Gasification
Combined Heat and Power
From Coal Fines

DE-FE0031520

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University of Kentucky, Center for Applied Energy Research

http://www.caer.uky.edu/powergen/home.shtml

Power Generation and Utility Fuels Group

Using Fossil Resources to Produce Clean Electricity

Post-Combustion CO_2 Capture	Solvent Development	Chemical Looping	Water Treatment	Corrosion	Modular Coal Conversion & Gasification
Process Integration and Scale-Up	Process Controls	Electro-chemistry	Membrane Separations	Analytical Methods Development	Combined Heat and Power

- About 35 researchers (engineers, scientists, technicians and students)
- 10-18 peer reviewed publications, annually
- 5-7 invention disclosures, annually
- 5-10 project proposal submitted, annually

Outline

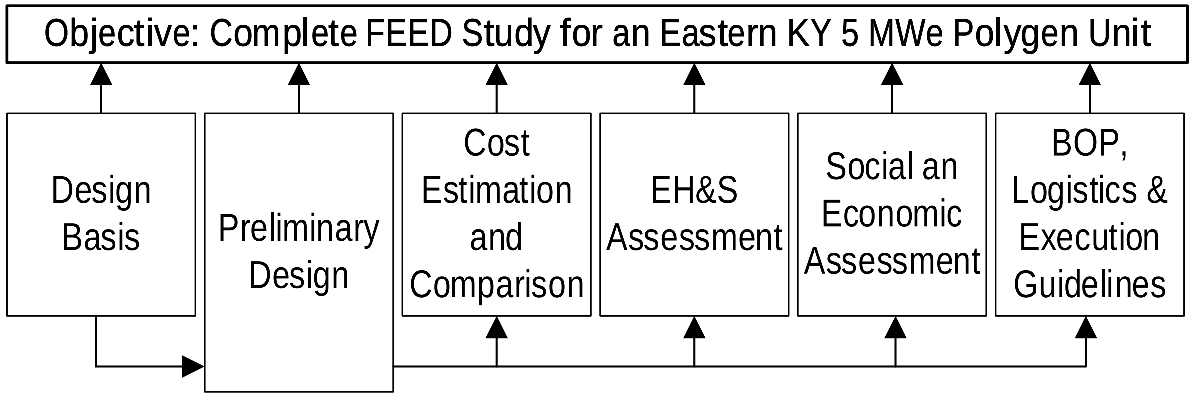
1. Project Background and Purpose
2. UKy-CAER Coal-based Polygeneraton Philosophy
3. Market and Economic Benefits
4. Alignment with Fossil Energy Objectives
5. Project Status
6. Technical Challenges, Next Steps and Outside Interest

Take Away

1. Small Scale Polygeneration is Applicable to Remote Areas like Appalachia, Economically and Environmentally
2. UKy-CAER Polygeneration Philosophy Supports the REMS Initiative through Standardization, Modularization, Fuel Flexibility and Simplification
3. Remote Polygeneration is of Interest to Local Governments and OEMs

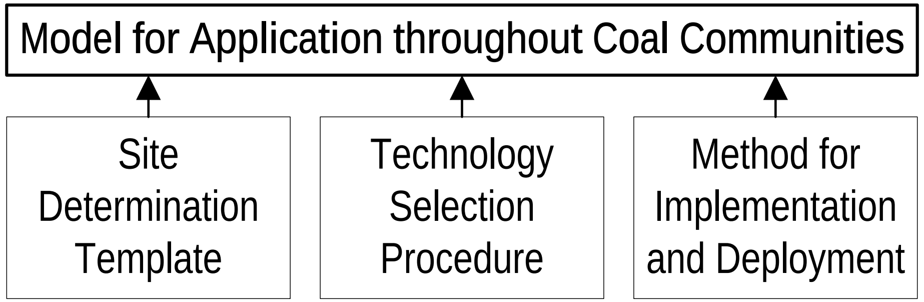
Project Purpose

- Complete a FEED study for a 5 MWe equivalent polygenerating unit to be located at an industrial park in Hazard, Eastern KY utilizing nearby waste coal fines as the feed
- Identify appropriate main components (technology selection and operating conditions)
- Components included in FEED study

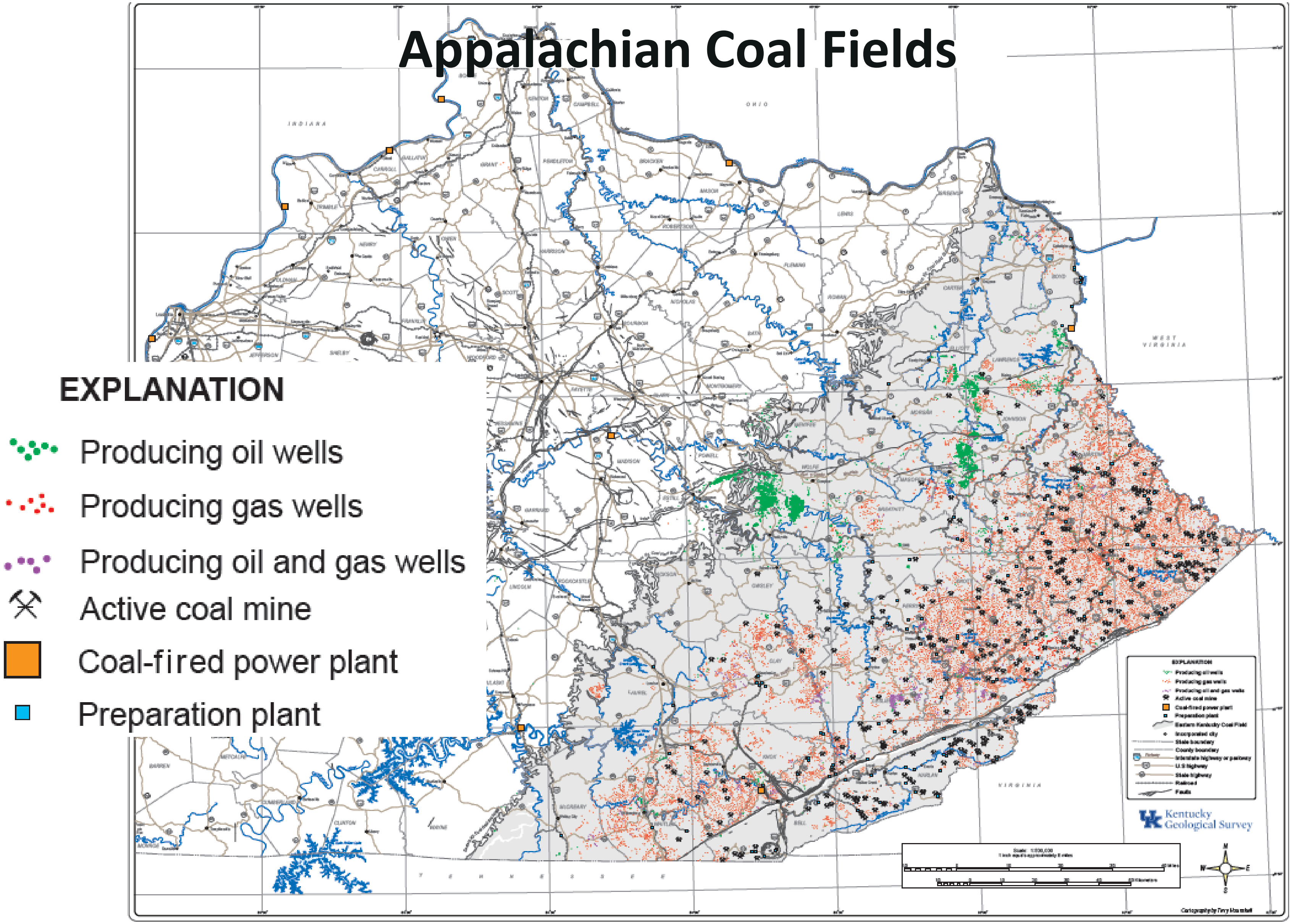


Project Goals

- Utilize local waste: refuse coal fines
- Develop a model for widespread application
- Develop cross-industry synergy in a rural, remote area
- Model for future economic development in depressed regions



Background


Appalachian Coal Fields
EXPLANATION
Producing oil wells
Producing gas wells
Producing oil and gas wells
Active coal mine
Coal-fired power plant
Preparation plant

