

Shale Gas and the Sustainability of the US Petrochemical Industry

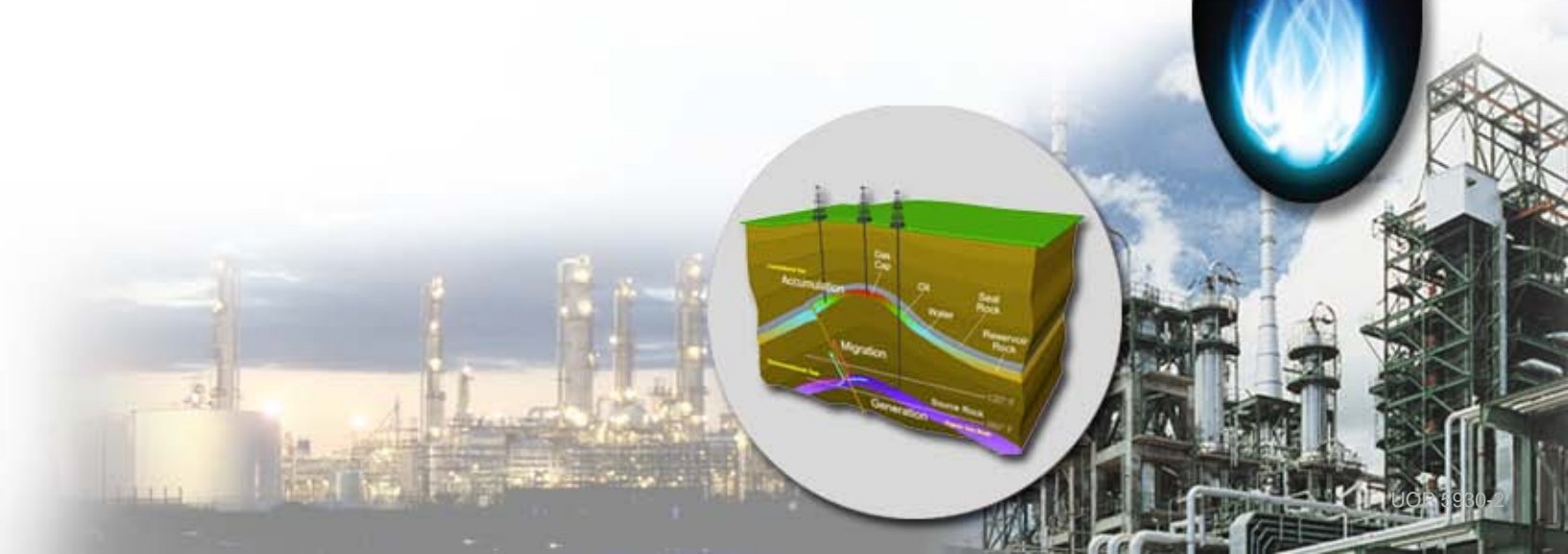
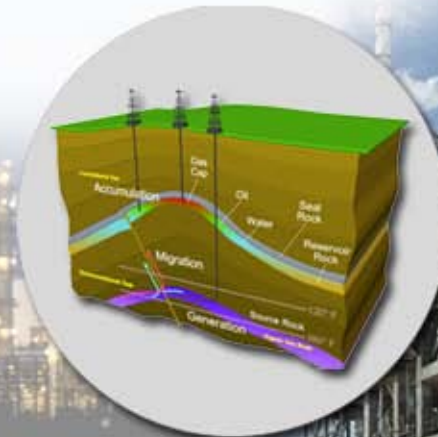
Clayton Sadler
UOP LLC, A Honeywell Company



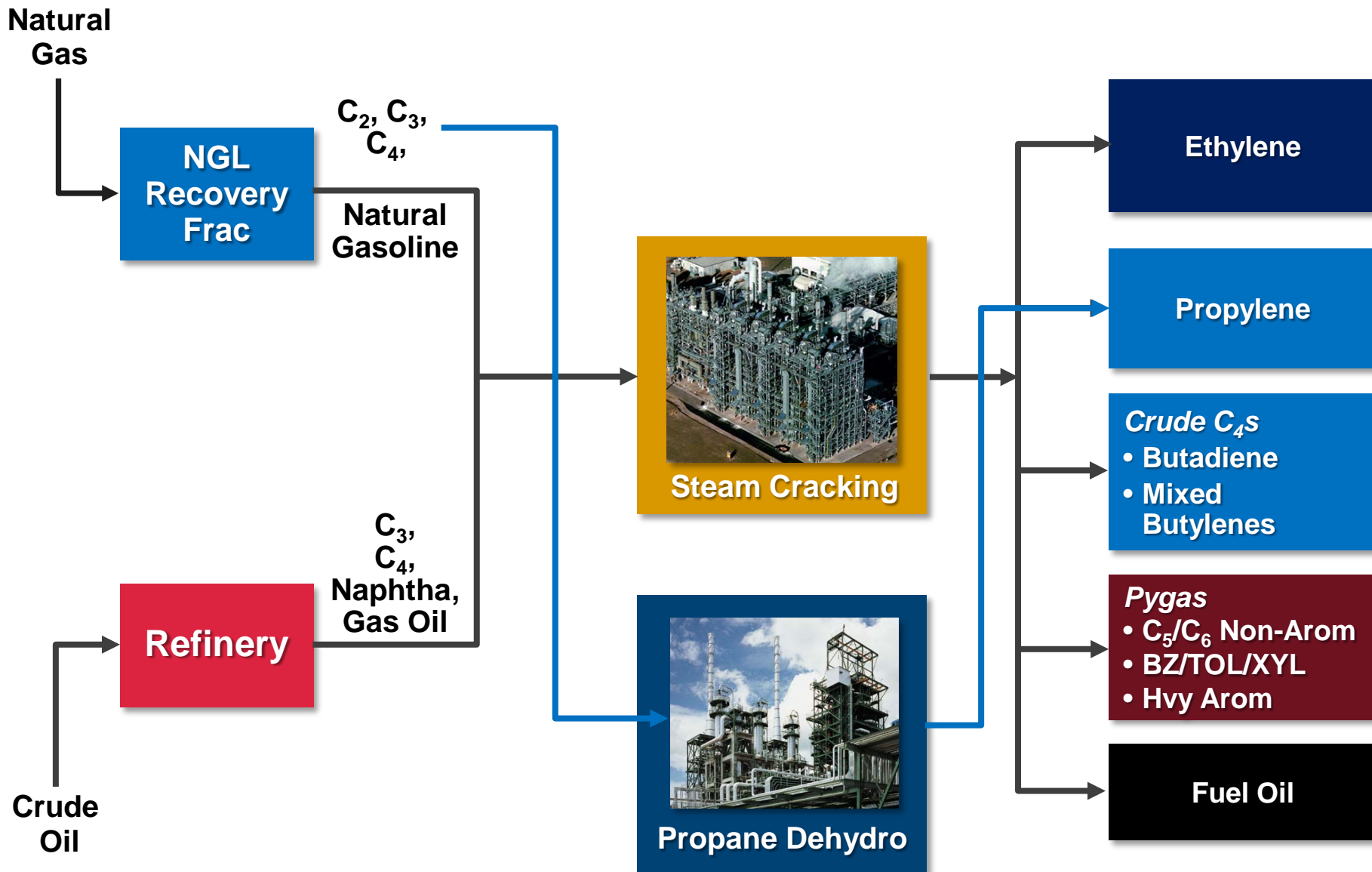
SMART CN Workshop on Sustainable Manufacturing
Oct. 31st, 2012
Pittsburgh, PA

