U.S. SHALE REVOLUTION AND ITS IMPACT ON GLOBAL ENERGY MARKETS

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INTERNATIONAL SUMMER SCHOOL - 2016
MODULE # 2

July 18, 2016
Moscow

www.fief.ru

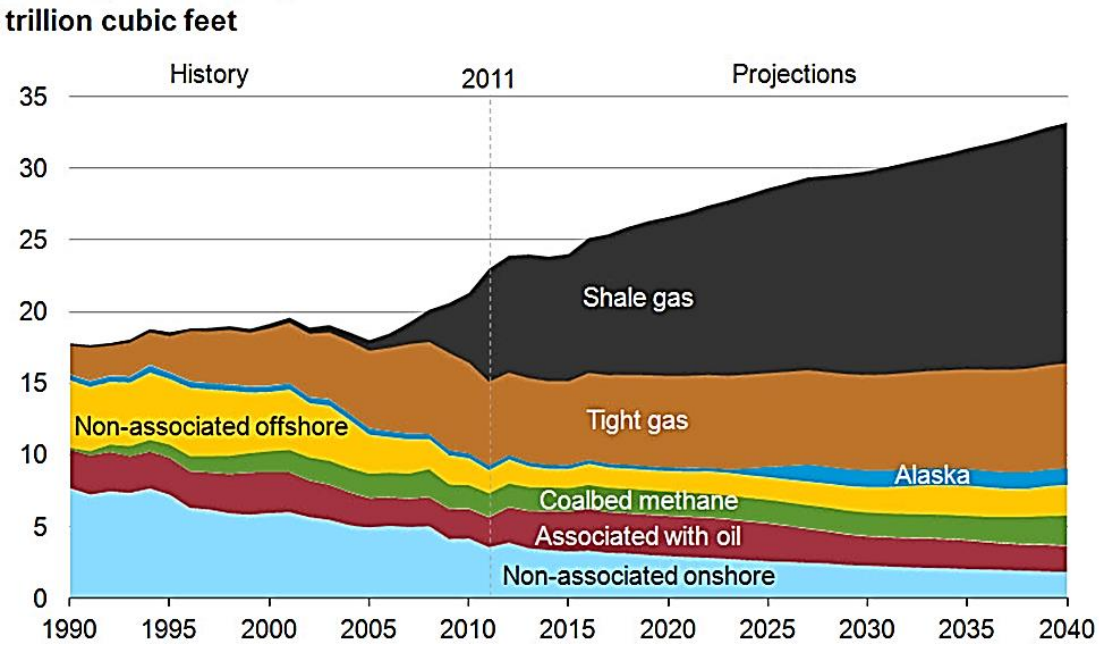
The book “Shale America” is PDF downloadable at the site fief.ru (Russian)

What is Shale?

Shale is a fine-grained sedimentary rock that forms from the compaction of silt and clay-size mineral particles. Black shale contains organic material that can generate oil and natural gas, and that can also trap the generated oil and natural gas within its pores.

Marcellus Shale outcrop exposing near-vertical natural fractures that cut across the naturally horizontal bedding planes.

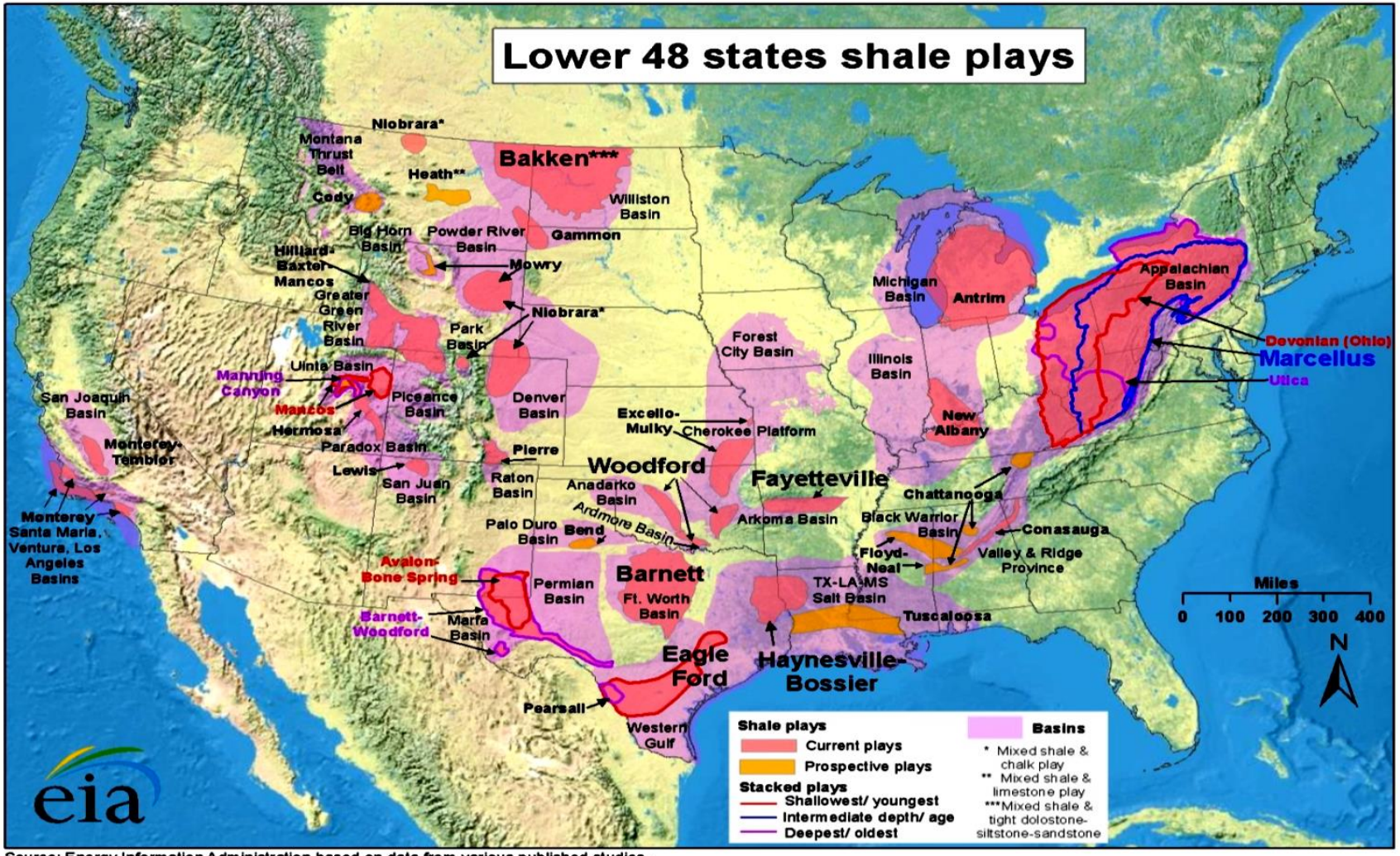
The Father of Shale Revolution



Source: U.S. Energy Information Administration

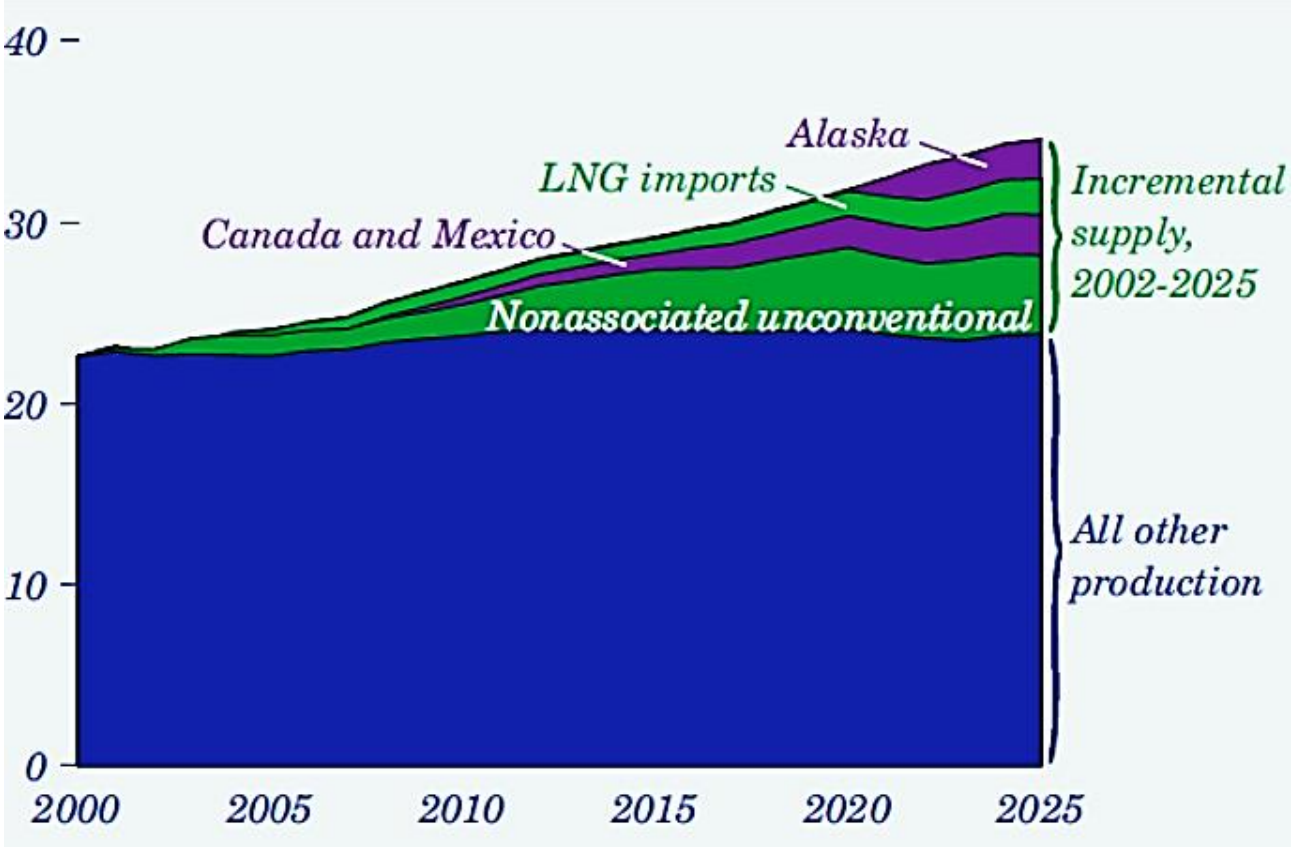
The father of shale revolution, George Mitchell (1919-2013) was the first to use hydraulic fracking in combination with horizontal drilling to crack open the Barnett shale play in Texas. He opened the door to development of shales worldwide. In 2002 Mitchell sold his company, Mitchell Enrgy & Development, for $3.5 billion to Devon Energy.

