2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

BIOMASS ENERGY GENERATION PROJECT

5/23/2013
Heat and Power

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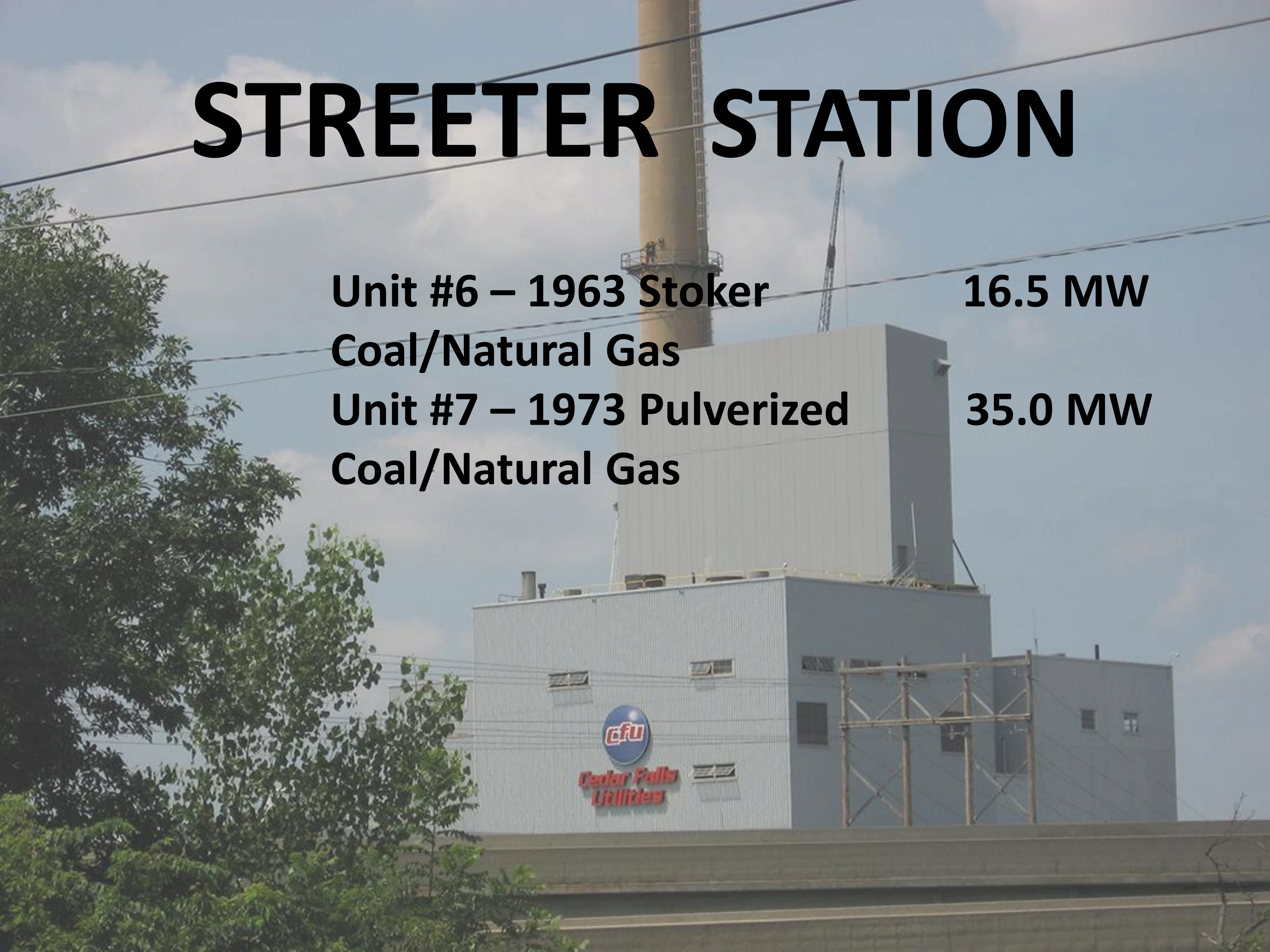
Cedar Falls Utilities

STREETER STATION

Unit #6 – 1963 Stoker Coal/Natural Gas	16.5 MW
Unit #7 – 1973 Pulverized Coal/Natural Gas	35.0 MW



Goal Statement & Project Overview

- Densification process to mimic stoker coal
  - ¾” to 1 ¼” chunks of coal
  - Suitable for corn stover and other energy crops
  - Compatible with the existing fuel handling equipment and boiler
  - Validity determined by test burns
- Test burn sequence
  - 20 ton lot for short burn
  - 2000 ton lot for extended test burn
- Long term project objective
  - Baseload generator using 100% renewable fuel

