DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

Drop-In Renewable Jet Fuel from Brown Grease via the Biofuels ISOCONVERSION™ Process

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System Development and Integration

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Project Overview

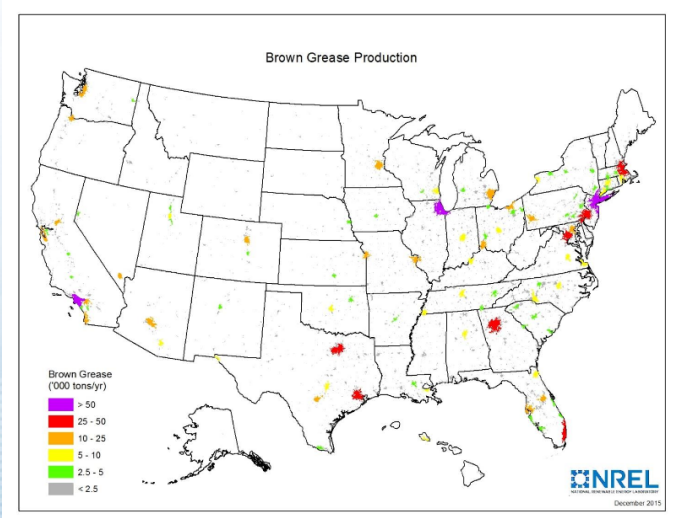
- "Drop-In Renewable Jet Fuel from Brown Grease via the Biofuels ISOCONVERSION™ (BIC) Process"
  - DE-EE0008506 was awarded 09/04/18
- Project goals
  - Clean up raw, low-cost, wet waste feed stocks (brown grease) from a variety of sources into an acceptable feedstock for the BIC process or other renewable fuel conversion technologies.
  - Demonstrate that Hydrothermal Cleanup (HCU) can economically clean wet waste (brown grease) and enable it to be converted into Jet and other renewable fuels at a mature price of ≤ $3 per GGE.

Project Overview

- Brown grease is a low-cost, wet waste feedstock that without significant pretreatment cannot be used in the production of renewable fuels due to high levels of contaminants
- The HCU process removes metals, phosphorus, and chlorine
- The clean brown grease is converted into jet fuel via Biofuels ISOCONVERSION (BIC)
- Catalytic Hydrothermolysis Jet (CHJ) produced by the BIC process was approved by ASTM as Annex 6 of D7566
  - Brown grease qualifies as a BIC feed stock in Annex 6

Project Overview

- The majority of brown grease is disposed of in landfills and tipping fees must be paid
- If an economical cleanup technology for brown grease can be demonstrated, a large supply of brown grease could be aggregated in the U.S.
- Resource analysis performed by National Renewable Energy Lab (NREL) estimates 1.7 million tons of brown grease is produced each year in the United States, corresponding to 501 million GGE.



Project Overview – Technical Risks

- Scaling in the HCU reactor – metal, phosphorus, and nitrogen (protein) contaminants in the feed can deposit on the reactor walls
  - Mitigate very high (1000s of ppm) calcium content by establishing a feed stock specification and by collecting from aggregators that do not neutralize with lime
  - Establish a nitrogen specification and/or pretreat to reduce protein content
  - Acidulate soaps in the HCU reactor using a weak acid
  - Perform periodic descaling the reactor (clean in place) using proven chemical flush protocols

Biofuels ISOCONVERSION (BIC) Process

Fats, Oils, and Greases

Hydrothermal Cleanup

Process to rapidly convert dirty fats, oils, and greases (FOGs) into clean lipids

Clean Fats, Oils, and Greases

Catalytic Hydrothermolysis

Supercritical water process converts FOGs from waste oils, plant oils, algae, and animal fats into a crude oil that contains the same hydrocarbon types as petroleum crude

CH Crude

Hydrotreater

Traditional hydrotreating technology saturates olefins and removes residual oxygenates

