U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Webinar: The Potential for Natural Gas to Enhance Biomass Technologies

Bioenergy Technologies Office

February 6, 2014
1:00 – 2:00 p.m.

Agenda

- Overview and Introduction
  - Katherine Barno, BCS, Inc.
- Bioenergy Technologies Office
  - Zia Haq and Prasad Gupte
- Advanced Research Projects Agency-Energy
  - Chad Haynes and Anthony Augustine
- Office of Fossil Energy/National Energy Technology Laboratory
  - Timothy Skone
- Question & Answer Session

Questions and Comments

Please type any questions into the question box during the webinar. The presenter(s) will answer as many as possible during the Q&A period at the end.

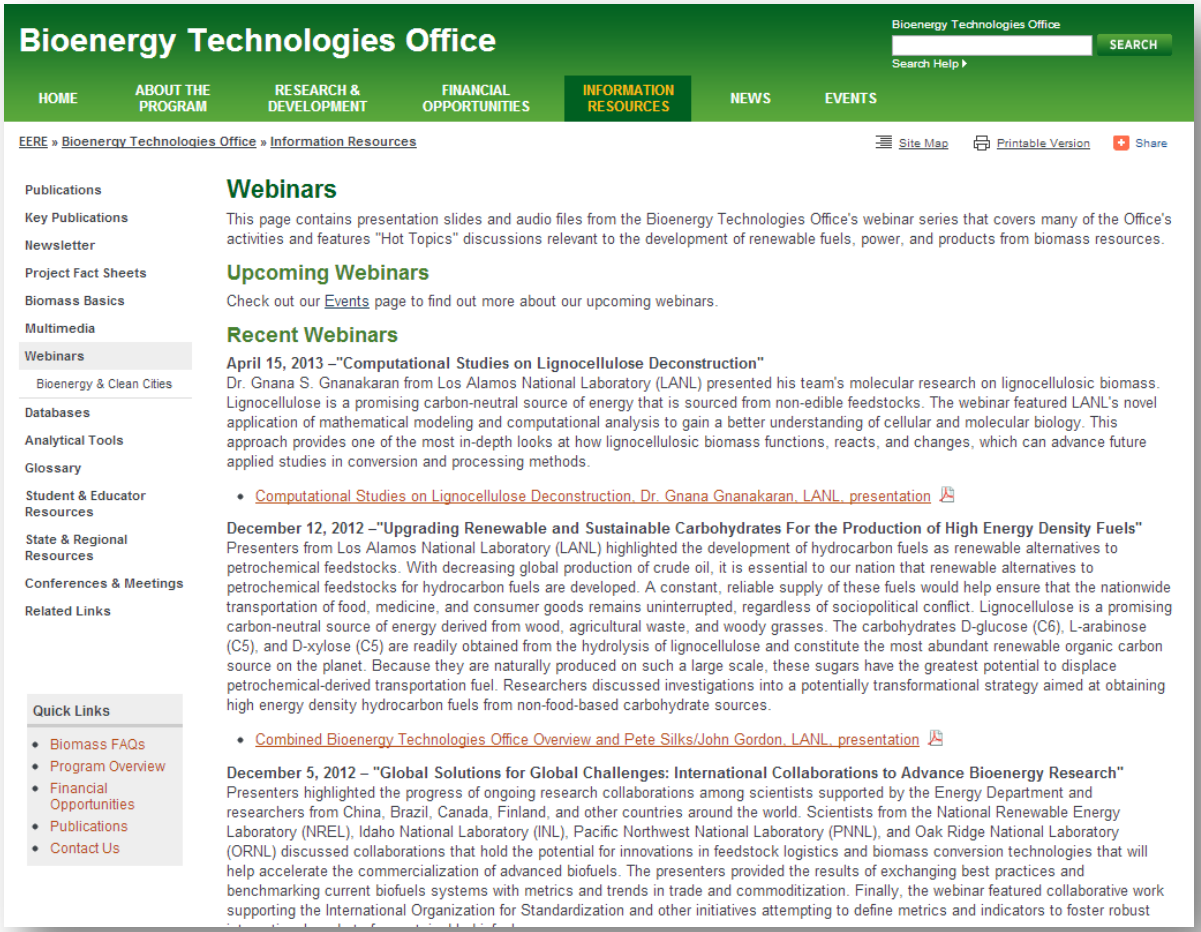
All slides from this presentation will be posted online within three weeks: www.eere.energy.gov/bioenergy/webinars.html

For general questions regarding the Bioenergy Technologies Office, please email us at: eere_biomass@ee.doe.gov

Bioenergy Technologies Office (BETO) Webinar Series

Started in May 2010 to highlight “hot topics” in biomass and bioenergy industry.

Find past webinars and today’s slides on the Office’s website: bioenergy.energy.gov/webinars.html



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BETO Vision, Mission, and Strategic Goal

Vision

A viable, sustainable domestic biomass industry that:

- Produces renewable biofuels, bioproducts, and biopower
- Enhances U.S. energy security
- Reduces our dependence on oil
- Provides environmental benefits, including reduced greenhouse gas (GHG) emissions
- Creates economic opportunities across the nation