Uop
A Honeywell Company

- Petrochemical process technology overview
- Impact of shale gas on petrochemical industry
- Shale gas and sustainability



Light Olefin Petrochemical Production Technology



The Situation 5 Years Ago

- **US natural gas production was in decline**
- **New LNG import terminals were being developed**
- **US Petrochemical Industry had oversupply of high cost assets**
 - High feedstock costs
 - Shrinking domestic demand
 - Trend in off-shoring of manufacturing

***Global Investment Focus was on Asia & Middle East
Capacity Rationalizations in North America***

Ethylene Cost of Production

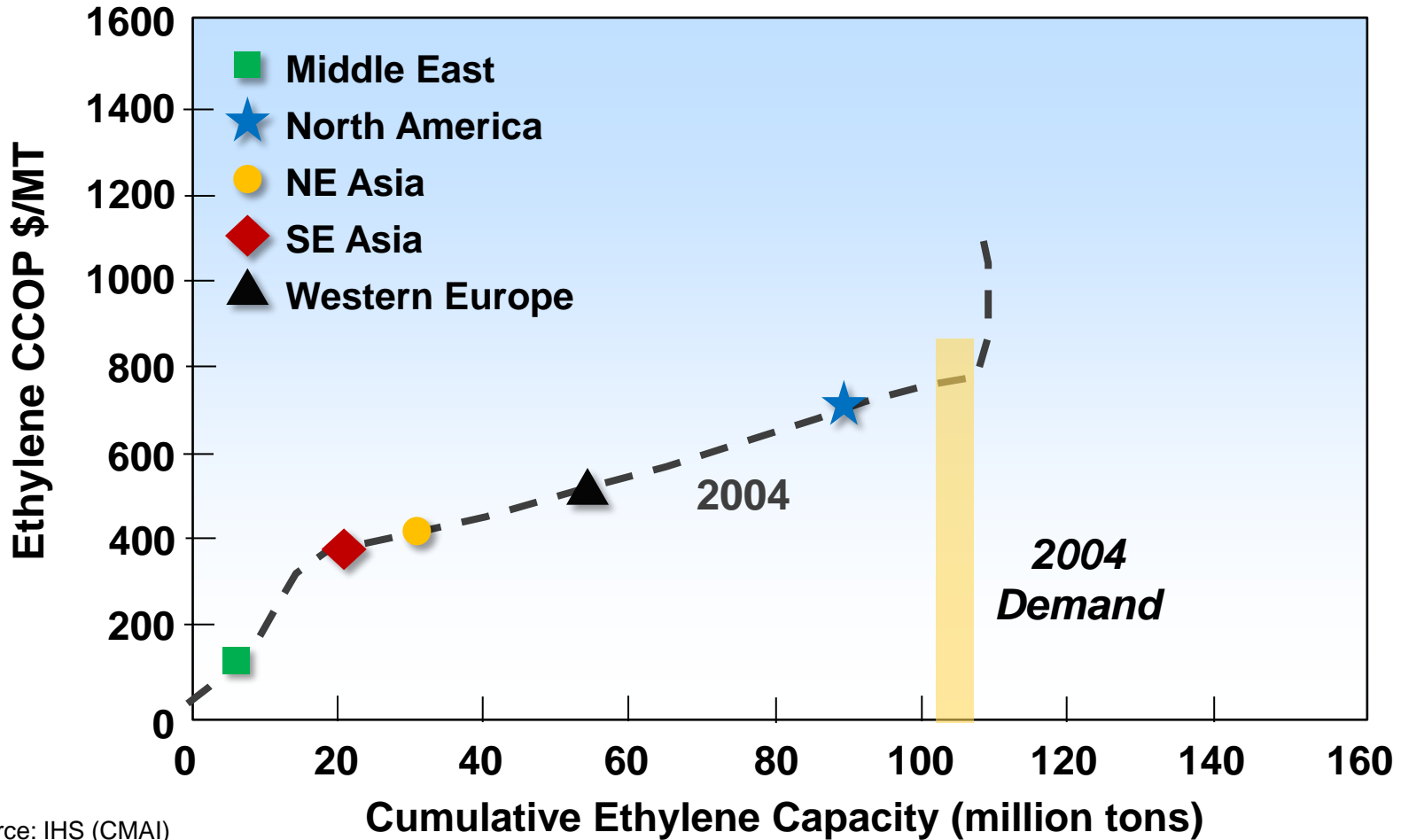
For most petrochemicals:

