

# Microwave-Assisted Gasification of Biochar: Effect of Operational Parameters and Biochar Composition on Syngas Production



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# Disclaimer



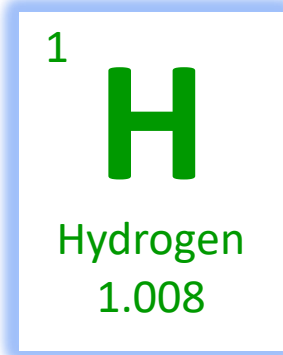
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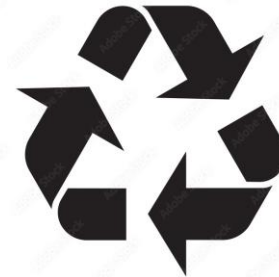
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# Hydrogen Production from Biomass/Plastic



## Hydrogen Production from Biomass/Plastic Gasification



**PLASTIC**



**Biomass Waste**

### Biomass Sources

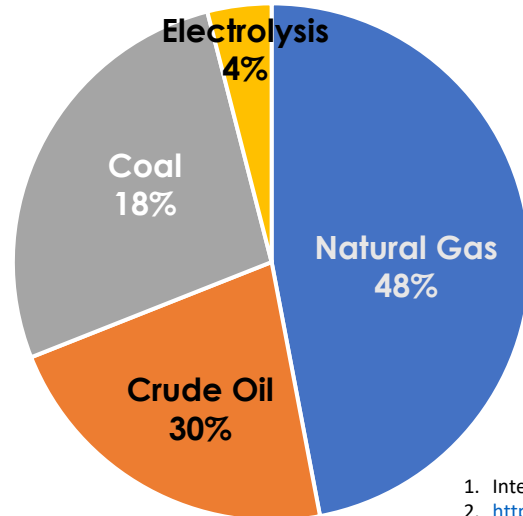
Agricultural wastes and residues

Forestry wastes and residues

Perennial crops

Municipal solid waster

### 2022 Global Hydrogen Production<sup>1</sup>



- Abundance of biomass available (up to 1 billion dry tons).<sup>2</sup>
- Majority of the plastic waste is landfilled or incinerated. Only 9% of the plastic waste is recycled.<sup>3</sup>

1. International Renewable Energy Agency

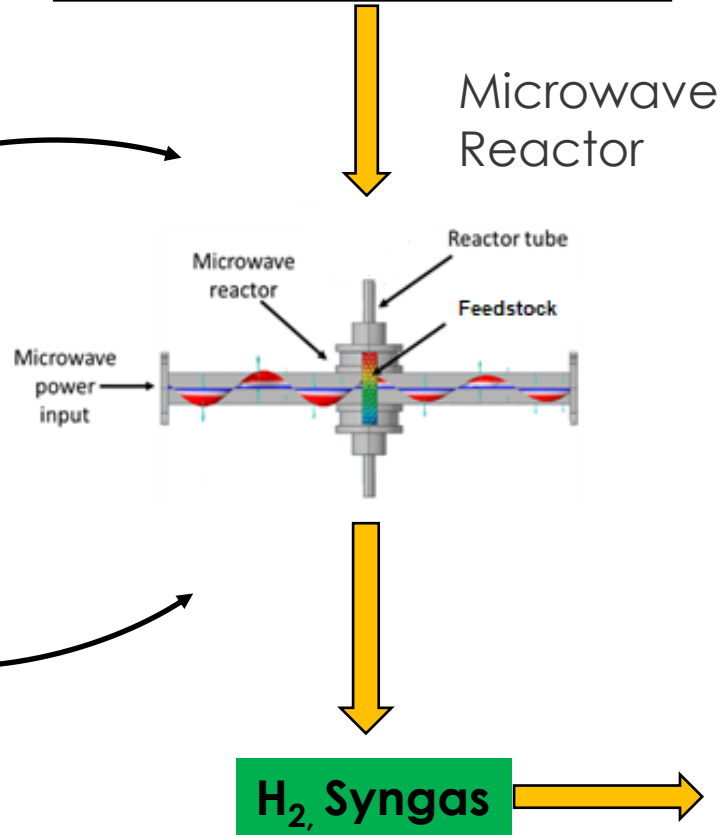
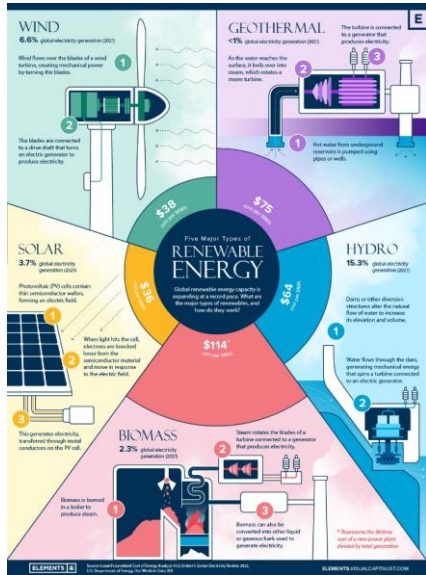
2. <https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification>

