Gasification Systems/C&CBTL Program Overview

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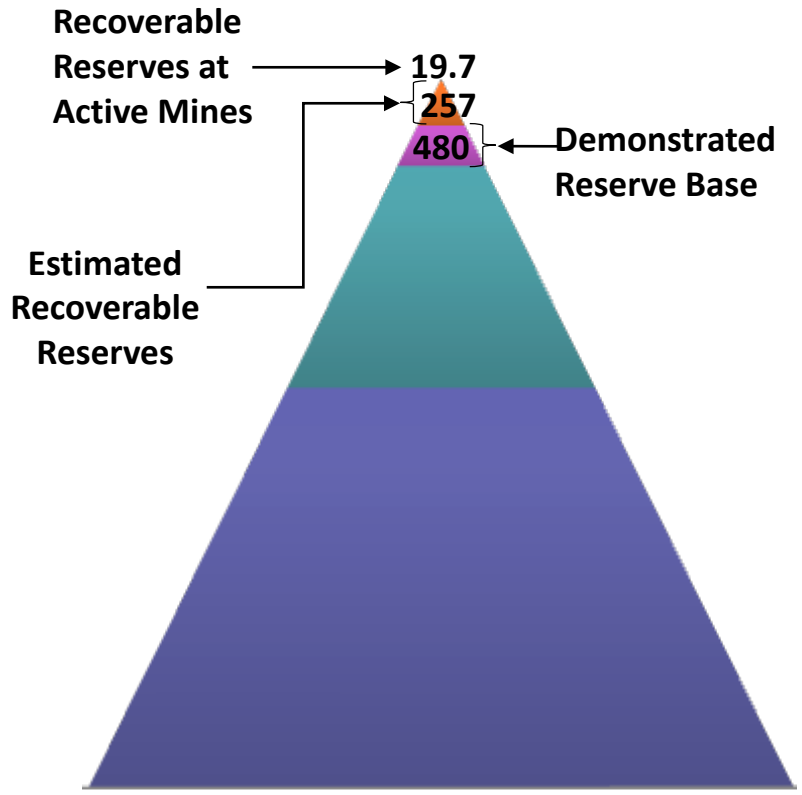
Why the Interest in Coal Gasification?

U.S. Has A Lot of Coal!

Energy Diversity and Security

Gasification can:

- ✓ Convert coal to power
- ✓ Convert coal to valuable products (chemicals/fuels)
- ✓ Superior environmental performance, including GHG
- ✓ Feasible for carbon capture