- **> 80% of cost of production is feedstock**
- **> 10% of cost of production is energy (fuel, steam, power)**
- **< 5% of cost of production is fixed costs**

Feedstock Costs Dominate

Ethylene Cost of Production

Ethylene Cash Cost Curve

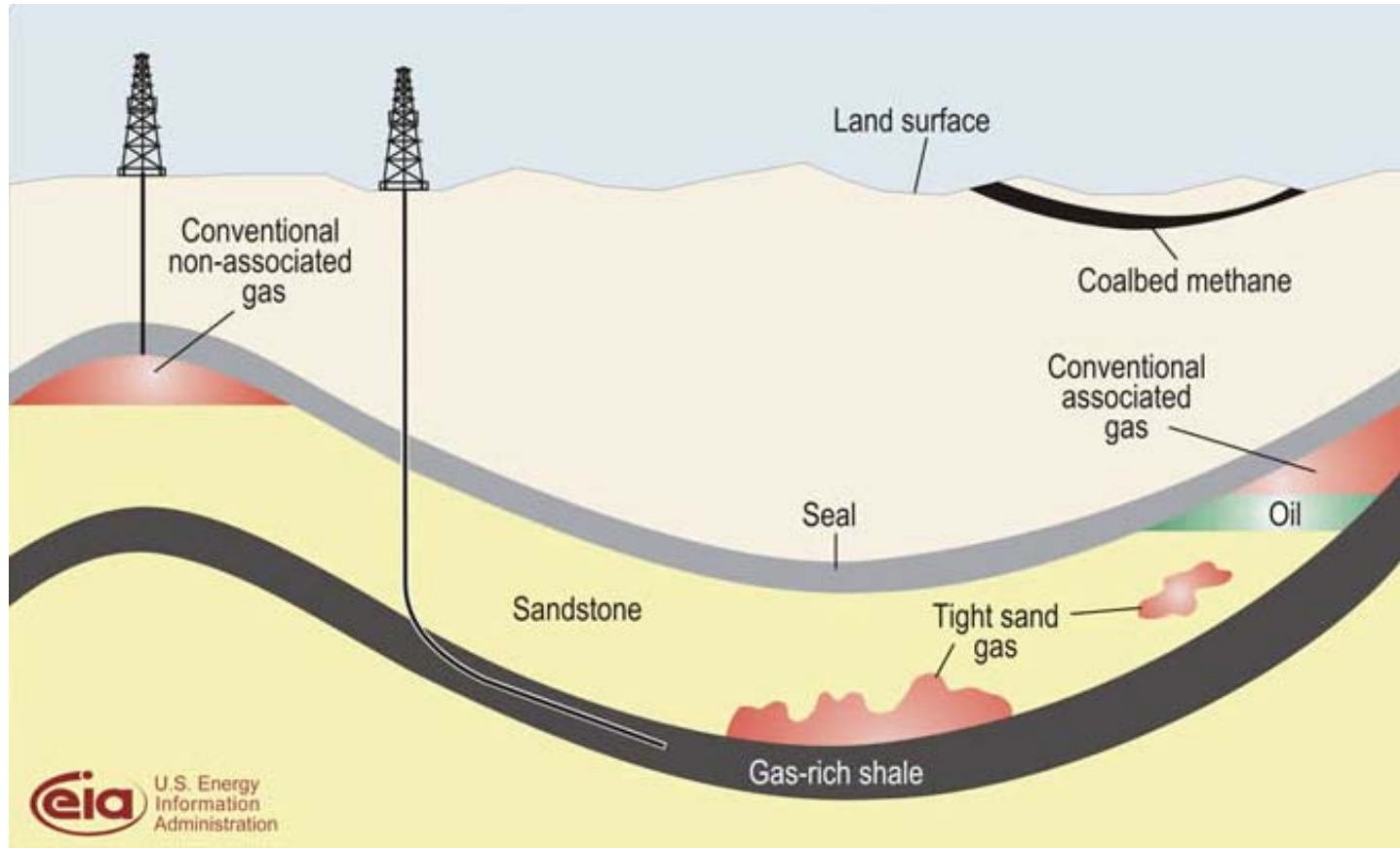


Source: IHS (CMAI)
2011 Curve: 2012 CMAI Conference (Graphical Analysis)
2004 Curve: 2005 World Light Olefins Analysis

US is Price Maker – What Could Change the Picture?

