2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Demonstration of Pyrolysis Biorefinery Concept for Biopower, Biomaterials and Biochar

May 20, 2013
Bio-Oil Technology Area Review

Dennis S Banasiak, PhD
Avello Bioenergy, Inc.

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

Avello Bioenergy™

Fueling opportunities™

Goals/Objective Statement

Project Goals:

- Design, Build and Operate 2.5 ton/day Integrated Pilot Plant
  - Wood and corn stover feedstocks
  - Make Products and Collect Engineering Data
  - Demonstrate continuous operation
- Pre-Commercial Testing of Products
  - Asphalt, Chemical, Fuel Oil, Transportation Fuels and Biochar Applications

Supports BETO Goals:

- Process integration and scale-up of novel Avello®FRAC fractionation technology, **(Tt-E, Tt-I, Tt-K)**
- Product demonstrations and R&D (including **Tt-G**)
  - Biofuel Oil™ combustion for power
  - Bioasphalt® for non-energy applications (petroleum replacement)
  - Feedstocks for specialty chemicals and advanced biofuels

Avello Bioenergy™

Fueling opportunities™

Project Quad Chart Overview

Timeline

- Project start date: TBD
- Project end date: 3 yrs. From start
- Percent complete: 0%

Budget

Total project funding: $8,967,012

- **DOE: $2,500,000**
- **Cost share: $6,467,012**

Funding received in FY 2011: $0

Funding in FY 2012 (proposed)

- DOE: $583k
- Cost share: $113.6k

Funding for FY 2013 (proposed)

- DOE: $1.917M
- Cost share: $2.53M

ARRA Funding - NO

Years the project has been funded & average annual funding -None

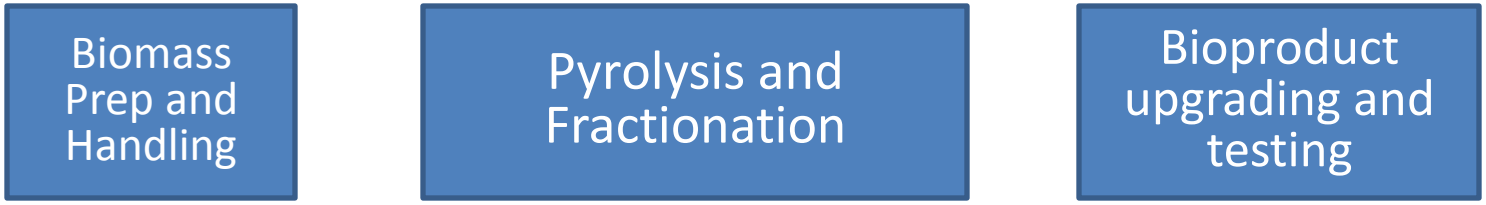
Barriers

- **Tt-E.** Liquefaction of Biomass and Bio-Oil Stability
- **Tt-K.** Bio-Oil Pathways Process Integration
- **Tt-I**. Sensors and Controls

Partners & Roles

- Avello – Lead
- ConTech – EPC
- Emerson – Engineering support
- Borregaard – Product R&D
- Cargill – Biofuel Oil demo
- Leading roofing company – Bioasphalt R&D
- Virent – Biofuels R&D
- ISU – Biomass and product R&D
- APAI, Iowa DOT, USDA – Advisors

Project Overview



- Process integration of the entire process train including
  - Biomass pre-processing
  - Pyrolysis conversion and fractionation of Bio-oil
  - Bio-oil fraction use and upgrading as petroleum replacement products
  - Front-end and back-end storage/logistics
  - Bioasphalt production (not shown above)

- Main technical barriers
  - Tt-E. Liquefaction of Biomass and Bio-Oil Stability
  - Tt-K. Bio-Oil Pathways Process Integration

