# Biomass Cofiring

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# Outline

- Historical Perspective & Definitions
- Merit & Benefits
- Co-Firing Program Goals & Issues
- The Tests & Projects
- Mission Accomplished

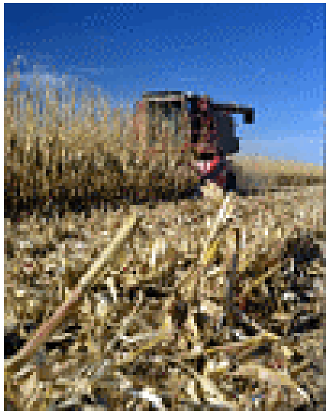
# Cofiring Abbreviated History

- 1994 – DOE FE/NETL initiated cofiring effort at national labs
- 1996 – DOE/EPRI Biomass Cofiring projects initiated
    - Seven existing coal-fired utility boilers
- 1998 – EE/OPT Biopower Program becomes primary funder
- 2000 – Biomass Cofiring Opportunities Solicitation
    - Two utility and two industrial-scale demos, seven feasibility/technology support activities
- 2001 – Ended emphasis on Cofiring
    - Utility cofiring techniques largely evaluated and demonstrated
- 2002 – Restructuring of EERE
- 2003 – Formally shifted emphasis to gasification-based bioenergy

# Definitions

- Biomass/coal cofiring
  - the combustion or cogasification of coal and biomass, or the combustion of coal with biomass-derived fuel gas
- Biomass
  - agricultural and forest products or residues derived from living plants
  - also applied to landfill gas and other organic wastes

Wood Residues



Agricultural Residues

Energy Crops

# General Merits

- Biomass is a renewable domestic resource and can contribute to local economic growth
  - Low cost $CO_2$ option with $SO_2$, NOx benefits
- Use of existing power plants offered advantages
  - increases biomass efficiency and reduces costs
  - provides biomass access to the current electricity market
- Landfill burdens may be reduced
- Initial step to expand market and develop infrastructure for biomass feedstocks.

# Benefits

## From a Power Producer's Perspective

- Reduction in fossil $SO_2$, $NO_x$ and $CO_2$ emissions
- Customer retention
- Hedge against potential future regulations
- Interest in "Green Power" markets
- Possible cost savings
  - Residues
  - Tax incentives
  - Fuel supply options

# Cofiring Program

## Goals

- Promote biomass use using the least cost approach
- Broaden the base of utilities employing cofiring
  - Reducing risk
  - Indentifying potential obstacles
  - Quantifying benefits
- Increase the number and type of cofiring techniques
- Provide the underpinning for advanced designs

# Technical Issues

- Existing boilers/systems designed for fossil fuels
- Diverse feedstock
- Feeding methods
- Boiler efficiency degradation
- Emissions
- Percentages
- Ash related issues
- Economics

# Technical Issues

- Uncertainties due to different biomass properties
  - Low densities
  - High alkali content in some varieties
  - Low heating value
  - High volatility
  - Typically Low S and N content

# NETL Utility Cofiring Tests

| Utility and Plant | Boiler Capacity and Type | Biomass Heat Input (max) | Biomass Type | Average Moisture | Coal Type | Biofuel Feeding |
|---|---|---|---|---|---|---|
| TVA Allen | 272 MW Cyclone | 10% | Sawdust | 44% | Illinois basin, Utah bituminous | Blending biomass & coal |
| TVA Colbert | 190 MW wall-fired | 1.5% | Sawdust | 44% | Eastern bituminous | Blending biomass & coal |
| NYSEG Greenidge | 108 MW tangential | 10% | Wood waste | 30% | Eastern bituminous | Separate injection |
| GPU Seward | 32 MW wall-fired | 10% | Sawdust | 44% | Eastern bituminous | Separate injection |
| MG&E Blount St. | 50 MW wall-fired | 10% | Switchgrass | 10% | Midwest bituminous | Separate injection |
| NIPSCO Mich. City | 469 MW cyclone | 6.5% | Urban wood waste | 30% | PRB, Shoshone | Blending biomass & coal |
| NIPSCO Bailly | 194 MW cyclone | 5-10% | Wood | 14% | Illinois, Shoshone | Blending (Trifire) |
| Allegheny Willow Ilnd | 188 MW cyclone | 5-10% | Sawdust | tbd | Eastern Bituminous | Blending (Trifire) |
| Allegheny Allbright | 150 MW tangential | 5-10% | Sawdust | tbd | Eastern Bituminous | Separate Injection |

