Staged-OMB for Modular Gasifier/Burner

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Overview

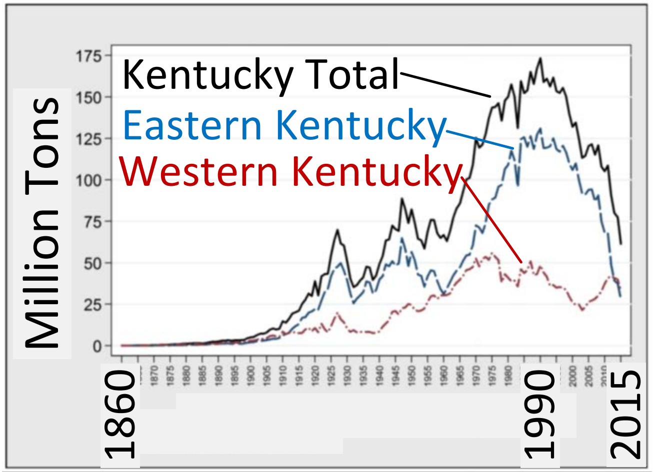
- Background
- Project Description and Objective(s)
- Project Schedule and Tasks
- Progress Update
- Conclusion

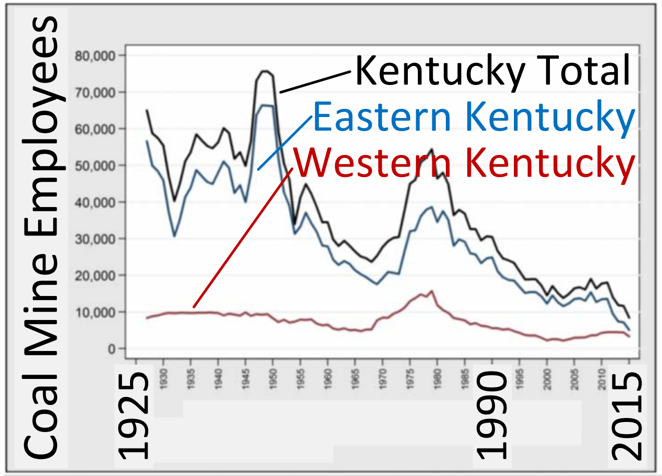
Key Takeaways

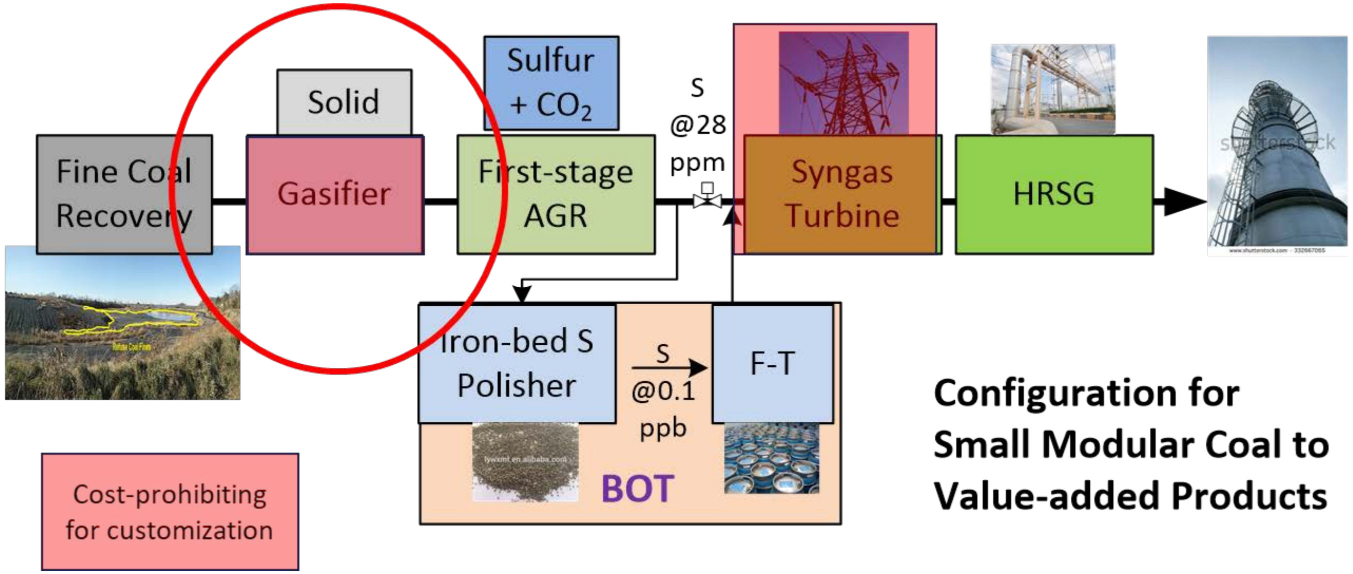
- UKy-CAER Polygeneration Philosophy Supports the REMS Initiative through Standardization, Modularization, and Fuel Flexibility
- Modular Gasifier for Small Scale Distributed Generation Systems
- Standardize for cost reduction
- Load flexibility with multiple burners
- Fuel Flexibility based on burner, particle size and additives, and operating temperature
- Stable Gasifier Operation at Multiple Different Operating Conditions

Background

- Eastern, KY is a remote, coal dependent area
  - Suffering from poor economy and job loss
- Benefit from local polygeneration units
  - Encourage Industry Development
  - Secondary environmental benefit of recovering coal fines
- REMS Concept
  - Small scale
  - Modular units to reduce cost
  - Locating distributed generation near raw material source
- EKY as target site for required modular gasification system

