

# Biological Technologies for Methane-to-Liquids ARPA-E Workshop

Ramon Gonzalez, Program Director  
Advanced Research Projects Agency – Energy  
U.S. Department of Energy

Washington, D.C.  
December 5, 2012

[www.arpa-e.energy.gov](http://www.arpa-e.energy.gov)



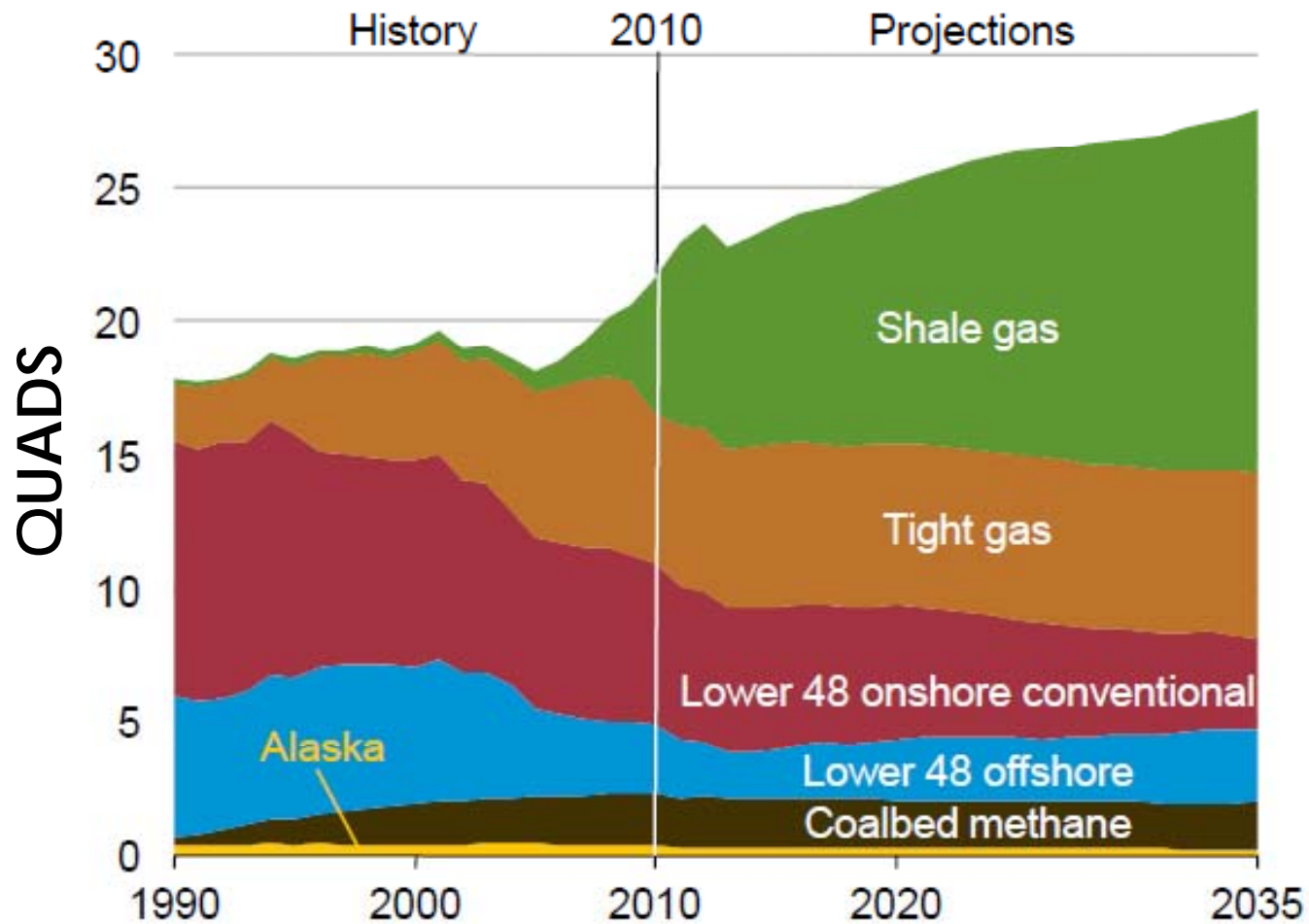
# OVERVIEW

- **Feedstock: source, production volume, composition**
- **Value chain**
- **Techno-economic analysis**

