DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-19-058

SECTION A. Project Title: Achieving High Operating Reliability for Continuous Feeding of Biomass into a High-pressure Reactor

SECTION B. Project Description and Purpose:

The proposed action addresses technical risks and improves understanding of how biomass properties influence preprocessing and conversion technologies in collaboration with Oak Ridge National Laboratory (ORNL), National Renewable Energy Laboratory (NREL), Red Rock Biofuels, LLC (RRB), and Forest Concepts, LLC (FC).

The purpose of the proposed action is improving operational reliability of continuously fed reactors via the following:

1. Reducing size of fuel grade wood feedstock (i.e., lodgepole pine, white (grand) fir, Douglas fir, and ponderosa pine)
2. Implementing a 5-inch screw feeder to minimize plugging and lessen wear at the compression zone
3. Improving data scalability between national laboratory process development units (PDUs) in Feedstock Conversion Interface Consortium (FCIC) and industrial applications using a 5-inch screw feeder.

The project includes operating a 4-inch feeder at NREL facilities and 5-inch feeder at INL facilities to evaluate the scalability of these feeders to industrial scales. The project encompasses the following tasks and deliverables:

Task Descriptions and Deliverables:

Task 1 - Biomass Procurement and Preprocessing (INL, RRB, FC)

Task 1.1 – Feedstock Procurement and Delivery (INL, RRB)
RRB supplies chipped forest residues to INL in at least two different batches.

Task 1.2 – Initial Feedstock Preprocessing (INL)
Feedstock homogeneity is sampled before and after preprocessing (i.e., resizing). Sample analysis involves measuring moisture content, ash content, type, particle size distribution, bulk density, porosity, compressibility, and static and dynamic friction to characterize effects of preprocessing. Initial feedstock preprocessing uses an air classifier and vibrating screens to remove large soil deposits, rocks, sand, and non-biomass debris. INL then stores the preprocessed materials in dry conditions for delivery to ORNL.

Task 1.3 – Feedstock Preprocessing for Parametric Testing (INL, FC)
This task addresses challenges associated with resizing various woody biomass reactor feedstocks into a bulk format that has an acceptable flow rate though the feeder system, can form an effective pressure-resistant plug in standard feeders, and achieves high conversion reactor yields. Feedstock type, particle size, and moisture content varies for each size reduction method, and FC has developed size reduction and screening equipment to reprocess fuel grade wood chips into uniform feedstocks with improved flowability and product yields. INL (using a hammer mill) and FC (using their equipment) will complete additional resizing to test the performance of INL's 5-inch Valmet Inc. plug screw feeder. The project also uses traditional hammer milling and resizing methods applied by ORNL to compare how the different size reduction methods affect feedstock performance at varying moisture and particle size distributions during continuous feeding to the plug screw feeder.

This task analyzes how resizing properties affect feed performance in the handling systems being evaluated. The project delivers sample aliquots to ORNL where effects on the plug screw feeder system from the feedstock type and the extent and method of size reduction will be determined under Task 2.

PC, INL, and RRB then create a preliminary design for a new size reduction and screening system to develop a final preferred feedstock specification.

Task 2 - Investigating and Addressing the Wear Issue of Plug Screw Feeders (ORNL)

Task 2.1 - Tribosystem Analysis of Plug Screw Feeders (ORNL)
ORNL performs Tribosystem analysis with input from INL, RRB, FC, and NREL, to determine (1) the ranges of contact pressure and sliding velocity at the interface between the plug screw feeders and the biomass plugs, and (2) the contact pressure and sliding velocities between the Crumbler® and biomass particles.

Task 2.2 - Candidate Surface Treatments (ORNL)
ORNL bench-scale tests several candidate surface treatments for the plug screw feeder (case-hardening or hard-face coatings). These tests treat small 316 and 2205 stainless steel coupons (current screw feeder materials) using the low-temperature carburization of stainless steels process (LTCSS) at Swagelok. Testing also evaluates the cold-sprayed Tungsten Carbide-Cobalt-Nickel (WC-Co-Ni) composite coating from United Technologies and other candidate treatments based on lab and field experiences.

Task 2.3 - Bench-Scale Accelerated Wear Testing and Analysis (ORNL)
ORNL performs bench-scale accelerated wear tests to evaluate and compare the wear-resistance of the plug screw feeder and Crumbler® materials (316 and 2205 stainless steels, etc.) without the candidate surface treatments. Microindentation quantifies the Vickers's hardness improvements resulting from the surface treatments. Loop abrasion tests (ASTM G 174) on the bare and treated stainless steels compares resistance to 2-body abrasive wear. ORNL examines the surface morphology using optical and electron microscopy and analyzes the surface composition using energy-dispersive X-ray spectroscopy.

