Shale Gas
-
From the Source Rock to the Market: An Uneven pathway

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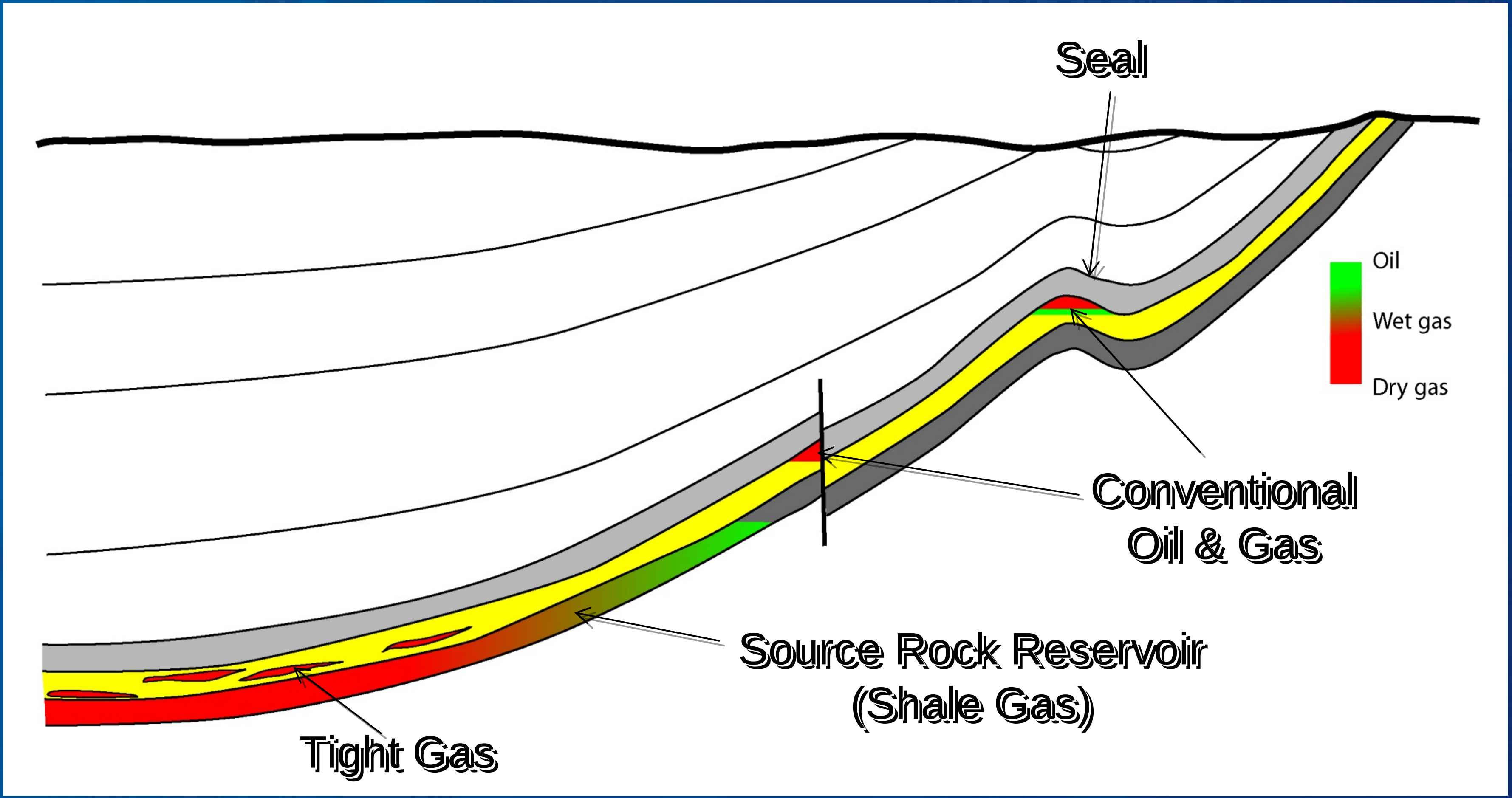
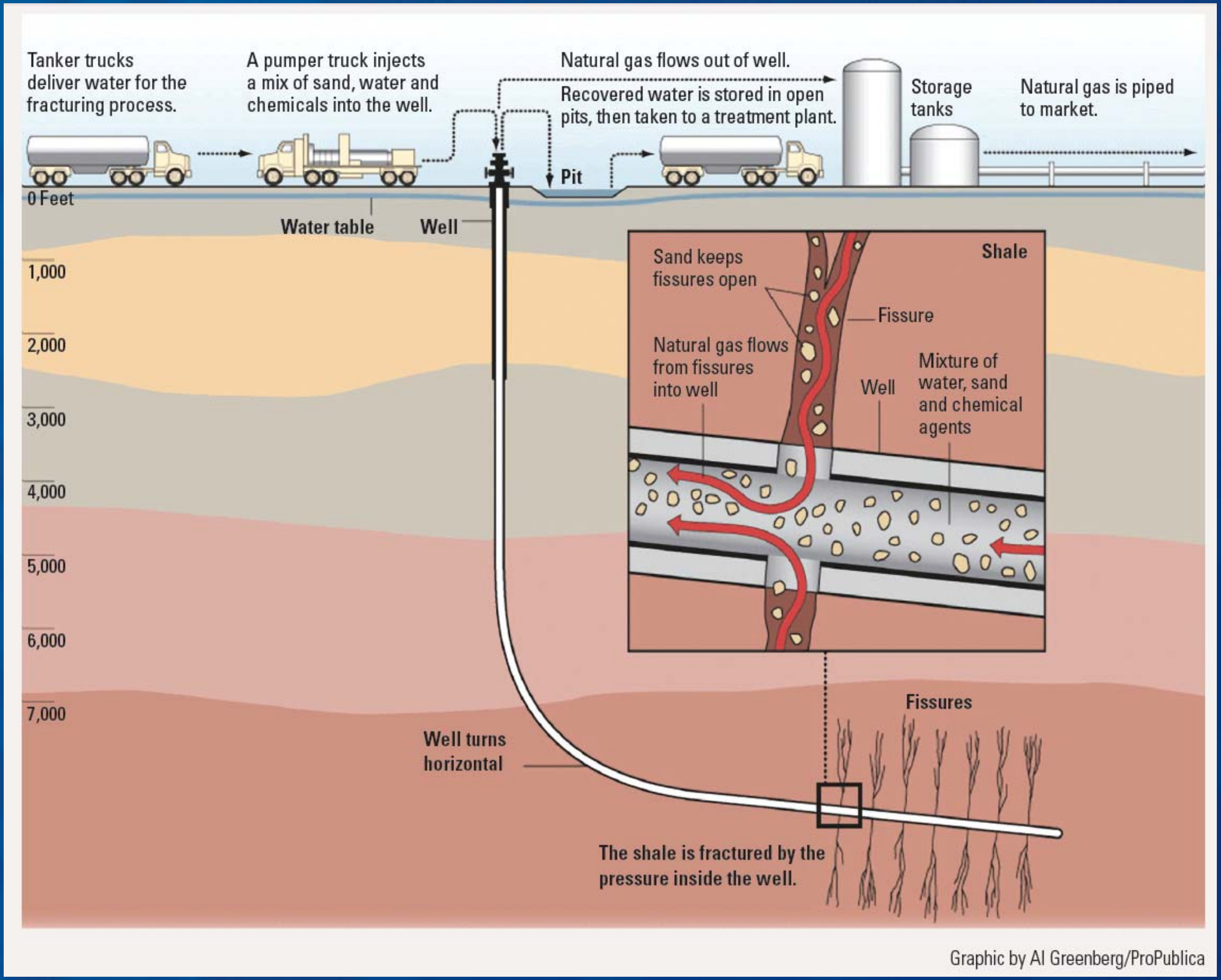
IFP TECHNOLOGIES (CANADA) INC.