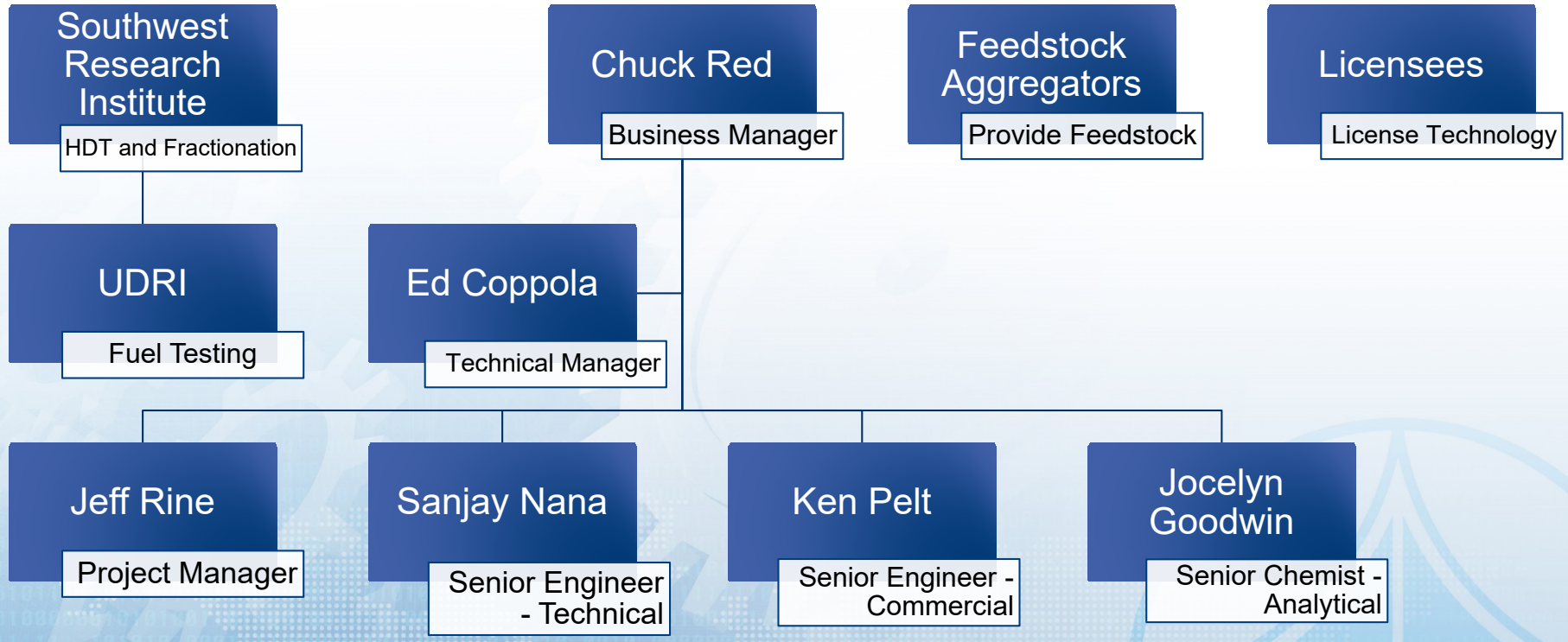
Pure Hydrocarbon Light Oil Stream

Distillation

Traditional distillation technology separates diesel, jet fuel, and naphtha molecules

Products - ReadiDiesel ReadiJet Naphtha

1 – Management – Project Structure



1 – Management – Team Members

- Principal Investigator (PI) – Ed Coppola
  - Also serves as Technical Manager (TM)
  - Leads technical efforts and provides technical guidance
  - Co-inventor of cleanup (HCU) and conversion technologies (CH)
- Project Manager (PM) – Jeff Rine
  - Primary contact with DOE
  - Manages budget and schedule
  - Communicates with TM, CM, and project team
- Commercialization Manager (CM) – Chuck Red
  - Provides guidance on business and commercial aspects

1 – Management – Project Risk

- Feedstock acquisition
  - Suppliers were reluctant to supply drum quantities resulting delays and difficulty finding representative brown greases
  - Resolved by teaming commercial partners interested in commercializing brown grease as a renewable fuel feed stock
- Feedstock consistency
  - Contamination levels varied greatly between samples, caused in large part by neutralization of the brown greases with lime
  - Resolved by obtaining samples that were not neutralized
- Scheduling issues
  - Delays cause by feed stock acquisition, Hurricane Michael, and COVID-19 lockdown and quarantines

2 - Approach

- Verification (Budget Period 1) Go / No-Go – *Complete*

- Analysis and Bench Scale Testing (Budget Period 2)
  - Survey of Brown Grease (BG) Feedstocks - *Complete*
  - Screening tests to evaluate processing aids – *Complete*
  - Optimization of HCU and CH conditions – *Complete*
  - Production of bench scale quantity of jet fuel meeting D7566 Annex 6 specifications – *In Progress* – Go / No-Go Point

2 - Approach

- Pilot scale production, preliminary engineering of full-scale system (Budget Period 3)
  - Production of CH crude by ARA in existing pilot systems
  - Hydrotreating of CH crude and distillation by Southwest Research Institute into 100+ gallons of jet and other fuels
  - Preliminary engineering of commercial system

2 - Approach

1. Initial verification
2. Identify, procure, and evaluate brown grease feedstocks
3. Perform screening tests on processing aids
4. Perform HCU optimization tests
5. Perform bench-scale CH conversion tests
6. Intermediate verification
7. Validate HCU performance at pilot scale
8. Produce clean brown grease from HCU
9. Validate CH performance at pilot scale
10. Produce CH syncrude from clean brown grease
11. Hydrotreat CH syncrude
12. Distill whole hydrotreated syncrude to produce spec jet fuel
13. Preliminary engineering for commercial system
14. Final verification

2 – Approach – Challenges

- Procurement of representative brown grease samples
- Identifying hydrotreating and distillation vendors of the appropriate size to produce 100+ gallons of jet fuel
  - Most facilities are much larger scale or too small to economically process the quantities necessary
  - Southwest Research Institute recently added larger pilot systems that are appropriate scale for this project.
- HCU and CH Reactor fouling
  - It was recently determined that protein contamination is the likely cause because phosphorus and metals contents are reduced to very low levels, but nitrogen is only partially reduced
  - Testing is in progress to resolve this issue

