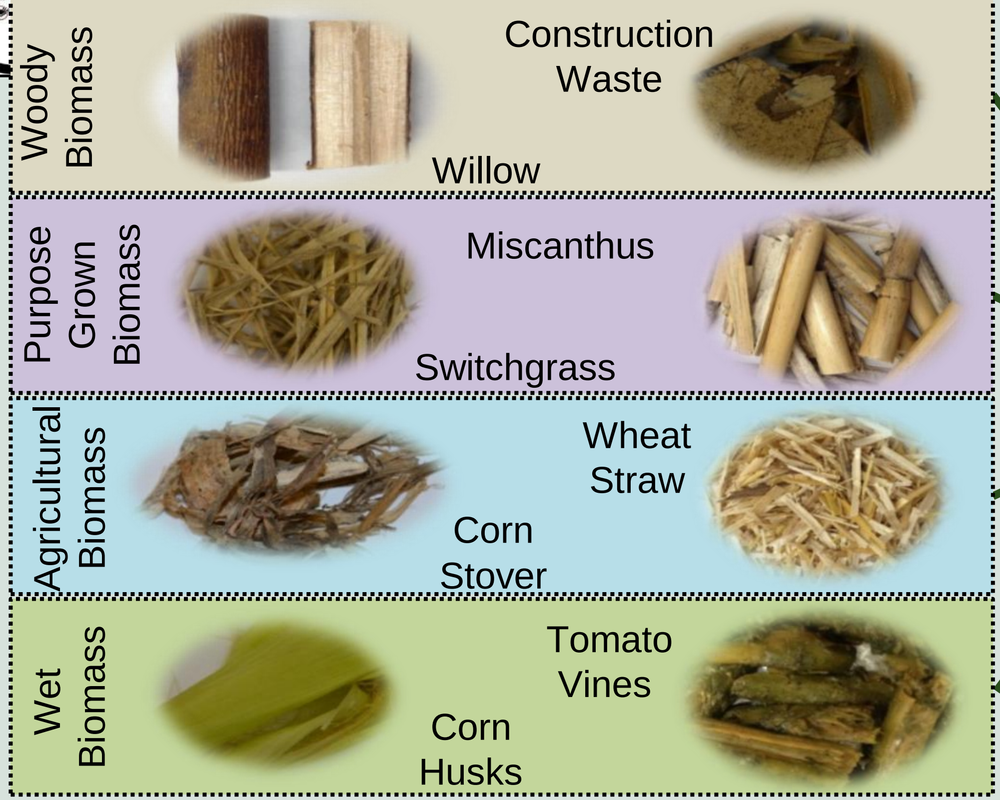
Gases, g
(5-10%)

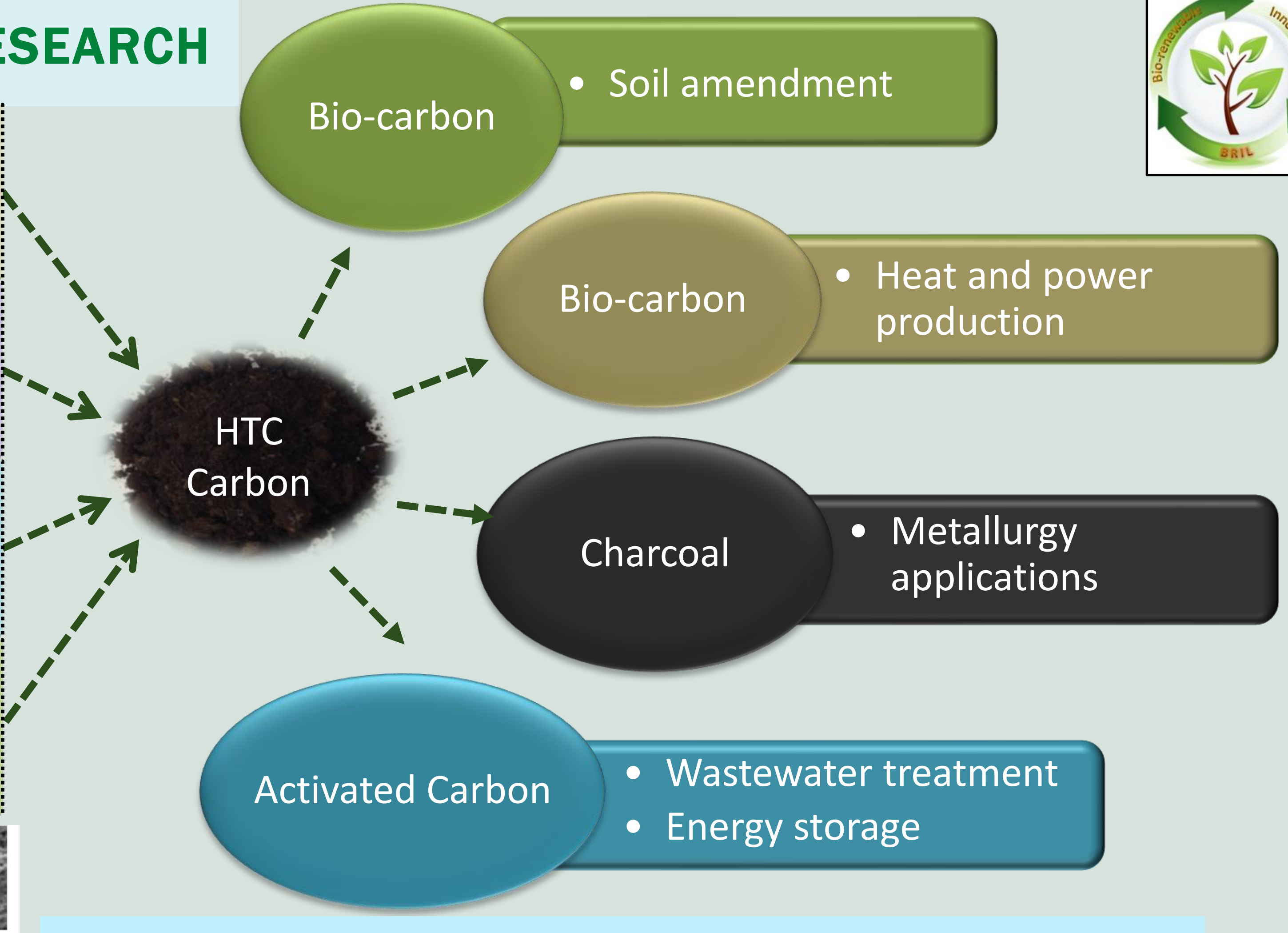
CO_2
CO
CH_4
H_2

Challenges Addressed

- Eliminates Drying Step
- Accommodate Biomass Variability
- Reduce Ash/Impurities
- Simple Process

BIOCARBON DEVELOPMENT RESEARCH





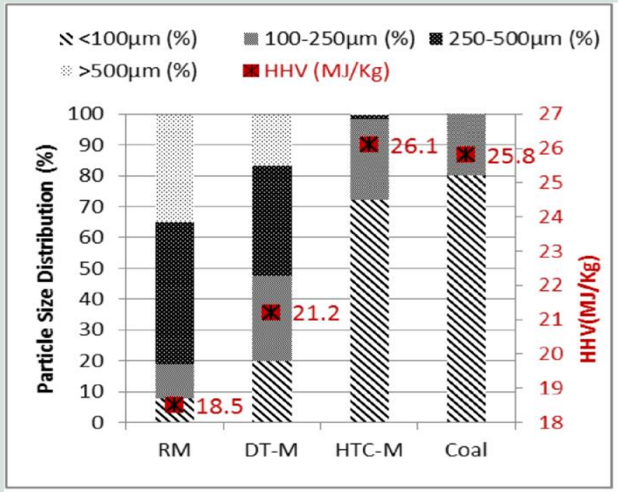
HTC Carbon

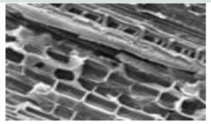
Bio-carbon
- Soil amendment

Bio-carbon
- Heat and power production

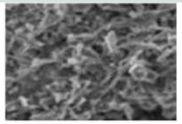
Charcoal
- Metallurgy applications

Activated Carbon
- Wastewater treatment
- Energy storage

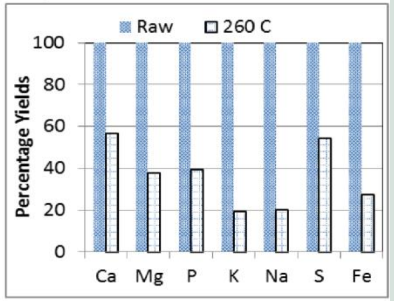




RM: difficult to grind



HTC-M: Easy to grind

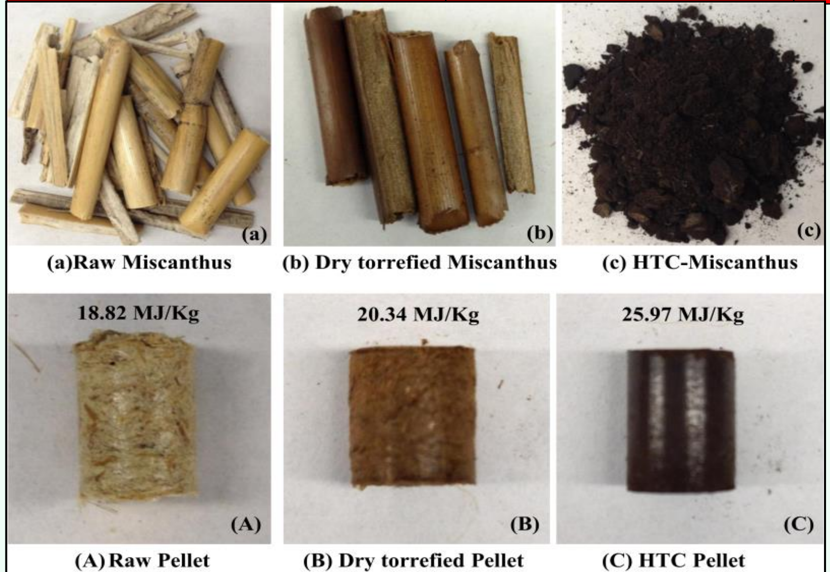


Significance:
- **HTC can be an ideal pre-treatment method to remove some of the barriers.**
- **Depending upon applications, it may require further processing**

Applied Energy 135, 182-191, 2014

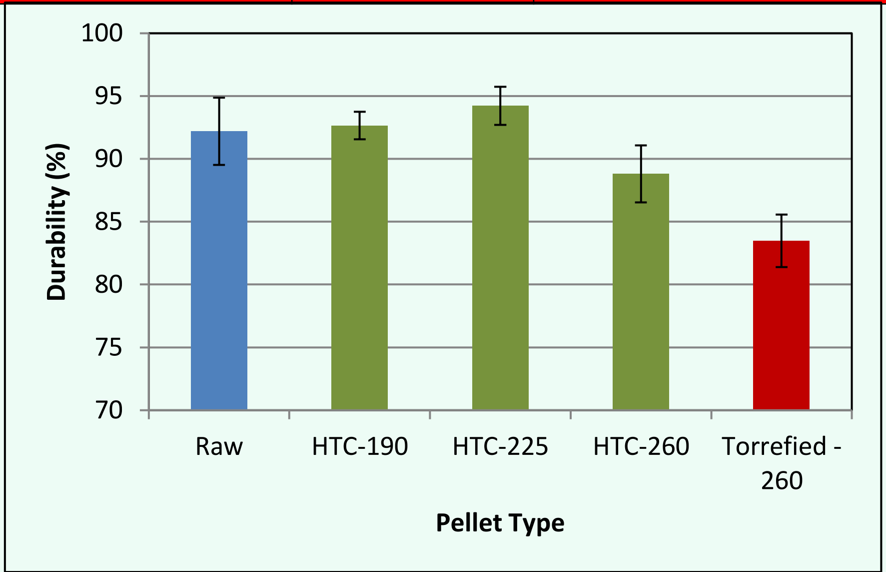
Effect on Mass and Energy Density

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

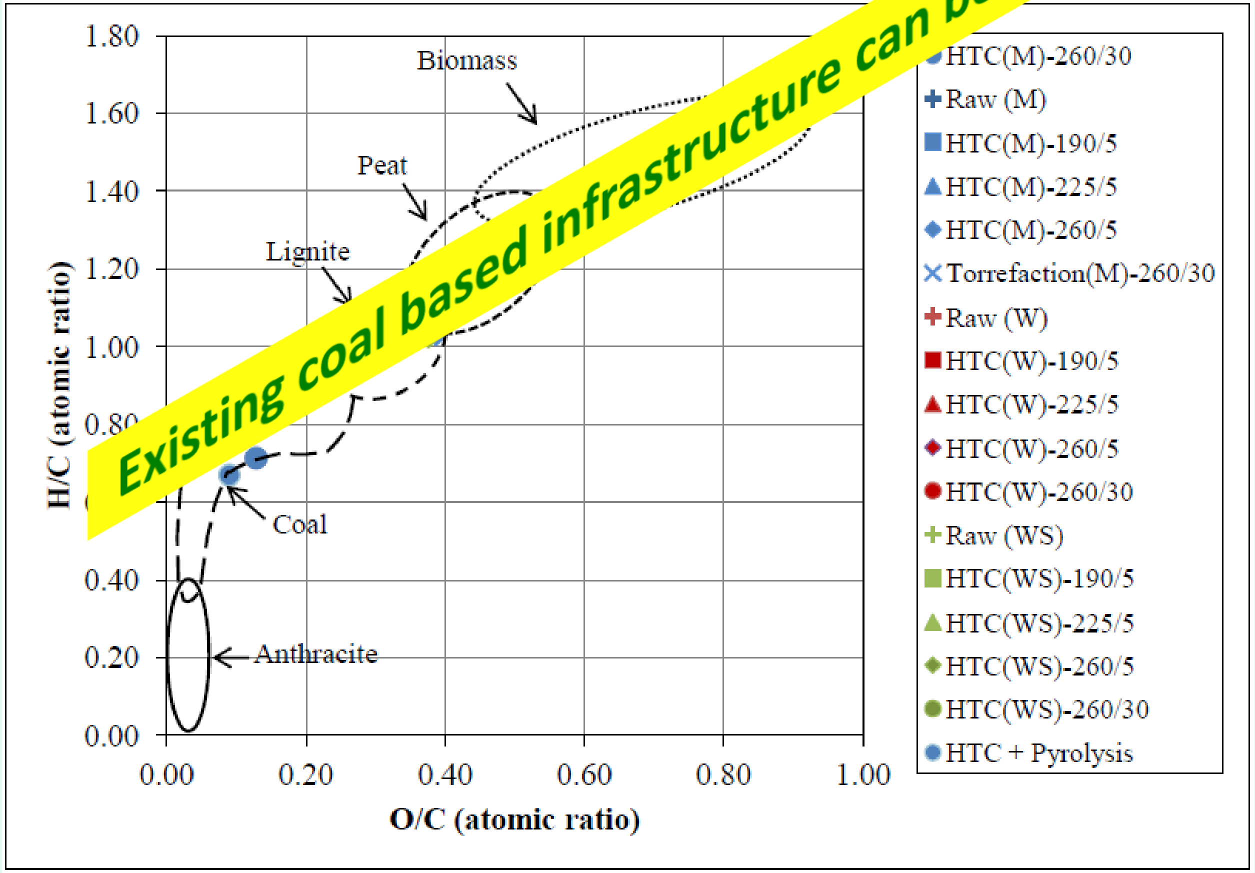
(A) Raw Pellet (B) Dry torrefied Pellet (C) HTC Pellet