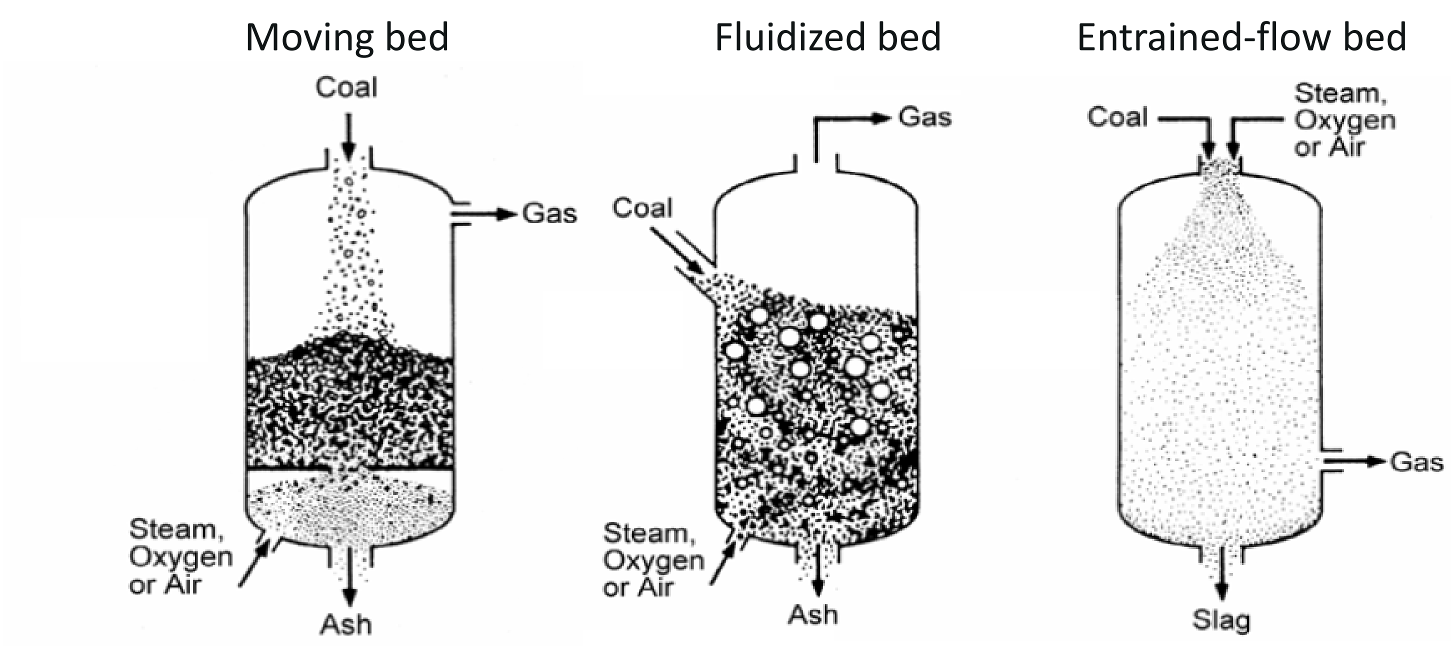






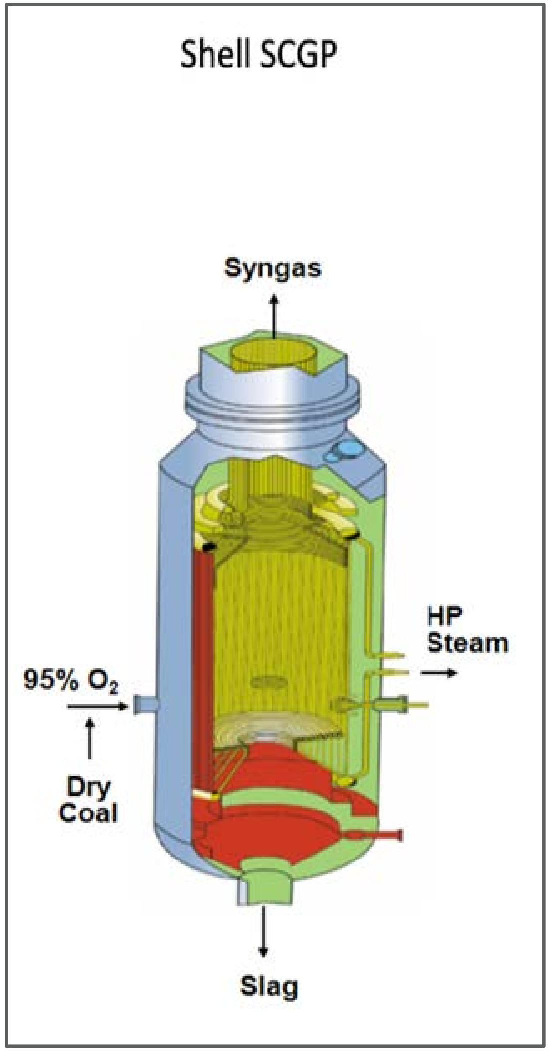
Configuration for Small Modular Coal to Value-added Products

Why Entrained Flow Gasification?

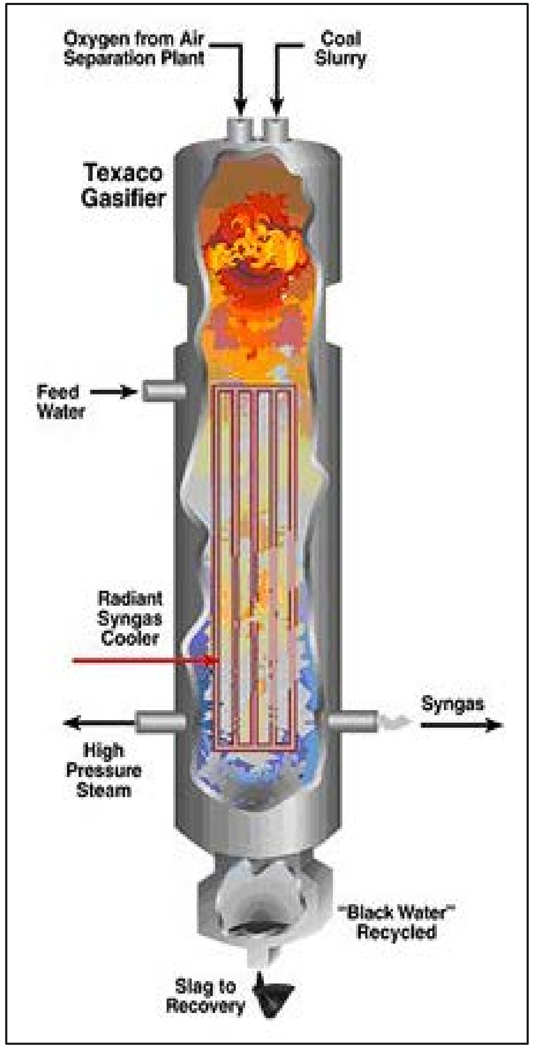


Process	Operation Temperature (°C)	Oxidant Demand	Steam Demand	Carbon Conversion	CH_4 concentration/ tar	H_2/CO (mol/mol)
Moving/fixed bed	425-850	low	/	low	>4% / high	2
Fluidized bed	900-1050	moderate	moderate	moderate	>2%/ low	0.6~0.7
Entrained flow	1250-1600	high	low	High>95%	<1000ppm/No tar	0.7

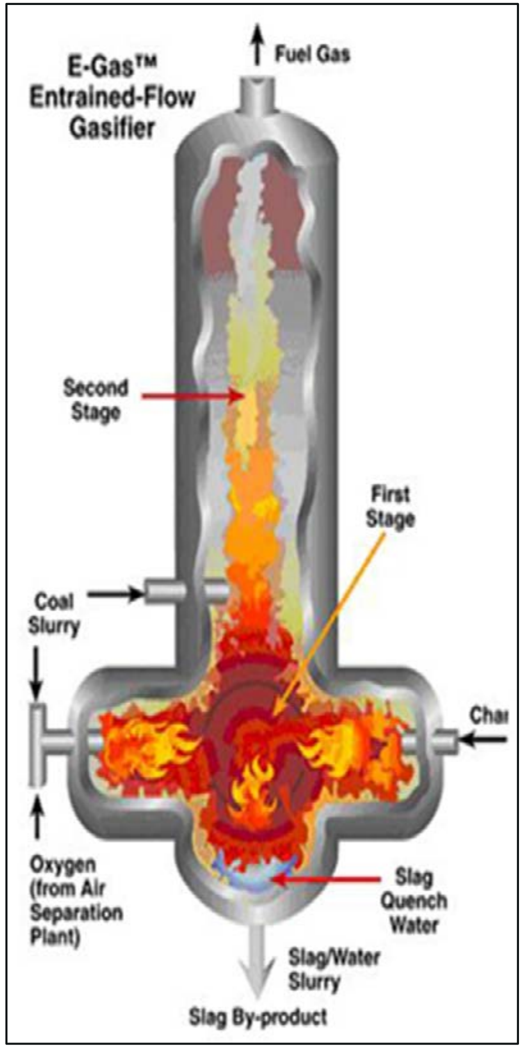
Background – Entrained Flow Technology



SHELL



GE (TEXACO)

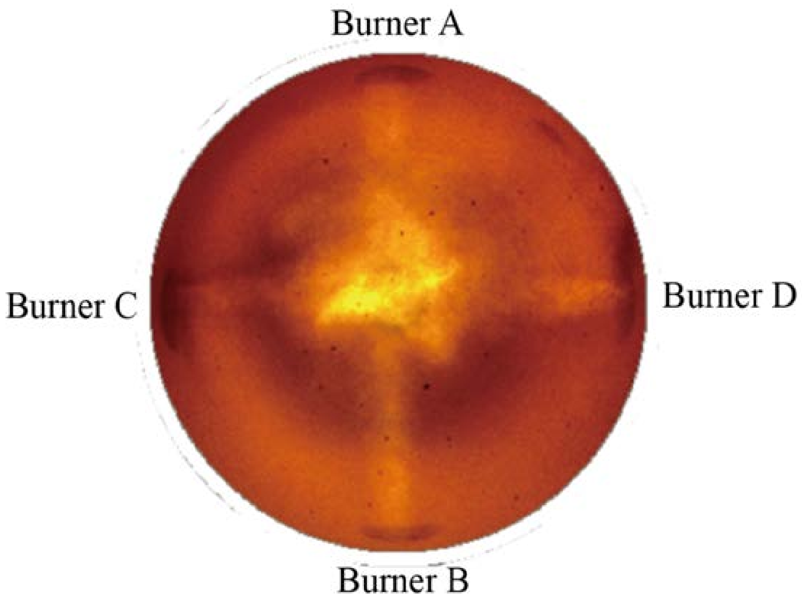


E-GAS

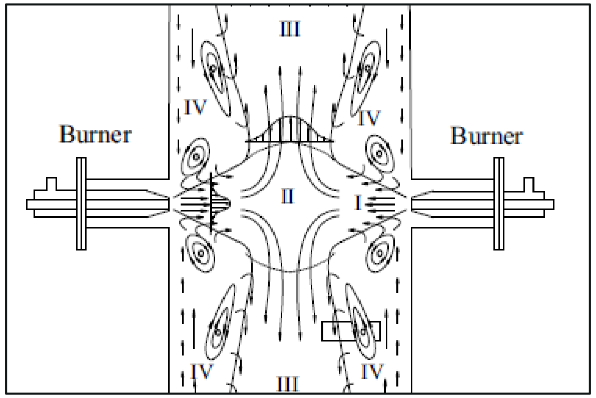
- Shell
  - Dry Feed
  - Multiple Burners
  - Membrane wall
- Texaco
  - Slurry based
  - Single feed from top
  - Refractory wall
- E-Gas
  - Slurry based
  - Multiple Burners
  - Multiple Stages