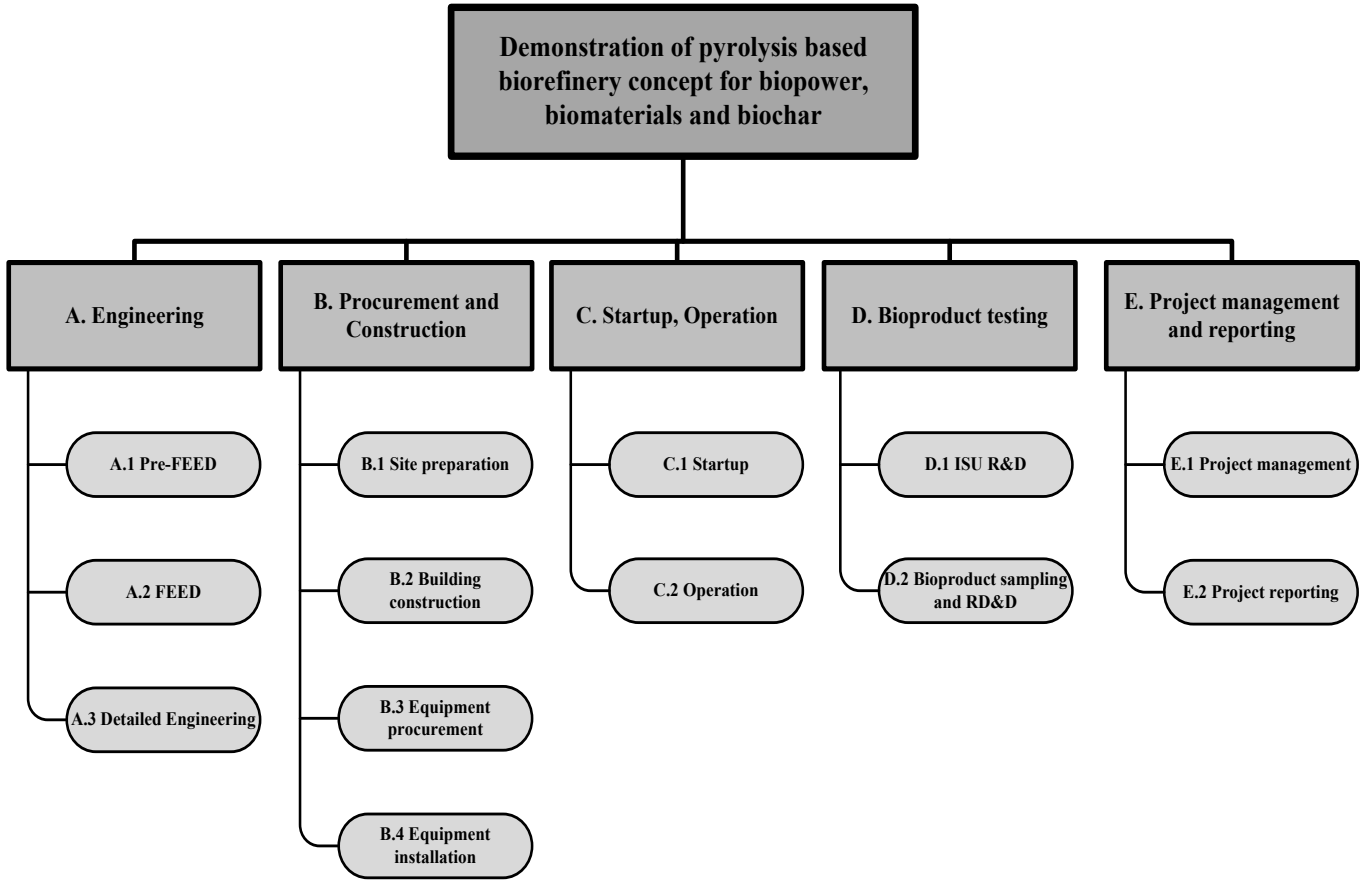
Avello Bioenergy™

Fueling opportunities™

1 - Approach

- Leverage PDU data and experience for scale-up
- Leverage market leader expertise in product evaluation and development
- Project milestones, schedule, and risk mitigation via PMP
- 5 project tasks
- Phase reviews after subtasks
- Go/No-Go decision point after detailed engineering → Budget Period 2
-

Work Breakdown Structure (from PMP)