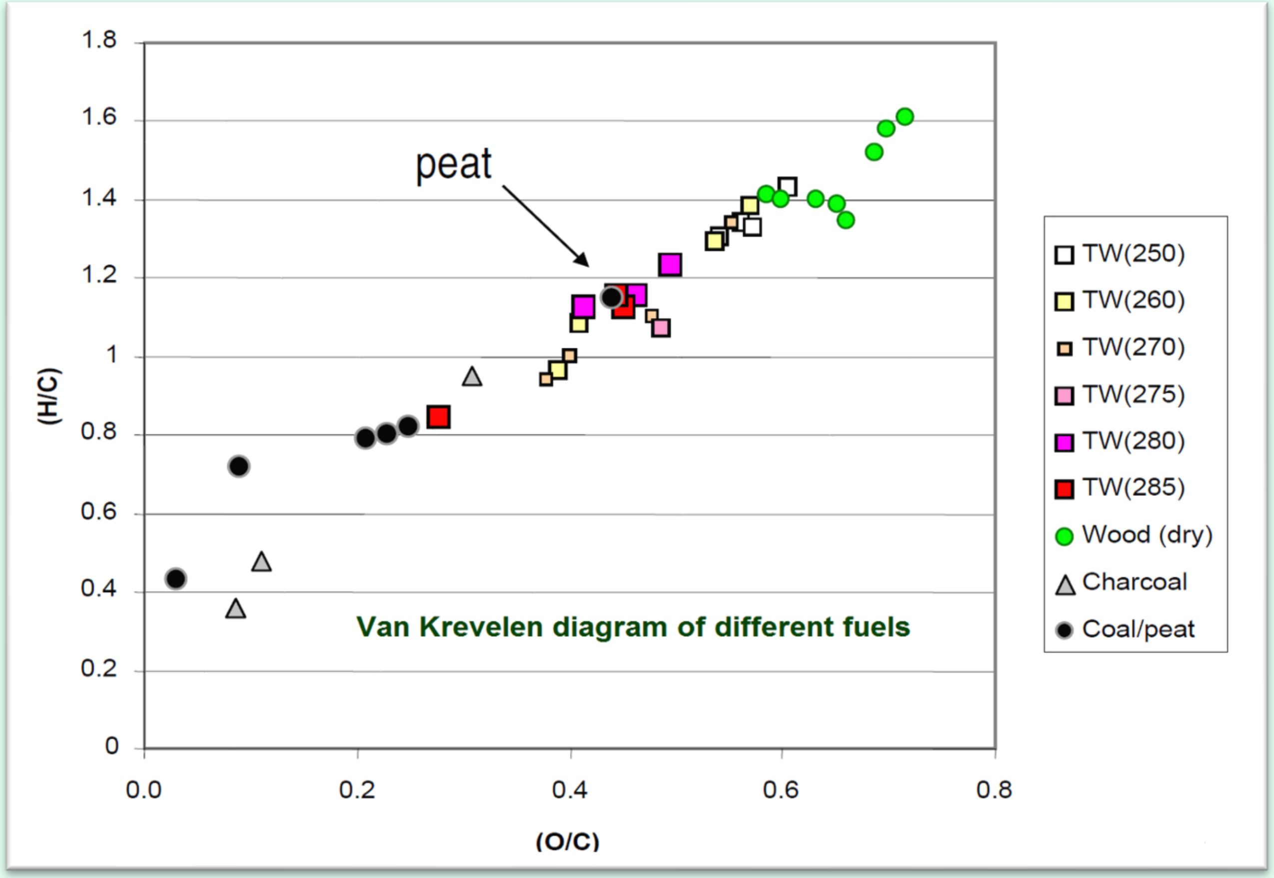


Reference: Applied Energy, Vol 135, 2014, Pages 182-191

Van Krevelen diagram (Effect on H/C-O/C Atomic Ratios):
Comparison of HTC and conventional torrefaction

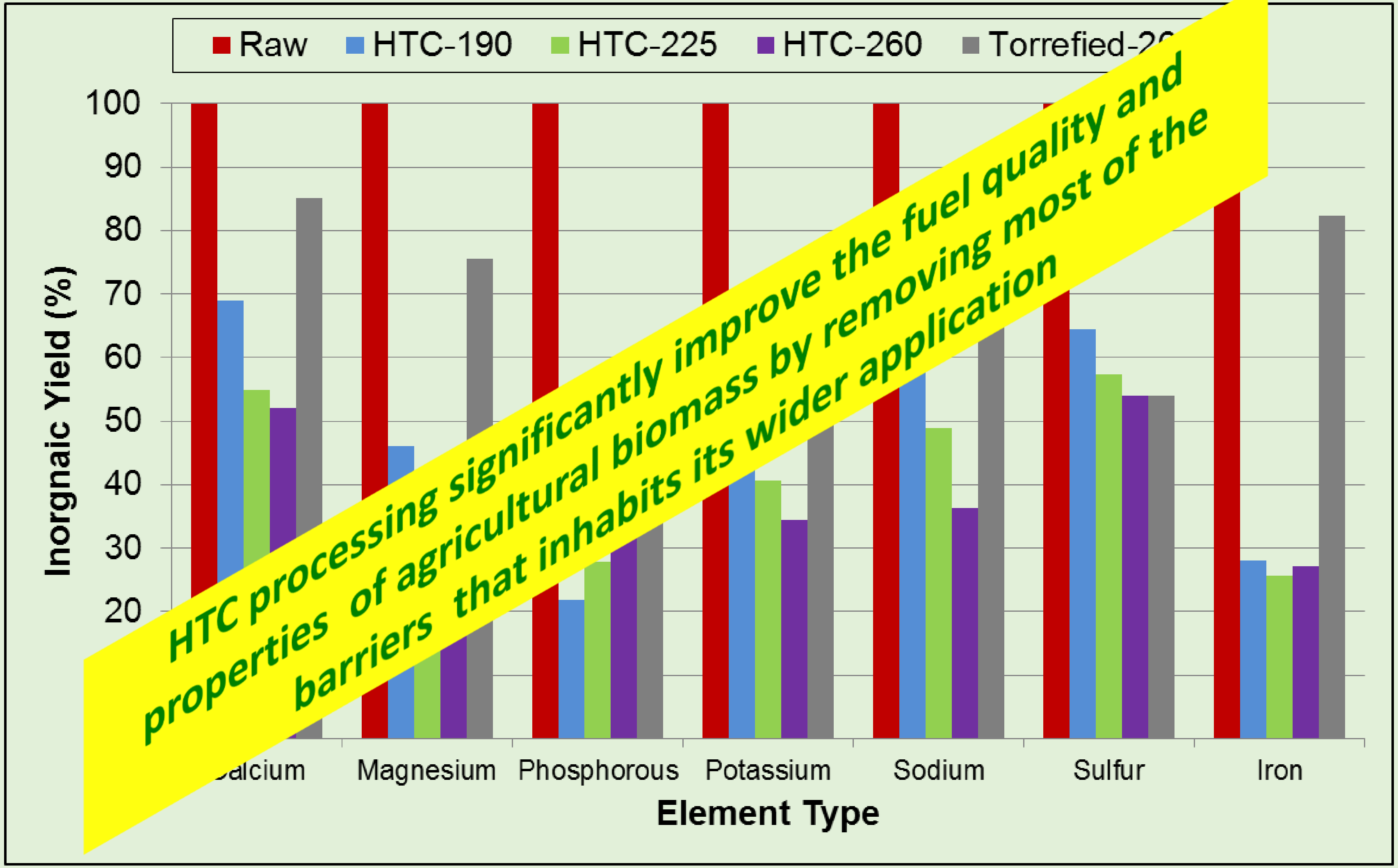
Existing coal based infrastructure can be used





Reference: Applied Energy, Vol 135, 2014, Pages 182-191

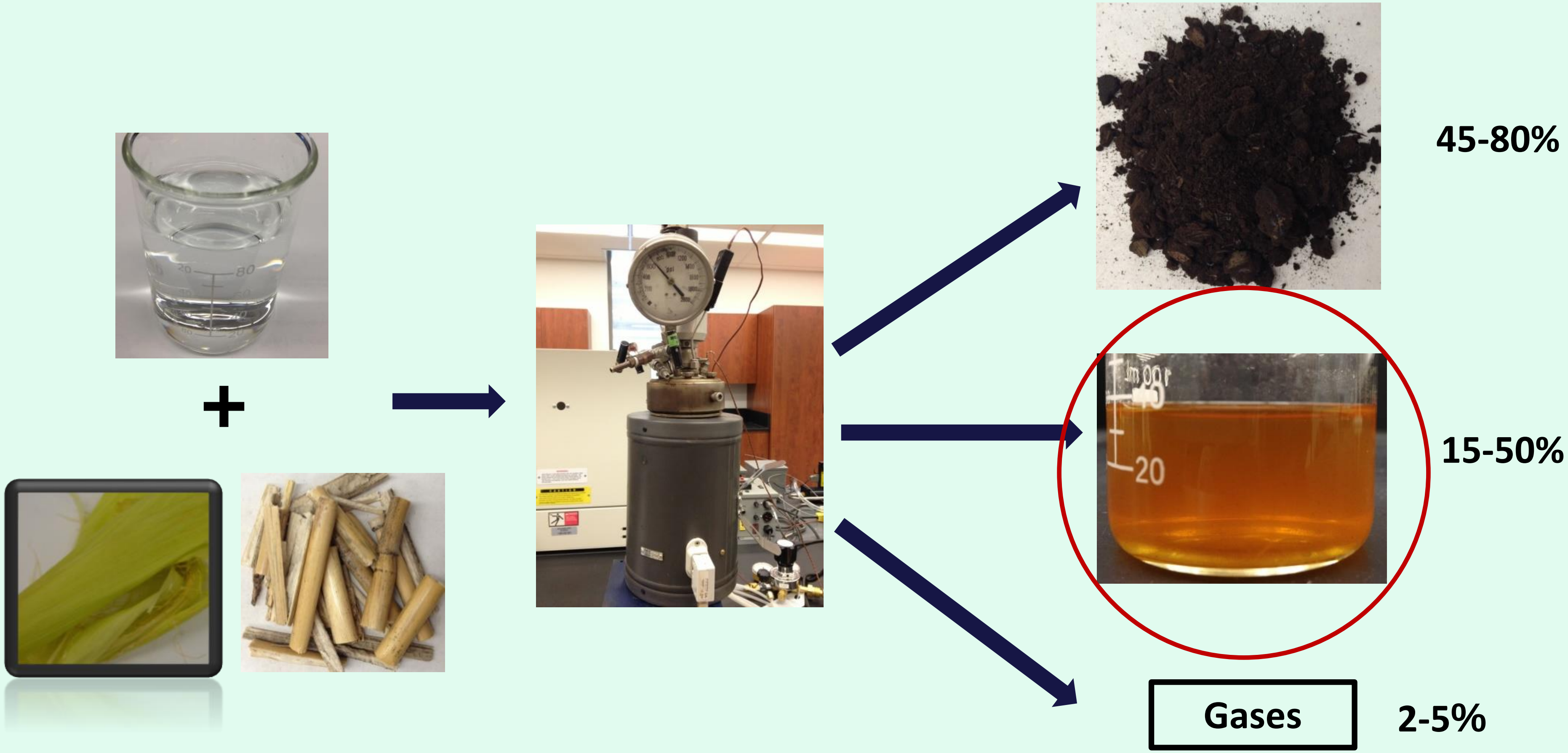
Effect of Pre-treatment on Alkali and Alkaline Content



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

Reference: Energy Conversion and Management, Vol 105, 2015, Pages 746-755

HTC Product Streams



45-80%

15-50%

Gases

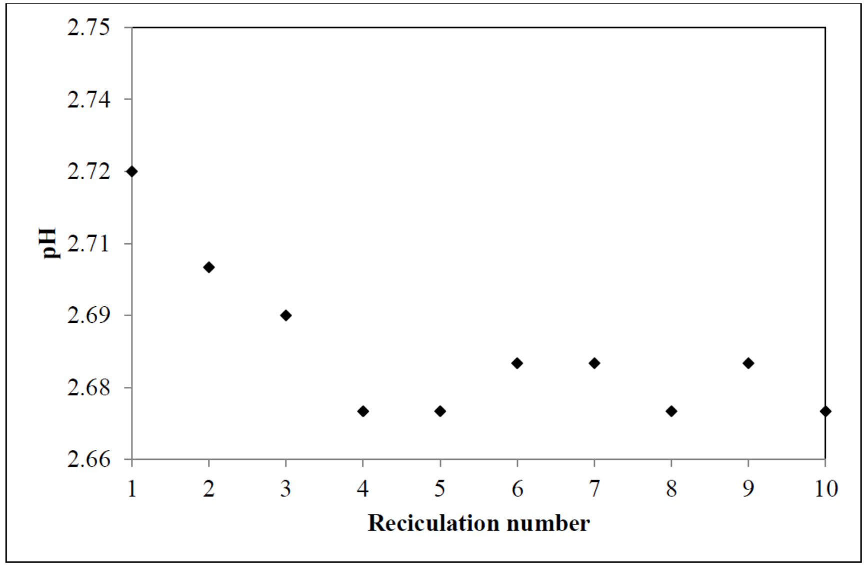
2-5%

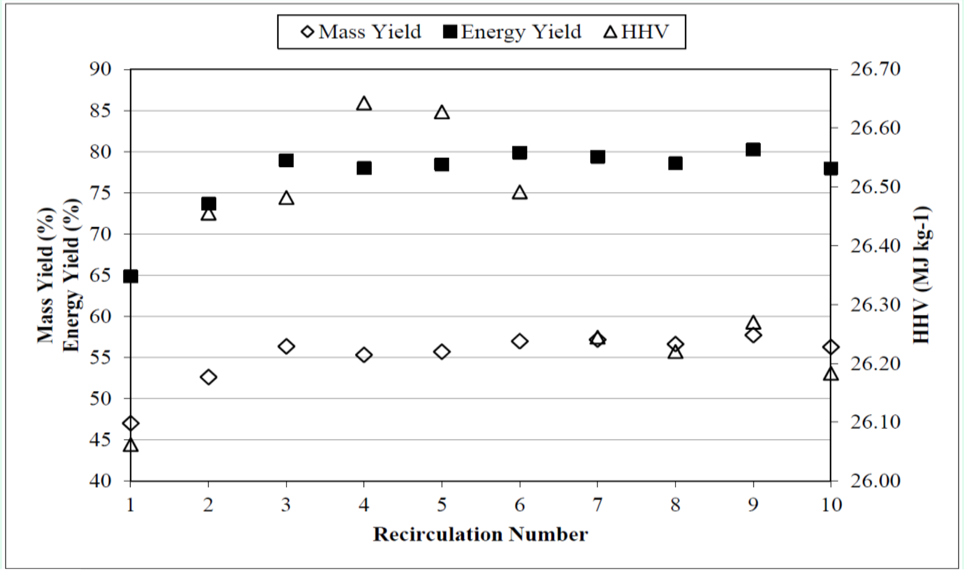
The distribution & properties of products strongly depend on reaction conditions!

