Enabling Low Carbon Feedstocks for Gasification

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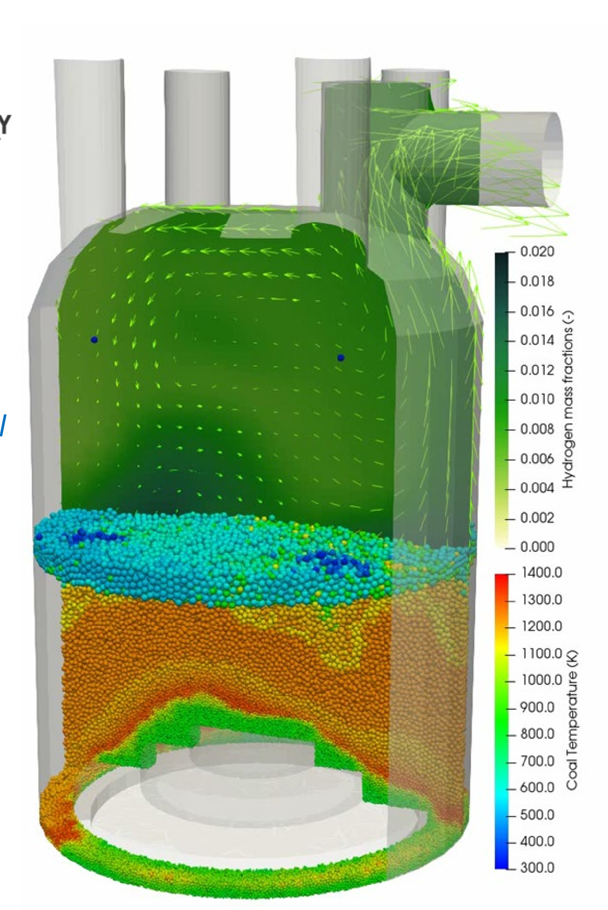
Introduction

Gasification of low-carbon feedstocks coupled with carbon capture and utilization and/or sequestration is of interest for low-cost production of hydrogen that can be utilized for power generation.[1] Of particular interest is the gasification of renewable and waste low-carbon feedstocks such as municipal solid waste (MSW), plastics, biomass, waste cellulosic and organic material, and other feedstocks that enable recycling of carbon sources. Research is needed to optimize the efficient conversion of these highly variable feedstocks in modular gasifiers that can be distributed geographically to reduce the cost of feedstock transportation.



Computational Fluid Dynamic (CFD) model of a gasifier showing the evolution of feedstock during gasification

[Graphic courtesy of Mehrdad Shahnam and the National Energy Technology Laboratory]

Objectives

Enable the Hydrogen Earth Shot[2,3] goals through:

(1) Characterize the chemistry and morphology of MSW and low carbon feedstocks at stages of the gasification process
(2) Investigate catalytic gasification for process intensification and overall lower net C emissions
(3) Perform Techno-Economic and Carbon Life-Cycle Analyses of distributed modular gasification of MSW

1 Dollar 1 Kilogram 1 Decade

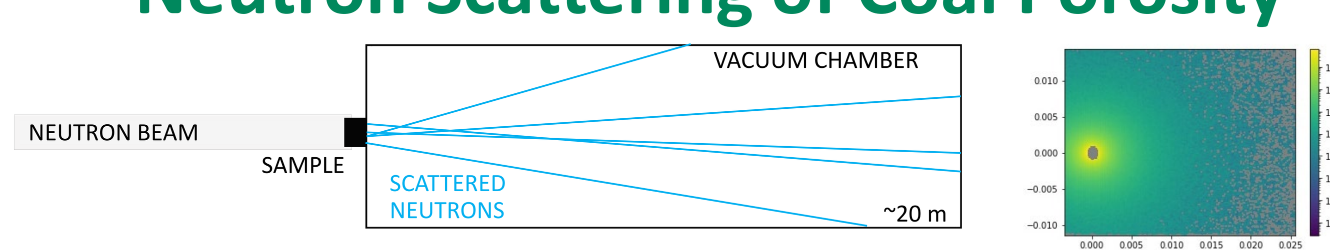
Approach

Utilize advanced materials science techniques including neutron science capabilities at the Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR) User Facilities.

