Natural Gas-Biomass to Liquids Workshop

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Technical Barriers and Greenhouse Gas Emissions/ Resource Potential

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Motivation for the Workshop

- The recent development of the increased availability of low cost natural gas has increased opportunities to consider the use of natural gas as a feedstock for conversion into liquid hydrocarbons (GTL).

- Co-conversion of natural gas with biomass (GBTL) has the potential of increasing yield of liquid product while also having lower greenhouse gas emissions relative to petroleum.

- DOE is interested in further understanding how the use of natural gas and biomass may be optimized and integrated into a conversion process to produce liquid fuels.
  - Office of Energy Efficiency and Renewable Energy
  - Office of Fossil Energy
  - ARPA-E

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Bioenergy Technologies Office Overview (BETO)

Mission: Through targeted RDD&D, enable sustainable, nationwide production of advanced biofuels that that will displace a share of petroleum-derived fuels, mitigate climate change, create American jobs, and increase U.S. energy security.

Research, Development, Demonstration, & Deployment

Feedstock Supply

Develop sustainable, secure, reliable, and affordable biomass feedstock supply.

Conversion R&D

Develop commercially viable technologies for converting biomass feedstocks into fungible, liquid transportation fuels, bioproducts and chemical intermediates

Demonstration & Deployment

Demonstrate and validate integrated technologies with successful construction and operation of cost-shared pilot, demonstration, and commercial scale facilities

Cross Cutting

Sustainability

Promote the positive economic, social, and environmental effects, while reducing potential negative impacts of biofuels

Strategic Analysis

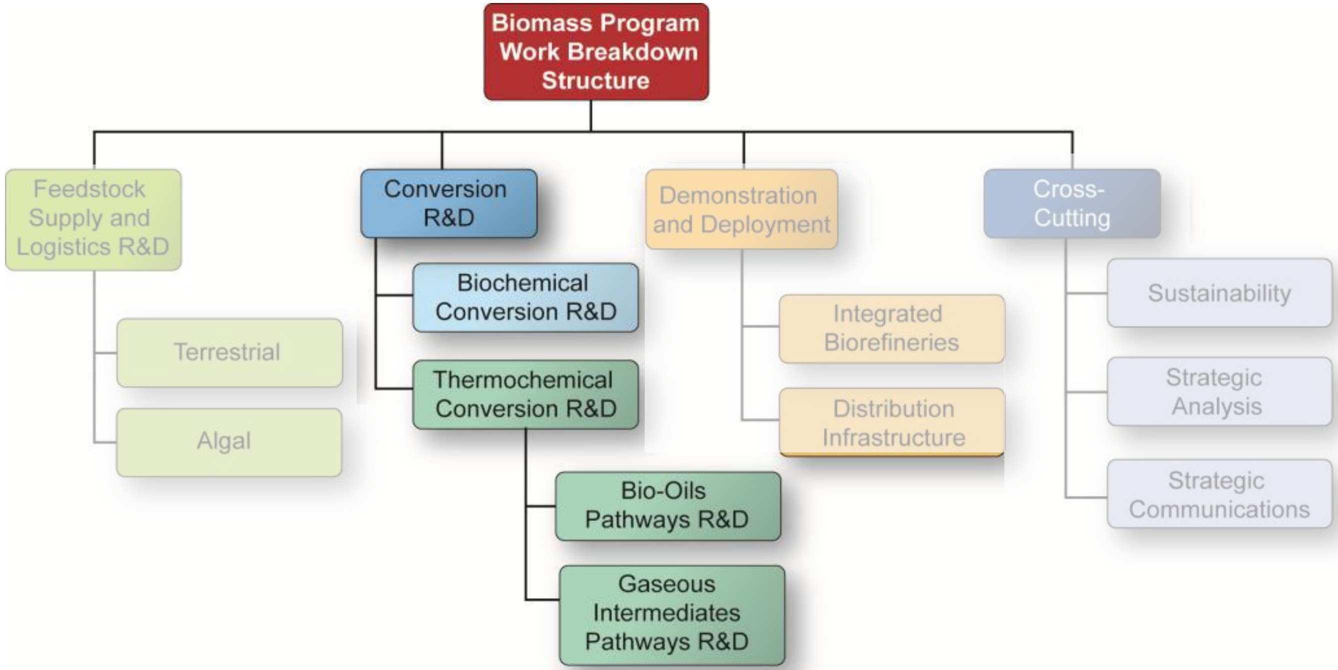
Provide context for decisions by establishing quantitative metrics, tracking progress toward goals, and informing portfolio planning and management

Conversion R&D

Conversion R&D is focused on developing commercially viable technologies to convert terrestrial and algal feedstocks into liquid fuels, as well as bioproducts and biopower.