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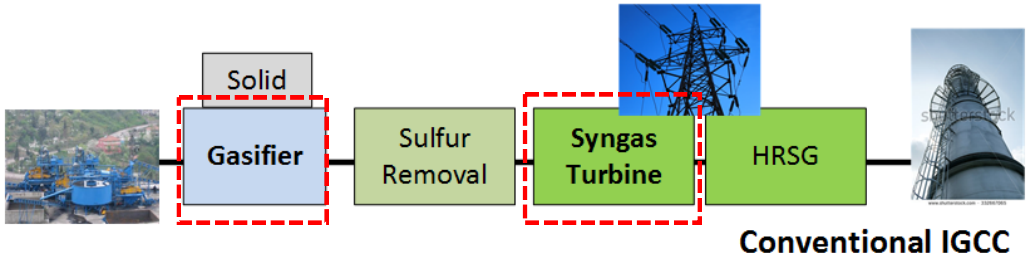
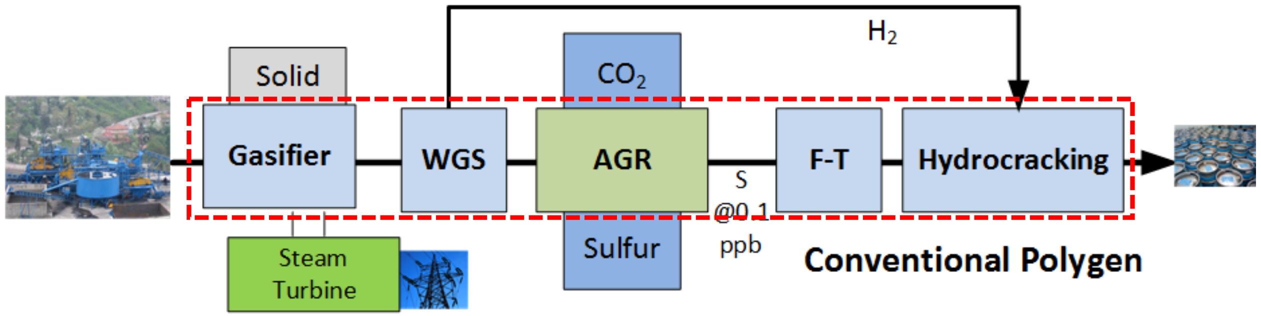
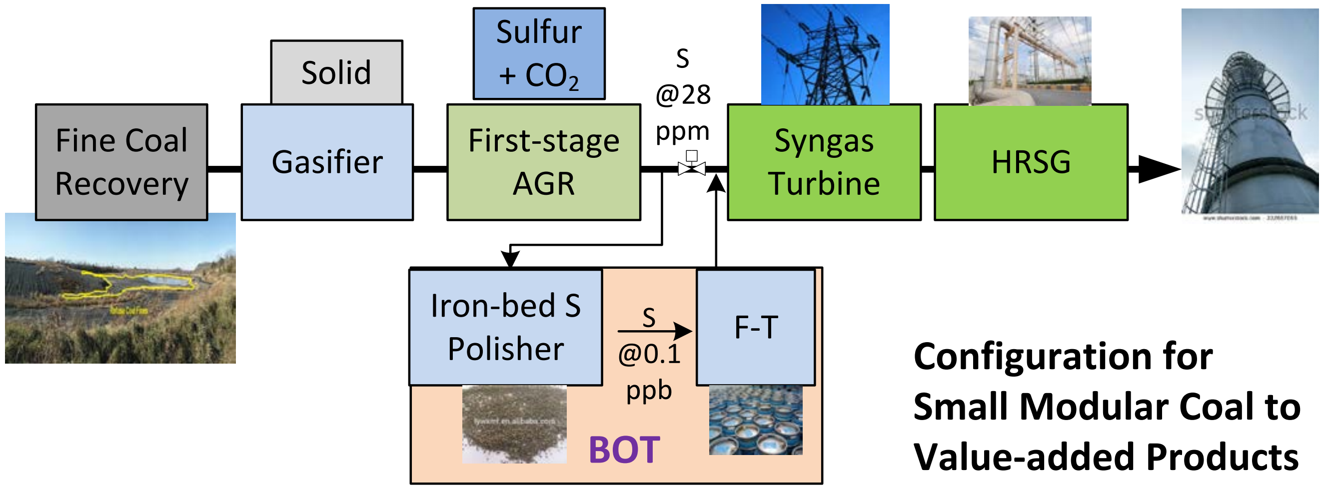
UKy-CAER Coal-based Polygeneration





Cost-prohibitive for Customization

Standardization + Modularization + Fuel Flexibility + Simplification = Distributed Power Success



Configuration for Small Modular Coal to Value-added Products

UKy-CAER Coal-based Polygeneration

Local heat and power generation with modular coal gasification and optional F-T synthesis
Three useful products: power, heat and liquid hydrocarbons

- Use a commercially available ASU ~2400 Nm^3/hr O_2 consumption

- Design the burner based on O_2 available
- Outside chamber and burner sized fixed
- Size inside chamber tubes to accommodate different kinds of coal

- Design power generation unit based on coal with lower heating value

- Excess syngas will go to F-T unit

- For power generation, meet EPA requirements, remove H_2S, minimal CO_2 and minimize AGR size

- Second stage H_2S removal bed before the F-T unit

Project Partnerships

Center for Applied Energy Research

Beijing Baoju Energy
Science & Technology Co. Ltd

TRIMERIC CORPORATION

SMG

Gay Brothers Lumber
Fourth Generation Lumber Company

Arq

BLACKHAWK MINING, LLC

Coal Fields Regional Industrial Authority

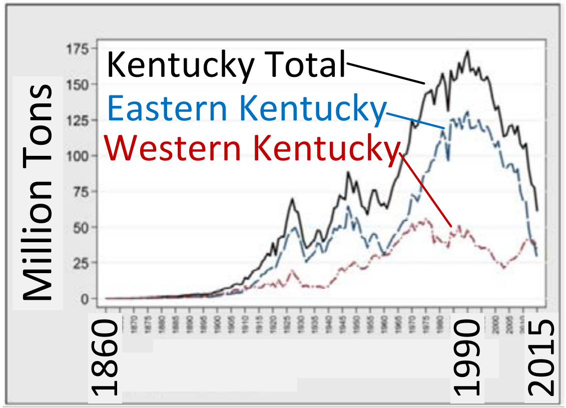
Market Benefits

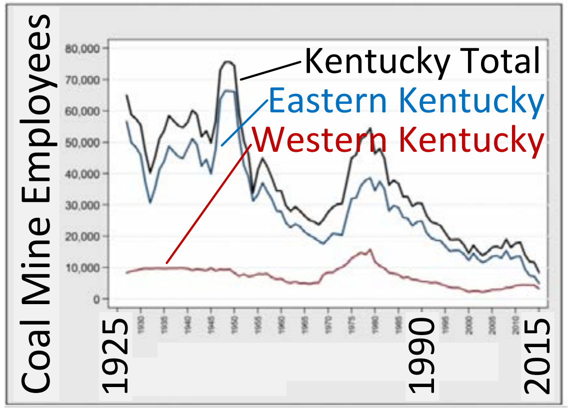
Eastern, KY is a remote, coal dependent area.

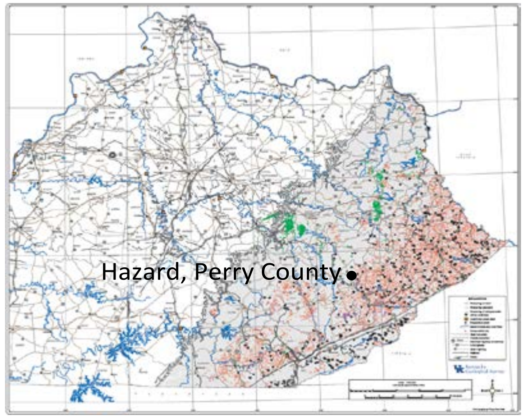
Perry County, KY Coal Preparation Plants				
Company	Plant	Nearest Town	Capacity (tph)	Fine Coal Recovery Circuit
Whitaker/Perry Co/ICG	#4 Plant	Hazard	750/950	HM Cyclone, Spirals
KEM/Pads Branch	Plant #25	Hazard	400	HM Cyclone, Spirals
Blue Diamond/ Blackhawk	Leatherwood	Leatherwood	800/1600	Concentrating Tables, Spirals, HM Cyclones
Lost Mountain	Harris Branch	Bulan	900	HM Cyclone
Kodak	Chester	Allock	350	Hydrocyclone
River Processing	Dunraven	Dunraven	350	Concentrating Tables, Hydrocyclone
Sunfire	#2 Plant	Combs	175	None
River Coal	Indian Head	Ned	180	None
Tesora	Wahoo	Bonneyman	420	None

