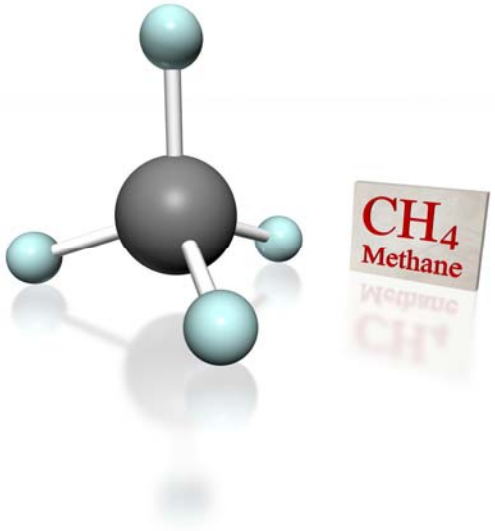
The Shale Gas Revolution: A Methane-to-Organic Chemicals Renaissance?

Or

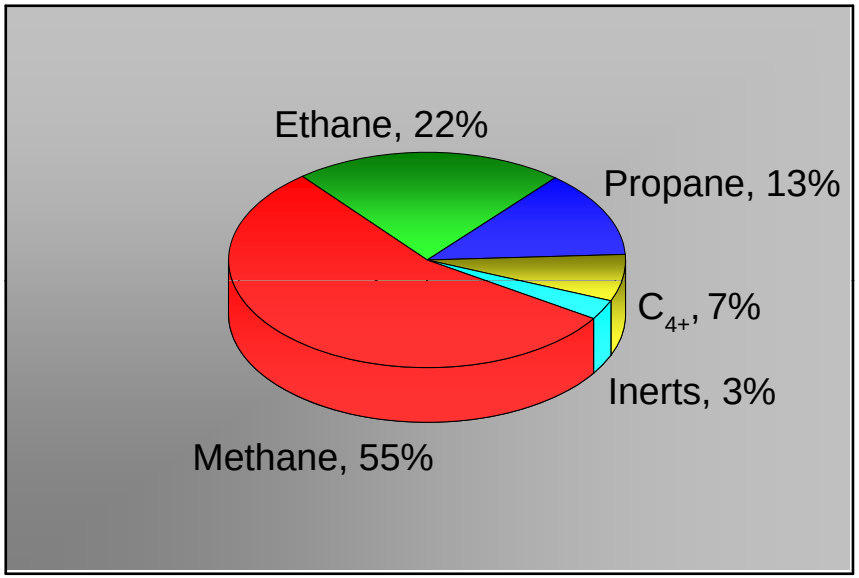
Methane: Fuel or Feedstock?



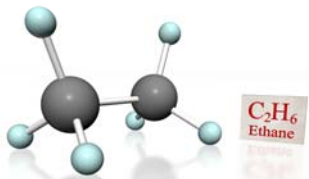
Eric E. Stangland
2014 Frontiers of Engineering
Irvine, California