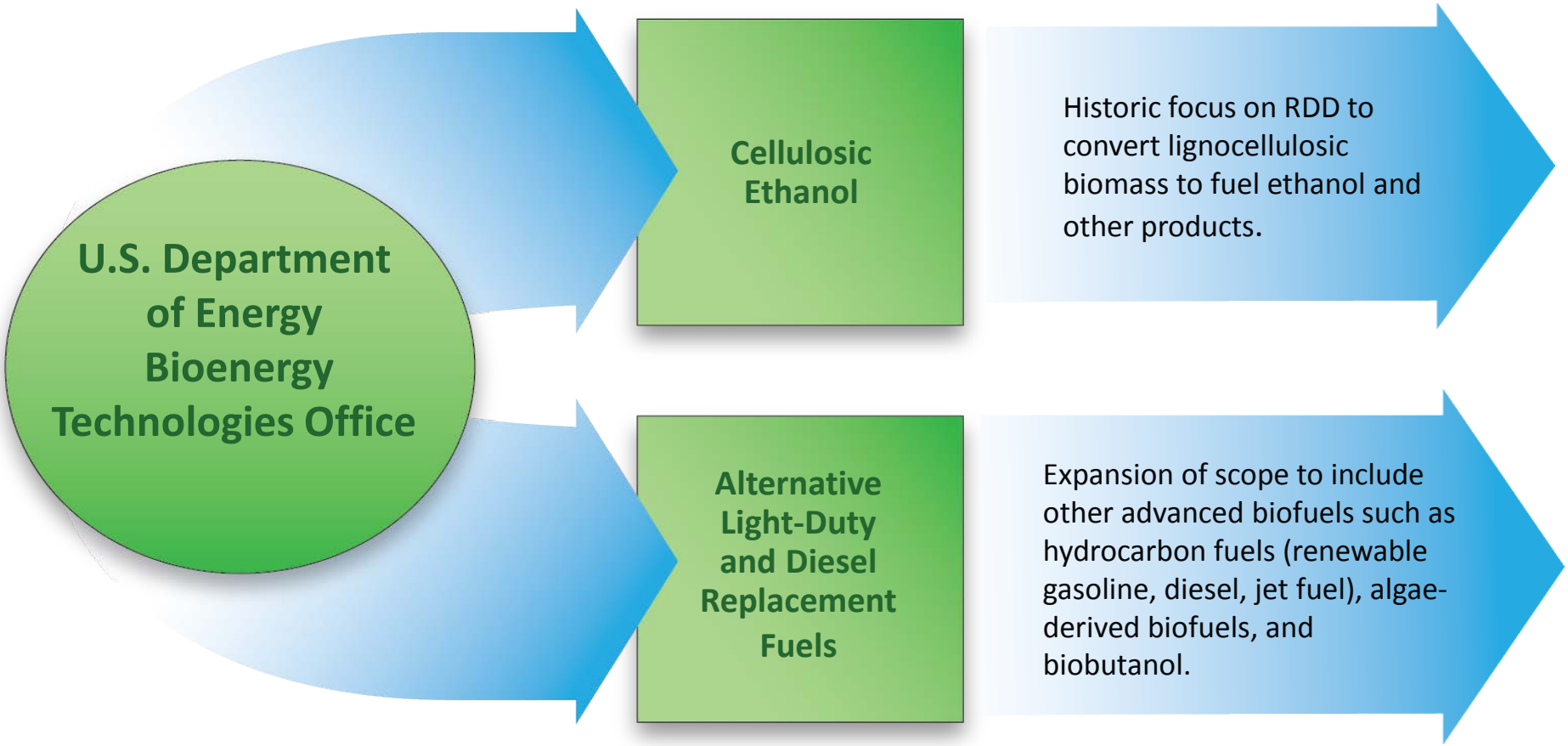
Mission

Develop and transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, and demonstration at increasing scales supported through public and private partnerships.

Strategic Goal

Develop commercially viable biomass technologies to enable the production of biofuels nationwide and reduce dependence on foreign oil through the creation of a new domestic bioenergy industry, thus supporting the EISA goal of 36 billion gallons per year of renewable transportation fuels by 2022, and increase biopower's contribution to national renewable energy goals by increasing biopower generating capacity.

Expanding Scope



The Bioenergy Technologies Office forms cost-share partnerships with key stakeholders to develop, demonstrate, and deploy technologies for advanced biofuels, bioproducts, and biopower from lignocellulosic and algal biomass.

The Role of Bioenergy

1. The need to reduce dependence on foreign oil and lower GHG emissions has renewed the urgency for developing sustainable biofuels, bioproducts, and biopower.

2. The transportation sector accounts for about two-thirds of U.S. oil consumption and contributes to one-third of the nation's GHG emissions.

3. Near-term, biomass is the only renewable resource that can supplement petroleum-based liquid transportation fuels, while reducing GHG emissions.

Biomass includes agricultural residues, forest resources, perennial grasses, woody energy crops, wastes (municipal solid waste, urban wood waste, and food waste), and algae, as well as other sources. It is unique among renewable energy resources in that it can be converted to fuels and chemicals—in addition to power.

The Potential for Natural Gas to Enhance Biomass Technologies

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Technical Barriers and Greenhouse Gas Emissions/Resource Potential

Zia Haq and Prasad Gupte
Department of Energy
Bioenergy Technologies Office

Motivation for the Workshop

- Increased availability of low cost natural gas
- Co-conversion of natural gas with biomass (GBTL) in order to increase yields while lowering 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
- Objective of workshop was 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