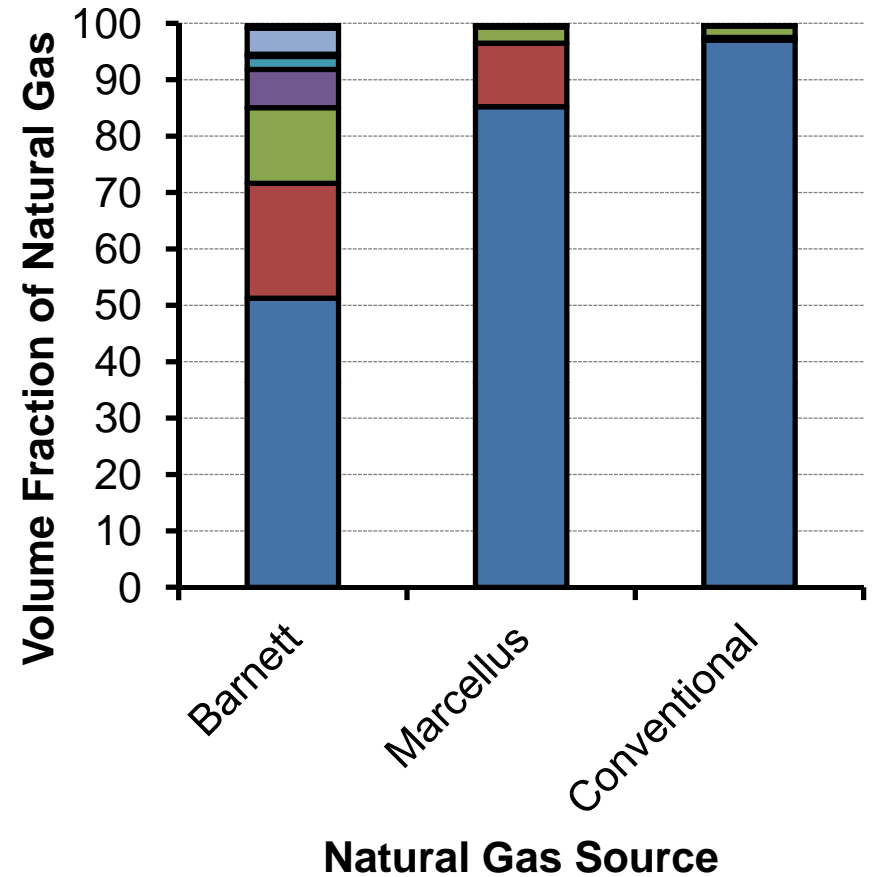
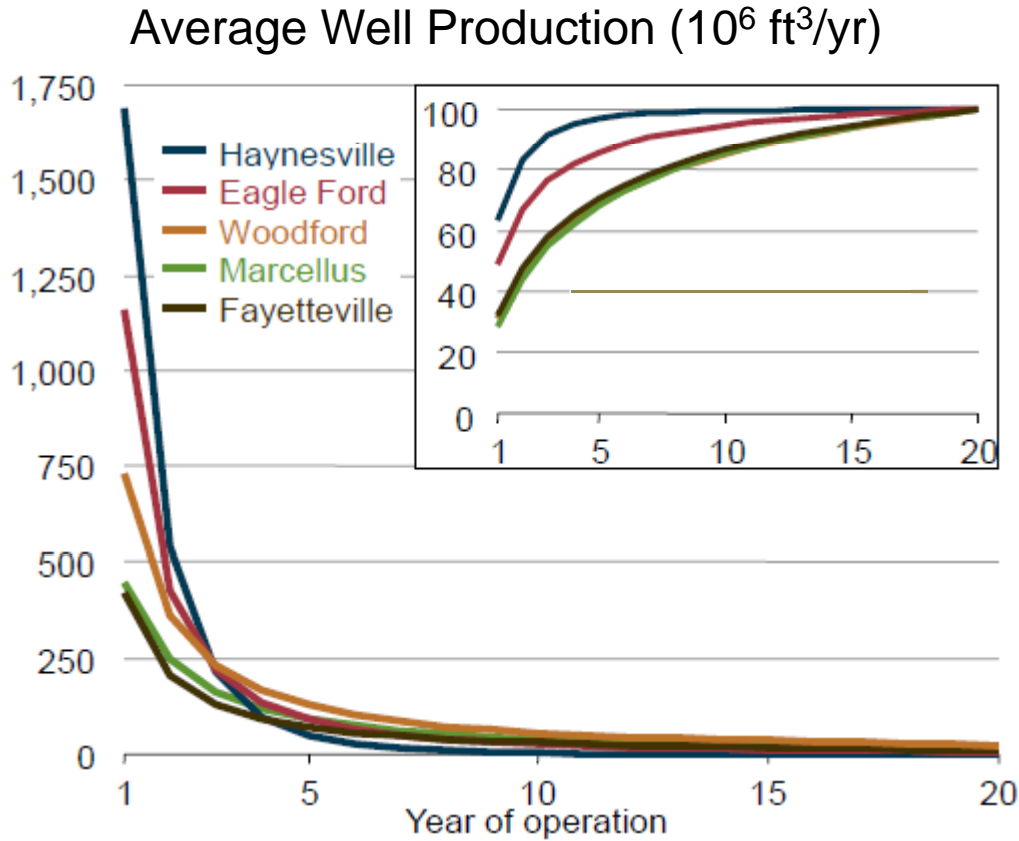
# OVERVIEW