Allegheny Energy Supply projects awarded in FY2000 and are in progress

# 11 Projects Awarded in FY2000

| Awardee | Title |
| --- | --- |
| Allegheny Energy Supply Co. | Designing an Opportunity Fuel with Biomass and Tire-Derived Fuel for Cofiring at Willow Island Generating Station |
| Southern Res. Institute | Development of a Validated Model for Use in Minimizing NOx Emissions and Maximizing Carbon Utilization when Cofiring Biomass with Coal |
| Univ. of Pittsburgh | Urban Wood/Coal co-firing in the NIOSH Boilerplant |
| Nexant LLC | Gasification Based Biomass Co-firing Project |
| Gas Technology Institute | Calla Energy Biomass Gasification Cofiring Project |
| Univ. of North Dakota -EERC | Cofiring Biomass with Lignite Coal |
| Iowa State University | Fuel Lean Biomass Reburning in Coal-Fired Boilers |
| University of Pittsburgh | Urban Wood/Coal Cofiring in the Bellefield Boilerplant |
| Penn State University | Feasibility Analysis for Installing a Circulated Fluidized Bed Boiler for Cofiring Multiple Biofuels and other Wastes with Coal at PSU |
| Texas A&M University | Cofiring of Coal: Feedlot and Litter Biomass Fuels |
| Univ of North Dakota –EERC | Cofiring of Biomass at the University of North Dakota |

# Projects Managed by DOE GFO

- Chariton Valley Project: cofiring switchgrass in southern Iowa
- Salix Consortium: growing and cofiring willow
- Southern Company, SRI, Auburn U: cofiring switchgrass at Gadsden Station
- Closed-loop biomass co-firing at Hawaiian Commercial & Sugar Co

# DOE Cofiring Project Summary

- Biomass Cofiring Program is concluding all on-going projects
- Proven as technically successful
- Useful information developed so that biomass cofiring can be implemented in utility scale boilers
- Not all participating utilities are still cofiring
  - Availability and cost of biomass (coal is relatively cheap)
  - Regulatory issues (new source review)
  - General industry uncertainty

# Accomplishments

- Viability demonstrated
- Addressed all technical issues
- Quantified minimal boiler efficiency/ capacity impacts
- Verified NOx, $SO_2$ & $CO_2$ reductions
- Developed feeding techniques
- Identified & solved most supply issues
- Developed economics
  - Initial models