Shale Gas Definition



Modified from Williams 2013

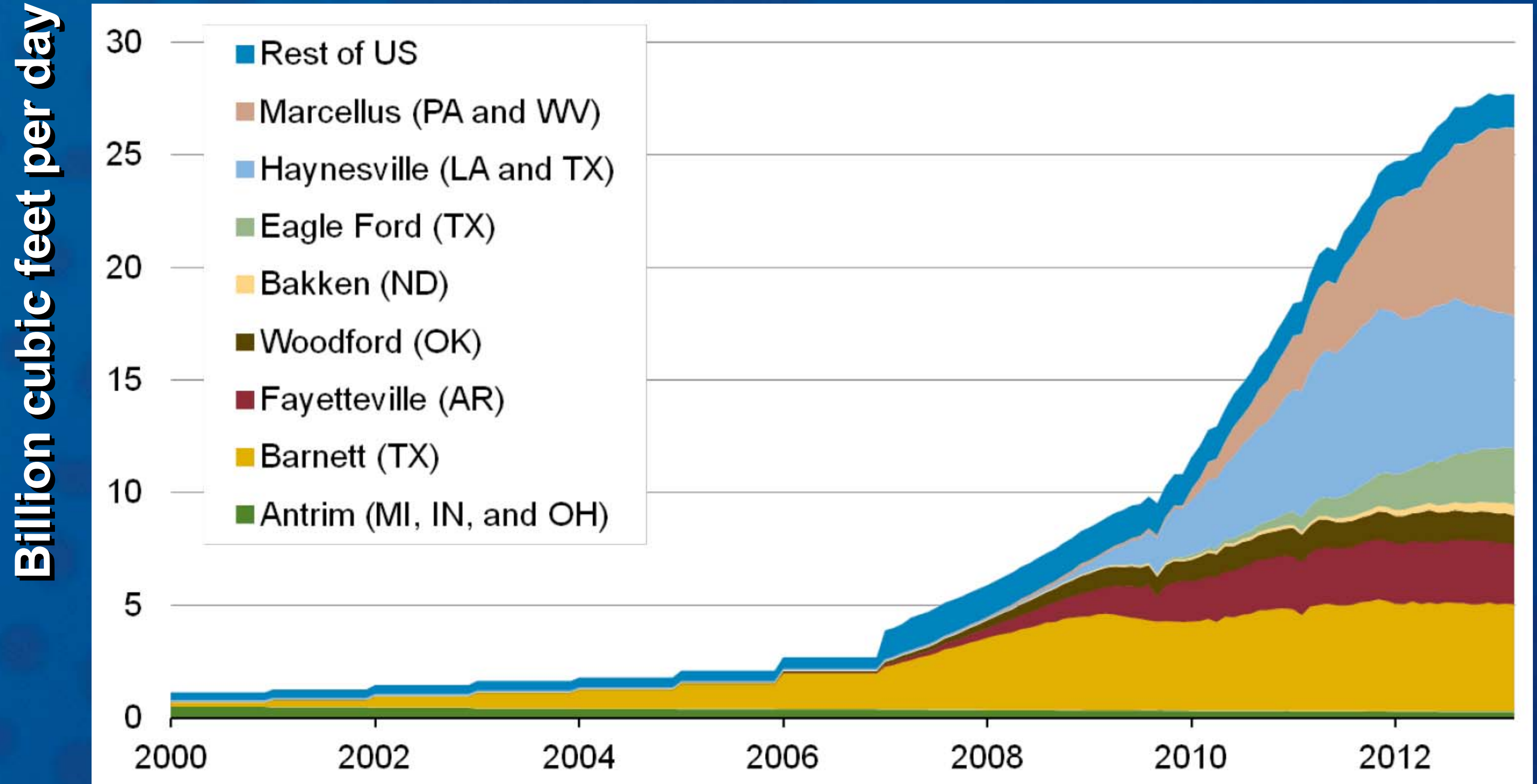
Production Methods



Burwen and Flegal 2013 (American Energy Innovation Council)

US Shale Gas Production

39% of U.S. Gas Production in 2012

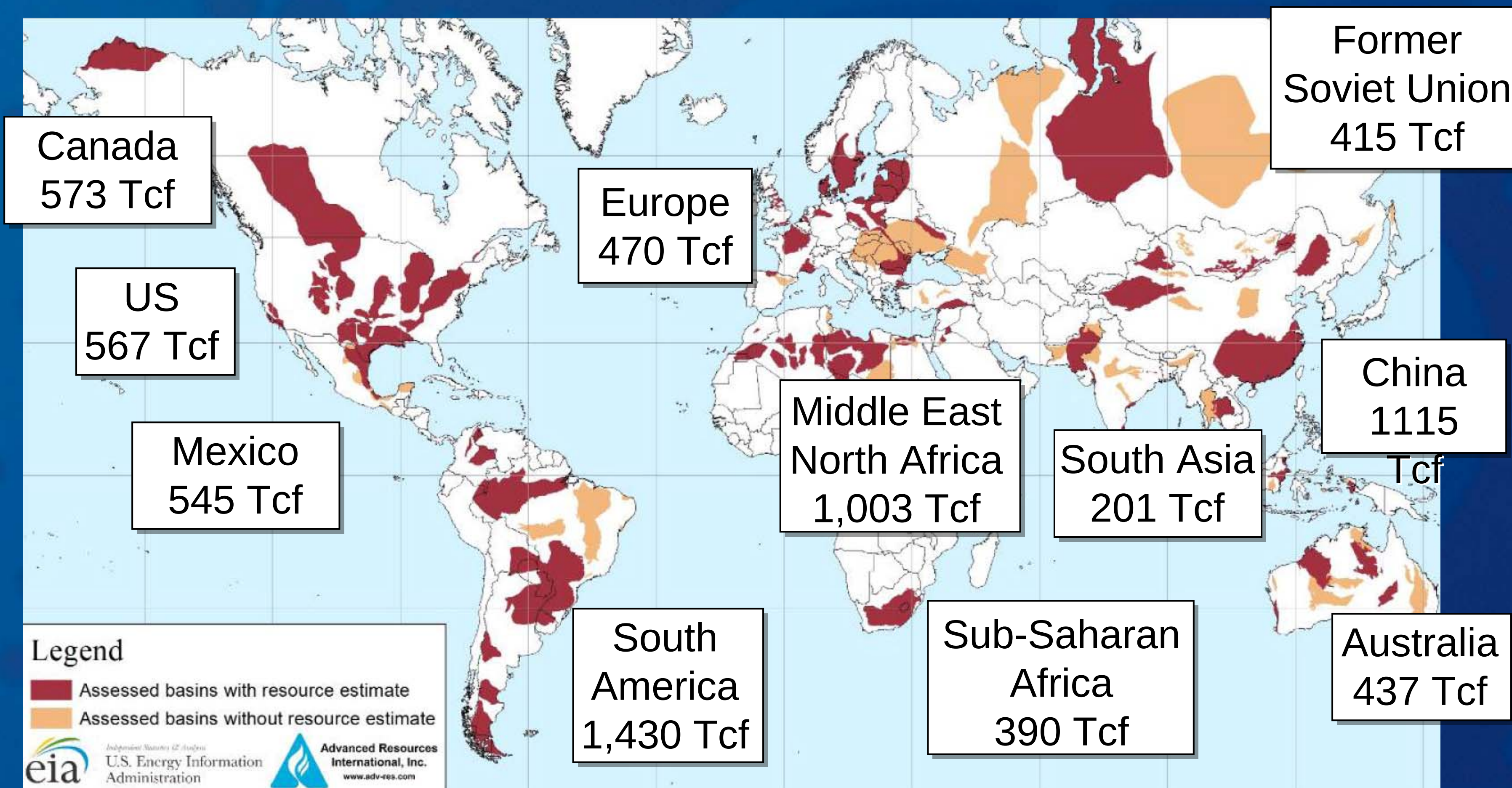


Sources: LCI Energy Insight gross withdrawal estimates as of March 2013 and converted to dry production estimates with EIA-calculated average gross-to-dry shrinkage factors by state and/or shale play.

Sieminski 2013, U.S. Energy Information Administration (march 2013)

