# DOE-ID NEPA CX DETERMINATION
# Idaho National Laboratory



CX Posting No.: DOE-ID-INL-20-082

**SECTION A. Project Title:** Fractionation of Lignocellulosic Biomass into High-Value Products

**SECTION B. Project Description and Purpose:**

This proposed project will lead to the verification of the INL's biomass fractionation technology, which produces multiple high-value products from herbaceous and woody biomass including two major products:

1. Conversion-ready lignocellulosic feedstock and
2. Moisture resistant biomass pellets.

Other coproducts, depending on biomass, include low molecular lignin, extractives, syrup, bio-oil, plant growth promoter.

The conversion- ready lignocellulosic feedstock can be used in an existing Generation 1 ethanol plant or in a stand-alone Generation 2 biofuel plant. It is expected that ethanol production can be increased up to 20% by incorporating ready-conversion lignocellulosic feedstock.

Having multiple, high-value products produce results in low feedstock cost. Furthermore, the conversion-ready feedstocks are tailored to meet specifications of the users. For example, the conversion-ready feedstocks derived from corn stover and hardwood tailored to bioconversion would have high enzymatic digestibility, low level of inhibitors (extractive, acetate, lignin) and be delivered in stable, densified form (e.g., pellets), which should improve the operational reliability of biorefinery. Wood pellets for thermochemical conversion would have low content of undesirable inorganic species and moisture.

**BACKGROUND AND PURPOSE**

Golden Leaf Energy Inc. is a small producer of biodiesel ad bio-lubricant. Golden Leaf Energy has an established customer base for biofuel and bio-based chemicals. Golden Leaf Energy has identified a market for cellulosic ethanol. Golden Leaf Energy plans to produce renewable chemicals from cellulosic ethanol via proprietary technologies.

The goal of this project is to evaluate the technical and economic feasibility of producing cellulosic ethanol using low cost biomass feedstock and process technology that can be synergistically integrated with the production of renewable chemicals.

INL has developed a patent pending process that incorporates sodium hydroxide or acid treatment in storage and mechanical disintegration to produce conversion-ready feedstock (CRF) and coproducts (lignin, bio-stimulant). The CRF can be used in conventional dry grind corn ethanol plant with minimal equipment and process modification. This approach should lower the capital and operating costs compared to traditional cellulosic ethanol technologies that integrated feedstock preprocessing, high-temperature pretreatment, and conversion (e.g., Abengoa Bioenergy, DuPont, POET-DSM).

Chinese tallow (Ct), an invasive hardwood species in the south eastern states and California, provides a low-cost feedstock as currently it does not have commercial value. The project will also investigate corn stover as it is the largest available agricultural residue.

**Overview**

The objectives of this 12-month project are to verify the performance of INL's biomass feedstock fractionation technology for producing conversion ready feedstock from corn stover and hardwood and identify potential commercial applications. The scope of the project includes wood and corn stover feedstock logistics, preprocessing and fractionation into conversion-ready feedstock and co-products, testing at bench and pilot scale to verify the sugar conversion yield from corn stover and a hardwood species, characterization of conversion-ready feedstock, application of conversion ready corn stover feedstock in Generation 1 ethanol plant, and techno-economic evaluation. The final deliverable of the project will include a preliminary techno-economic evaluation of commercial applications of INL's biomass fractionation process and recommended path forward for commercialization.

INL's fractionation technology, combined with Golden leaf Energy's mobile, modular feedstock supply systems, will form a highly effective biomass conversion technology that lowers technical and economic barriers in growing a bioeconomy.

The project will evaluate the technical feasibility and process economics of the INL's anaerobic biomass storage, fractionation, and high-moisture pelleting processes and to provide preliminary data to Golden Leaf Energy for evaluating the potential commercialization of INL's processes integrated with Golden Leaf Energy's technologies for converting biomass to ethanol and renewable chemicals.