Shale Gas for Chemical Production

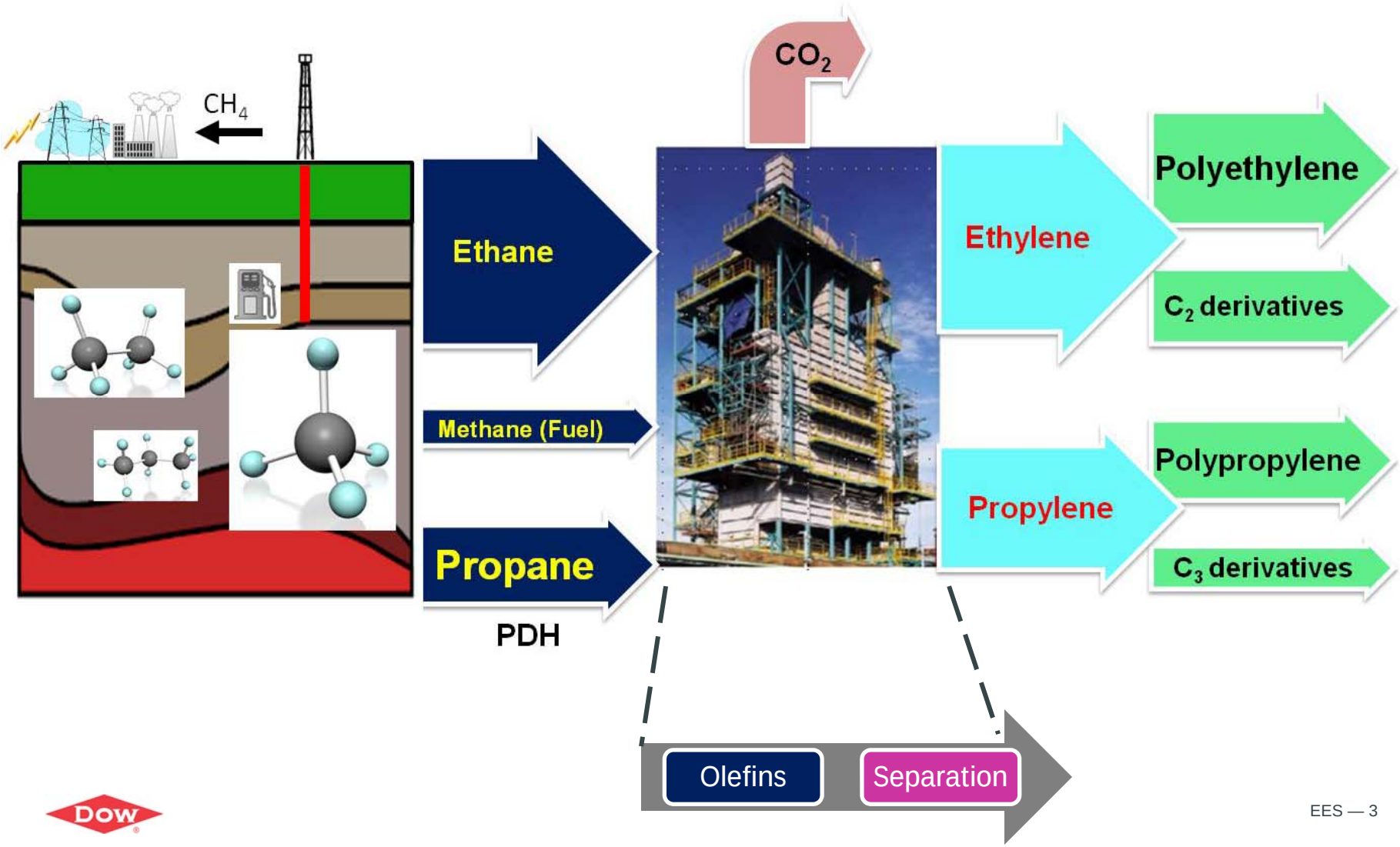
Typical Bakken Wellhead Gas Composition



Source: Wocken et al, EERC presentation at 21st Williston Basin Petroleum Confernece, 2013