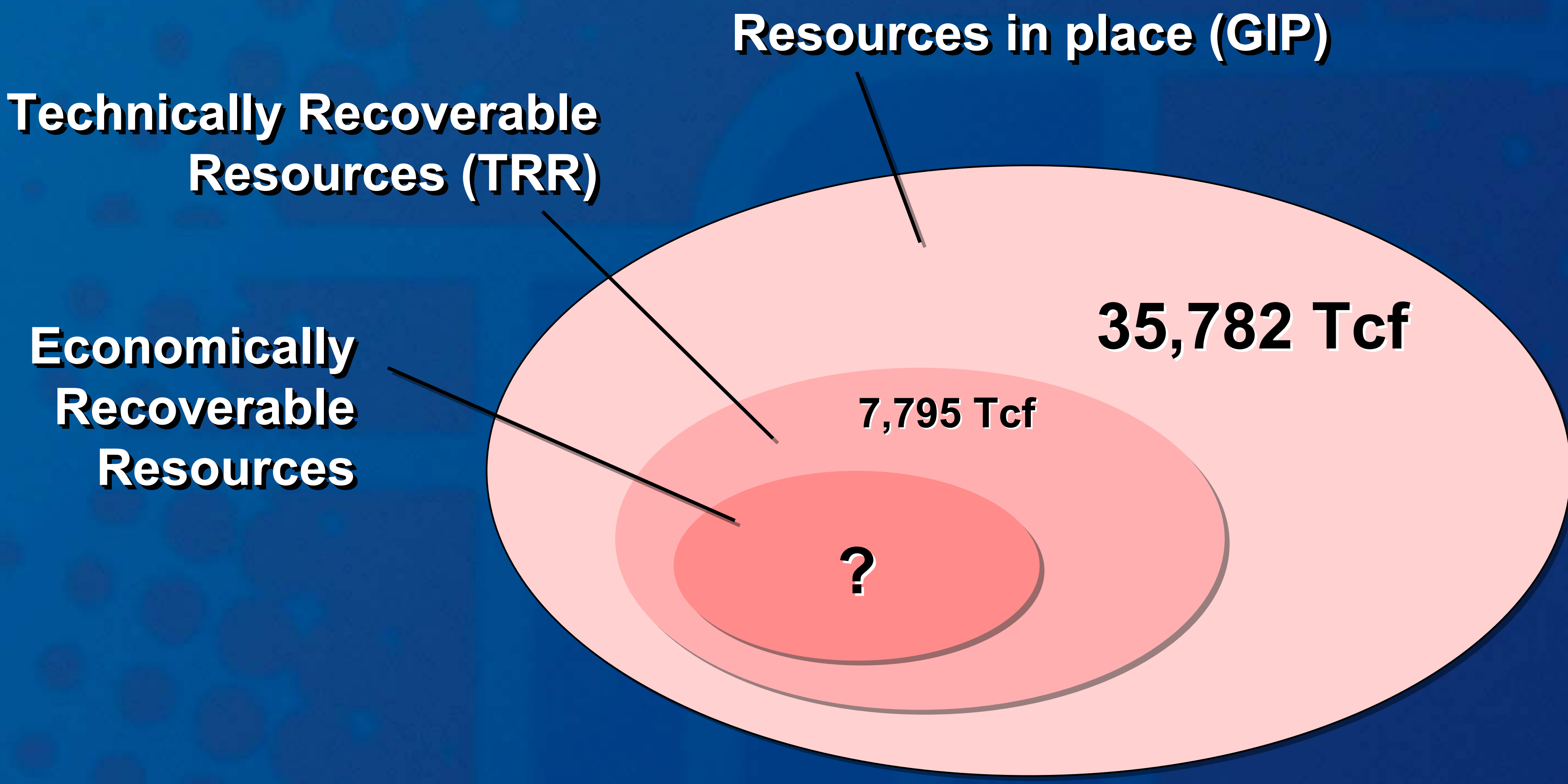
Shale Gas World Resources (TRR)

GIP: 35,782 TRR: 7,795 Tcf + 47% of TRR



Technically recoverable shale gas resources in the world. source: EIA – June 2013

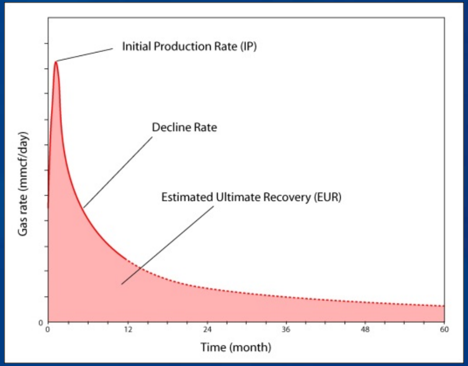
Shale Gas World Resources



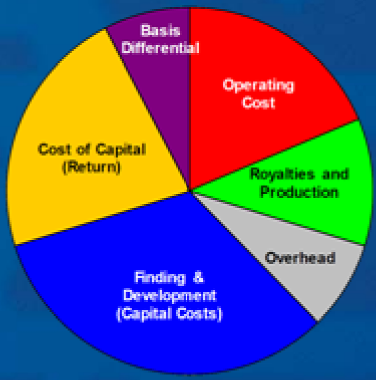
After Medlock and Hartley 2010

Economically Recoverable Resources

Well Productivity



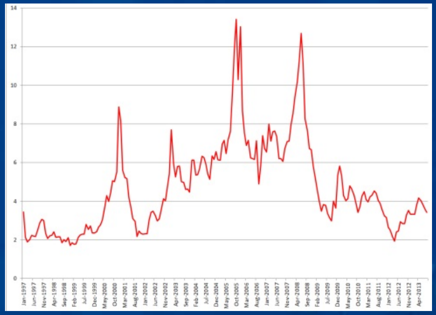
Full Cycle Gas Costs



Ziff 2011

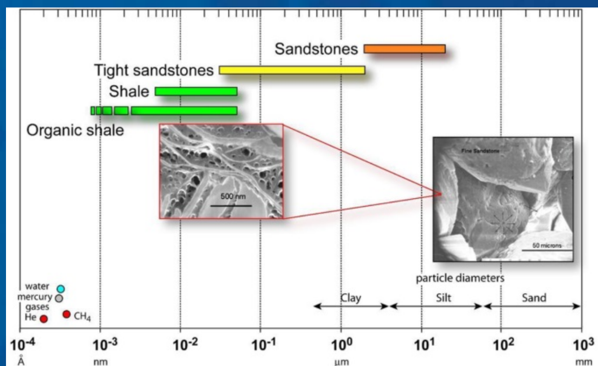
ERR ?

Price of Gas



Shale Gas Development Strategy

Economy of scale: the "Shale Gas Factory"

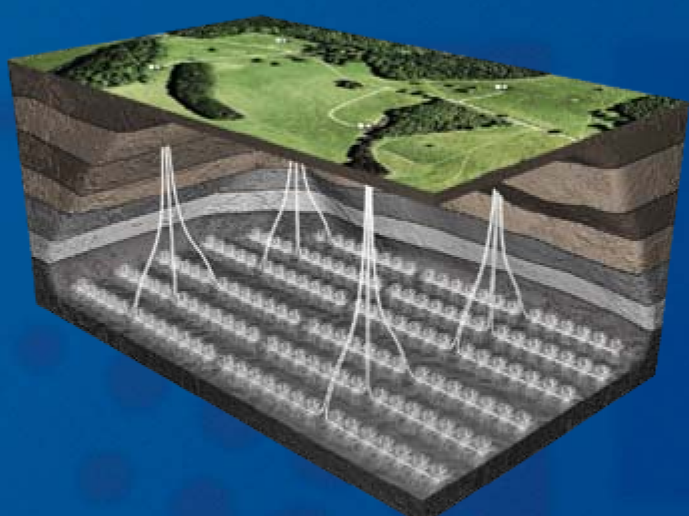


Based on Nelson 209 and Passey et al 2010

- A lot of wells are required in order to drain the reservoir efficiently

- Long horizontal wells with multistage hydraulic fracturing are expensive: high capex

- Economy of scale needed to lower the F&D costs on a per $/mcf basis



Ross and Smrecak 2010 (Marcellus)