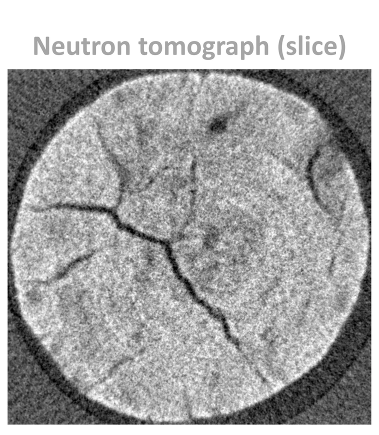
Experimental Results

Previous research (FEAB325) demonstrated the characterization of coal gasification with neutron scattering and imaging techniques. In the current project (kick-off date March 3, 2023), neutron and additional techniques are being applied to MSW and components of MSW.

Neutron Scattering of Coal Porosity

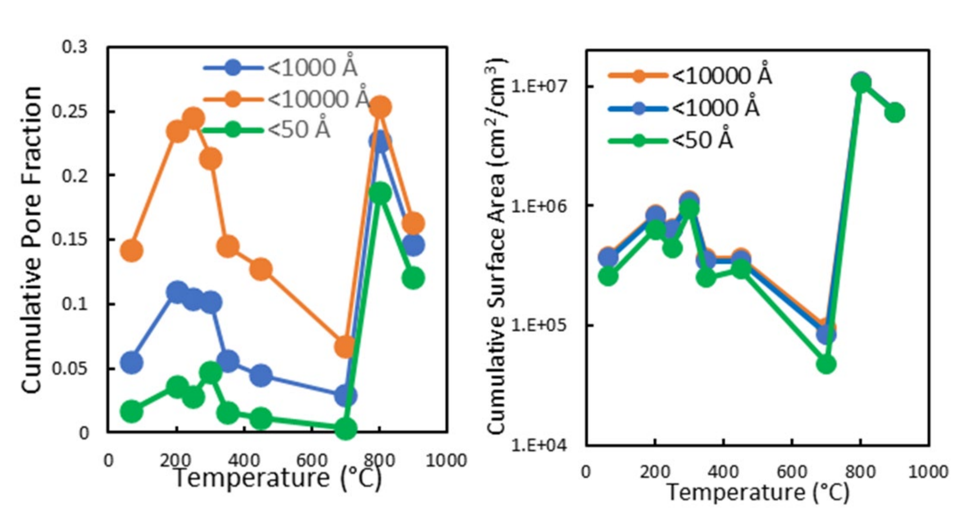


Neutron scattering allows measurement and characterization of the porosity of feedstocks including <5 nm pore sizes