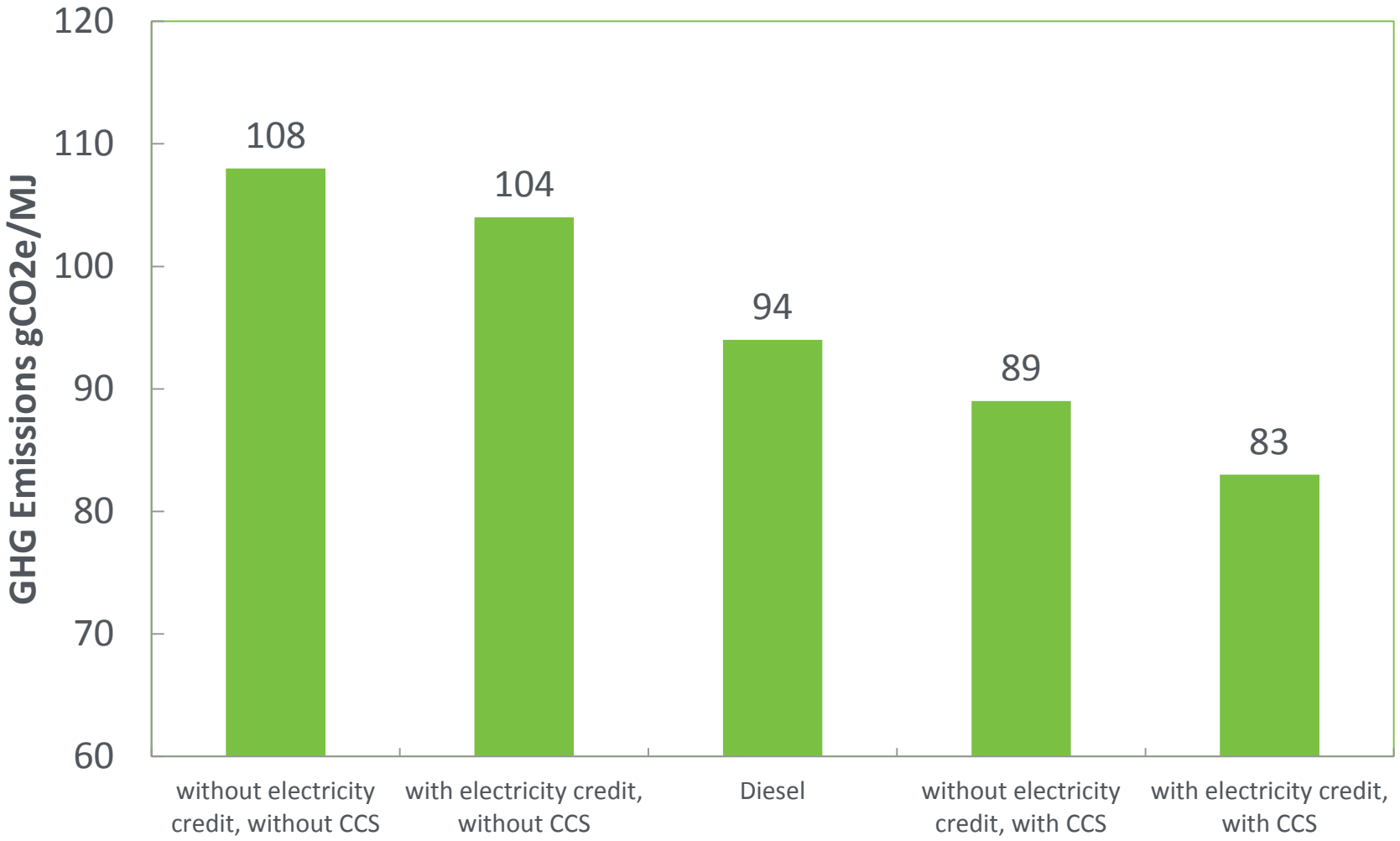
Workshop Attendees

Verdigris Capital

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

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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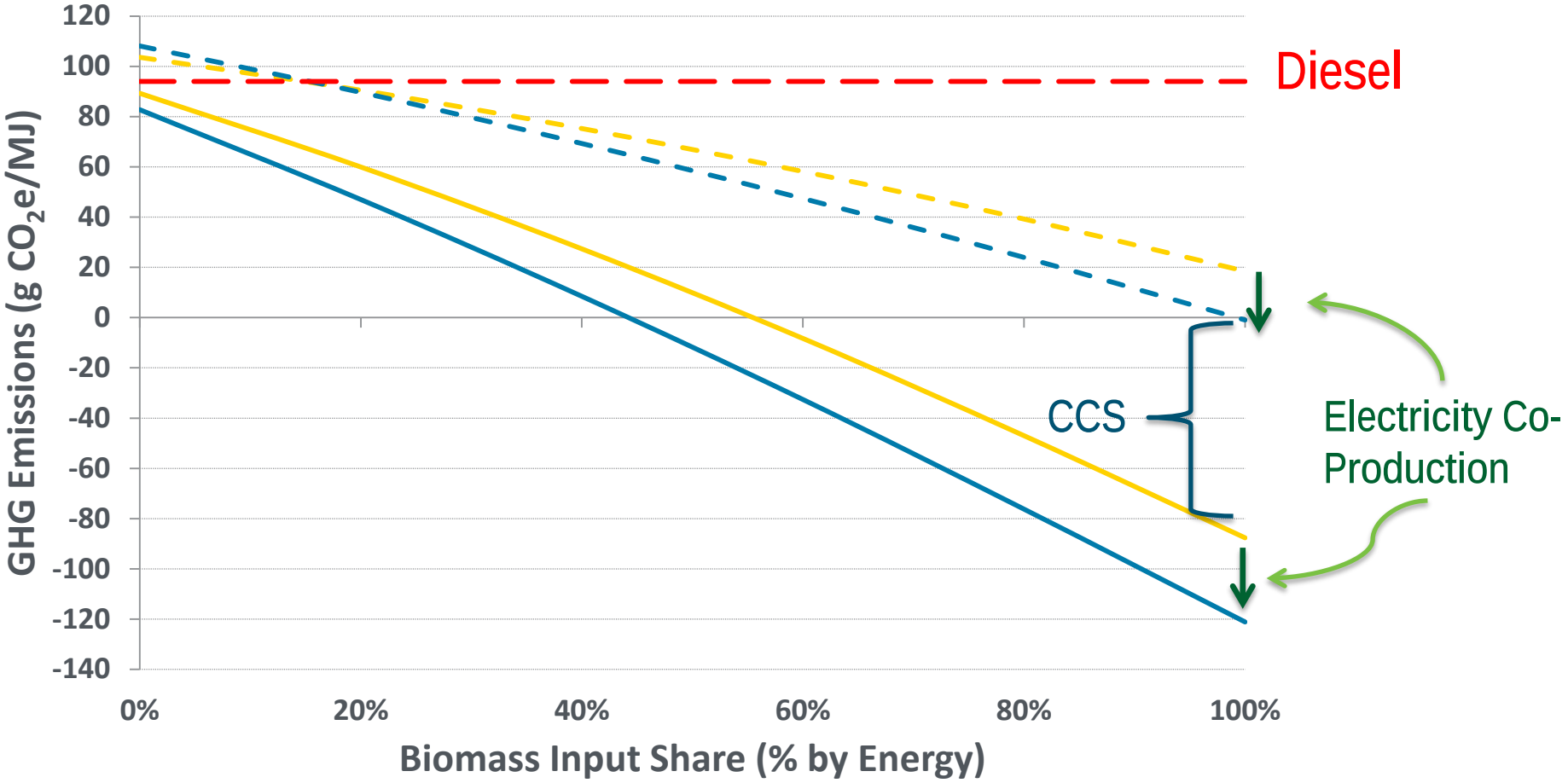
Preliminary Results – GHG as a Function of Biomass Shares



- 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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Results

- Key takeaways from workshop:
  - Rationale for integrating biomass and natural gas resources to produce liquid transportation fuels is: greenhouse gas reduction and the need for a specific C/H ratio in the fuel
  - GBTL processes can produce transportation fuels with 50% lower GHG emissions if substantial amounts of lignocellulosic biomass is co-processed with natural gas
  - GBTL processes have significantly higher yields than processes converting only biomass
  - Stranded biomass and stranded natural gas offer near-term opportunities to utilize currently unutilized feedstocks
  - Research challenges: down-scaling GTL systems, improved catalysts, biochemical conversion processes, feeding biomass into pressurized systems, production of co-products, and many more.

Contact Information

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Department of Energy: Advanced Research Projects Agency-Energy

Chad Haynes, SETA

Anthony Augustine, T2M Advisor

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Methane Bioconversion via REMOTE: Reducing Emissions using Methanotrophic Organisms for Transportation Energy