U.S. Shale Gas Well Cost

Well cost in prolific U.S Shale Plays average **M$ 3 to M$ 8**

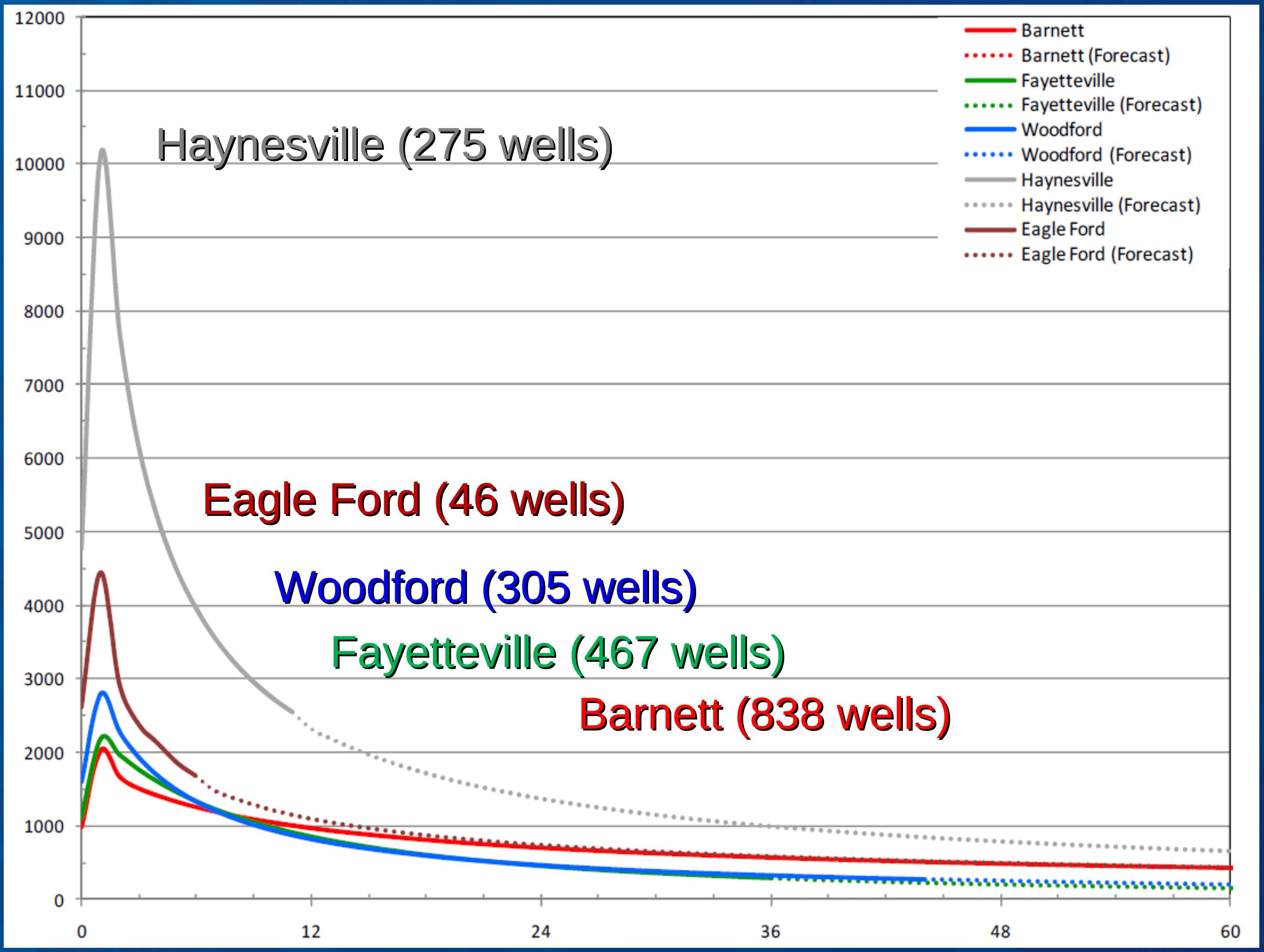
Shale Gas Plays	F&D ($/Mcfe)	LOE ($/Mcfe)	T&F ($/Mcfe)	Royalty Rate	Leasehold Costs ($/Acre)	Permitting Fee	Prepping Fees	Well Cost
Marcellus	$1.25	$0.90	$0.29	15%	$2,500	$2,500	$400,000	$3,500,000
Antrim	$0.70	$1.50	$0.29	20%	$3,200	$2,500	$45,714	$400,000
New Albany	$1.00	$1.50	$0.29	20%	$25,000	$2,500	$102,857	$900,000
Fayetteville	$1.38	$1.30	$0.09	13%	$5,000	$2,500	$320,000	$2,800,000
Barnett	$1.05	$1.85	$0.11	25%	$25,000	$2,500	$342,857	$3,000,000
Haynesville	$1.25	$1.50	$0.09	25%	$25,000	$2,500	$914,286	$8,000,000
Cana Woodford	$1.64	$0.30	$0.09	20%	$25,000	$2,500	$914,286	$8,000,000
Eagle Ford	$1.50	$1.50	$0.09	25%	$25,000	$2,500	$662,857	$5,800,000
Utica	$2.05	$1.67	$0.29	13%	$8,200	$2,500	$371,429	$3,250,000
Devonian	$1.30	$1.50	$0.29	20%	$8,200	$2,500	$200,000	$1,750,000
Woodford	$1.88	$1.25	$0.09	27%	$6,500	$2,500	$765,714	$6,700,000

Cohen 2013 (Harvard Kennedy School)

F&D: Finding and Development
LOE: Lease Operating Expense
T&F: Transport and Fractionation

Shale Gas Well Productivity

Production Rate (mcf/d)

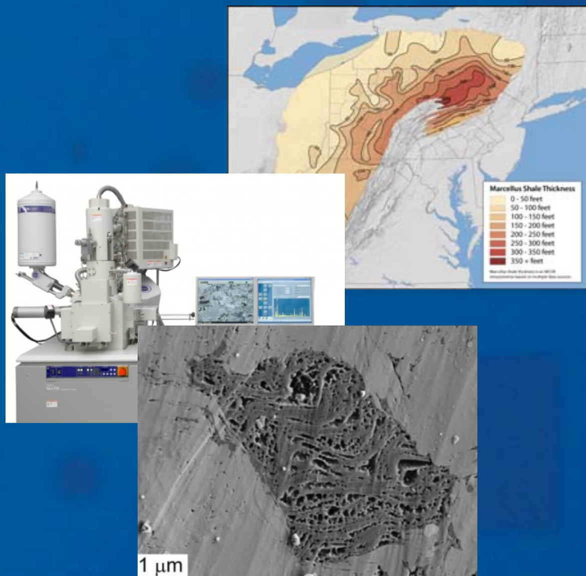


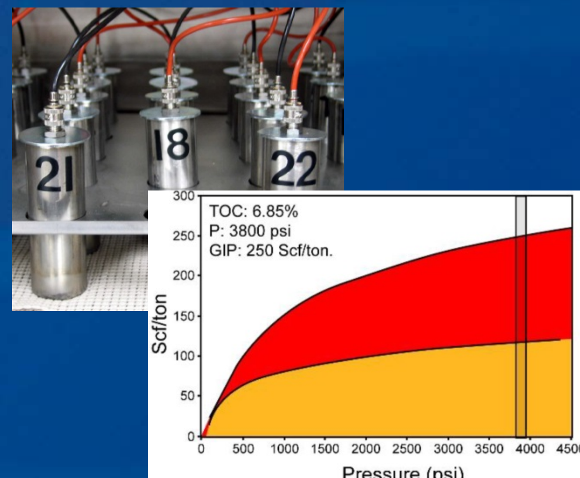
Time (months)

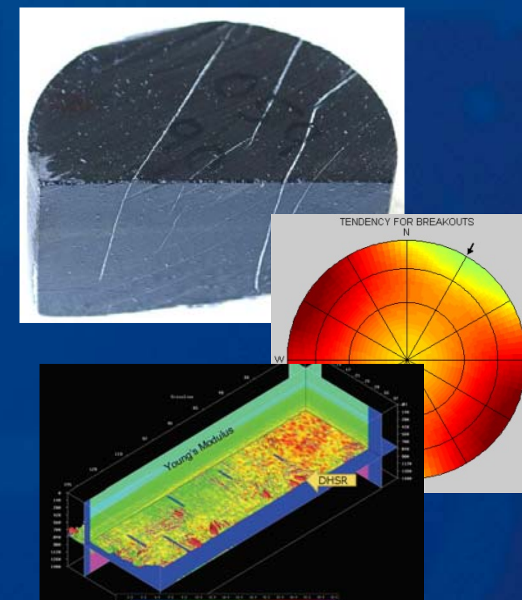
(Baihly et al 2010)

Controls on productivity

Geology





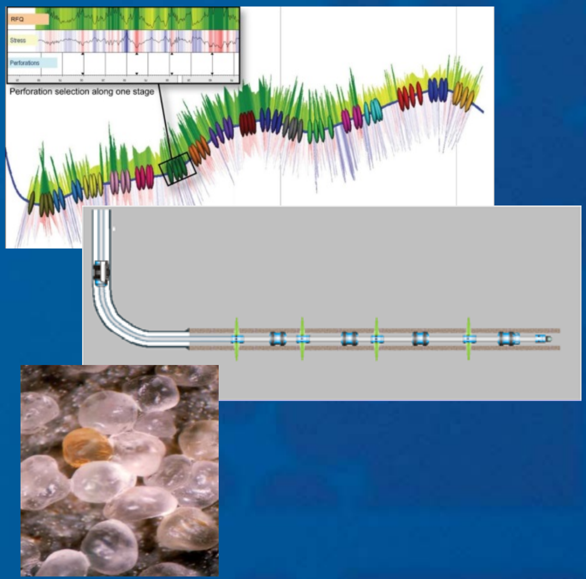


- Thickness
- Organic matter
- Thermal maturity
- Porosity
- Permeability
- Mineralogy

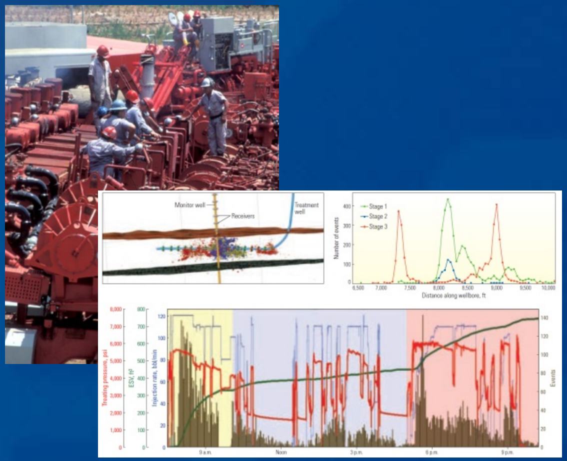
- Free gas
- Adsorbed gas
- Pressure
- Temperature