The Shale Revolution

Schematic Geology of Natural Gas Resources

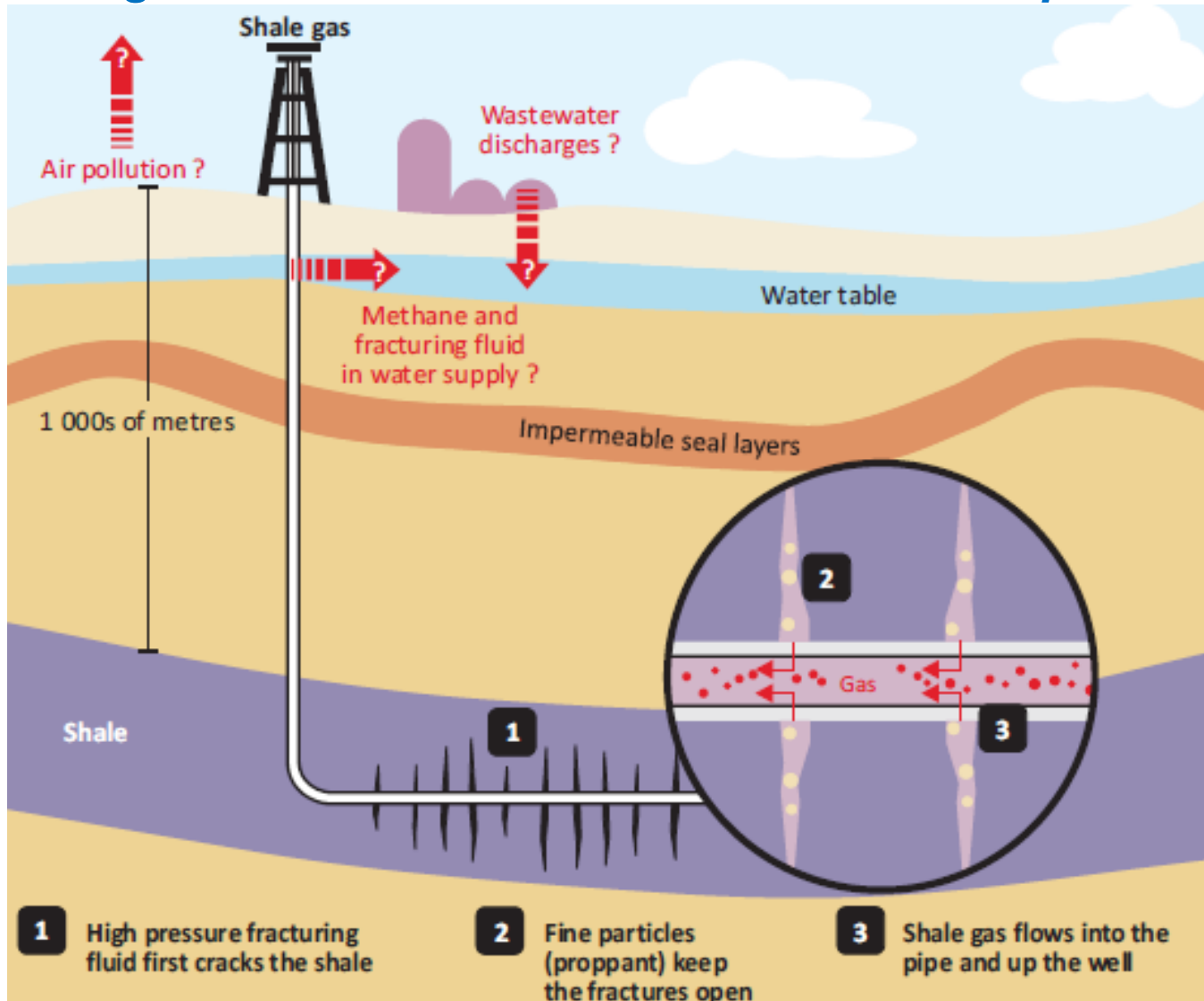


Conventional Gas: Harder to find easier to produce

Unconventional Gas: Easier to find, harder to produce

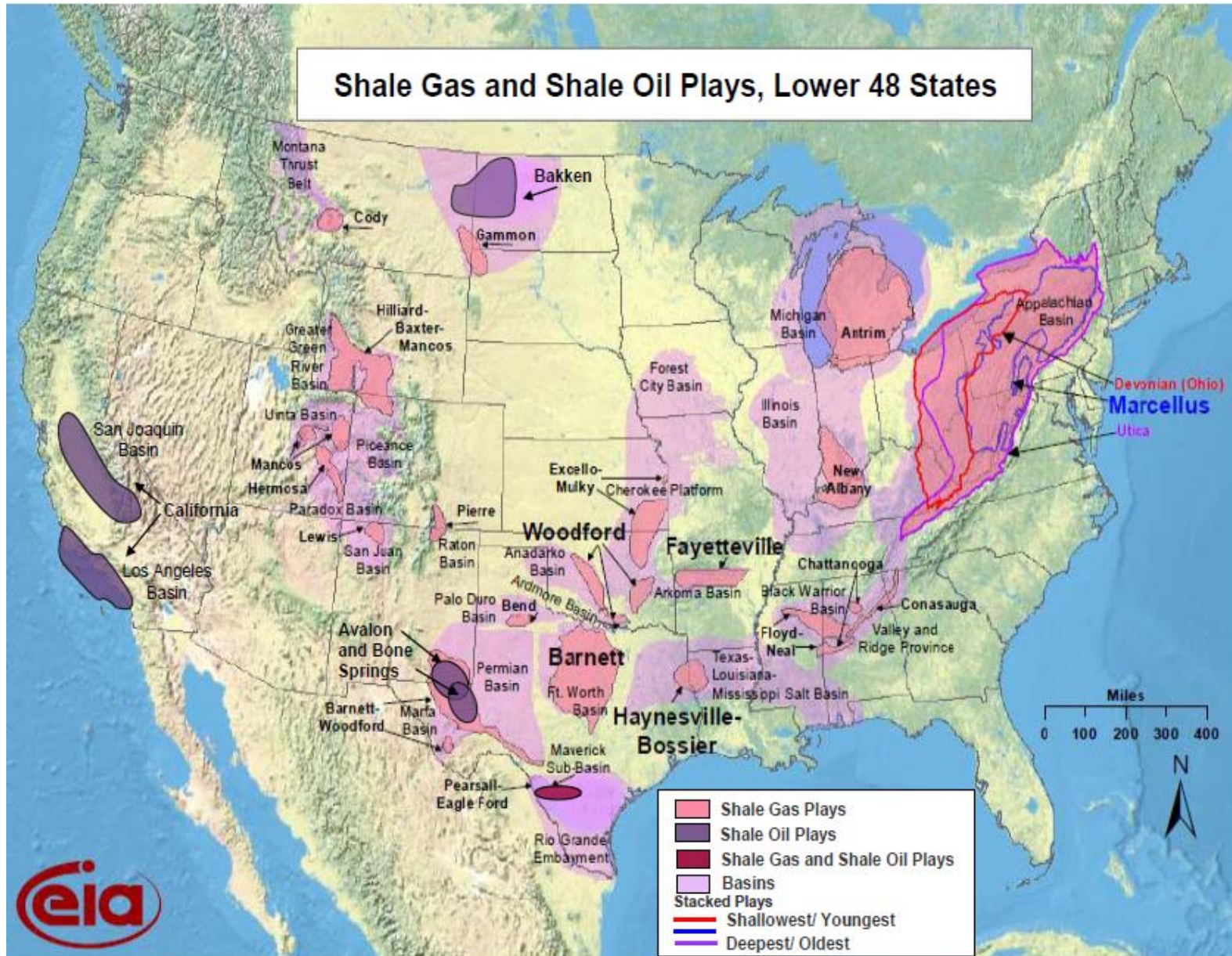