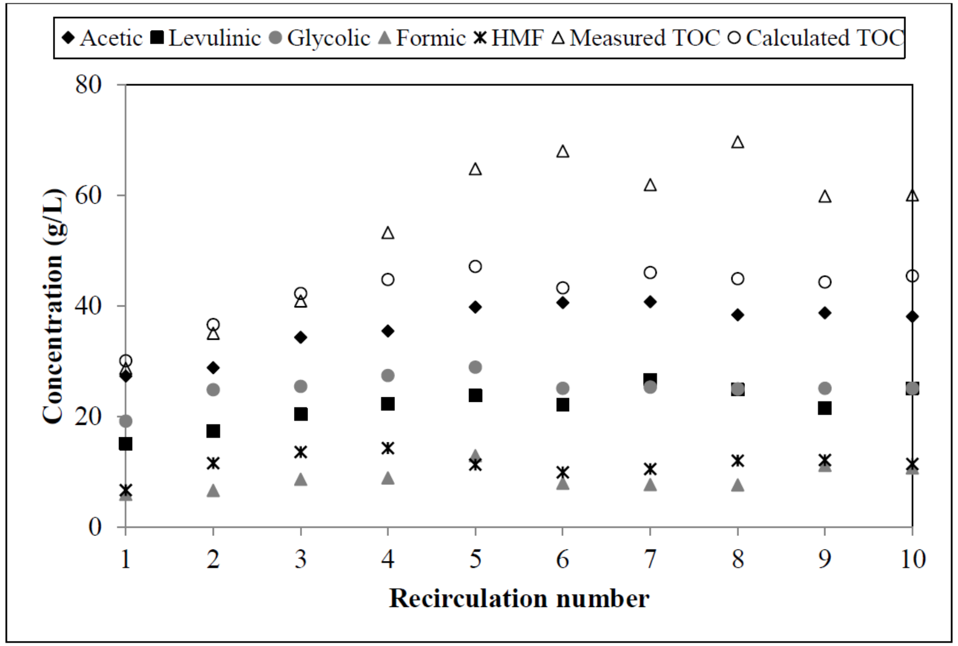
Process water from the hydrothermal carbonization of biomass: a waste or a valuable product?

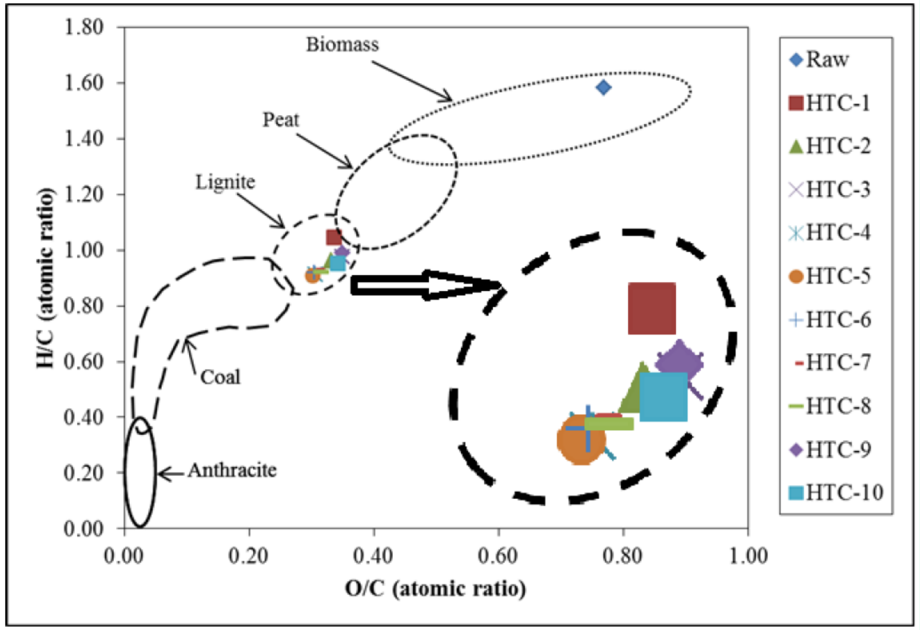
Waste Biomass Valor, 1-9, 2017

Recycling of Process water

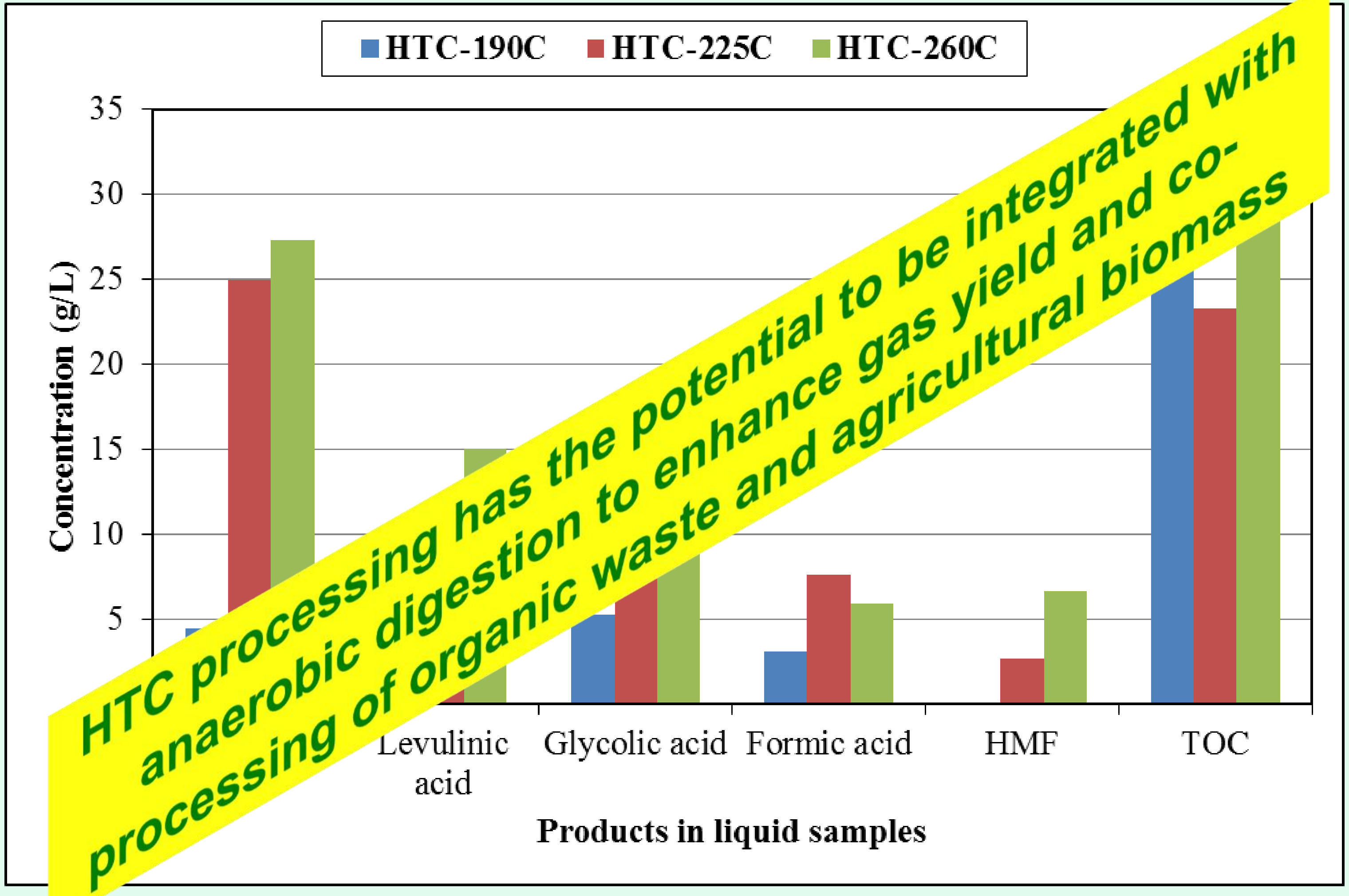








Characterization of HTC Process Water



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

Example 1

Bioenergy and biofertilizer from hydrothermal treated corn residue: a circular economy concept

Example 1: Bioenergy and biofertilizer from hydrothermal treated corn residue: a circular economy concept

Corn residue

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Energy

Volume 165, Part B, 15 December 2018, Pages 370-384

Biocarbon, biomethane and biofertilizer from corn residue: A hybrid thermo-chemical and biochemical approach

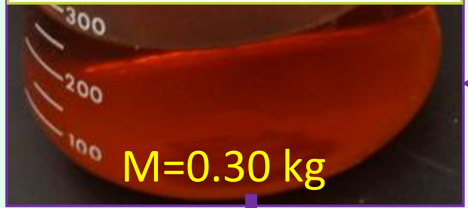
Subhash Paul, Animesh Dutta, Fantahun Defersha

M=1 kg_{dry}; E=18.13 MJ

Hydrothermal process

M loss = 0.23 kg

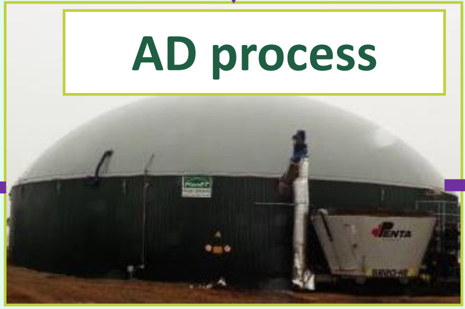
Liquid (HTPW)



M=0.30 kg

Biocarbon for different application

M=0.47 kg; E=10.91 MJ



AD process

Biogas

Biomethane

E = 3.35 MJ

Digestate (Biofertilizer)

Recovery N=31%, P=23%, K=26%, S=19%

Significance: Overall energy recovery efficiency=79%.

CASE STUDY 1: NUMERICAL ANALYSIS OF AN INTEGRATED HTC-AD SYSTEM FOR POWER GENERATION

Ref: Process

Open Access Feature Paper Article

Numerical Comparison of a Combined Hydrothermal Carbonization and Anaerobic Digestion System with Direct Combustion of Biomass for Power Production

by Mohammad Heidari [1], Shakirudeen Salaudeen [1], Omid Norouzi [1], Bishnu Acharya [2] and Animesh Dutta [1,*]

[1] School of Engineering, University of Guelph, Guelph, ON N1G 2W1, Canada

[2] School of Sustainable Design Engineering, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada

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Processes **2020**, *8*(1), 43; https://doi.org/10.3390/pr8010043

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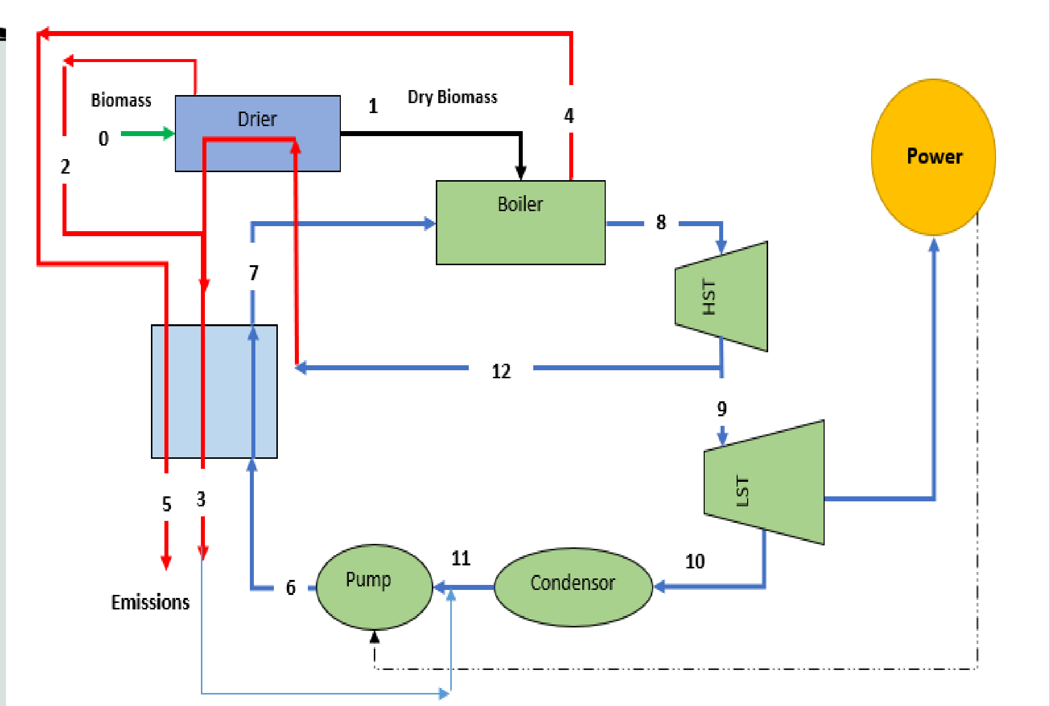
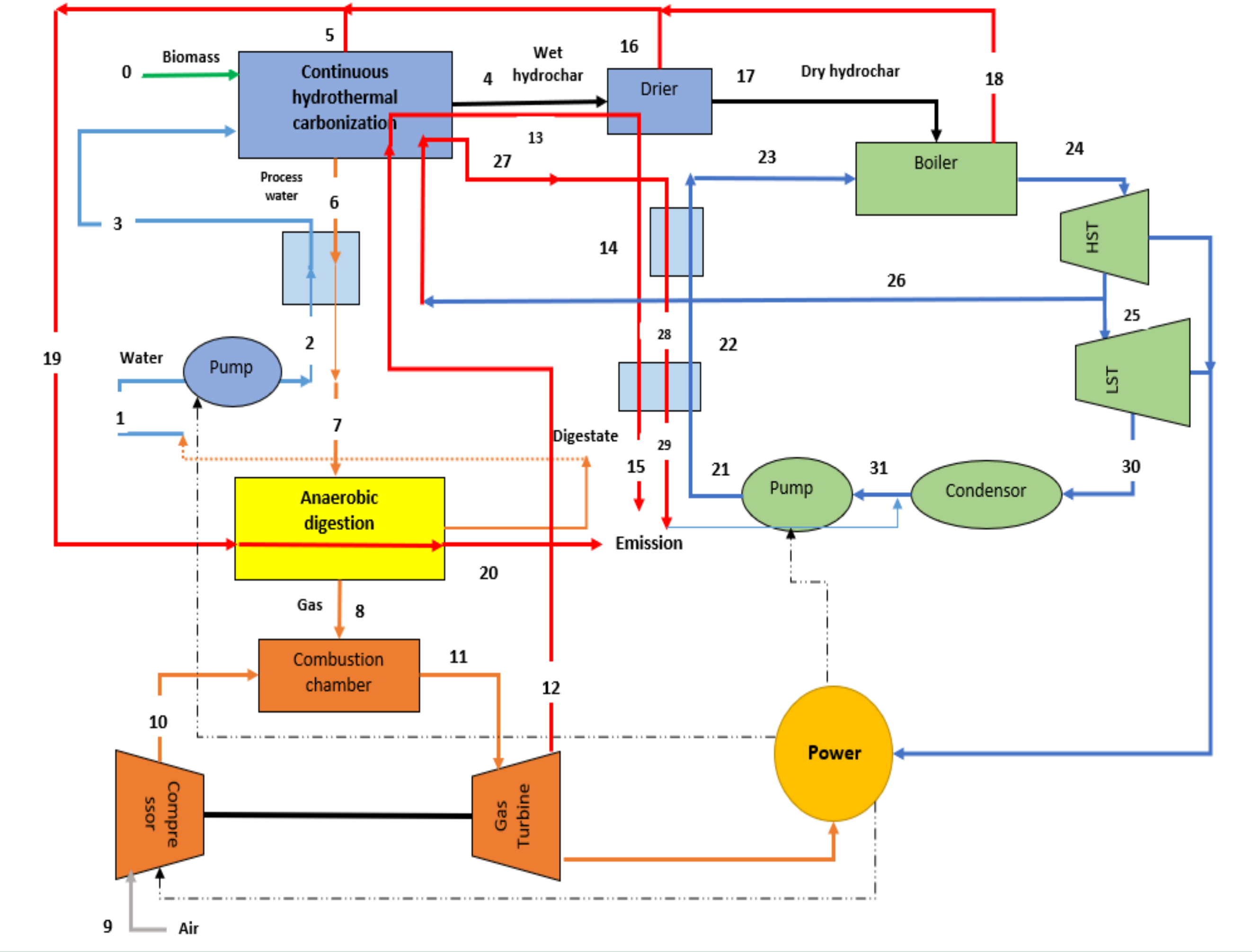
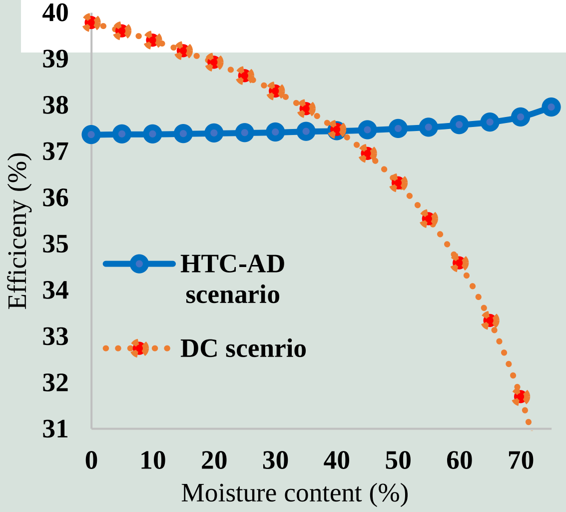
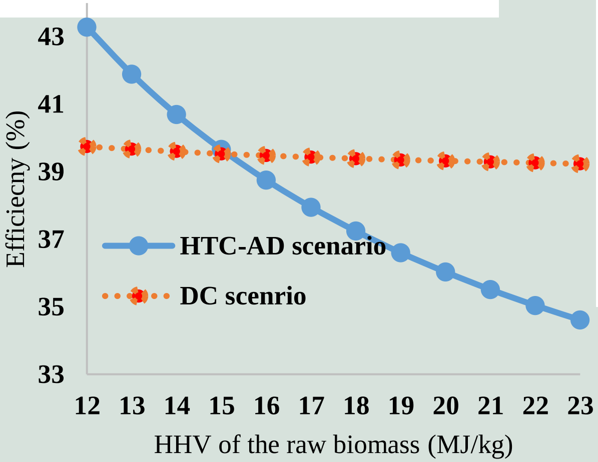
(This article belongs to the Special Issue Anaerobic Digestion Processes)