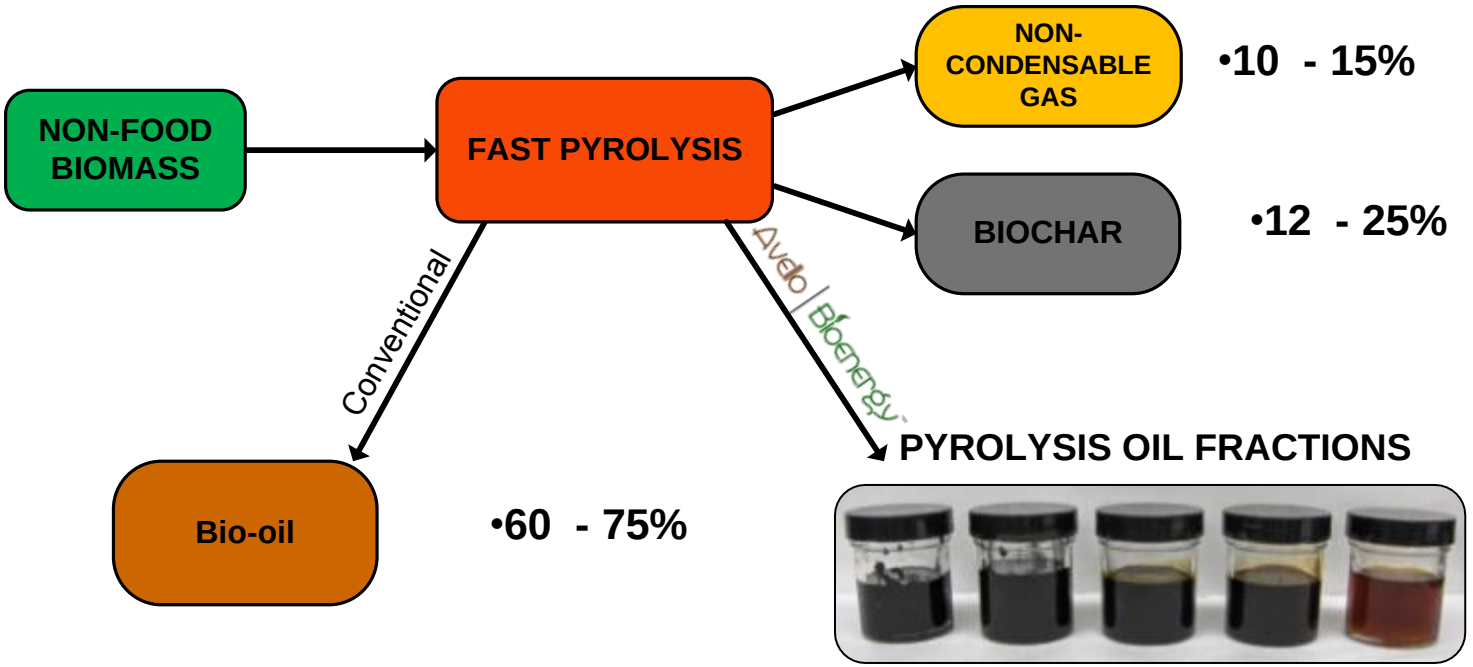
Avello Bioenergy™

Fueling opportunities™

2 - Technical Background and Planned Activities

- Current status of technology
- Project Overview
- Project Site
- Project Workflow
- Project RD&D

Avello™FRAC Technology Differentiation



Single Fraction
- Corrosive, poor properties
- Complex chemical mixture

Multiple Fractions
- Separate acids and water
- Higher energy, less corrosive, more stable