The key aspects of this process include:

- Anaerobic and chemical treatment of biomass during storage
- Fractionation of biomass into conversion-ready feedstock and high-value coproducts
- High-moisture pelleting to increase the bulk density and stabilize the feedstock

The processes have been verified at bench scale showing an improvement in theoretical glucose yield from 23.1% to 44.5% and an improvement in theoretical xylose yield from 8.9% to 23.1% from ground corn stover. It is expected that with further optimization work, higher sugar yield is achievable. Pelleting does not affect the enzyme digestibility. Project will apply this alkali and mechanical shear pretreatment to corn stover and Ct. The pretreated biomass will be analyzed for chemical composition and enzymatic hydrolysis sugar yield.

**Tasks Descriptions and Deliverables:**

**Task 1**: Chemical treatment of biomass during storage

This task will be carried out at both INL's and Golden Leaf Energy's facilities. The goal of treatment is to achieve an enzymatic hydrolysis glucose yield of greater than 45%.

Golden Leaf Energy will harvest Ct from infested area in Mississippi. The trees will be de-branched, and the leaves and seeds will be stripped off. Large branches and logs with diameters greater than about 3 inches will be chipped using a brush chipper to produce coarse chips. The chips will be trucked to INL for further size reduction. INL will use a knife mill to reduce the coarse Ct chips to less than 0.5 inch before impregnation with sodium hydroxide and sulfuric acid.

Sodium hydroxide impregnation (at 4% and 6% NaOH:dry biomass ratio) will be blended with milled biomass using a ribbon blender and stored in anaerobic reactors for 2 weeks to accomplish good distribution of chemical throughout the bulk of the biomass (corn stover and Ct) while minimizing dry matter loss. The moisture content of biomass is maintained at about 50% wet weight basis. The treatment aims to remove acetyl groups from hemicellulose and solubilizing lignin, thus making cellulose more accessible to enzymatic attack. Likewise, sulfuric acid treatment will also be applied to corn stover and Ct at 3% and 5% acid:dry biomass ratio. Anaerobic 20-L reactors will be utilized to store chemical treated corn stover and Ct to obtain about 3 kg (dry weight) for subsequent experiments. Storage stability metrics from both alkali and acidic experiments will include parameters such as gas production (e.g. $CO_2$, $CH_4$, CO), total dry matter preservation, and pH.

Following the anaerobic storage period, the chemical impregnated biomass materials will be transferred to sealed containers and heated to 90°C for 24 hours in an oven. The heat treatment is expected to solubilize a portion of the extractives, hemicellulose, and lignin.

Recovery of solubilized extractives, hemicellulose and lignin from the treated biomass materials will be accomplished using a column percolator. Treated biomass materials will be washed with 90°C dilute acid or alkali to match the caustic or acid concentrations used in-storage treatment, followed by a hot (90°C) water wash to rinse out most of the alkali or acid from the fibers. The washed solids will have an estimated moisture content of 80% (wet basis) and will then be dewatered using a lab roller press.

A flat die pellet mill will be modified to function as a lab roller press for dewatering the treated & washed biomass. A screen will be placed on the flat die. The rollers compress and shear the treated biomass as the die rotates. A vacuum will be applied below the screen to draw away the liquid. The compression and shearing of the treated biomass will help to remove most of the surface bound moisture and deconstruct the fibers. This lab-scale roller press mimics the features of an industrial scale roller press. For dewatering studies, the pellet mill will be run at low speeds. The target moisture for dewatering studies is to reduce the moisture content of the biomass to about 35 wt% (wet basis).

The composition of the washed fiber and the liquid extract will be determined using standard Laboratory Analytical Protocols defined by the National Renewable Energy Laboratory. Mass recovery yield of extract and washed fibers will be determined.

**Task 2**: High moisture pelleting

This task will be carried out at INL's facility.

Based on the pretreatment results, one sample each of dewatered biomass materials will be air dried at 50°C to about 25% moisture and pelleted using the high moisture pelleting process developed by INL. The air-dried fibers will be pelletized using a flat die pellet mill. Control pellets will be generated using milled raw biomass.