Biochemical Conversion R&D efforts focus on pathways for producing sugars and other carbohydrate intermediates, from biomass followed by conversion to finished fuels.

Thermochemical Conversion R&D is focused on pathways producing bio-oil and gaseous intermediates from biomass followed by upgrading to finished fuels.



Life Cycle Analysis

- GREET model (Argonne National Laboratory) used to account for GHG emissions along entire supply chain
- Process: biomass gasification, blending of synthesis gas and natural gas, followed by Fischer-Tropsch conversion of synthesis gas to diesel
- Biomass feedstock: corn stover, conversion efficiency 60 gallons/ton
- Methane leakage: 1.19% (recovery 0.44%, processing 0.16%, transmission 0.36%, distribution 0.23%) – Source: EPA 2013 GHG Inventory
- Cases: with and without electricity co-production (from medium grade steam), with and without carbon capture and sequestration (90% capture from conversion facility)
- Similar analysis done by DOE-NETL, Iowa State University, and Princeton University

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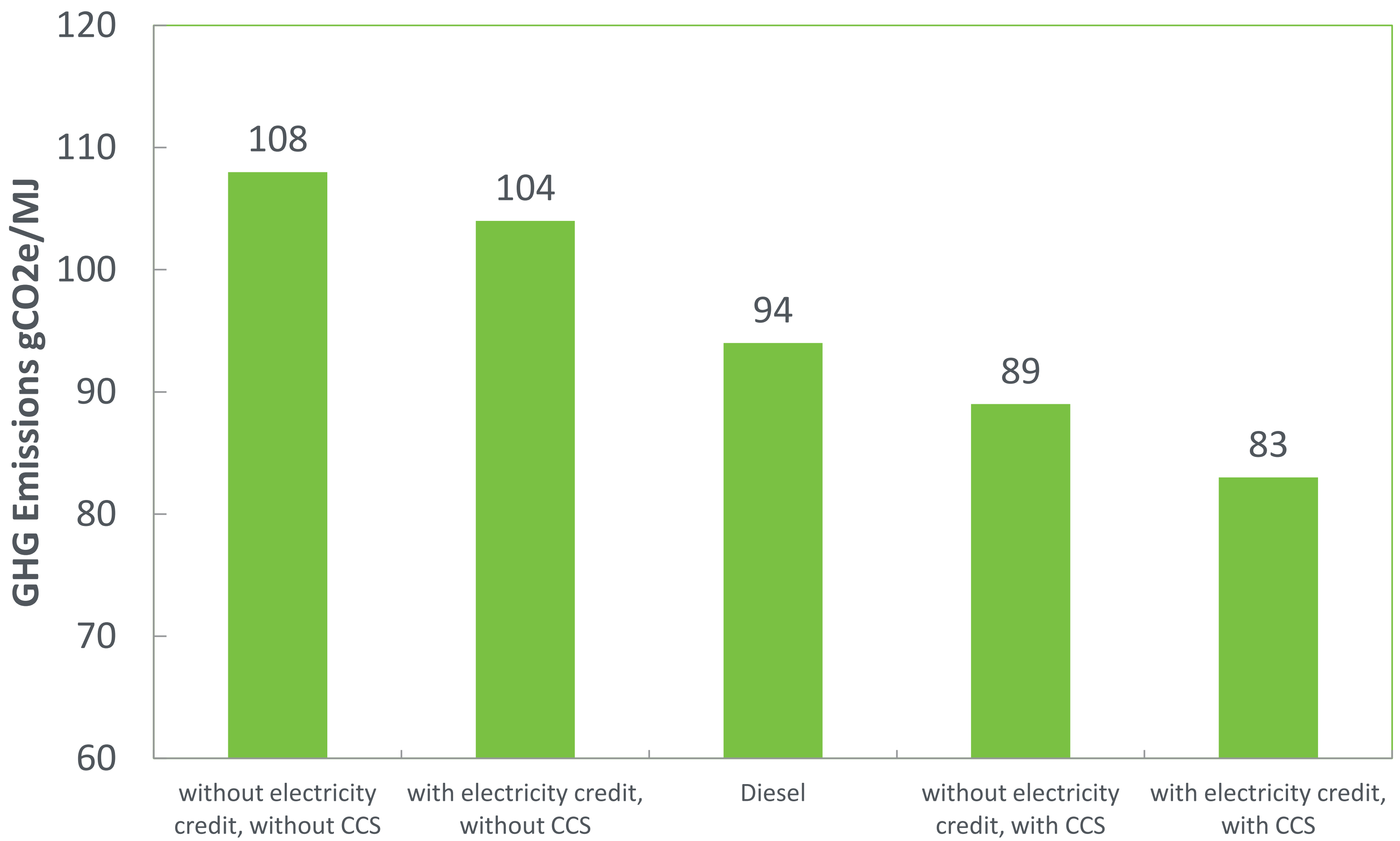
Preliminary LCA Results – GTL GHG Emissions – No Biomass