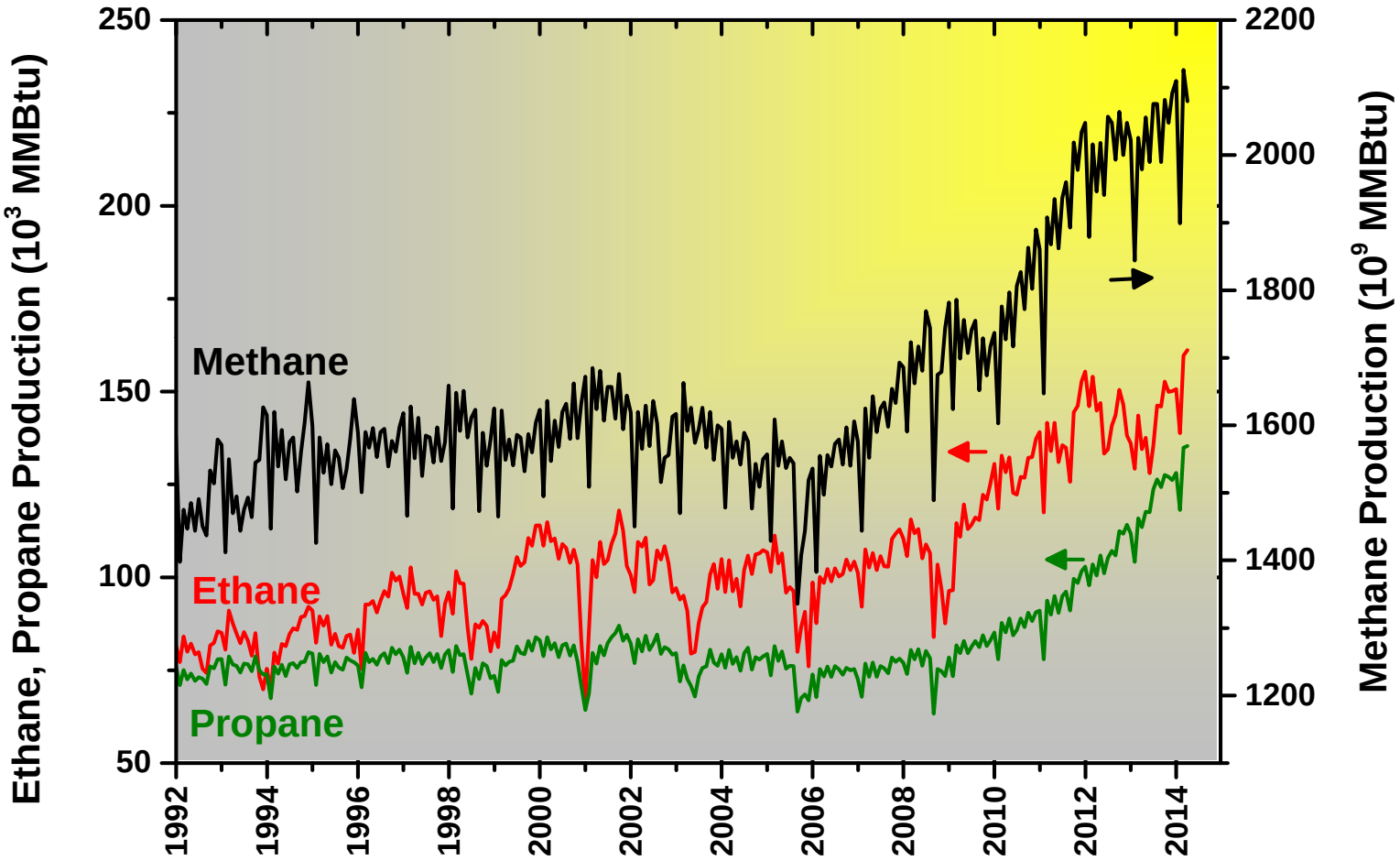
Steam Cracking of Alkanes



Light Hydrocarbon Cracker-8, TX

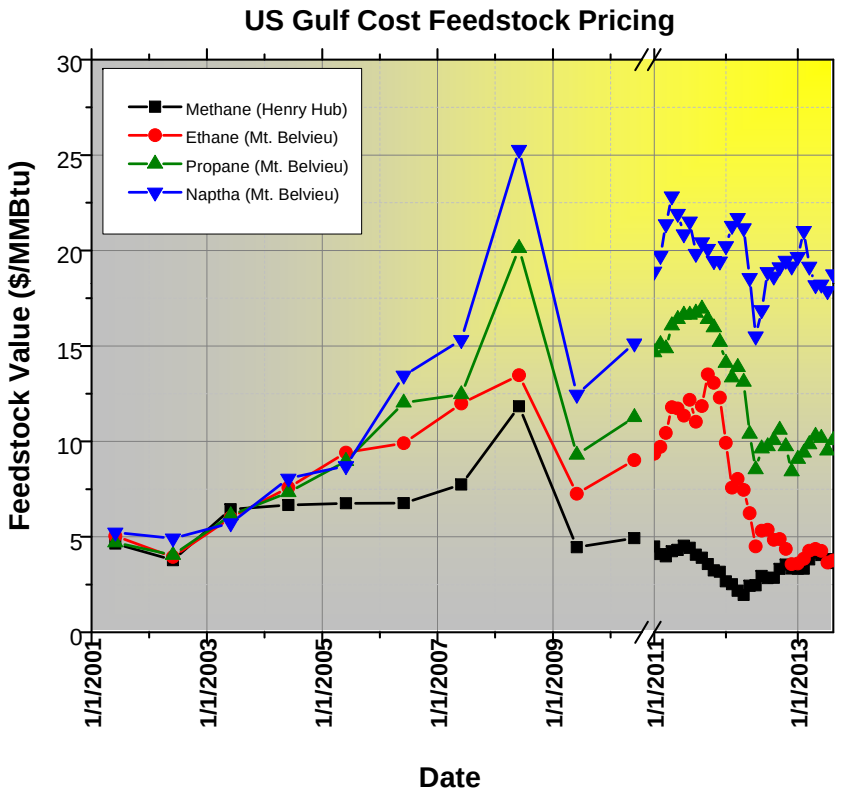
Modern plant can make 1500 kta ethylene, or 171,000 kg/hr (376,000 lb/hr).