- **Feedstock: source, production volume, composition**
- Value chain
- Techno-economic analysis

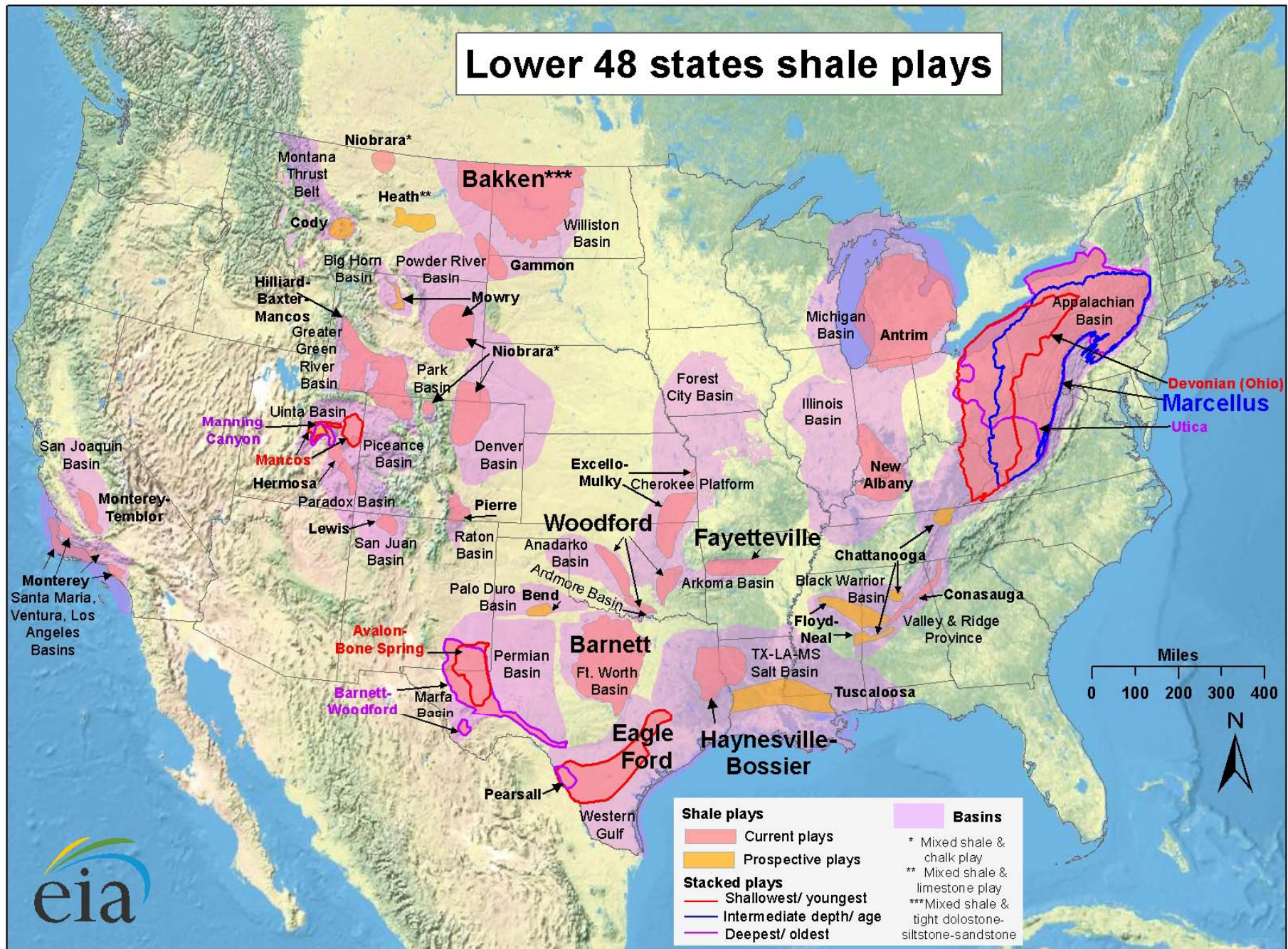
# Major Sources of Methane



# Variability of Shale Gas



# Lower 48 states shale plays



Source: Energy Information Administration based on data from various published studies.  
 Updated: May 9, 2011

# Mobile/Movable/Modular?

## SHELL PRELUDE FLNG FACILITY

Boeing 747 (71m long)



Queen Mary 2 (345m)



Shell Prelude FLNG (488m)

### KEY FACTS

- The Prelude facility will be 488m long and 74m wide
- It will stay moored in water 250m deep for 25 years