- Mechanical properties
- Stress orientation
- Natural fractures

Controls on productivity



Drilling, Completion and Stimulation

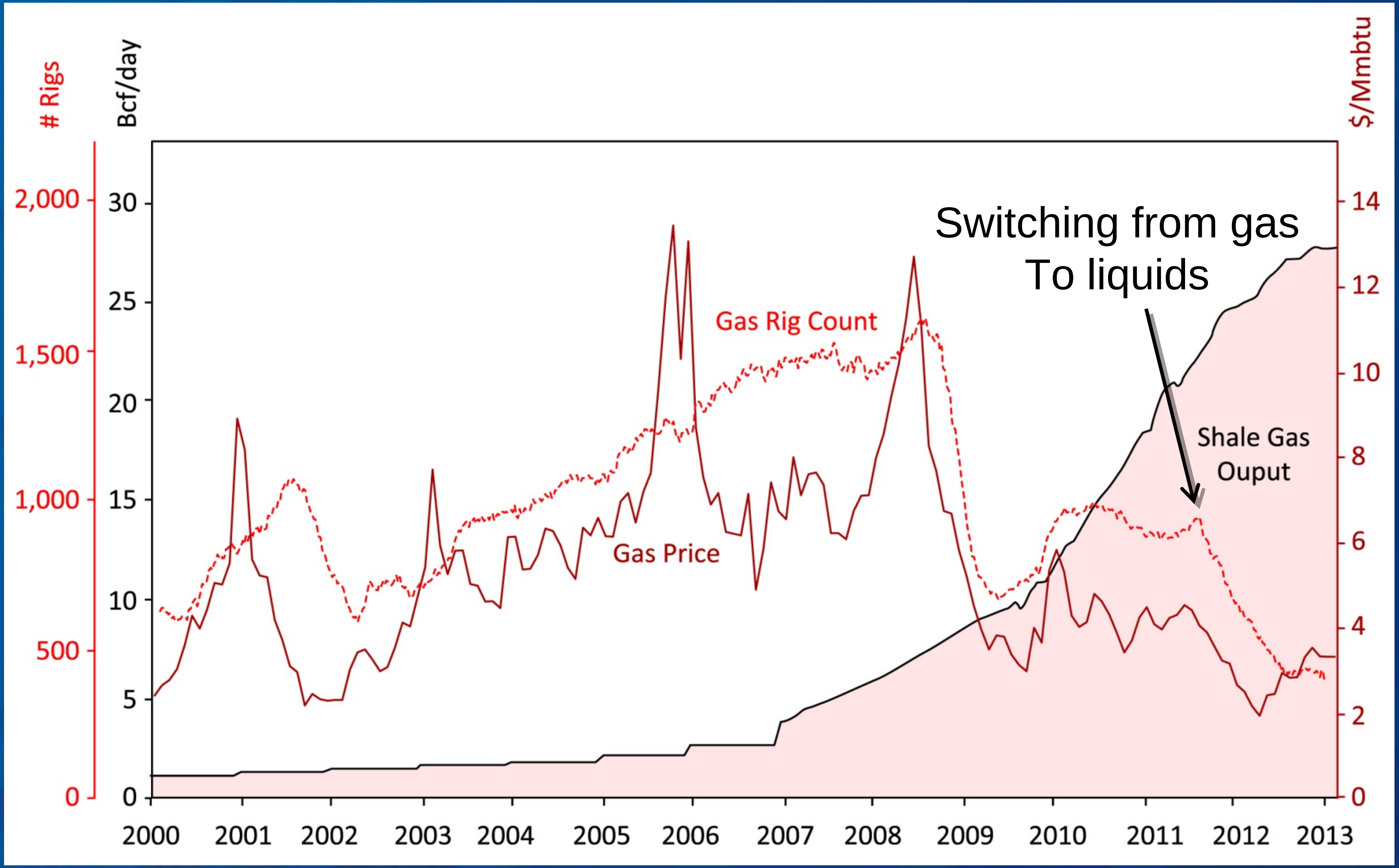


- Geosteering
- Horizontal length
- Open/cased hole
- # of frac stages
- Clusters position

- Treating pressure
- Injection rate
- Fluid type/volume
- Proppant type/volume
- Fluid additives

- Well spacing
- Diversion
- Simo-frac
- Zipper frac

Gas Price: The Shale Gas Glut

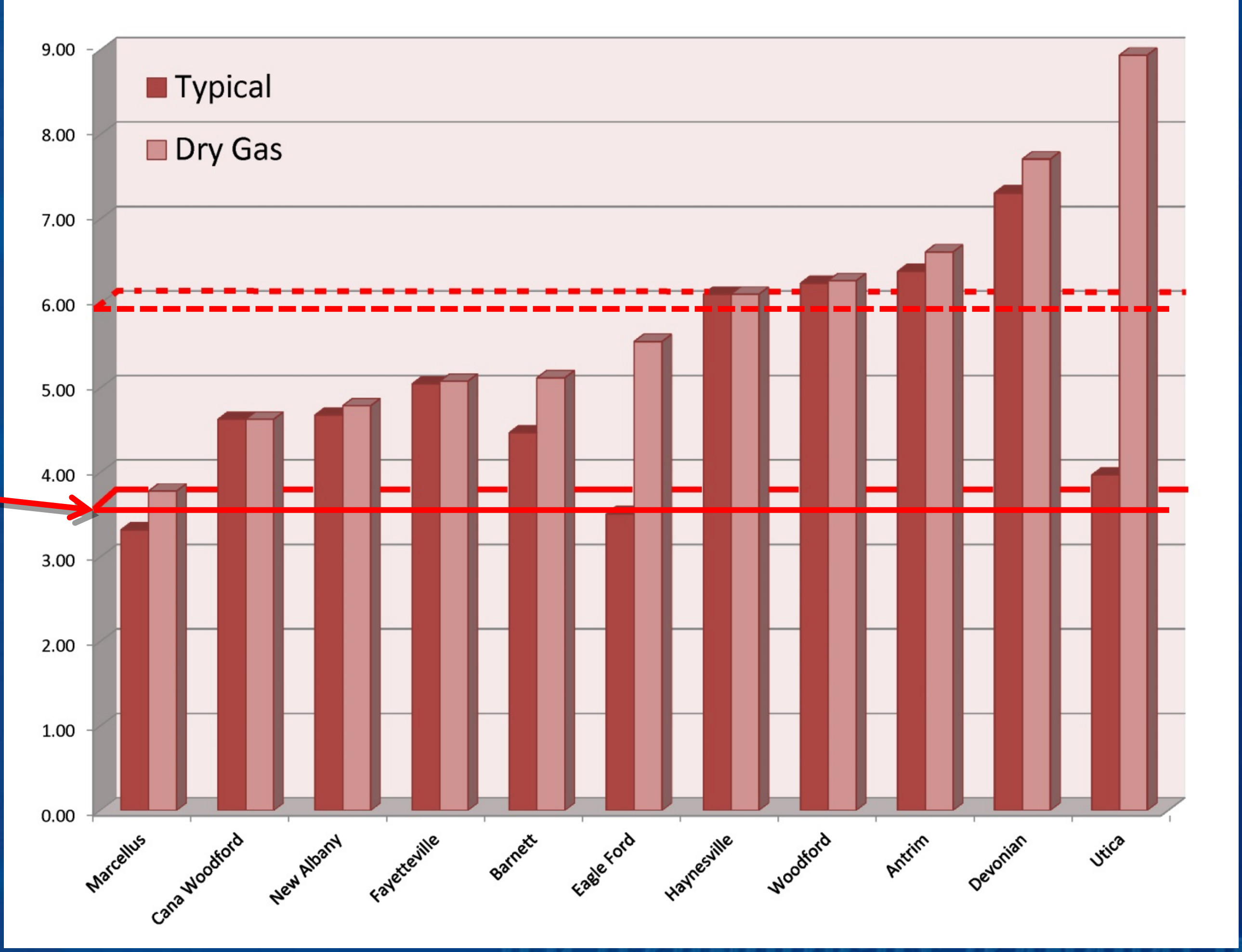


Source (EIA, Baker Hughes)

Shale Breakeven Price

Full cycle cost discounted cash flow analysis (10% IRR)