US Production of Light Hydrocarbons



Source: ICIS pricing, EIA

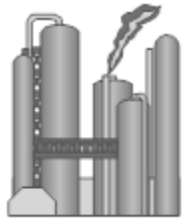
Chemical Investment Due to Shale Gas



Source: ICIS pricing, EIA

2023 Projections

148 capital investment projects worth $100 B

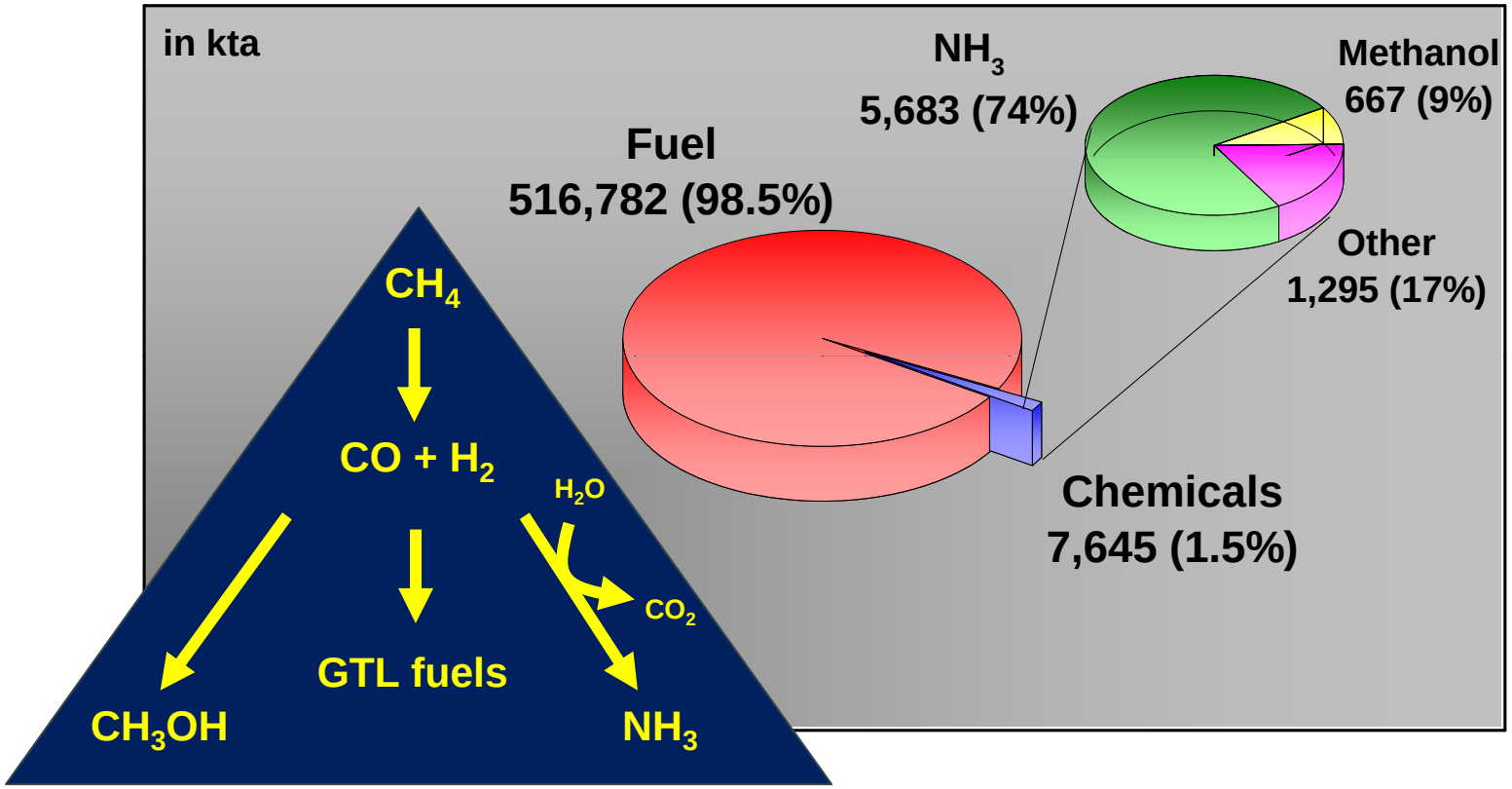


637,000 direct/indirect new chemical jobs

$244 B in new economic output

Source: American Chemistry Council