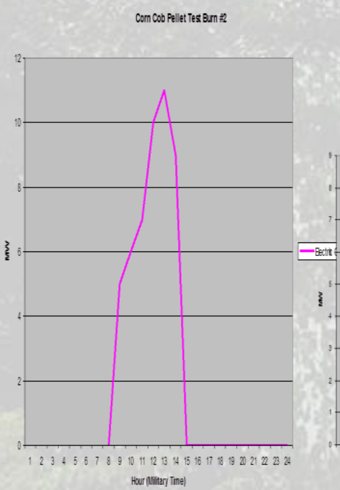
- In 2000, The Board of CFU challenged CFU staff to research the possibility of 10% renewable electricity by 2010. Baseload operation of Unit #6 using renewable fuels would provide 25% renewable electricity. A series of test burns of potential renewable fuel options for Unit #6 followed. This current series of test burns focuses on identifying a densification process and supply chain capable of providing the quantity and quality of fuel needed for baseload operation.

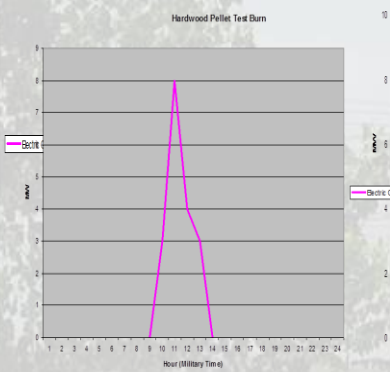
FIRST SERIES OF TEST BURNS

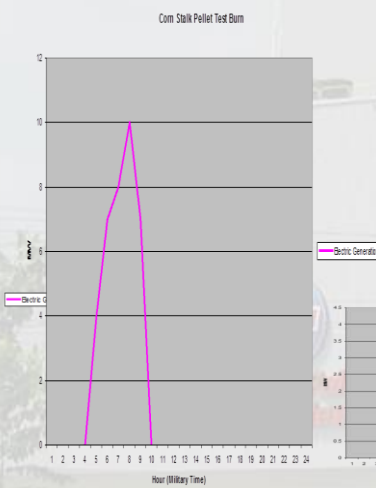
Corn Cob	Wood	Corn Stover	Corn Stover	Oat Hulls	Switchgrass
7/23/04	3/23/05	3/23/05	3/22/06	3/23/06	3/24/06

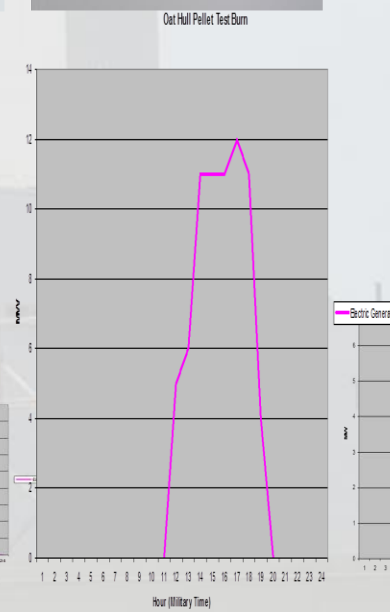


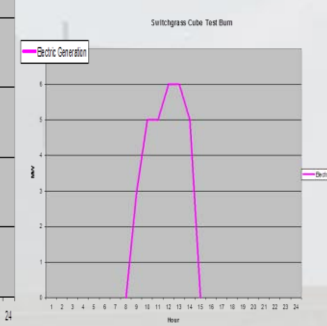












Quad Chart Overview

Timeline

- Started: 4/22/2009
- Completion: 12/31/2013
- 18% completed

Budget

2010 - $14,971 / $3,743
2011 - $10,974 / $2,743
2012 - $27,476 / $6,869
2013 - $200,000 / $50,000
5 yrs. / $15,000 / yr.