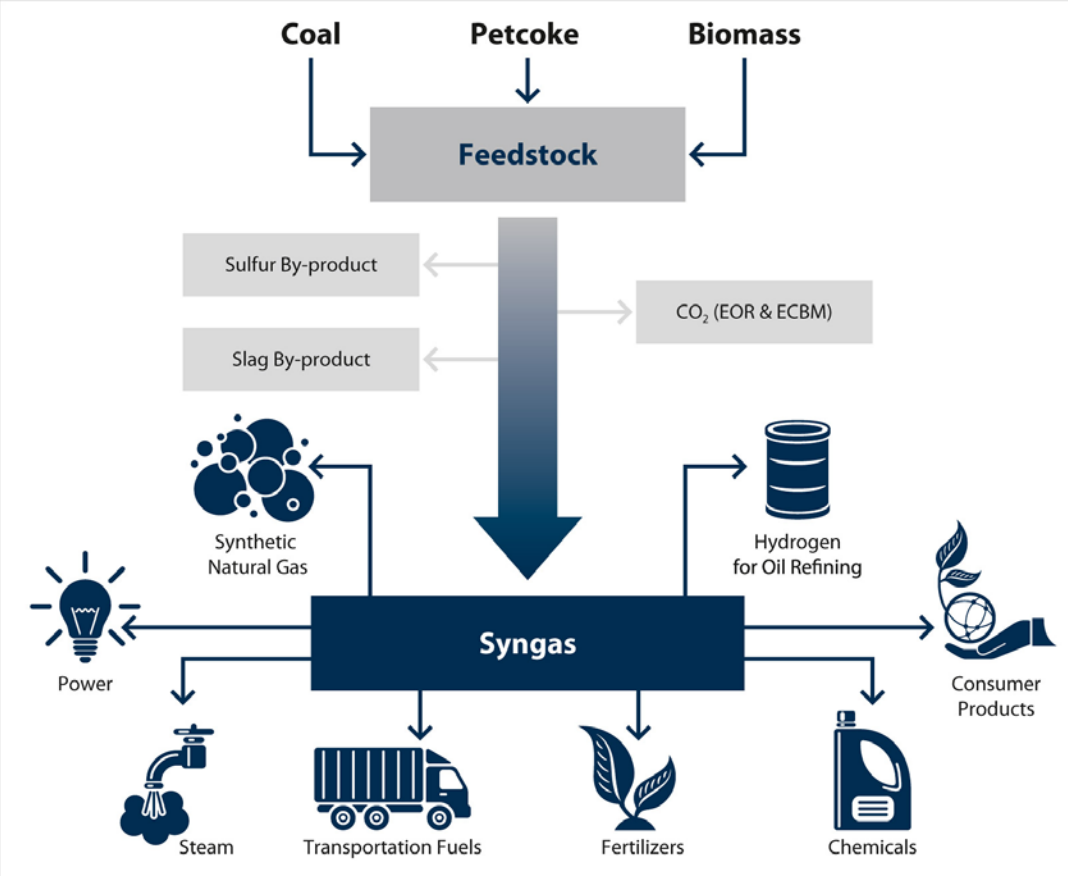


U.S. Coal Resources
billion short tons

Benefits and Products of Gasification

Gasification can be

- Used to make: hydrogen, fertilizer, chemicals (methanol, plastics, etc.) and transportation fuels
- Lowest cost option to make power with almost total carbon dioxide (CO_2) capture and storage



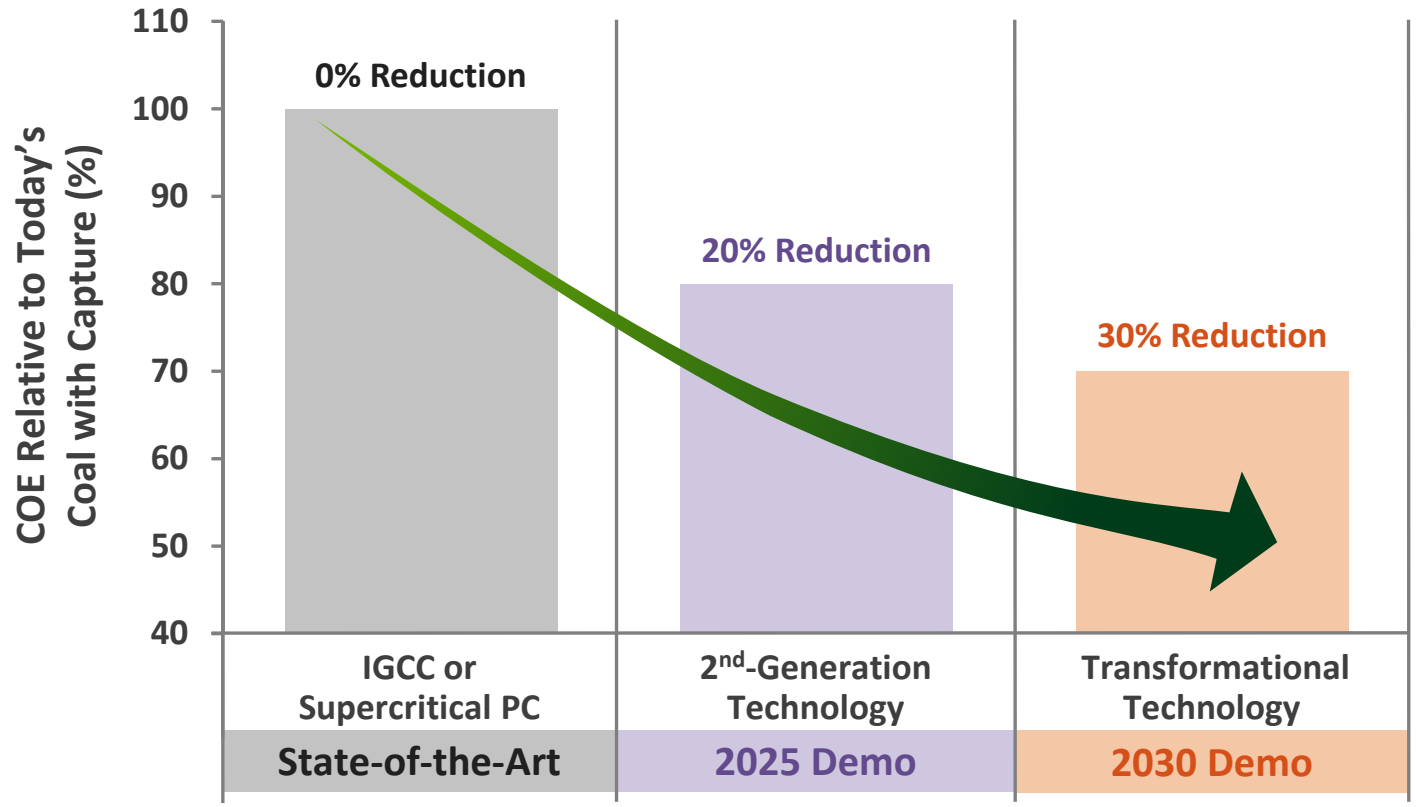
Gasification can play in the global market, including developing countries