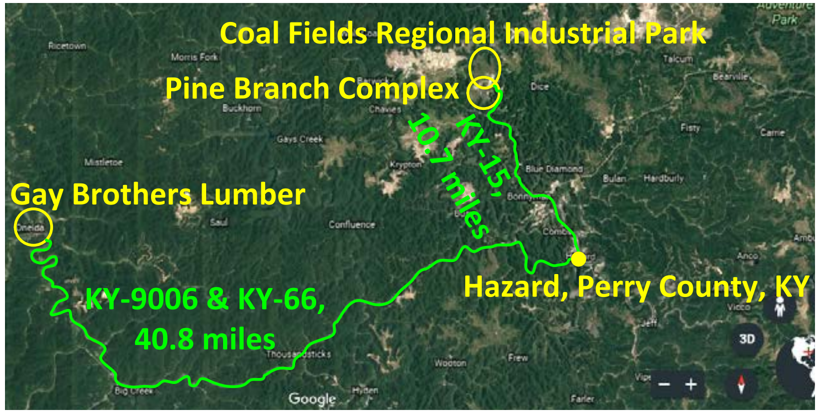
Economic Benefits

- Suffering from poor economy and job loss
- Local polygeneration units will
  - Encourage industry location in industrial parks
  - Provide jobs
  - Provide secondary environmental benefit of recovering coal fines and capping impoundments
- Use local sites in Perry County as representative of sites throughout Eastern, KY and Appalachia









Project Alignment to Fossil Energy Objectives

- 5 MWe energy conversion technology
- Will produce power, heat and liquid hydrocarbons at relatively small scale
- Economically compared to large scale state-of–the art technology
- Technology can be scaled up by modular expansion
- Modules to be pre-fabricated and deployed in remote areas, while maintaining advantages in cost and flexibility
- Supports Radically Engineered Modular Systems (REMS) Initiative

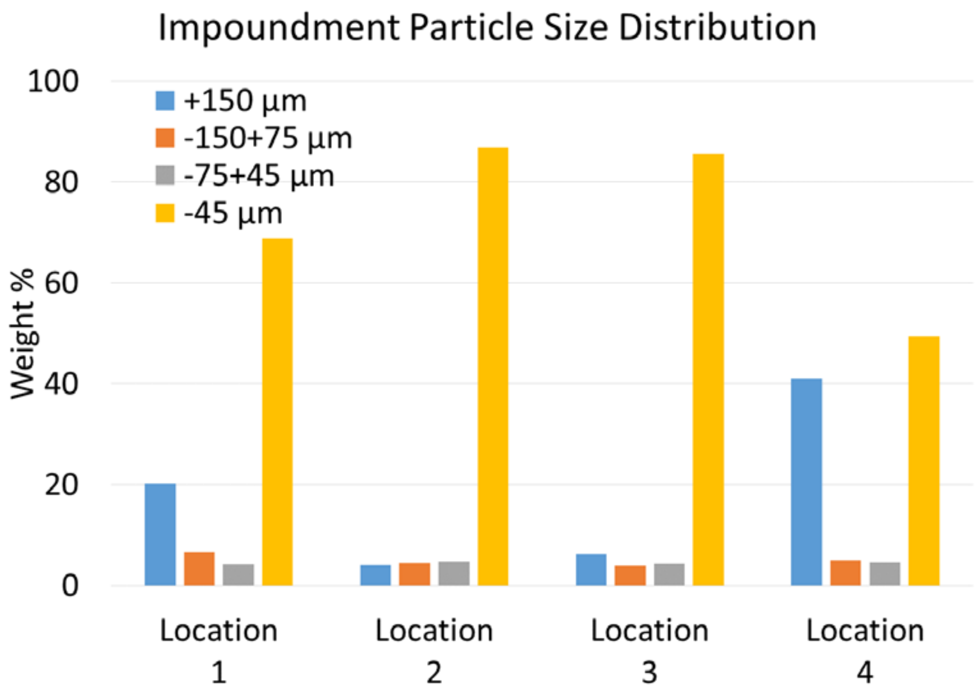
Technology to Market Path

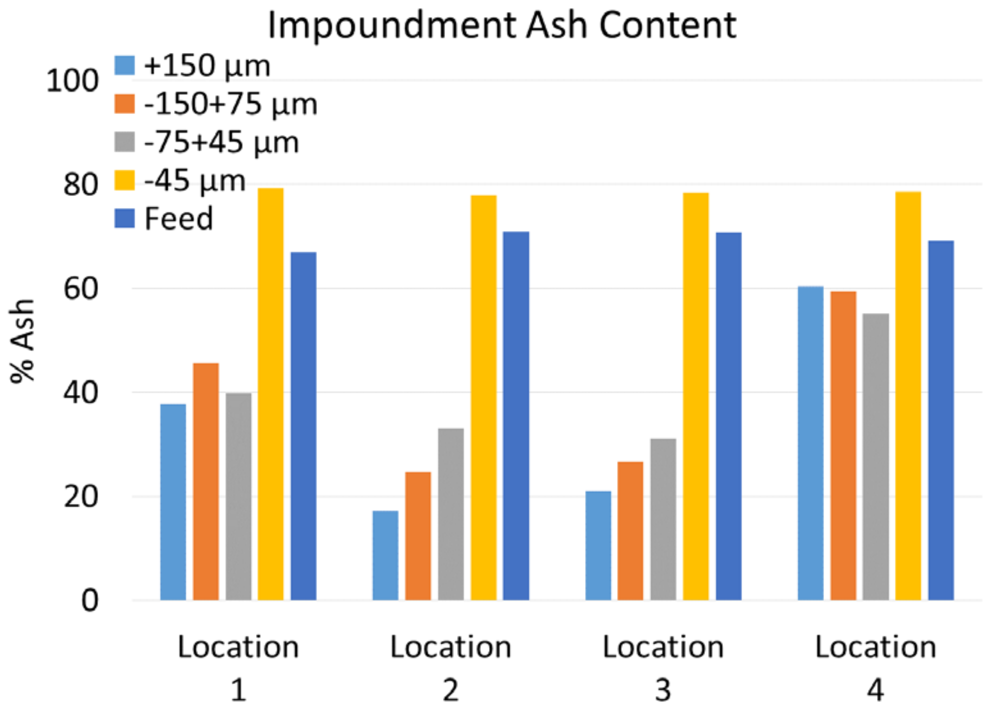
- Establish future partnership with General Electric Power, who expressed interest in a microgrid demonstration
- Establish build, operate and transfer (BOT) relationship for the F-T part of this application

Project Status

Impoundment Survey

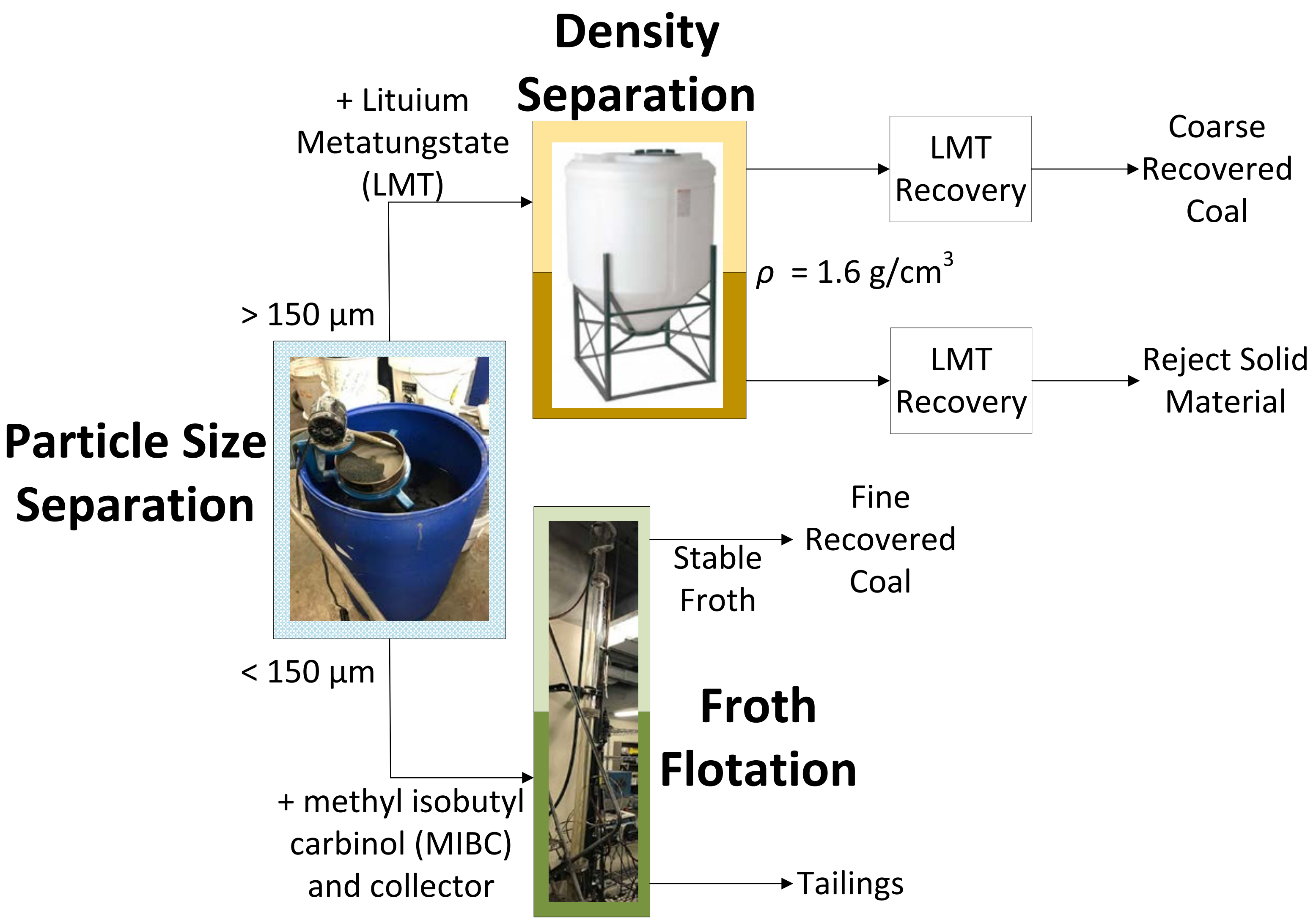
	Moisture (wt%)	VM (wt%)	FC (wt%)	Ash (wt%)	C (wt%)	H (wt%)	N (wt%)	O (wt%)	S (wt%)	GCV (Btu/lb)
Impoundment 1	2.07	14.5	14.36	69.06	22.44	2.16	0.31	5.47	0.56	1483
Impoundment 2	1.85	13.37	14.83	69.95	22.29	2.08	0.31	4.93	0.44	563
Impoundment 3	1.58	15.22	15.89	67.31	23.49	2.14	0.38	5.87	0.81	2294
Impoundment 4	1.86	16.7	16.66	64.79	25.45	2.27	0.35	6.63	0.52	1862