U.S. Shale Plays



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

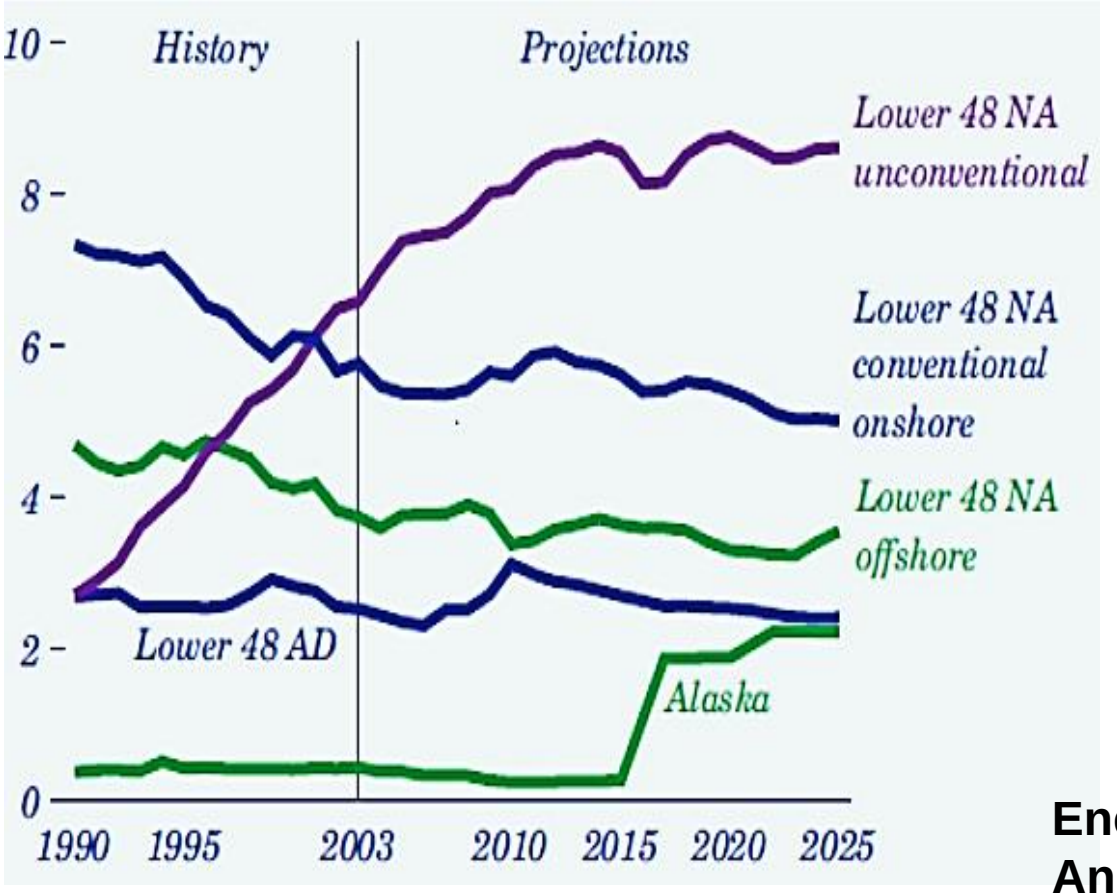
Major sources of incremental natural gas supply, 2002-2025 (trillion cubic feet)



Source: Annual Energy Outlook 2003 With Projections to 2025

EIA AEO 2005: Unconventional Production Becomes the Largest Source of U.S. Gas Supply

Natural gas production by source, 1990-2025 (trillion cubic feet)

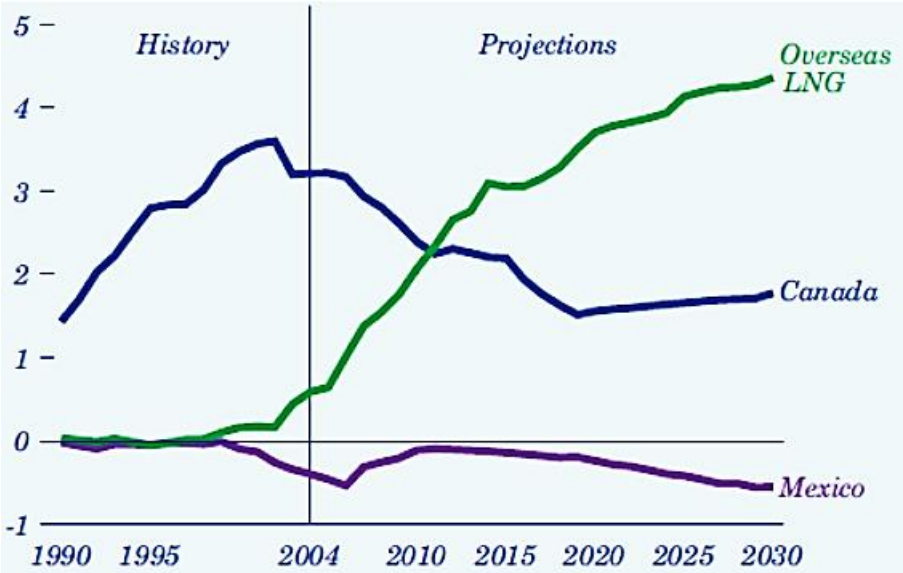


"As a result of technological improvements and rising natural gas prices, natural gas production from relatively abundant unconventional sources (tight sands, shale, and coalbed methane) is projected to increase more rapidly than conventional production. Lower 48 unconventional gas production grows from 6.6 trillion cubic feet in 2003 to 8.6 trillion cubic feet in 2025 and from 35 percent of total lower 48 production in 2003 to 44 percent in 2025".

Energy Information Administration / Annual Energy Outlook 2005

EIA AEO 2006: imports of natural gas rise to meet increasing domestic consumption

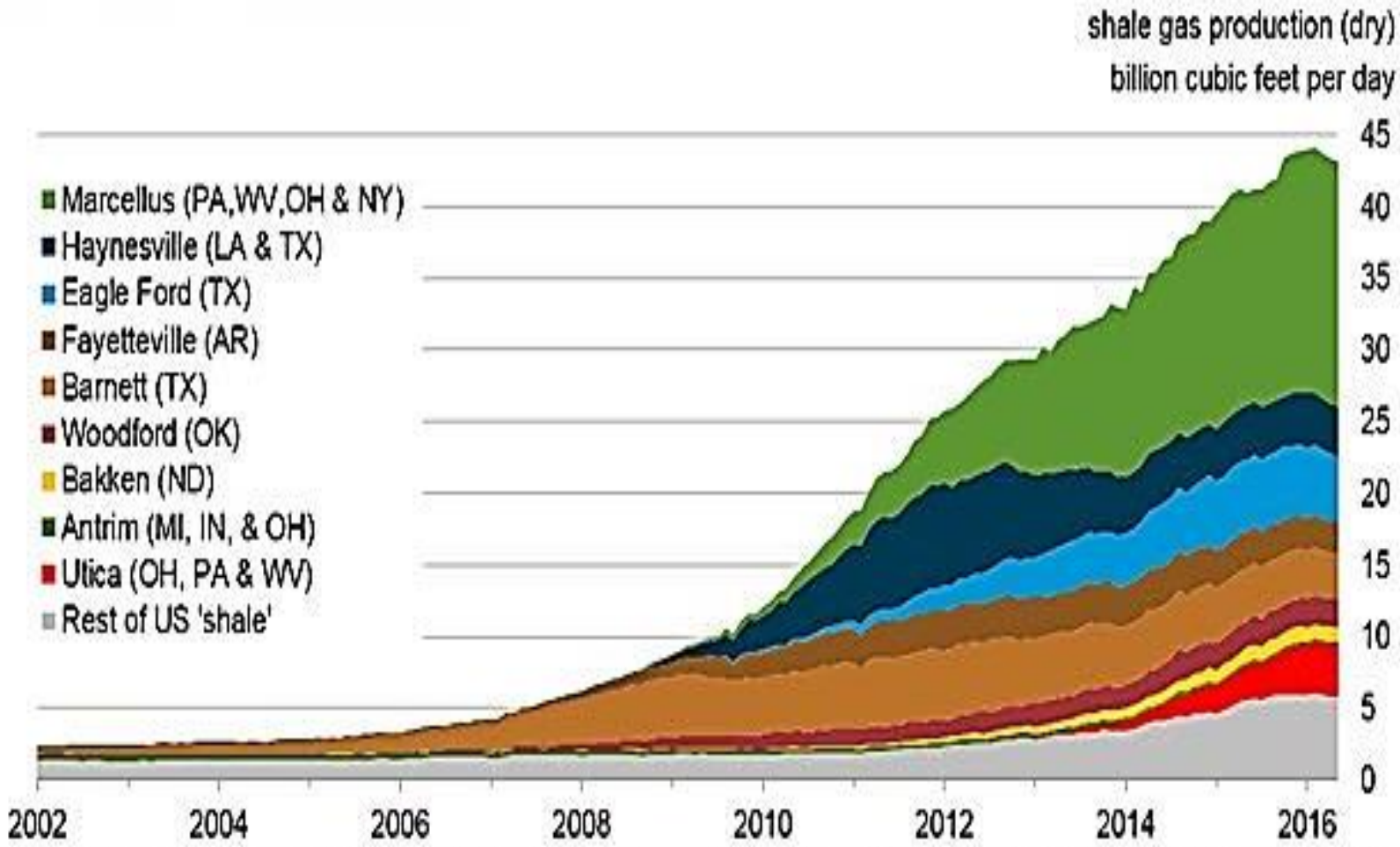
Net U.S. imports of natural gas by source, 1990-2030 (trillion cubic feet)



Source: Energy Information Administration / Annual Energy Outlook 2006

With U.S. natural gas production declining, imports of natural gas rise to meet increasing domestic consumption. After 2019, net imports from Canada begin to increase, as unconventional production eventually offsets the decline in conventional production. Net imports of natural gas from Canada total 1.8 trillion cubic feet in 2030. Most of the projected growth in U.S. natural gas imports is in the form of LNG. The total capacity of U.S. LNG receiving terminals increases rapidly, from 1.4 trillion cubic feet in 2004 to 4.9 trillion cubic feet in 2015, when net LNG imports total 3.1 trillion cubic feet. Construction of new LNG terminals slows after 2015. With terminal capacity of 5.8 trillion cubic feet in 2030, U.S. net LNG imports total 4.4 trillion cubic feet.