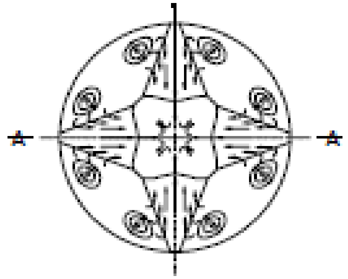
Figures from NETL website: https://netl.doe.gov/

Background – CAER 1 TPD Unit



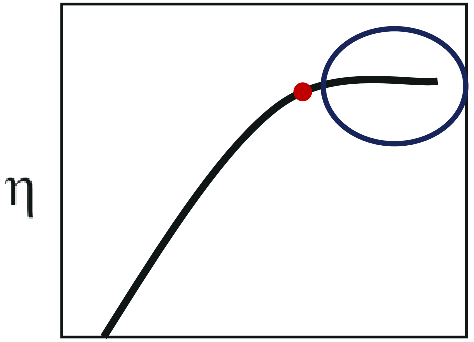
Background – Established Collaboration



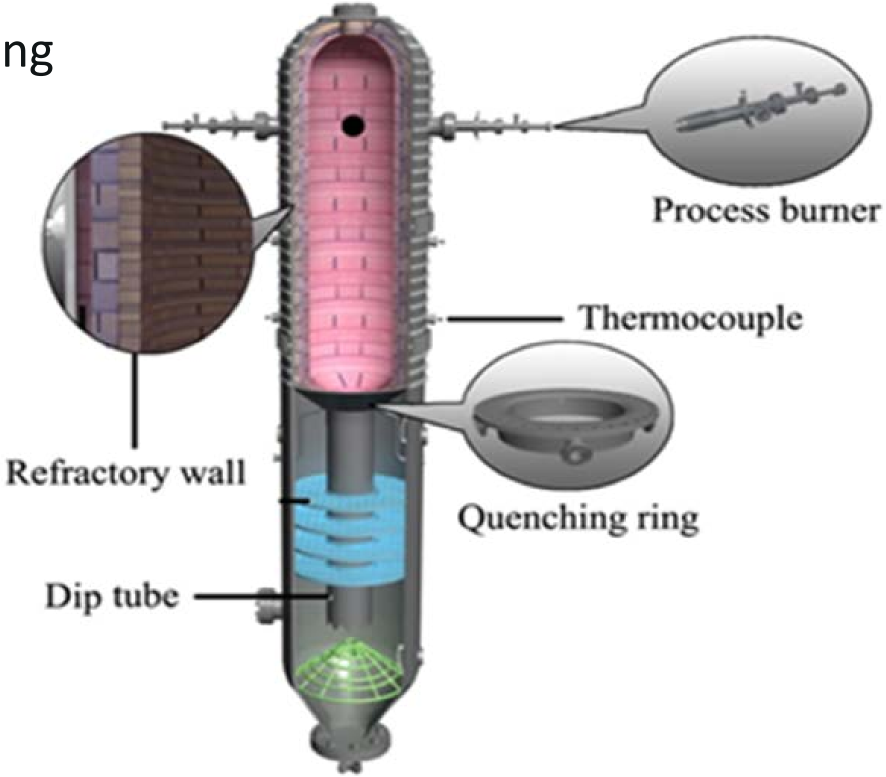


Flow fields of OMB gasifier from large cold model

Coal Types	Fuel Conversion, %
Hualu Hengsheng Coal	98.3
Yankuang Cathay Coal	98.8
Xinneng Fenghuang Coal	99.2
Shenhua Ningxia Coal	98.9
Anhui Huayi Coal	98.9
Yingde Anyang Coal	99.3
Henan Xinlianxin Coal	98.7
Inner Mongolia Rongxin Coal	99.6
Xinjiang Xinlianxin Coal	99.1
Ordos Guotai Coal	99.2



- 4 burners in same plane create impinging zone.
- Strong mixture of gas and solids
- Flow pattern and residence time distribution of fuel are relatively independent of the gasifier size
- Especially suitable for small-scale modular application



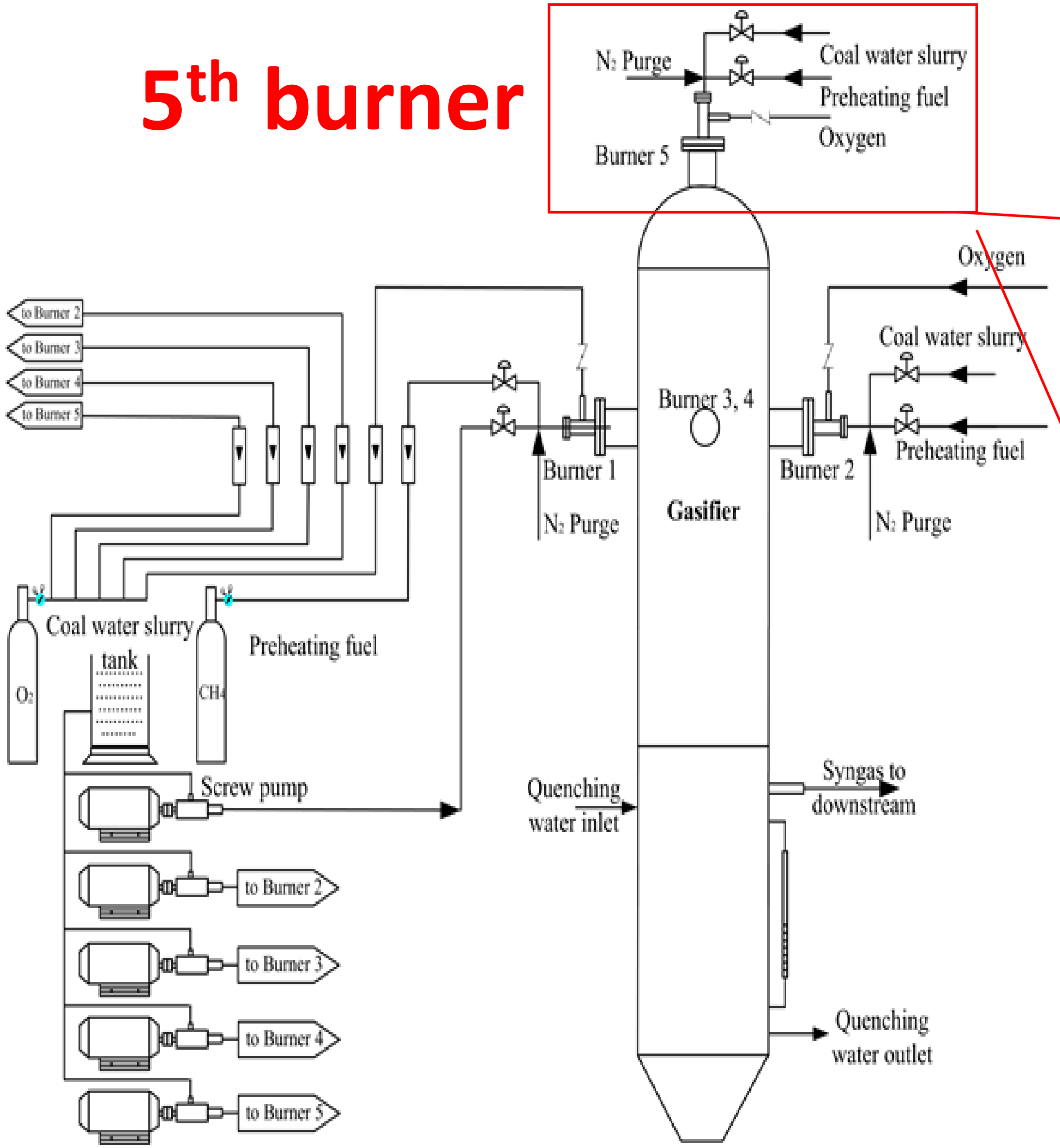
- Scale-up demonstrated
- Small scale study needed