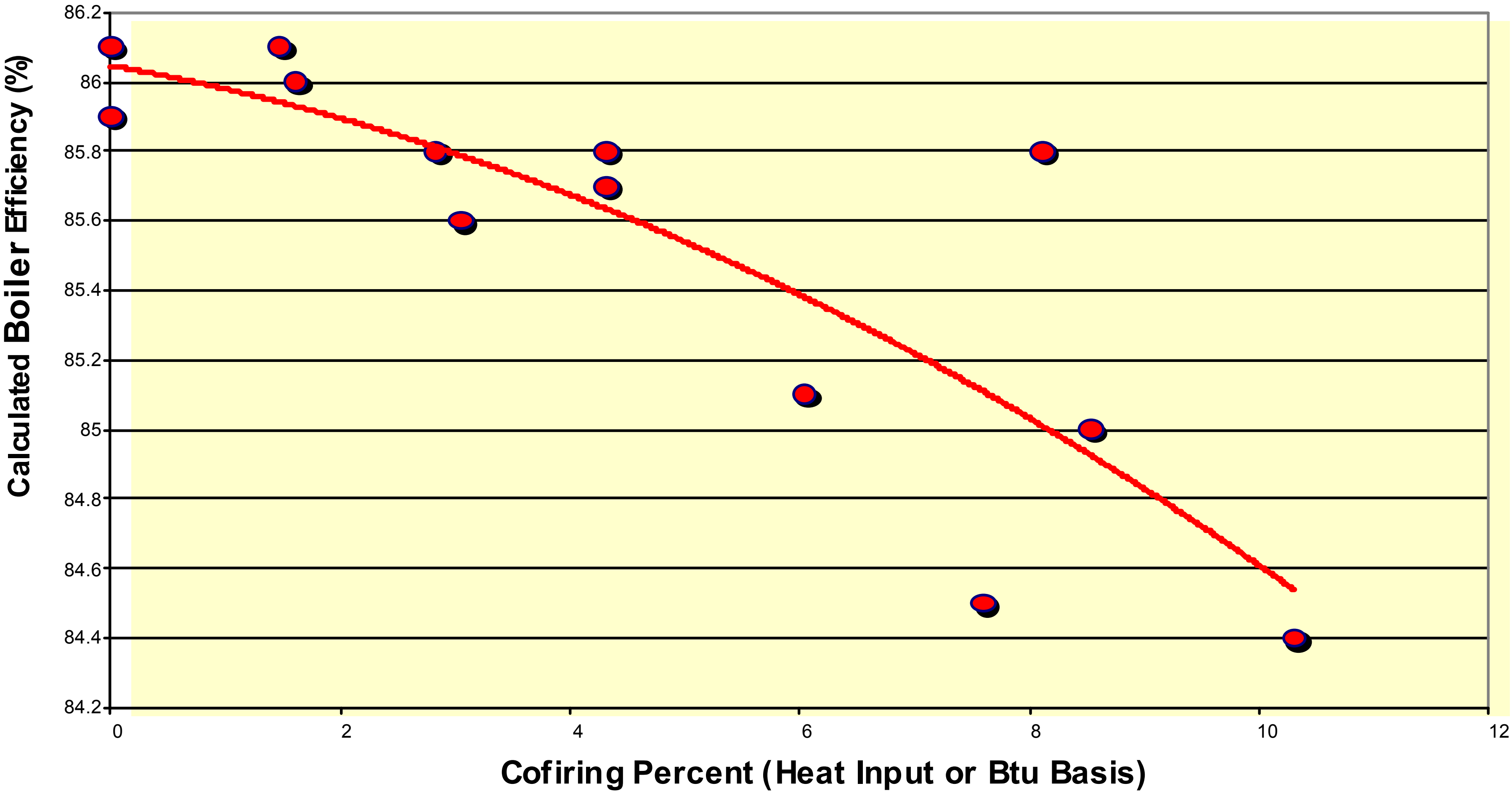
# END

# Testing Factors and Results

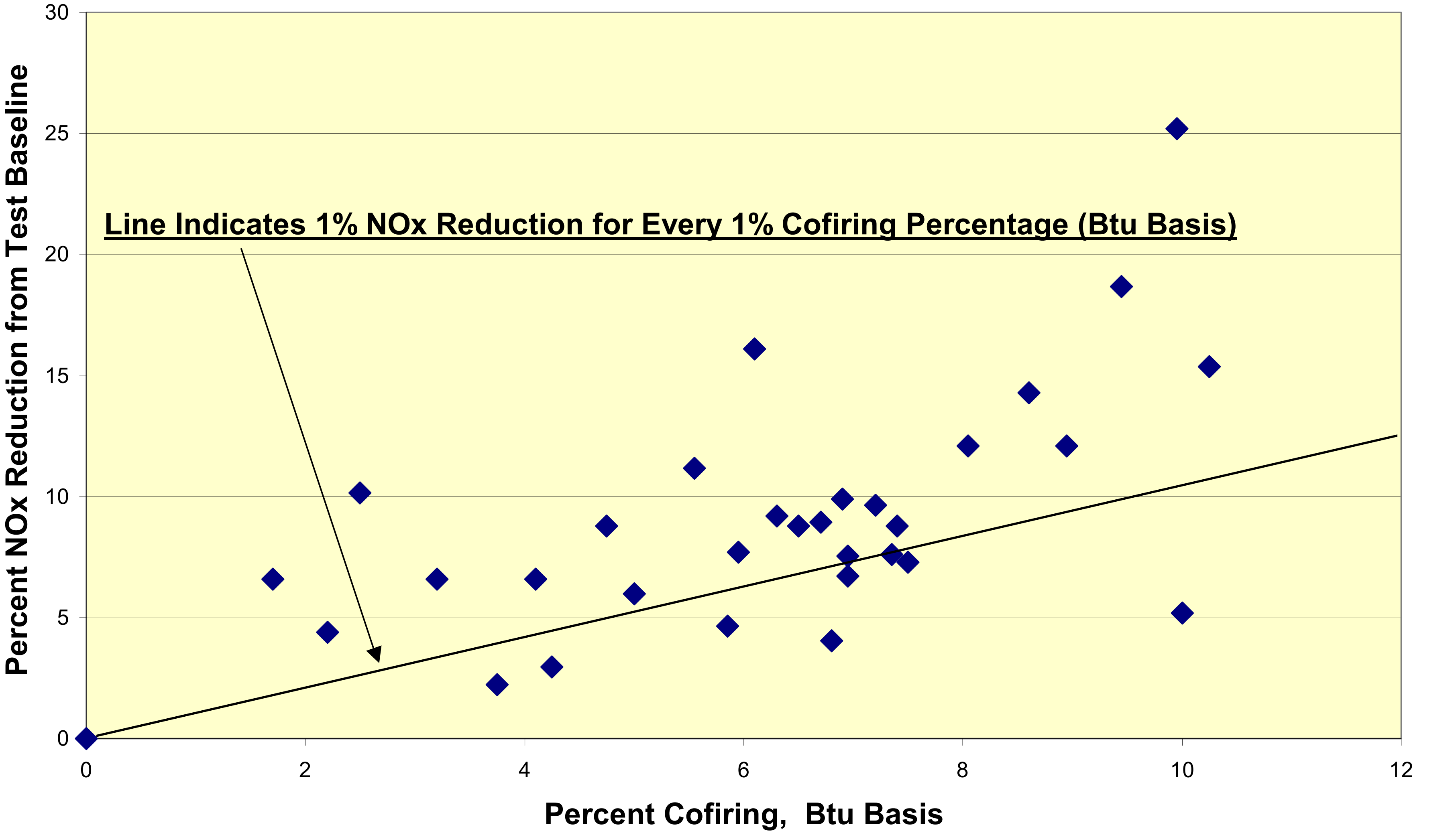
| | Pulverized Coal | Cyclone | Stoker |
|---|---|---|---|
| **Blended Feed** | << Separate Feed | 10% by heat | 10% by heat |
| **Separate Feed** | 10% by heat | Not Utilized | Not Utilized |
| **Constraints** | Pulverizer<br>Feeder | Feeder | Feeder/Handling |