Avello Bioenergy™

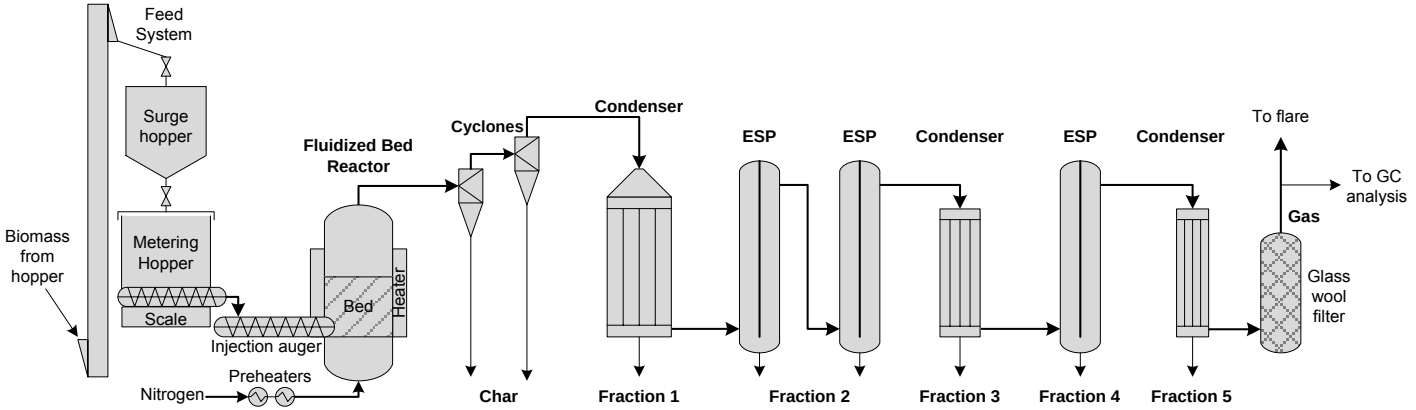
Fueling opportunities™

Avello®FRAC Pilot Plant

•Liquid Product Recovery

•Feed System

•Reactor and Cyclones



Avello Bioenergy™

Fueling opportunities™

Status of Technologies


•*Courtesy of ISU*


•**Waveland Trail**
•Franklin Ave. & 55th St., Des Moines

Fractionation Technology

- ¼ ton/day pilot plant
- > 525 hours operation
- Multiple feedstocks
  - Cornstover, Pine, Oak, Switchgrass
- Multiple 24hr/day continuous campaigns
- Strategic Partner sample evaluation

Bioasphalt® binder

- Developed by Dr. Chris Williams (ISU)
- Meets AASHTO specs
- October 2010, IDOT Demo in Polk County
  - 10' x 1 mile trail
  - 3% additive to petroleum asphalt binder
  - Standard blending and paving equipment

Avello Bioenergy™