Significance:

HTC-AD scenario shows a better performance compared to DC one when the moisture content of the biomass is over 40%

Proposed Concept: Waste to Wealth: A Circular Economy Based Approach

Resources, Conservation & Recycling 130 (2018) 164–174

ELSEVIER

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Review

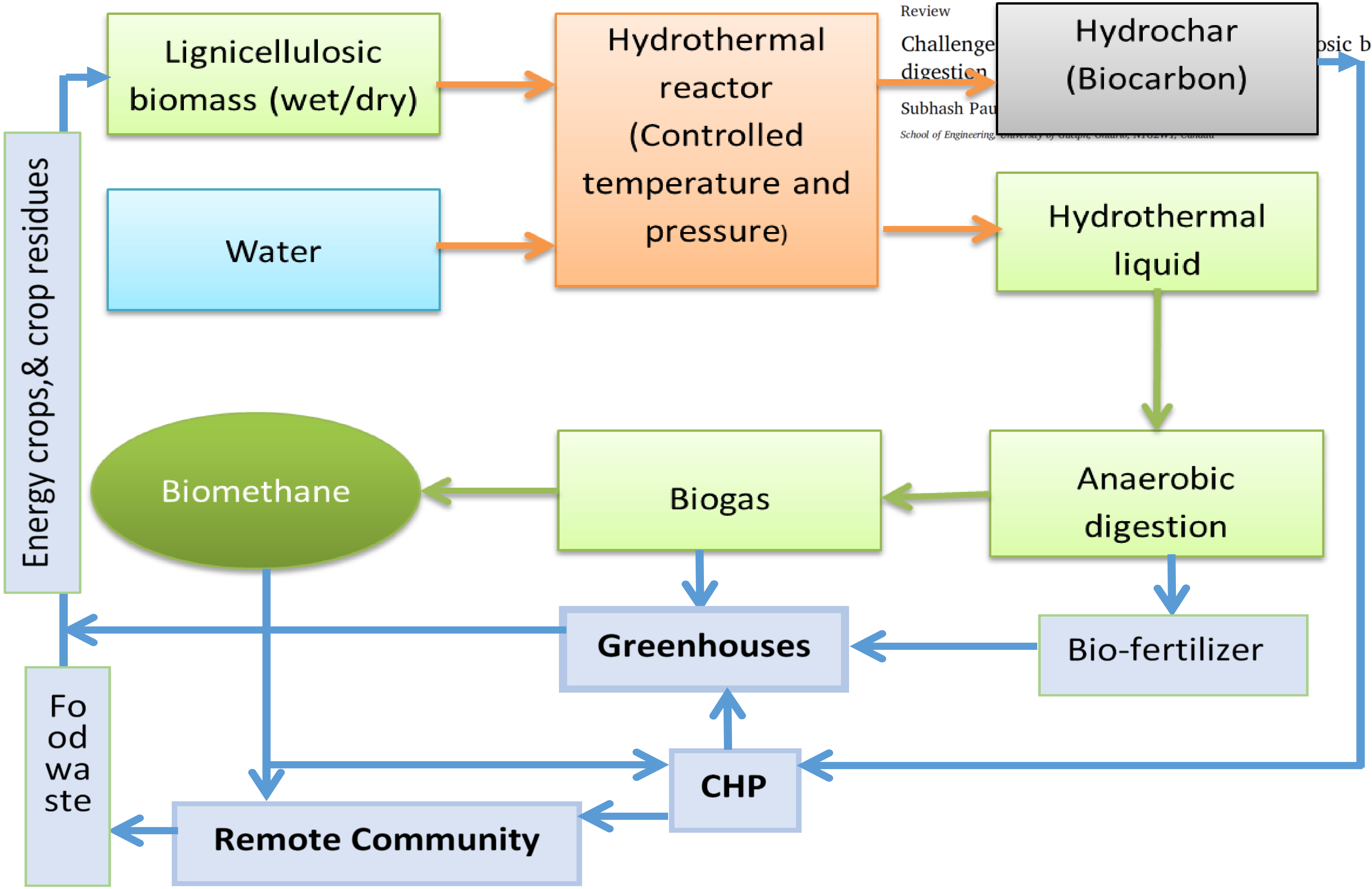
Challenge

osic biomass for anaerobic

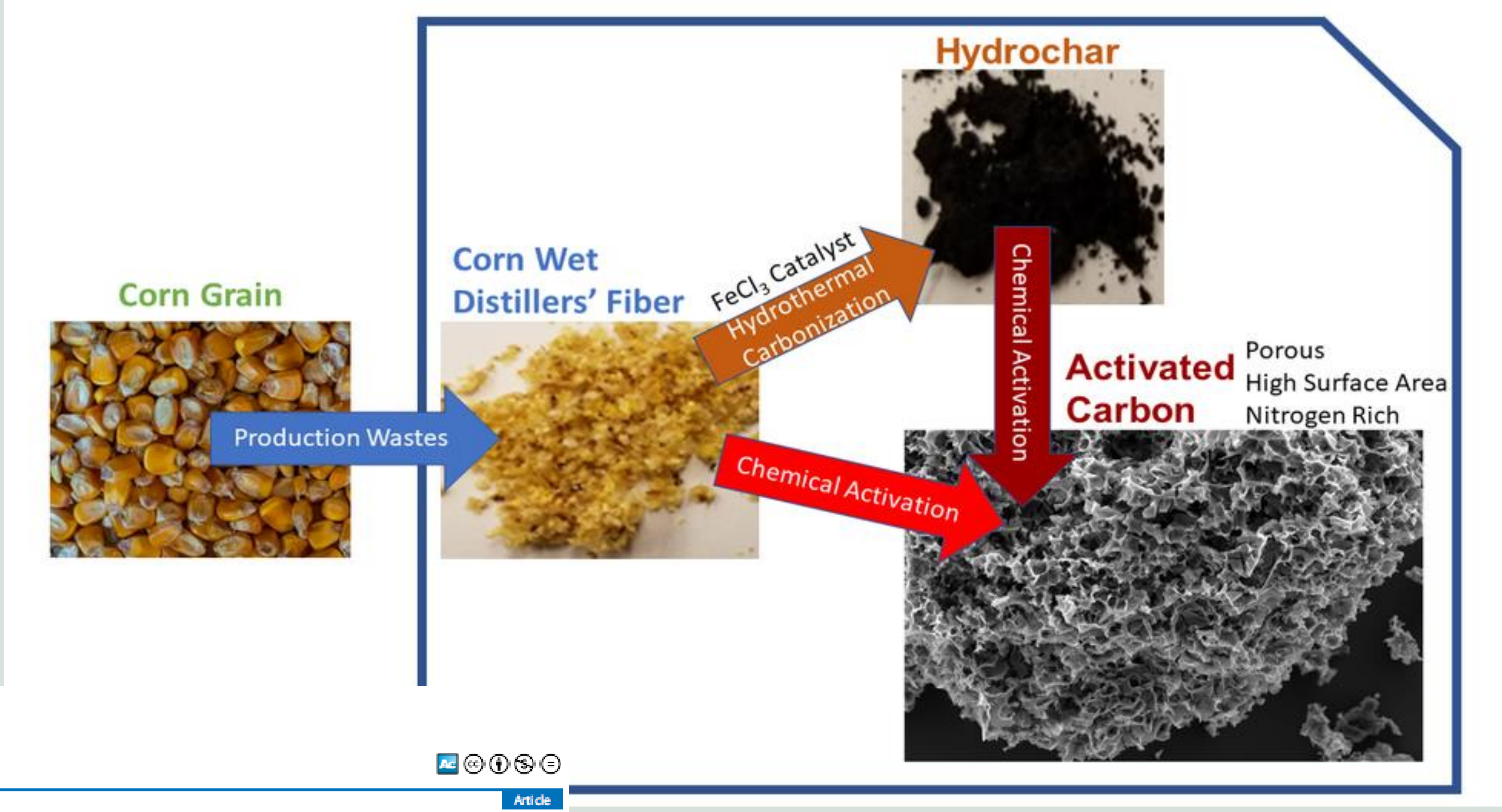
digestion

Subhash Pau

School of Engineering,



EX. 2: A TUNABLE APPROACH FOR ACTIVATED CARBON PRODUCTION FROM LOW VALUE BIOMASS



Corn Grain

Production Wastes

Corn Wet Distillers' Fiber

$FeCl_3$ Catalyst Hydrothermal Carbonization

Hydrochar

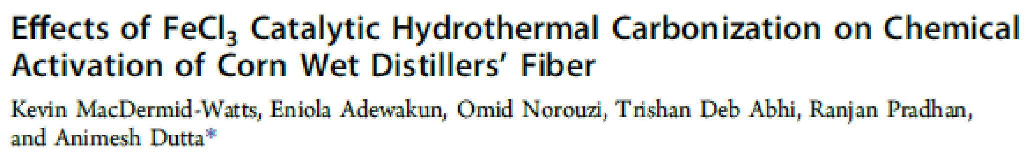
Chemical Activation

Chemical Activation

Activated Carbon

Porous
High Surface Area
Nitrogen Rich

ACS OMEGA



http://pubs.acs.org/journal/acsodf

Article

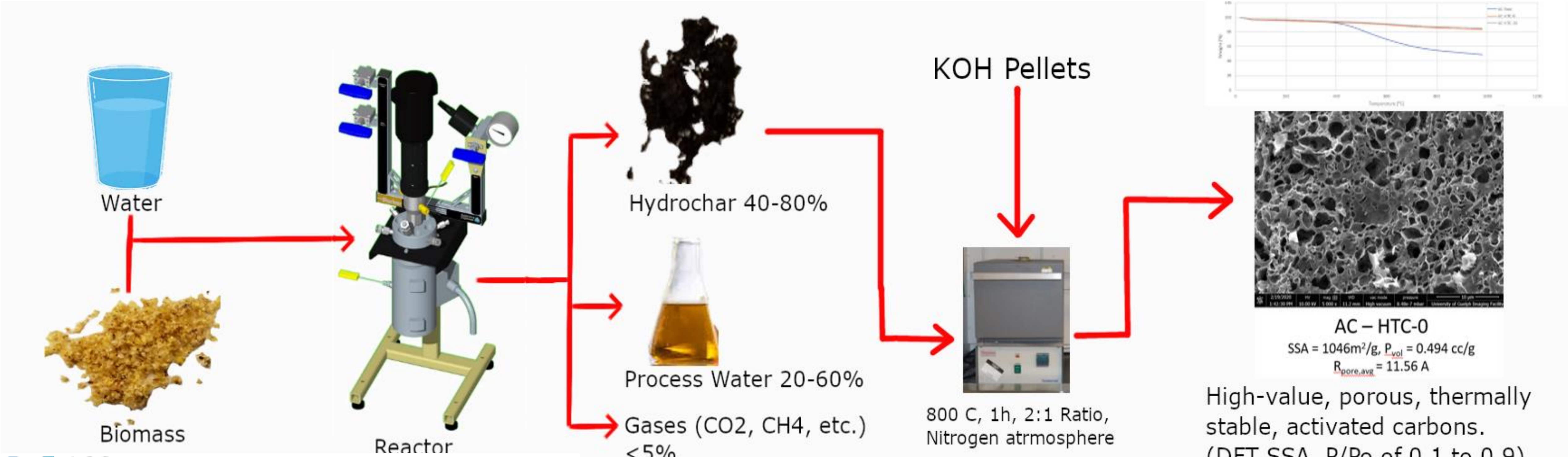
Effects of $FeCl_3$ Catalytic Hydrothermal Carbonization on Chemical Activation of Corn Wet Distillers' Fiber

Kevin MacDermid-Watts, Eniola Adewakun, Omid Norouzi, Trishan Deb Abhi, Ranjan Pradhan, and Animesh Dutta*

Ex. 2 Continued: A Tunable Approach for Activated Carbon Production from Low Value Biomass

Significance:

- Valuable, high quality activated carbons can be produced through a 2-step HTC and chemical activation procedure.
- Applications in heavy metal removal, water filtration, gas storage, super capacitors, and many more.