| | |
|---|---|
| COSTS | Expressed per unit of power capacity on biomass, not on total capacity of the unit<br>Blending on the order of $50/kW<br>- requires no separate flow and injection path for the biomass fuel<br>Separate Feed on the order of $200/kW<br>- cost for additional feeders, handling equipment, etc. |
| EFFICIENCY | Can reduce by a small amount (0.5 to 1.5%).<br>Values from various tests have some scatter but the dependence is mainly due to the BTU content of coals cofired |
| SO2 | Decrease –direct fuel substitution |
| CO2 | Decrease –direct fuel substitution (CO2 neutral) |
| NOx | Decrease to no change<br>Biomass has higher volatile contents and lower fuel nitrogen content than coal |

# Small Effect on Efficiency



# Average $NO_x$ Emissions Reduction



# Feed Methods and Percentages

- Two primary methods were developed:
  - Blending - the biomass and coal in the fuel handling system and feeding blend to the boiler
  - Separate feed - prepping and injecting biomass separately from coal > no impact to the conventional coal delivery system
- Percentages
  - PC boilers: 2% by heat using Blend Feed, 10% by heat using Separate Feed
  - Cyclones: 10-15% by heat using Blend Feed
  - Stokers: 20% by heat

# Capital Costs

- Depends on feeding methods and boiler types
  - Most costs associated with Storage and Handling
- PC Boilers:
  - \$50/(kw of biomass) for blend feed
  - \$200/(kw of biomass) for separate feed
- Cyclone Boilers:
  - \$50-100/(kw of biomass) for blend feed

- *Note that the cost per total plant capacity is much lower (e.g. it costs \$20/kw for a PC boiler cofiring 10% biomass by heat)*

# Ash Related Issues Depend on Biomass

- High alkali matter (potassium, sodium) in biofuels is a concern, alkali sulfates deposits are resistant to soot blowing.
- Woody biofuels have little ash, other biomass as alfalfa can contain significant concentration of ash, and can be rich in alkali metals.
- Concentration of alkali matter may not be universally problematical. In cyclone or other slagging combustors, concentration of calcium and other alkalis can reduce ash fusion temperature, and improve slag tapping.
- Tests in Michigan City #12 boiler show no significant impact on the composition of fly ash (10% cofiring by mass using wood).