U.S. Dry Shale Gas Production



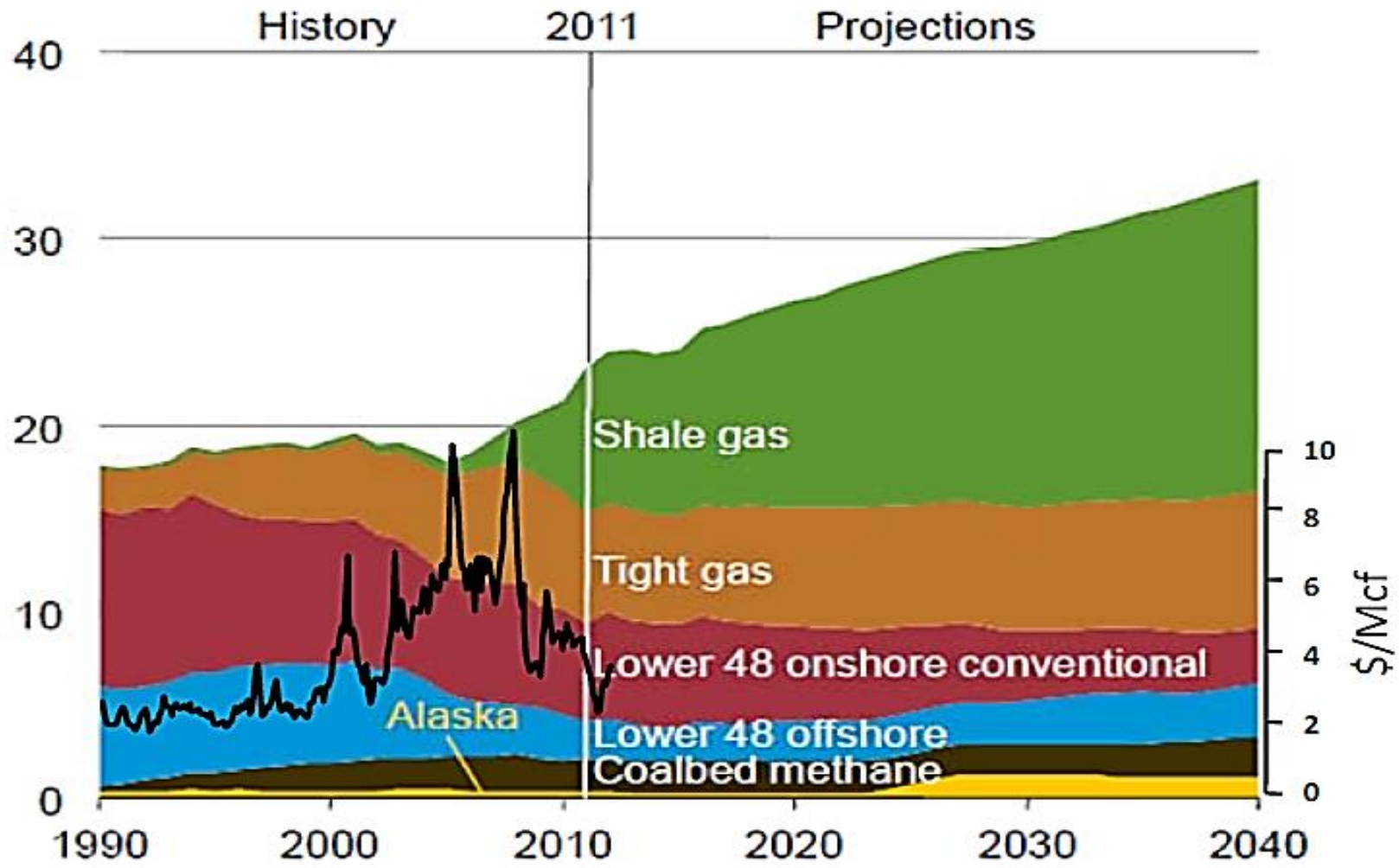
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through May 2016 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).

Top 20 U.S. gas companies in 2009

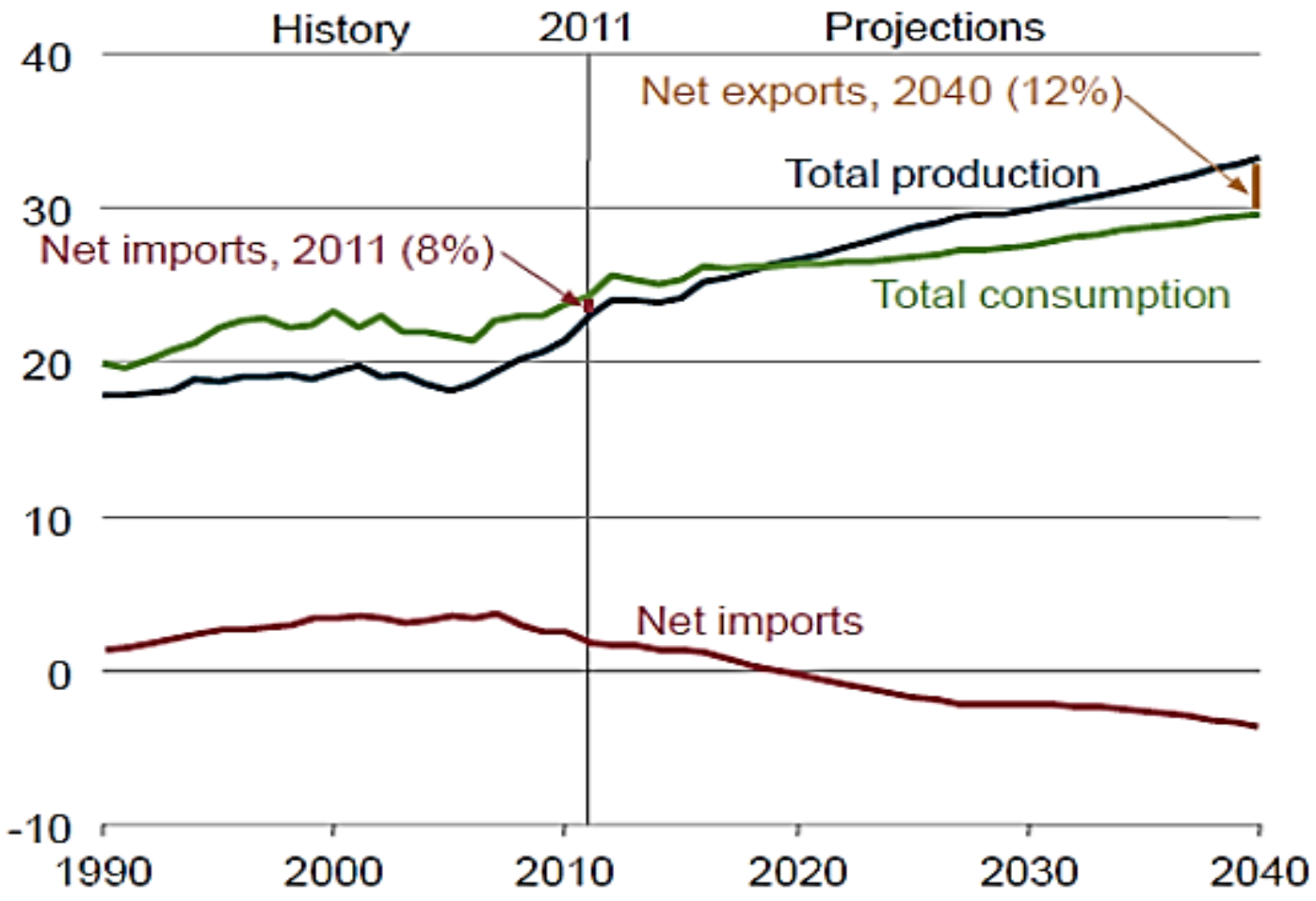
№ по рейтингу	Компания	Управление (данные EIA)		Владение (данные SEC)	
		Запасы	Добыча	Запасы	Добыча
1	BP PLC	(w)	1 016,6	15 216,0	907,0
2	CHESAPEAKE OPERATING INC	(w)	1 235,1	13 510,0	835,0
3	XTO ENERGY INC	(w)	1 097,3	12 501,7	855,0
4	ENCANA OIL & GAS INC	(w)	801,6	5 713,0	590,0
5	CONOCOPHILLIPS CO	(w)	1 208,1	10,742.0	850,0
6	DEVON ENERGY CORP	(w)	969,0	8 469.0	743,0
7	EXXONMOBIL CORP	(w)	521,4	11 688,0	566,0
8	E O G RESOURCES INC	(w)	576,7	6 350,1	422,3
9	ANADARKO PETROLEUM CORP	(w)	1 027,9	7 764,0	817,0
10	ULTRA PETROLEUM INC	(w)	228,7	3 736,6	172,2
11	511QUESTAR COR	(w)	337,6	2 525,0	168,7
12	THE WILLIAMS COMPANIES INC	(w)	547,0	4 255,0	435,0
13	SOUTHWESTERN ENERGY PRODUCTION CO	(w)	425,2	3 650,3	299,7
14	EQUITABLE RESOURCES INC	(w)	138,1	4 056,1	104,3
15	NEWFIELD EXPLORATION CO	(w)	246,1	2 605,0	172,0
16	PETROHAWK OPERATING CO	(w)	244,1	2 700,0	174,0
17	OCCIDENTAL PETROLEUM CORP	(w)	325,0	2 799,0	232,0
18	PIONEER NATURAL RESOURCES USA INC	(w)	215,9	2 450,1	147,5
19	APACHE CORP	(w)	355,7	2,440,3	243,6
20	SHELL OIL CO	(w)	495,9	2 258,0	399,0
Примечание. Управление: Форма EIA-23. Владение: Формы SEC 10-K, 20-F и 40-F. (w) = withheld (запасы не разглашаются)					
100 КРУПНЕЙШИХ КОМПАНИЙ США ПО ЗАПАСАМ ГАЗА		251 694,4	17 965,5	163 905,7	12 582,4
ВСЕГО ЗАПАСЫ И ДОБЫЧА ГАЗА В США		283 879,0	22 537,0		