Water

Biomass

Reactor

Hydrochar 40-80%

Process Water 20-60%

Gases (CO2, CH4, etc.) <5%

KOH Pellets

800 C, 1h, 2:1 Ratio,
Nitrogen atrmosphere

AC – HTC-0
SSA = 1046m^2/g, P_{vol} = 0.494 cc/g
$R_{pore,avg}$ = 11.56 A

High-value, porous, thermally stable, activated carbons.
(DFT SSA, P/Po of 0.1 to 0.9)

ACS OMEGA

http://pubs.acs.org/journal/acsodf

Article

Effects of $FeCl_3$ Catalytic Hydrothermal Carbonization on Chemical Activation of Corn Wet Distillers' Fiber

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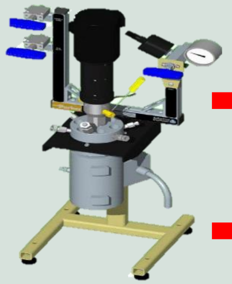
PROPOSED NOVEL PROCESS

Proposed 2-Stage Process: GO Assisted HTC of Corn Fiber With KOH Activation

Corn Fiber → HTC (180-240°C, 1hr) → **GO-Assisted Hydrochar** → KOH Activation (700°C, 1hr) → **High-value, Thermally Stable Activated Carbon for Advanced Applications**

Graphene Oxide (1:300-1:1000, GO:CF) →

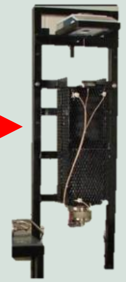
Water →

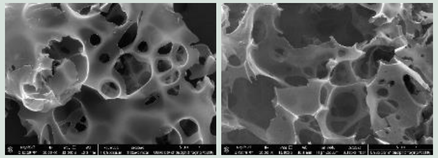


→ Process Water (20-60%)

→ Gases (CO$_2$, CO$_4$, etc. <5%)

Potassium Hydroxide (3:1 KOH to hydrochar) →





Corn fiber is high in moisture and nitrogen content[1]:

Low-value by-product of corn ethanol industry[1]

Suitable for HTC, enhancement of H$_2$ storage properties from N$_2$ functionality[2]

Addition of GO (C$_{140}$H$_{42}$O$_{20}$):

Act as catalyst during HTC, enhance morphology of hydrochar[3,4]

Promote HTC reactions and facilitate carbonization[3,4]

HTC for carbonization step

Enhances pore formation and degree of carbonization[5,6]

Consumes less energy than conventional carbonization methods[6]

Reduction in ash content and impurities[6]

Chemical Activation with KOH

Promote formation of micropores[7]

Higher surface area[7]

Surface Area and Porosity

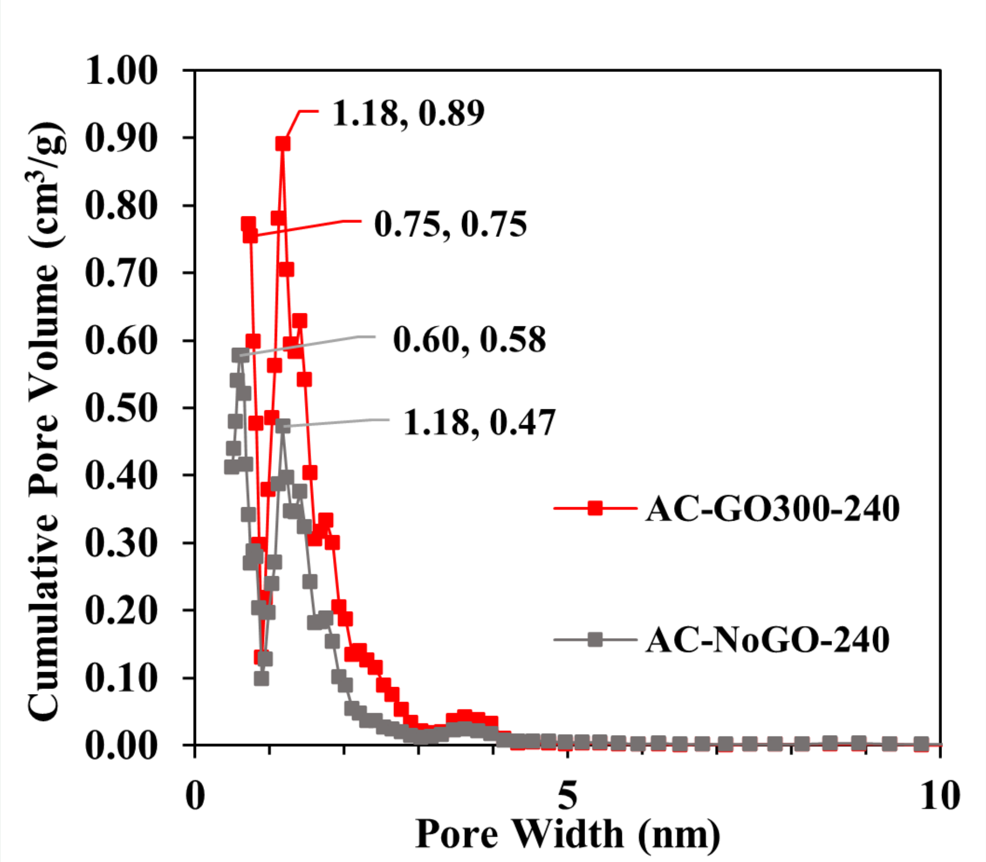
RESULTS

	Nomenclature	BET Specific Surface Area (m²/g)	Total Pore Volume (cm³/g)	Micropore Volume (cm³/g)
Hydrochar	NoGO-240	1.52	-	-
	GO1000-240	1.59	-	-
	GO800-240	3.43	-	-
	GO300-240	5.89	-	-
AC	AC-NoGO-240	1942.71	0.875	0.383
	AC-GO1000-240	2253.72	0.999	0.668
	AC-GO900-240	1866.16	0.829	0.558
	AC-GO800-240	1960.36	0.899	0.451
	AC-GO700-240	2023.19	0.912	0.477
	AC-GO600-240	1908.94	0.888	0.420
	AC-GO500-240	2144.96	0.989	0.489
	AC-GO400-240	1952.76	0.979	0.233
	AC-GO300-240	2549.10	1.098	0.486

Pore Size Distribution

RESULTS

Nomenclature	Micropore Volume (cm^3/g)
AC-NoGO-240	0.383
AC-GO1000-240	0.668
AC-GO900-240	0.558
AC-GO800-240	0.451
AC-GO700-240	0.477
AC-GO600-240	0.420
AC-GO500-240	0.489
AC-GO400-240	0.233
AC-GO300-240	0.486

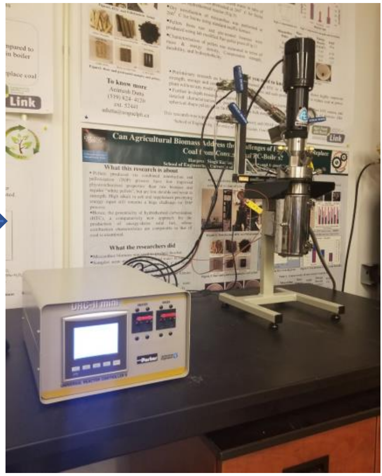


- **Increased micropore volume** indicates added stability, resistance to pore enlargement from KOH activation

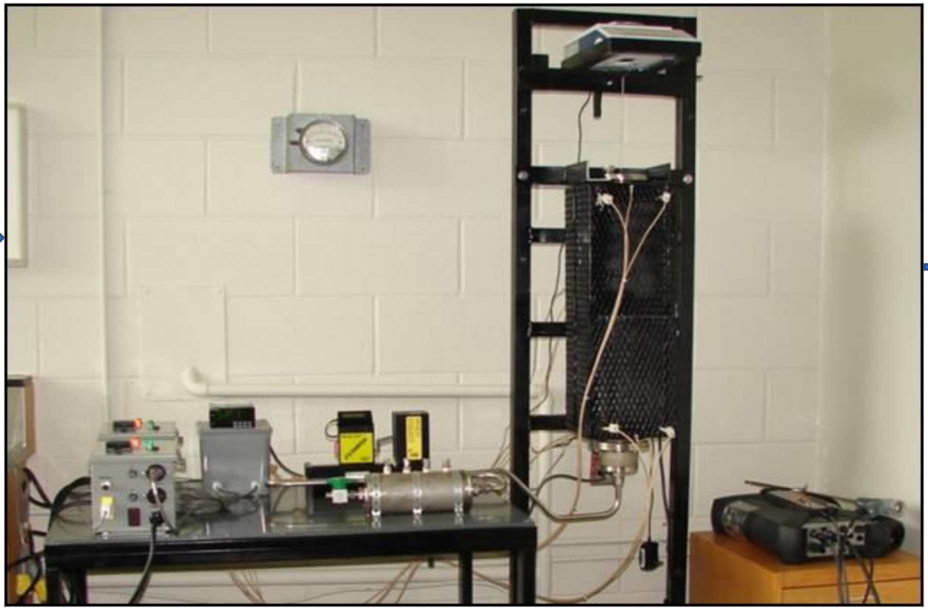
Hydrogen Storage Potential

- Most effective in micropores (0.7nm)
- Requires high surface area
- Presence of surface functional groups
- N-doping without extra step

Case Study 3: Miscunthus/Switchgrass to Biocabon for Iron and Steel Industries: A Tunable Approach



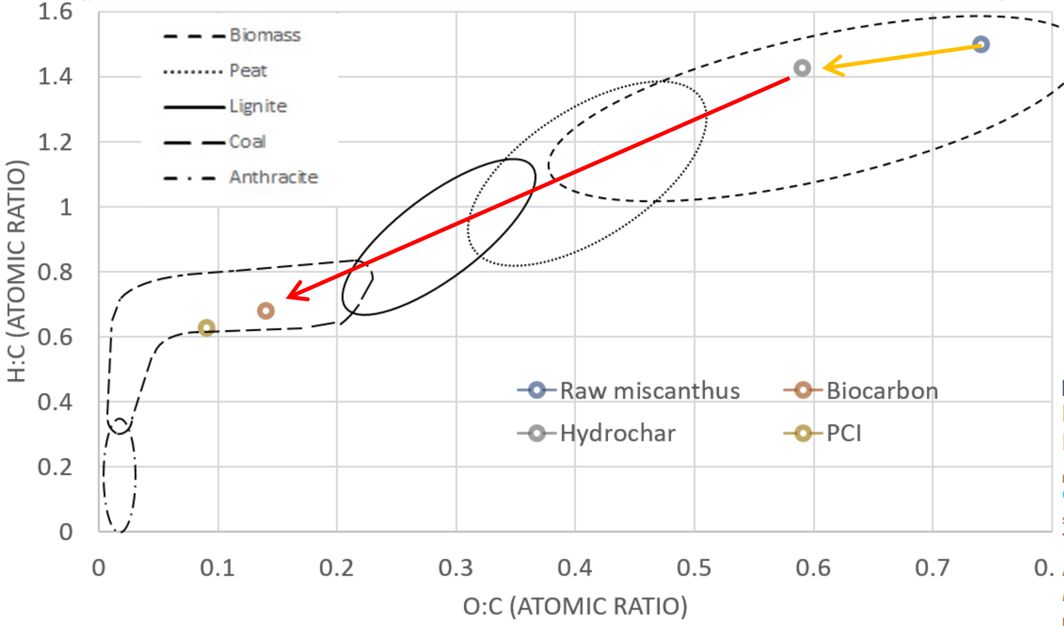
Hydrochar	
C(%)	**52.2**
H(%)	6.2
N(%)	0.05
S(%)	0
O(%)	**41.31**
Ash(%)	**0.24**
FC(%)	15.1
VM(%)	84.66
HHV (MJ/Kg)	**20.37**



Biocarbon	
C(%)	**79.67**
H(%)	4.5
N(%)	0.35
S(%)	0
O(%)	**14.69**
Ash(%)	**0.79**
FC(%)	63.71
VM(%)	35.5
HHV (MJ/Kg)	**32.59**

PCI coal	
C(%)	**77.66**
H(%)	4.1
N(%)	1.76
S(%)	0.3
O(%)	**9.53**
Ash(%)	**6.65**
FC(%)	56.94
VM(%)	36.41
HHV (MJ/Kg)	**32.07**

Properties	Raw Switchgrass	Torrefied-290
%C	**44.76 ± 2.04**	**64.28 ± 2.42**
%H	6.04 ± 0.62	4.34 ± 0.69
%N	0.66 ± 0. 08	0.68 ± 0.13
%S	0	0
%O	**44.09 ± 1.87**	**23.58 ± 1.87**
HHV (MJ/Kg)	**17.13 ± 1.49**	**26.04 ± 1.91**
%VM	84.3 ± 3.18	50.35 ± 2.72
%Ash	**4.45 ± 0.23**	**7.12 ± 0.38**
%FC	11.25 ± 0.8	42.53 ± 1.83



Miscanthus to Biocarbon for Canadian Iron and Ste
Industries: An Innovative Approach

by Trishan Deb Abhi, Omid Norouzi, Kevin Macdermid-Watts, Mohammad Heidari, Syeda Tasnim and Animesh Dutta *

School of Engineering, University of Guelph, Guelph, ON N1G 2W1, Canada
* Author to whom correspondence should be addressed.

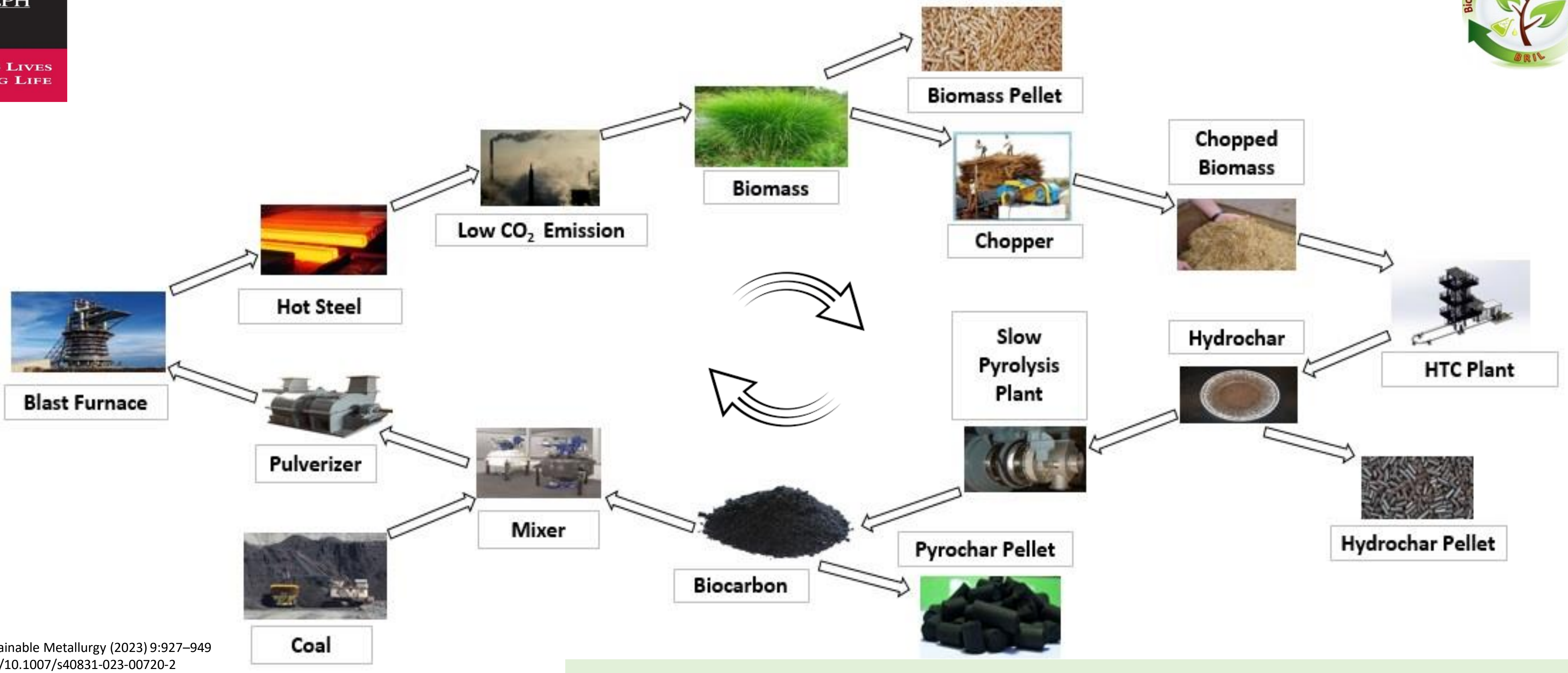
Academic Editor: Prasad Kaparaju

Energies **2021**, *14*(15), 4493; https://doi.org/10.3390/en14154493

Received: 15 June 2021 / Revised: 20 July 2021 / Accepted: 23 July 2021 / Published: 25 July 2021