Project Status

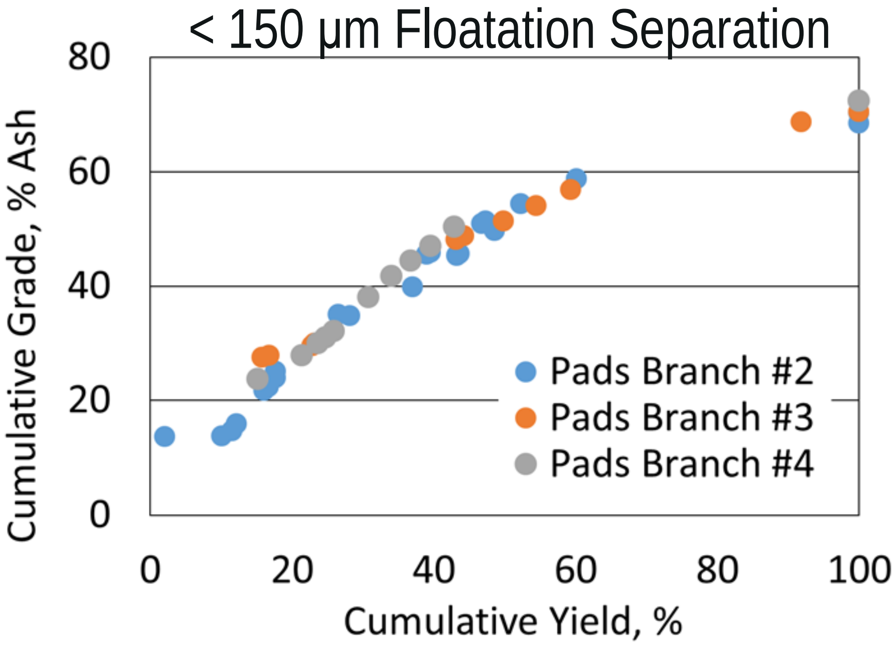
Coal Recovery

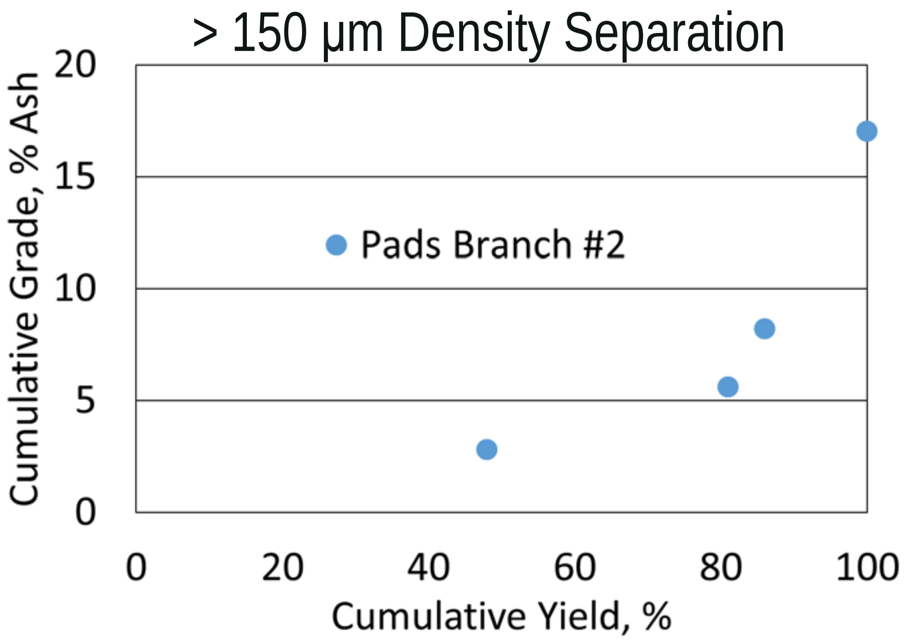


Project Status

Recoverable Coal

Target feed slurry of < 15% ash





Proximate, Ultimate and Heating Value Analysis Results from the Recovered Coal Product (Dry Basis)

	VM (wt%)	FC (wt%)	Ash (wt%)	C (wt%)	H (wt%)	N (wt%)	O (wt%)	S (wt%)	GCV (Btu/lb)
Fuel for Proposed CHP	27.8-29.8	56.9-61.2	11.0-13.3	69.4-75.3	4.3-4.6	1.3-1.4	7.2-10.0	0.8-0.9	12,500-13,000

Project Status

Coal-Water Slurry

Design Basis CWS	
Property	Value
Coal Concentration (wt%, Air Dried)	56
Dispersant Concentration (wt%)	0.5
Bulk Density (g/mL)	1.15
Apparent Viscosity (cP)	365
Flowability	A
Stability	A

Coal-Biomass-Water Slurry

Sawdust had to be dried, shredded and re-saturated with water

Particles < 250 um were used

50.3 wt% (dry basis) Recovered Coal

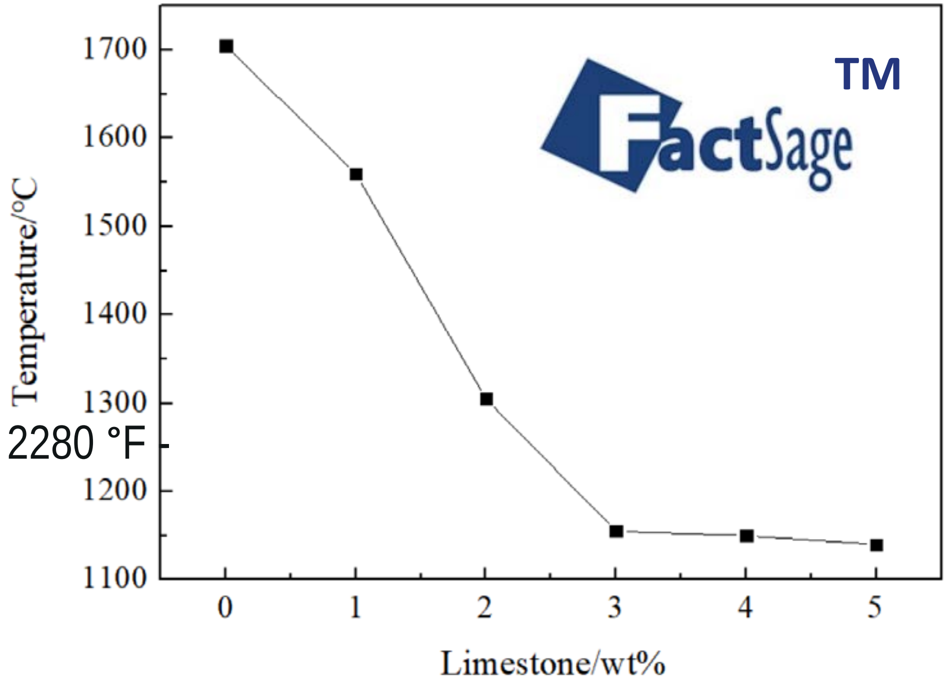
0.6 wt% (dry basis) Sawdust

0.5 wt% Surfactant

Project Status

Ash Analysis

Proposed CHP Gasification Unit Design Basis Design Basis Coal Feedstock AFTs	
Reducing Environment, Bulk Impoundment Material Ash Fusibility Temperatures	°F
Initial Deformation Temperature	2478
Softening Temperature	2701
Hemispherical Temperature	2716
Flow Temperature	2737