Fueling opportunities™

Biofuel Oil™ Combustion

~1 gal/hr EZ-1 residential burner with Econox inline nozzle heater from Carlin Combustion Technologies

- Fraction 3 tested as-is in conventional home heating burner by Brookhaven National Laboratory
- Acceptable performance and reduced emissions compared to ULSD

Property	Biofuel Oil[1]	Conventional Pyrolysis Oil[2]	No. 2 Fuel Oil[2]
Moisture content (wt%)	7	20 - 25	< 1.0
HHV (BTU/gal)	96,000	72,000 – 80,000	138,500

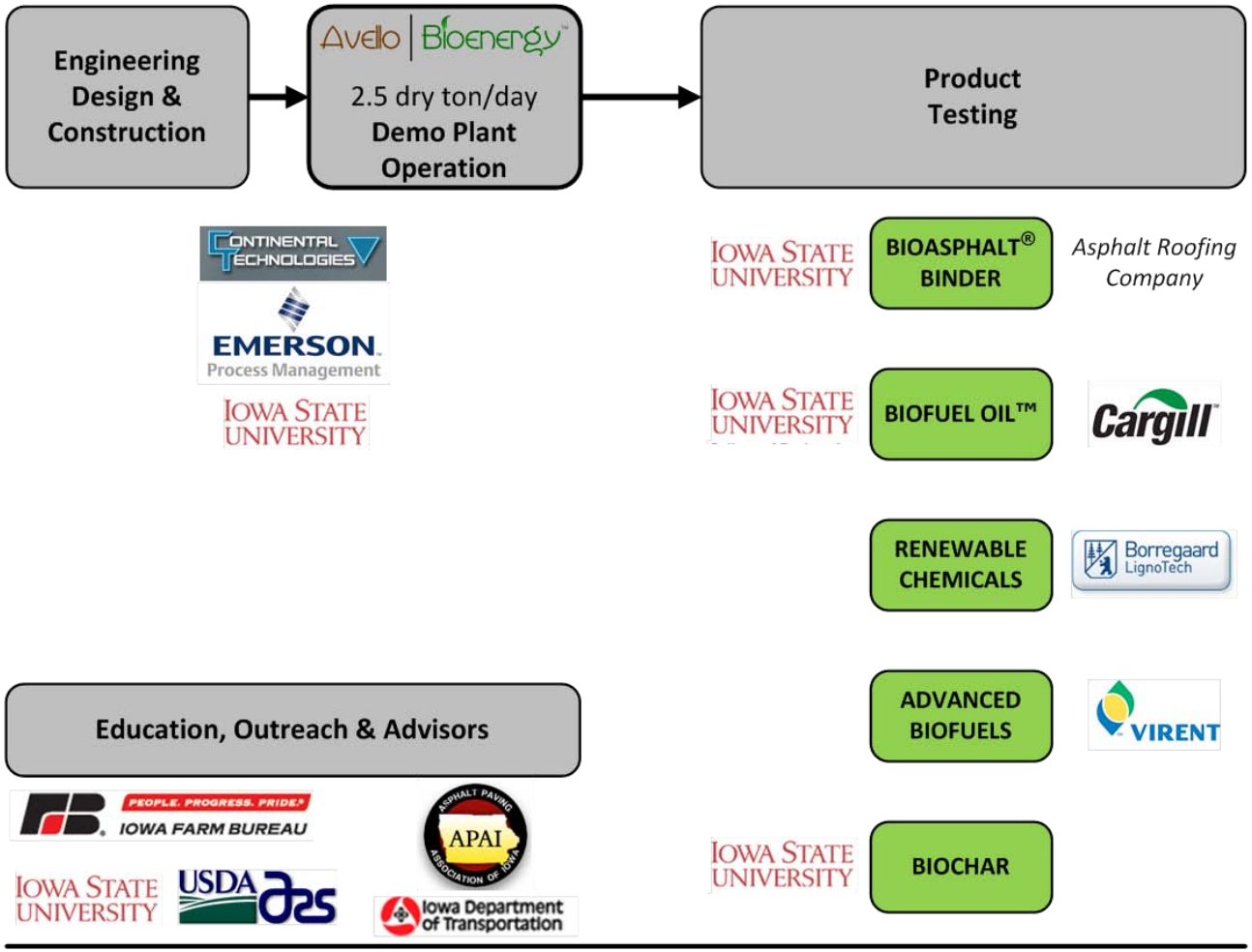
1. From Red Oak feedstock. Properties shown for specific sample tested by Brookhaven National Laboratory in combustion application (May 2012).
2. Easterly, James L. "Assessment of Bio-Oil as a Replacement for Heating Oil." 1 Nov. 2002. Web: <http://www.nrbp.org/pdfs/pub34.pdf>.