(This article belongs to the Special Issue Carbonization of Biomass for Energy Production)

Ex. 3 Continued: Overall Approach Industry relevance



Journal of Sustainable Metallurgy (2023) 9:927–949
https://doi.org/10.1007/s40831-023-00720-2
REVIEW ARTICLE

Challenges and Opportunities of Agricultural Biomass as a Replacement for PCI Coal in the Ironmaking Blast Furnace:

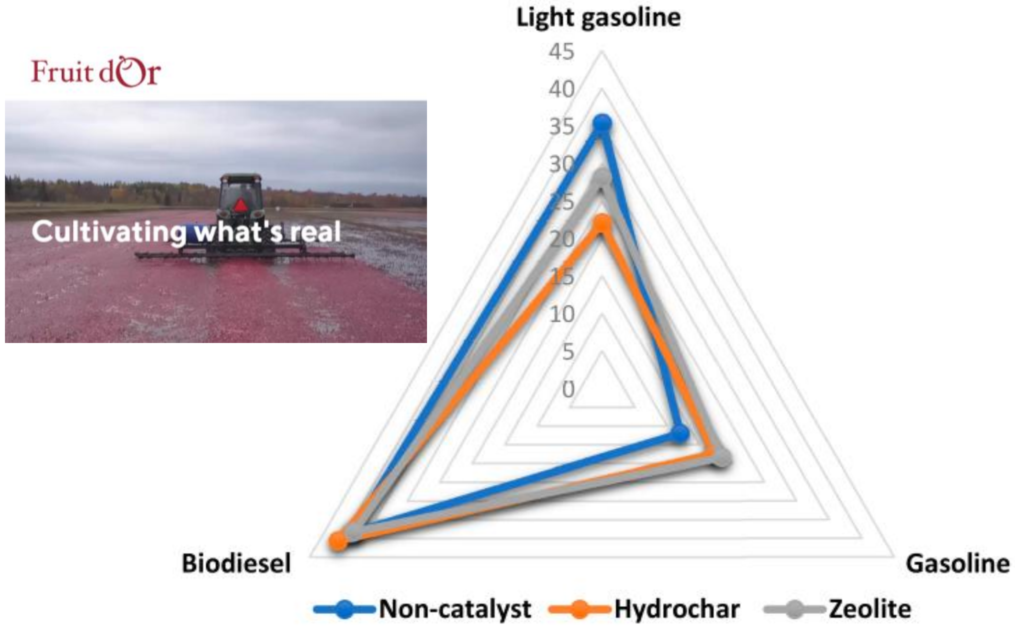
A Review

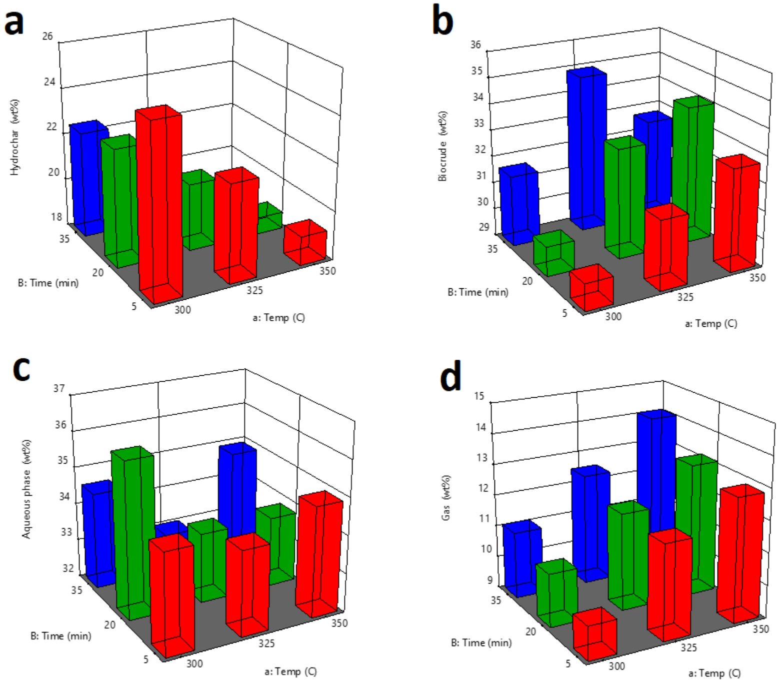
Trishan Deb Abhi[1] · Kevin MacDermid-Watts[1] · Shakirudeen A. Salaudeen[2] · Aneela Hayder[1] · Ka Wing Ng[3] · Ted Todoschuk[4] · Animesh Dutta[1]

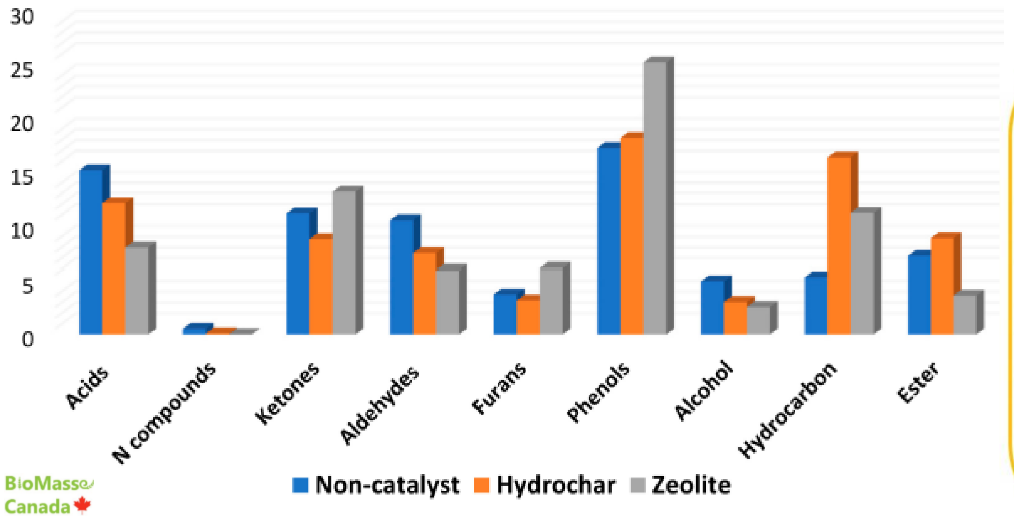
Significance:

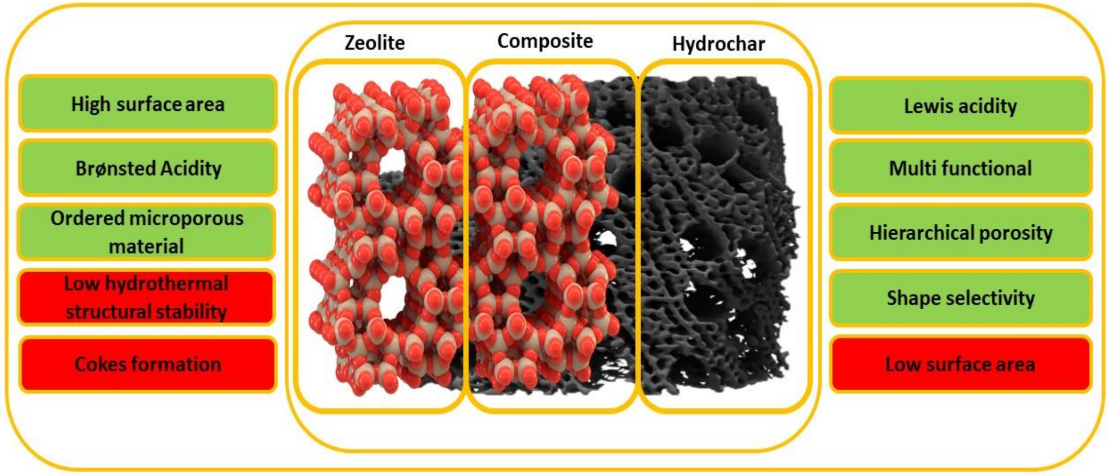
- Integrated HTC and slow pyrolysis of high ash low grade biomass
- Biocarbon with less ash content and good combustion behavior
- Partial replacement of fossil carbon in blast furnace iron making process
- Reduction of GHGs emission

Case Study 4: New Insights for the Future Design of Composites Composed of Hydrochar and Zeolite from Cranberry Pomace. Ref: Energies 13 (24), 6600, 2020









High surface area

Brønsted Acidity

Ordered microporous material

Low hydrothermal structural stability

Cokes formation

Lewis acidity

Multi functional

Hierarchical porosity

Shape selectivity

Low surface area


scientific reports

Article | Open Access | Published: 08 March 2021

Integrated hybrid architecture of metal and biochar for high performance asymmetric supercapacitors

Omid Norouzi, S. E. M. Pourhosseini, Hamid Reza Naderi, Francesco Di Maria & Animesh Dutta

Scientific Reports **11**, Article number: 5387 (2021) | Cite this article

2220 Accesses | **12** Citations | **1** Altmetric | Metrics

A catalyst based on hydrochar and zeolite (hydrochar/zeolite composite) can resolve present limitations and challenges by:

- Creating meso/macropores into the micropores structure of the zeolite;
- Increasing the number of accessible active sites for macromolecules;
- Enhancing the thermal stability of the zeolite;
- Creating 3D interconnected structure using activated hydrochar

Case Study 4: Design of a ternary 3D composite from hydrochar, zeolite and magnetite powder for direct conversion of biomass to gasoline


Volume 412 15 May 2021 ISSN 1385-8947

ELSEVIER

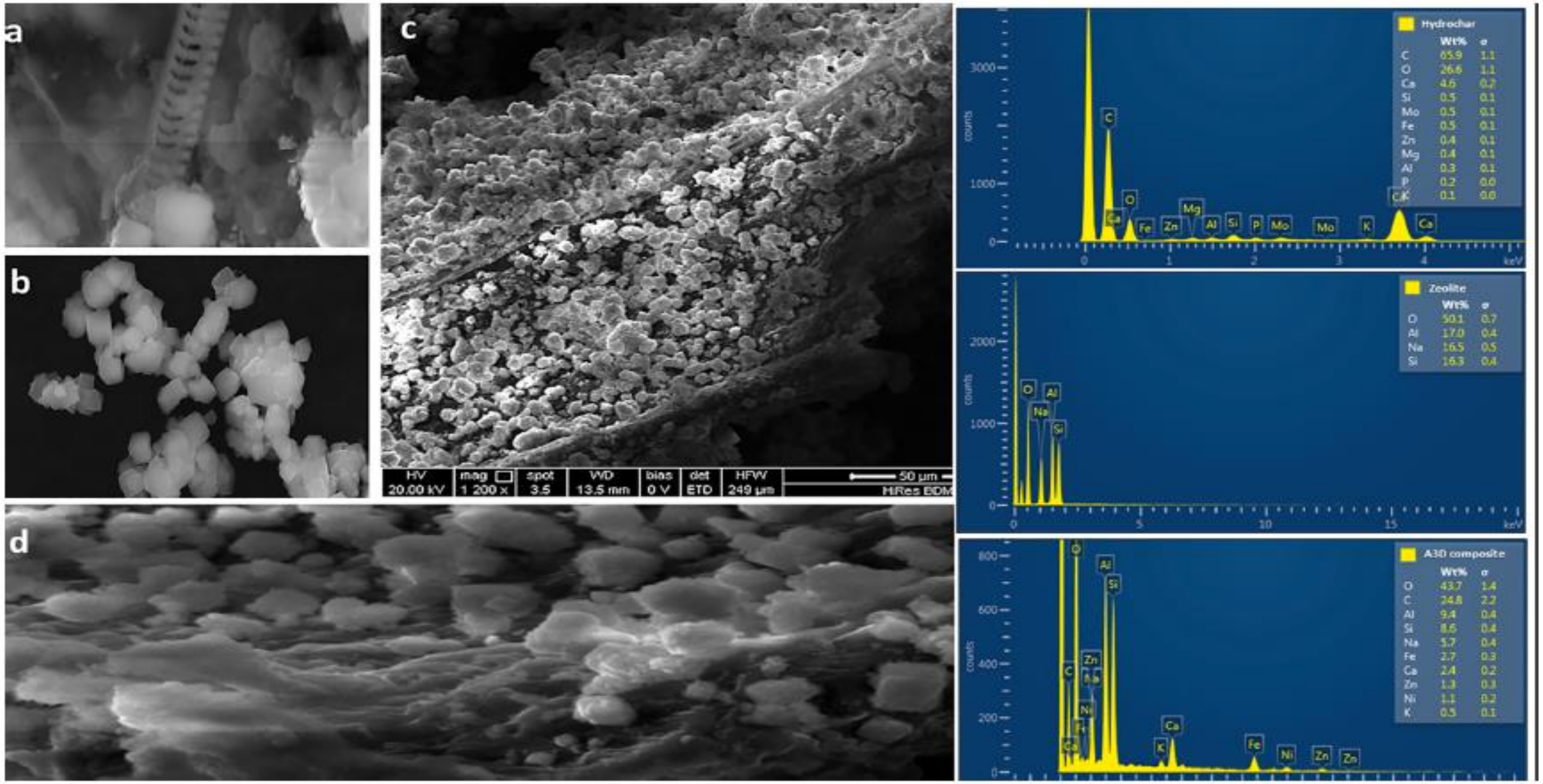
CEJ CHEMICAL ENGINEERING JOURNAL

OZONATION OF SULFAMETHOXAZOLE
Ordered Mesoporous Alumina
Fe-doping (4.7 wt.% Fe)
O_3
Al_2O_3
X_{TOC} = 86%
ADSORPTION removal
Poor catalytic contribution
EVAPORATION-INDUCED SELF-ASSEMBLY

FEATURED ARTICLE
ENVIRONMENTAL CHEMICAL ENGINEERING
On disclosing the role of mesoporous alumina in the ozonation of sulfamethoxazole: Adsorption vs. Catalysis
Carla di Luca, Natalia Inchaurrondo, Mireia Marcé, Rodrigo Parra, Santiago Esplugas, Patricia Haure

Wanqian Guo, Qi Zhao, Juanshan Du, Huazhe Wang, Xiaofan Li, Nanqi Ren

Vol. 410, 15 April 2021, 128323



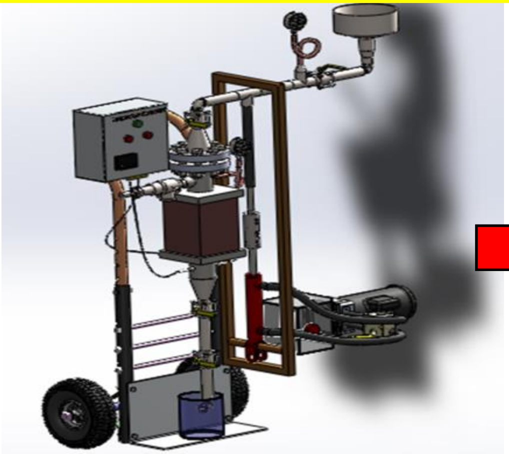
- ➢ We have synthesized a zeolite-hydrochar composite using a simple one-step hydrothermal liquefaction (HTL) process.
- ➢ hierarchically structured porosity of the composite facilitates diffusion of macromolecules and their derivatives inside the composite and improves the accessibility to lewis acid sites.
- ➢ The chemical interaction of hydrochar/zeolite was confirmed by XRD and SEM-EDS analyses

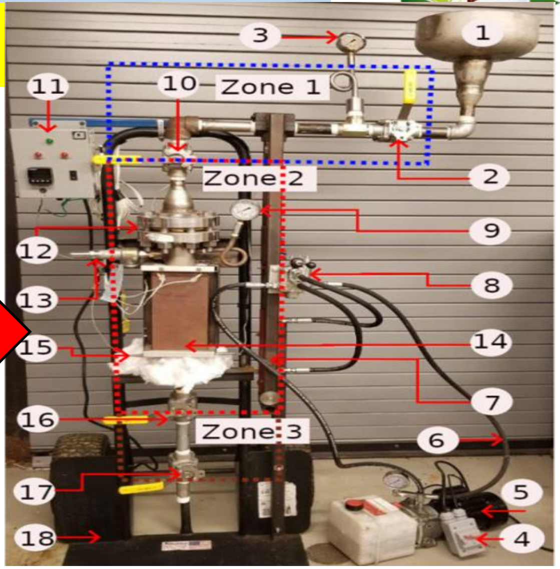
Technical Progress

Lab scale continuous hydrothermal carbonization (HTC) reactor

A lab-scale continuous hydrothermal carbonization (HTC) reactor is developed and validated.