- First production in 2017 of at least 3.6 million tonnes of LNG per year
- It will create 1000 jobs and add \$45 billion to the economy



**About 9 acres**

<http://www.theaustralian.com.au/business/mining-energy/bn-prelude-floating-plant-has-shell-fired-for-lng/story-e6frg9ef-1226059923612>

<http://www.bloomberg.com/news/2012-09-19/shell-leads-lng-competitors-out-to-sea-with-biggest-ship-energy.html>



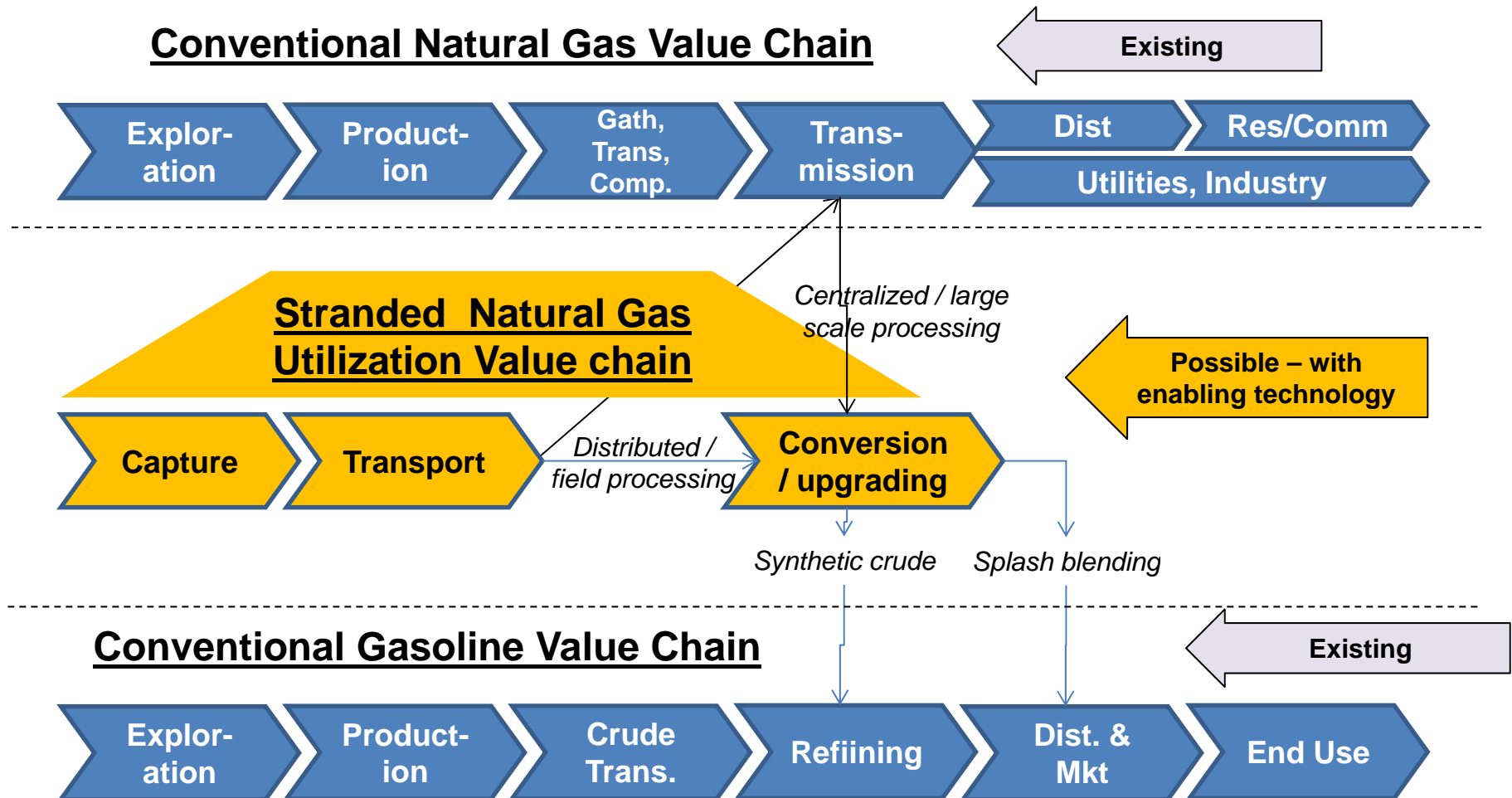
**Typical ethanol plant sits on a 15 acre site with not much consideration given to space/footprint limitations.**