Ramon Gonzalez, Program Director

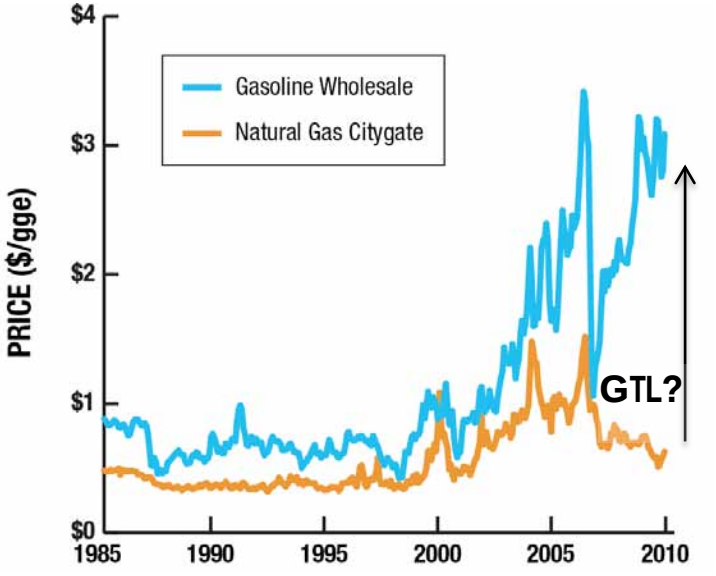
Ramon.gonzalez”at”hq.doe.gov

Chad Haynes, SETA

Anthony Augustine, T2M Advisor

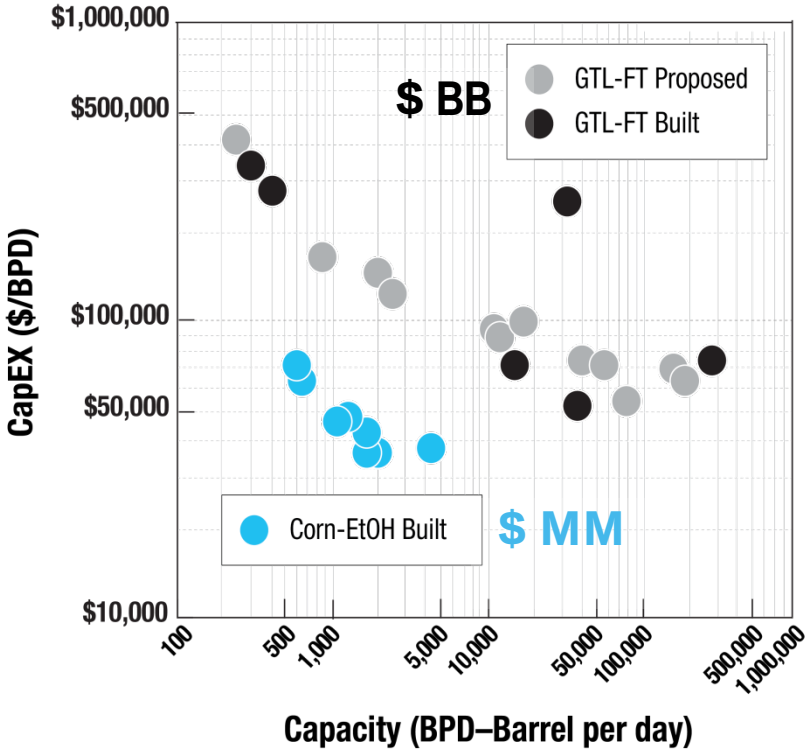
Opportunity for CH_4 Bioconversion

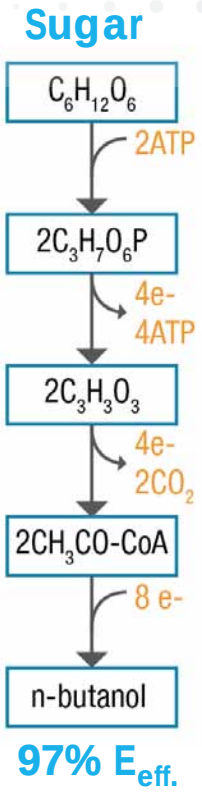
Natural gas and petroleum: Price spread



But what about high CapEx of GTL?

Bioconversion: Low CapEx & high efficiency



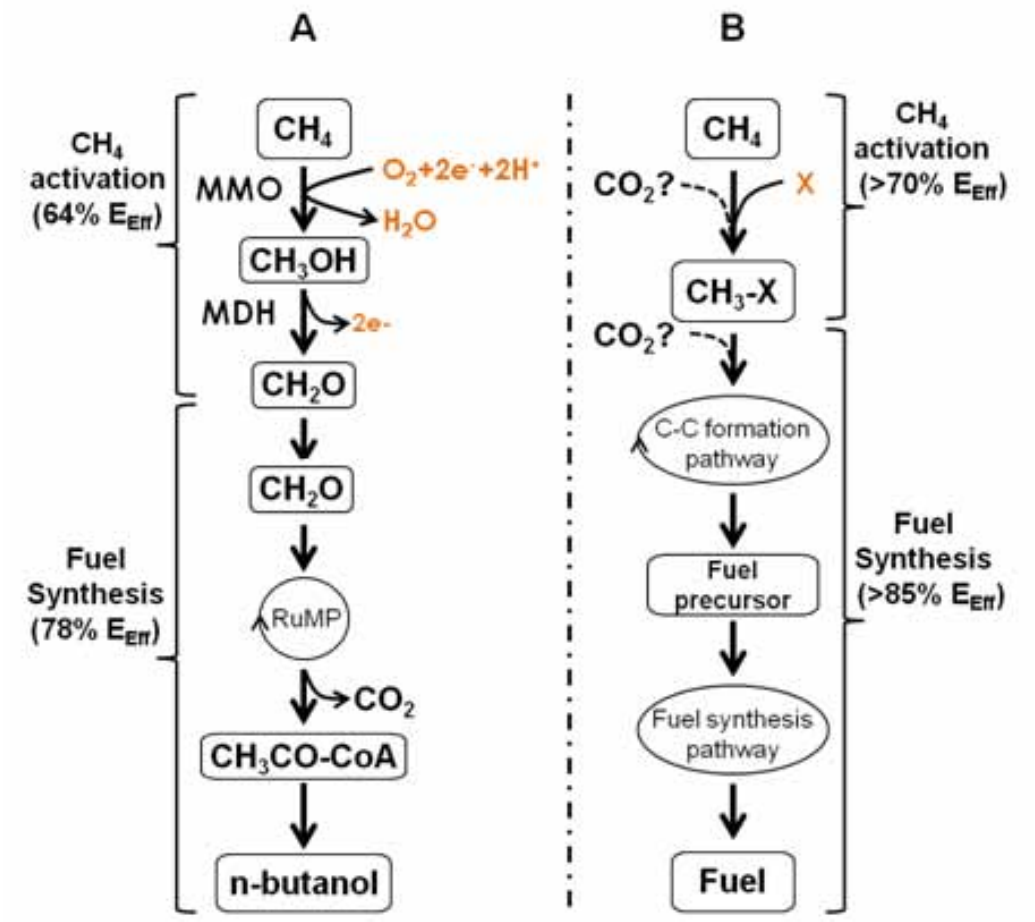


Gonzalez & Haynes, 2013. *Nat. Chem. Biol.*; Conrado & Gonzalez, 2013. *Science* (MSs under review)

Natural Gas Bioconversion (REMOTE*)