Source: Premium Engineering http://www.premen.ru/en/content/gasification/

Fossil Energy – Coal Research Program Goals

Driving Down the Cost of Electricity of Coal Power with CCS

Cost of Electricity Reduction Targets



Goals are for greenfield plants. Costs include compression to 2,215 psia, but exclude CO_2 transport and storage costs.

Economic Challenges & Opportunities

Gasification Systems

Challenges

- Low natural gas prices
- Lack of stringent Greenhouse Gas (GHG) control legislation: Gasification based power is expected to compete well in a high-carbon capture future

Opportunities

- High value products from coal via syngas production/conversion
- Economic stability through diversified power sources
- Set stage for significant GHG control across globe through reduced cost of electricity with CCS

Feed Systems

- Oxygen separation
- Expand fuel flexibility
- Increase efficiency and reliability, and improve economics

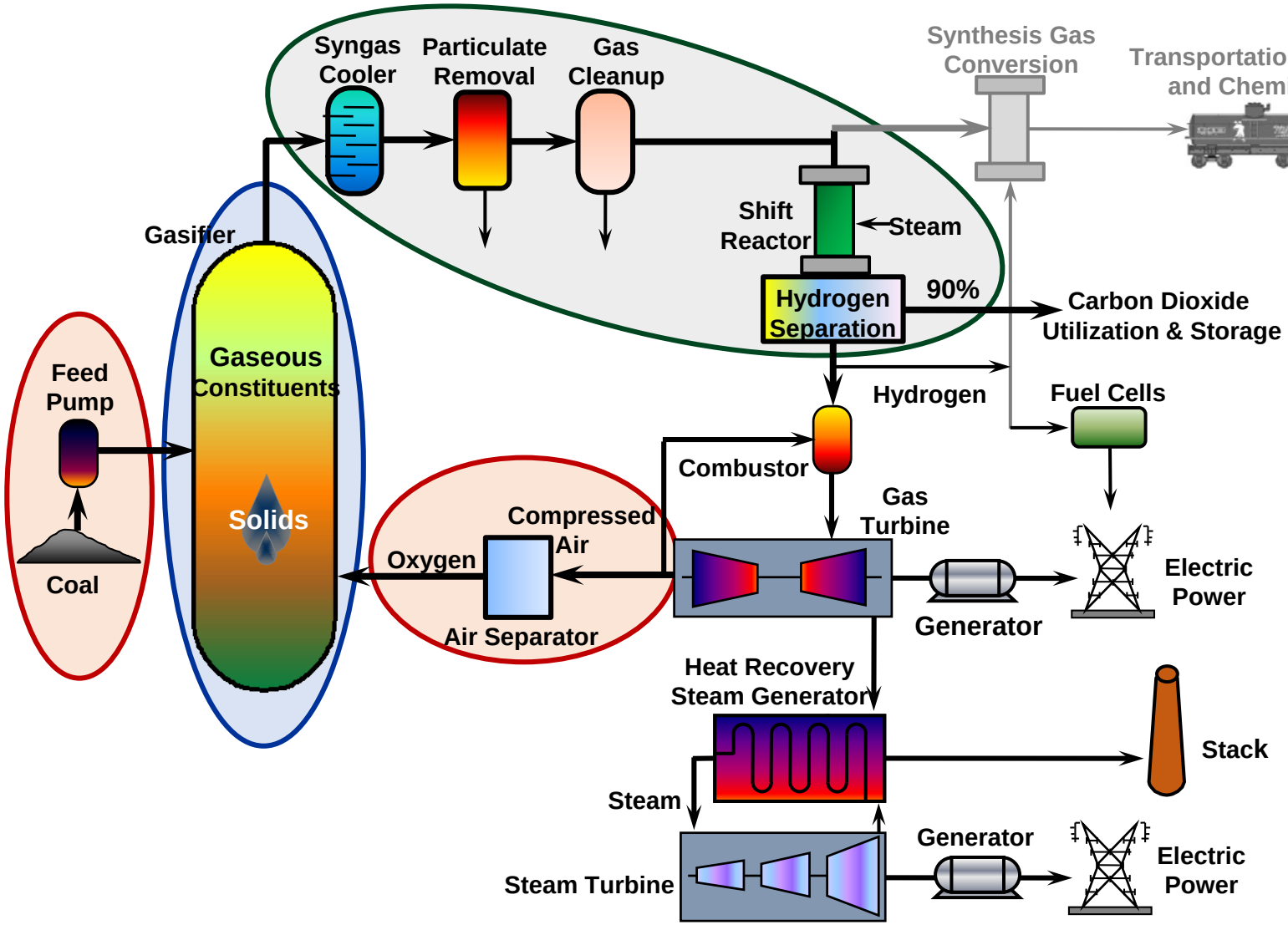
Gasifier Optimization and Plant Supporting Systems

- Improve reliability
- Increase efficiency and reliability, and improve economics

Syngas Supporting Systems

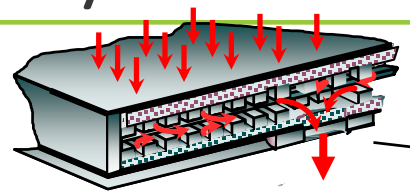
- Hydrogen and carbon dioxide separation
- Control multi-contaminants to extremely low levels
- Increase efficiency and reliability, and improve economics

Gasification Systems Program

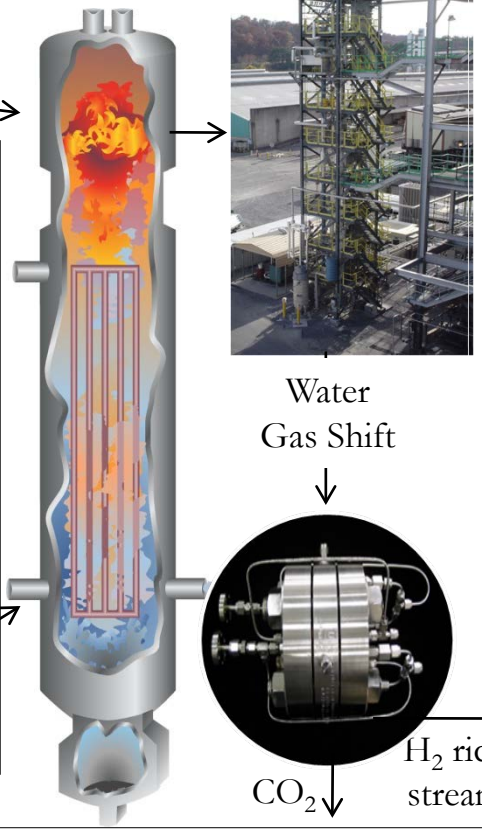


Feed Systems
Gasifier Optimization
Syngas Processing

Gasification Systems Program Projects



Oxygen



Water Gas Shift

H_2 rich stream

CO_2

FEED SYSTEMS

Bench Scale

GTI O_2 Production via Contactor
Praxair Hollow Fiber Air Separation
HiFunda ION-Electron Membrane
TDA Air Separation Systems
RTI O_2 Modular Systems
Thermosolv O_2 Modular Systems
USC O_2 Separation Fiber Membranes
APCI Advanced Cryogenic Air Separation