The Shale Revolution

Figure 1.3 ▷ Shale Gas Production Techniques



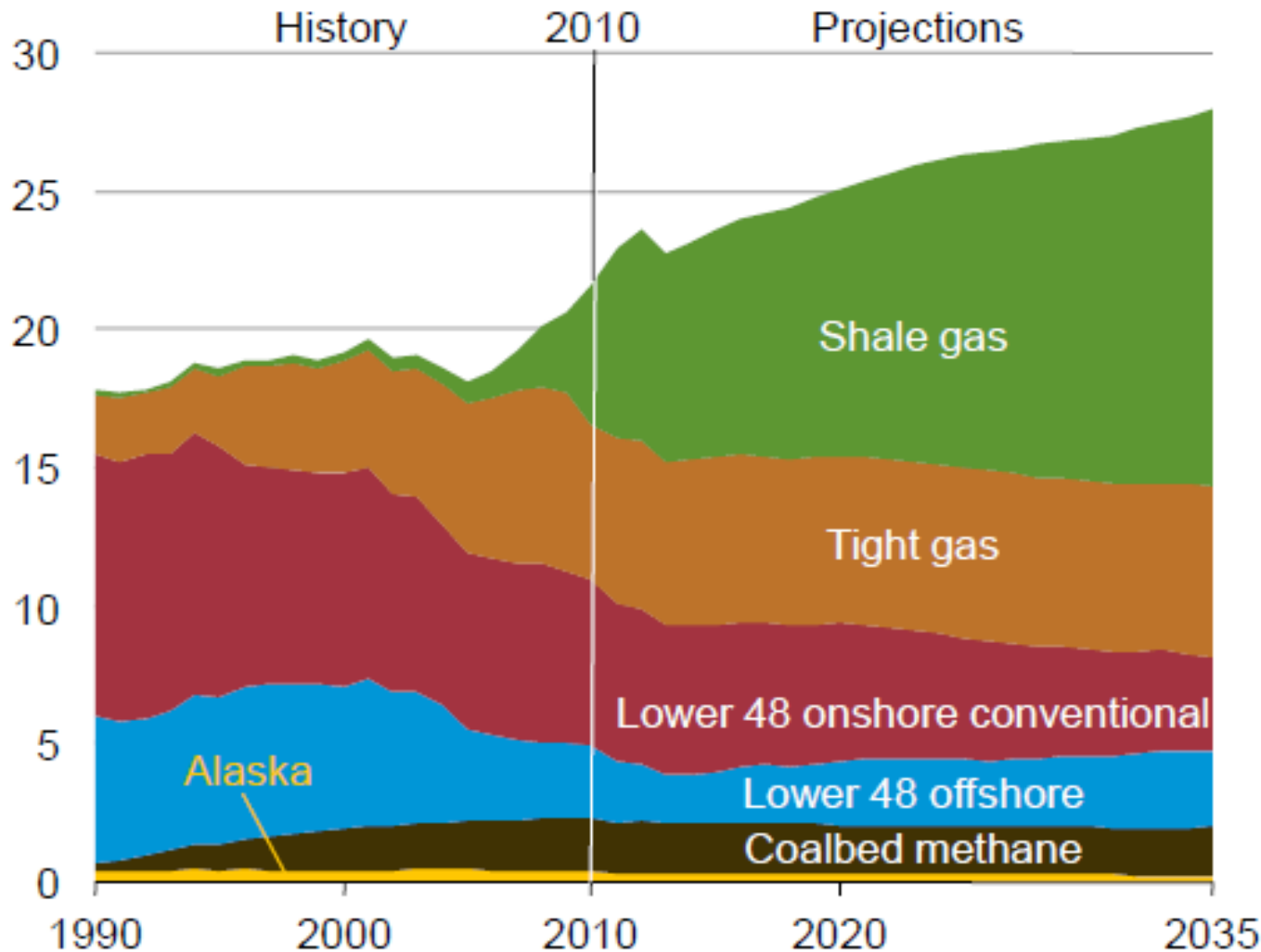
IEA 2012 WEO
Golden Rules
Report

US Shale Plays



Shale Gas Impact on US Production

Figure 107. Natural gas production by source, 1990-2035 (trillion cubic feet)