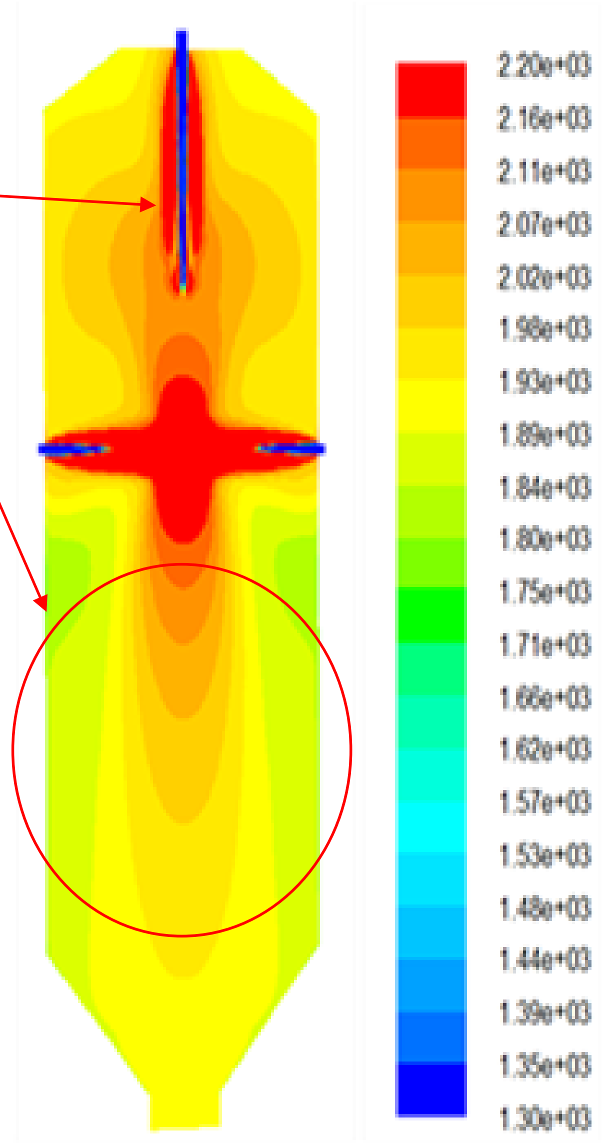
Project Objectives and Proposed Activity

1. Load Flexibility
   - Multi-layer – installation of 5th burner
2. Fuel Flexibility
   - Robust slurry – particle size and additives.
   - In-situ H_2S removal and COS hydrolysis – circulation of Fe-based sorbent
3. Standardization
   - ASU determined burners
   - Gasifier design
4. Techno-Economic Analysis

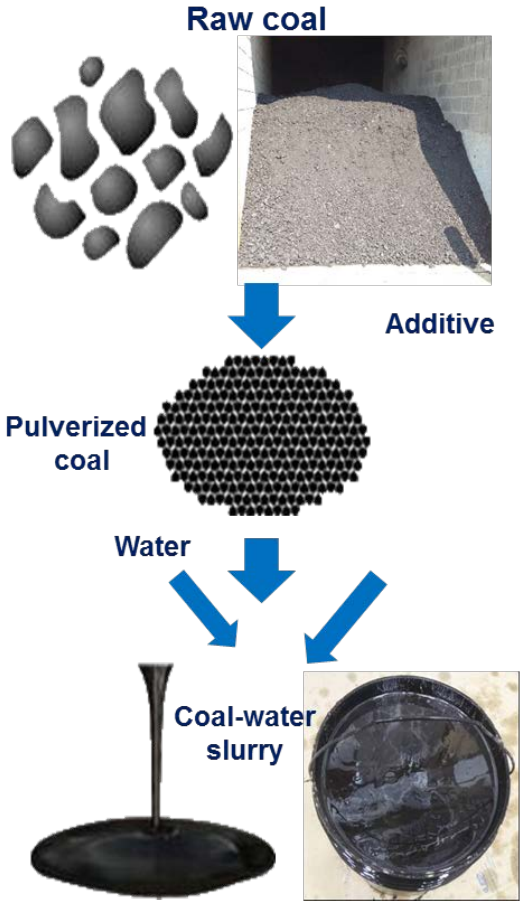
Technical Approach – Loading Flexibility