Источник: EIA, Top 100 Operators: Proved Reserves and Production, Operated vs Owned, 2009

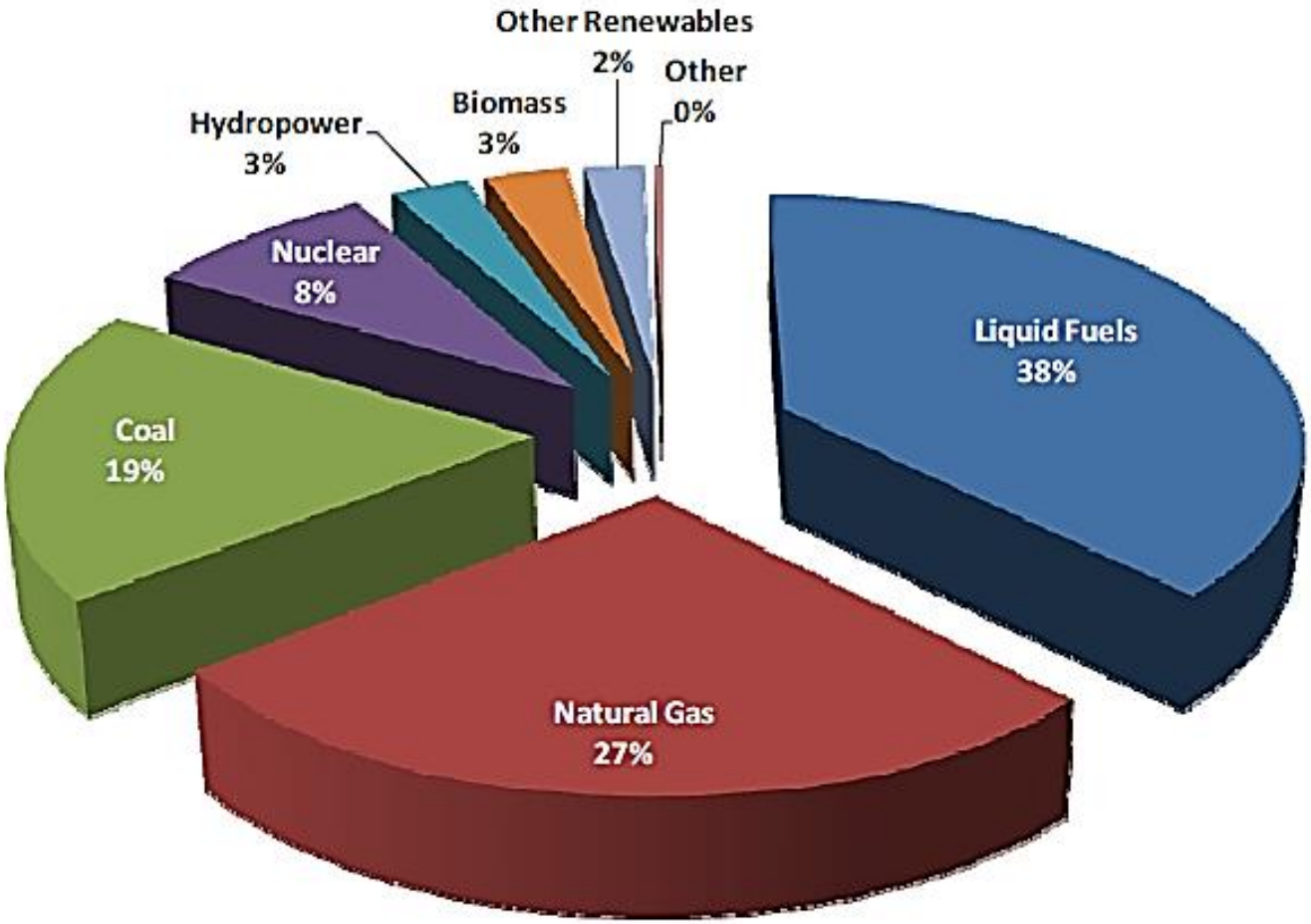
Natural gas production by source, 1990-2040 (trillion cubic feet) with historical U.S. natural gas wellhead price ($/Mcf)



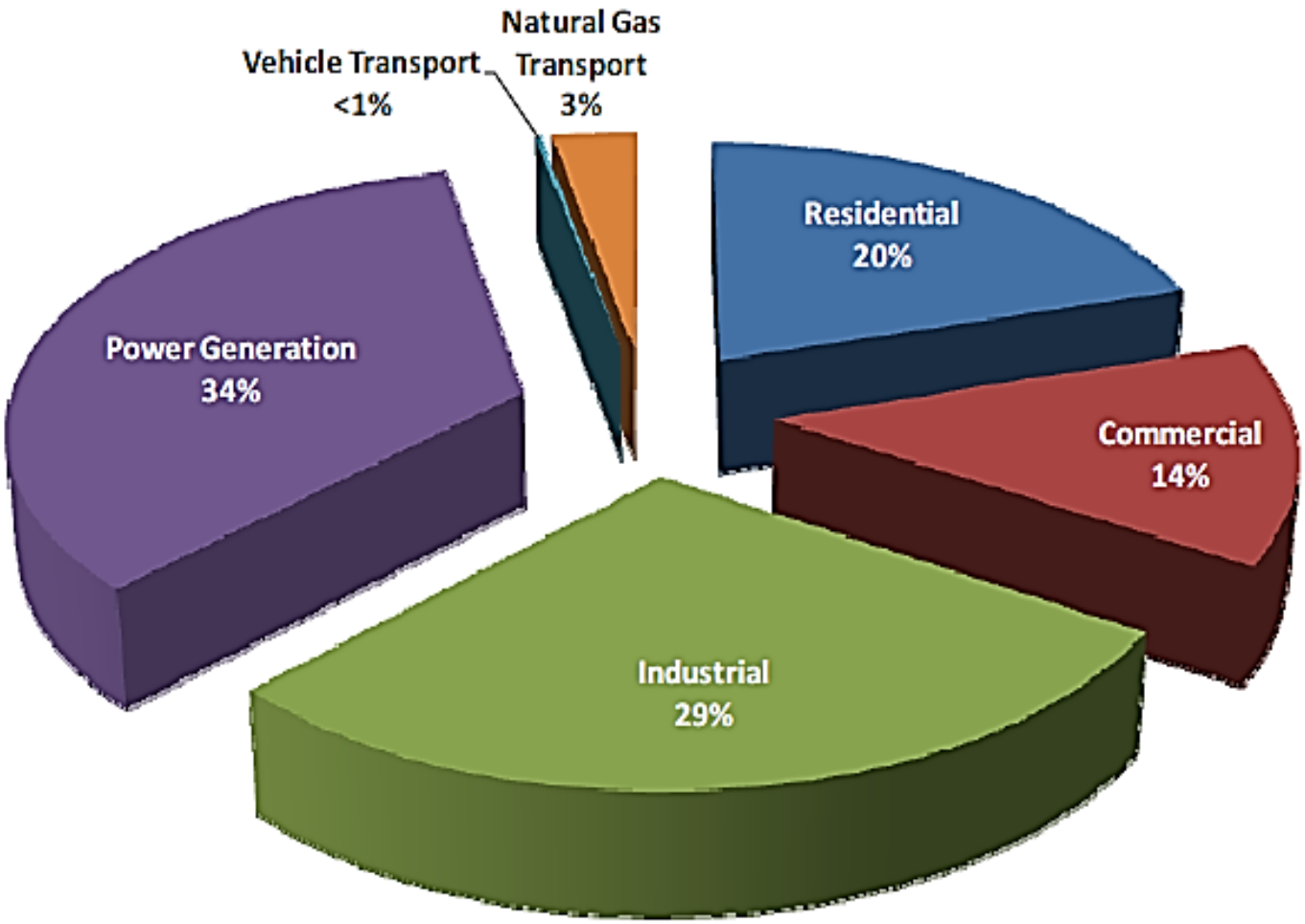
Total U.S. natural gas production, consumption, and net imports, 1990-2040, trillion cubic feet (EIA AEO 2013 Reference Case)



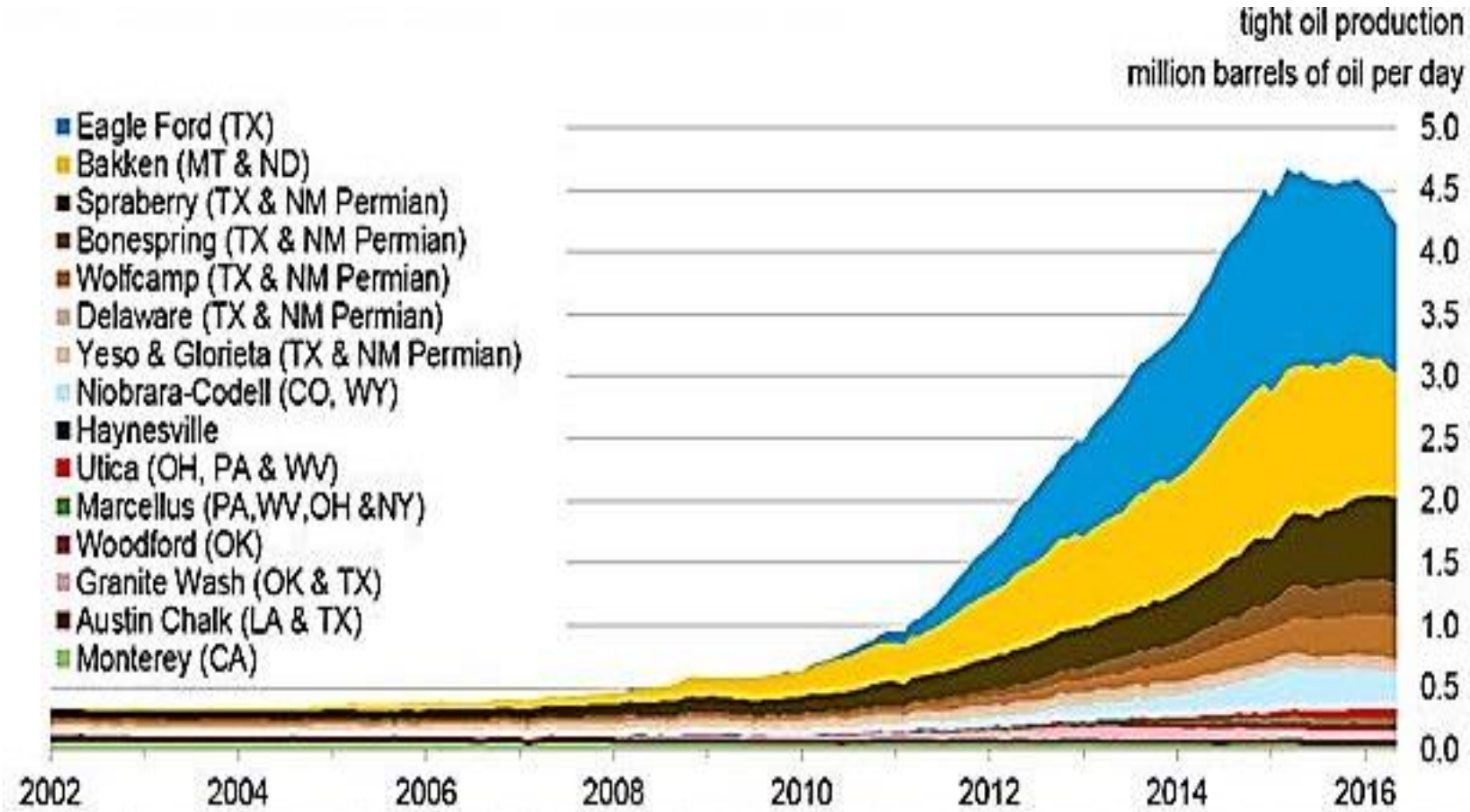
2013 U.S. energy consumption by source, on an energy content basis (EIA AEO2013 data tables)