Barriers

- Energy Crop yields
- Appropriate densification
- Sustainable combustion
- Full generation capacity
- Boiler compatibility

Partners

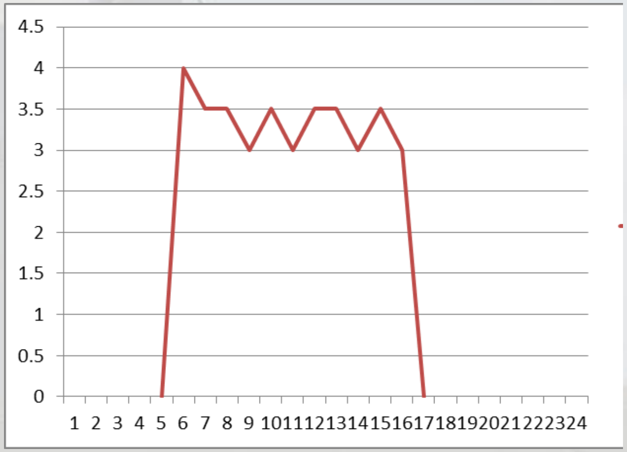
Pro-Hay (Warren & Baerg)
Raceland Raw Sugar/Alstrom
Show Me Energy (Bliss)
Robert White Industries (W&B)
University of Northern Iowa
Tallgrass Prairie Center
Idaho National Lab (Bliss)
Pellet Technologies (Modified CPM)
Larksen (Modified W&B)

1 - Approach

- Stokers were replaced in 2007
- Proposed three short duration test burns (20 tons)
  - All were capable of producing 2000 tons of fuel, if needed
  1. Cubed prairie grasses
     - Investigate additional herbaceous fuel sources
     - Improve quality of the cubes
  2. Pelleted agricultural byproducts and
     - Retest ¼” pellets with new stokers
  3. Sugar cane bagasse bripells
     - Investigate a new densification option and herbaceous source
- Proposed one long duration (10 day) test burn
  - 2000 tons of fuel
  - Evaluate compatibility of the fuel with the boiler

2 - Accomplishments/ Progress/Results - 2009

- Cubed prairie grass test (seed mix used for restoration and DOT)
  - Spring custom harvest of grasses yielded below target (1.3 T/Acre)
  - Densified to 1 ¼” with W & B cuber with evaluation of binding agents
  - Poor densification, the densified fuel disintegrated with handling
  - During final test burn, combustion was unsustainable
  - 19.8 Tons - $7,803.56 - 6707 BTU/lb

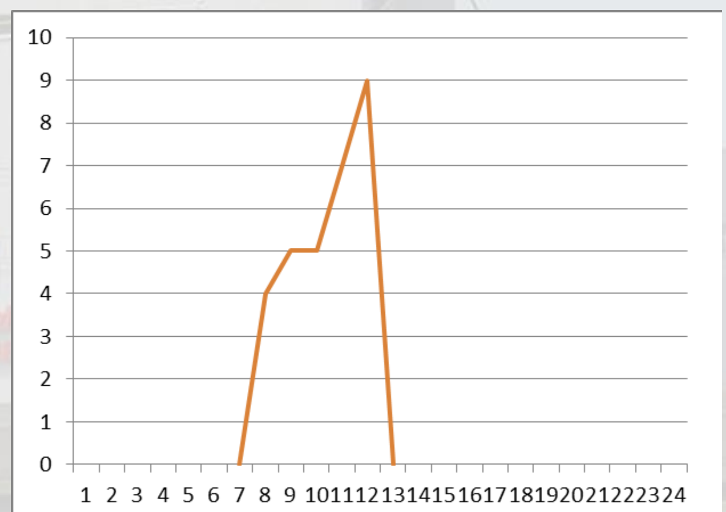


2 - Accomplishments/ Progress/Results - 2010

- Cubed field corn stover sourced in Indiana
  - Densified to 1 ¼” with W & B cuber with bentonite binder
  - Satisfactory densification, delayed combustion
  - During final test burn, combustion was unsustainable
  - 21.2 Tons - $2,855.11 - 6306 BTU/lb

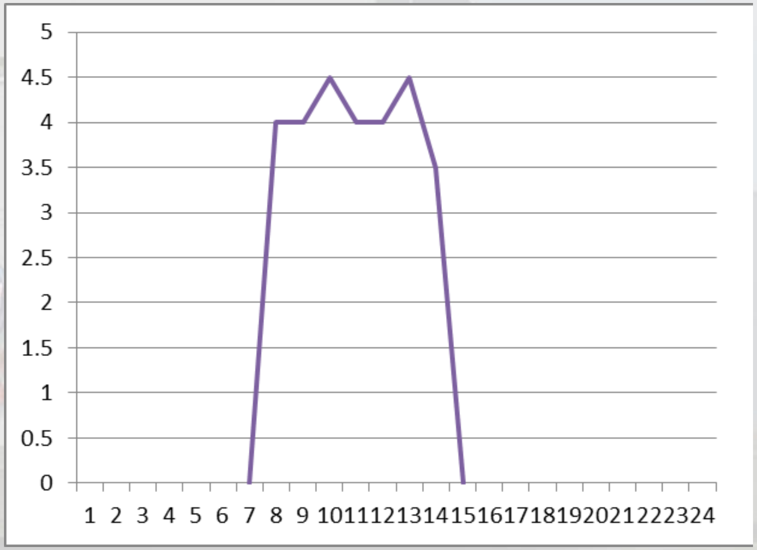
2 - Accomplishments/ Progress/Results - 2010