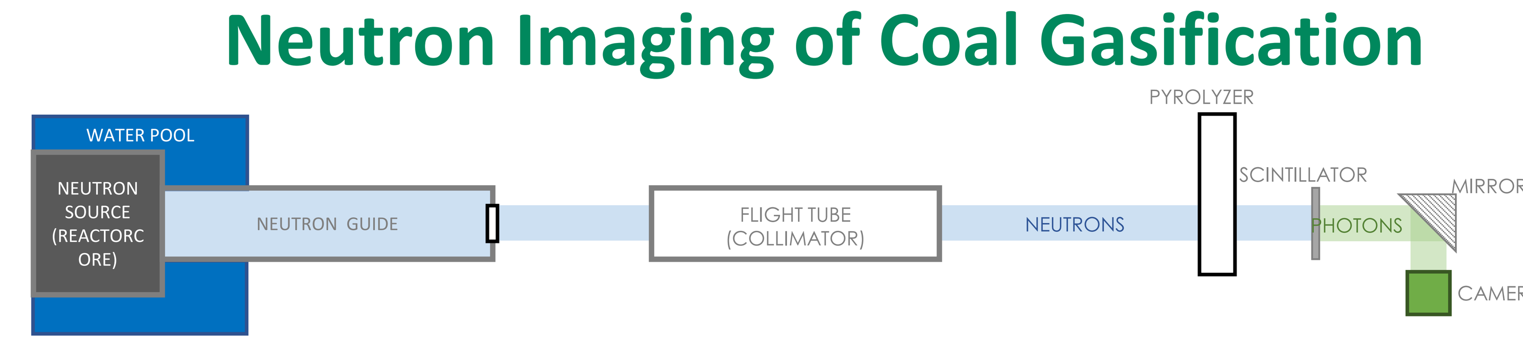


Left: Neutron tomograph Usibelli Sub-Bituminous Coal showing fine grain structure and porosity as well as larger fissures

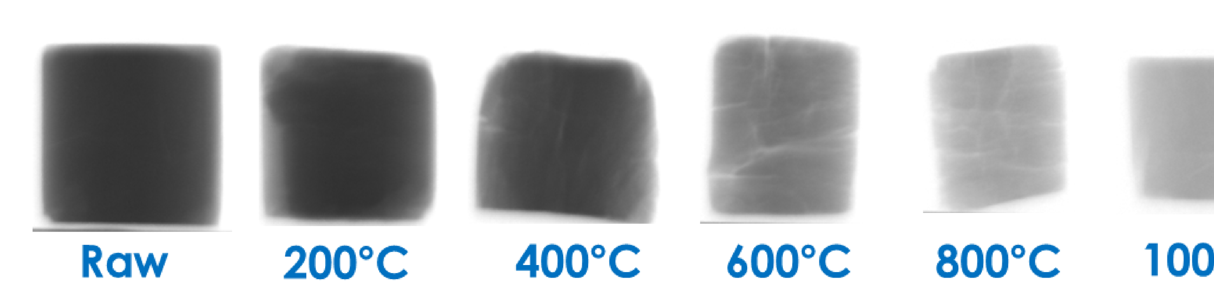
Right: Cumulative pore fraction and cumulative surface area for Usibelli Sub-Bituminous coal sample