3. <https://wha-international.com/hydrogen-in-industry/>

# Proposed Approach: Microwave Gasification

Feedstock: Biomass, Waste plastics

## Coupling with Energy Resources



Microwave Reactor

## Process Intensification

- Process modularity
- Efficient rapid heating and promoting favorable reaction
- Electrification of process – **cleaner H<sub>2</sub>**

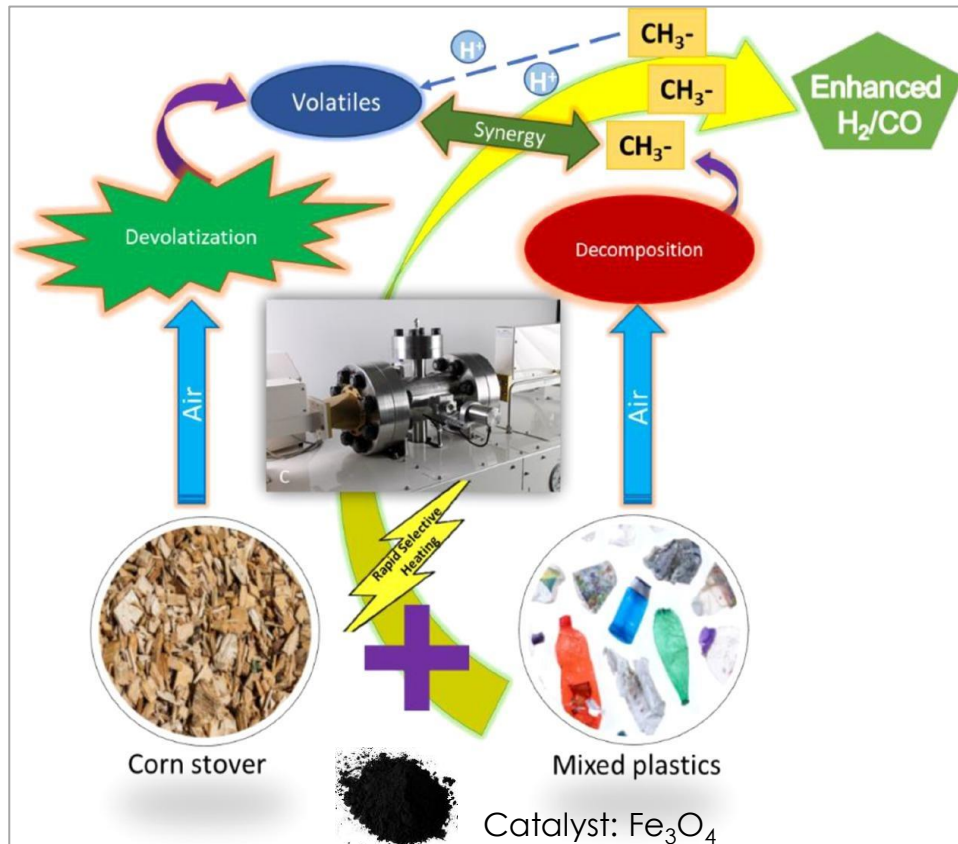


H<sub>2</sub>, Syngas

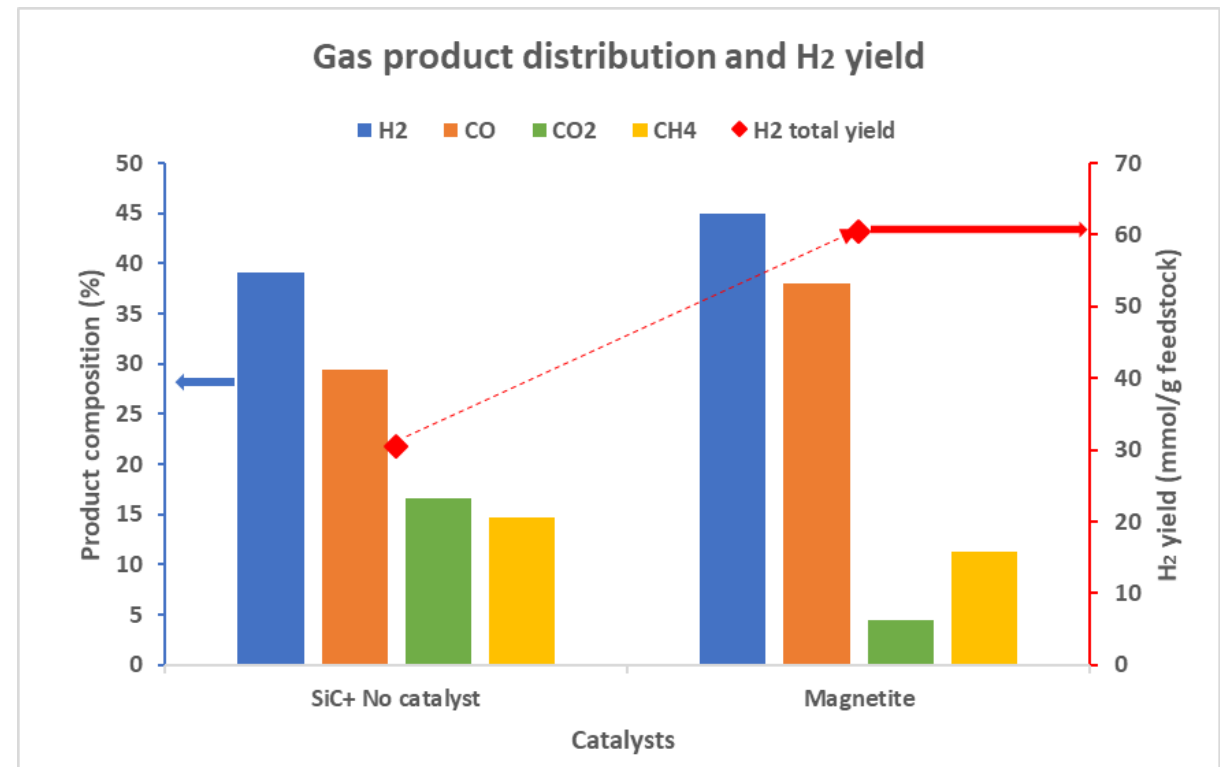
Fuels & Chemicals