- If CCS is not utilized then GTL GHG emissions can be higher than diesel with no biomass
- The use of CCS (90% carbon removal) results in GHG emissions below diesel
- Source: GREET Model, Argonne National Laboratory

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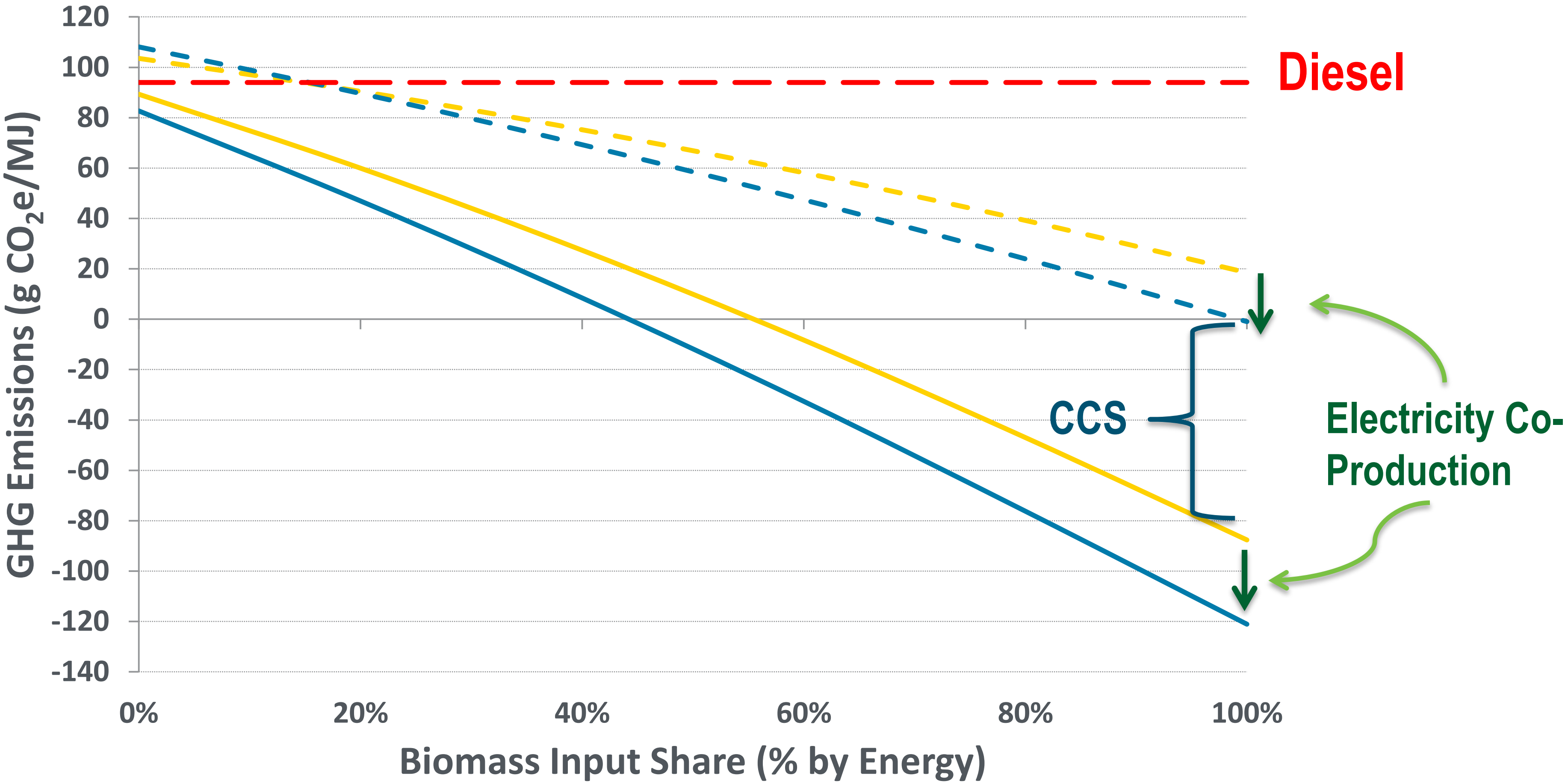
Preliminary Results – GHG as a Function of Biomass Shares