Ramon Gonzalez: Program Director, ARPA-E

Reconceptualizing methane bioconversion



New Biocatalysts

- C & E efficiency
- Kinetics

New Bioreactors & Processes

- Mass & heat transfer
- Kinetics

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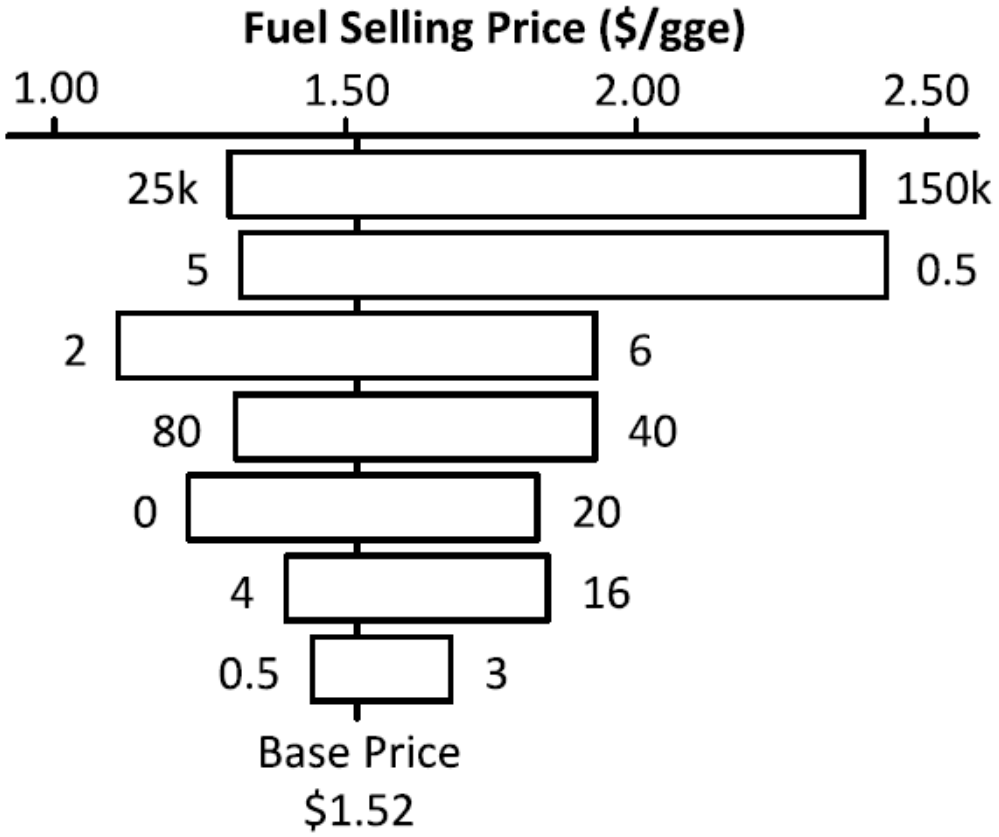
*REMOTE: Reducing Emissions using Methanotrophic Organisms for Transportation Energy

Gonzalez & Haynes, 2013. Nat. Chem. Biol.; Conrado & Gonzalez, 2013. Science (MSs under review)

Impact of natural gas bioconversion: Cost-effective, plus small C footprint

Cost Components with Base Assumptions
CapEx – $50k/bpd
Productivity – 2 g/L/hr
NG Price – $4/mmBtu
Energy Efficiency – 60%
Profit (IRR) – 10%
Separations – 8 MJ/kg
Gas Transfer – 1.5 kW/m^3



Gonzalez & Haynes, 2013. *Nat. Chem. Biol.*; Conrado & Gonzalez, 2013. *Science* (MSs under review)

REMOTE primary technical targets defined by TEA analysis

CATEGORY 1: High-Efficiency Biological Activation of Methane

ID	Parameter	Primary targets
1.1	Energy Efficiency	> 66%
1.2	Turnover Frequency	> 10/s
1.3	Specific Activity	> 5 $\mu mol_{CH4}/g_{total\ cell\ protein}/s$

CATEGORY 2: High-Efficiency Biological Synthesis of Fuel

ID	Parameter	Primary targets
2.1	Pathway Energy Efficiency	> 64%
2.2	Pathway Carbon Yield	> 67%
2.3	Pathway Kinetics	> 1 $g_{fuel}/g_{CDW}/hr$

CATEGORY 3: Process Intensification Approaches for Biological Methane Conversion

ID	Parameter	Primary targets
3.1	Overall Process CapEx	< $100,000/BPD (when calculated for a 500 BPD scale)
3.2	Process Energy Efficiency	> 25% (overall) > 35% (metabolic)
3.3	Process Intensification	> 10 $g_{fuel}/L_{system}/hr$ > 25 $g_{fuel}/L_{reactor}/hr$ > 50 $g_{CH4}/L_{reactor}/hr$ > 400 kW/m^3 heat removal

REMOTE Portfolio (16* projects, ~$39M)

CAT 1: High-Efficiency Biological Activation of Methane

Anaerobic

University of Michigan

Arzeda

Aerobic

Berkeley Lab

Northwestern University

CAT 1 & 2

MIT

Penn State

University of Delaware

MOgene — Data Driven. Insight Generating.

CAT 2: High-Efficiency Biological Synthesis of Fuel

coskata

UCLA

UC Davis

University of Washington

CAT 3: Process Intensification Approaches for Biological Methane Conversion

LanzaTech — Spearheading Biofuel Production Technology

CALYSTA Energy™

greenlight BIOSCIENCES

OSU Oregon State University

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***Includes 1 OPEN 2012 project and 15 REMOTE projects**

Seedling

Where is the opportunity for synergy with BETO?