# Corn Stover/Plastics Microwave Gasification

## Reaction Mechanism



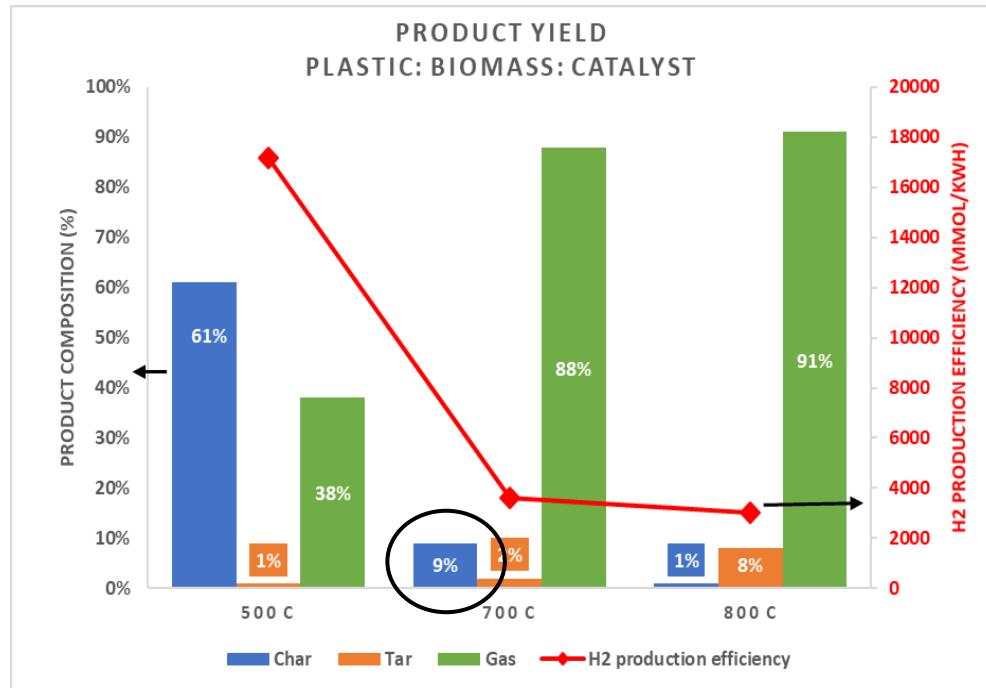
## Enhanced $\text{H}_2/\text{CO}$ Production



Abedin et al., 2023 *Energy Conversion and Management*, Volume 280, 116774, ISSN 0196-8904.

Abedin et al., 2024 *International Journal of Hydrogen Energy*, In Press.

## Formation of Tar and Char



Abedin et al., 2023 [Energy Conversion](#).

Abedin et al., 2024 [International Journal of Hydrogen Energy](#), *In Press*.