3 - Impact

- The use of brown grease to produce renewable fuels will:
  - Reduce waste going to landfills
  - Provide a very low-cost, low-CI feedstock for renewable fuels
  - Reduce the cost of sustainable aviation fuel (SAF)
- Patent
  - The HCU process was previously patented (US Patent # 10,071,322)
  - Additional patents are pending

3 - Impact

- Commercialization
  - The BIC process has been licensed to multiple parties
    - 2 licensees have completed the third stage of front-end loading engineering (FEL-3)
    - 1 licensee is in FEL-3
  - Two commercial partners plan to use brown grease for a portion of their feed stock
  - Multiple licenses are pending for the HCU process as a pretreatment for other renewable fuel processes
  - At least one of these licensees plans to use brown grease as a portion of their feed stock

4 – Progress and Outcomes – Technical Accomplishments

- A survey of available brown grease feedstocks was conducted, and their properties were tabulated.
- Screening tests led to the selection of HCU aids and reaction conditions.
- Jet fuel meeting ASTM D7566 Annex 6 specifications has been produced from brown grease.

4 – Progress and Outcomes – Technical Accomplishments

Analysis	Method	D7566 Annex 6 Jet A Requirements	Jet Fuel from BG 140-249°C	Units
TAN	D3242	Max 0.015	0.0102	mg KOH/g
SG (@60°F)	D4052	0.775 – 0.840	0.7795	
Sulfur	D5453	Max 15	1.16	ppm
Flash Point	D56	Min 38	40	°C
Freeze Point	D2386	Max -40 Jet A Max -47 Jet A-1	-45.5	°C
Total aromatics	D6379	8.0 – 20.0	9.21	% m/m
Distillation	D2887 converted to D86			
10%		Max 205	167	°C
FBP		Max 300	240	°C
Distillation Slope T90-10		Min 40	57	°C
Distillation Slope T50-10		Min 15	29	°C

4 – Progress and Outcomes – Technical Accomplishments

- The contaminants in brown grease were significantly reduced by the HCU process.

Sample ID	Contaminants (mg/L)						
	P	Ca	Mg	Na	K	Fe	N
Feed	23.5	148.5	1.8	34.6	9.9	174.3	1100
HCU Product	1.6	3.1	0.3	7.8	0.8	0.5	956.8

4 – Progress and Outcomes – Milestones

Milestone 2.4: Brown Grease Characterized – Report to EERE detailing the characteristics of each brown grease procured.

Milestone 3.3.3: HCU Aids Evaluated Characterized – Report to EERE detailing the process impact of each aid evaluated

Milestone 4.3: Bench Scale HCU Testing Complete – Run report indicating product yields for each temperature and residence time tested.

Milestone 5.4: Bench Scale CH Testing Complete – Run report indicating product yields for each temperature and residence time tested. ***In Progress***

Milestone 7.3: Initial HCU Pilot Test Complete – Comparison table indicating yields and product quality of pilot and bench tests.

Milestone 8.6: HCU Production Complete – 400+ gallons of clean Brown Grease

Milestone 10.5: CH Production Complete – 400+ gallons of "syncrude"

Milestone 12.6: Hydrotreater Campaign Complete – 400+ gallons of WHLP

Milestone 13.6: Distillation Campaign Complete – 100+ gallons of jet fuel

Milestone 14.4.5: Capital Cost Estimate Complete – DSCE (+/- 30%) report from Chemex

Milestone 14.5: Operating and Manufacturing Unit Cost Complete – Report to EERE with bottom line manufacturing cost per gallon of jet fuel produced

Summary

- Brown grease is an underutilized, low-cost wet waste feedstock for renewable fuel production
- HCU reduces the contaminant levels in brown grease to the point that it can be used in renewable fuels processes
- CH converts the cleaned up brown grease to syncrude that is hydrotreated and distilled into renewable fuels
- Jet fuel meeting ASTM D7566 Annex 6 specifications has been produced from 100% brown grease at pilot scale
- Work is underway to optimize conditions and produce 100+ gallons of jet fuel meeting ASTM D7566 Annex 6 specifications from brown grease

Quad Chart Overview

Timeline

- Project start date: 01 October 2018
- Project end date: 29 July 2022

	FY20 Costed	Total Award
DOE Funding	$284,315	$2,360,000
Project Cost Share	$71,106	$591,431

Project Partners

- Multiple licensees considering use of brown grease as a renewable feed stock

Project Goal

- Enhance the HCU process to convert raw, low-cost, wet waste feed stocks (brown grease) from a variety of sources into an acceptable feedstock for the CH process or other renewable fuel conversion technology.
- Demonstrate that the HCU process can be performed cost effectively on wet waste (brown grease) such that the resulting product(s) can be converted to renewable fuel at a mature price of $\leq$ $3 per GGE.

End of Project Milestone

- Produce 100+ gallons of jet fuel from brown grease.
- Complete preliminary engineering, including cost estimates on a commercial facility

Funding Mechanism

DE-FOA-0001926 2018

Topic Area 1: Drop-In Renewable Jet Fuel Blend stocks