Options to tuning the ash flow T to ~2280 °F

- Blending with another type of coal
- Addition of ~2 wt% (dry basis) $CaCO_3$

Project Status

Leachate Analysis

RCRA Regulated Elements in Feed Coal Ash, Feed Coal Ash Leachate and Gasification Slag Leachate						
RCRA Regulated Element	As	Se	Ag	Cd	Pb	Ba
Solid Hazardous Material Limit by TCLP (ppm)	5	1	5	1	5	100
Expected Pads Branch Recovered Coal Product Slag Leachate Concentrations (ppm)	0.001	0.017	7E-05	0.007	0.016	0.131

Project Status

Initial EH&S Assessment

The following Regulations need to be considered:

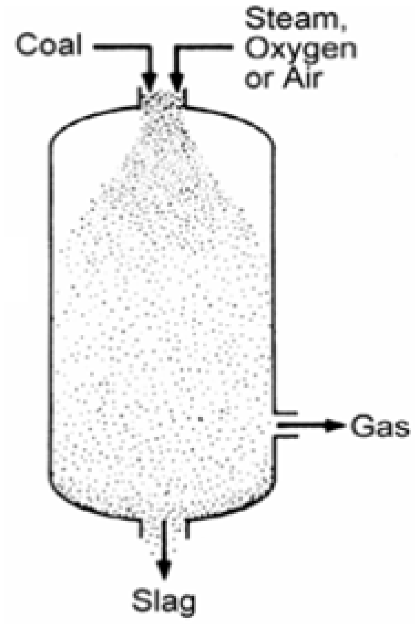
1. Clean Air Act (CAA) Potential Requirements
2. Clean Water Act (CWA) Potential Requirements
3. Comprehensive Environmental Responses, Compensation and Liability Act (CERCLA) Potential Requirements
4. Mine Safety and Health Act (MSHA) Requirements
5. Occupational Safety and Health Act (OSHA) Requirements
6. Resource, Conservation and Recovery Act (RCRA) Waste Management Potential Requirements
7. Surface Mine Control and Reclamation Act (SMCRA) Requirements
8. Toxic Substances Control Act (TSCA) Potential Requirements
9. National Environmental Policy Act (NEPA) Potential Requirements
10. Kentucky Public Service Commission (PSC) Transmission Siting Board Potential Requirements
11. Regional Transmission Organization (RTO) Potential Requirements
12. Federal Aviation Administration (FAA) Potential Requirements

Project Status

Technology and Major Component Selection

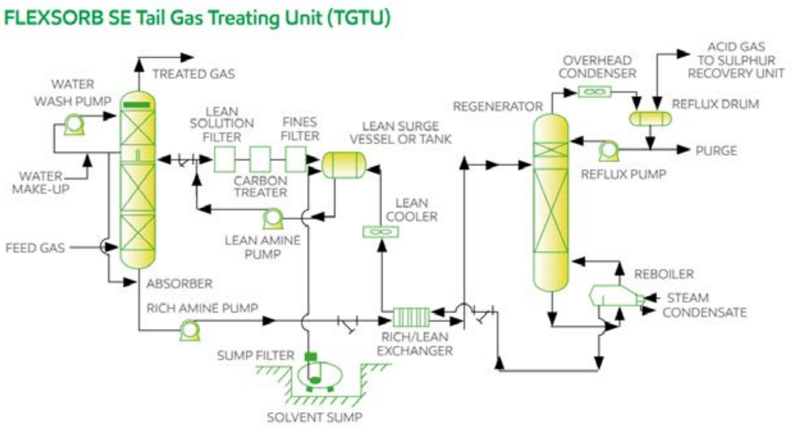
Entrained Flow Gasifier

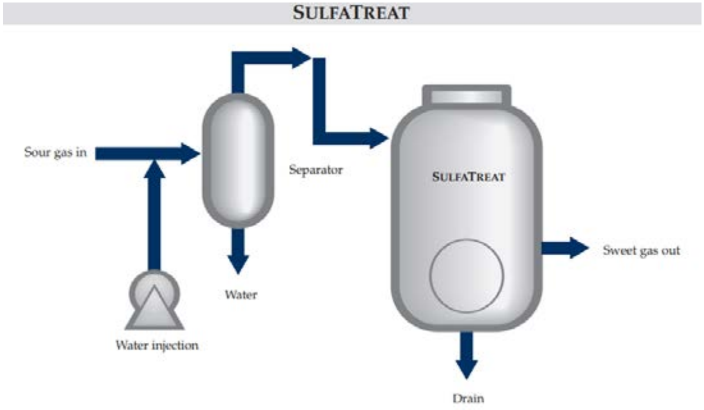
- Maximum fuel and operation flexibility



Aqueous amine (MDEA) to concentrate the acid gas stream followed by a solid scavenger (Schlumberger's Sulfa Treat Technology)

- Using just a solid sorbent at the gasifier outlet has a very high cost because the saturation point is low
- Merichem's LO-CAT® liquid redox technology may be a more economical process option, but increases process complexity and ExxonMobil's Flexsorb™ may be a potential alternative to MDEA





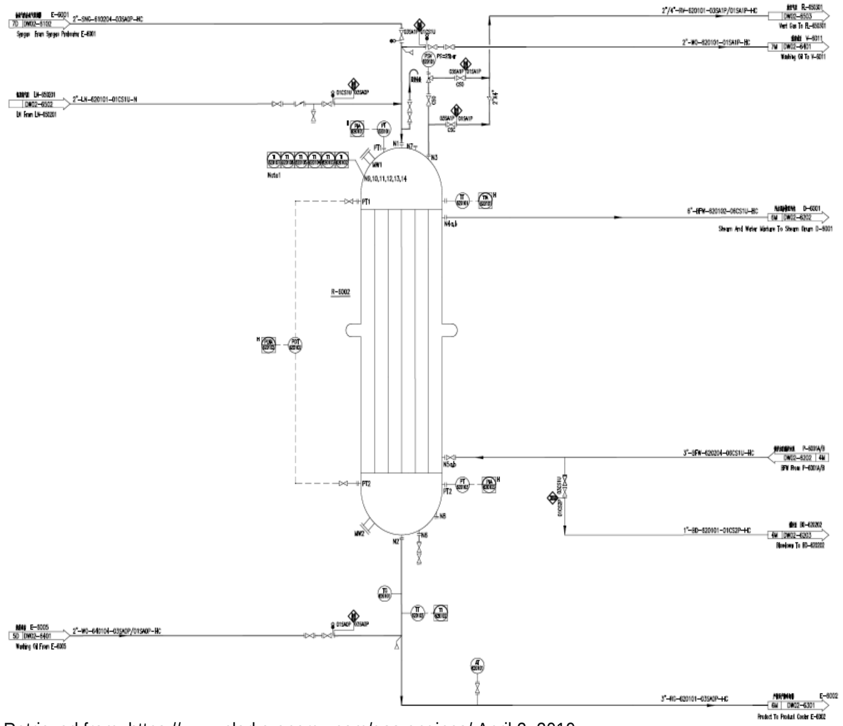
ExxonMobil. Retrieved from https://www.exxonmobilchemical.com/sitecore/content/ExxonMobil%20Chemicals/Chemicals/Global/Website/library/Asset/2017/07/21/07/33/76C1A4D31BC746DABFA394F010E5B680. February 15, 2019.
Schlumberger. Retrieved from http://www.vaportech. com/files/comm_id_13/products/sulfatreat__product_bulletin.pdf. February 15, 2019.