# OVERVIEW

- Feedstock: source, production volume, composition
- **Value chain**
- Techno-economic analysis



# Value Chains for Natural Gas and Gasoline



# OVERVIEW

- Feedstock: source, production volume, composition
- Value chain
- **Techno-economic analysis**

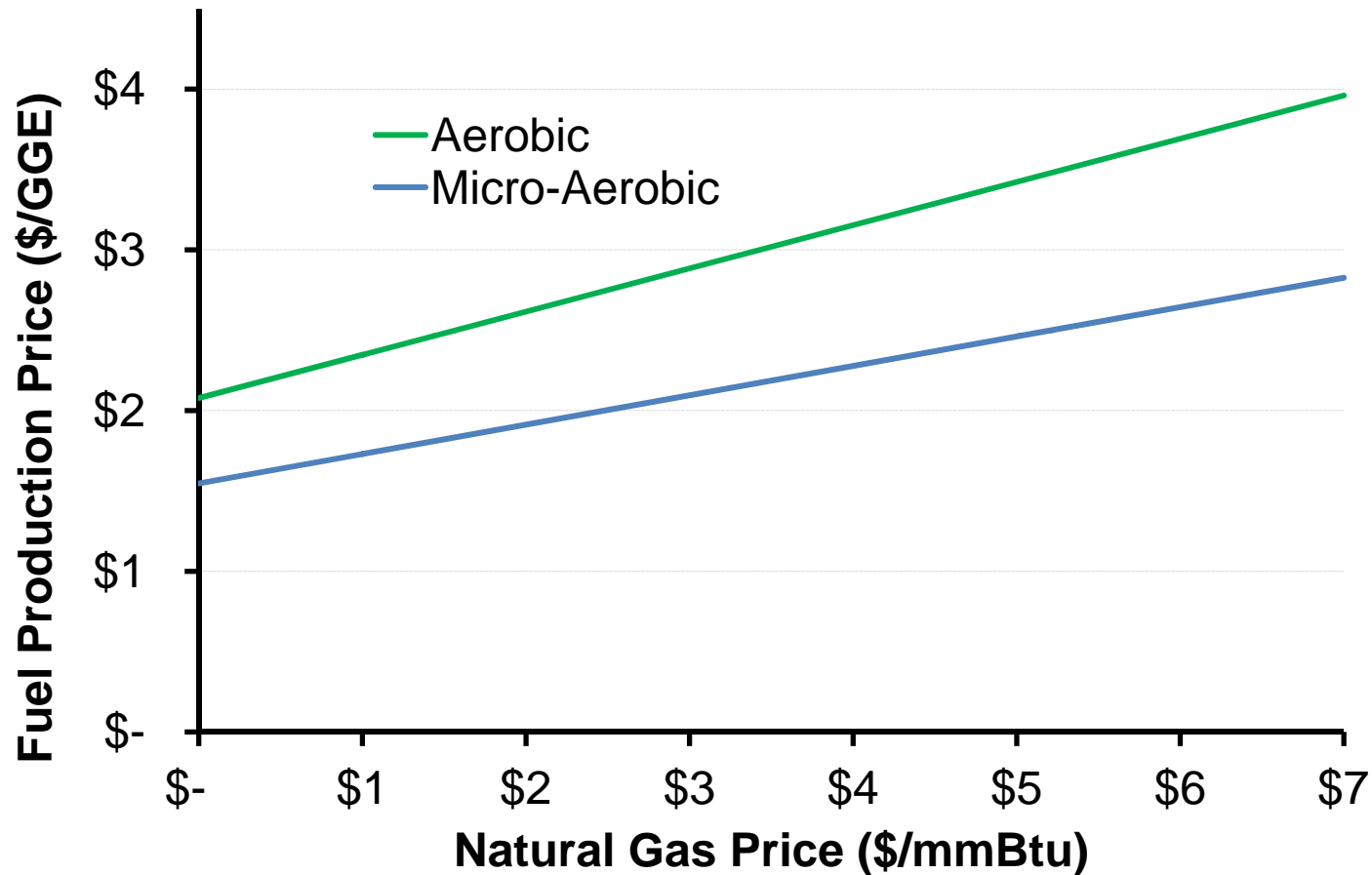
# Bioconversion Pathways to Butanol from NG