Avello Bioenergy™

Fueling opportunities™

Project Overview/Partners

Avello Bioenergy Demonstration Plant Project Partners



Avello Bioenergy™

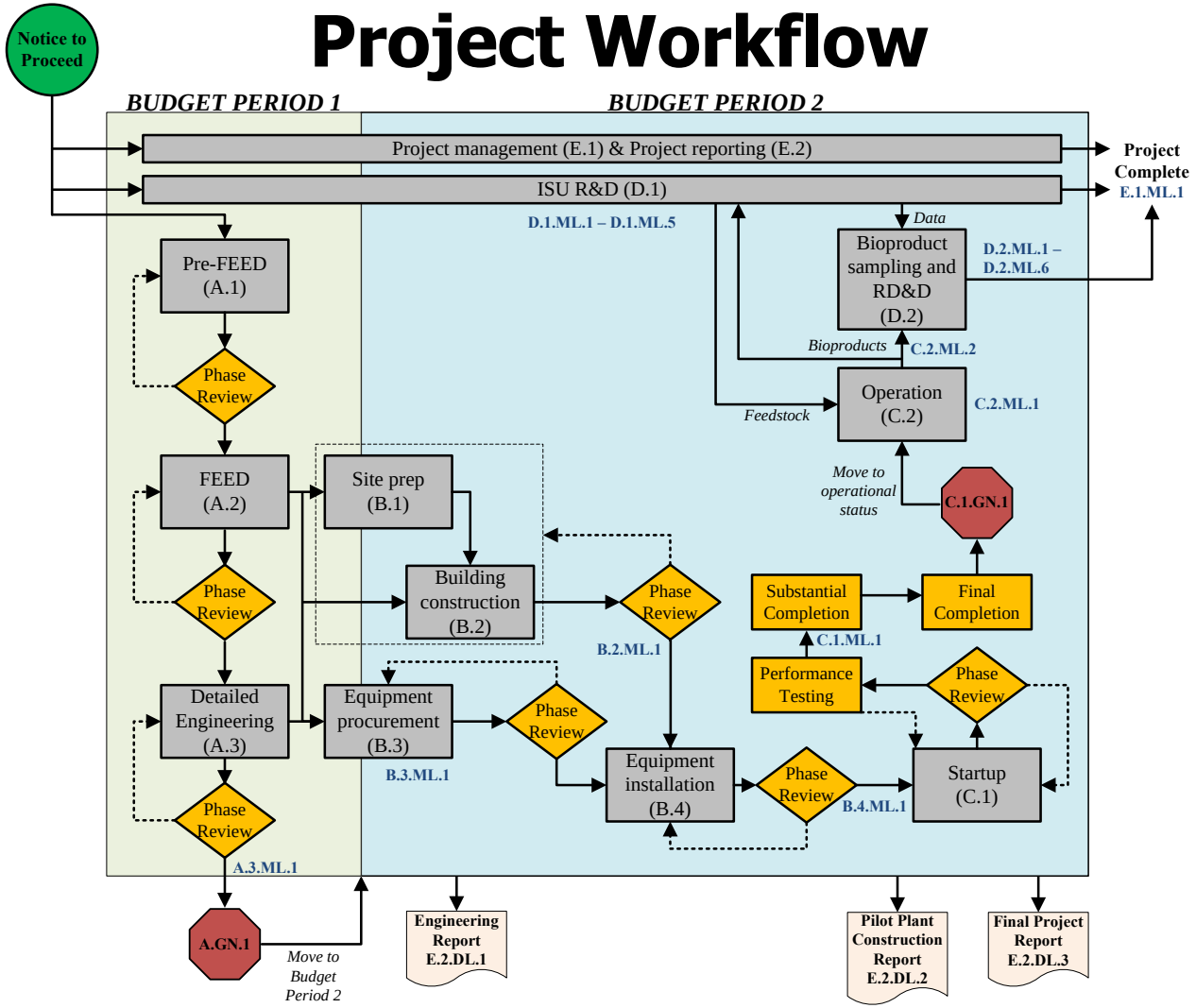
Fueling opportunities™

BCRF Site

* Approximate size and location shown for lease area

Fueling opportunities™

Project Workflow



Fueling opportunities™

Project RD&D

Feedstocks

- **ISU ABE Dept., Matt Darr**
- **AGCO**
- Single pass stover baling
- Switchgrass likely
- Harvest, Storage, Transport (HST)
- Pre-treatment
- Torrefaction?

Bioasphalt® binder

- **ISU CCEE Dept., Chris Williams**
- Performance testing & verifications
- Coordinate up to 4 demo paving projects with **IA DOT** and **APAI**

- **Roofing Company**
- Roofing asphalt formulations
- Analysis, blending, modifying, performance testing

Biofuel Oil™

- **ISU ME Dept., Terry Meyer & Song-C. Kong**
- **Goodrich Engine Components**
- **John Deere Power Systems**
- Non-transport biofuel blends
- Combustion testing: furnace (heat) and stationary engine (power)
- Emissions analysis

- **Cargill**
- Co-fire test burn
- Renewable power & reduced CO_2 profile for biofuels

Chemicals

- **Borregaard LignoTech**
  Analysis, characterization, screening, modifying
- Specialty, high-value chemical applications

Biofuels

- **Virent**
- Feasibility study
- Bench and pilot scale testing
- Utilize BioForming to convert Biooil fractions to drop in fuels.
- Proof-of-concept completed

Biochar

- **ISU ABE Dept., Matt Darr**
- Post-production handling and processing
- Investigate densification methods

3 - Relevance

- Project focuses on petroleum replacement products (fuels, materials, chemicals) that reduce dependence on foreign oil
  - Seek to prove commercial feasibility (economic and technical) of products
  - Seek to demonstrate compatibility within existing infrastructure (fuel, transportation, chemical)
  - Remove water and acid from bio-oil for new downstream processing schemes
- Joint development with public and private partnerships to leverage expertise, cut cost
- Evaluate various biomass feedstocks to quantify risk (feedstock supply critical risk)
- Test high performance separation technology (conversion critical risk)
- Test biopower demonstration and deployment (demonstration and deployment risk)

Avello Bioenergy™

Fueling opportunities™

4 - Critical Success Factors

- Critical success factors (managed using PMP):
  - Process Scale-up, product performance and compatibility with existing infrastructure (technical)
  - Market acceptance, product cost (market)
  - Project Management