5th burner





Technical Approach - Fuel Flexibility

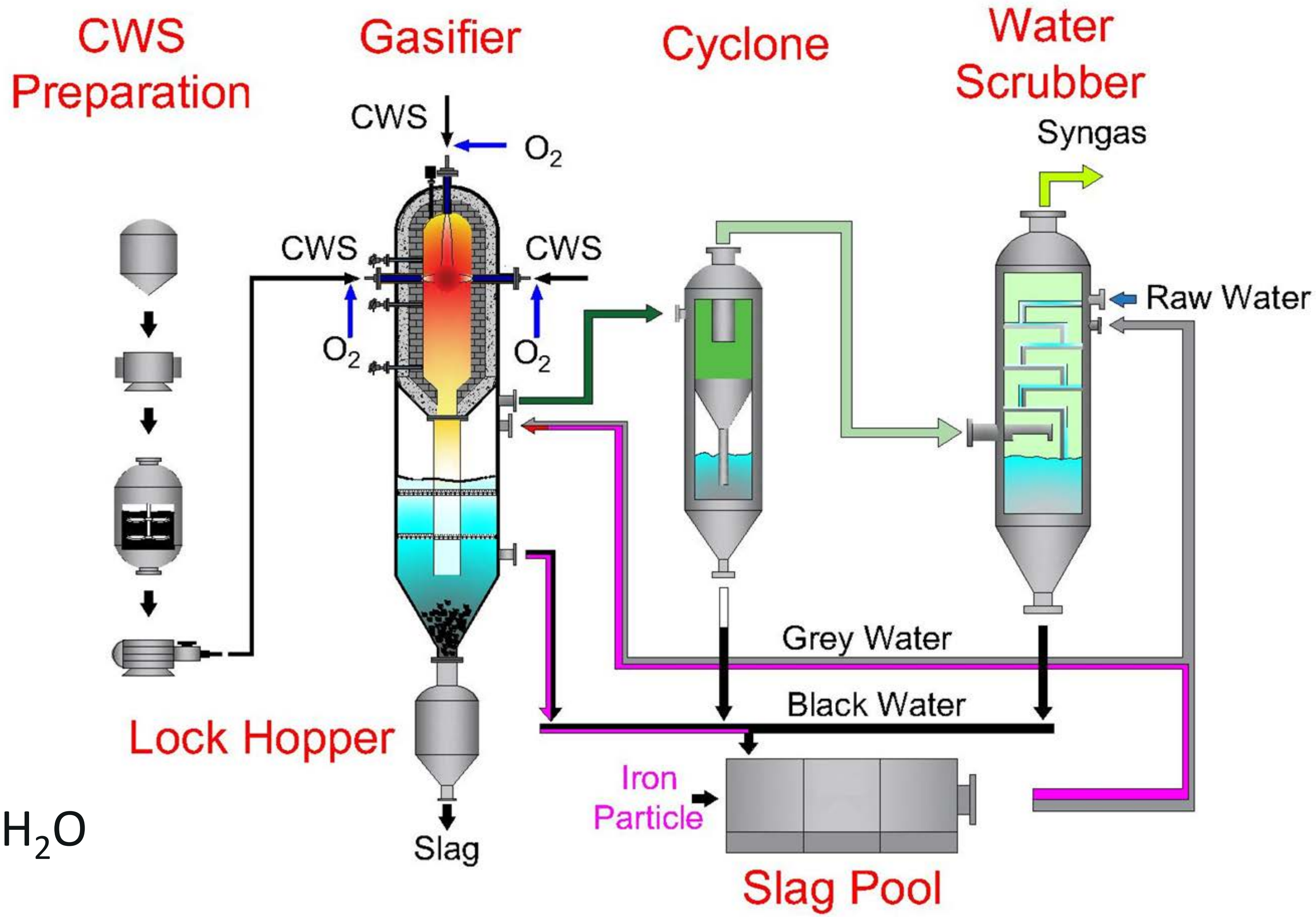


Typical Properties of CWS

Average particle size (μm)	Mass concentration	Viscosity (mPa·s)
<50	<60%	<250

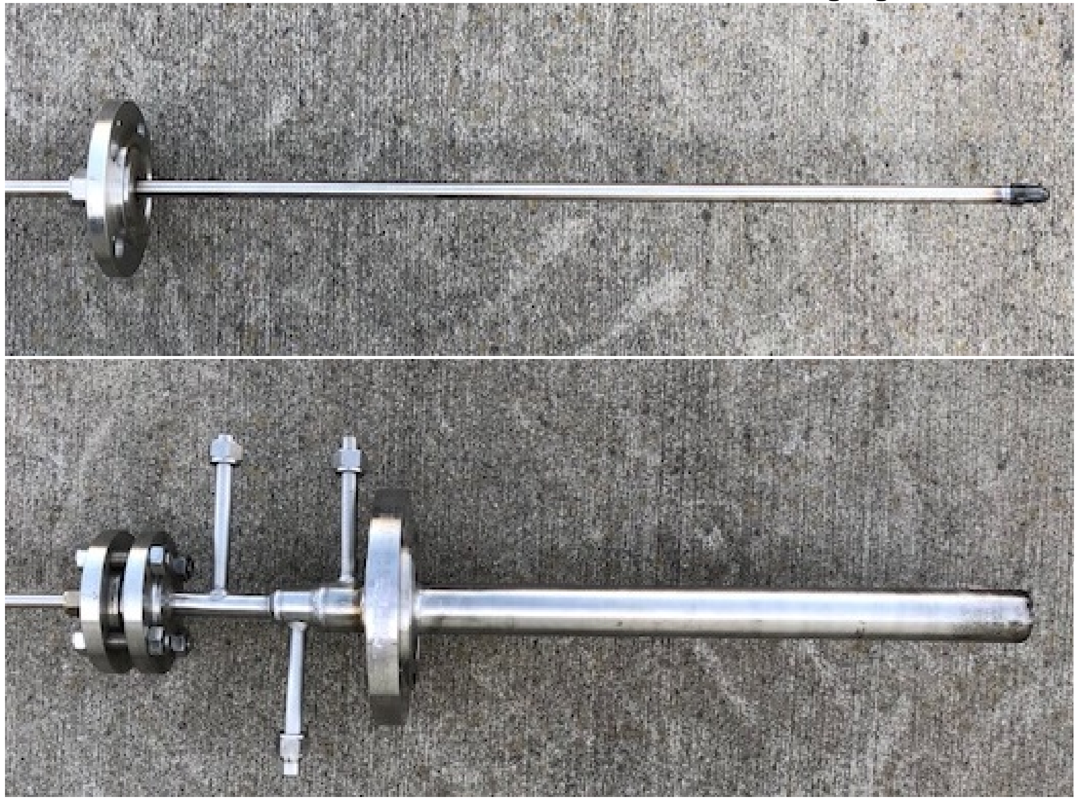
Technical Approach – Fuel Flexibility

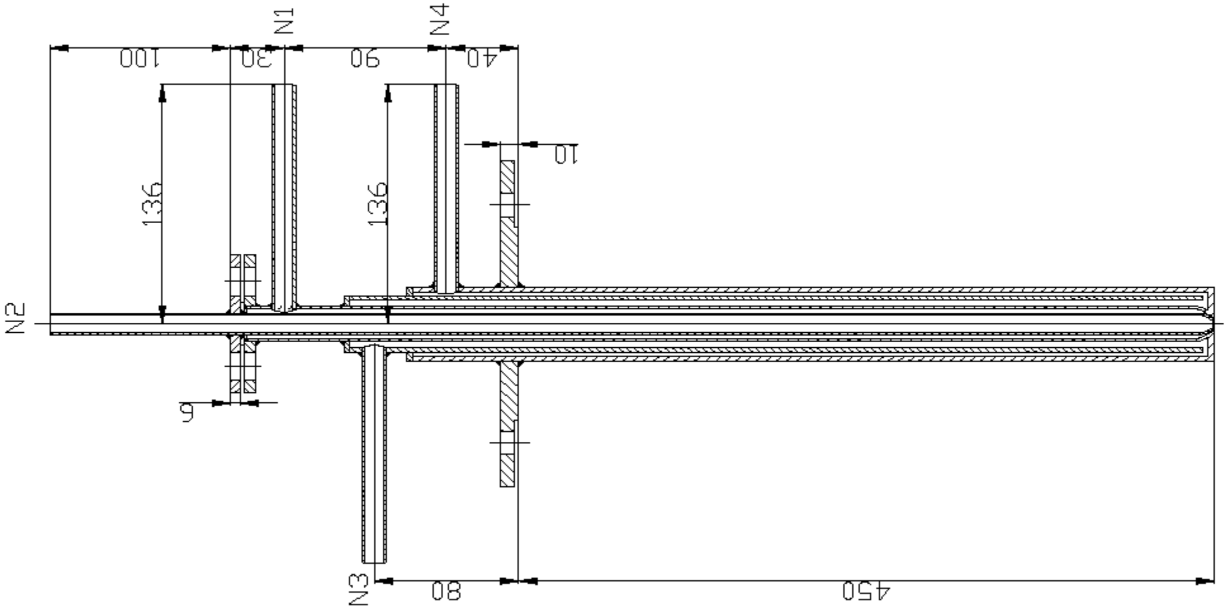
- Iron-based industrial byproduct injection at various concentration in Quench water
- Residence time
- Temperature



$$Fe(OH)_2 + H_2S \Rightarrow FeS + 2H_2O$$

Technical Approach - Burner Standardization





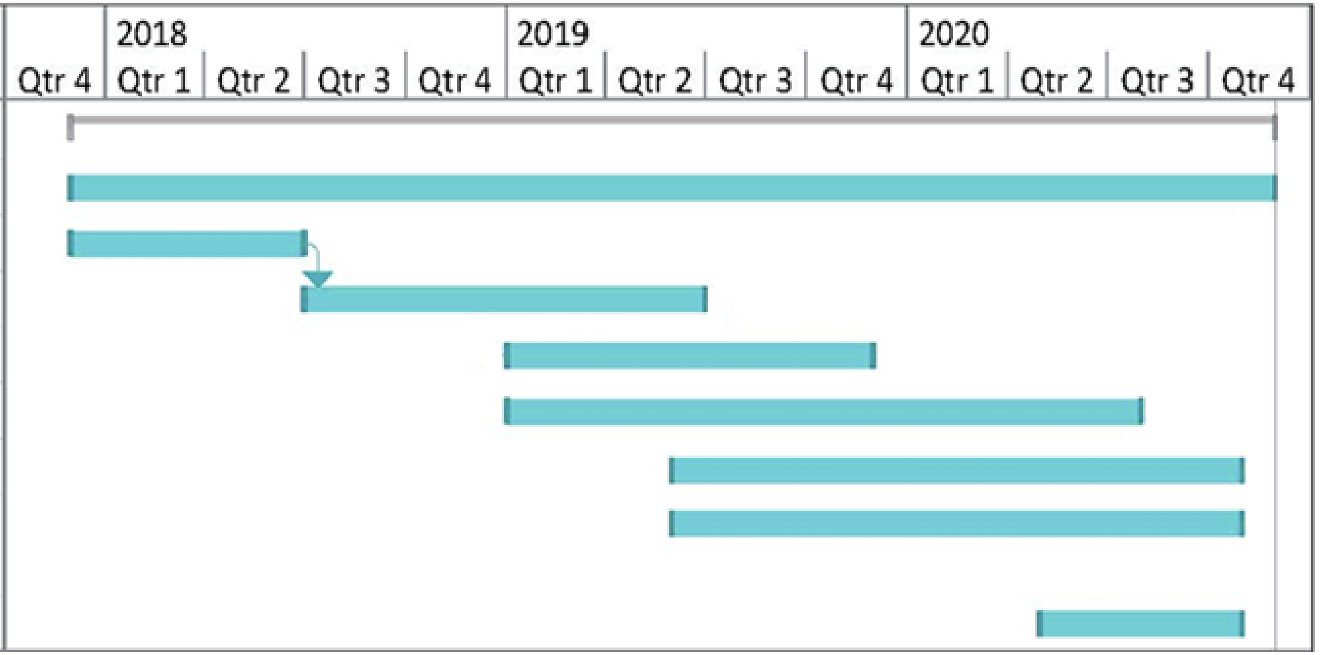
- Standardize
- ASU is the determiner
- Then oxygen channel clearance
- Coal Feed rate
- Slurry velocity & tip clearance

Project Structure and Task Assignment

Project Participant	Scope of Work
UKy-CAER	• Project lead • Schedule and overall project management • OMB pilot modification design and construction • Develop testing plan • Staged-OMB operation and testing • Data analysis • Feed characterization • Develop final staged-OMB design based on test and model results
East China University of Science and Technology (ECUST)	• 3-D modeling of the staged-OMB gasifier based on results from testing • Utilize 3-D model to optimize the staged-OMB process • Provide suggestions for process and unit modifications to improve flexibility and efficiency • Technical support on operation of UKy-CAER OMB pilot unit based on knowledge and experience from previous operations and development
Trimeric Corporation	• Perform techno-economic analysis • Estimate construction costs • Estimate operating costs • Economic comparison to commercial scale • Determine economic viability of system

Project Schedule

Task Name	Start	Finish
Staged OMB for Modular Gasifier/Burner	12/1/17	11/30/20
1 Project Management and Planning	12/1/17	11/30/20
2 Construction of the Staged-OMB Gasifier	12/1/17	6/30/18
3 Parametric Study of Staged-OMB	7/1/18	6/30/19
4 Fuel Flexibility with Fuel Blend	1/2/19	11/30/19
5 In-situ WGS Development	1/2/19	7/31/20
6 Burner Testing	6/1/19	10/31/20
7 3-D Simulation of Staged-OMB Gasifier and Burner Effect	6/1/19	10/31/20
8 Technical and Economic Analysis	5/1/20	10/31/20