2013 U.S. natural gas consumption by sector (EIA AEO 2013 data tables)

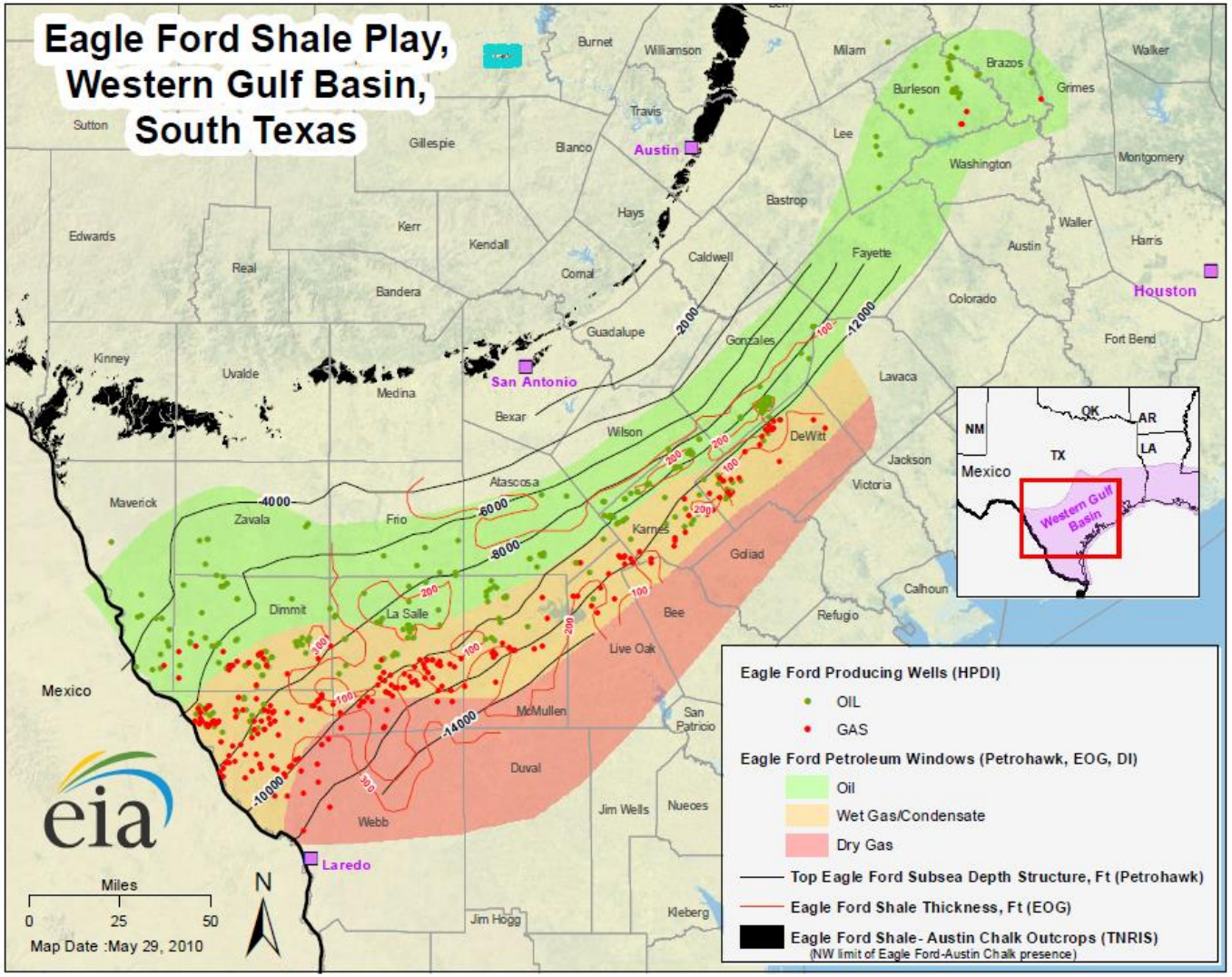


U.S. Tight Oil Production – Selected Plays

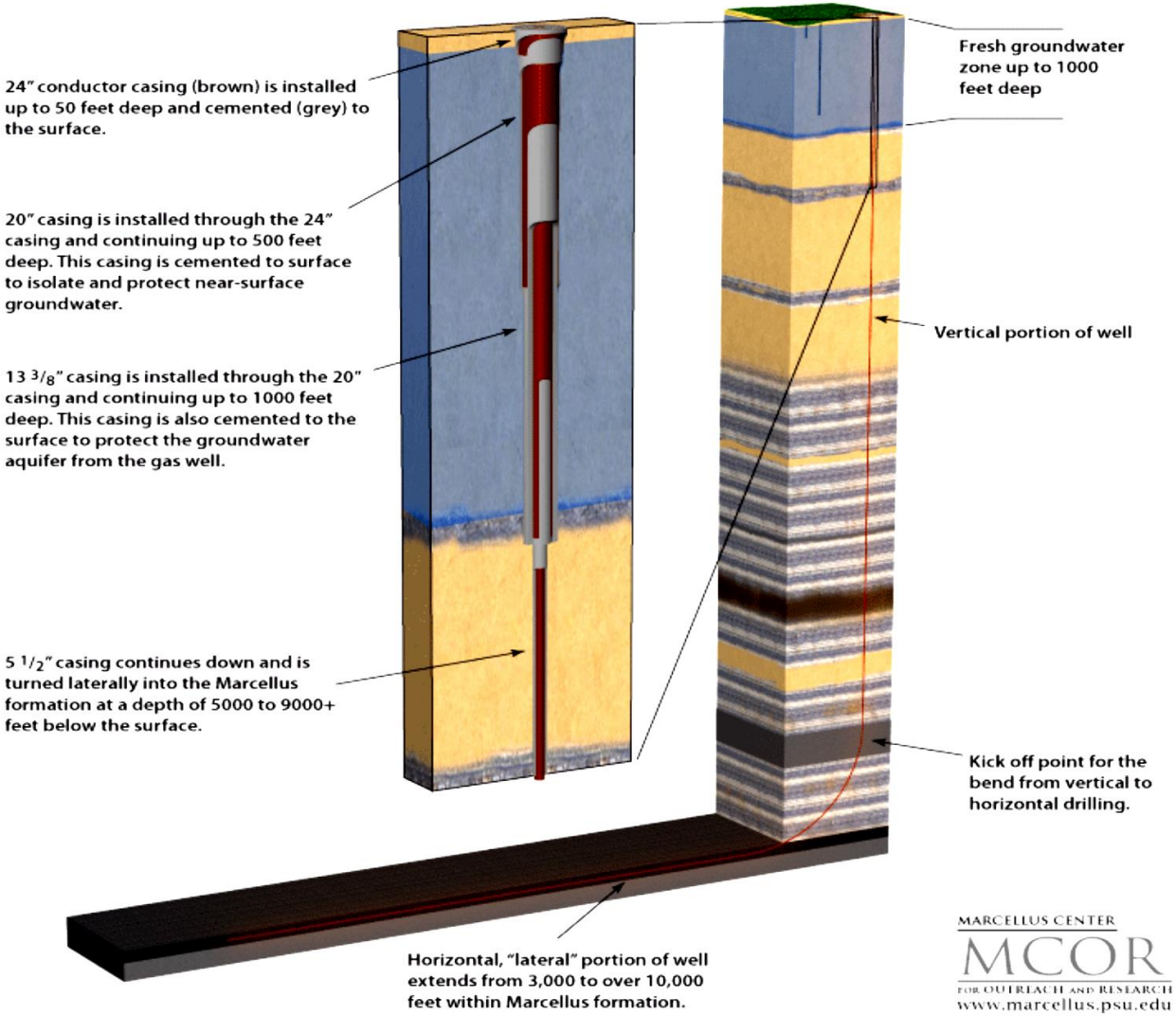


Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through May 2016 and represent EIA's official tight oil estimates, but are not survey data. State abbreviations indicate primary state(s).

