Thermochemical Conversion of Rice Straw to Ethanol

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Project Support

City of Gridley Bio-Fuels Project
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DOE Office of the Biomass Program

Project Collaboration

Collaborations

Biomass Conversion Technologies (Indirect Gasification Technology)
Choren Technologies (Indirect Gasification Technology)
Desert Research Institute (Environmental and Chemical Analysis)
Gas Technology Institute (Syngas Purification)
Rentech (Gas to Liquids (GTL) Technology)
Johnson Mathey (GTL Catalyst Technology)
Universal Oil Products (UOP) (GTL Catalyst Technology)
General Electric Energy (Electricity and Heat Production)
Renewable Energy Institute International (System Validation)
NERAC (Science, Technology & Intellectual Property Information Service)
Black and Veatch (Production System Design & Process Guarantees)
Butte County Air Quality Management District
Northern California Power Agency
California EPA and California Energy Commission

Project Goals and Objectives

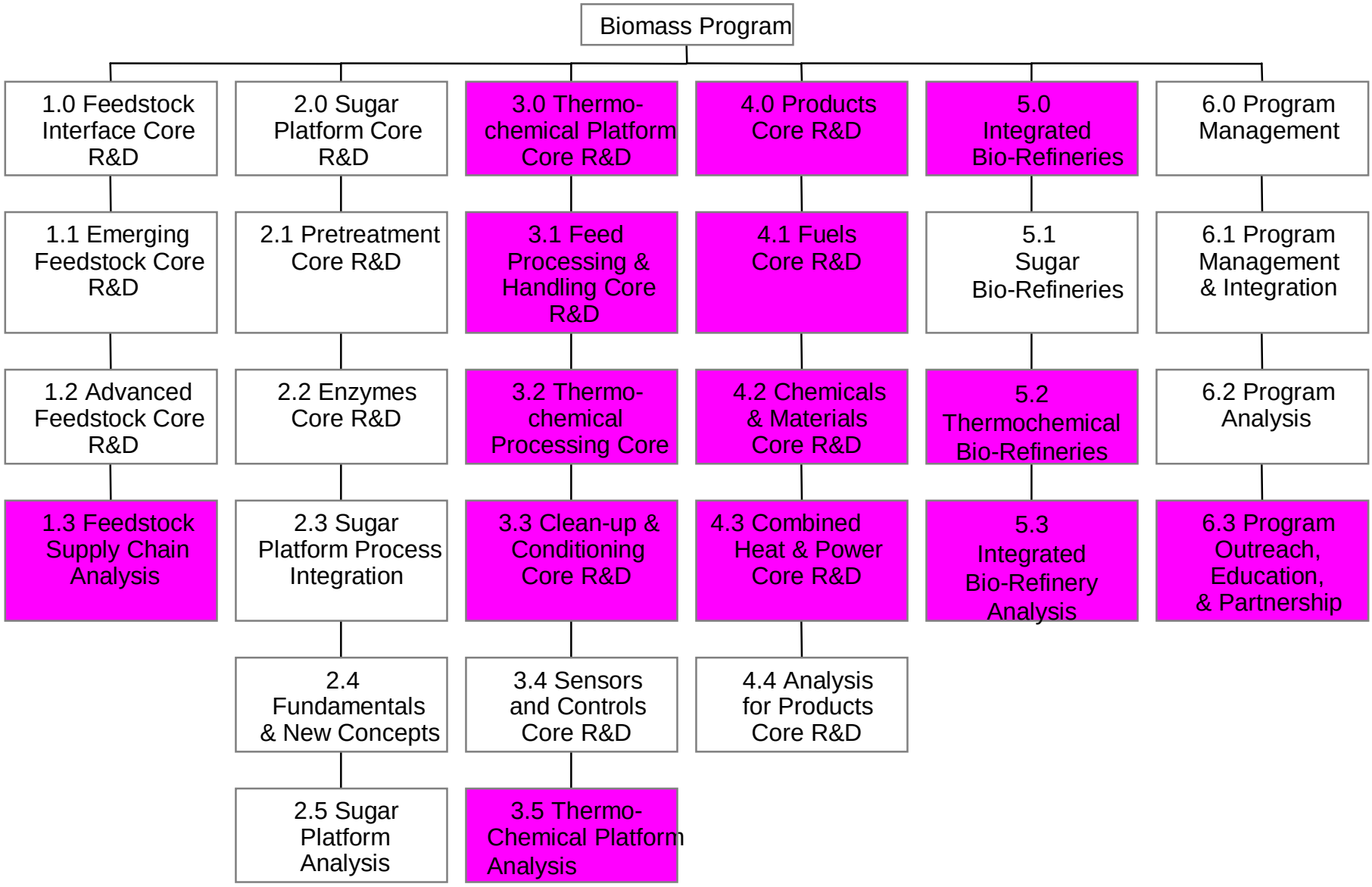
Develop a Bio-Refinery Technology for the Conversion of Rice Straw to Ethanol, Electricity and Heat