Conceptual Design





Springer Link

Original Article | Published: 06 August 2020

Product evaluation of hydrothermal carbonization of biomass: semi-continuous vs. batch feeding

Mohammad Heidari, Omid Norouzi, Kevin MacDermid-Watts, Bishnu Acharya, Yongsheng Zhang & Animesh Dutta

Biomass Conversion and Biorefinery **12**, 15–25 (2022) | Cite this article

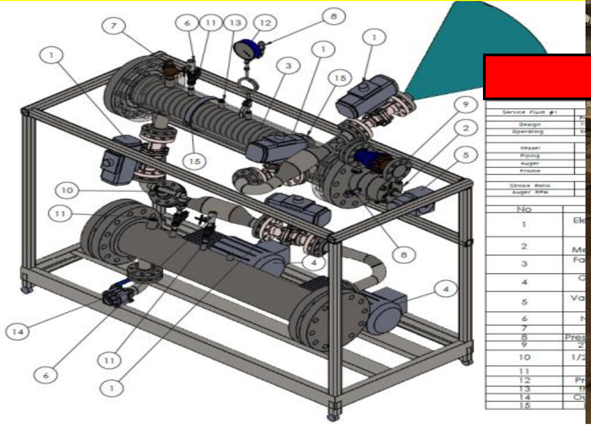
479 Accesses | **10** Citations | Metrics

Continuous HTC is favorable due to the enhancement of primary carbonization and suppression of secondary carbonization; higher qualities of the hydrochar can be obtained.

Pilot scale continuous hydrothermal carbonization (HTC) reactor

A continuous pilot scale HTC reactor being developed. The process was validated with laboratory scale trials.

Conceptual Design

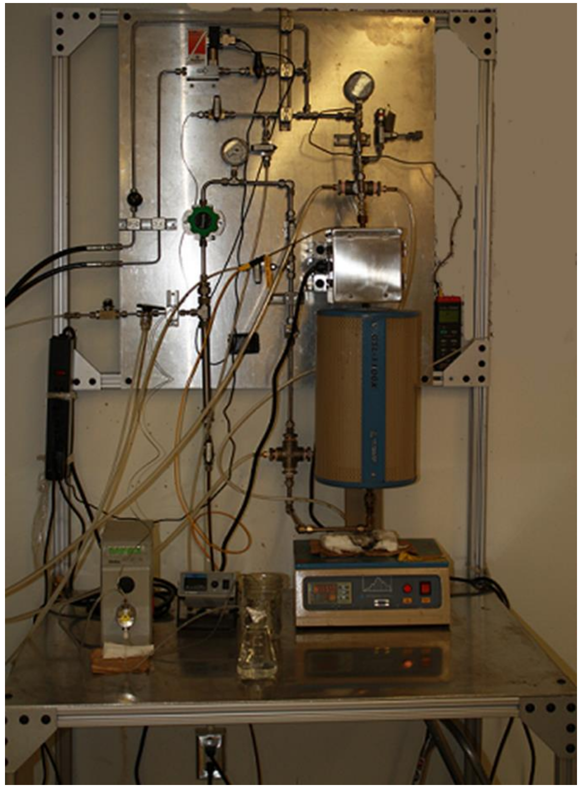


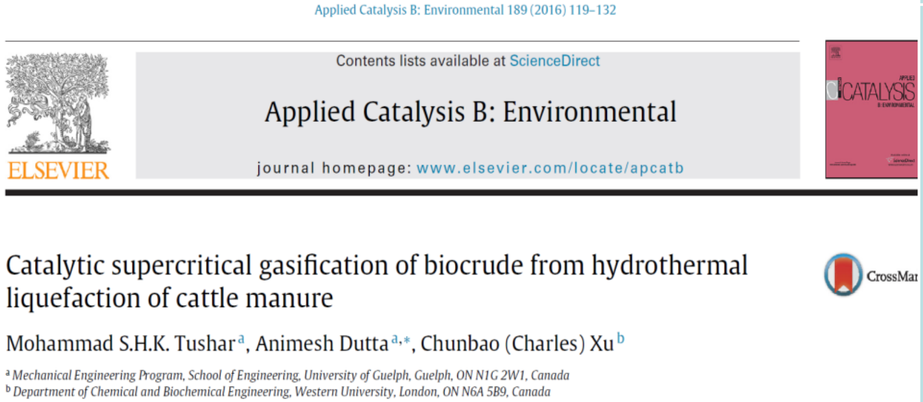
Opportunities for renewable hydrogen and chemicals from waste resources

Funding from NSERC, AAFC and OMAFRA

UNIVERSITY of GUELPH

Catalytic Supercritical Gasification of Biocrude from Hydrothermal Liquefaction of Cattle Manure





Applied Catalysis B: Environmental 189 (2016) 119–132

Contents lists available at ScienceDirect

Applied Catalysis B: Environmental

journal homepage: www.elsevier.com/locate/apcatb

Catalytic supercritical gasification of biocrude from hydrothermal liquefaction of cattle manure

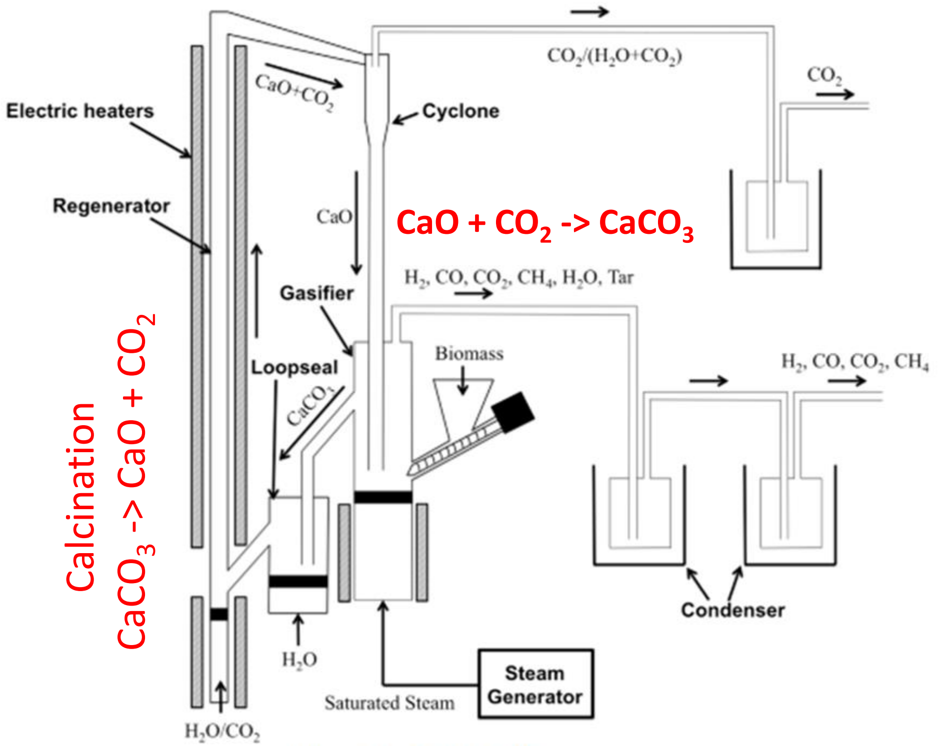
Mohammad S.H.K. Tushar[a], Animesh Dutta[a,*], Chunbao (Charles) Xu[b]

[a] Mechanical Engineering Program, School of Engineering, University of Guelph, Guelph, ON N1G 2W1, Canada
[b] Department of Chemical and Biochemical Engineering, Western University, London, ON N6A 5B9, Canada

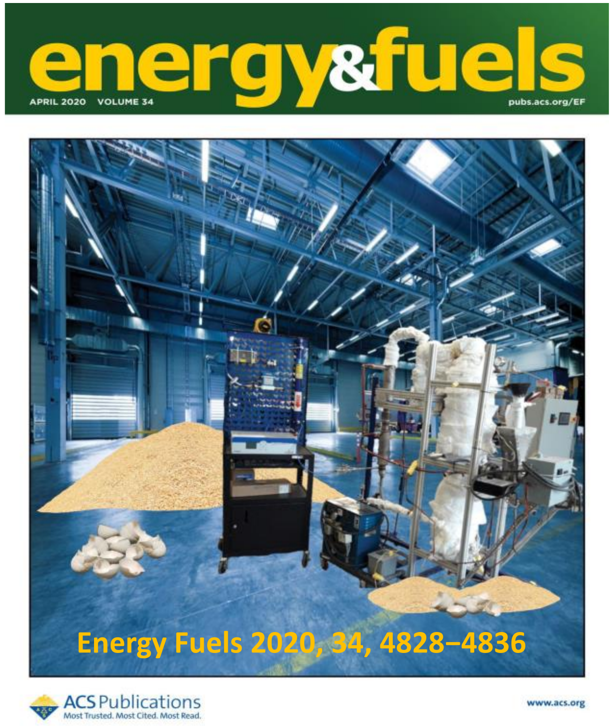
Comparison of hydrogen yield and CGE to other researches

Study and experimental conditions	Catalytic condition	Hydrogen Yield (mol/mol$_{carbon}$)	Carbon Gasification Efficiency
Present study **Cattle manure biocrude** **(700 °C, 25 MPa)**	**Unanalyzed**	**0.50**	**0.89**
	Ni10%-Ru0.08%/Al_2O_3-ZrO_2	**1.10**	**0.95**
Zhang et al. Sludge and waste newspaper biocrude (700 °C, 24 MPa)	Unanalyzed	0.52	0.90
	Ni10%-Ru0.1%/Al_2O_3	0.49	0.97
	Ni10%-Ru0.1%/AC	0.85	0.92
Byrd et al. Switchgrass biocrude (600 °C, 25 MPa)	Ru/TiO_2	0.81	0.78
	Ru/ZrO_2	--	0.67
	Ni/TiO_2	0.69	0.74
	Ni/ZrO_2	0.95	0.96
	Co/TiO_2	0.56	0.83
	Co/ZrO_2	0.71	1.02

Hydrogen-rich gas stream from steam gasification of biomass: Eggshell as a CO_2 sorbent



Schematic of CFB-CLG


energy&fuels

APRIL 2020 VOLUME 34

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Energy Fuels 2020, 34, 4828–4836

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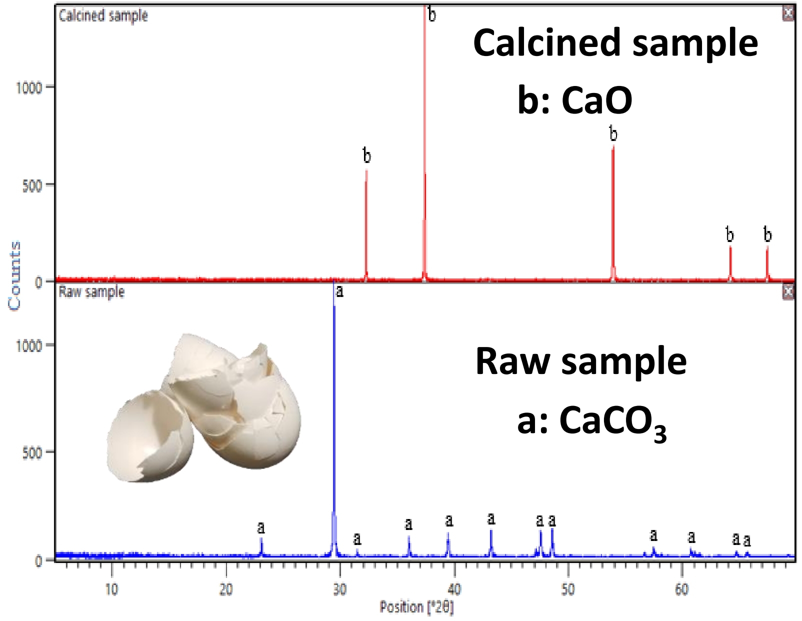
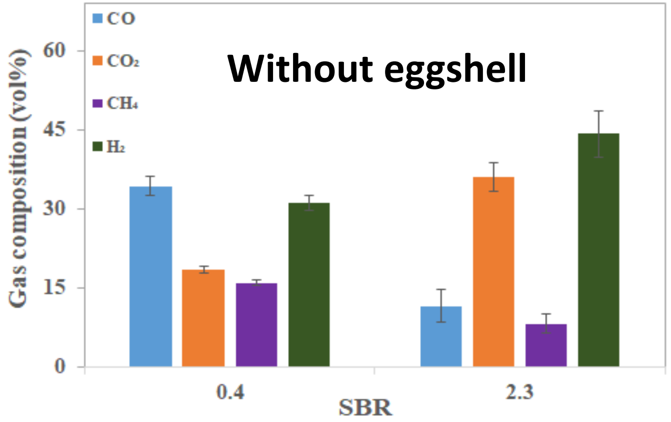
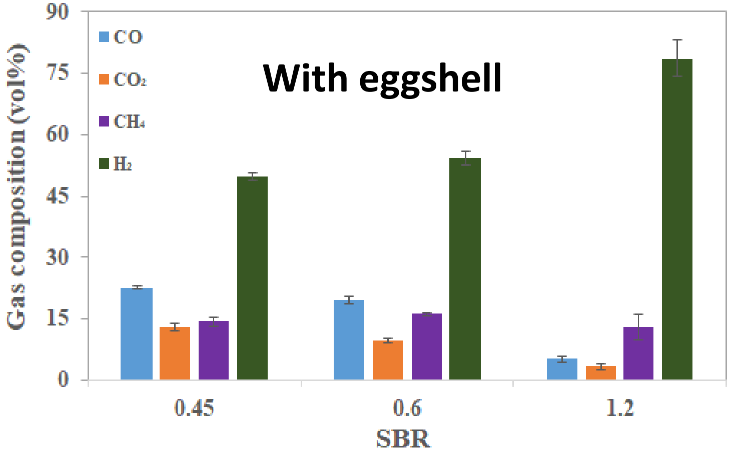


XRD results show that eggshell is mainly $CaCO_3$

Eggshell has been converted from $CaCO_3$ to CaO


Without eggshell


With eggshell

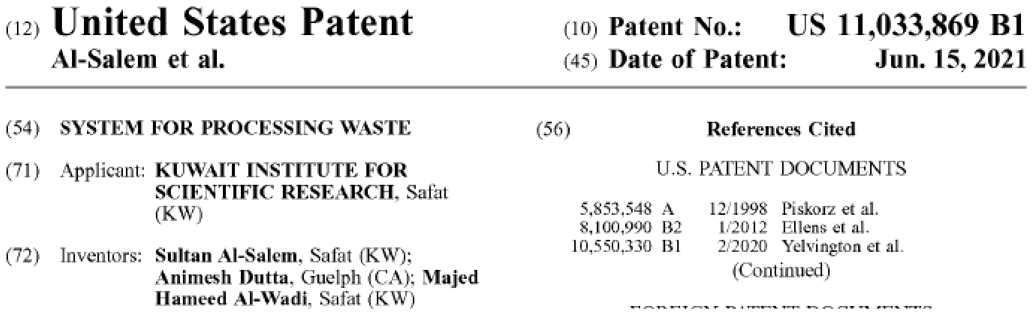
- The utilization of eggshell in gasification has been experimentally investigated.
- The inclusion of calcined eggshell in the process reduced CO_2 concentration and increased hydrogen concentration

Pilot Plant System for Processing Waste

Brief system description

- The pilot plant system for the conversion of waste was recently patented by the United States Patent and Trademark Office (USPTO, US 11,033,869 B1, 2021)
- The system has both a fixed bed reactor and a fluidized bed reactor, which may be operated separately or simultaneously.