Pilot Scale

GTI Dry Coal Feed Pump
Praxair Oxygen Transport Membrane

SYNGAS PROCESSING SYSTEMS

Bench Scale

UK Chemical Looping
UW Catalytic Gasification
VPI Catalytic Gasification
TDA Small Particle Kinetic Benefits

Pilot Scale

RTI Warm Gas Cleanup
Alstom Chemical Looping
OSU Chemical Looping (x2)
TDA Integrated CO_2 Removal & WGS (x2)

GASIFIER OPTIMIZATION AND PLANT SUPPORTING SYSTEMS

Bench-scale

RIC Microbial Enhanced Coalbed Systems
RIC Process and Reaction Intensification
RIC Virtual Reactor Design, Validation, and Optimization
RIC Modular Studies
Montana St Opt. of Microbial Activity (x2)
Univ. of Utah Ceramic Proppant
SIU Optimized Microbial
PSU MECBM

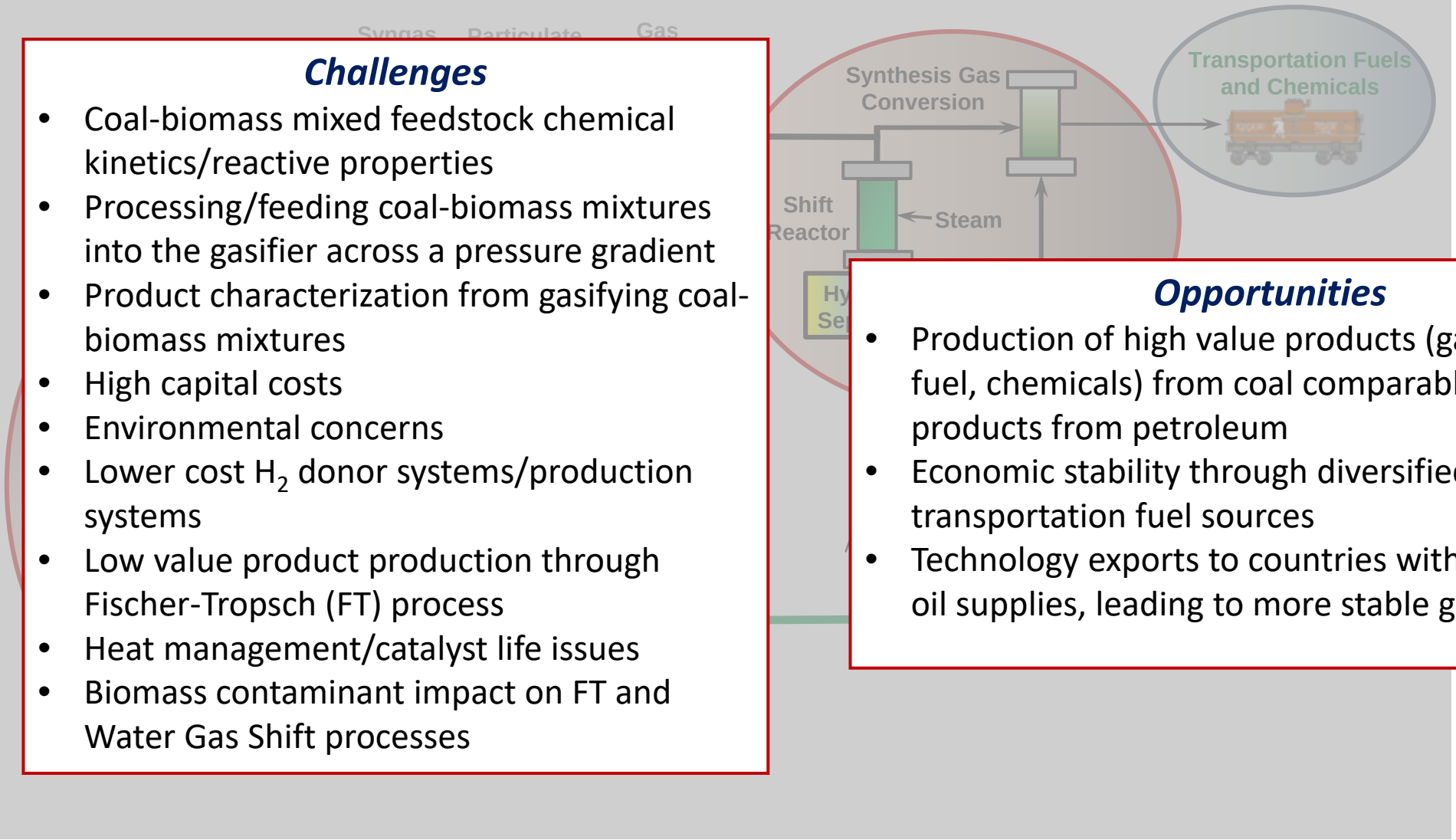
DOE Vision for Coal and Coal-Biomass to Liquids