Task 3 - Develop Engineering Calculations to Scale from 4-Inch to 5-Inch Plug Screw Feeder (NREL)

Task 3.1 - Generate New Performance Data for 4-Inch Plug Flow Compression Screw Feeders (NREL)
NREL tests at least two continuous 4-inch feeder and reactor systems feeding against pressure (inert gas and steam) with feedstocks tested in Task 1 supplied by RRB and INL. These tests generate data for predictive flow and plug formation models and engineering scale-up calculations informing scale-up to the 5-inch plug flow compression screw feeder and modified reactor at INL. These tests give baseline performance data using plug screw feeders used in pioneer biorefineries for comparison to the new plug screw feeder design. After initial testing, the project applies a smaller set of experiments using the two reactor systems based on RRB feedstock specifications.

Task 3.2 - Develop Scale-Up/Transfer Functions to Commercial-Scale Feeders (NREL)
NREL uses RRB feedstock performance data obtained in Task 3.1 to derive scale-up engineering calculations based on geometric, mechanic, thermal, and chemical similarities between the 4-inch plug flow compression feeder and reactor systems at NREL and the 5-inch plug flow compression screw feeder and modified reactor system being proposed for installation at INL. These calculations will be validated using the new 5-inch feeder system when it is installed and operating. In addition, transfer functions developed from the 4-inch and 5-inch plug flow compression screw feeders and reactor will be available to inform the designs for further scale up for RRB.

Task 4 - Parametric Studies to Determine Performance of 5-Inch Feeder (INL, RRB)

Task 4.1 – Install 5-inch Screw Feeder and Accompanying Receiving and Discharge Bins at INL (INL)
For this task, INL installs the following equipment on the Chemical Preconversion System (CPS) for plug flow feeding tests applicable to industrial scale up:

Atmospheric Metering Bin - The Metering Bin holds a certain quantity of raw material and eliminates flow fluctuations or interruptions before the pre-compression screw or plug screw feeder. The bin prevents raw material bridging and segregation.

Atmospheric Pre-Compression and Force Feeding Screw - The pre-compression screw is a light duty plug screw feeder having a final compression ratio of about 2.5:1 that densifies biomass. By controlling the ratio between the speeds of the pre-compression screw and plug screw feeder and the throughput rate, the system can be fine-tuned to process a wide range of feedstocks without excessive energy use and machinery wear.

Plug Screw Feeder - The plug screw feeder compresses loose biomass into a hard pressure-tight plug and forces it into the pressurized part of the system.

The CPS removes inorganic contaminants such as calcium or nitrogen from biomass feedstocks and improves feedstock quality. With the CPS, feedstocks once considered too contaminated to be useful can be treated then used.

Task 4.2 – Bench Scale Tests to Measure Feedstock Properties (INL)
This task measures physical feedstock characteristics for each feedstock specification, including moisture, ash content, particle size distribution, particle size morphology, bulk density, compressibility, permeability, porosity, and slow- and fast-shear. These will be measured using the following methods:

- Moisture content: Moisture content will be measured using mass loss during drying at 105°C for 24 hours.
- Particle size distribution: Sieve classification of materials will be performed according to ASABE Standard S310.4 using a standard forage separator or a standard Ro-tap separator according to ASAE S319.3.
- Particle morphology: A qualitative examination of particle morphology will be performed using Keyence microscopy techniques that exist at Contractor 1's facility. In addition, aspect ratios and surface roughness will be quantified using methods published by Keyence.
- Ash type and content: Ash type and content will be measured by mass loss to ashing using published techniques in Contractor 1's biomass characterization laboratory and/or with the assistance of Huffman Hazen Laboratories.
- Bulk Density, compressibility and permeability: Material will be placed into an instrumented and automated load frame to compress a known quantity in a cylindrical vessel. Prior to compression, the bulk density will be noted. At set compression steps, permeability tests will be performed by applying a pressure drop across the vessel and measuring air flow through the feedstock (ASTM D 6539-00 method).
- Shear: An automated RST-01 pc ring shear tester will be used to measure both shear strength and wall friction according to ASTM standard D6773-02.