Eagle Ford Shale Play

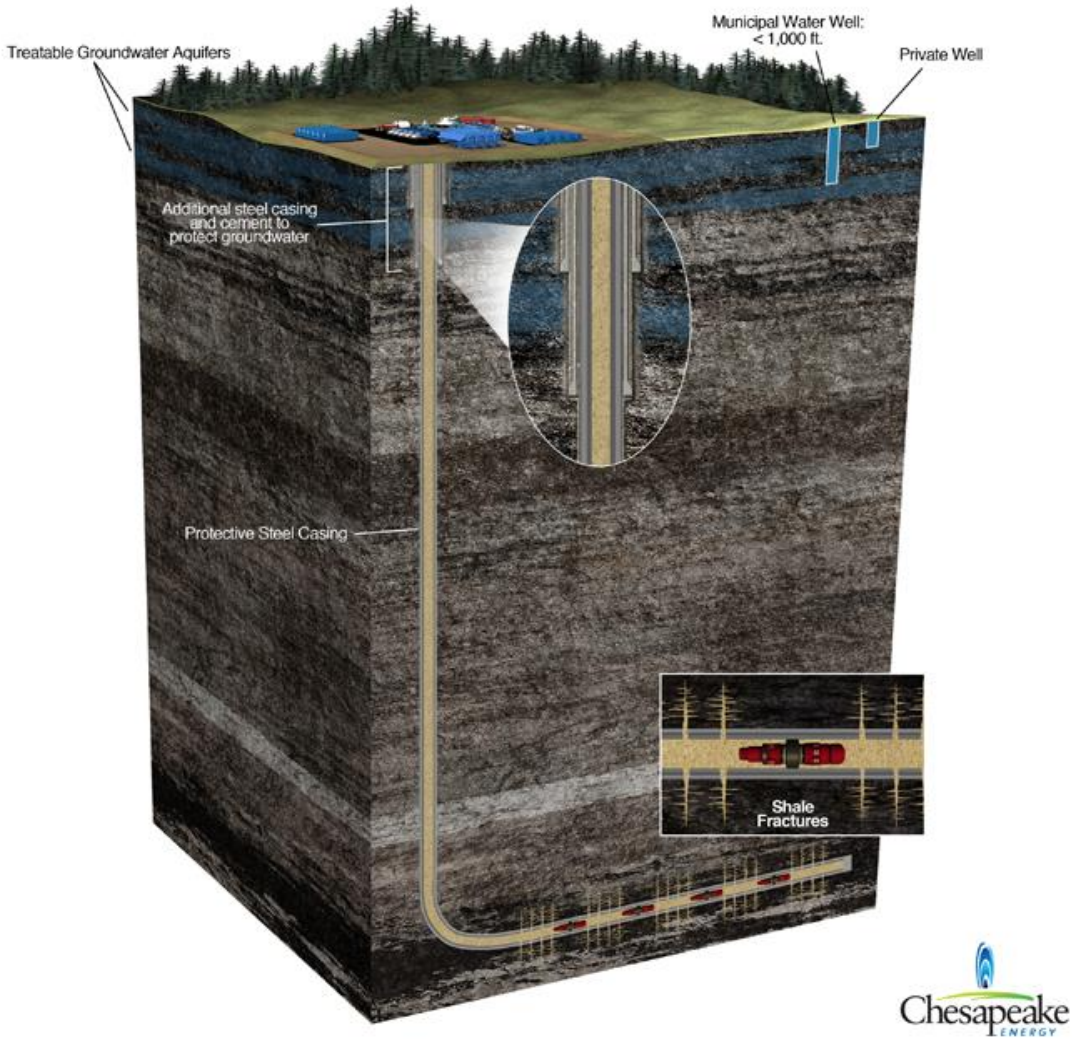


Schematic of a typical horizontal Marcellus shale well (Penn State Marcellus Center for Outreach and Research website)

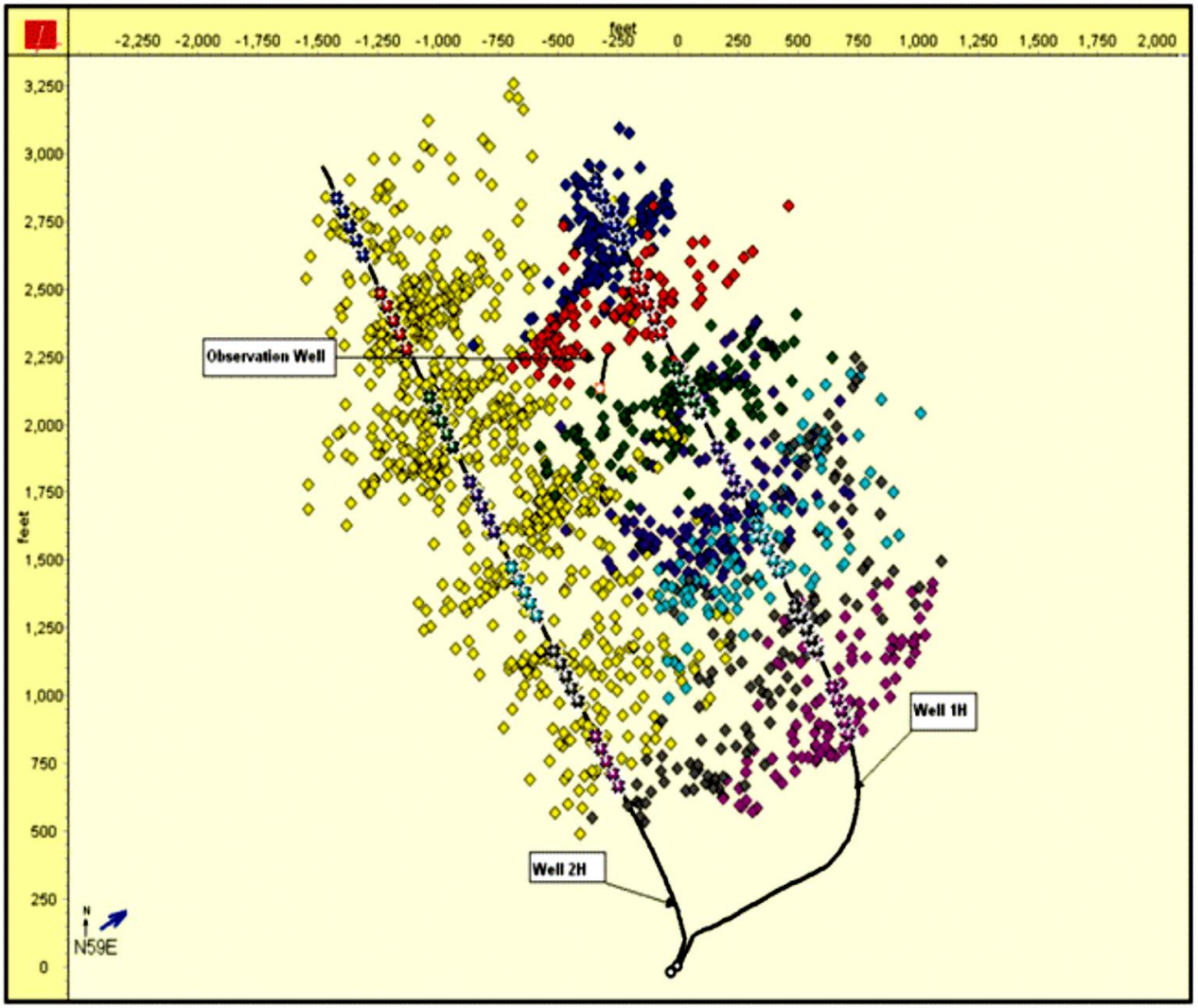


Marcellus well site during hydraulic fracturing operations

Schematic showing multiple fracturing treatment stages in horizontal well lateral (Chesapeake Energy)

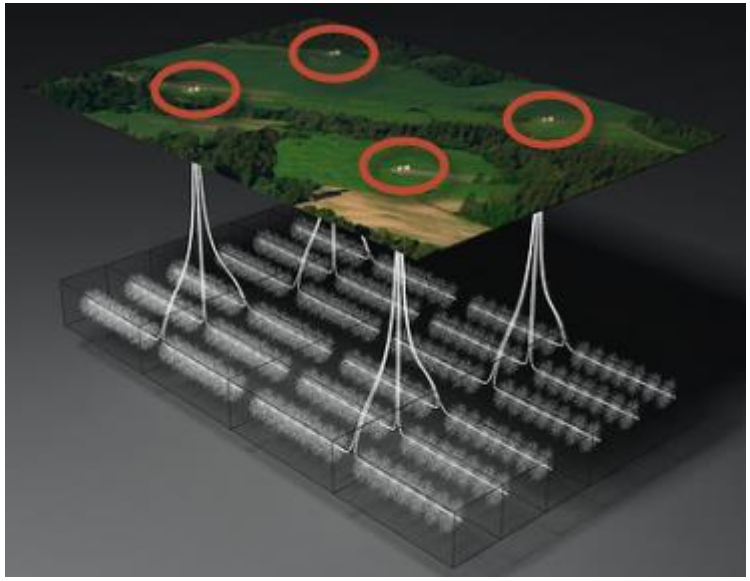


Data from microseismic monitoring reveal how hydraulic fractures extend from a lateral wellbore and interact with fractures created along adjacent parallel laterals (AOGR, 2012)