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$

+

$6CH_4 + 2CO_2 \rightarrow 4CH_3CH_2OH$

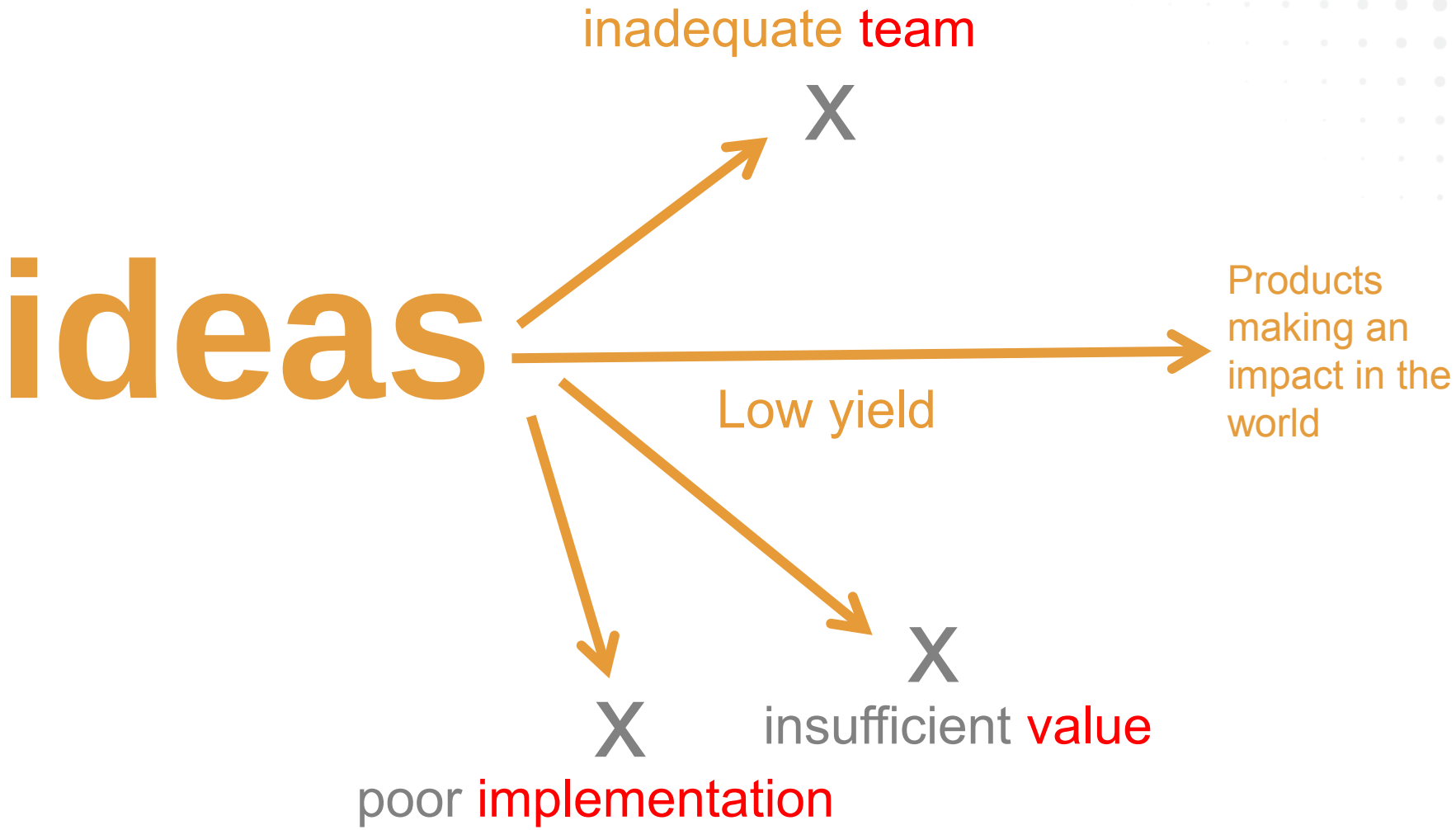
Biomass sugar is CARBON rich

Methane is ENERGY rich

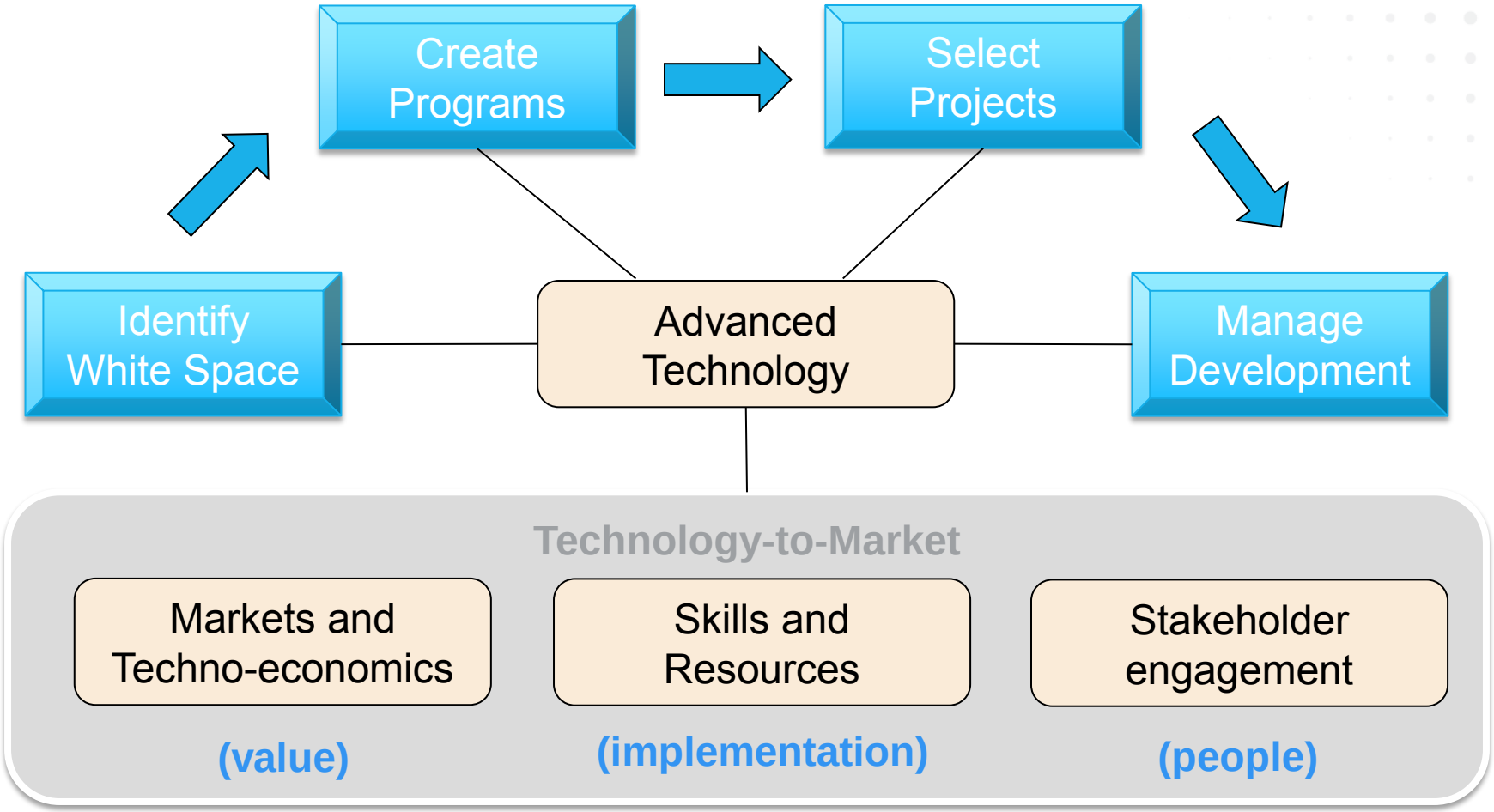
$C_6H_{12}O_6 + 6CH_4 \rightarrow 6CH_3CH_2OH$

100% carbon conversion from biomass + methane

ARPA-E Tech-2-Market (T2M) – Improving the Yield



Changing the Model



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Department of Energy: Fossil Energy/National Energy Technology Laboratory

Timothy Skone

Lead General Engineer

OSEAP - Planning Team

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Department of Energy: Fossil Energy/NETL

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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

CTL Fuel: Program Mandates

- FY13 - $20M was added in Air Force RDT&E funds (USAF only) *to improve emissions of CTL fuel*
  - Enable CTL to be a *competitive* alternative energy source to meet the goals in the DOD's Operational Energy Strategy and Implementation Plan
  - The Secretary of the Air Force is directed, in consultation with the ASD (OEPP), to inform the congressional defense committees 30 days prior to any obligation or expenditure of these funds

- FY14 - The Secretary of the Air Force is directed by SASC to provide a detailed spending plan for the $20M CTL RDT&E program July 31, 2013 *(sent 10/1/2013)*

- FY14 – The Secretary of Defense, in consultation with the Secretary of Energy, will report to the committee on the feasibility of potential technologies that could enable coal-based fuels to meet the requirements of the DOD consistent with section 526 of the Energy Independence and Security Act of 2007.
  - Propose joint research on the most promising technologies for the capture of carbon, reduction of GHG emissions, and other approaches that could enable coal-based liquid fuels to be procured pursuant to § 526 EISA 2007