- **Enable cost-competitive U.S. production of ultra-clean liquid transportation fuels (gasoline, diesel/jet fuel)**
  - At or below lifecycle greenhouse gas (GHG) emissions from conventional petroleum
- **Either drop-in fuels or refinery feedstock**
- **Combine fossil technologies with renewable or other low carbon footprint technologies to reduce overall GHG emissions impact**
- **Novel hydrogen production technologies**

TECHNOLOGIES EXIST TO DO THIS NOW – except for cost

NEED TO DEVELOP LOWER COST AND MORE EFFICIENT TECHNOLOGIES

Coal and Coal-Biomass to Liquids Technical Challenges and Opportunities



Challenges

- Coal-biomass mixed feedstock chemical kinetics/reactive properties
- Processing/feeding coal-biomass mixtures into the gasifier across a pressure gradient
- Product characterization from gasifying coal-biomass mixtures
- High capital costs
- Environmental concerns
- Lower cost H_2 donor systems/production systems
- Low value product production through Fischer-Tropsch (FT) process
- Heat management/catalyst life issues
- Biomass contaminant impact on FT and Water Gas Shift processes

Opportunities

- Production of high value products (gasoline, jet fuel, chemicals) from coal comparable to similar products from petroleum
- Economic stability through diversified transportation fuel sources
- Technology exports to countries with low domestic oil supplies, leading to more stable global oil prices