## Study of Biochar Microwave Reaction



Microwave  
Gasification

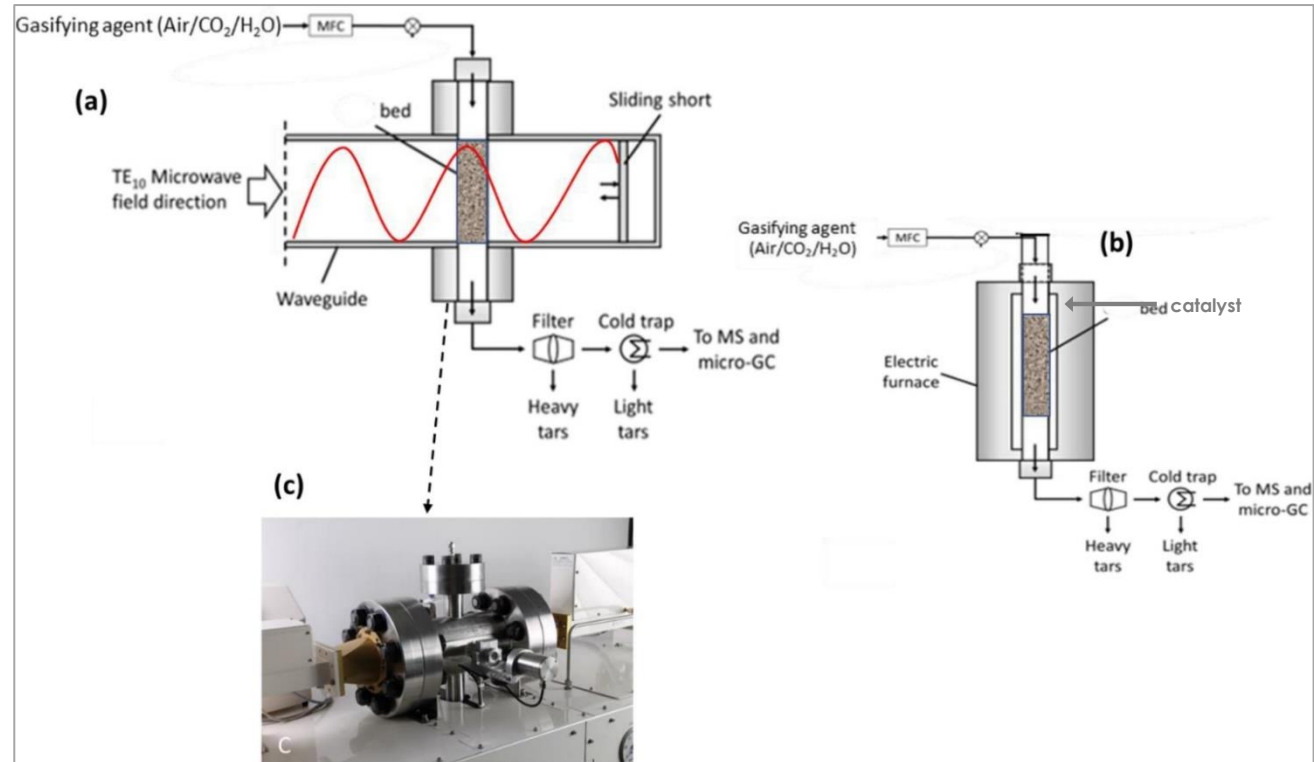


Syngas + Tar + Char

- Formation of char reduces reaction efficiency in large scale units.
- Char gasification is kinetically sluggish.
- Char is active in microwave.

# Microwave Reactor Setup

## Microwave Reactor



Abedin et al., 2023 *Energy Conversion and Management*,  
Volume 280, 116774, ISSN 0196-8904.

