R&D with NREL's Davison Circulating Riser System

The Davison circulating riser (DCR) is the National Renewable Energy Laboratory's (NREL's) pilot-scale recirculating riser reactor system. Coupled with an upstream fluid-bed pyrolysis system, it permits evaluation of catalytic cracking of biogenic feedstocks, as well as coprocessing of biogenic and fossil feedstocks in a commercially relevant pilot fluid catalytic cracker.

Using the DCR, NREL researchers can conduct experiments on ex situ catalytic fast pyrolysis of biogenic feedstocks and refinery coprocessing with petroleum feedstocks in a pilot-scale fluid catalytic cracking system to produce a range of fuels and chemicals with significant biogenic content. The system can directly feed pyrolysis vapors into the riser and includes hot gas filtration to produce a high-quality bio-oil vapor product. Hot vapor analysis by molecular beam mass spectrometry is available at multiple sampling points in the system to develop a more fundamental understanding of the process chemistry.

Generated data include:

- Mass and carbon balances.
- Biogenic carbon content determination (14C) for all products including gaseous products and carbon-on-catalyst.
- Complete analytical workup of whole-oil products and fractions (naphtha, jet, and diesel), including elemental analysis (carbon, hydrogen, nitrogen, oxygen, and sulfur), hydrocarbon types (paraffins, isoparaffins, aromatics, naphthenes, and olefins), ASTM simulated distillation, and two-dimensional gas chromatography/time-of-flight mass spectroscopy.
- Performance comparisons for yield and product quality across feedstocks and catalysts.
- Post-reaction analysis of catalysts to determine poisoning/fouling.

Core Capabilities

Process Flexibility

Our researchers have extensive experience with a wide variety of biogenic feedstocks ranging from vegetable oils to bio-oil. Custom modifications to the DCR system provide access to high-quality data with excellent mass and carbon balance closure.

Pressure (bar)	1–4
Riser temperature (°C)	500–575
Regenerator temperature (°C)	650–750
Stripper temperature (°C)	500–600
Total catalyst volume (L)	1.5–3.5
Catalyst circulation rate (kg/h)	2.5–15
Liquid feed rate (kg/h)	0.3–1.5
Riser vapor residence time (s)	1–5

Hot Gas Filtration and Online Analysis

Hot gas filtration is used to remove alkali and char particles from fast pyrolysis vapors to improve catalyst lifetime in downstream operations. Online hot gas analysis is provided by molecular beam mass spectrometry for vapors and gas chromatography for non-condensable gases.

Catalyst Evaluation

We have tested a wide range of commercial and experimental cracking catalysts. Zeolites and metal-modified zeolites have been evaluated for hydrocarbon production and for their ability to direct biogenic carbon to specific products. Continuous 8-hour runs at a nominal feed rate of 1 kg/h generate sufficient product to allow for separations into fractions by distillation and facilitates characterization of fuels and chemical products.

Conversion to Finished Fuels and Chemicals

Products from the DCR can be further upgraded to finished fuels and chemicals such as hydrotreating of the jet fuel fraction to produce sustainable aviation fuel (SAF) blendstocks with diesel and naphtha as coproducts.

NREL's two-story fluid catalytic cracking reactors (fluid catalytic cracking riser, 2-kg catalyst, stripper, and regenerator) are coupled with a custom biomass pyrolyzer (not shown) to produce fuels and chemicals from varied feedstocks. *Photo by Dennis Schroeder, NREL 49314*

Recent Successes

NREL's latest accomplishments include demonstrating the production of high-quality SAF blendstocks from woody biomass using the DCR in its tandem pyrolysis/riser cracking mode, coupled with hydrotreating of the jet fuel fraction. The blendstock contained significant quantities of cycloparaffins, which could allow for replacement of fossil aromatics in SAF, leading to a reduction in jet engine emissions and contrail formation.

Other contract work for industry has focused on feedstock and catalyst evaluation with major petroleum and catalyst company sponsorship.

DCR catalytic fast pyrolysis oil JM ZSM-5

Hydrotreated catalytic fast pyrolysis oil

Gasoline and diesel blendstocks

Highlighted Publications and Presentations

"Cycloalkane-Rich Sustainable Aviation Fuel Production via Hydrotreating Lignocellulosic Biomass-Derived Catalytic Fast Pyrolysis Oils." *Sustainable Energy & Fuels* 8 (2024): 5504–5513. doi.org/10.1039/d4se01151a.

"Opening Pathways for the Conversion of Woody Biomass Into Sustainable Aviation Fuel via Catalytic Fast Pyrolysis and Hydrotreating." *Green Chemistry* 26 (2024): 9768–9781. doi.org/10.1039/D4GC03333G.

"Diesel Production via Standalone and Co-Hydrotreating of Catalytic Fast Pyrolysis Oil." *Energy Advances* 3 (2024): 1121–1131. doi.org/10.1039/D4YA00098F.

"Sustainable Marine Fuel Production Through Mild Hydrotreating of Catalytic Fast Pyrolysis Oil." *Fuel* 398 (2025): 135455. doi.org/10.1016/j.fuel.2025.135455.

"Opportunities and Challenges for Hydrotreating of Catalytic Fast Pyrolysis Oils to Fuels." Presented at tcbiomass2024, September 10, 2024, Chicago, IL. www.gti.energy/wp-content/uploads/2024/09/40-tcbiomass2024-Presentation-Kristiina-lisa-V2.pdf.

Find Out More

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Cover image: NREL researchers monitor the upstream pyrolyzer in the DCR. *Photo by Dennis Schroeder, NREL 49325*

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