2012 US Methane Utilization



By comparison, 2012 Ethylene Capacity = 24,000 kta
Plenty of methane available for chemical use

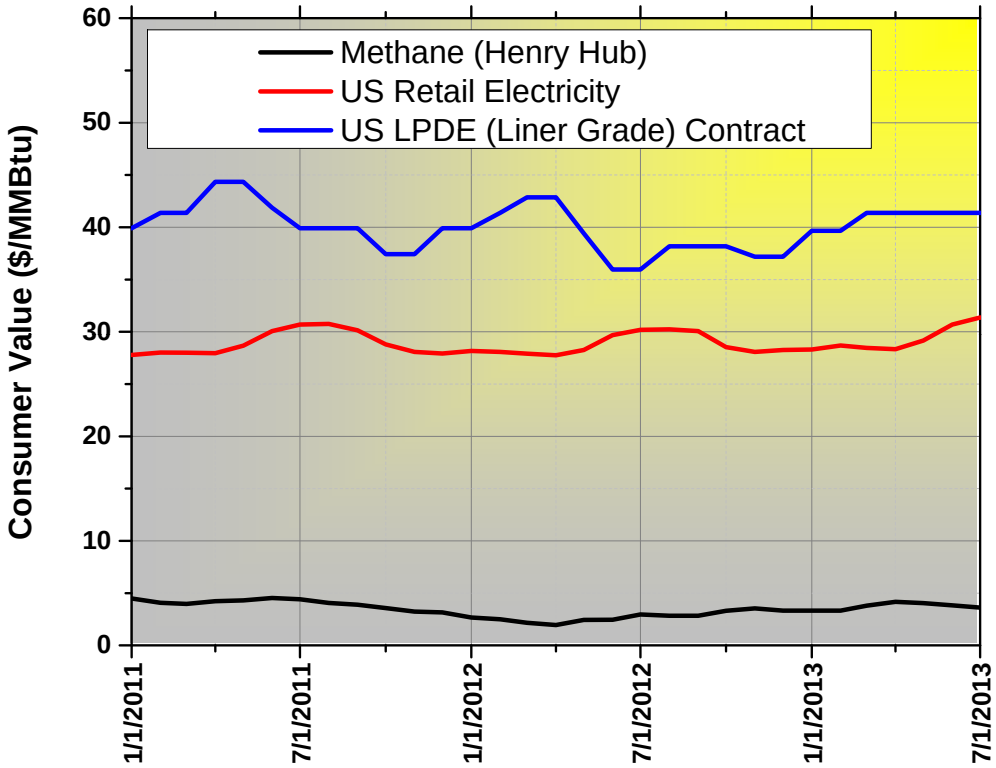
Dilemma: Fuel or Feedstock?

Risk vs. Reward

Current

Future?

Customer Valuation



Source: ICIS pricing, EIA

US consumers are willing to pay more for plastic than electricity.
Why not turn methane into plastic?