- If CCS is not used, a GHG reduction of 50% below diesel baseline can be achieved with about 65% biomass input (by energy)
- If CCS is used then a GHG reduction of 50% below diesel baseline can be achieved with about 30% biomass input (by energy)
- Source: GREET Model, Argonne National Laboratory

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Department of Energy: Fossil Energy(FE)/NETL

Services
Petroleum Reserves
International Cooperation
Natural Gas Regulation
Advisory Committees

Science & Innovation
Clean Coal
Carbon Capture and Storage
Oil & Gas

Plays a key role in helping the United States meet its continually growing need for secure, reasonably priced and environmentally sound fossil energy supplies

Primary mission is to ensure the nation can continue to rely on traditional resources for clean, secure and affordable energy while enhancing environmental protection

Features RD&D activities that made significant advancements in the areas of fossil conversion to liquid fuels and chemicals

Supporting work to reduce the carbon footprint of coal derived liquids by incorporating the co-feeding of biomass and carbon capture

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DOE FE Studies Add National Perspective

CTL/CBTL/GTL Analysis Results	Fact	Fiction
CTL/CBTL/GTL with Carbon Capture and Storage Produces more CO_2 than the Average of U.S. Refineries		✓
Lower Life Cycle GHG Emissions than 2005 Petroleum Baseline	✓	
Lower Life Cycle GHG Emissions than Venezuelan Heavy Crude	✓	
Co-gasifying Coal with non-Food Source Biomass (~30% by wt) Can Reduce GHG Emissions 60% Below Petroleum Baseline	✓	
Will Not Compete for Food-based Biomass Resources	✓	
FT Fuels from CTL/CBTL/GTL Plants with CCS will Contribute to National Climate Change Reduction Goals	✓	

Providing Balanced Solutions Today to Meet Tomorrows Challenges

Natural Gas and Biomass to Liquids (GBTL) scenarios have not been directly modeled as part of the current research. Based on CBTL research, addition of biomass is anticipated to lower GHG emissions while increasing product costs (due to higher biomass feedstock costs).

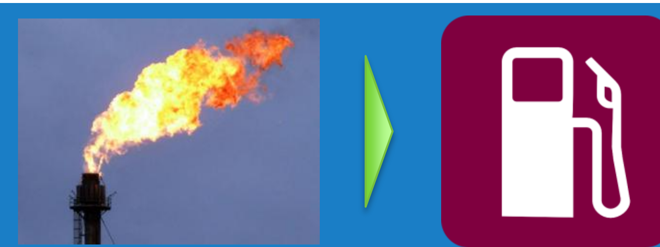
ARPA-E REMOTE: Reducing Emissions using Methanotrophic Organisms for Transportation Energy