Project Status

Technology and Major Component Selection

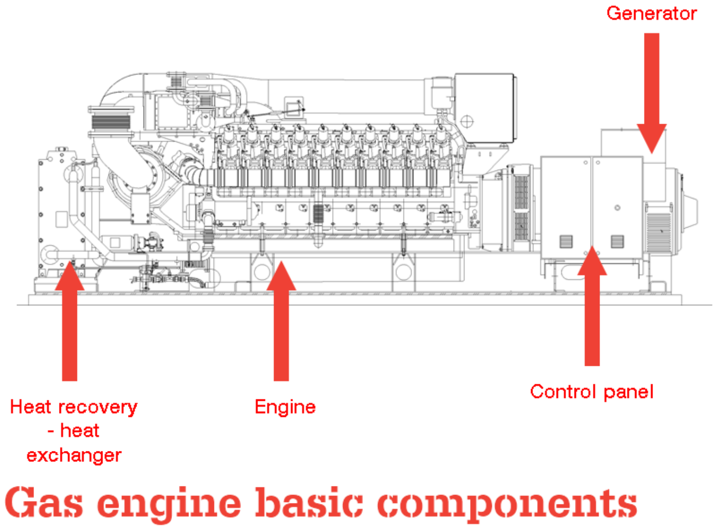
Once-Through at 60% F-T

- Recirculation is complicated
- Fe catalyst does not require WGS



Reciprocating Internal Combustion Engines for Power Generation

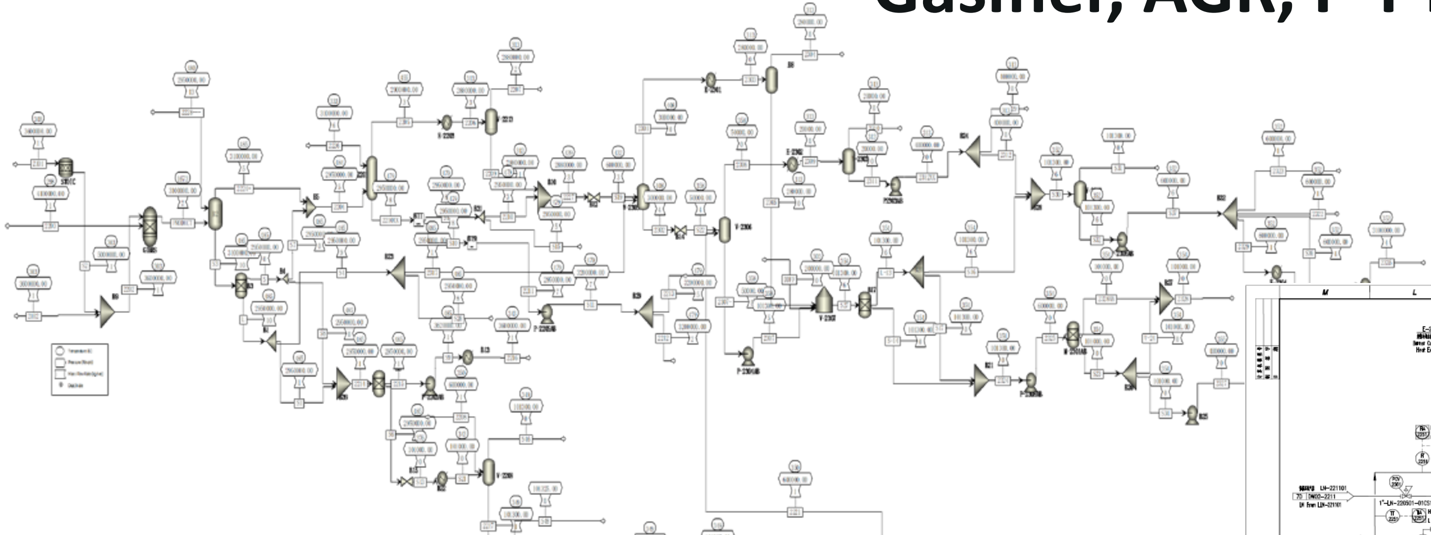
- GE Jenbacher engines
- Likely three engines required

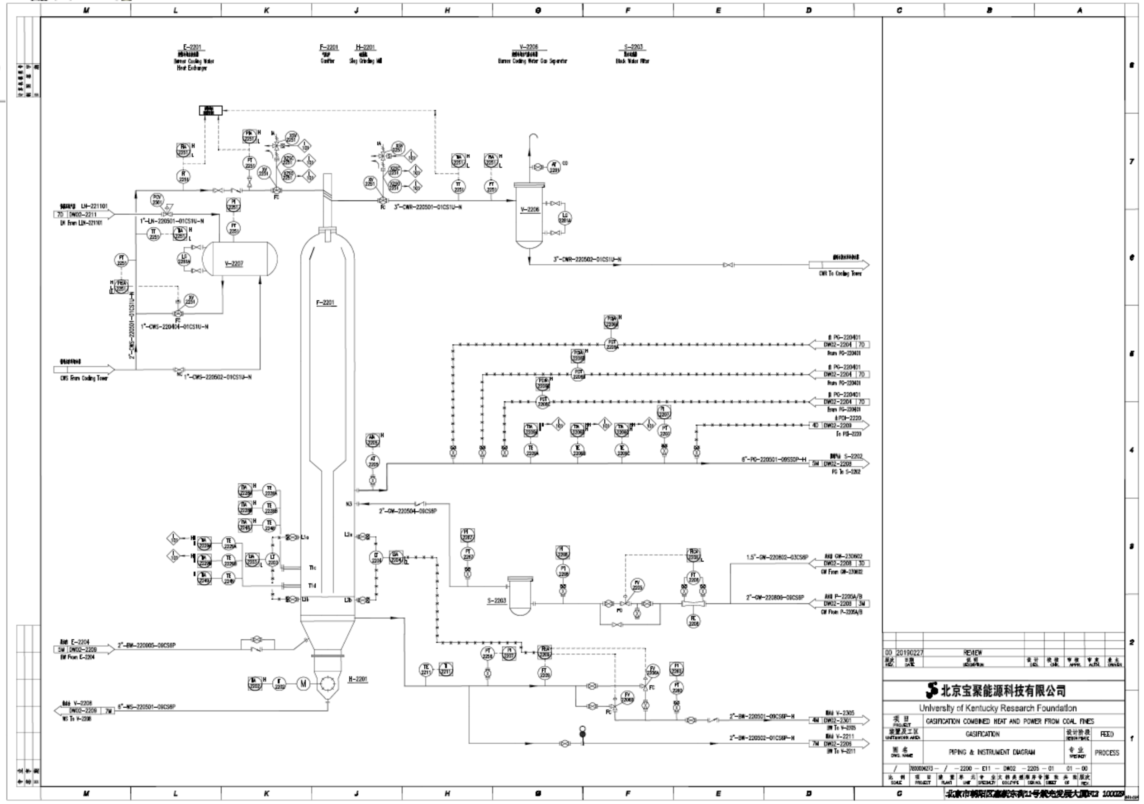


Clarke-energy. Retrieved from: https://www.clarke-energy.com/gas-engines/ April 2, 2019.

Project Status

Gasifier, AGR, F-T FEED





- Aspen Plus and HYSYS® models complete with H&MB stream tables
- Process Design Package is complete including PFD and P&ID sets
- Technologies selected for gasifier and F-T systems
- Utilities and waste streams estimated

Project Status

Major Equipment and Power Consumption

Reactors, Heat Exchangers, Columns, Vessels, Tanks, Pumps, Agitators, Filters, Mixers, Separators and a Mill
Medium, Operating Conditions, Design Conditions, Size, Weight, Material of Construction and Recommended Spares