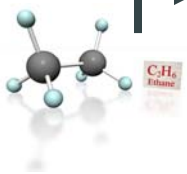
Known Methane-to Chemical-Routes (not-inclusive)

Methanol-to-Olefins (MTO)

Syngas → Methanol → Olefins → Separation

O_2 (ASU)

Oxidative Methane Coupling (OCM)



Olefins → Separation

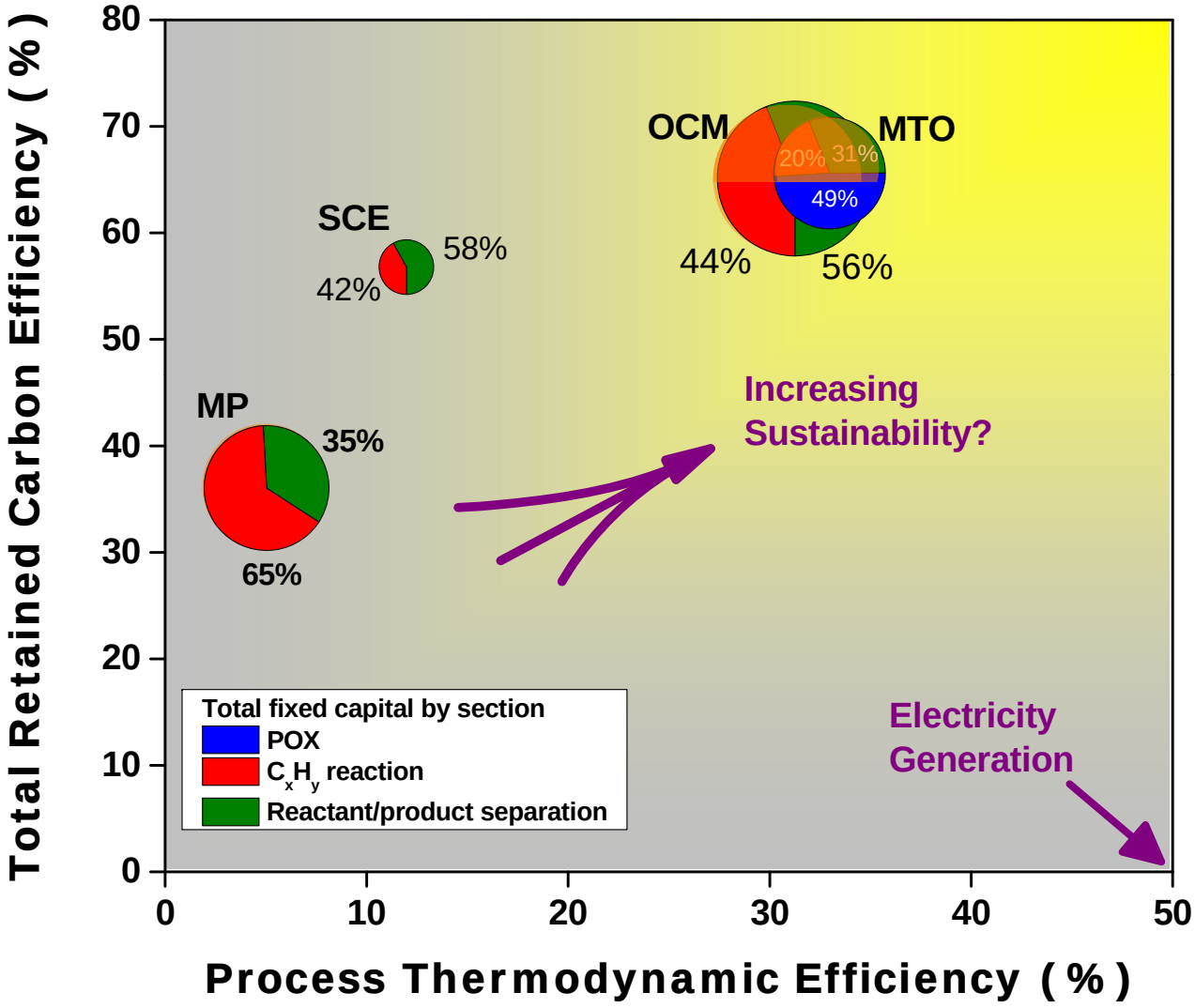
O_2 (ASU)