- **Aerobic Case 1** (53%  $E_{\text{eff}}$ , 66%  $C_{\text{eff}}$ )
  - ▶  $6\text{CH}_4 + 6\text{O}_2 \Rightarrow \text{C}_4\text{H}_{10}\text{O} + 7\text{H}_2\text{O} + 2\text{CO}_2$
- **Hypothetical Mixed-Feedstock Case** (69%  $E_{\text{eff}}$ , 80%  $C_{\text{eff}}$ )
  - ▶  $\text{CH}_4 + 2\text{C}_2\text{H}_6 + 3\text{O}_2 \Rightarrow \text{C}_4\text{H}_{10}\text{O} + 3\text{H}_2\text{O} + \text{CO}_2$
- **Hypothetical Micro-Aerobic Case** (79%  $E_{\text{eff}}$ , 100%  $C_{\text{eff}}$ )
  - ▶  $4\text{CH}_4 + 2\text{O}_2 \Rightarrow \text{C}_4\text{H}_{10}\text{O} + 3\text{H}_2\text{O}$

# Key Assumptions for Techno Economic Analysis

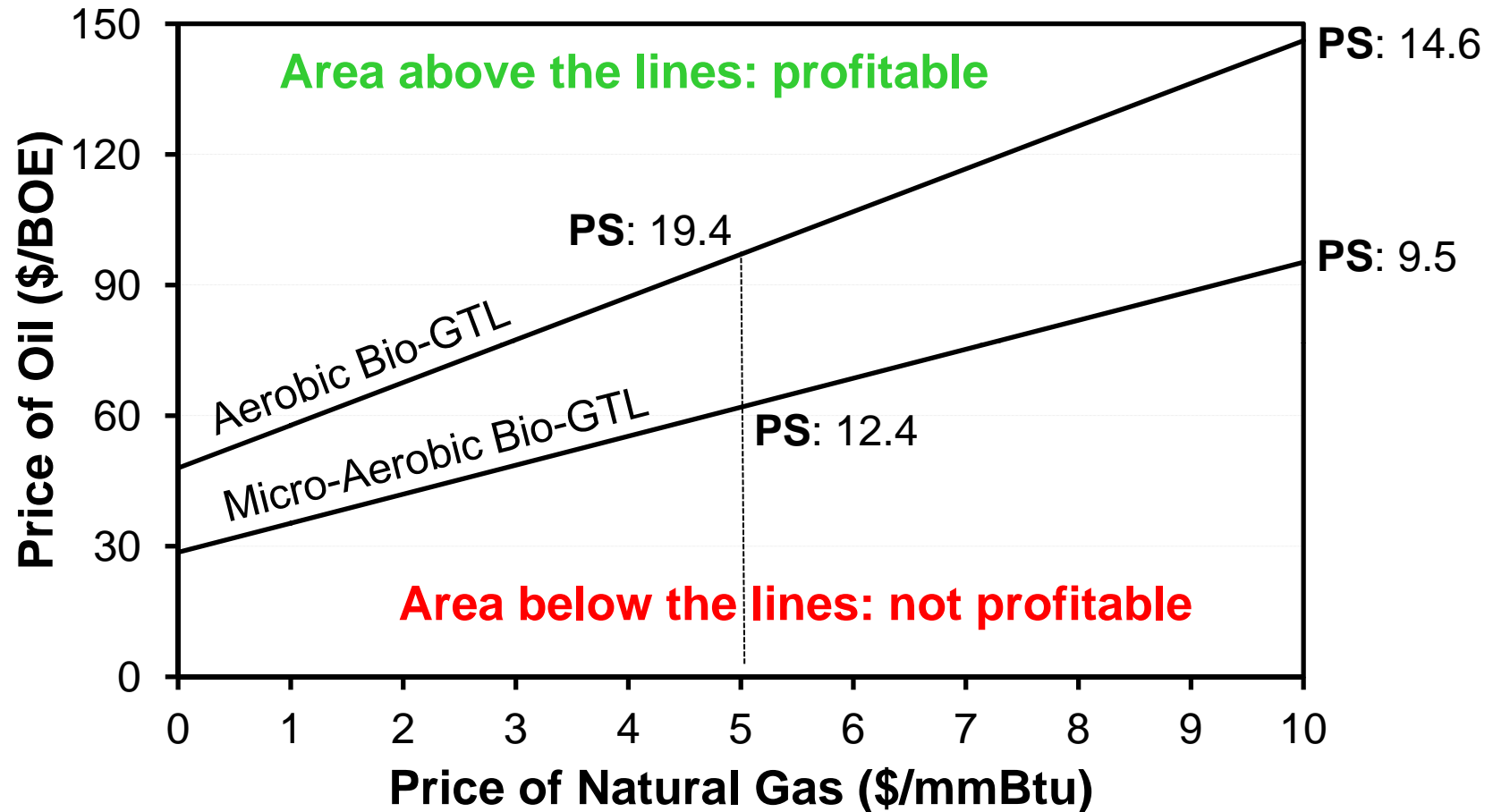
- **Aerobic Case**
  - ▶  $21\text{CH}_4 + 22.5\text{O}_2 \Rightarrow \text{C}_{14}\text{H}_{26}\text{O}_2 + 29\text{H}_2\text{O} + 7\text{CO}_2$
- **Micro-Aerobic Case**
  - ▶  $14\text{CH}_4 + 8.5\text{O}_2 \Rightarrow \text{C}_{14}\text{H}_{26}\text{O}_2 + 7\text{H}_2\text{O}$
- “Conventional” natural gas
- n<sup>th</sup> plant design
- 1000 BOE/day production rate
- Stoichiometric methane, air feed
- Semi-continuous operation
- Fatty acid production
- 6 g L<sup>-1</sup> hr<sup>-1</sup> productivity