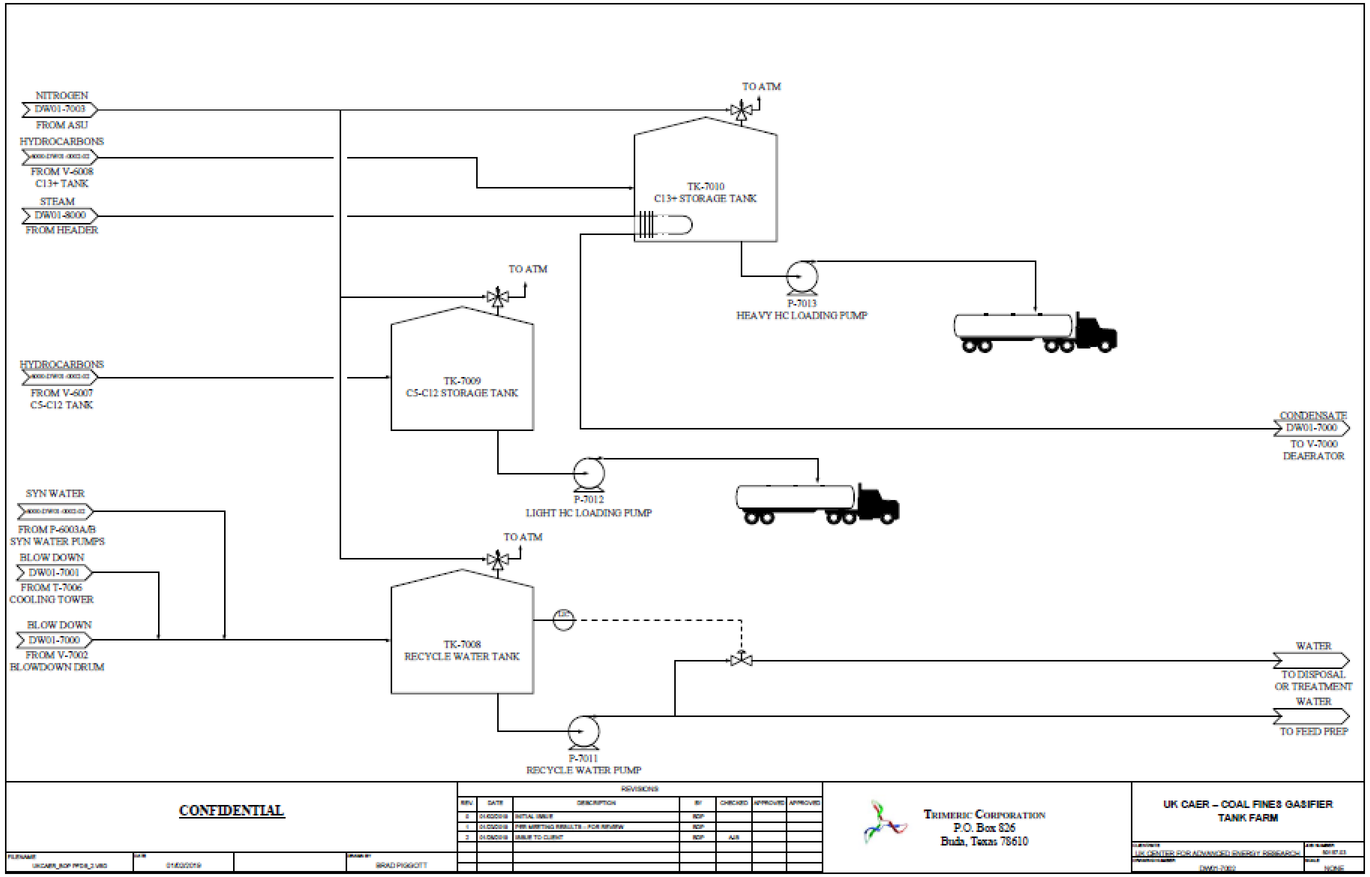
HEAT EXCHANGERS														
NO.	TAG NO.	NAME	MEDIUM	OPERATING CONDITION		DESIGN CONDITION		SIZE		HEAT LOADING (KW)	HEAT TRANSFER AREA (m2)	MATERIAL	METAL WEIGHT	
				TEMPRATURE (IN/OUT) ( )	PRESSURE (MPaG)	TEMPERATURE ( )	PRESSURE (MPaG)	DIAMETER (mm)	LENGTH/HEIGHT (mm)				WEIGHT (TOTAL)	ALLOY WEIGHT
1	E-2201	Burner cooling water heat exchanger	Shell：CWS/CWR	25/35	1.5	60	2	450	Shell: 5370	134	38	CS	2000	
			Tube：cooling water	45/35	0.4	80	0.7		Tube: 4500			304		700
2	E-2204	Lock hopper circulating water cooler	Shell：CWS/CWR	25/35	0.4	60	0.7	325	5220	360	10	CS	910	
			Tube：black water	150/70	3.52	200	4.5		Tube: 4500			304		210
3	E-2203	Raw Gas Cooler	Shell：Raw gas	182/40	2.8	310	3.5	650	7300	2770	96	CS	5130	
			Tube：CWS/CWR	25/35	0.4	80	0.7		Tube: 4500			304		1820
4	E-2301	HP flash gas cooler	Shell：CWS/CWR	25/35	0.4	80	0.7	650	5660	3540	90	CS	4360	
			Tube：Flash gas	135/40	0.2	170	0.5		Tube: 4500			304		1640
6	E-2304	Waste water cooler	Shell：CWS/CWR	25/35	0.4	80	0.7	400	5290	181.9	33	CS	1990	
			Tube：Waste water	61/40	0.5	80	0.7		Tube: 4500			304		680
7	E-2302	Vacuum Cooler	Shell：CWS/CWR	25/35	0.4	80	0.7	700	5700	2150	109	CS	5120	
			Tube：Flash Gas	85/40	-0.05	120	-0.1/0.4		Tube: 4500			304		1980

TOWERS														
NO.	TAG NO.	NAME	MEDIUM	OPERATING CONDITION		DESIGN CONDITION		SIZE		CAPACITY (m3)	MATERIAL	TOTAL METAL		MATERIAL
				℃ TEMPERATURE ( )	PRESSURE (MPaG)	℃ TEMPERATURE ( )	PRESSURE (MPaG)	DIAMETER (mm)	T-T (mm)			WEIGHT(TOTAL)	ALLOY WEIGHT	
1	T-2201	Water Scrubber	Raw gas / Black Water Raw Syngas	210	2.8	280	4	1200	4200	4.8	13MnNiMoR+316L(4mm)	3400	1000	

Project Status

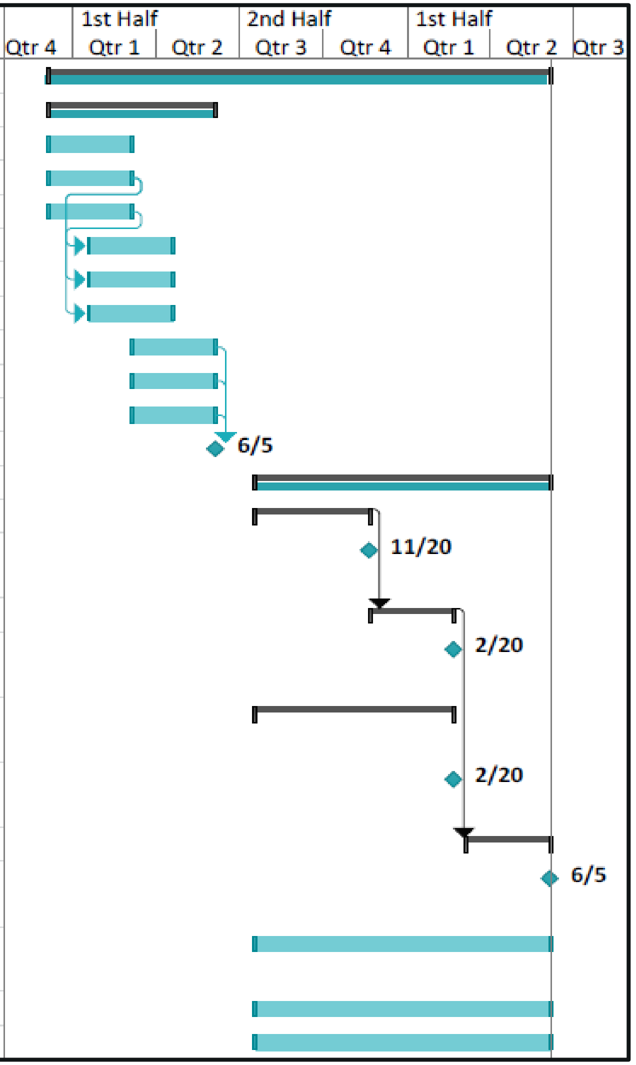
BOP Systems

- PFD set complete
- Technologies selected for sulfur removal and power generation systems
- Steam system analysis complete



Project Status

Task Name	Start	Finish
1 Project Management and Planning	Wed 12/6/17	Wed 6/5/19
2 Project Design Basis	Wed 12/6/17	Tue 6/5/18
2.1 Host Site Visit	Wed 12/6/17	Mon 3/5/18
2.2 Coal Fines Impoundment Site(s) Visit	Wed 12/6/17	Mon 3/5/18
2.3 Biomass Site Visit	Wed 12/6/17	Mon 3/5/18
2.4 Project Management and Planning	Thu 1/18/18	Thu 4/19/18
2.5 Coal Feedstock Characterization	Thu 1/18/18	Thu 4/19/18
2.6 Biomass Feedstock Characterization	Thu 1/18/18	Thu 4/19/18
2.7 Slurry Prep and Characterization	Tue 3/6/18	Tue 6/5/18
2.8 Fuel Mix Optimization	Tue 3/6/18	Tue 6/5/18
2.9 Coal and Biomass Ashing and Leach Testin	Tue 3/6/18	Tue 6/5/18
2.10 Milestone: Project Design Basis Complete	Tue 6/5/18	Tue 6/5/18
3 Basic Engineering Design Elements	Thu 7/19/18	Wed 6/5/19
3.1 Process Engineering	Thu 7/19/18	Tue 11/20/18
3.1.1 Milestone: Polygeneration Process Basic Engineering Design Complete	*Tue 11/20/18*	*Tue 11/20/18*
3.2 Technology Cost and Schedule Estimate	Wed 11/21/18	Wed 2/20/19
3.2.1 Milestone: Polygeneration Process Cost Estimation Complete	*Wed 2/20/19*	*Wed 2/20/19*
3.3 Initial Environmental, Health and Safety (EH&S) Assessment	Thu 7/19/18	Wed 2/20/19
3.3.1 Milestone: Polygeneration Process EH&S Assessment Complete	*Wed 2/20/19*	*Wed 2/20/19*
3.4 Social and Economic Impact Assessment	Wed 3/6/19	Wed 6/5/19
3.4.1 Milestone: Polygeneration Process Social and Economic Impact Assessment Complete	*Wed 6/5/19*	*Wed 6/5/19*
3.5 Technology Execution and Management Guidelines and Procedures	Thu 7/19/18	Wed 6/5/19
3.6 Logistical Summary	Thu 7/19/18	Wed 6/5/19
3.7 Balance of Plant Requirements	Thu 7/19/18	Wed 6/5/19