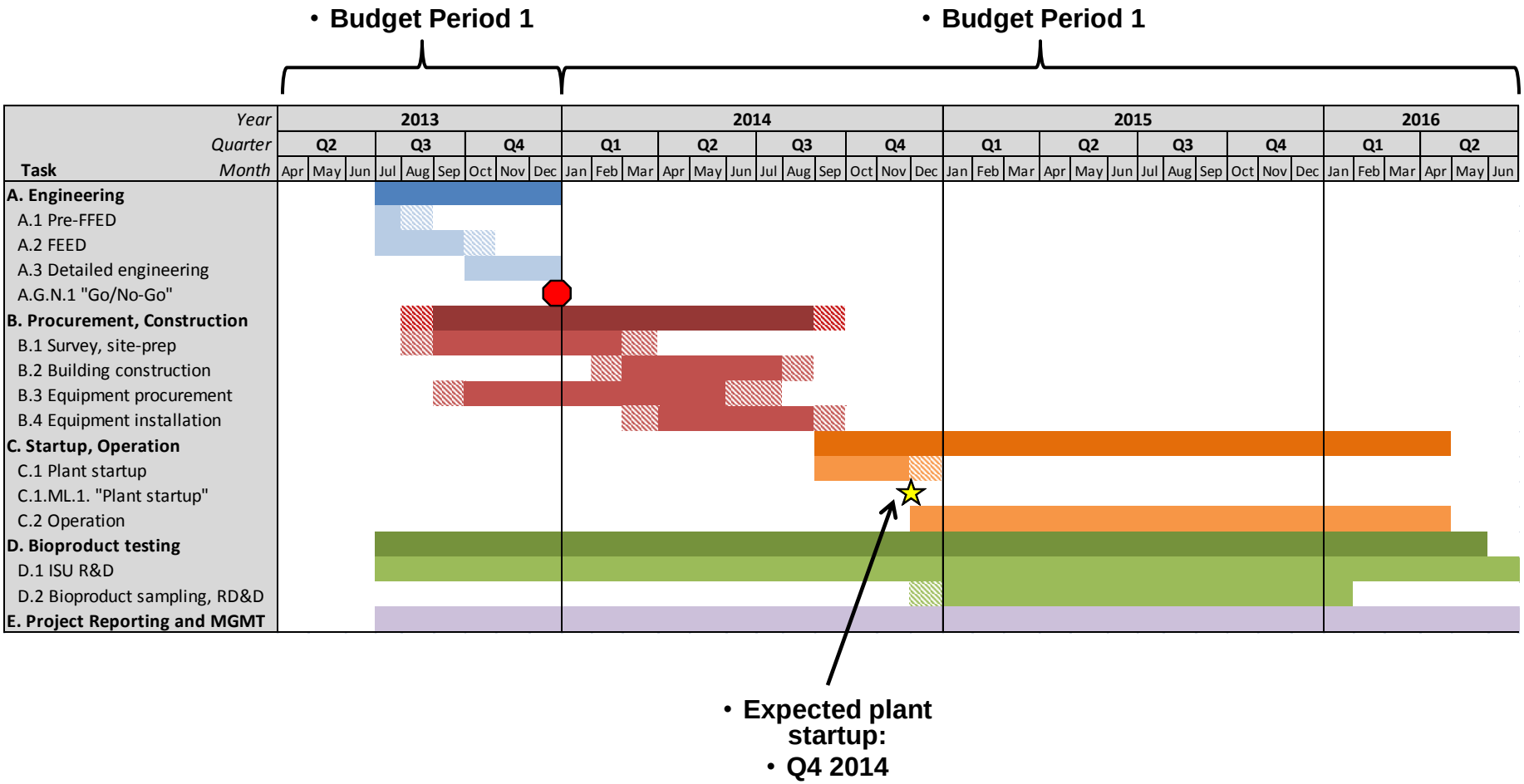
- Top Challenges:
  - Process scale-up: uniting solid feedstock processing with liquid processing; using commercial equipment for bio-oil applications
  - Product/Markets: demonstration petroleum product replacement viability

- Successfully advancing technology:
  - Prove process scalability
  - Prove commercial end-use applications, market acceptance, compatibility