FOA Topic Areas

- **Area of Interest 1** – Hybrid CTL Processes for Jet Fuel Production - Includes natural gas and biomass hybrid systems
- **Area of Interest 2** – Process Intensification for Coal Conversion for Jet Fuel Production
- **Area of Interest 3** – Innovative Non-Traditional Coal Conversion Processes for Jet Fuel Production
- **Area of Interest 4** – Commercialization Analysis for Construction of a Site Specific CTL Facility (DOE Funded)

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

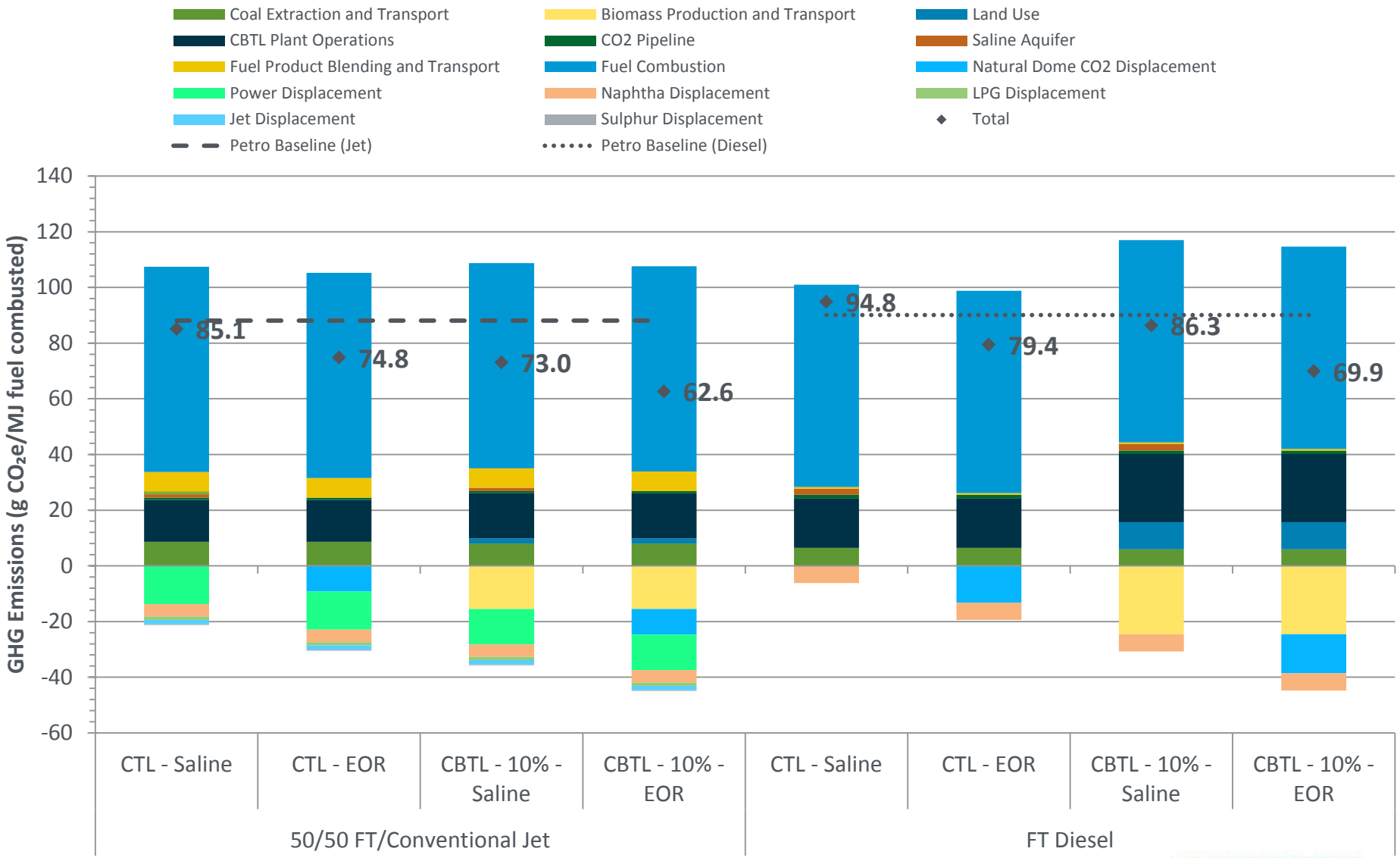
Natural Gas and Biomass to Liquids (GBTL) scenarios have not been directly modeled as part of the current research. Based on CBTL research, addition of biomass is anticipated to lower GHG emissions while increasing product costs (due to higher biomass feedstock costs).

A sampling of relevant publications

DOE FE Research has Focused on Coal and Coal/Biomass Liquids (CBTL) and Natural Gas Liquids (GTL) via Fischer-Tropsch (FT) with Carbon Capture

- Analysis of Natural Gas-to-Liquid Transportation Fuels via Fischer-Tropsch, DOE/NETL-2013/1597, September 2013
- Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact, NETL/DOE-2012/1542; Publication Date: May 2012 (Report Date: December 2011)
- Life Cycle Greenhouse Gas Analysis of Advanced Jet Propulsion Fuels: Fischer-Tropsch Based SPK-1 Case Study, Interagency Workgroup, September 2011
- Affordable, Low-Carbon Diesel Fuel form Domestic Coal and Biomass, DOE/NETL-2009/1349, January 2009
- Development of Baseline Data and Analysis of Greenhouse Gas Emissions of Petroleum-Based Fuels: Report and Model, DOE/NETL-2009/1346, November 2008