Project Success Criteria	
Date	Success Criteria
6/5/18	Acceptable feed slurry demonstrated for design basis.
6/30/19	Completed preliminary design package for polygeneration unit to be located in Eastern KY.
6/30/19	Demonstration that the polygeneration unit can be modularized.
9/30/19	Demonstration of economically viable option of CHP with small scale, locally installed polygeneration units throughout Eastern KY.

Results Apply to Strategic Goals

1. Supports Radically Engineered Modular Systems (REMS) Initiative
2. Site Determination Template
   Economic, environmental and social assessments
   Proximity to and logistics of recovering waste coal fines
   Local energy demands
3. Technology Selection Procedure for Niche Applications
   - Gasification, acid gas cleanup, F-T synthesis, and combined heat and power (CHP) production
   - Address each niche application and the regional demands of Eastern KY
   - Small, modular equipment and processes for easier deployment
4. Deployment Method throughout Coal Communities
   - Environmentally sound
   - Supported by local governments
   - Motivates private business participation

Next Steps

1. Cost Estimation and Comparison
2. EH&S Assessment
3. Social and Economic Impact Assessment

Technical Challenges

1. Safe Method Removing Impoundment Material
2. Permitting Associated with Returning Solid Material to the Impoundment
3. Sulfur Recovery for a Usable Product
4. Maintaining the Feed Slurry Heating Value with Reasonable Flowability with Biomass Included

George Peterson. March 11, 2018. Fairbanks Daily News Miner. Retrieved from: http://www.newsminer.com/features/sundays/community_features/trove-of-photos-shines-light-on-life-at-gold-dredge/article_902cd2b4-2421-11e8-9716-170adebbc7c4.html April 2, 2019.

Outside Interest

Other Impoundment Locations


Calla Refuse and Impoundment Site in Irvine, KY

Hazard Perry County Economic Development Alliance

General Electric Power

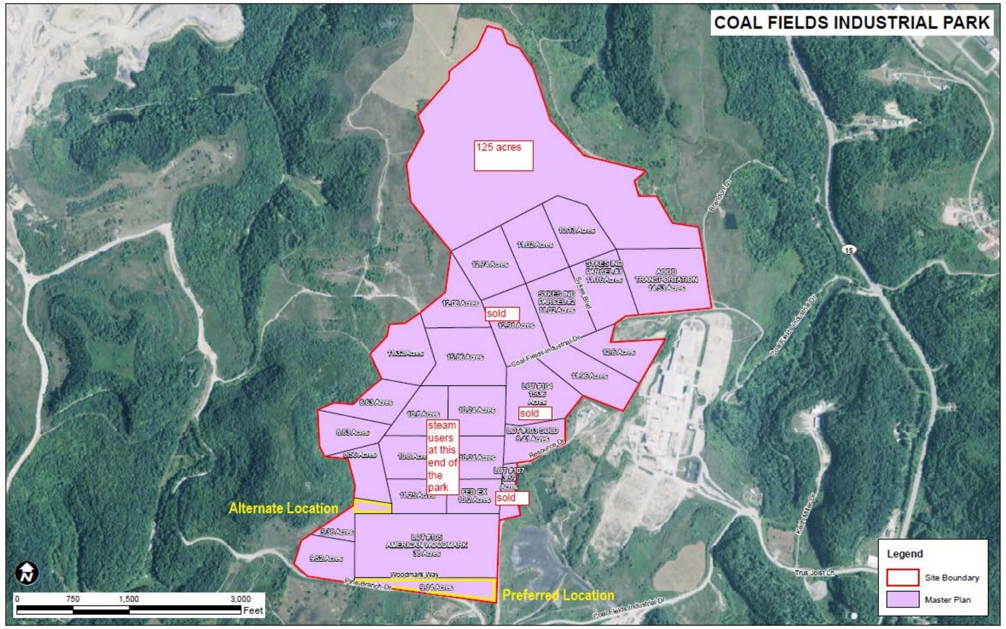
Owning the system, using GE turbine technology and selling heat and power

Sanju Material and Environmental Co.

Build, operate and transfer (BOT) relationship for the F-T part of this application

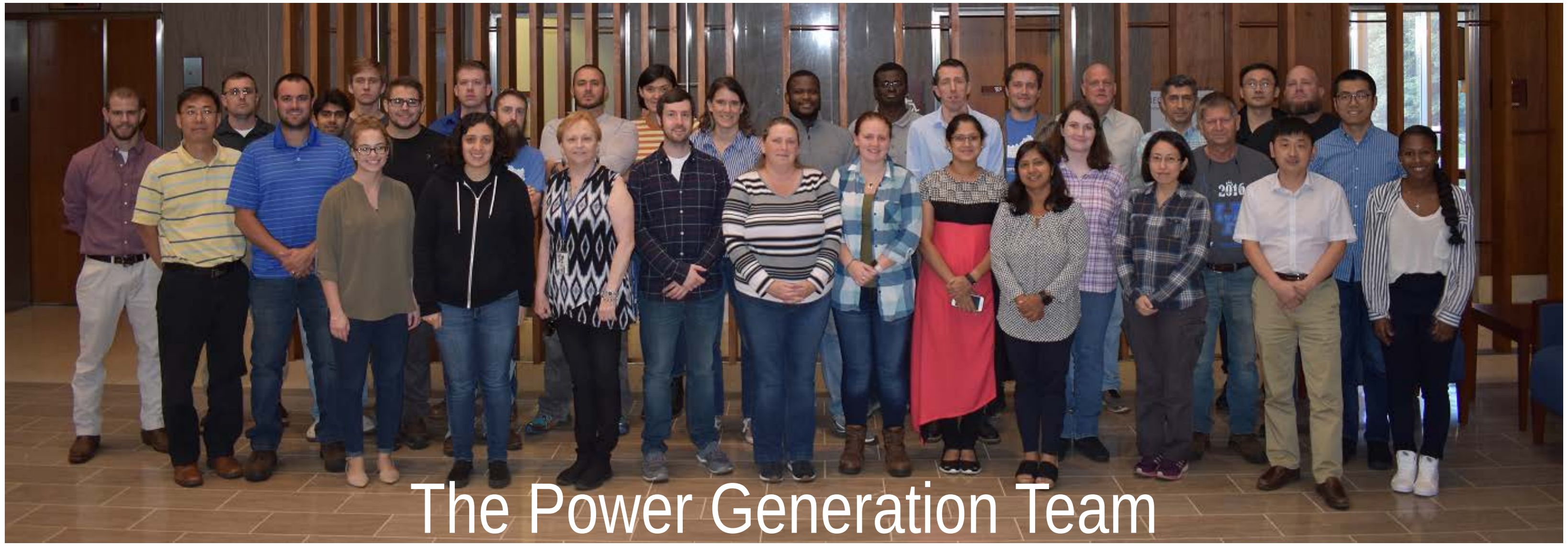
Take Away

1. UKy-CAER has plan for distributed power success
2. At this scale, use of recovered impoundment coal is feasible for gasification and also offers a secondary environmental benefit
3. The project team is ready to continue the design and work with DOE toward demonstration in Eastern KY



Acknowledgements

U.S. DOE-NETL: David Lyons and Steve Markovich
UKy-CAER: Jack Groppo and Moushumi Sarma
BJST: Xiangkun Ren, Ting Cao, Edward Wu and Yankun Song
Trimeric: Andrew Sexton, Brad Piggot, Austyn Vance and Anne Ryan
SMG: Clay Whitney and Steward McCollam
Coal Fields Regional Industrial Authority, Blackhawk Mining, Arq and Gay Brothers Lumber


The Power Generation Team