Henry Hub Spot
Sept 2013
3.62$/MMbtu

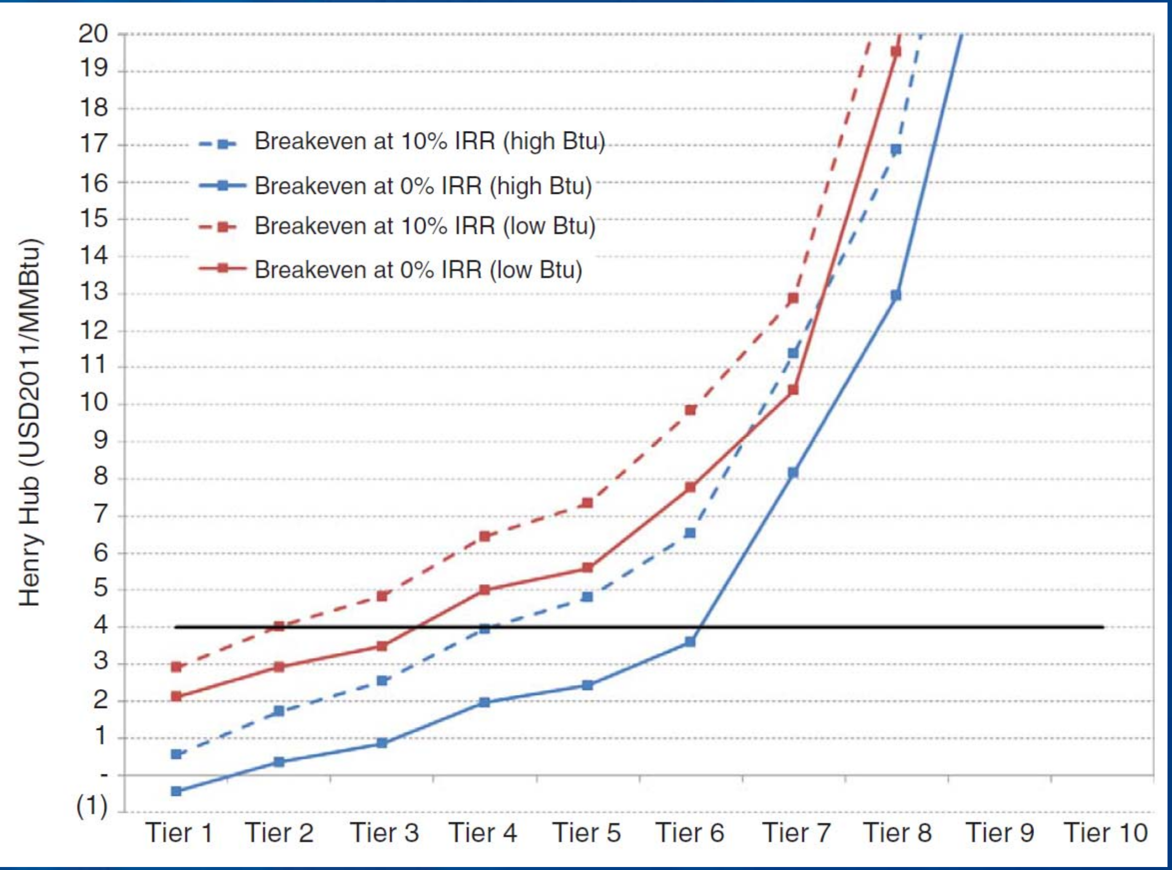


(Source: Cohen 2013, Harvard Kennedy School)