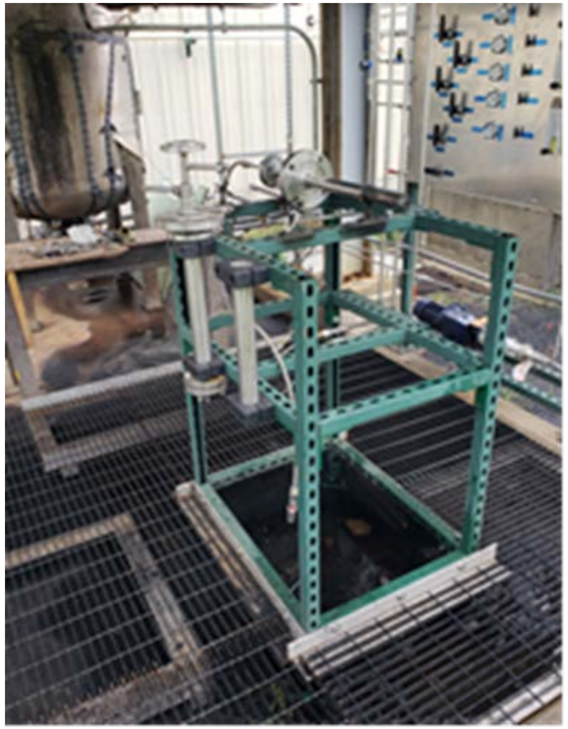


Construction and Modifications

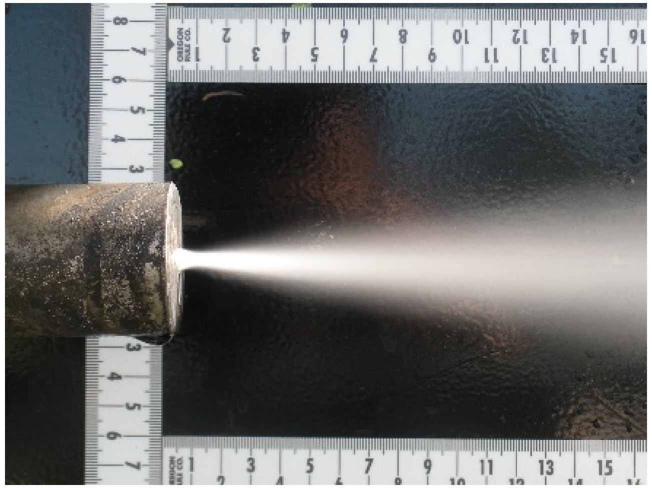



- 5th Burner
  - Supports
  - MFC's
  - Slurry and Gas Control Valves
  - Modified 5th burner flange
  - Mechanical installation
  - Control Cables and Connections
- Cyclone Separator
- Weigh Belt Feeder

Burner Modification and Testing



- Burner Test Stand
  - Set Jig for Burner Installation
  - Atomization Testing
  - Burner Testing
- Industrial burner
  - Velocity:100~120m/s



Burner	Tip	Jacket	Velocity	Modified V
A	6.9 mm	7.47 mm	85 m/s	>100 m/s
B	6.7 mm	7.21 mm	90 m/s	>100 m/s
C	7.0 mm	7.54 mm	85 m/s	>100 m/s
D	6.8 mm	7.34 mm	87 m/s	>100 m/s

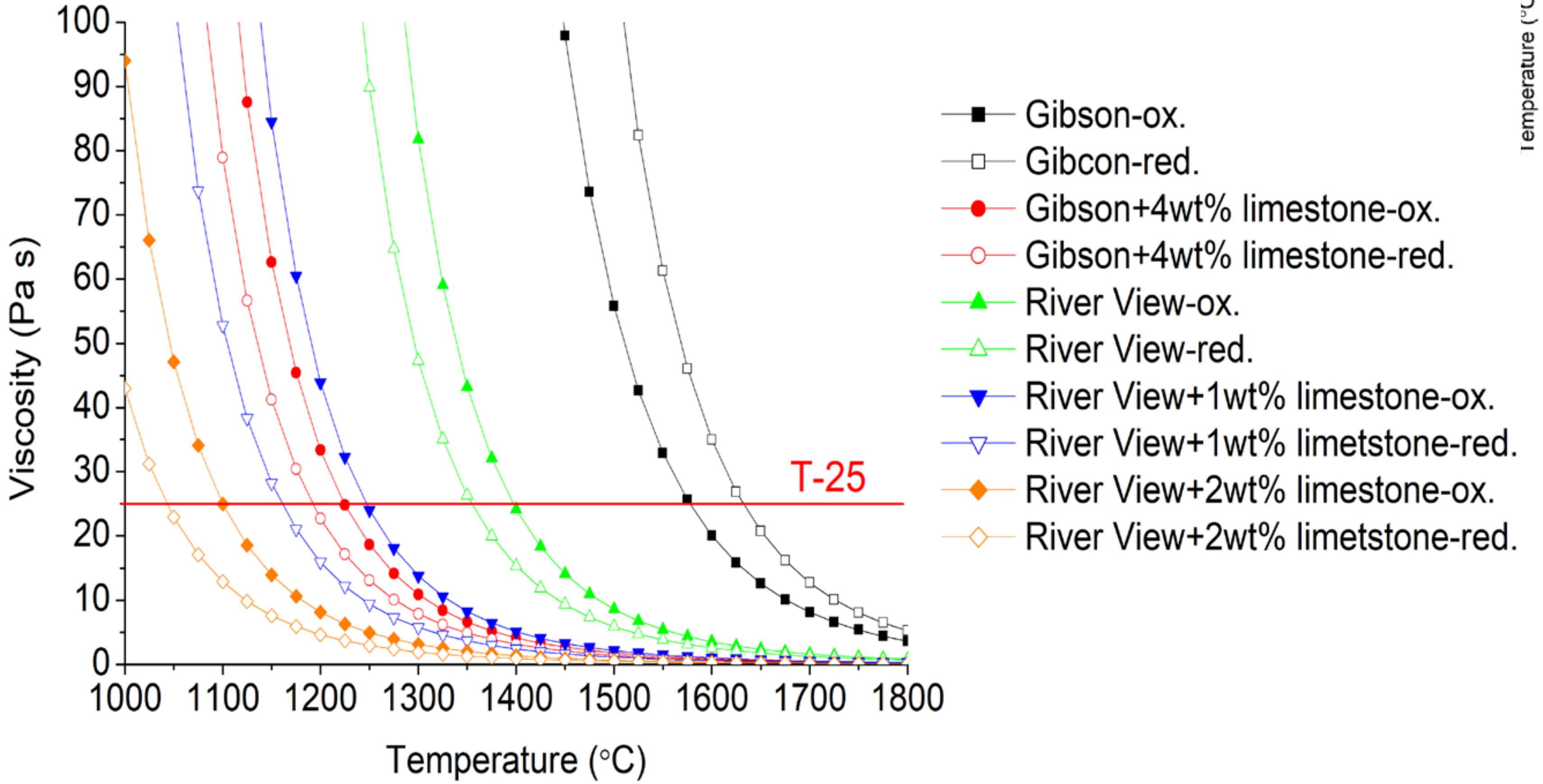
Fuel Flexibility - Coal and Slag Analysis

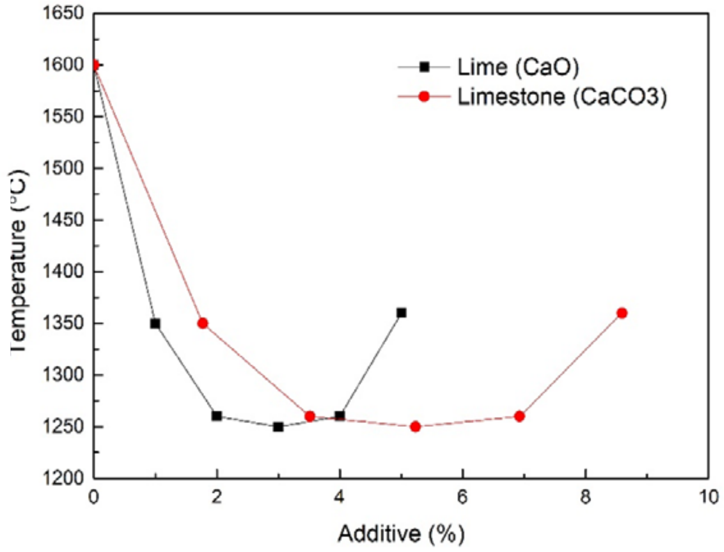
Parameter	Gibson coal	River View coal	PRB coal ACM	PRB coal SCM	PRB coal CRM
Moisture (%)	14.47	12.14	26.11	24.94	29.64
Volatiles (%)	31.15	35.62	31.68	31.53	31.17
Ash (%)	6.63	8.19	5.42	4.14	5.17
Fixed C (%)	47.75	44.05	37.44	39.54	34.5
S (%)	1.2	2.92	0.25	0.33	0.29
C (%)	64.26	63.05	51.92	54.05	49.27
H (%)	4.52	4.64	3.57	3.78	3.48
O (%)	7.47	6.35	12.6	11.51	11.9
N (%)	1.45	1.45	0.77	0.65	0.72
BTU/lb	11535	11514	8800	9350	8425
FT-reducing (℃)	1337	1198	1215	1198	1217
FT-oxidizing (℃)	1404	1346	1249	1336	1249
T-25 (℃)	1440	1298	1197	1159	1215