Example CTL/CBTL Life Cycle GHG Results



Source: Timothy J. Skone, NETL; Alternative Fuels Analysis, August 2013

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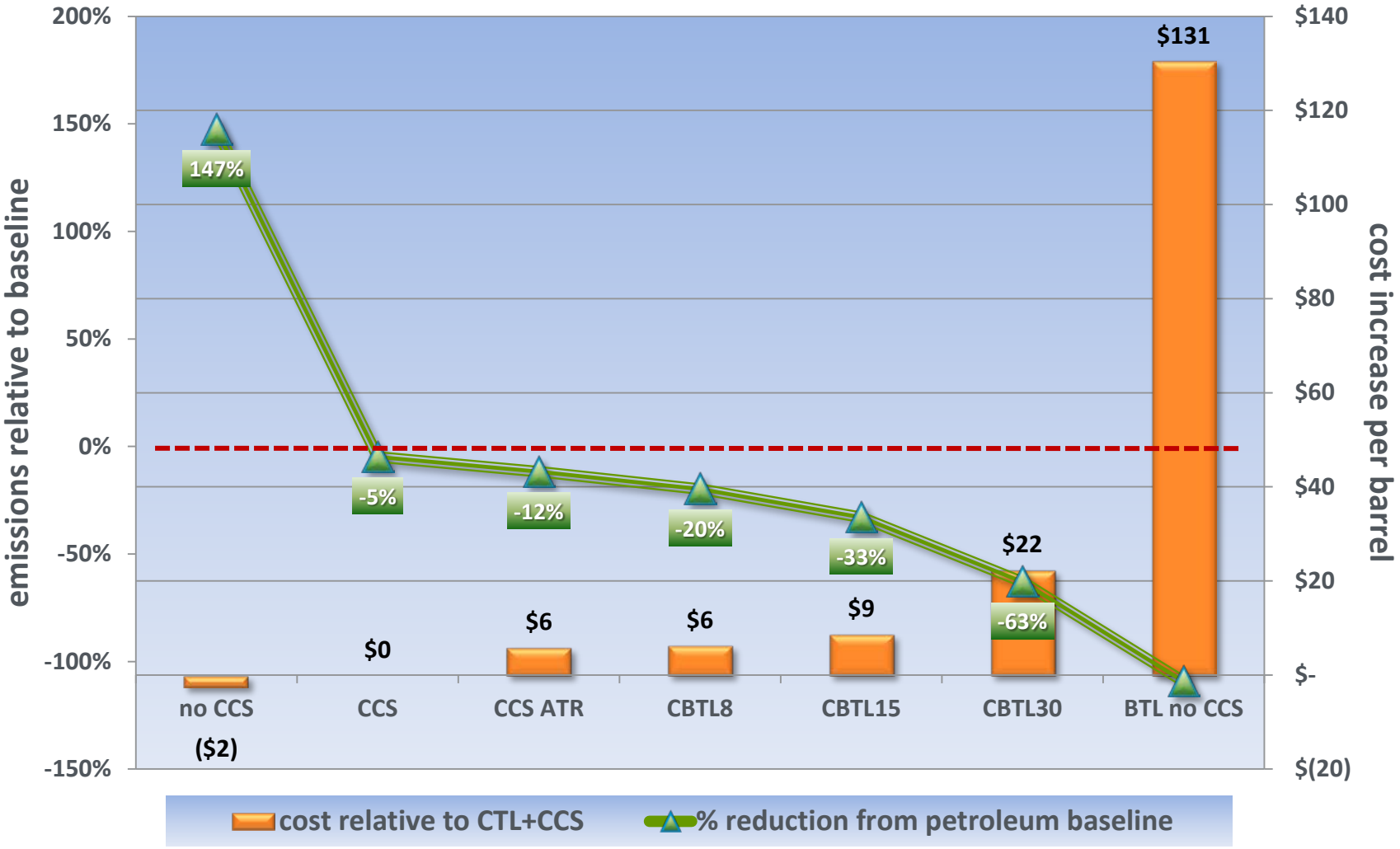
Example Cost/Benefit of Adding Biomass to Fischer-Tropsch Fuels Production



Source: NETL, Affordable, Low-Carbon Diesel Fuel form Domestic Coal and Biomass, DOE/NETL-2009/1349, January 2009

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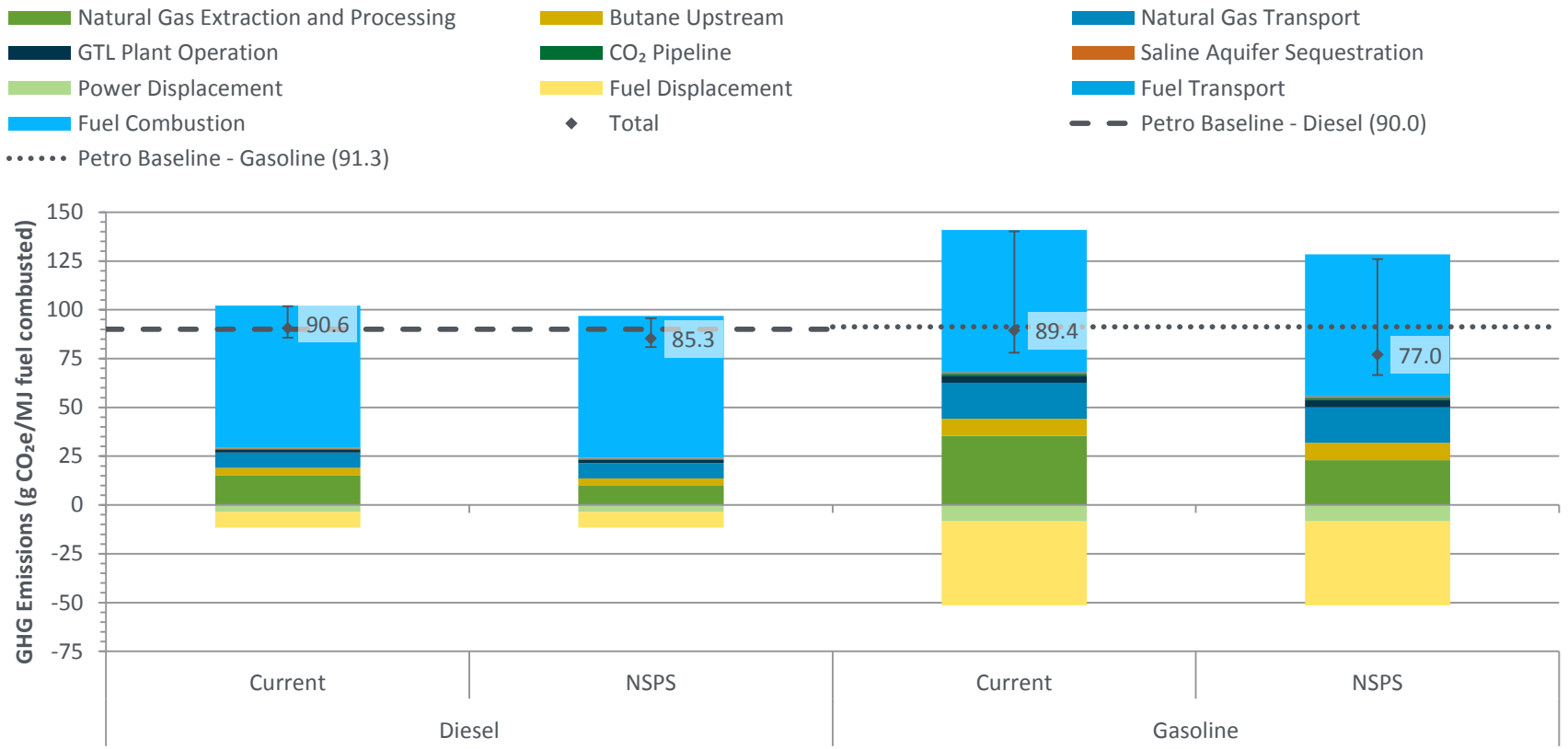
Example GTL Life Cycle GHG Results



- Current natural gas extraction practices result in GTL fuels close to petroleum baseline -- NSPS implementation will reduce GTL fuels below petroleum baseline
- Uncertainty straddles the baseline and is driven by upstream natural gas uncertainty and displacement uncertainty
- GTL plant is optimized for diesel production, which is why diesel life cycle has less displacement than gasoline results
- Source: Analysis of Natural Gas-to-Liquid Transportation Fuels via Fischer-Tropsch, DOE/NETL-2013/1597, September 2013

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Final Questions?

Thank you!