A picture of the patented pilot plant



(12) **United States Patent**
Al-Salem et al.

(10) **Patent No.: US 11,033,869 B1**
(45) **Date of Patent: Jun. 15, 2021**

(54) **SYSTEM FOR PROCESSING WASTE**

(71) Applicant: **KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH**, Safat (KW)

(72) Inventors: **Sultan Al-Salem**, Safat (KW); **Animesh Dutta**, Guelph (CA); **Majed Hameed Al-Wadi**, Safat (KW)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,853,548	A	12/1998	Piskorz et al.
8,100,990	B2	1/2012	Ellens et al.
10,550,330	B1	2/2020	Yelvington et al.

(Continued)

Introduction (USDOE Project)

Plastic and Tire waste Management

Issues

- Over 90% of plastic waste and 65% of tire waste find their way to landfills
- Non-biodegradable in nature
- Disturb the land and marine environment

Opportunities

- High heating value of plastics (40-42 MJ/kg) and tires (28-32 MJ/kg)
- Commercial waste to energy technologies (such as pyrolysis) available in market

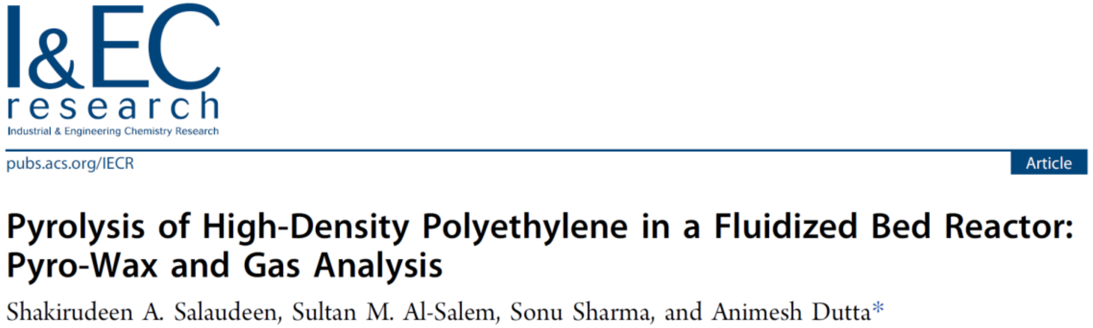
Chemical Upcycling of Waste Plastics

Analysis of Pyrolytic Wax from Plastics (HDPE)

- The recovery of wax from the pyrolysis of high-density polyethylene in a patented pilot scale system has been investigated.
- Pyrolysis experiments were performed at 500 C in the fluidized bed section of the patented system.
- Characterizations of the feedstocks and obtained waxes were conducted with TGA-DSC, FTIR, GCMS, elemental analysis, and heating value.

Product distribution from the experiment

	Product distribution
Total feed (kg)	5.00
Wax (wt.%)	45.56
Oil (wt.%)	9.00
Char (wt.%)	0.10
Gas (wt.%)	45.34



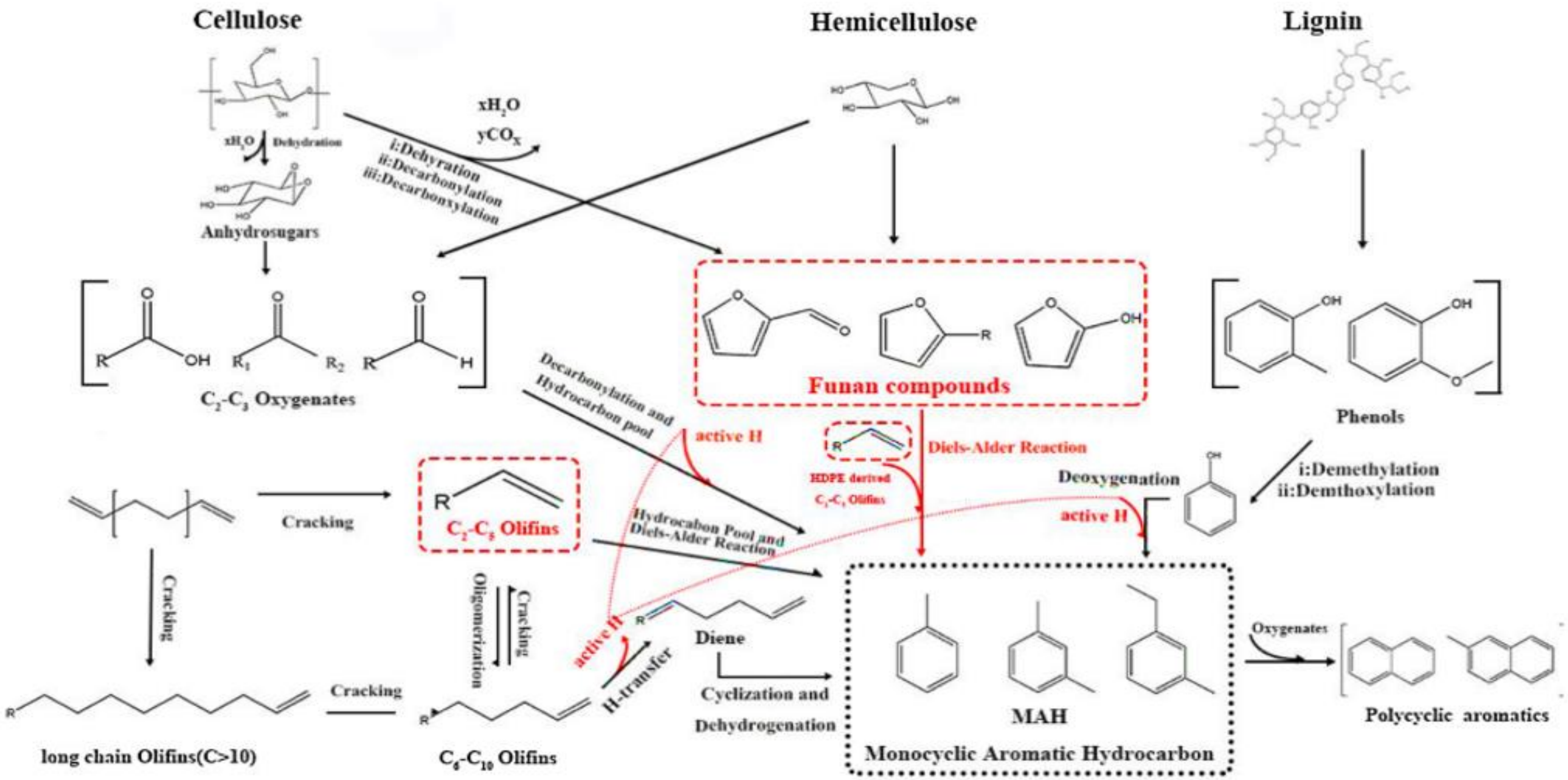
I&EC research
Industrial & Engineering Chemistry Research

pubs.acs.org/IECR
Article

Pyrolysis of High-Density Polyethylene in a Fluidized Bed Reactor: Pyro-Wax and Gas Analysis

Shakirudeen A. Salaudeen, Sultan M. Al-Salem, Sonu Sharma, and Animesh Dutta*

Possible reaction pathway for aromatic hydrocarbons formation of co conversion of plastic and biomass



Current International Collaborator

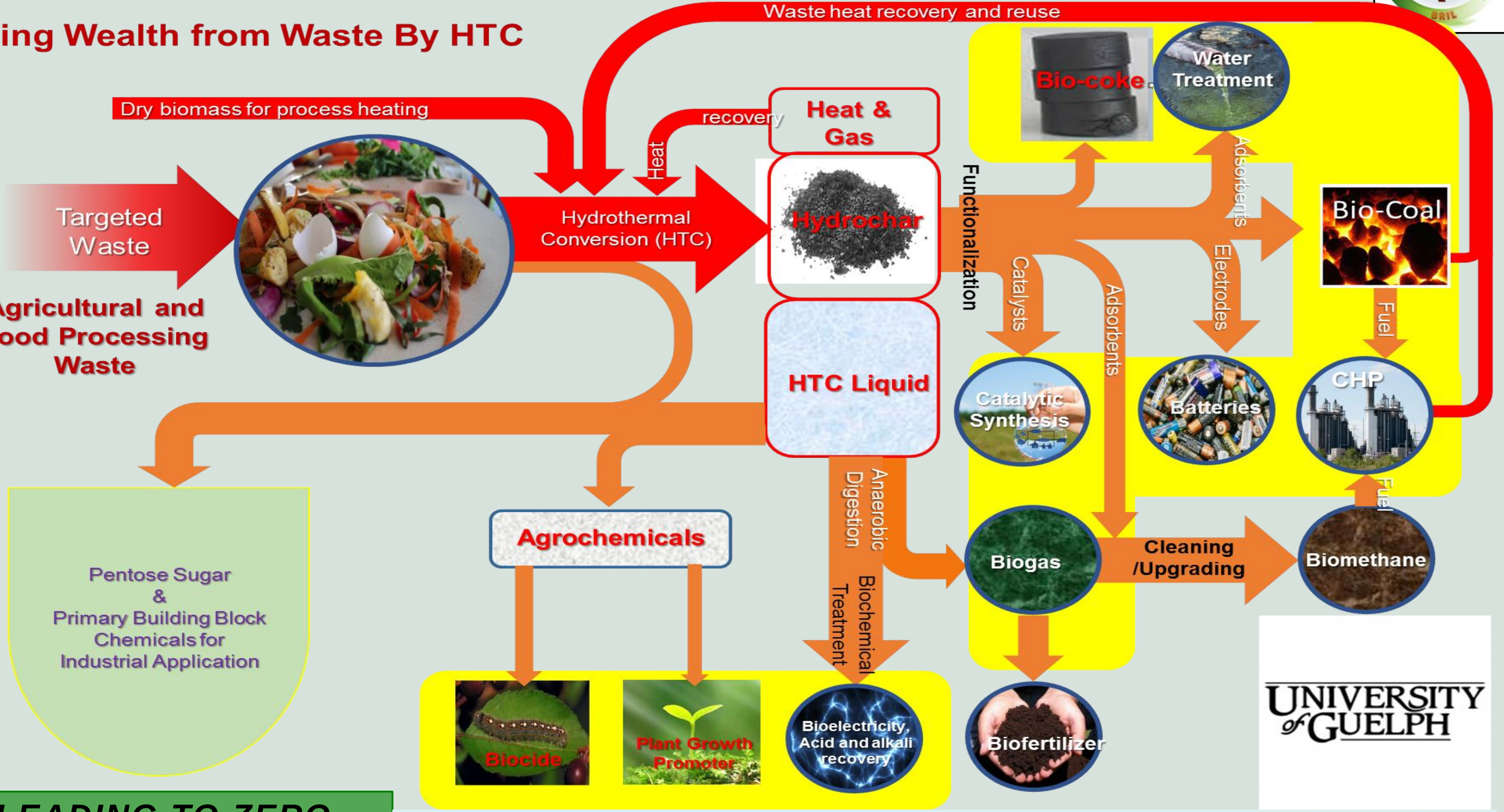
Research Project:

- Chemical Upcycling of Waste Plastic (USDOE) (CUWP.org) (Prof. George Hubber, University of Wisconsin-Madison, and Prof. Robert Brown, Iowa State University)
- Waste Plastic Pyrolysis: (Dr. Sultan al-Salem, KISR, Kuwait)
- Hydrothermal Carbonization research: (Dr. K Yoshikawa, Tokyo Institute of Technology, Japan, Dr. Kangil Chris Choe, Kinava, Korea, Dr. Brajesh Dube, IIT Kharagpur, India, Dr. Luca Fiori, Italy, Dr. Toufiq Reza, Florida Institute of Technology, USA)
- Renewable Methene (Dr. Francesco Di Maria, Universita di Perugia, Italy, Professor A. Nzihou of IMT-MA, France)

Approach: Preprocess greenhouse residues, energy crops, crop residues, municipal green bin fruit processing wastes through HTC processing.

Approach Under Evaluation

Creating Wealth from Waste By HTC


Targeted Waste

Agricultural and Food Processing Waste

Dry biomass for process heating

Waste heat recovery and reuse

Hydrothermal Conversion (HTC)

Heat recovery

Heat & Gas

Hydrochar

HTC Liquid

Functionalization

Bio-coke

Water Treatment

Adsorbents

Bio-Coal

Catalysts

Adsorbents

Electrodes

Fuel

Catalytic Synthesis

Batteries

CHP

Fuel

Anaerobic Digestion

Biogas

Cleaning /Upgrading

Biomethane

Biochemical Treatment

Agrochemicals

Pentose Sugar
&
Primary Building Block Chemicals for Industrial Application

Biocide

Plant Growth Promoter

Bioelectricity, Acid and alkali recovery

Biofertilizer

LEADING TO ZERO-WASTE SOLUTIONS

HTC products from low quality agri-food residue can be a potential newer value chain

UNIVERSITY of GUELPH

BRIL TEAM

Bio-renewable Innovation Lab
BRIL

Thank You for Your Time

Contact: adutta@uoguelph.ca

https://www.uoguelph.ca/engineering/faculty/adutta

RÉSEAU BIOFUELNET CANADA

Acknowledgement

BioMasse Canada

CINDAR POWER DEVELOPMENTS INC.

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

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NSERC CRSNG

Ministry of Agriculture, Food & Rural Affairs

Ontario
Ministry of the Environment and Climate Change

Shrimp Canada

Ontario
Ministry of Research and Innovation