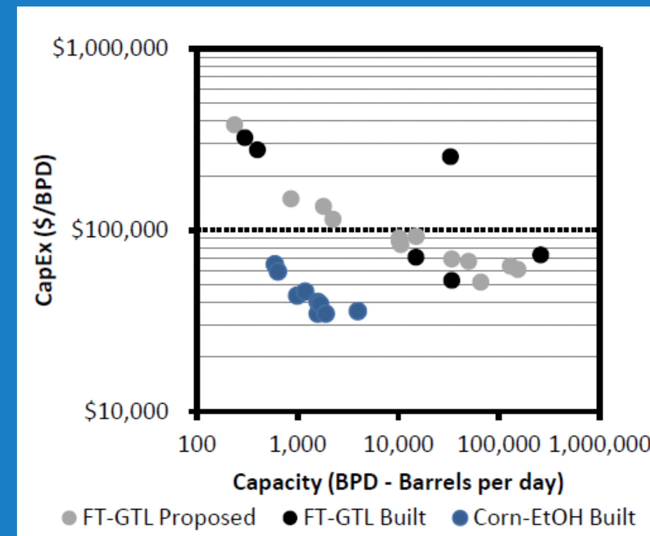
MOTIVATION

- Increasing price spread between natural gas and petroleum on an energy basis encourages natural gas use in transportation.
- Current GTL is challenged by high capital costs and technologically complex processes.
- Bioconversion of methane is a viable option for GTL **if technologies addressing energy efficiency, carbon yield, and kinetics are developed.**

OBJECTIVES

- **New Biocatalysts (CAT 1 & 2):**
  - Develop new, more efficient biological routes to activate methane.
  - Engineer metabolic pathways to convert activated methane to liquid fuel with high energy density.
- **New Bioreactors/Processes (CAT 3):**
  - Develop process intensification for methane bioconversion.





CATEGORY 1: High-Efficiency Biological Activation of Methane

CATEGORY 2: High-Efficiency Biological Synthesis of Fuel

CATEGORY 3: Process Intensification Approaches for Biological Methane Conversion

CHANGING WHAT'S POSSIBLE

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ARPA-E MOVE: Methane Opportunities for Vehicular Energy

- **Mission**
- Low-cost natural gas storage technologies that will enable the widespread use of natural gas passenger cars

Program Director	Dr. Dane Boysen
Year	2012
Projects	13
Total Investment	$30 Million

Goals

- 5-yr payback for light-duty natural gas vehicles (assuming $2/GGE fuel price spread)
- Conformable tanks
- Convenient, low-cost at-home refueling

Approaches

Minimize system cost for compression and storage

Approach 1: Low pressure storage (< 500 psi)

- Sorbent materials with energy density equal to CNG

Approach 2: High pressure storage (3,600 psi)

- High strength, conformable tanks with low cost home compression

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ARPA-E Open FOA 2012: GTL Projects

Pratt & Whitney, Rocketdyne – Turbo-POx For Ultra Low-Cost Gasoline

- Compact, high pressure partial oxidation gas turbo expander for incorporation into GTL process
- Benefits: rapid production of syngas, competitive production of gasoline, co-produce power, access to stranded resources

U. Colorado – Atomic Layer Deposition for Creating Liquid Fuels from NG

- Microstructure reactors created by ALD
- Benefits: reduce manufacturing complexity, reduce heat transport distance, ALD promotes full utilization of metal catalyst

MIT – Small and Efficient Reformer for Converting NG to Liquid Fuels

- Compact GTL using engine-based reformer
- Benefits: off-the-shelf equipment, distributed generation

Bio2Electric – Methane Converter to Electricity and Fuel

- Electrochemical catalytic oxidative coupling of methane (OCM) to ethylene
- Benefits: generates electricity, different product stream than syngas, access to stranded resources

GTI – Methane to Methanol Fuel: A Low Temperature Process

- Continuous regeneration of metal oxide catalyst in a NiMH battery at RT
- Benefits: methanol in water – potential use as a biological feedstock, hydrogen as a co-product, access to stranded resources

Ceramatec – NG Reactor for Remote Chemical Conversion

- Catalytic conversion of NG to benzene and H_2
- Benefits: reduce benzene raw material cost, maintain US leadership in $50B market w/ 4% growth, access to stranded resources

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Today's Mission

- The objective of this workshop will be to obtain input from industry, academia, research establishments, and other experts to identify the pre-competitive R&D and scale-up challenges to commercializing GBTL.
  - Focus ***more*** on more clearly defining the ***problems***
  - Focus ***less*** on potential ***solutions***

- To enable networking and collaboration for stakeholders in this emerging area.