## Part 1

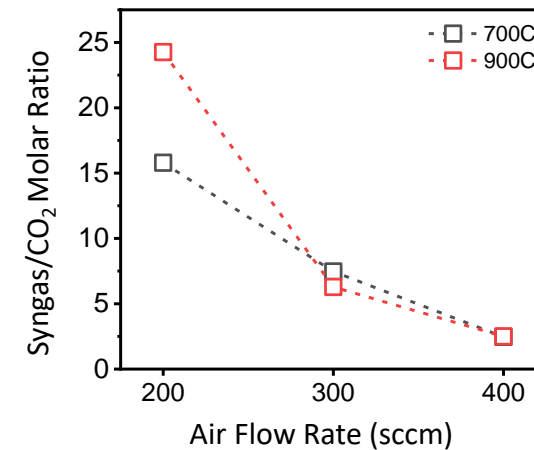
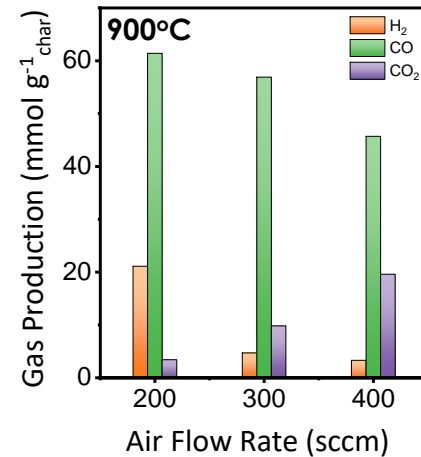
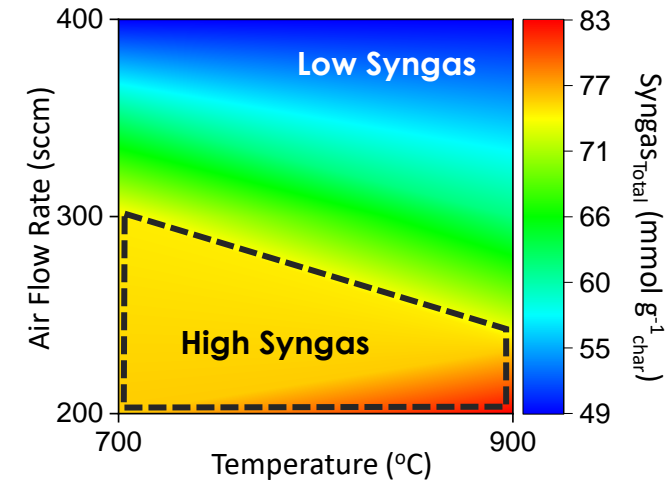
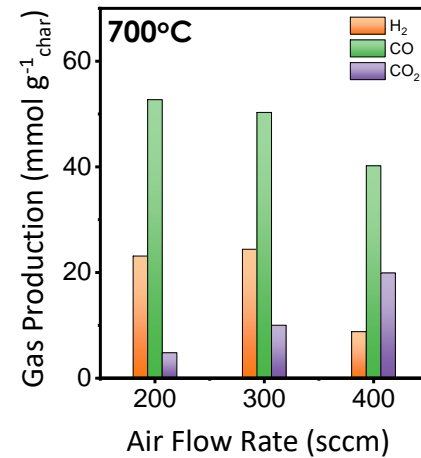
# Parametric Optimization of Microwave-Assisted Catalytic Gasification of Corn Stover Biochar

### Goals:

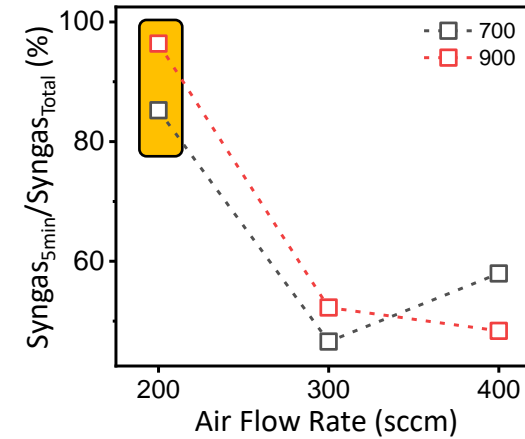
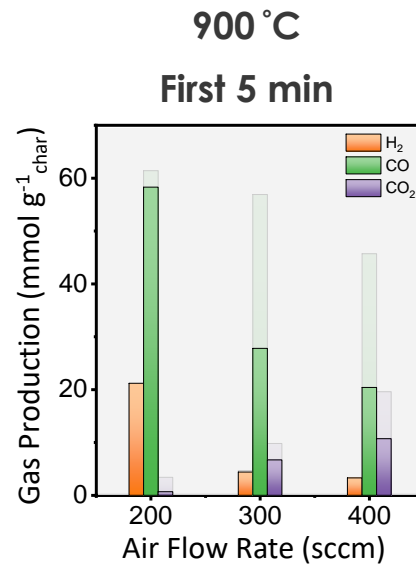
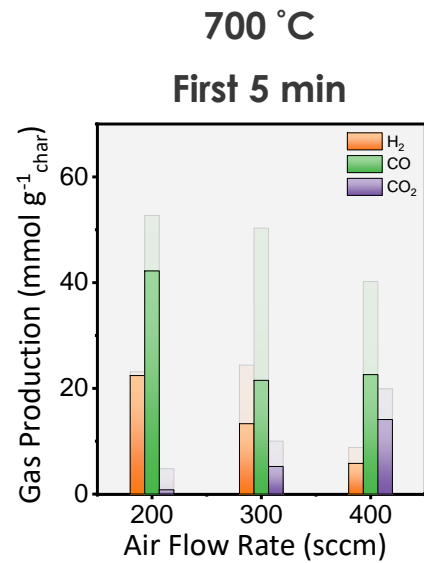
- ✓ Effect of Temperature
- ✓ Effect of Space Velocity
- ✓ Syngas/CO<sub>2</sub> Ratio

# Effect of Temperatures and Char/Gasifying Ratio

- Highest total syngas at air flow rate of 200 to 300 sccm.
- Lowest total syngas at air flow rate of 400 sccm.
- Higher air flow leads to lower hydrogen generation.
- Highest syngas selectivity at 200 sccm.