Methane Pyrolysis

Acetylene/ Syngas → Hydrogenation → Separation → CO methanation

O_2 (ASU)

Methane-to-Chemicals Efficiency vs. Cost



Routes to Ethylene

Methanol-to-Olefins (MTO)

Syngas/ Methanol → Olefins → Separation → Ethylene

O_2 (ASU)

Oxidative Methane Coupling (OCM)

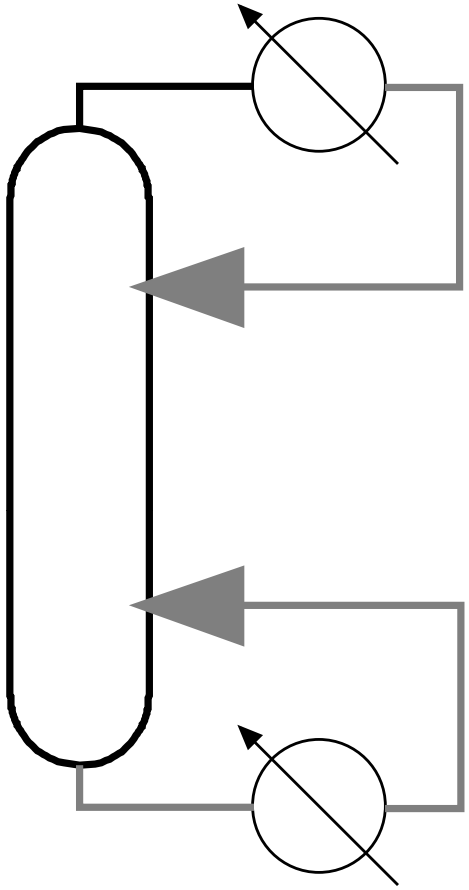
Olefins → Separation → Ethylene

O_2 (ASU)

Olefins → Separation → Ethylene

Distillation…

Established technology
Easily scaled
Low capital, low risk



Low energy efficiency

…accounts for 90-95% of all separations in the petrochemical industry and up to 30% of overall industry energy usage.

Light Hydrocarbon Cracker-8, TX

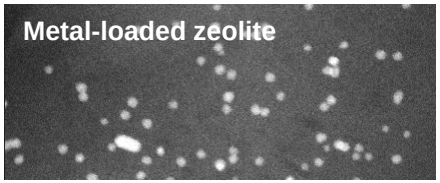
Cryogenic Distillation Train

Cracking furnaces

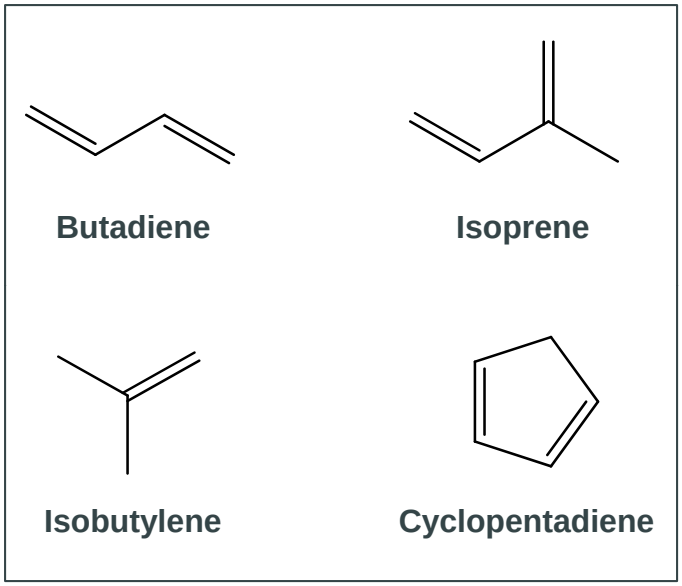
Next Generation Chemical Plant

What technology is needed to utilize all components of shale gas for organic chemical production?