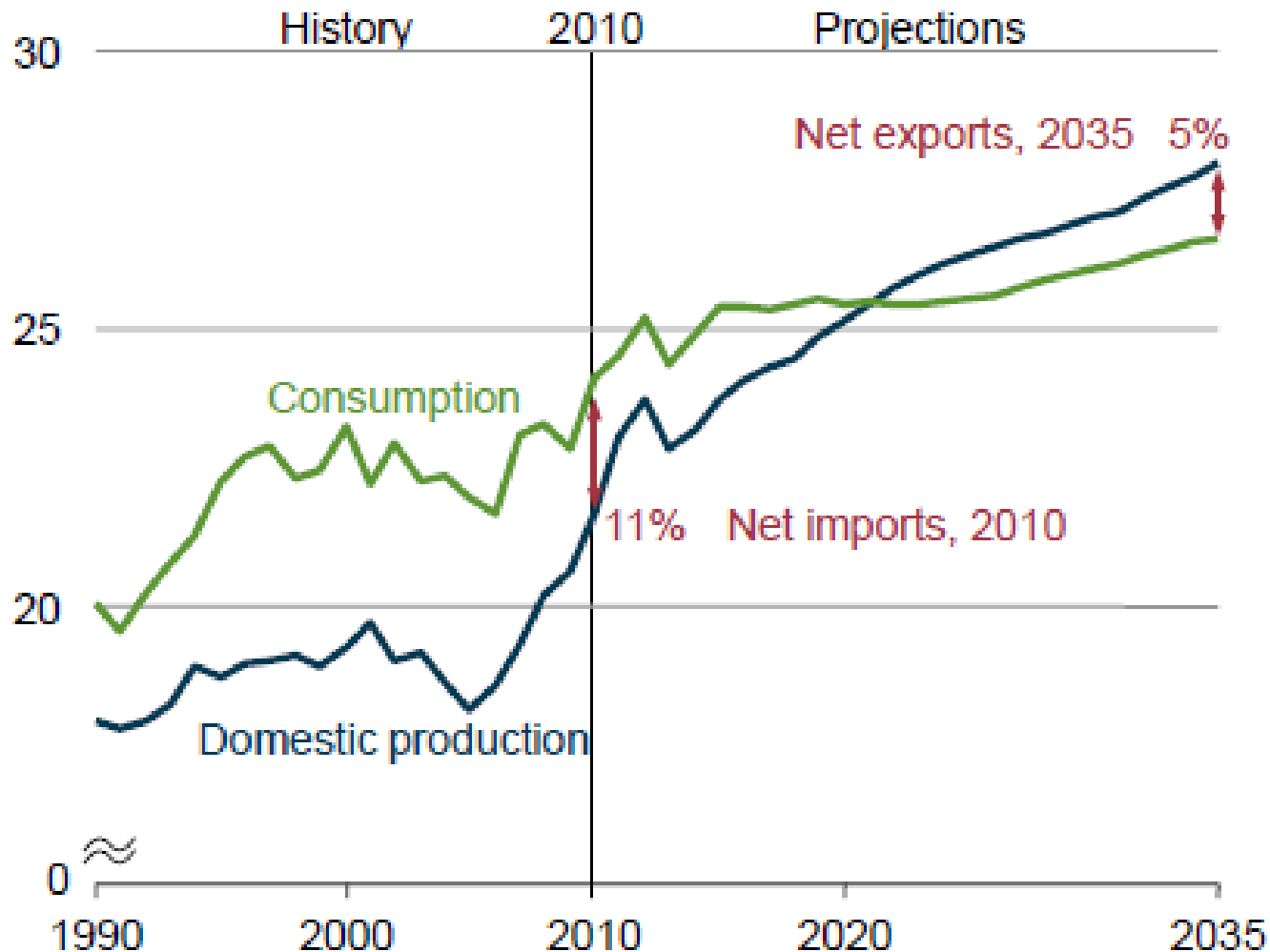


Source: DOE/EIA
2012 Annual
Energy Outlook

**Shale Gas Production Projected Account for 49% in 2035
(up from 23% in 2010)**

Shale Gas Impact on Net Imports

Figure 106. Total U.S. natural gas production, consumption, and net imports, 1990-2035 (trillion cubic feet)