Fuel Flexibility - Coal and Slag Analysis

Oxides	Gibson coal	Gibson coal +4% $CaCO_3$	River view	River view +1%$CaCO_3$	River view +2%$CaCO_3$	PRB-ACM	PRB-CRM	PRB-SCM
SiO_2	55.19	43.43	45.88	41.12	37.19	30.82	32.62	28.99
Al_2O_3	23.84	18.76	18.02	16.15	14.60	15.95	18.81	17.59
Fe_2O_3	11.50	9.05	19.04	17.07	15.43	6.66	5.67	4.95
CaO	1.45	**22.45**	6.07	**15.81**	**23.87**	**24.93**	**22.37**	**17.04**
MgO	1.25	0.99	0.85	0.77	0.69	5.59	3.98	4.13
Na_2O	1.56	1.22	1.00	0.89	0.81	1.52	9.54	8.16
K_2O	2.83	2.23	2.31	2.07	1.87	0.27	0.34	0.45
P_2O_5	0.46	0.36	0.13	0.12	0.11	1.73	1.06	0.27
TiO_2	1.25	0.99	1.02	0.91	0.82	1.27	1.46	1.32
SO_3	0.66	0.52	5.68	5.09	4.60	9.15	9.54	13.42

Ash Fusion Temperature and Slag Viscosity





- Property of Illinois Basin Coal
  - High Si and Al
  - High ash fusion temperature
  - High viscosity
  - Poor slag flow

- Limestone addition
  - Increased Ca
  - Lower AFT
  - Lower viscosity
  - Suitable flow property

Operation Results Summary – Gibson Coal

Condition	Baseline	Condition 1	Condition 2
Burner	4	2	2
Overall Loading	100%	60%	27%
Slurry Flow Rate (L/hr)	67	48	19
Temperature (°C)	1350	1300	1350
Pressure (Mpag)	0.1	0.1	0.1
CWS Solid (%)	53	45	50
Additive for dispersant (CWS)	Daracem 55	Daracem 55	Daracem 55
O/C	1.1:1	1.0:1	1.3:1
Heating Value Ratio (%NG/%Coal)	0%/100%	19%/81%	43%/57%
Syngas			
H_2	24.51	20.72	30.25
N_2	2.93	2.17	0.78
CO	28.94	19.68	28.76
CO_2	40.89	51.85	34.64
H_2O	2.54	5.44	5.45
H_2S	0.18	0.12	0.11
COS	0.02	0.01	0.01
CO+ H_2	53.45	40.4	59.01
H_2/CO	0.85	1.06	1.06
CO/CO_2	0.71	0.39	0.84
H_2S/COS	9	12	11
HHV (MJ/m^3)	6.22	4.71	6.88
LHV(MJ/m^3)	5.78	4.33	6.33
Carbon conversion (%)	91	71	87

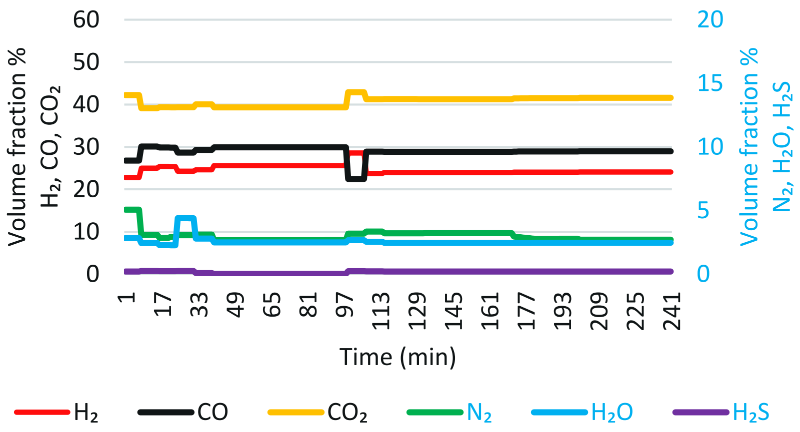
Results - Syngas Composition

Baseline:

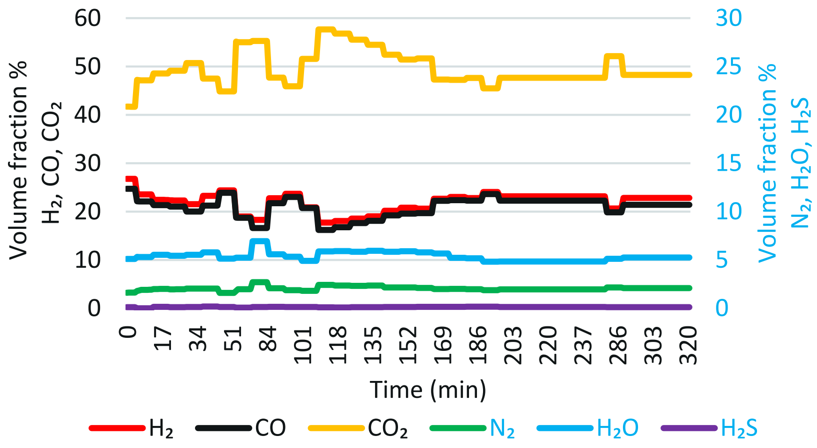
- Four burners-1350°C
  - CO:29vol%, CO_2:41vol%, H_2:25vol%

Parametric:

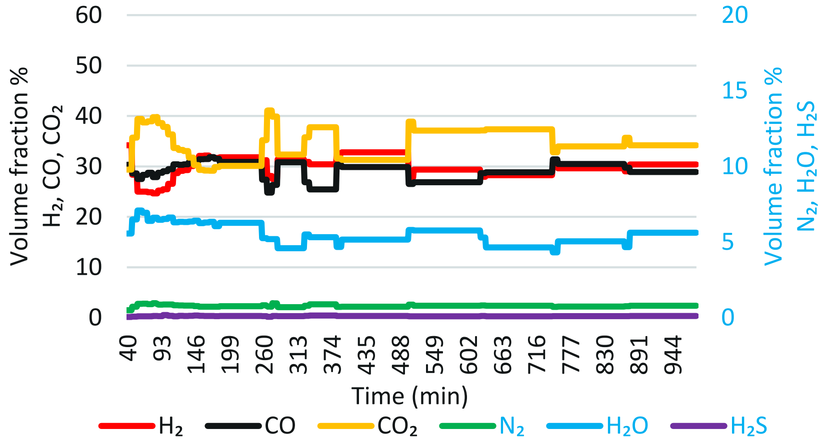
- Two burners-CWS + NG -1300 °C
  - CO:21vol%, CO_2:52vol%, H_2:20vol%
- Two burners-CWS + NG -1350 °C
  - CO:30vol%, CO_2:35vol%, H_2:29vol%



Baseline- Four burners -1350℃



Two burners - 1300℃



Two burners - 1350℃

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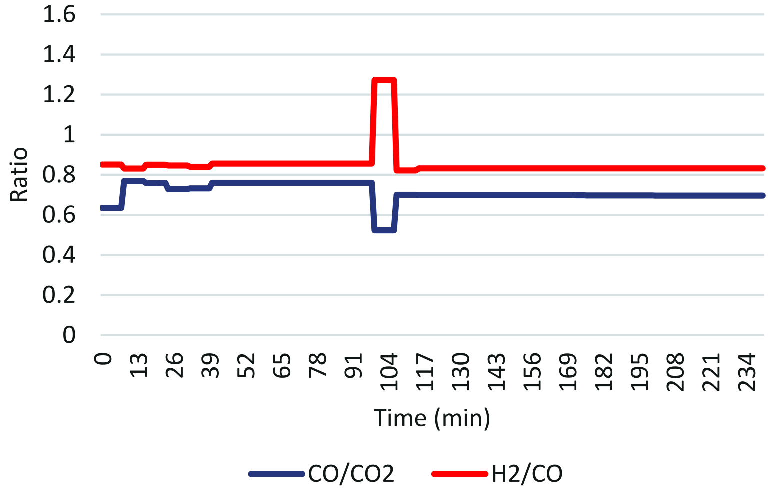
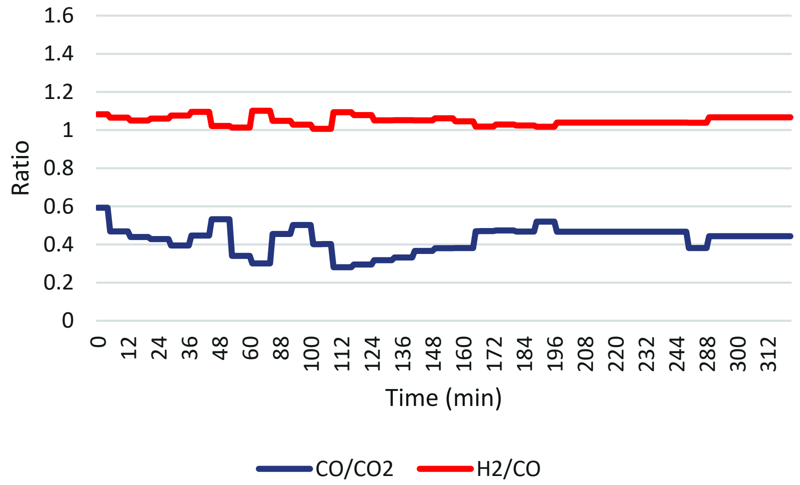
Results – H_2/CO and CO/CO_2