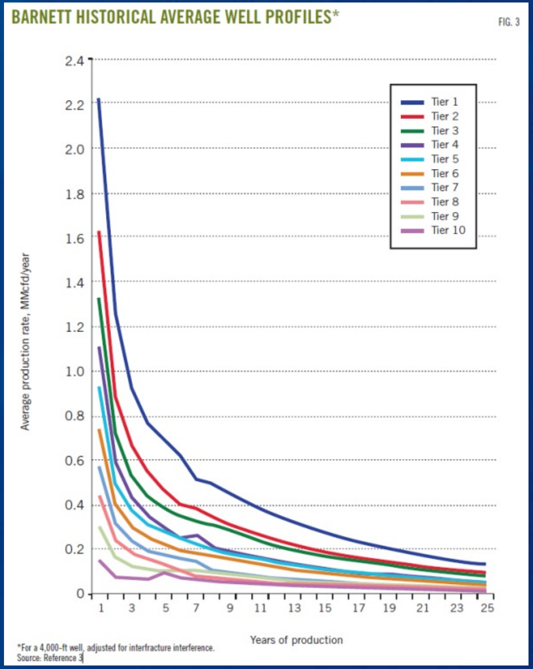
Shale Breakeven Price

Barnett Tiers 1 to 4 still profitable at current gas price

Breakeven gas price

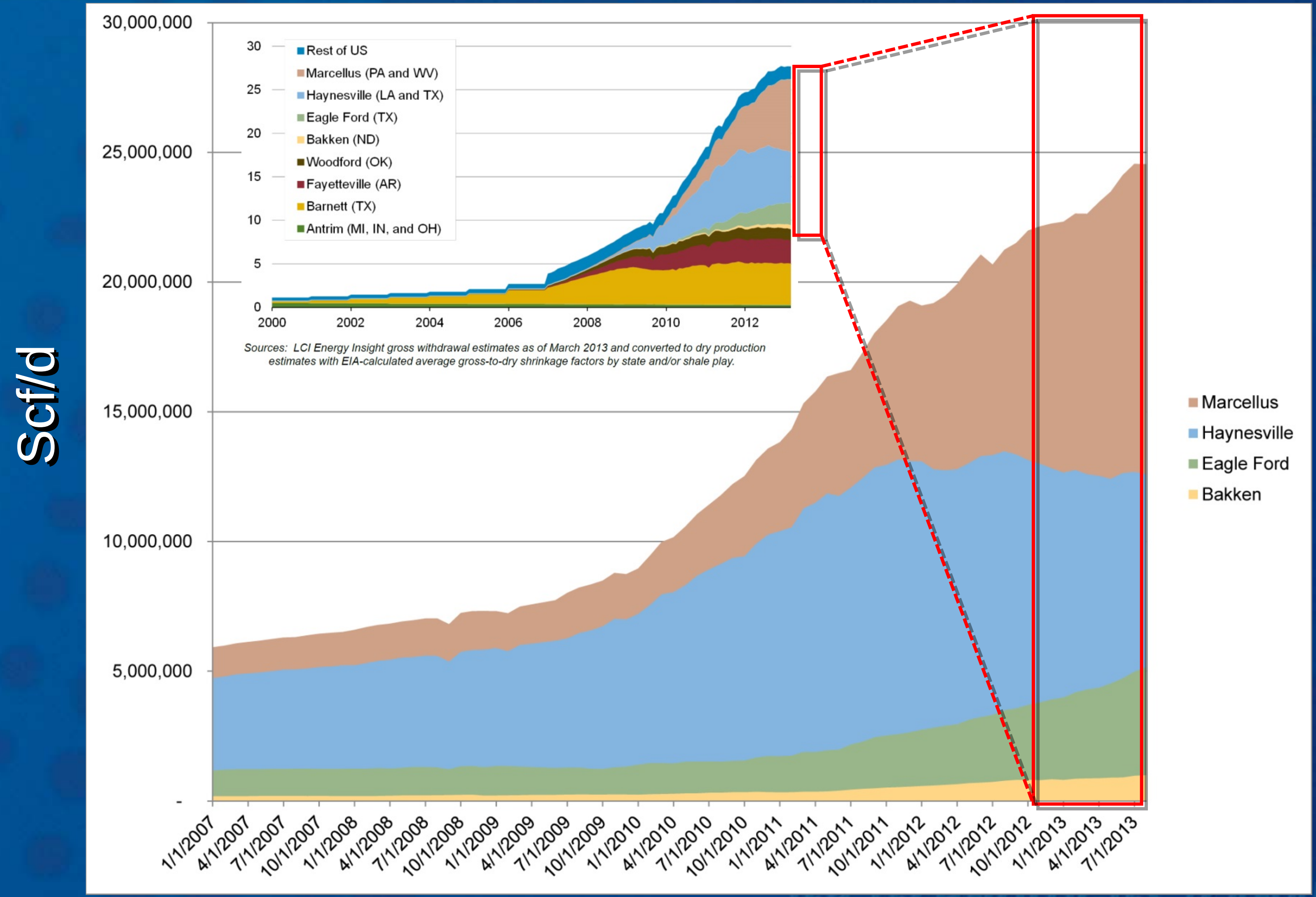


Tier's productivity



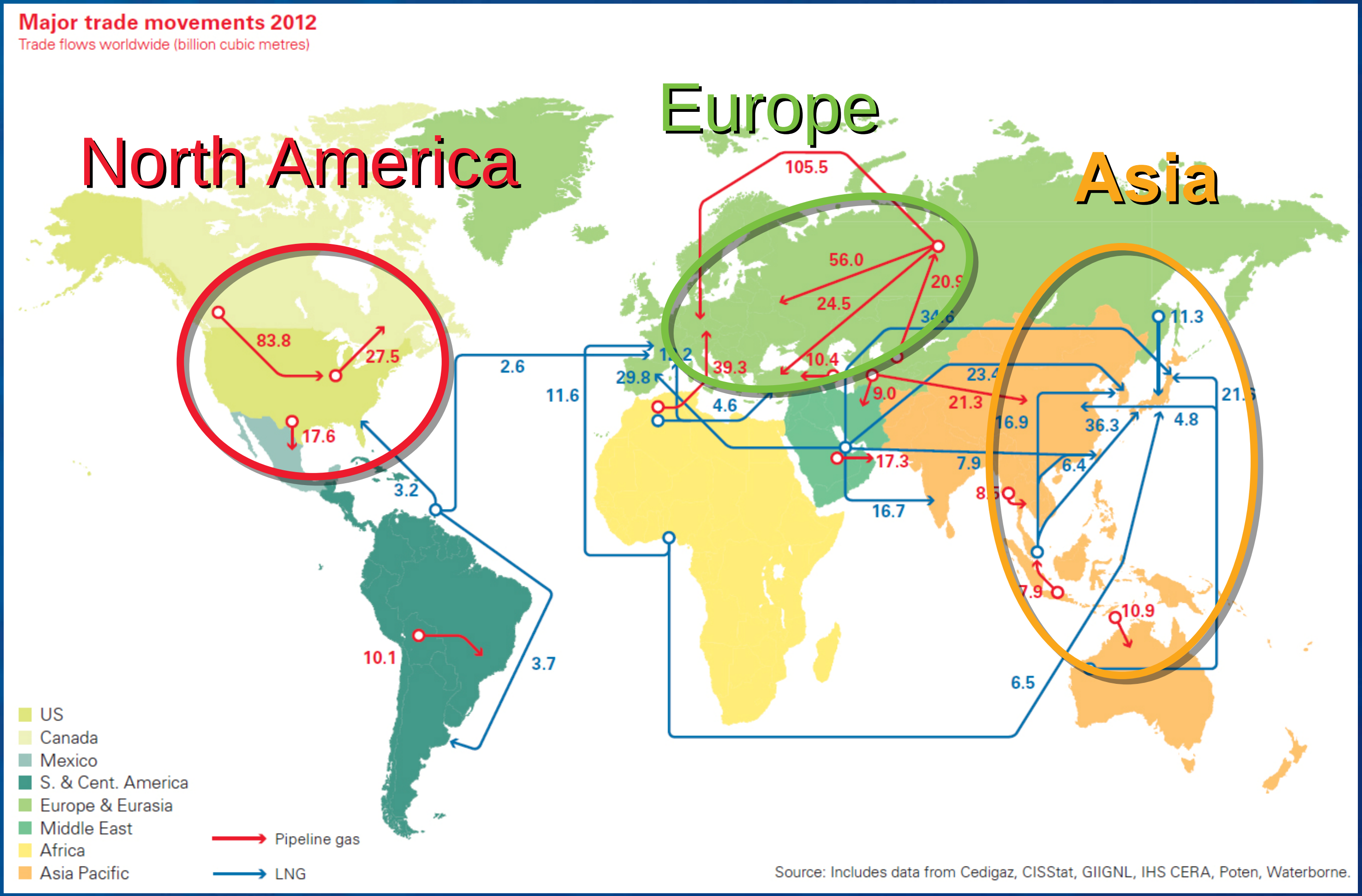
Browning et al 2013 (Bureau of Economic Geology)

Latest Production Data



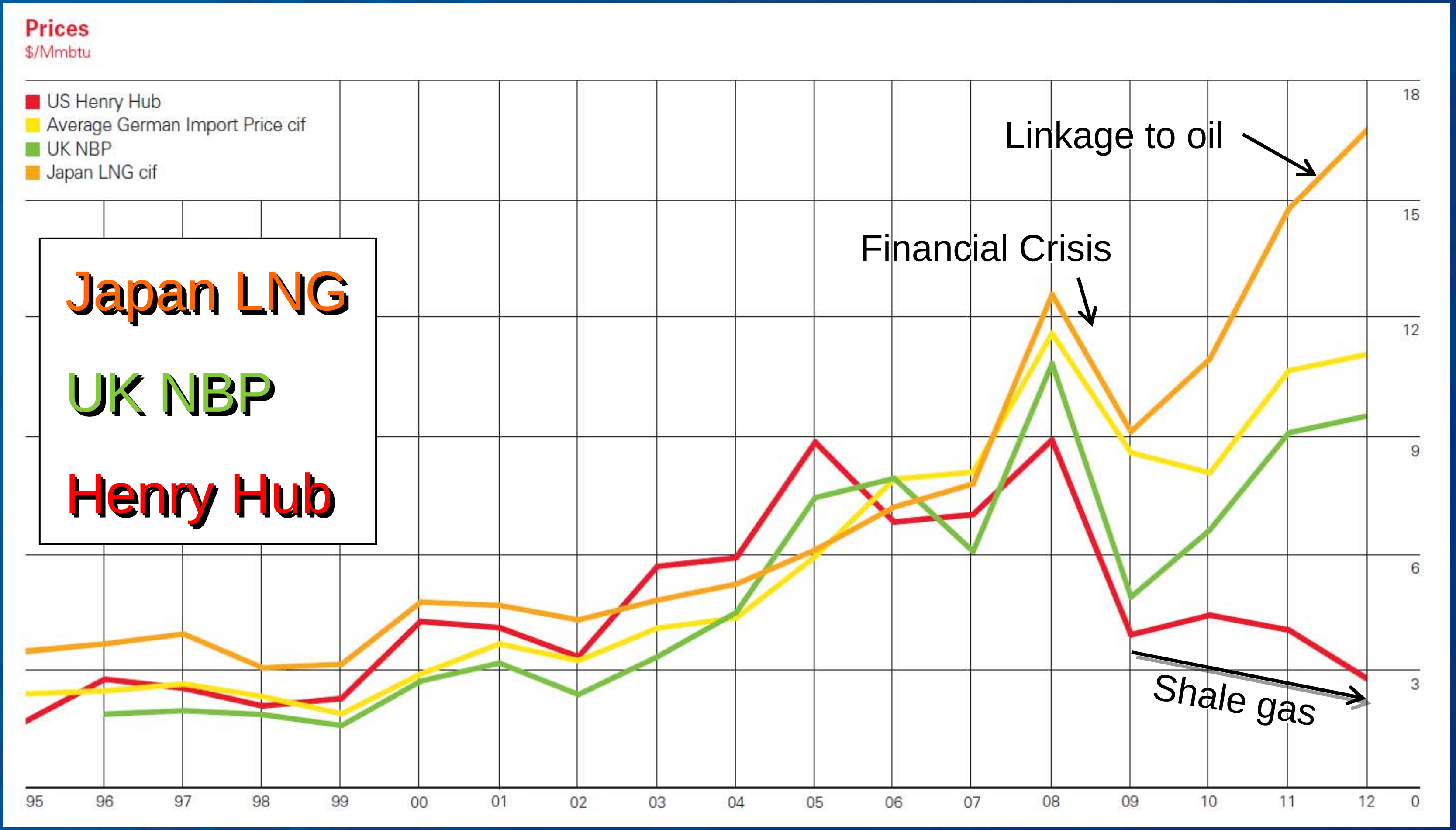
EIA – Drilling Productivity Report October 2013

Gas Regional markets



Gas Trade Movement 2012 - BP Statistical Review 2013

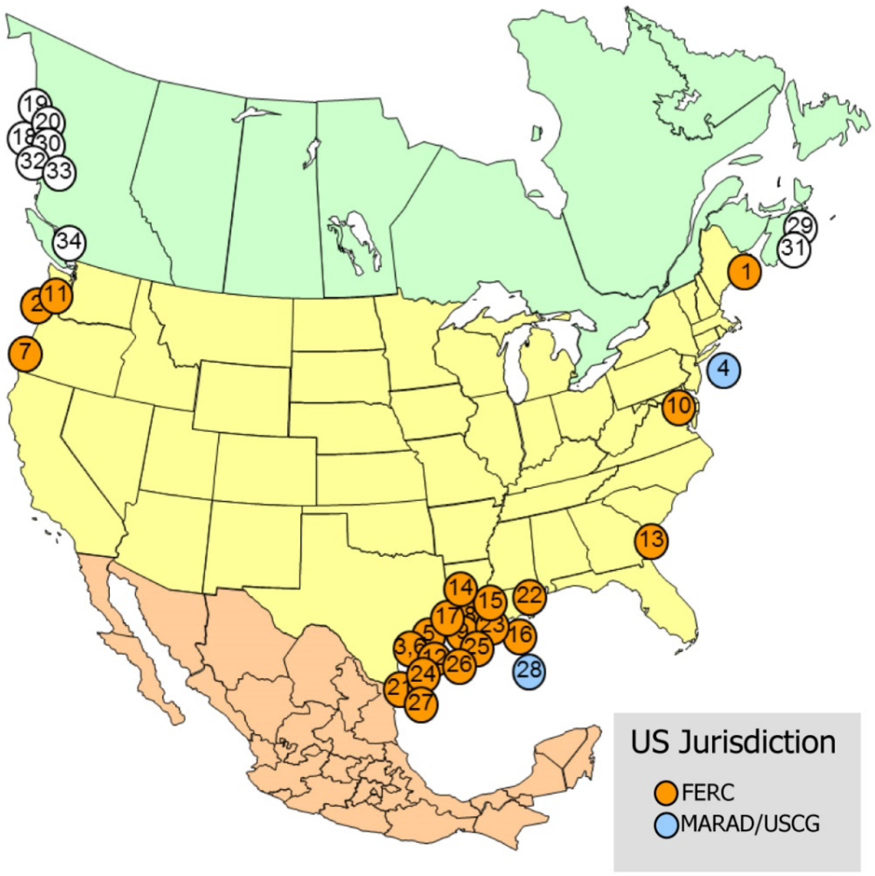
Natural Gas Price Differential



BP Statistical Review 2013

North American LNG Export

Pipline + Liquefaction + Shipping + Regasification ≈ 4-6 $/mcf



Import Terminal

PROPOSED TO FERC

1. **Robbinston, ME:** 0.5 Bcfd (Kestrel Energy - Downeast LNG)
2. **Astoria, OR:** 0.5 Bcfd (Oregon LNG)
3. **Corpus Christi, TX:** 0.4 Bcfd (Cheniere – Corpus Christi LNG)

POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS

4. **Offshore New York:** 0.4 Bcfd (Liberty Natural – Port Ambrose)

Export Terminal

PROPOSED TO FERC

5. **Freeport, TX:** 1.8 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction)*
6. **Corpus Christi, TX:** 2.1 Bcfd (Cheniere – Corpus Christi LNG)*
7. **Coos Bay, OR:** 0.9 Bcfd (Jordan Cove Energy Project)*
8. **Lake Charles, LA:** 2.4 Bcfd (Southern Union - Trunkline LNG)
9. **Hackberry, LA:** 1.7 Bcfd (Sempra – Cameron LNG)*
10. **Cove Point, MD:** 0.82 Bcfd (Dominion – Cove Point LNG)*
11. **Astoria, OR:** 1.25 Bcfd (Oregon LNG)*
12. **Lavaca Bay, TX:** 1.38 Bcfd (Excelerate Liquefaction)
13. **Elba Island, GA:** 0.35 Bcfd (Southern LNG Company)
14. **Sabine Pass; LA:** 1.3 Bcfd (Sabine Pass Liquefaction)
15. **Lake Charles, LA:** 1.07 Bcfd (Magnolia LNG)
16. **Plaquemines Parish, LA:** 1.07 Bcfd (CE FLNG)
17. **Sabine Pass, TX:** 2.1 Bcfd (ExxonMobil – Golden Pass)

PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

18. **Kitimat, BC:** 0.7 Bcfd (Apache Canada Ltd.)
19. **Douglas Island, BC:** 0.25 Bcfd (BC LNG Export Cooperative)
20. **Kitimat, BC:** 3.23 Bcfd (LNG Canada)

POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS

21. **Brownsville, TX:** 2.8 Bcfd (Gulf Coast LNG Export)
22. **Pascagoula, MS:** 1.5 Bcfd (Gulf LNG Liquefaction)
23. **Cameron Parish, LA:** 0.16 Bcfd (Waller LNG Services)
24. **Ingleside, TX:** 1.09 Bcfd (Pangea LNG (North America))
25. **Cameron Parish, LA:** 0.20 Bcfd (Gasfin Development)
26. **Cameron Parish, LA:** 0.67 Bcfd (Venture Global)
27. **Brownsville, TX:** 3.2 Bcfd (Eos LNG & Barca LNG)
28. **Gulf of Mexico:** 3.22 Bcfd (Main Pass - Freeport-McMoRan)

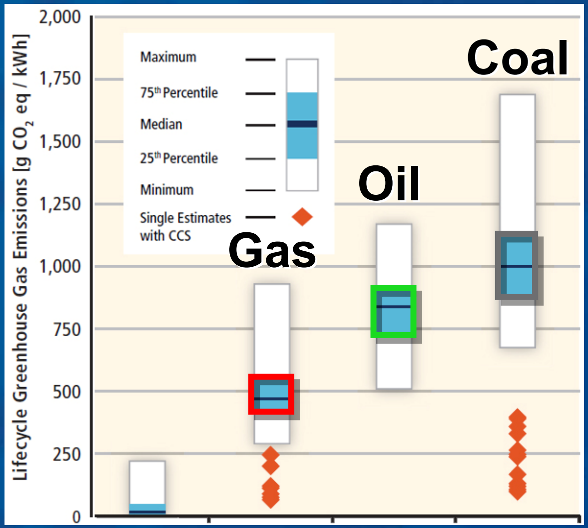
POTENTIAL CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

29. **Goldboro, NS:** 0.67 Bcfd (Pieridae Energy Canada)
30. **Prince Rupert Island, BC:** 4.2 Bcfd (BG Group)
31. **Melford, NS:** 1.8 Bcfd (H-Energy)
32. **Prince Rupert Island, BC:** 2.5 Bcfd (Pacific Northwest LNG)
33. **Prince Rupert Island, BC:** 3.8 Bcfd (ExxonMobil – Imperial)
34. **Squamish, BC:** 0.27 Bcfd (Woodfibre LNG Export)

DOE – FERC – Sept 2013

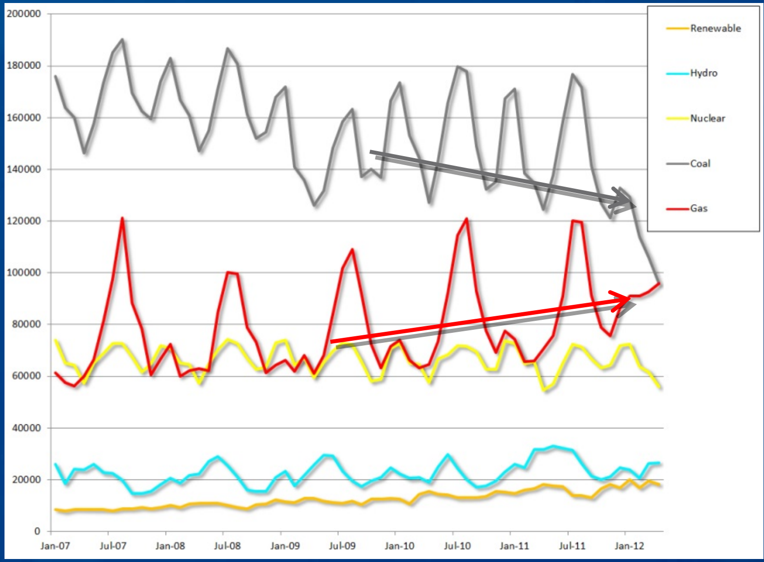
Shale Gas and Energy Transition

GHG Emissions for Electricity

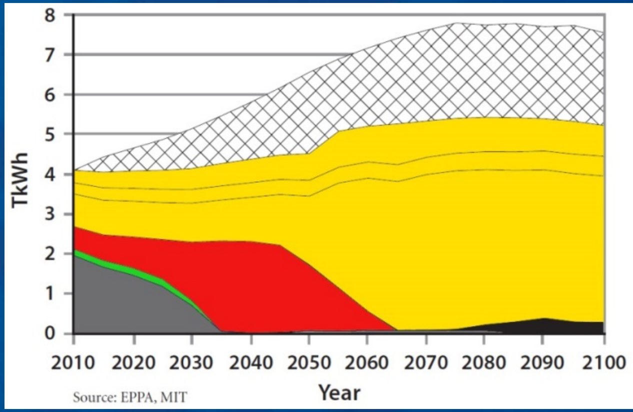


IPCC 2012

U.S. Power Generation



Source: EIA 2012



MIT Study 2012

Long term U.S. power fuel mix
(GHG price-based policy scenario)

Gas
Reduce Use
Oil
Non-fossil
Coal

Final Remarks - 1

- Shale gas technically recoverable resources are enormous (1000s Tcf)

- North American experience has demonstrated that part of this resource can be produced at a moderate cost (but it is not “cheap gas”)

- Shale gas plays are very heterogeneous and complex systems:

    - Delineating “sweet spot” areas

    - Optimizing well placement and stimulation design

Final Remarks - 2

- Most U.S. dry gas production from shale is not economic at current low gas price
- Liquid rich part and best tiers still are
- Long term U.S. shale gas production is still uncertain:
    - Detailed integrated analysis on new shale plays will help
    - Most recent data shows increasing productivity (Marcellus)
- Long term shale gas production will depend on future gas demand and on the ability of the industry to drive production cost down
- Opportunity for the development of trans-pacific LNG trade between North America and Asia

Final Remarks - 3

- Gas has the potential to minimize GHG emissions (and other pollutants) as a “bridge” to low-carbon future
- Life cycle GHG emission and other environmental risks associated with shale gas must be well understood, controlled and minimized
- Government incentives and air quality standards will have a strong impact on the competition between gas and coal for electricity generation