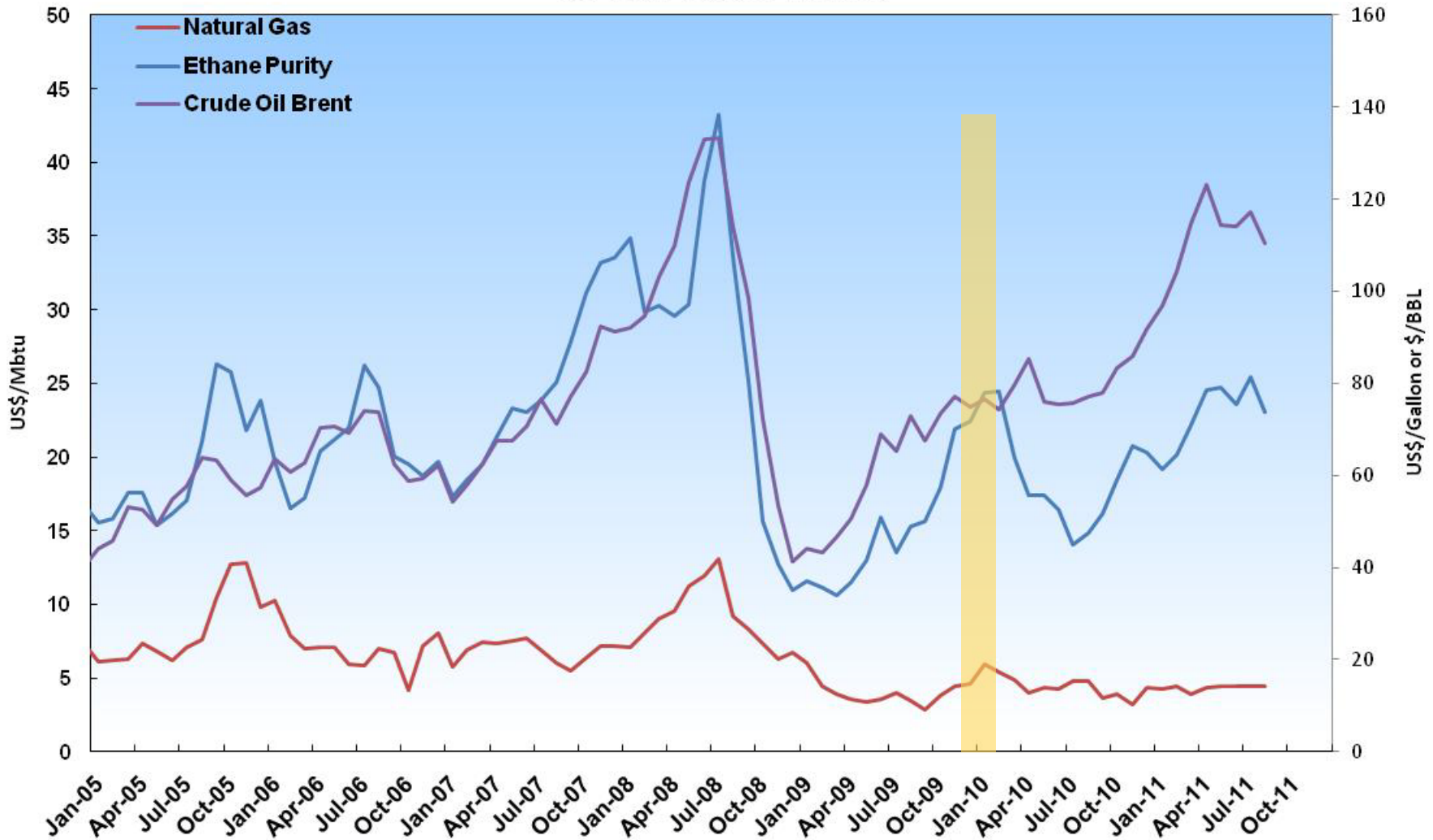


Source: DOE/EIA
2012 Annual
Energy Outlook

US Projected to be Net Exporter of Natural Gas around 2022

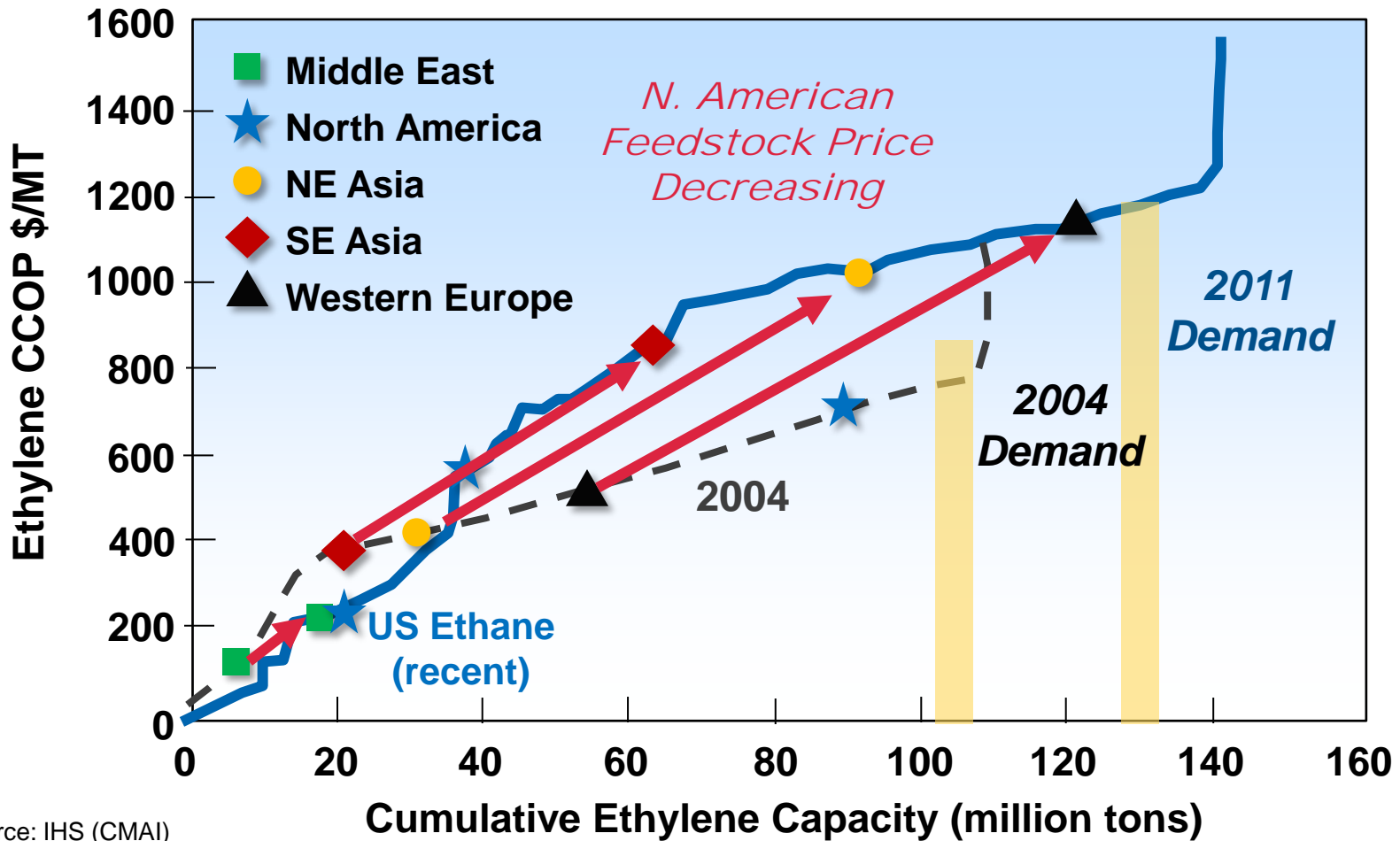
Shale Gas Impact on Ethane Price

US Gulf Coast Prices



Change in N. American Cost of Production

Ethylene Cash Cost Curve

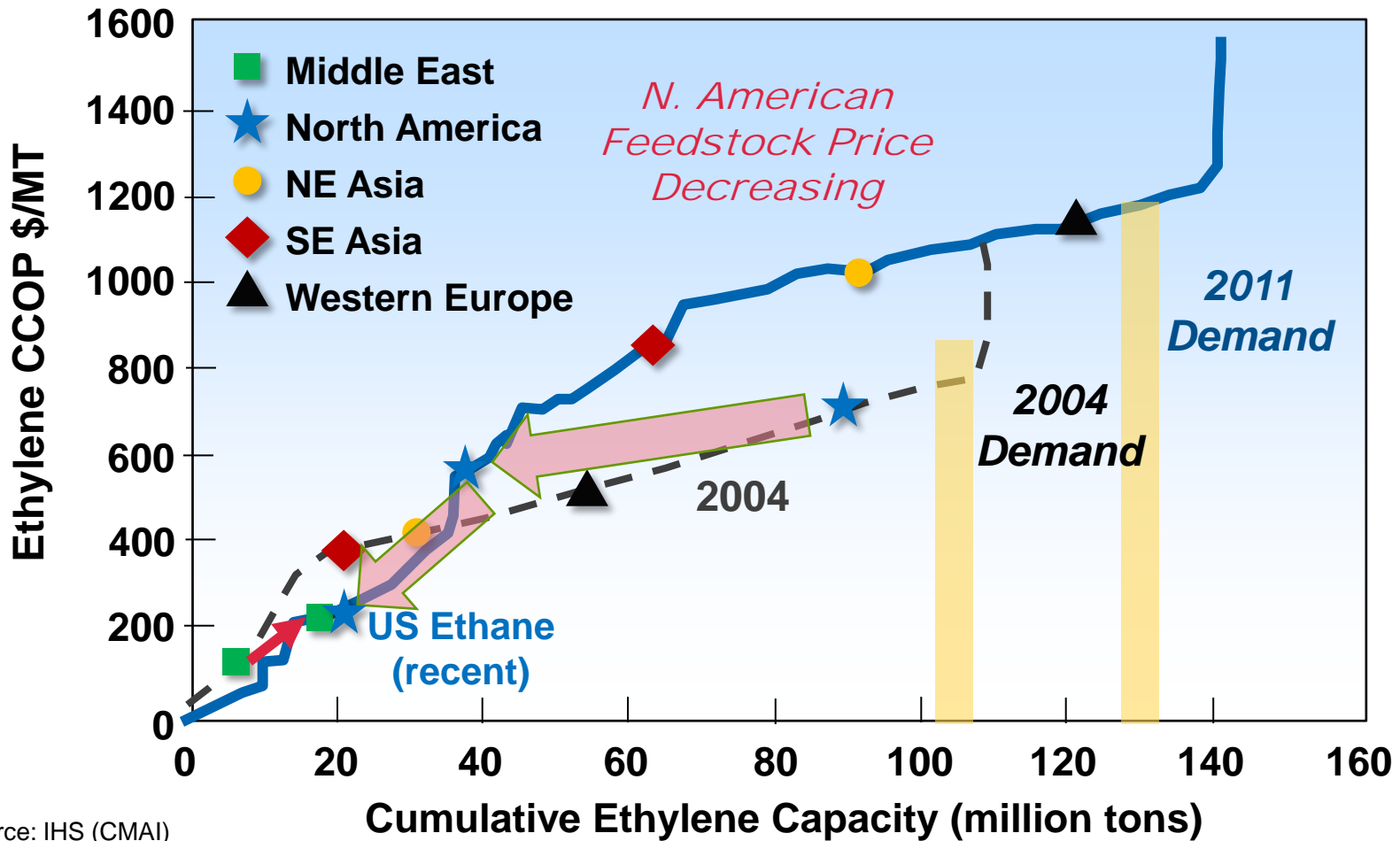


Source: IHS (CMAI)
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Cost Advantaged Feedstock Changes N. American Position on Cost Curve

Change in N. American Cost of Production

Ethylene Cash Cost Curve



Source: IHS (CMAI)
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Cost Advantaged Feedstock Changes N. American Position on Cost Curve

Shale Gas Impact on US PC Industry

- **Advantaged feedstock position due to shale development**
- **Strong ethylene demand and operating rates**
 - Strong recovery from recession
 - Elimination of significant production capacity from 2008 – 2010
- **Attracting Large Investments (Dow, Shell, Others)**
- **Co-product shortages have led to high prices**
 - A result of the shift to light feed slate
 - Increased investments in on-purpose co-product production

Shale Gas and Sustainability

- **Economic**
- **Social**
- **Environmental**



Economic Dimension

- **U.S. Petrochemical Industry**
 - Cost advantage feed (from crude oil based naphtha to NGL ethane)
 - Investment in ethylene capacity expansions in progress
 - Investments in co-product production also occurring (propane dehydro, on-purpose BD)
- **Impact on US economy overall through lower energy costs**
 - Lower heating and electricity costs
 - Estimated to save an average of \$926 per household between 2012 and 2015 and increase to \$2000 per household in 2035
 - Potential to have large impact on transportation costs
 - Gas at \$2.50/MMBTU equivalent to \$15/eq bbl oil vs. crude at \$100/bbl
 - Fleet vehicles already switching over to CNG
 - LNG an option to increase range for long haul freight vehicles

Social Dimension