Residual solids from enzymatic hydrolysis (see Task 4) will still be present despite efforts to delignify them during long-term storage. These solids will contain significant convertible carbon since they will be enriched in lignin, and thus they represent a value-added product. It is hypothesized that these pellets can be used as black pellets that behave similarly to coal, and they also will have favorable properties for outdoor storage due to their hydrophobic nature. This value-added opportunity will be explored by performing single-pellet tests on residual biomass after enzymatic hydrolysis. Pellet durability tests and energy content will be assessed to define a value to corn stover and Ct residues.

**Task 3**: High-moisture pellet drying

This task will be carried out at INL's facility.

High-moisture pellet drying tests will be conducted using a laboratory scale grain dryer available at INL's facility. These studies will help to understand drying kinetics and the impact of drying process variables (drying temperature, residence time, and air flow rates) on the pellet properties (density and durability) and energy consumption. Data will be collected for pellet drying to understand the moisture loss with respect drying time. The final pellets are termed conversion ready feedstock (CRF).

**Task 4**: Determination of enzymatic hydrolysis sugar yield of CRF

This task will be carried out at INL's facility.

The CRF will be milled, slurried and heat sterilized prior to carrying out standard enzyme hydrolysis test using commercial cellulases and hemicelluloses to determine the sugar yield. Untreated milled corn stover and Ct will also be subjected to the enzyme hydrolysis test as control. Enzymatic hydrolysis will be performed according to the method by Worfrum et al. (2017) with 10% solids and a 5-day incubation.

**Task 5**: Investigate the wear issues of perforated plate in the flat die pellet mill

This task will be carried out by Oakridge National Laboratory.

Worn perforated plates in the modified flat die pellet mill will first be characterized to determine the dominant wear modes. Based on that, an appropriate bench-scale wear test will be identified. Tribosystem analysis will be conducted to design the testing parameters (load, sliding speed, and duration) to best simulate the wear process at the actual component. Candidate materials will be evaluated using the bench-scale wear test. Results will be benchmarked against the current materials of the component. The top candidate material(s) will be identified based on their wear performance, scalability, and cost.

**Task 6**: Techno-economic evaluation

This task will be carried out at INL's facility.

Using data generated from Tasks 1 to 5 and data from Golden Leaf Energy regarding feedstock harvesting, collection and preprocessing, a preliminary technoeconomic evaluation will be carried out to assess the economic viability of the integrated process for producing CRF, cellulosic sugars and co-products (i.e. black pellets from enzyme hydrolysis residual, extractives).

## SECTION C. Environmental Aspects or Potential Sources of Impact:

**Air Emissions**

Potential for fugitive (nuisance) dusts from biomass comminution and handling. Corn stover will be hammermilled using a small hammer mill which has a dust filter/collector. This hammer mill (the Schutte Buffalo) is regularly used in the PDU to prepare samples for various projects.

**Discharging to Surface-, Storm-, or Ground Water**

N/A

**Disturbing Cultural or Biological Resources**

Chinese tallow is an invasive species. A permit for import may be required by the Idaho Department of Agriculture prior to importation. However, if there is no viability (biomass is coming chipped and stripped of leaves and seeds), a permeit may not be necessary.

**Generating and Managing Waste**

Industrial, hazardous, and municipal waste have the potential to be generated. Municipal waste includes common lab waste, PPE, wipes, and extracted feedstock materials. Waste discharged to the sewer system would include common washwater and waste subjected to elementary neutralization. All solid waste will be managed by WGS. Waste water discharged to the sewer system would meet standards established in the city sewer regulations.

Non-hazardous waste includes milled biomass for disposal in municipal waste disposal facility ("Hatch Pit"). Samples will be maintained for the useful life of the biomass material and will be disposed of as non-hazardous waste thereafter.

**Releasing Contaminants**

When chemicals are used during the project there is the potential for spills that could impact the environment (air, water, soil)

**Using, Reusing, and Conserving Natural Resources**

Biomass includes Chinese tallow (not regulated under IDAPA 02.06.09). Waste biomass will be taken to the "Hatch Pit" or the Bonneville County Transfer Station for disposal.

**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, 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:11/18/2020