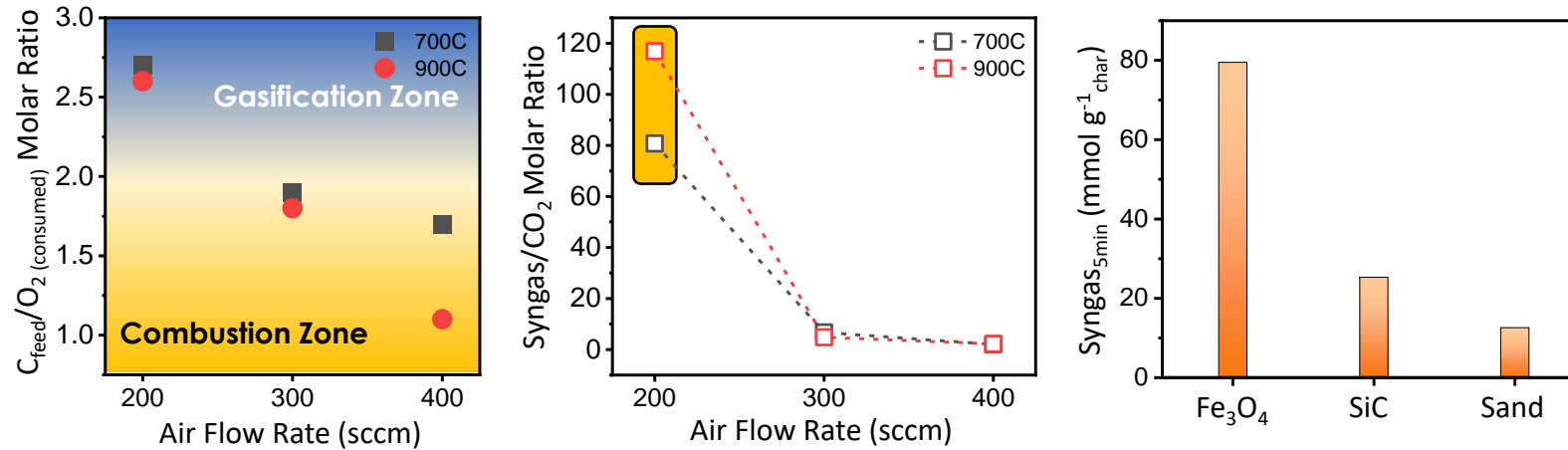


# Total Syngas vs. 5 min Syngas Production



- Lower flow rate leads to faster reaction completion.

# Total Syngas vs. 5 min Syngas Production



- Higher air flow leads reaction to combustion zone when  $C_{\text{feed}}/O_2(\text{consumed})$  ratio is close to 1:1.
- Lower air flow favors formation syngas over CO<sub>2</sub> and leads to faster reaction completion.
- In the presence of Fe<sub>3</sub>O<sub>4</sub>, the production of syngas is 2.5-fold higher than that of SiC.