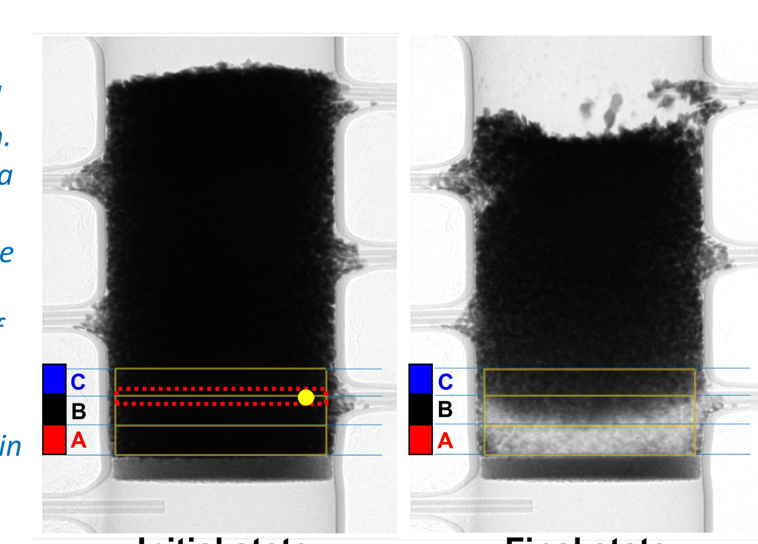
Neutron Imaging of Coal Gasification

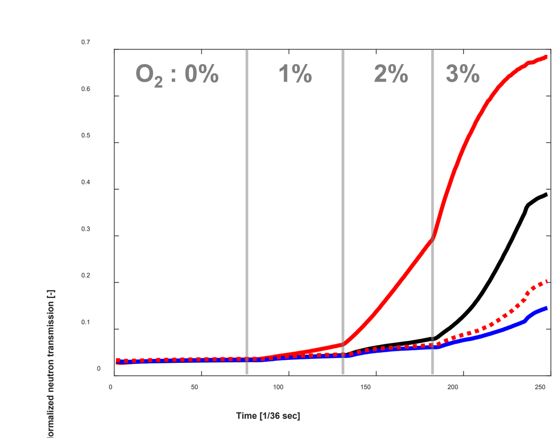


Neutron imaging of Sub-bituminous coal during pyrolysis. As hydrogen evolves from the sample, more neutrons pass through the sample resulting in a lighter contrast image.



Neutron imaging of a bed of coal during gasification. Heated gas flow through a porous frit supporting the bed of coal particles above results in gasification and hydrogen evolution out of the sample beginning at the bottom of the bed. Particle shrinkage results in the bed dropping as well.





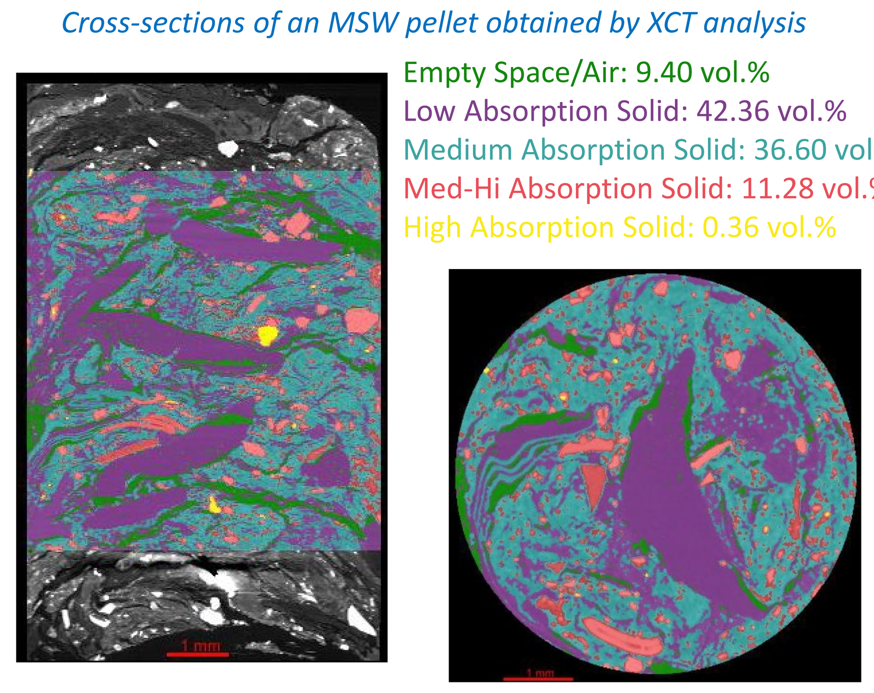
Neutron transmission as a function of time for the neutron imaging data shown at left.

X-Ray Computed Tomography (XCT) of MSW

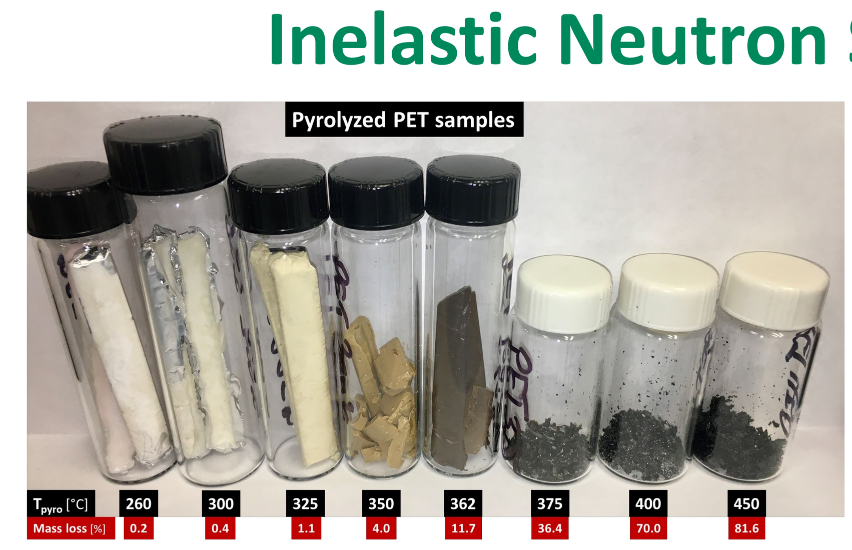
X-Ray Computed Tomography (XCT) of pellets of pre-processed MSW provides insights into the complex physical and chemical composition of the MSW. Ekamor pelletized the MSW pellet after size reduction and de-watering at Ekamor's Sustainability Center.