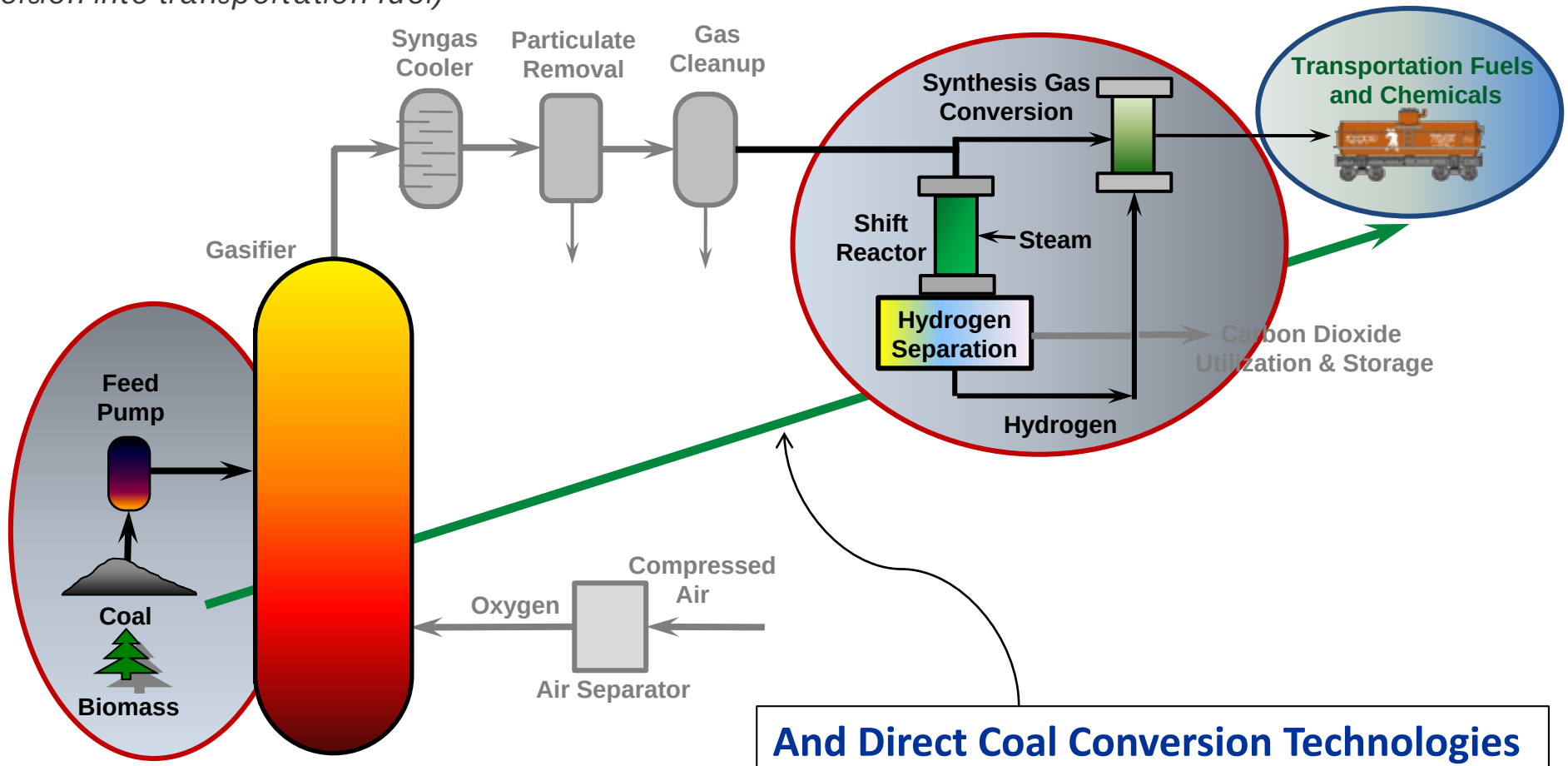
Coal and Coal-Biomass to Liquids Program

Key Technologies

- **Coal-Biomass Feed and Gasification –** Use of biomass mixed with coal to reduce the greenhouse gas (GHG) impact of traditional coal to liquids (CTL) approaches, technologies of interest include:
  - Coal-biomass feed systems
  - Optimization of coal-biomass gasification, and use of resultant syngas
- **Advanced Fuels Synthesis –** Catalyst and reactor optimization for producing liquid hydrocarbon fuels from syngas resulting from gasification of coal-biomass mixtures, technologies of interest include:
  - Advanced syngas processing through intensification/co-production/co-feeding in a Fischer-Tropsch plant to produce (primarily) diesel fuel
  - Improvements to direct coal liquefaction (DCL) processes
  - Hybrid systems using a combination of DCL and syngas-based liquid fuel production (may also include co-production/co-feeding systems)
  - GHG emission reduction technologies other than carbon capture and storage or biomass co-feed

Coal and Coal-Biomass to Liquids Program

Gasification-Based Technologies: Coal-Biomass Feed and Gasification, and Advanced Fuels Synthesis (syngas conversion into transportation fuel)