- Densified agricultural byproducts sourced in Missouri
  - Densified into ¼ inch pellet
  - Product handled and stoked well
  - Fuel scattered on the grate, efficiency loss
  - Increased generation until fuel ran out
  - Stokers had more capacity
  - 22.5 Tons - $4002.50 - 6874 BTU/lb



2 - Accomplishments/ Progress/Results - 2010

- Cubed sweet corn stover sourced in California
  - Densified to 1 ¼” with W & B 2-way cuber with $CaCO_3$ binder
  - Excess densification, excessively elongated cubes
  - During final test burn, combustion was sustainable
  - Maximum stoking capacity below generator capacity (4MW)
  - Ash slagged on the grate
  - 19.4 Tons - $11,855.60 - 6069 BTU/lb

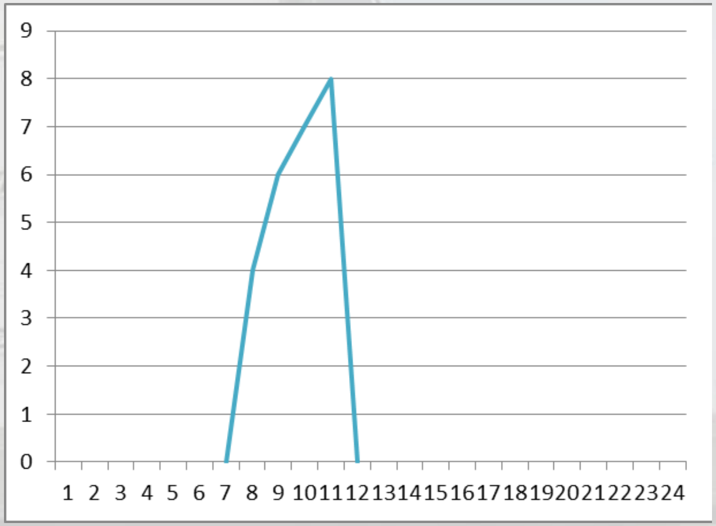


2 - Accomplishments/ Progress/Results - 2011

- Densified sugar cane bagasse from Louisiana
  - Densified into 4 cm bripell
  - Delay in production of product
  - Mixed product, fresh and aged bagasse
  - Large pieces damaged conveyor, test aborted
  - 20 Tons - $19,980 – 8652 BTU/lb

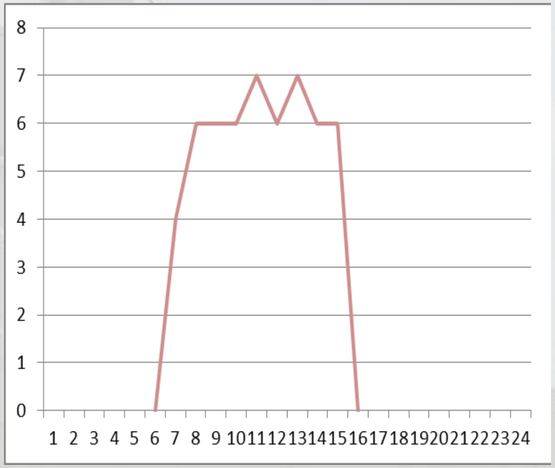
2 - Accomplishments/ Progress/Results - 2011

- Cubed corn stover sourced in Minnesota
  - Densified to 1 ¼" with W & B cuber using "cylindrical" die without binder
  - Ideal densification, some elongated cubes, fresh product
  - During final test burn, combustion was sustainable
  - Maximum stoking capacity below generator capacity (8MW)
  - 15.3 Tons - $13,717.03 - 6233 BTU/lb