## Part 2

# Microwave-Assisted Catalytic Gasification of Biochar with Different Composition

### Goals:

- ✓ Composition-Performance Relationship
- ✓ Syngas/CO<sub>2</sub> Ratio

# Proximate Analysis of Biomass Samples

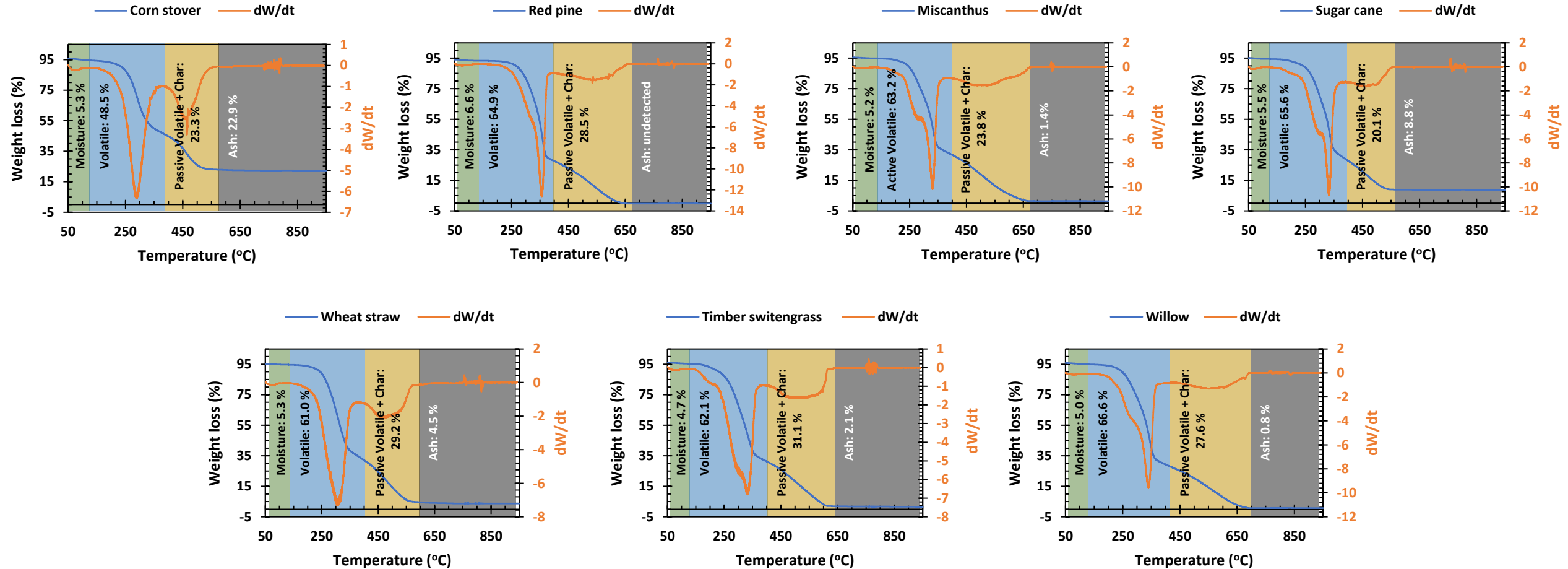
Biomass	Prox. Moisture* (%)	Prox. Ash* (%)	TGA-Based Moisture (%)	TGA-Based Active Volatile** (%)	TGA-Based Passive Volatile + Char*** (%)	TGA-Based Ash (%)
Corn stover	5.68	11.27	5.3	48.5	23.3	22.9
Red pine	7.31	1.16	6.6	64.9	28.5	undetected
Miscanthus	5.6	2.91	5.2	63.2	30.2	1.4
Sugar cane	5.16	10.7	5.5	65.6	20.1	8.8
Wheat straw	8.24	4.84	5.3	61.0	29.2	4.5
Timber switchgrass	5.93	2.88	4.7	62.1	31.1	2.1
Willow	5.73	3.08	5.0	66.6	27.6	0.8

\*Analysis based on proximate analysis.