Avello Bioenergy™

Fueling opportunities™

Future Work



- Assumes July 1 kick-off

Avello Bioenergy™

Fueling opportunities™

Summary

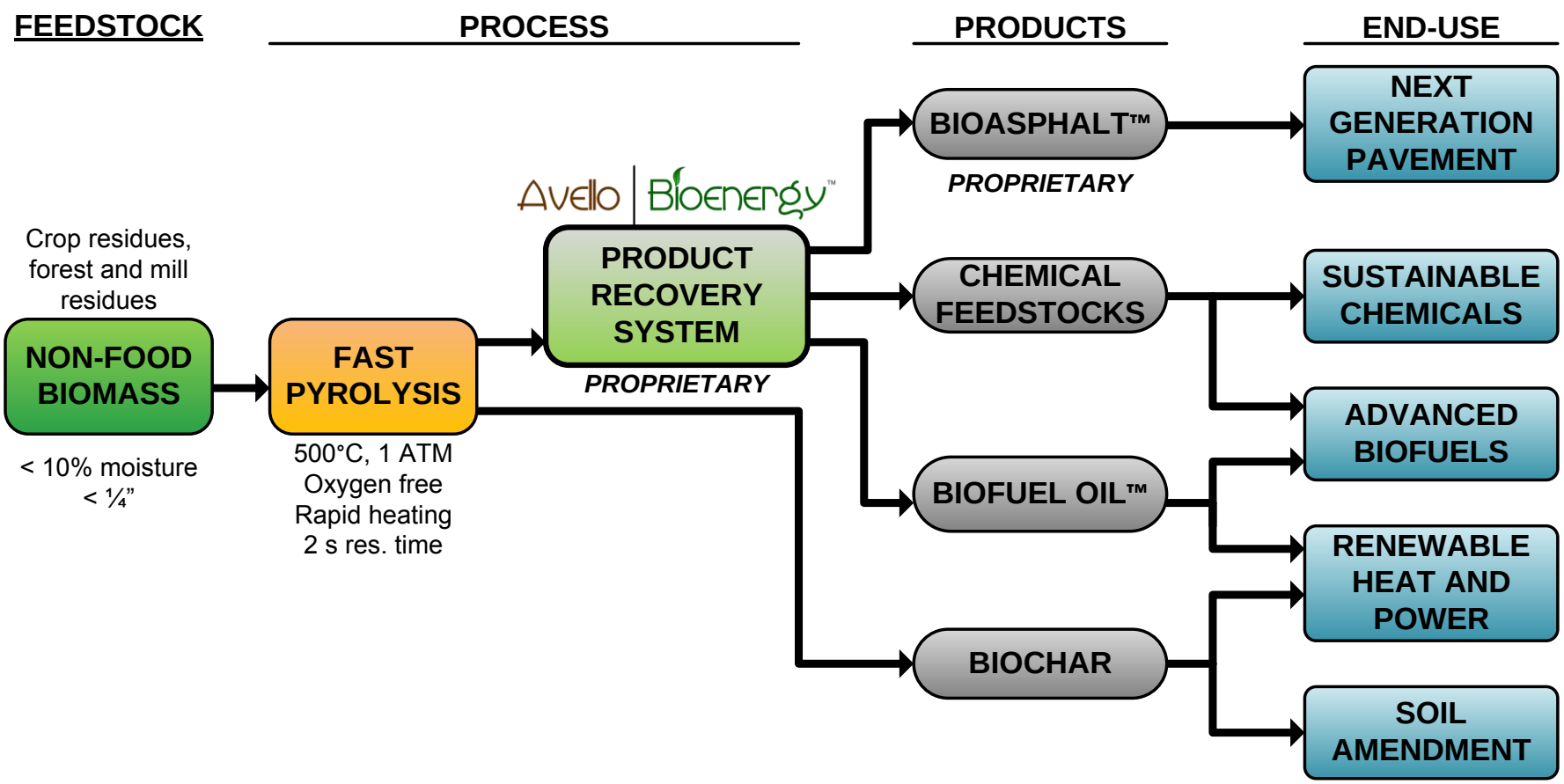
- Large integrated pilot scale plant and commercial product testing will build upon previous developmental scale work, refine economics and prepare for commercial scale up
- Public and private partnerships to leverage expertise, cut costs, increase probability of successful project
- Management team, advisors, and partnerships to manage critical success factors and solve/minimize challenges

Avello Bioenergy™

Fueling opportunities™

Additional Slides

Avello Bioenergy Fast Pyrolysis Technology Platform



Avello Bioenergy™

Fueling opportunities™