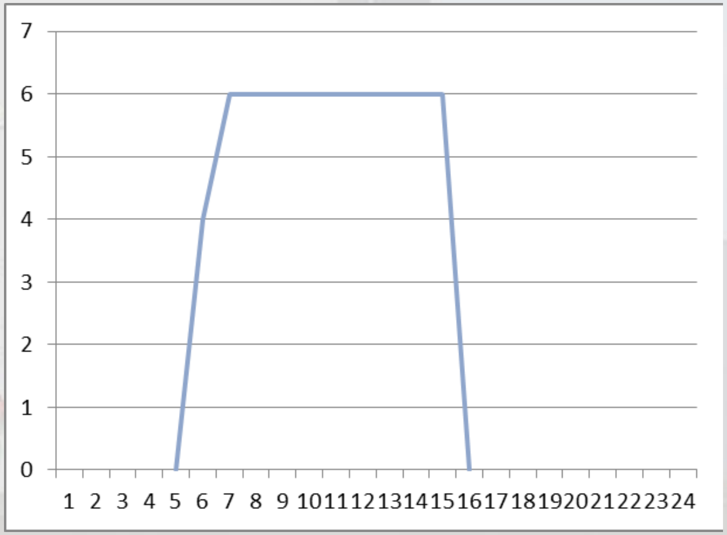
2 - Accomplishments/ Progress/Results - 2012

- Pelleted energy crop raised by UNI Tallgrass Prairie Center
  - Custom harvest of energy crop yielded below target (1.7 T/Acre)
  - Attempt to densify into 5/8” CPM pellet unsuccessful
  - Successfully densified into robust 1/4” CPM pellet
  - During final test burn, combustion was sustainable
  - Required stack testing prevented stoking capacity determination
  - 40.1 Tons - $29,754.97 - 6561 BTU/lb



2 - Accomplishments/ Progress/Results - 2012

- Pelleted corn stover sourced in Iowa
  - Successfully densified into robust 5/8” CPM pellet
  - During final test burn, combustion was sustainable
  - Required stack testing prevented stoking capacity determination
  - 100.1 Tons - $34,345.37 - 5466 BTU/lb



Project Management

- Harvested energy crop yields were both below target
- Unsuccessful test burn of the cubed grasses lead to a series of test burns of cubed fuel to produce a viable product
  - All subsequent cubed fuels used corn stover
  - Ultimately demonstrated 1 ¼” dimension too large
- Successful test burn of ¼” pellets demonstrated potential but an inefficiency
- Aborted test burn of bripell reiterated size limitation
- Non standard densification sizes and processes to obtain the desired fuel sizes
  - Focused on final pellet size of ½” to 1”

3 - Relevance

- **DOE Strategic Goals**
  - Improving Herbaceous Crop Yields
    - Selection of existing native prairie plants
    - Harvest opportunity in the spring
  - Mechanical Pre-processing
    - Viable product with lowest embedded energy cost
  - Thermal Conversion
    - Matching harvest window with lowest moisture content of raw material to minimize or eliminate drying
- **Electric Generation Goals**
  - Renewable fuel which mimics stoker coal
    - Appropriate fuel for stokers and fluidized bed boilers
- **Renewable Energy Goals**
  - Incremental steps in developing a solid fuel supply chain
  - Processes common to other fuel supply chains

4 - Critical Success Factors

- Identifying a densification process which will provide fuel suited to the electric generation unit and minimize the energy embedded in preparation of the raw material. Significant savings can be achieved by minimizing the cost of size reduction.

- Developing a supply chain will require coordination with potential suppliers.
  - Potential feedstock supply of 100,000 tons
  - Densification equipment capable of producing fuel at the same rate as the fuel is used.
  - This will be a slow process of matching supply with demand, and will require measured steps of increases in production and consumption.
  - Development of the supply chain is dependent on fuel compatibility with the boiler.

- Specifications for the raw material and densification process required to mimic stoker coal will be universally applicable to any stoker fired or fluidized bed boiler. The fuel can be fired 100% renewable or blended with coal.

- Cost of the fuel

5. Future Work

- Cubed corn stover sourced in Iowa
  - Densified to 1” with W & B cuber using “cylindrical” die without binder
  - Test burn to be scheduled when fuel is available
  - Determine viability, sustainable combustion and capacity
- Extended test burn
  - Fuel specifications will produce size known to perform and reach generation capacity.
  - Boiler will be inspected after extended test burn for any visible evidence of incompatibility with the fuel
- Continuing research after completion of the project
  - Increasing BTU content of corn stover
    - High pressure densification
    - 15% plastic film blend for binding and increased BTU’s
    - Existing or new sources from industrial waste streams
  - Beneficial use of ash for soil amendments or fertilizer.

Summary

- Key factors influencing quantity, quality and cost of renewable fuel
  - Crop yield in tons per acre
  - Size of densified product
  - Viability of densification process
    - Initial durability
    - Shelf life
    - Stoking
    - Generation capacity
  - Impact on boiler
  - Requirements for continuous generation