An "E5" Assessment Approach has been Utilized to Evaluate the Potential Viability of the Conversion Technologies:

- Economic (E1) viability
- High energy efficiency (E2)
- Least impact on the environment (E3)
- Evaluation (E4) of the reliability of the technology
- Most effective (E5) socio-political solution

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Project Strategic Fit



Project Strategic Fit

Technology Fit to the City of Gridley's Business Objectives

- The type of system developed by Pearson Technologies (direct gasification) has a high potential of producing ethanol and electricity from waste rice straw and biomass waste:

  - ✓ E1 – Ethanol can be produced at competitive prices ($1.09-1.39/gallon)
  - ✓ E2 – The energy efficiency for conversion of rice straw to electricity is excellent and to ethanol is good
  - ✓ E3 – The production system is not expected to create any adverse effects on the environment
  - ✓ E4 – There is a high probability that a commercial plant for the production of electricity will be successful. More work will be required to validate the viability of a full-scale plant for the production of ethanol
  - ✓ E5 – It is anticipated that this technology will be acceptable to all relevant stakeholders

Vision for Validation of Demonstration Plants by FY08

	Estimated Completion Date		
	Pearson (40 ton/day)	BCT (25 ton/day)	Choren (40 ton/day)
Design	4/06	2/06	Completed
Build	6/07	2/07	8/06
Validation	6/08	2/08	8/07

Project Approach

Development (Current Effort)

Test and validate all unit processes and chemical/physical processes on a 8 ton/day pilot plant:

- ✓ Characterize products
- ✓ Delineate primary chemical processes
- ✓ Assess the energy efficiency for each unit process
- ✓ Determine mass flows and balances for major chemical components
- ✓ Carry our environmental measurements
- ✓ Determine the effectiveness of syngas cleanup and conditioning processes
- ✓ Determine catalyst efficiencies for conversion of syngas to alcohols
- ✓ Determine catalyst durability and life

Project Approach

Technical Barriers and How They are Being Addressed

- Assess the capability of the Pearson system to practically and economically produce high yields of ethanol (>100 gallons/ton of rice straw). High yields will be dependent upon the practicality of recycling secondary products and incorporating secondary conversion processes to increase ethanol yields.
  - ✓ Carry out additional work on the Pilot Plant to qualitatively and quantitatively determine the alcohol products from the Fisher-Tropsch (F-T) catalyst.
  - ✓ Validate the reverse water gas-shift reactor, PSA system and other processes in the Pilot Plant.
  - ✓ Design and build a Demonstration Plant to validate proposed waste recycling and secondary conversion (e.g. reverse water gas-shift) processes.

Project Approach

Technical Barriers and How They are Being Addressed

- The effect of syngas contaminants on the long-term efficiency and durability of the Fisher-Tropsch (F-T) catalyst needs further evaluation:
  - ✓ Carry out chemical analysis for trace contaminants (potential poisons) in the Syngas
  - ✓ Semi-continuously monitor (8-16 hour intervals) the F-T alcohol and secondary reaction products over several hundred hours of catalyst operation.

Economic and Technical Targets

Produce ethanol from waste rice straw that meets the following targets:

- Feedstock cost of ≤ $30/ton or less (delivered to production plant)
- Feedstock supply guarantee for ≥ 10 years
- Plant feedstock capability of 350-500 tons/day
- Production up-time: 329 days/year @ 24 hrs/day
- Ethanol product meets or exceeds ASTM and SAE specifications
- Ethanol production cost of ≤ market price (currently averages $1.40/gallon)
- Electricity production cost of ≤ market price (currently averages $0.075/kWh (off-peak load) and $0.085/kWh (peak load)
- Production return on investment: ≥ 20%

Project Tasks

Risks Associated with Meeting the Project Targets & Objectives

- Technical Risks
  - ✓ Processes for the production of ethanol have not been sufficiently validated at the pilot plant or demonstration plant level.
- Equipment Reliability
  - ✓ The pilot systems have not been operated for adequate periods of time, therefore potential reliability can not be adequately assessed.
- Business and Market
  - ✓ The fuel and/or electricity can be produced at a competitive cost and that project investors will realize a good return on investment as long as energy costs do not drop significantly from current levels.
- Environmental and Compliance
  - ✓ We do not envision any significant environmental compliance issues.
- Intellectual Property
  - ✓ There is limited IP protection for the associated technologies