New Chemistry



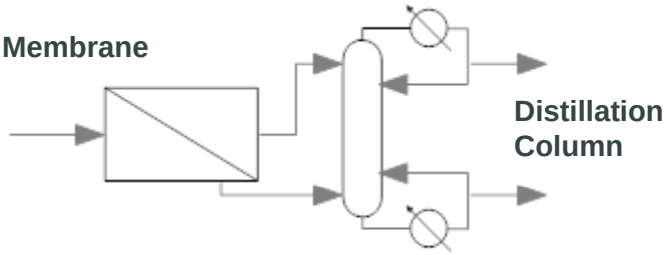
New catalysts that utilize <u>oxygen</u> to convert methane (alkanes), <u>exclusively</u> to olefins

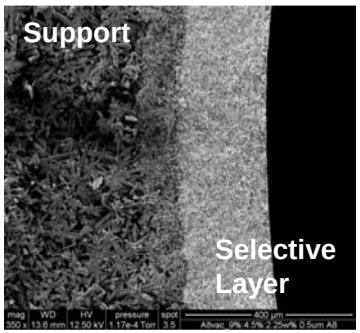


New chemistries from lighter hydrocarbons to supplement C_4 and C_5 shortages

New Mass-transfer Agents

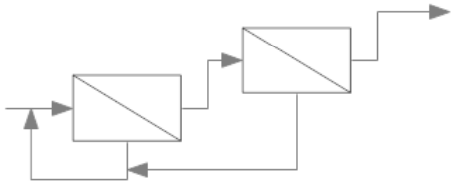
Short-term: hybrid schemes



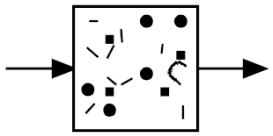


High-temperature stable
porous metals and ceramic
membranes with high flux & selectivity

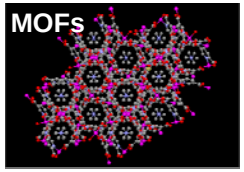
Long-term: Distillation replacement

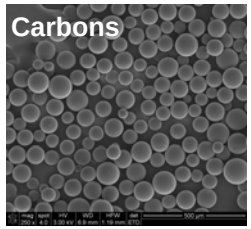


Membrane Cascade

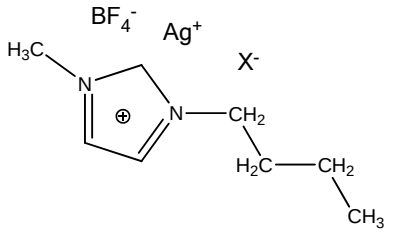


Absorption/Adsorption



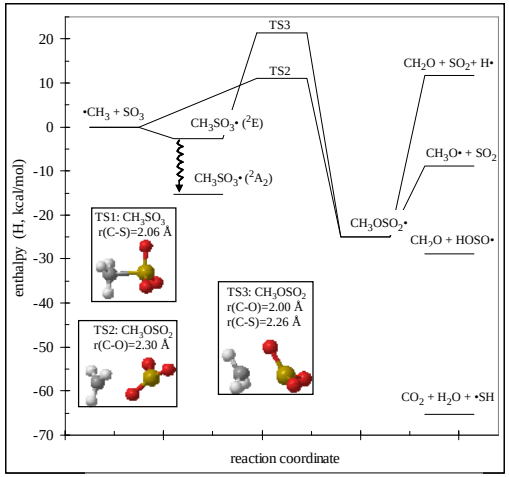


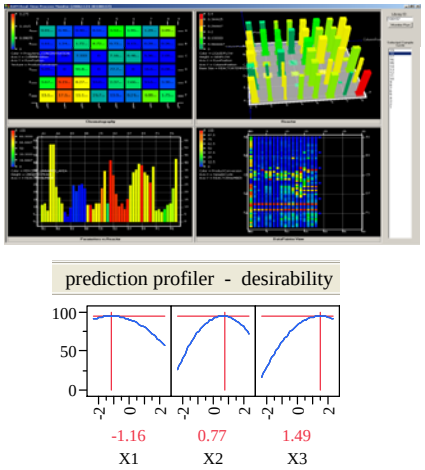
Silver-salt Ionic Liquid



Sorbents with significantly higher
selective capacity

Improved Computation and Logic





Hybrid and advanced plants will require advanced process control

Advanced *ab initio* modeling with complementary informatics and high-throughput experimentation

New US Chemical Industry is Dawning

Methane-to-Chemical Energy Usage