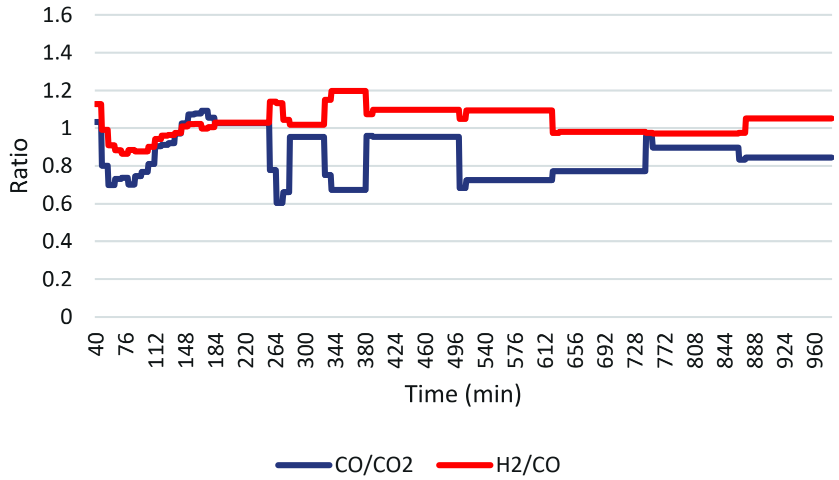


Baseline- Four burners -1350℃



Two burners - 1300℃

- Baseline:
  CO/CO_2: 0.71 H_2/CO:0.85
- Parametric:
  - Two burners-CWS + NG -1300 ℃
    CO/CO_2: 0.39 H_2/CO:1.06
  - Two burners-CWS + NG -1350 ℃
    CO/CO_2: 0.84 H_2/CO:1.06



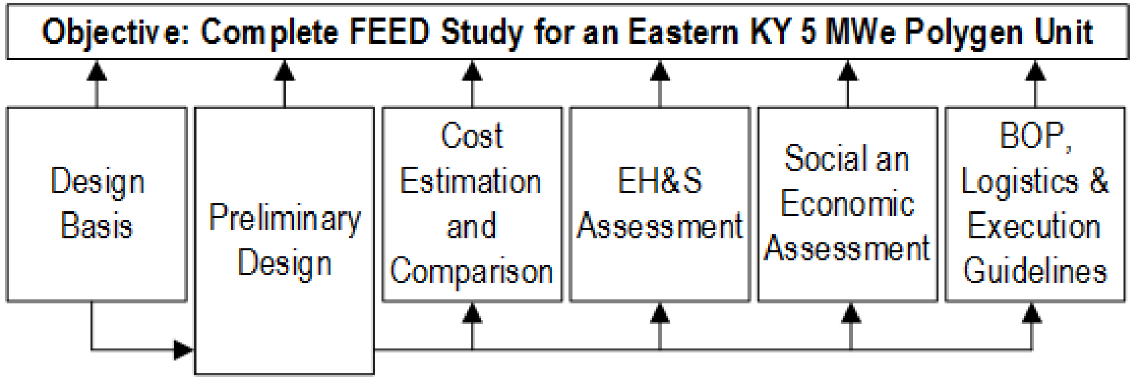
Two burners - 1350℃

Project Management Plan – Success Criteria

Planned Date	Success Criteria
6/30/2018	Completion of the pilot scale staged-OMB modifications and reactor ready for operation
10/31/2019	Gather data from the staged-OMB parametric testing showing improvements of the process modifications on flexibility and efficiency
05/31/2019	Gather data from in-situ WGS testing
05/31/2019	Improve carbon conversion of staged-OMB from baseline OMB conversion and cold gas efficiency by 2% with variation in feedstocks
07/31/2020	Completion of the 3-D modeling of staged-OMB process based on data from UKy-CAER testing
10/31/2020	A finalized engineering process design and Aspen-Plus based simulation model; equipment list and sizing; technical-economic analysis including capital and O&M cost estimates; for the 1-5MW scale

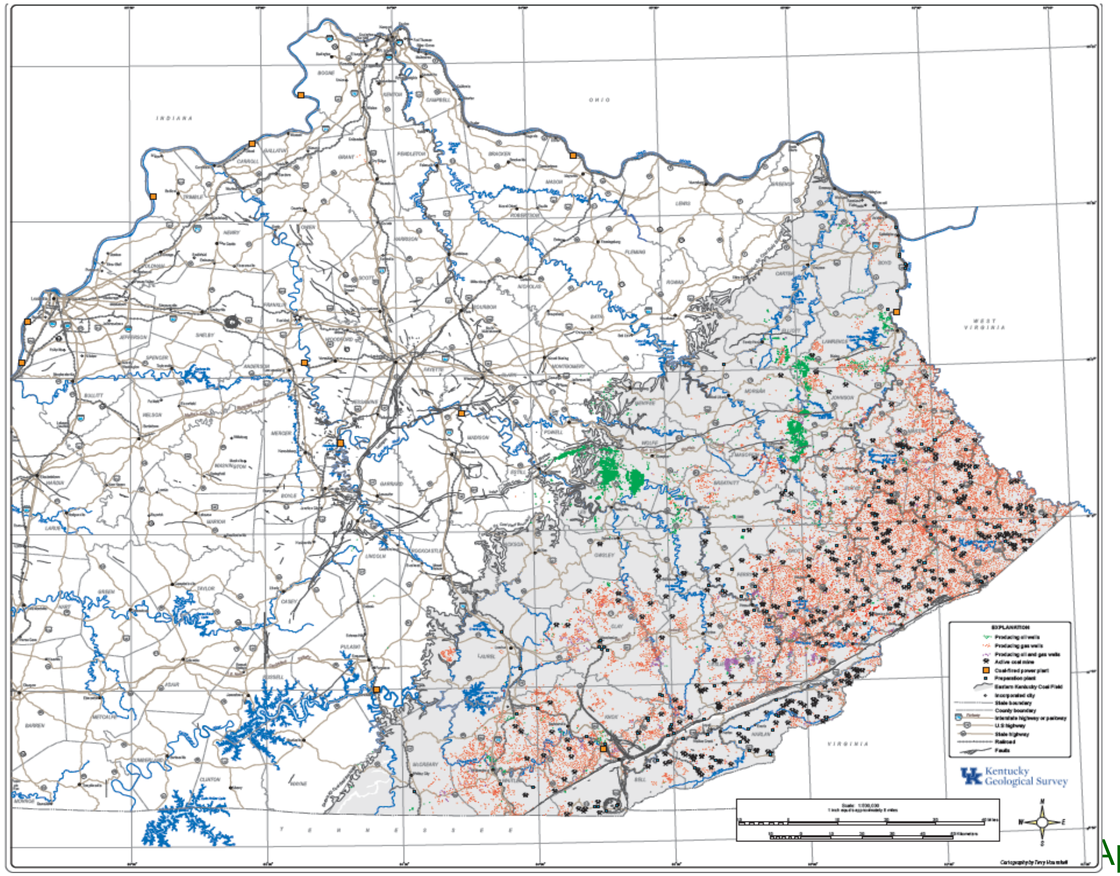
Market Benefit/Technology to Market Path

- Application for modular gasifier to be used in Combined Heat and Power Polygeneration unit



EXPLANATION

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



Conclusion

Project Status

- Construction and modification completed on schedule
- Parametric operation expected to be completed by end of summer on schedule
- Fuel flexibility on-going
- Burner testing to begin this year

Key Takeaways

- Modularize Gasifier for Small Scale Distributed Generation Systems
- Standardize for cost reduction
- Load flexibility with multiple burners
- Fuel Flexibility:
  - Burners
  - Particle Size
  - Additives
- Stable Gasifier Operation at Multiple Different Operating Conditions

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