Biochemical & Thermochemical High Throughput Characterization of Feedstocks

March 23, 2015

Biochemical & Thermochemical Conversion

Garold Gresham
Corrie Nichole (CoPI)

Idaho National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information
**Goal Statement**

**Goal:** Enable consistent high throughput characterization of large numbers of biomass samples

- Support BETO’s 2017 goal of producing optimized dynamic blendstocks that meet cost, quality, & conversion targets
- Understand variability & bound specifications to allow blendstock formulation
- Support development of feedstock specifications/grades & quality control options for exchange-point valorization
Quad Chart Overview

Timeline

– Project start date: Nov. 2014
– Project end date: 2017
– Percent complete: 5%

Barriers

– Ft-G  Feedstock Quality & Monitoring
– Ft-J  Biomass Material Properties
– Bt-B  Biomass Variability

Budget

<table>
<thead>
<tr>
<th></th>
<th>Total Costs FY 10 – 12*</th>
<th>FY 13 Costs‡</th>
<th>FY 14 Costs*</th>
<th>Total Planned Funding (FY 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.1.303 Thermo</td>
<td>$715K</td>
<td>$433K</td>
<td>$227K</td>
<td>$250K</td>
</tr>
<tr>
<td>2.6.2.106 Bio</td>
<td>$369K</td>
<td>$1,106K</td>
<td>$215K</td>
<td>$285K</td>
</tr>
</tbody>
</table>

*Equipment budget
‡Research/Equipment budget

Partners

– Idaho National Lab – TC Interface, BC Interface & BFNUF
– Eberbach Corporation – in-kind hardware support & robotics expertise
– BYUI – potential BYUI professor sabbatical
Project Overview

Context:

- Currently sample comminution & sample preparation must be performed on any sample requiring detailed characterization
- Major hurdle to rapid-screening methods & exchange-point quality control
  - E.g., preparation & transfer of ~450 samples for NIR compositional characterization; greater than 2000 samples characterized overall
    - 415 man hours (8 staff members) resulting in ~1 man hr/sample
- Impacts all aspects of research within the Feedstock Platform
  - FS Blending Strategies, Storage, Interface, Densification, Preprocessing, RFP, Analysis, BFNUF, SOT, FGIS approach

Project Objectives:

- Develop automated sample preparation methodology to reduce human interactions & increase sample throughput
2 – Technical Approach

- Automated sample preparation allows analysis of large sample numbers using rapid-screening techniques to optimize overall sample throughput
  - LIBS screening
  - NIR screening
  - Other conventional techniques

LIBS Spectra

NIR Spectroscopy

- LIBS Spectra
- NIR Spectroscopy
- Other conventional techniques
2 – Technical Approach

• High throughput comminution based on Thomas Scientific Wiley Mill or consistent morphology

• Optimize comminution process
  – Improve mill performance
  – Improve mill throughput cycle

• Automate core processes
  – Operator provides queuing system
  – Autonomous operation for input, grinding, collection & cleanup

• Semi-Automated Sample tracking
  – Linked to Bioenergy Feedstock Library
2 – Technical Approach

Process Flow

• Samples placed in conveyer queue
• Robot removes container from queue & introduces sample to inlet hopper
• Sample ground through mill
• Ground sample collected into bucket
• New sample is re-barcode
• Robot places sample onto outlet conveyor
• Robot cleans mill to eliminate x-contamination
2 – Technical Approach

• Thomas Scientific Wiley Mill – mill box geometry & sieve critical to achieving correct particle morphology
• Automated system to feed & collect sample from mill – leveraging existing robotic system
• Mill will be monitored – system will control feed rate to ensure optimal mill performance
• Data collection & control feedback during milling process – grinding energy, temperature, etc.
2 – Technical Approach

• PaR Systems Robotic Manipulator
  – 6-DOF Robotic Manipulator
  – 5 ft. Reach
  – 60 lb. Payload Capacity
  – Sealed (wash down capable)
• Leveraged from Yucca Mountain Project
  – Hardware leveraged value ~$500K
  – Development effort leveraged
    (software interface, control, etc.)
• Staff robotic expertise leveraged from extensive experience on Yucca Mountain project & commercial collaborator
Top technical challenges:

• Consistent feeding of mill with sample materials that have different characteristics (i.e. woody vs. herbaceous)

• Wiley mill cooling – initially designed for low-volume grinding

• Cleaning & sample recovery
  – Some sample segregation occurs via electrostatic attraction of fines to grinder surfaces & outlet tube
  – Incomplete recovery of sample can impact analytical results
2 – Management Approach

Success Factors

• Integration with Feedstock Conversion Interface projects & BFNUF is critical for project success

• Collaboration with Eberbach Corp. provides an opportunity to work directly with the grinder manufacturer

• Ability to generate large feedstock data set in a rapid manner will support all aspects of BETO Program
  – Exchange-point specifications

Approach

• Project execution has been divided into milestones based on development of subsystems & interaction of subsystems

• Leverages extensive experience with complex robotic systems
3 – Technical Progress

Project is in the early stages

- Equipment & software procurement completed
- Mill & PaR robot co-located in laboratory
- Development of operating procedures
- CAD models of project for planning purposes
- Electronic control hardware setup
- Software leveraged from previous projects
4 – Relevance

- **BETO MYPP Contributions**
  - Enables understanding of variability & bounding of specifications that will allow blendstock formulation through robust & timely data sets
  - Supports development of feedstock specifications/grades & quality control options
  - Supports BETO’s 2017 goal of producing optimized dynamic blendstocks that meet cost, quality, & conversion targets

- **Impact**
  - Advances current state of technology for using of rapid-screening techniques
  - Provides robust & temporal data sets for practical dynamic blend options

- **Stakeholders**
  - **Researchers**: provides larger & more timely data sets
  - **Industry**: informs biomass end users on biomass strategy, dynamic blend options & fundamental to exchange-point characterization
  - **Policy Makers**: clear understanding of blend pathways to achieving sustainable energy options and valorization of feedstocks
5 – Future Work

• **Initial effort for the development of a fully automated sample analysis system to:**
  – Further improve both the consistency & efficiency of biomass sample analysis
  – Establish fundamental approach for exchange-point characterization

• **Development of functional robotic biomass grinding work cell to support the analysis of a large sample sets**

• **This work will focus on the challenges associated with:**
  – Feeding biomass materials of different characteristics in an even & consistent manner
  – Optimizing sample metrics for conventional & rapid screening techniques
  – Reducing ~ 1 hr/sample barrier
Summary

• Overview
  – Sample comminution is a major hurdle to rapid-screening methods & exchange-point quality control

• Approach
  – Automated high throughput biomass processing enables substantial improvements over current methods while retaining current processing method benefits

• Relevance
  – Provides larger & more timely data sets for researchers & industry to better develop practical dynamic blend options
  – Foundation for “FGIS-like” exchange-point sample inspection

• Future work
  – This work is the initial effort in development of novel state-of-the-art high volume, high throughput comminution & analysis of biomass samples
Acronyms

- BC – Biochemical
- BETO – Bioenergy Technology Office
- BFNUF – INL Biofuels National User Facility
- BYUI – Brigham Young University - Idaho
- CAD – Computer-aided design
- CoPI – Co - Principle Investigator
- DOF – Degrees of freedom
- FGIS – USDA, Federal Grain Inspection Service
- FY – Fiscal Year
- PaR – PaR Systems, Inc.
- RFP – Regional Feedstock Partnership
- SOT – State of Technology
- TC – Thermochemical
- VFD – Variable frequency drive