- **Employment**

- Direct employment opportunities in shale gas (and oil) industry
- Indirect jobs in supplying steel, equipment, trucking, support services
- Direct and indirect shale oil and shale gas supported 1.7 million U.S. jobs this year (IHS Global Insight)
- Additional jobs supported due industries locating in US to take advantage of lower energy costs vs. relocating overseas (such as PC)

- **Energy Security**

- US projected to be net natural gas exporter by 2022
- Shale oil will largely eliminate overseas oil imports by 2020
- Mitigate Energy Security Threats
 - Political instability of foreign energy producers
 - Price manipulation, competition for resources
 - Natural disasters, terrorism

Environmental Dimension

- **Benefits**

- US electricity from gas increased from 20% in 2006 to 25% in 2012, mainly at the expense of coal (decrease in HAP)
- Over past 5 years US GHG emissions declined by 450 MT (largest anywhere in the world)

- **Concerns**

- Water Use and treatment and disposal of wastewater
- Contamination of groundwater
- Air emissions (diesel gen sets for fracking wells, trucking, methane)
- Earthquakes (fracking operations intersect existing faults)
- IEA suggest principles for address environmental impacts
- Estimated to increase well costs by 7%

- **Shale gas has already had a dramatic impact on US Petrochemical Industry and US energy supply**
- **Positive impacts with respect to employment and security on the social dimension**
- **Environmental impact**
 - **Replace coal with cleaner burning natural gas**
 - **Concerns with shale gas production are real**
 - **Cost effective solutions have been proposed to effectively manage these risks**

***Shale Gas/Oil can be a Bridge to the Future.
Renewables R&D Still Required.***

- **IHS/CMAI - North American Olefins Overview - 2012**
- **IEA World Energy Outlook 2012**
- **DOE/EIA, Annual Energy Outlook 2012**
- **The Future of Natural Gas, MIT Study 2010**
- **Gas works, Economist, July 2012**