Task 4.3 – Measuring Performance during Plug Flow Testing (INL, RRB)
To determine plug formation efficiency, various particle type/size/moisture combination are fed into the screw feeder with zero reactor back pressure and at ambient temperature. Parameters including torque exerted by the screw feed, power consumed by the screw feed, and weight and volume of the liquid pressed out of the feedstock by the screw feed are measured. During each run, the screw feed and hopper feed are adjusted at least twice, and the same measurements and observations recorded. If a plug does not form, then an alternate plug pipe having different geometry is used and the tests repeated.

Following initial tests, INL selects a smaller matrix using feedback from RRB and ORNL. INL then tests the selected particle type/size/moisture combinations under pressure in the CPS. Once a plug forms, the steam pressure in the CPS ramps up steadily, either to 200 psig or to the point the plug fails. Each pressure increment is maintained until steady-state is achieved. If the plug fails, INL may test additional plug pipe geometries to determine if a plug can be formed that will maintain integrity at a higher reactor pressure. These tests examine plug feeder output to evaluate the relationships between feedstock characteristics, moisture content, plug feeder operational parameters, and likelihood of gasification issues within the reactor.

Task 4.4 – Measuring Performance during Plug Flow Testing (INL, RRB)

INL selects the mid-point condition from those tested in Task 4.3 for a final set of tests using feedstock from the INL bioenergy feedstock library. INL tests these materials in the same manner as those described in Tasks 4.2 and 4.3.

Task 5 - Techno-Economic Assessment (TEA) (INL, ORNL, NREL, RRB, FC)

Task 5.1 – TEA (INL, RRB, NREL, ORNL, FC)
Preliminary TEAs evaluating FC's Crumbler technology and the screw feeder give a basis for the initial and final TEA. The project works with the INL Analysis Team to complete an initial feedstock specific TEA and a final TEA. The initial TEA informs decision making as the project goes along, including a Go/No-Go milestone regarding the choice of size reduction methods for the parametric studies in Task 4. The final project TEA informs RRB's feedstock, processing, and screw-feed design/treatment for demonstration and commercialization.

This task generates a techno-economic evaluation of various processing and feedstock blend options for RRB to make informed decisions on research progression and the best option for RBB plant start-up and operation. The most important aspect is achieving high operating reliability of the feed system. The TEA identifies optimal process conditions and properties of feedstock and blends.

Task 6 - Project Wrap Up and Final Reporting (INL, ORNL, NREL, RRB, FC)

Task 6.1 - Project Wrap Up and Final Reporting (INL, RRB, NREL, ORNL, FC)
The proposed action delivers a final report summarizing project deliverables and findings to the DOE Bioenergy Technologies Office and all project partners. The final report includes the final TEA and a report describing the potential impact on RRB's demonstration and conversion facility development and the benefits of having two screw feeders at different scale available at two national laboratory PDUs. The final report addressing objectives and deliverables will be delivered to the Office of Scientific and Technical Information (OSTI).

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

The proposed action does not burn any material but does heat treat materials to measure certain characteristics such as moisture content. Air emissions from portable generators, stationary units such as the Process Demonstration Unit (PDU), Thermochemical Treatment of Biomass, fugitive dust from grinding activities, discharges from laboratory hoods, and fugitive releases of SF_6 as part of biomass bale permeability studies are anticipated. Emissions from portable generators are exempt since the generators are used only a few days per year and will be moved to storage following each use. Emissions from the PDU, Torrefaction Unit and Lab emissions are addressed in APADs INL-14- 005 R1, INL-12- 001, INL-13- 002, and INL-12- 010, respectively. Fugitive dust control is addressed under PDU operating procedures.

Generating and Managing Waste

The proposed action is expected to generate waste biomass and other industrial waste. Small amounts of lab wastewater are discharged to the Idaho Falls sewer system in accordance with city regulations. Waste biomass, ranging in quantities from a few pounds to tons, may be disposed at the Bonneville County landfill; alternative options, such as composting, are under investigation. Waste Generator Services (WGS) manages all solid waste.

Releasing Contaminants

Small amounts of chemical contaminants may be released to the Idaho Falls sewer system in accordance with city regulations.

Using, Reusing, and Conserving Natural Resources

The primary purpose of this work is to investigate methods by which energy may be recovered from biomass, replacing other sources of energy.

SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification:

Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not "connected" to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

References: 10 CFR 1021, Appendix B to subpart D, items B3.6, "Small-scale research and development, laboratory operations, and pilot projects"

Justification: The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment."

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jason Sturm, DOE-ID NEPA Compliance Officer on: 09/23/2019