Potential Markets and Customers

- Municipal Utilities - Gridley is a Municipal utility and a member of a consortium of municipal utilities in California
  - ✓ Electricity and renewable energy to meet RPS requirements
- Energy Sector
  - ✓ Gasoline Distributors that can use ethanol
- Manufacturing Sector
  - ✓ Co-location at food processing plant in Gridley - it can use waste heat in lieu of natural gas boilers for food processing

Current Production Cost Objectives

- Ethanol production cost ≤ wholesale market value
- Electricity production cost of ≤ wholesale market value

Dynamics of Current and Future Market Shifts

- The major market drivers for the success of biomass to energy and/or fuel production plants are:
  - ✓ The average wholesale price of energy/fuels remaining at ≥ 2005 levels in the future
  - ✓ The continued promulgation of Renewable Portfolio Standards (RPS)
  - ✓ The increasing costs of waste biomass disposal
  - ✓ The need to reduce greenhouse gas emissions
- A significant increase in the competition for various waste biomass resources will decrease its availability for the production of fuels and electricity

Competitive Advantage

Duration of Window of Opportunity

- The long-term (5-10 years and beyond) potential opportunity for this technology is high
- A Go/No-Go decision for a full-scale production plant in Gridley will be made in early 2007.

Competing Technologies

- Corn starch/sugar to ethanol production facilities
- Enzymatic and acid/base hydrolysis of cellulosic materials followed by aerobic digestion to produce ethanol and other economically viable products using an integrated bio-refinery concept
- Direct gasification (with oxygen or air) of biomass and conversion of synthesis gas to ethanol

Competitive Advantage

Advantages of the Indirect Biomass Thermochemical Gasification/Fuel Production Approach Compared to Competitive Technologies

- Higher conversion of biomass to products
- Higher energy conversion efficiencies
- Low levels of air, water and solid waste effluents
- The fuel and/or energy products can be produced at competitive costs
- Fuel, electricity and heat can be co-produced

Progress and Accomplishments

Major Accomplishments

- The CA vehicle code was changed so that trucks could accommodate larger hay bale sizes, resulting in reduced transportation costs ($25-$30/ton range.
- Effective and efficient grinding process were developed for the processing of rice straw to produce material as small as 3/16".
- The *indirect* thermo-chemical biomass conversion technology was found to be superior to other biomass conversion technologies with respect to:
  - ✓ Greater than 99% conversion of biomass to energy and/or fuels
  - ✓ Biomass is pyrolyzed and gasified without air or oxygen resulting in the production of high-energy content syngas (350-550 Btu/SCF).
  - ✓ There are minimal emissions of air and water effluents and the ash is non-hazardous.
  - ✓ The syngas composition can be controlled to optimize the production of ethanol or electricity.

Progress and Accomplishments

Major Accomplishments and Findings

- Thermochemical models were developed to determine the chemistry, energy balances and mass balances for the conversion system.
- Ethanol is produced economically at good yields (80-100 gallons/ton rice straw) using specially formulated F-T catalysts.
- An alternative, mixed alcohol (C1-C7) product is being evaluated as a potential lower-cost, high-octane fuel additive.
- The ash and silica are co-products for which commercial markets are being evaluated.
- Fuel, electricity and heat are co-produced – the excess heat can be used to provide energy for a co-located host yielding thermal efficiencies up to 45%.
- A number of collaborative partnerships have been developed which have resulted in a significant leveraging of this project's resources.

Future Efforts

1) Complete evaluation of Pearson Technologies *Pilot* plant. Monitor the design, build and validation of the *Demonstration* plant. Carry out a competitive evaluation of the BCT and Choren technologies. Continue collaborations with key organizations and forge new collaborations as necessary to enhance the project.

2) Complete a supplemental marketing assessment for various options of producing ethanol, electricity and heat.

3) Complete development of the rice straw material and handling systems for the full-scale Gridley production plant.

4) Complete the environmental assessment for a full-scale plant at the proposed Gridley site.

Future Efforts

5) Complete financial projections, identify risk issues, mitigation requirements and financial information for capital debt and O&M requirements.

6) Complete interim reports, final reports, technical papers and presentations.

7) A *Go/No-Go* decision for a full-scale production plant in Gridley will be made in early 2007.
   - Several investors have expressed interest in funding these production plants.
   - Black and Veatch is financing the production system design for Pearson Technologies in order to develop process guarantees.