# Status of NETL awards

| | | |
|---|---|---|
| TVA Allen | 272 MW cyclone | No- management decision |
| TVA Colbert | 190 MW wall-fired | Yes- when available |
| NYSEG Greenidge | 108 MW tangential | Yes |
| GPU Seward | 32 MW wall-fired | No- plant closed |
| MG&E Blount St | 50 MW wall-fired | Yes |
| NIPSCO Mich.City | 469 MW cyclone | No-regulatory impasse |
| NIPSCO BAILLY | 194 MW cyclone | No-regulatory impasse |
| NIOSH Pittsburgh | 55000 #/hr stoker | No-wood supply unavailable |
| APS Willow Island | 188 MW cyclone | Tests in progress |
| APS Albright | 150 MW tangential | Tests in progress |

# Status - FY2000 Awards

| | |
|---|---|
| Allegheny Energy* Supply | **Willow Island tests are concluding, Mill installation is underway at Allbright** |
| Southern Research Institute | **Project completed resulting in first generation cofiring combustion model based on pilot-scale tests** |
| University of Pittsburgh (2) | **Stoker tests were completed at two sites. Finding an economical supply of wood and particulate emissions in an urban environment turned out to be problems** |
| Nexant LLC | **Completed chicken liter indirect cofiring feasibility studies for two utilities. While technically feasible, costs were found too high to proceed into demonstrations** |
| * Only AES project is still active | |

# Status - FY2000 Awards

| | |
|---|---|
| Gas Technology Institute | **The study to determine the feasibility of cofiring biomass-based gasification fuel gas in a small utility boiler was completed. Owners seeking financing.** |
| Univ. of North Dakota EERC (2) | **Lab testing was used to generate data to enable economic and technical assessment of biomass/low rank coal cofiring in municipal-sized stokers.**<br>**No significant problems were found and financing for one unit is being sought.** |
| Penn State Univ. | **DOE sponsored lab studies of locally available crop residues, sawdust and animal wastes have formed the basis for the FBC design now being considered by the university** |

# Status - FY2000 Awards

| | |
|---|---|
| Texas A&M | **Lab. combustion and gasification tests were conducted using liter- or primarily feedlot manure-coal blends in order to develop data on NOx emissions and ash fouling. Reburning produce disproportionately large NOx reductions while ash behavior was manageable** |
| Iowa State | **Advanced biomass reburning study was concluded noting no significant reductions above the baseline.** |

# Projects Managed by DOE Golden Office

- Chariton Valley Project: cofiring switchgrass in southern Iowa
  - Testing in progress
- Salix Consortium: growing and cofiring willow
- Southern Company, SRI, Auburn U: cofiring switchgrass at Gadsden Station
  - Cofiring routinely
- Closed-loop biomass co-firing at Hawaiian Commercial & Sugar Co: cofiring a closed-loop biomass - fiber cane

# TECO Polk Station IGCC

## FY01 Cooperative Agreement

- Demonstration of closed loop biomass in 220 MW IGCC using a high pressure Texaco gasifier
- 55% petcoke, 44% coal and 1% biomass test blend.
- 8.8 tons of coarsely ground eucalyptus used for the 8.5 hr test burn
- Ground eucalyptus was blended with the normal coal and petcoke mixture to form slurry that was fed to the gasifier.
- Emissions from Unit 1 did not increase and no other major technical impediments were found
- Permitting problems prevent future cofiring in this unit

# Open Issues

- Impact of ash on slagging, fouling, and SCR catalysts for herbaceous biomass
  - Further study possibly needed.
  - Impact is different for different biomass at different types of boilers with different coals (note that wood biomass has little impact, while herbaceous biomass may have problems with alkali).
- Fly ash application
  - Effect on ash used for cement additive needs to be examined.
  - ASTM needs to take action to address applicability.
- Animal waste
  - Need further study because of large quantity and significant environmental benefits.