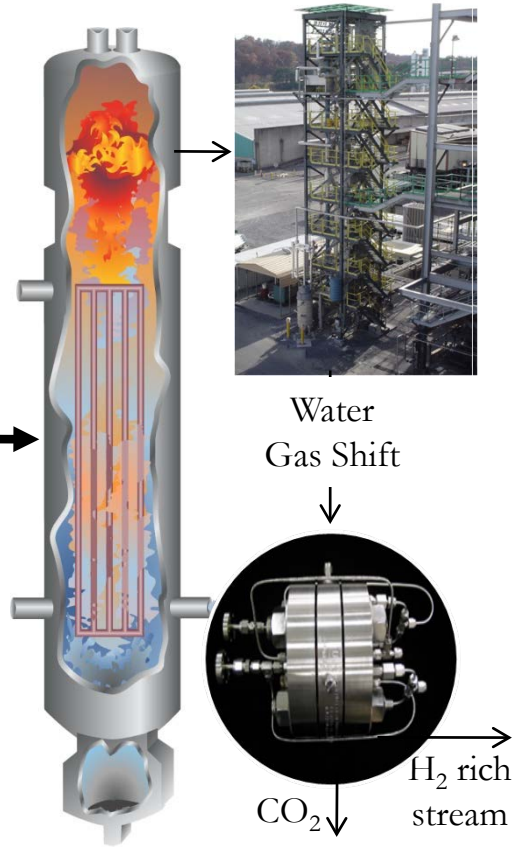
KEY: Gray shaded areas are not applicable to C&CBTL Program

And Direct Coal Conversion Technologies (which don't use gasification at all)

C&CBTL Program Projects

COAL-BIOMASS FEED AND GASIFICATION

Princeton	Synthetic Jet Fuel Production from Lignite/Biomass w/ CO2 Capture
Battelle	Direct CTL Jet Fuel from Biomass Derived Solvents



ADVANCED FUELS SYNTHESIS

Bench Scale

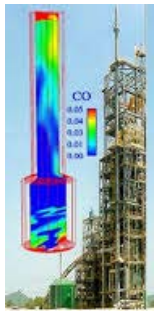
RTI	Hybrid CTL Process
Altex	GHG-reduced CBTL Jet Fuel Process
Cerametec	GHG Reduction and Cost-Competitive Mil-Spec Jet Fuel from CTL
H-Quest	Wave Liquefaction Machanisms for Coal/Biomass Jet Fuel Production
SRI	Indirect Liquefaction of Coal-Biomass for Jet Fuel Production
TDA	Poison Resistant WGS Catalysts for Biomass/Coal Gasification
RIC	FT Catalyst Development and Testing
RIC	Biomass to Syngas Reactor Application and Validation
RIC	Modular Studies

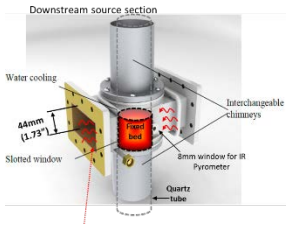
Pilot Scale

UK	C&CBTL Gasification and Syngas Conversion via FT

RIC: NETL's Research and Innovation Center

Modular Systems : NETL-RIC Research Areas





- **Microbial Enhanced Coalbed Systems (MECS)**
  - Coal-to-Methane Characterization and Stimulation
  - Micro-Field Laboratory
- **Process and Reaction Intensification**
  - Microwave Reactions for Gasification
  - Non-Traditional Thermal Reactors
  - Enabling Materials and Manufacturing Technologies
  - Gasification Test Stand
  - Oxygen Carrier Development
  - Fischer-Tropsch Catalyst Development and Testing
  - CHP Reactor Design, Construction, and Testing
  - CTL Reactor Design, Construction, and Testing
- **Virtual Reactor Design, Validation, and Optimization**
  - Simulation-Based Optimization Toolset
  - CFD Application and Validation for Chemical Looping Devices
  - Biomass to Syngas Reactor Application and Validation
- **Defining and Evaluating Modular Performance and Cost Metrics**
  - Gasification Feasibility Study for 1 MWe Coal to Power
  - C&CBTL Feasibility Study for 1MWe Coal to Liquids
  - A 1 MWe Coal to Heat and Power Process with Improved Economics
  - A 1 MWe Coal to Liquids Process with Improved Economics

Modular Gasification-Based Energy Systems Workshop

- **Being held tomorrow 10:15am – 4:00pm**
- **Will consist of two distinct sessions**
  - Morning session will be a panel discussion on the past, present, and future of modular energy systems
  - Afternoon session consist of several breakout session covering modular energy system topics including
    - Regional/location-based niche opportunities - Markets and products
    - Component level R&D needs
    - Roadmap development
- **Please plan to join us for this timely workshop**

Questions?

For more information, please contact:

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