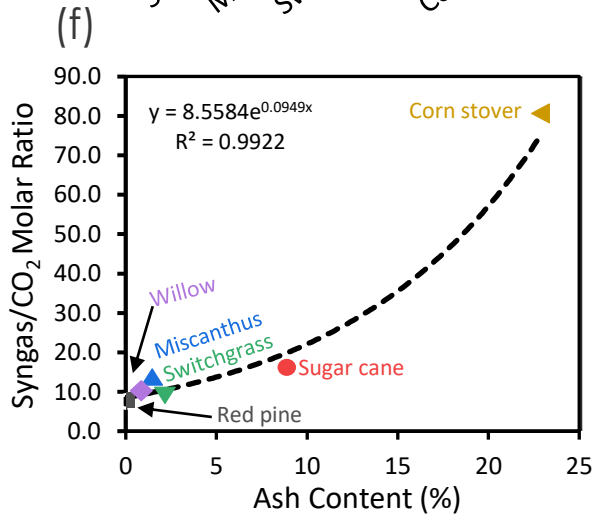
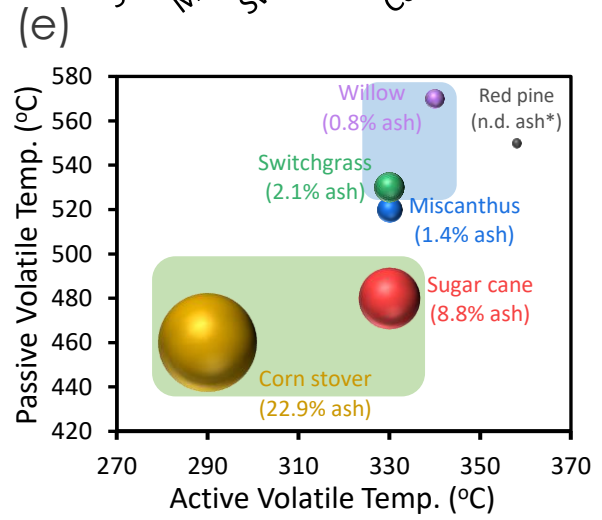
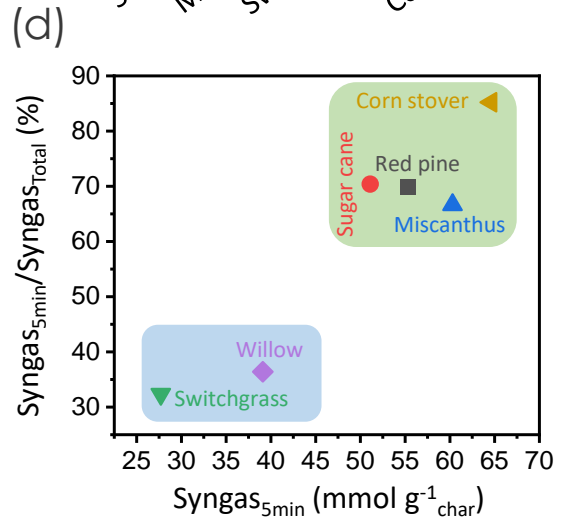
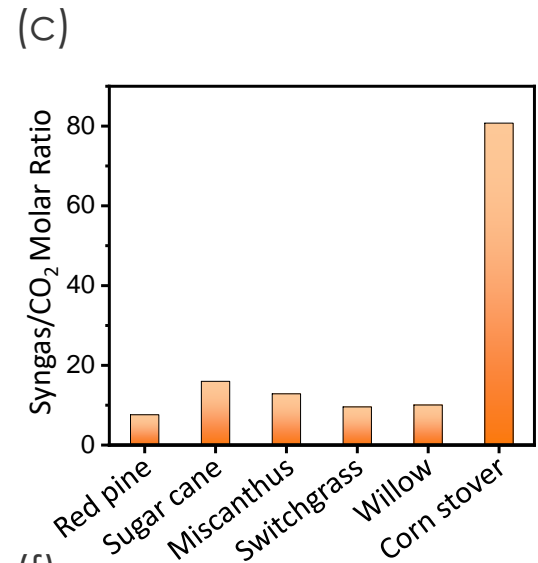
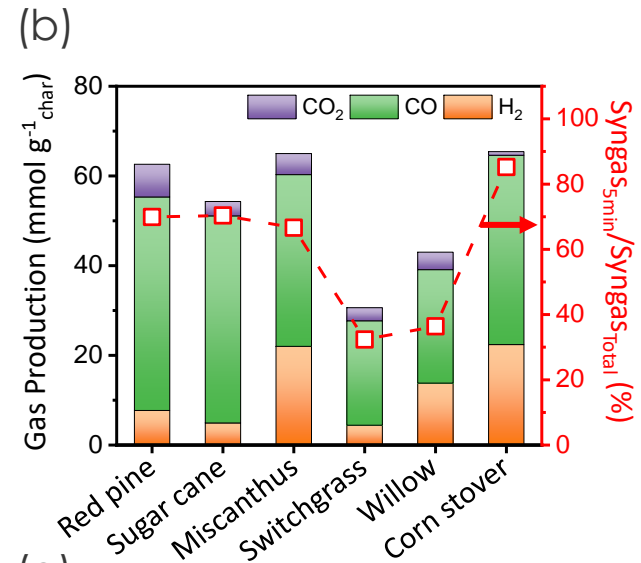
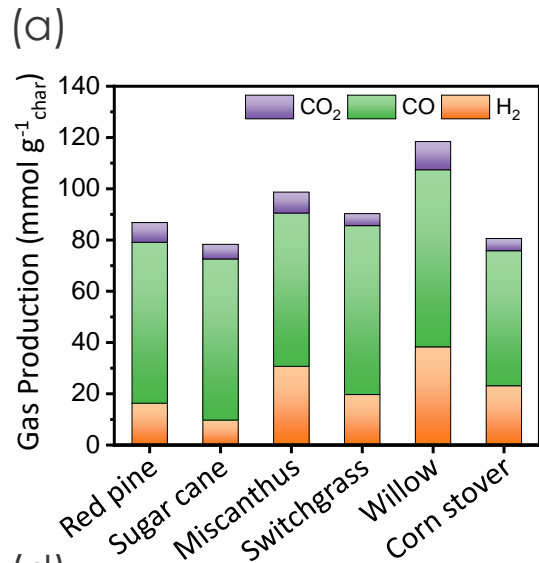
\*\*Analysis based on thermal gravimetric analysis (TGA) for the weight loss around 250-400 °C.

\*\*\*Analysis based on thermal gravimetric analysis (TGA) for the weight loss around 400-650 °C.

# TGA of Biomass Samples



# MAG Performance for Different Biochars



# Acknowledgments

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This work was performed in support of the U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management's Gasification Program and executed through the National Energy Technology Laboratory (NETL) Research & Innovation Center's Advanced Reaction Systems Field Work Proposal.



# The mWave Technology Team

- Diverse team of more than a dozen scientists and engineers
- Access to extensive techno-economic analysis & computational modeling capabilities



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