- The feedback generated today will be made available shortly after this event.

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Workshop Process

- To enable fruitful discussion, today's workshop will be broken up into two tracks:
  - Technical Barriers
  - Greenhouse Gas Emissions and Resource Potential
- Questions will be discussed first at tables, then as a group within each track.
  - Please elect a 'reporter' to capture your table's ideas and share your thoughts with the room.
- Notetakers are in each room to capture discussion in detail.
- A general session will close the day so each track can report out.
  - The general session presentation will need one reporter to present from each track.
  - Allows participants to hear and reflect the comments in the other track

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Agenda – GHG Emissions/Resource Potential

11:00 a.m. – 11:30 a.m.	*Opening Welcome Session*
11:30 a.m. – 12:30 p.m.	*Networking Lunch*
12:30 p.m. – 12:40 p.m.	GHG Emissions
12:40 p.m. – 12:50 p.m.	Baseline Assumptions
12:50 p.m. – 1:00 p.m.	Geospatial Availability
1:00 p.m. – 2:00 p.m.	Report Out and Open Discussion
2:00 p.m. – 2:30 p.m.	*Break*
2:30 p.m. – 2:40 p.m.	Price Sensitivity
2:40 p.m. – 2:50 p.m.	Gas Processing
2:50 p.m. – 3:00 p.m.	Natural Gas Benefits
3:00 p.m. – 3:30 p.m.	Report Out and Open Discussion
3:30 p.m. – 3:40 p.m.	Techno-economic Analysis
3:40 p.m. – 3:50 p.m.	Plant Size
3:50 p.m. – 4:00 p.m.	Other Technologies
4:00 p.m. – 4:30 p.m.	Report Out and Open Discussion
4:30 p.m. – 4:45 p.m.	*Break*
4:45 p.m. – 5:15 p.m.	*General Session Report Out*

Agenda – Technical Barriers

11:00 a.m. – 11:30 a.m.	*Opening Welcome Session*
11:30 a.m. – 12:30 p.m.	*Networking Lunch*
12:30 p.m. – 12:40 p.m.	Feeding Systems
12:40 p.m. – 12:50 p.m.	Methane Activation
12:50 p.m. – 1:00 p.m.	Catalyst development (for biomass integrated with natural gas)
1:00 p.m. – 2:00 p.m.	Report Out and Open Discussion
2:00 p.m. – 2:30 p.m.	*Break*
2:30 p.m. – 2:40 p.m.	Product/Scale Choices and Optimization
2:40 p.m. – 2:50 p.m.	Novel Technologies
2:50 p.m. – 3:00 p.m.	Capital Costs
3:00 p.m. – 3:30 p.m.	Report Out and Open Discussion
3:30 p.m. – 3:40 p.m.	Deployment Challenges
3:40 p.m. – 3:50 p.m.	Techno-economic Analysis
3:50 p.m. – 4:30 p.m.	Report Out and Open Discussion
4:30 p.m. – 4:45 p.m.	*Break*
4:45 p.m. – 5:15 p.m.	*General Session Report Out*

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Rules for the Day

- Everyone should have the opportunity to speak; no wrong ideas.
- There will be no attribution to comments (Chatham House Rules).
- Index cards on the table can be used to capture additional thoughts.
- No need to reach a consensus, looking for all perspectives.
- Creative thinking and discussion is encouraged; however focus on the overall topic (challenges of co-conversion)
  - For each question, there are examples to catalyze the discussion.
  - Latitude to go beyond the examples.
  - Additional issues and thoughts may be raised and held in a “Parking Lot” to be addressed during open discussion as time allows.
- Please be considerate with respect to use of electronics.

Thank you !

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