- >95% yield
- Fatty acid to diesel finishing

# Preliminary assessment of impact of technology platform and NG price on fuel price



**CapEx of \$100,000/(BOE/d) at small scales**

# Preliminary breakeven curves for Bio-GTL conversion



Price Spread (PS): Price Oil/Price Natural Gas  
Today's PS: 25

# Preliminary/ballpark economics

	Bio-GTL (micro)	Sasol GTL, LA
Plant capacity [boe/d]	1,000	96,000
NG price [\$/1,000 scf]	3.60	3.60
Fuel selling price [\$/gal]	2.31	4.00
CapEx [\$]	100 Million	11-14 Billion
CapEx [\$/ (boe/d)]	100,000	114,000-146,000

**One-step cost-effective conversion of methane to liquid transportation fuels at small scale allowing access to remote/stranded gas**

# Afternoon Session

- Considerations, challenges, opportunities
- Scaling / Intensification / Process Integration
- Temporal, spatial impact, gas composition
  - ▶ Therefore we need small modular



# Workshop agenda, afternoon

1:45-2:00

Break & Room Change

2:00-3:45

Breakout Session D (Franklin)

Breakout Session E (Wright)

Breakout Session F (Carver)

3:45-4:15

Networking Break

4:15-4:45

Breakout session reports

4:45-5:15

Summary & next steps