Processed MSW before (above) and after (right) pelletization

Cross-sections of an MSW pellet obtained by XCT analysis



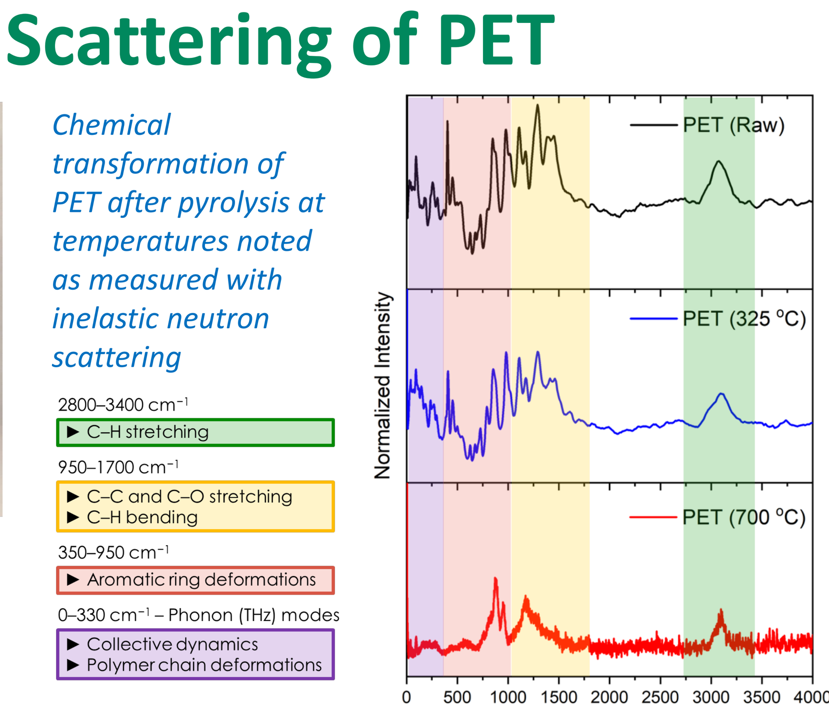
Inelastic Neutron Scattering of PET



Samples of Polyethylene terephthalate (PET) after pyrolysis at increasing temperatures (from left to right)

PET or PETE Polyethylene Terephthalate

Chemical transformation of PET after pyrolysis at temperatures noted as measured with inelastic neutron scattering



Summary

By utilizing advanced techniques, critical chemical and physical characterization of feedstocks undergoing gasification can be utilized to inform modeling and design of modular gasifiers to enable cost-effective hydrogen generation and low carbon emissions.

Acknowledgements

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References

[1]"Strategic Vision – The Role of Fossil Energy and Carbon Management in Achieving Net-Zero-Greenhouse Gas Emissions", DOE Fossil Energy and Carbon Management, 2022; available at https://www.energy.gov/fecm/strategic-vision-role-fecm-achieving-net-zero-greenhouse-gas-emissions
[2]DOE National Clean Hydrogen Strategy and Roadmap (September 2022); available at www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html
[3]www.energy.gov/eere/fuelcells/hydrogen-shot