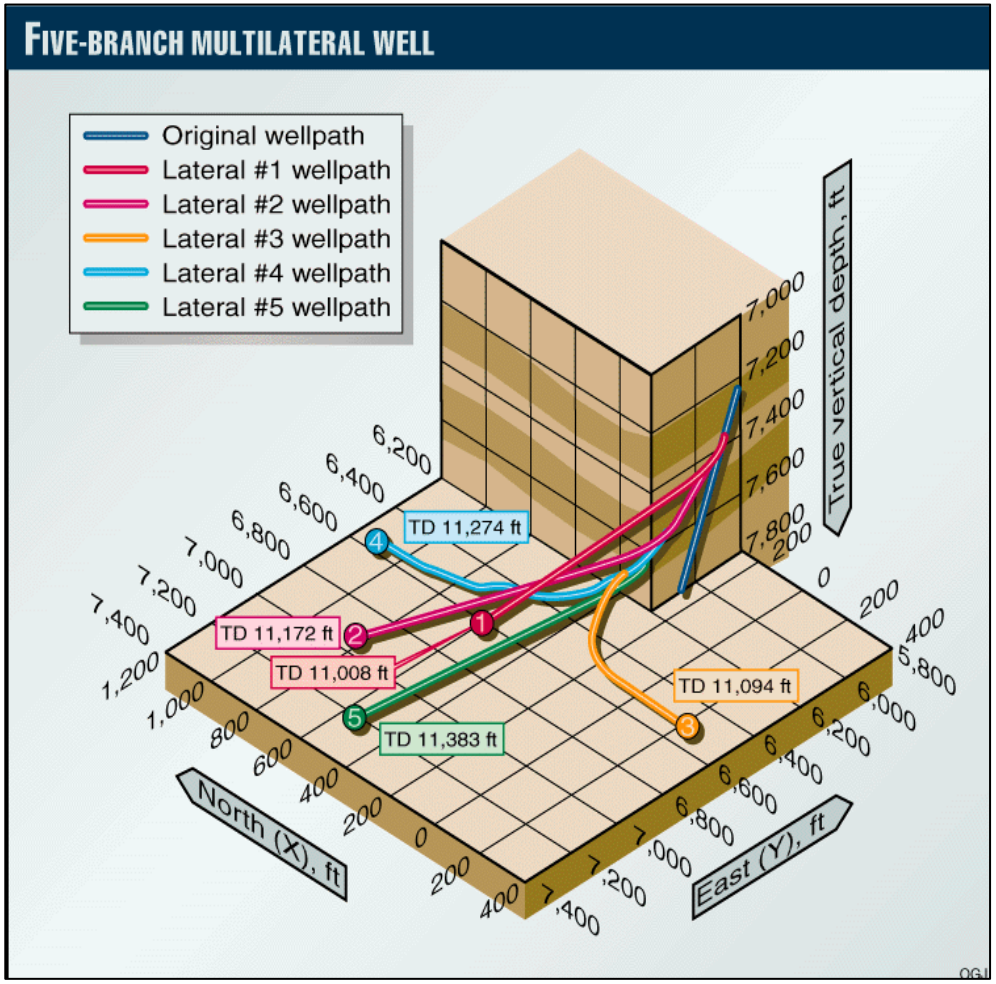


Advanced drilling technologies

Pad drilling



Source: Statoil

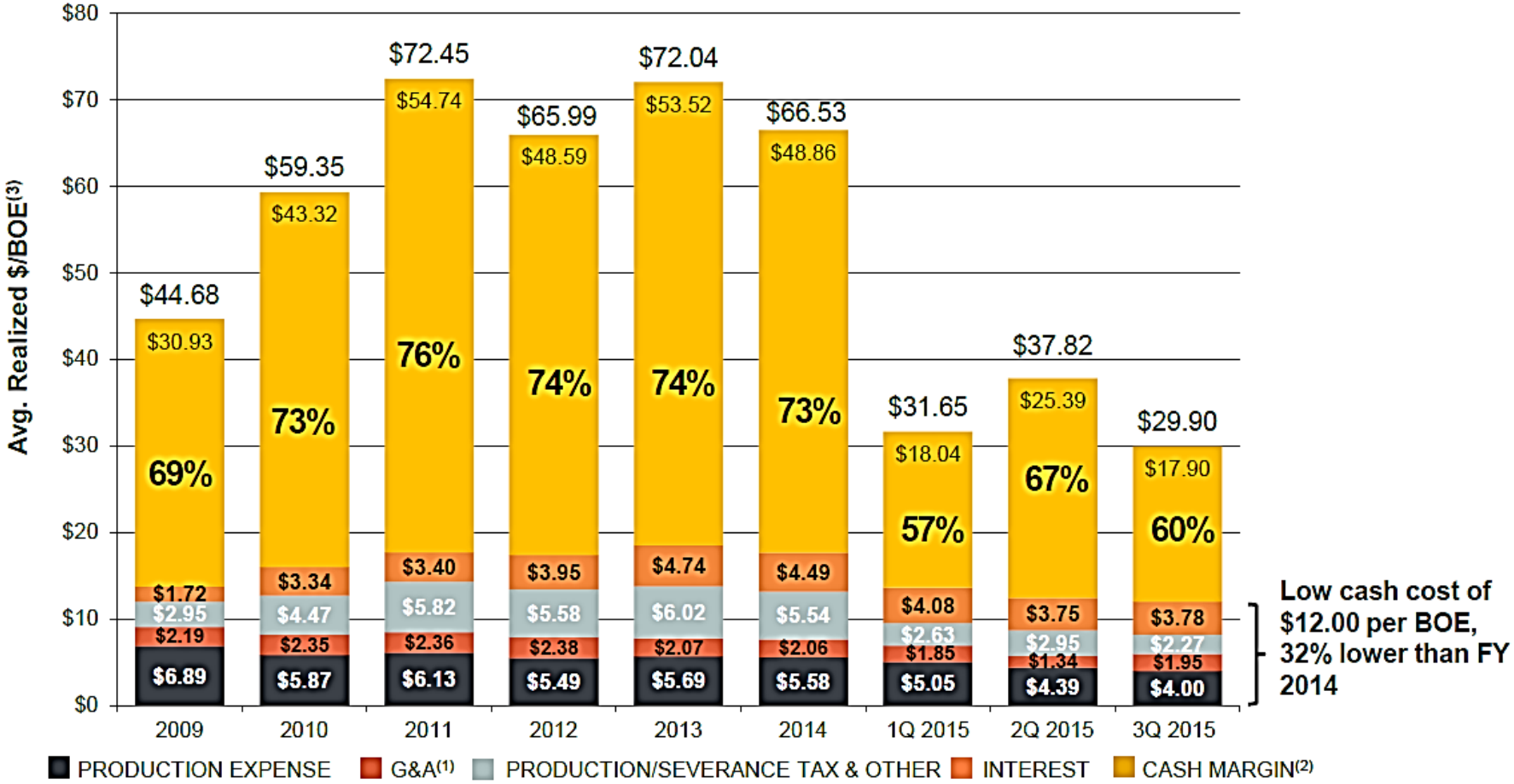


Source: Oil & Gas Journal

The Schramm T500XD is specifically designed for horizontal and directional drilling to a total depth of 15,000 ft or more.

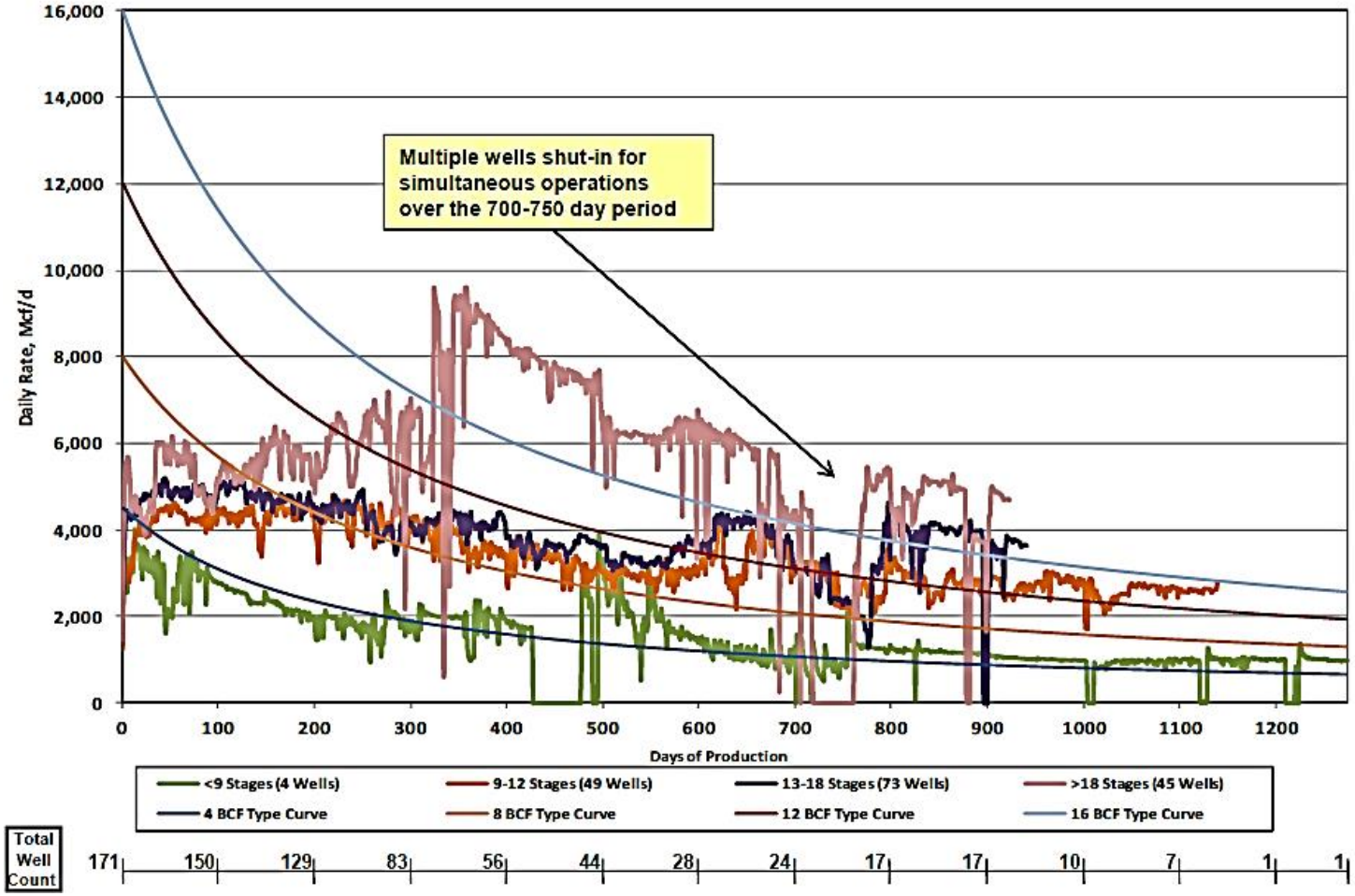
Schramm has launched its T500XD Telemast 500,000 lb hoist capacity drill rig currently headed to the Marcellus and Utica shales. The rig has a full 360° walking portability for fast moves from hole to hole without the traditional limits of two axis pad mounted designs. The T500XD also offers a full communication interface connectivity to third-party data acquisition providers that utilize the internet or dedicated satellite communications systems to remote operation centers in multiple locations.