# Chariton Valley Biomass Project

- Project Start / End Dates: **1996 / 2006**
- Project Description:
  - Biomass Power for Rural Development Project
  - Switchgrass growth, harvesting, storage, and cofiring with coal
  - Feedstock development is major project component
  - Host plant is Alliant Energy's 726 MW Ottumwa Generating Station in southern Iowa
  - T-fired PC boiler firing Powder River Basin coal
  - Key technical issues include air permitting, ash acceptance, and long-term boiler impacts





# CV Biomass Project (cont.)

| Project Goals | Project Results |
|---|---|
| **Prove technical feasibility of switchgrass cofiring at an operating power plant** | **Short-term test burns have been successful; Long-term test is needed** |
| **Establish switchgrass fields** | **4,000 acres of switchgrass under management** |
| **Improve crop yields** | **Yields have improved from < 2 tons/acre to > 4 tons/acre (single fields as high as 10 tons/acre)** |
| **Research on environmental impacts** | **Carbon sequestration, soil erosion, air emission, and habitat benefits documented** |
| **Develop & demonstrate supply network (harvest, transport, storage)** | **New harvester developed & demonstrated; critical parts of supply network demonstrated** |
| **Document economics and identify critical paths to project success** | **Economic analysis performed for all aspects of project; received positive feedback from independent expert peer review panel** |
| **Install biomass system capable of operating on a commercial basis** | **Final system design completed (based on Danish plant); Next step is under consideration** |

# C V Biomass Project (cont.)

Project Status:

- In pre-commercial testing phase
- Recently completed 1-month test burn
  - Very positive emissions results obtained
  - Ash samples collected for testing—state approval expected based on preliminary results
  - Minimal impact on plant performance / efficiency
- Next step is long-term test burn (2000 hr)

# Salix Consortium:

## Growing and Cofiring Willow

- Project period (Phase I & II): February 1, 1996 to January 31, 2004

- Project task list/goals:
  - Task 1 – Feedstock Production and Infrastructure: acreage scale-up to 500 acres and nursery production
  - Task 2 – Power Plant Conversion and Testing: Dunkirk plant retrofits and cofiring emissions testing
  - Task 3 – System Optimization and Experimental Studies: crop R&D, environmental studies, and operation improvements
  - Task 4 – Enterprise Development: business development and outreach

# Salix Consortium

***Fields of Willow Energy Crops***

- Project activities and results
  - Positive benefits documented for avian habitat
  - Breeding program resulted in a 20% increase in yields
  - Dunkirk fuel processing system delivers up to 14 MW
  - Emission test results prove $NO_X$ and $SO_2$ reductions
  - Approximately 360 acres commercially ready
  - Green Power Market activity: Cofiring inclusion effort in E.O. 111 and RPS, competitively priced WillowWatts product with two institutional buyers and several marketers interested
  - Consortium working with landowners to layout details of long-term willow production contracts
  - Consortium working with NRG on contract for tolling electric conversion services

- Project cost summary (includes retrofit and systems & emissions testing
  - DOE: $3.95 Million
  - Cost-Share: 50/50

- Project status
  - Currently seeking regulatory approval for commercial operation
  - Target date for operation – Q3 2004

# Salix updated status

- The cost of the Dunkirk Cofiring installation was $3.95 Million. Other costs associated with the cofiring portion of the project include the week long environmental testing program and somewhat unique efforts associated with the development of DEC and Attorney General's understanding of the benefits of the biomass project to secure permits. Cost share on the project was 50/50. NRG is currently estimating what upgrades it must make to go fully commercial (final controls integration, some improvements to truck access, etc) but that will all be at NRG expense (or additional cost share from the DOE

# Development of a BioReburn System

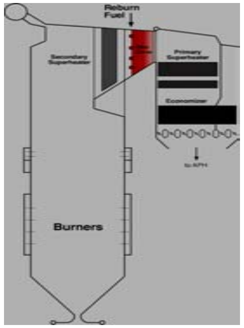
- Project period: October 1, 2001 to June 30, 2002

*Sutton Station*

- Project task list / goals
  - Fuel supply assessment
  - Gasifier and ReBurn design and integration
  - First order economic evaluation
  - Design tradeoff analysis
  - System testing and development plan

# Sutton Station

- Project activities and results
  - Identified ~800k tpy of biomass resources
  - ~ 10,000 tons/month under $1.50/MMBtu
  - NOx reductions on the order of 70% expected
  - Economic analysis indicated BioReburn technology would require both NOx credits and green power incentives
- Project costs
  - DOE funding: $275,000
  - PGN cost-share: 25%
  - Follow-on work funded by PGN
- Project status
  - BioReburn / gasifier integration option on hold
  - Results of initial study led encouraged PGN to pursue simple cofiring integration as a first step
  - Blended biomass cofiring systems tests at Sutton's Unit 1 planned for May 2004
  - They examined gasification as NOx control strategy, decided to examine biomass burning (cofiring) as initial strategy.




***Reburn & Gasifier System***