Continental Resources' oil production economics



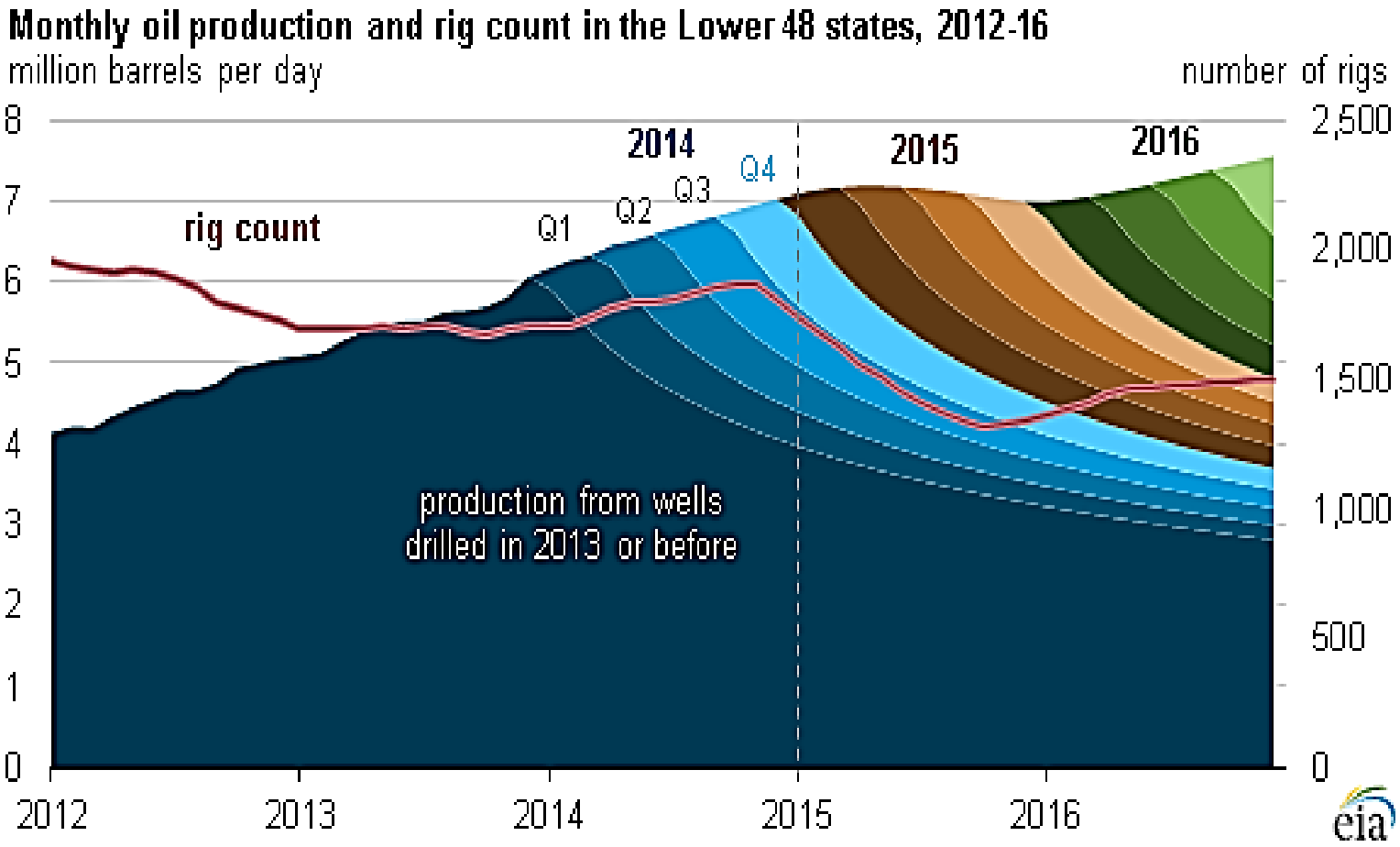
1. EXCLUDES G&A RELATED TO EQUITY BASED COMPENSATION AND RELOCATION EXPENSE
2. SEE "CONTINUING TO DELIVER STRONG MARGINS" IN THE APPENDIX FOR THE METHOD OF CALCULATING CASH MARGIN
3. BASED ON AVERAGE OIL EQUIVALENT PRICE (EXCLUDING DERIVATIVES AND INCLUDING NATURAL GAS)

Effectiveness of multi-stage fracturing the Marcellus Shale



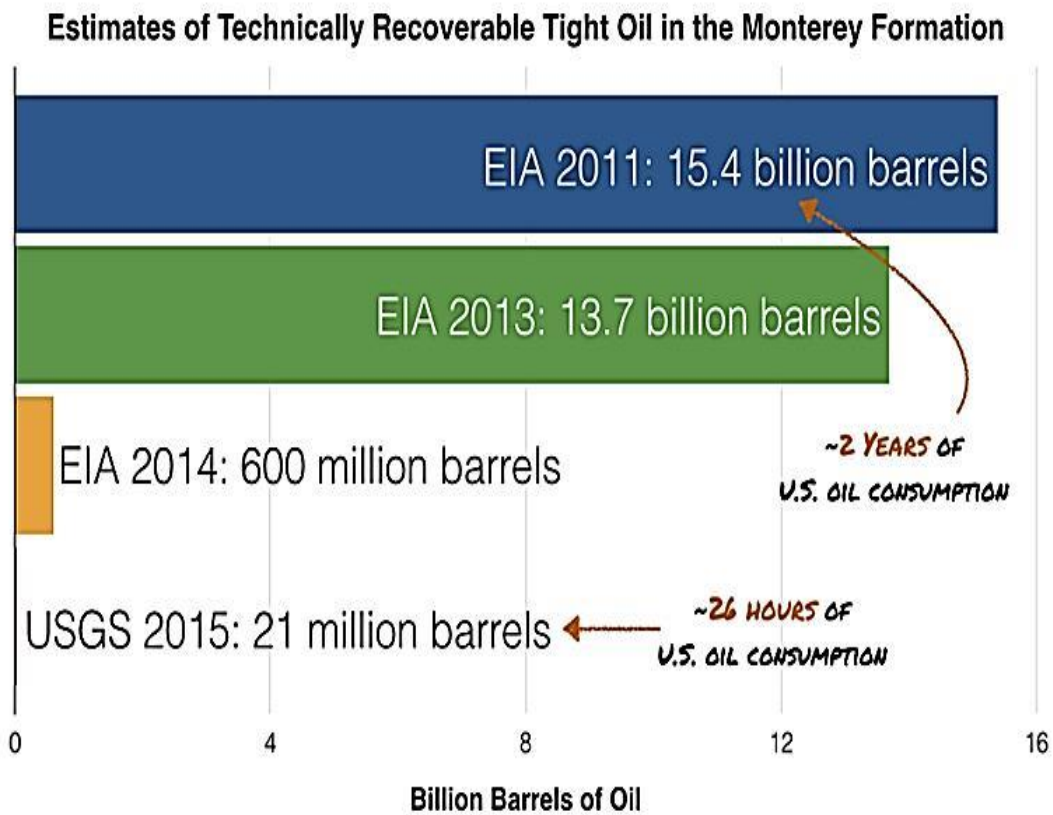
Source: Southwestern Energy, by December 31, 2013

Oil production and rig count outlook for 2016



Источник: U.S. EIA, January *Short-Term Energy Outlook*

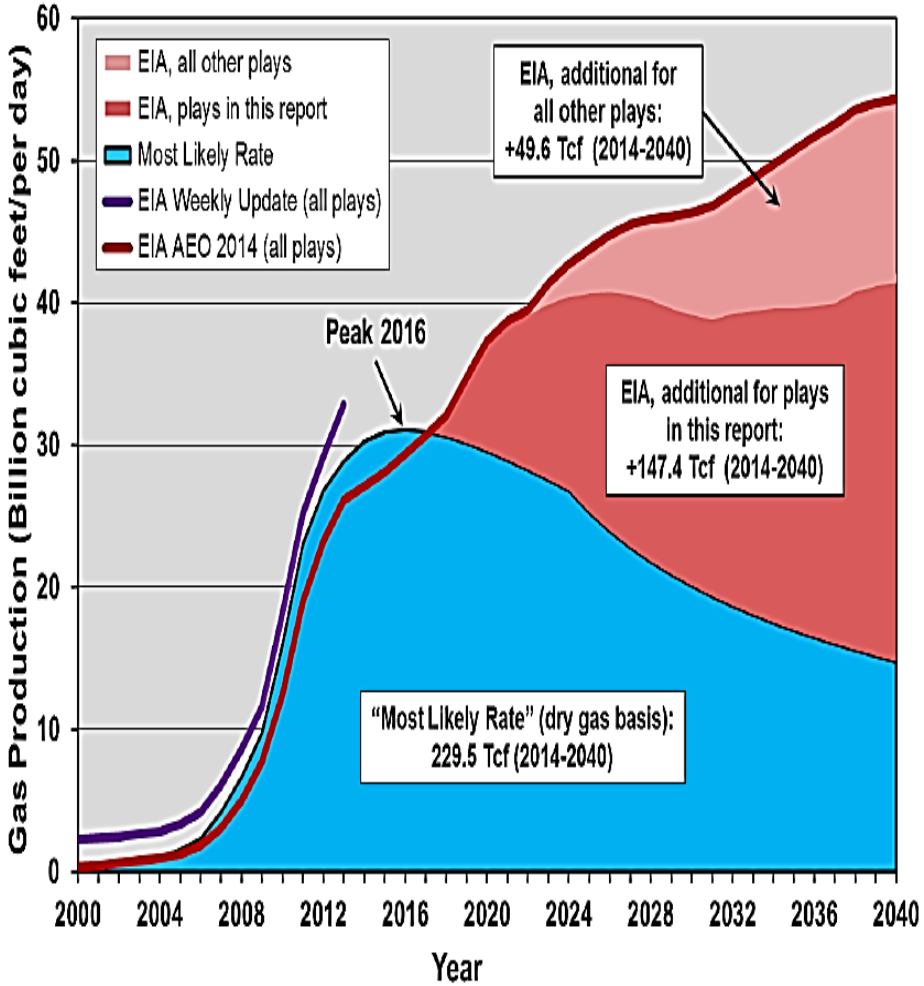
J. David Hughes, Drilling California: A Reality Check on the Monterey Shale



In 2011, the EIA published a report that stated the Monterey Shale in California had 15.4 billion barrels of recoverable oil, or two-thirds of the then estimated recoverable tight oil in the US. The EIA subsequently downgraded its estimate to 13.7 billion barrels in 2013. Post Carbon Institute and PSE Healthy Energy published the report *Drilling California: A Reality Check on the Monterey Shale*, which concluded that the EIA's estimate was vastly overstated. In May 2014, EIA downgraded its estimate by 96% to 600 million barrels.

In October 2015, the U.S. Geological Survey (USGS) released a report stating that the mean technically recoverable oil resource in the Monterey was just 21 million barrels, a further 96% downgrade from the revised 2014 EIA estimate.

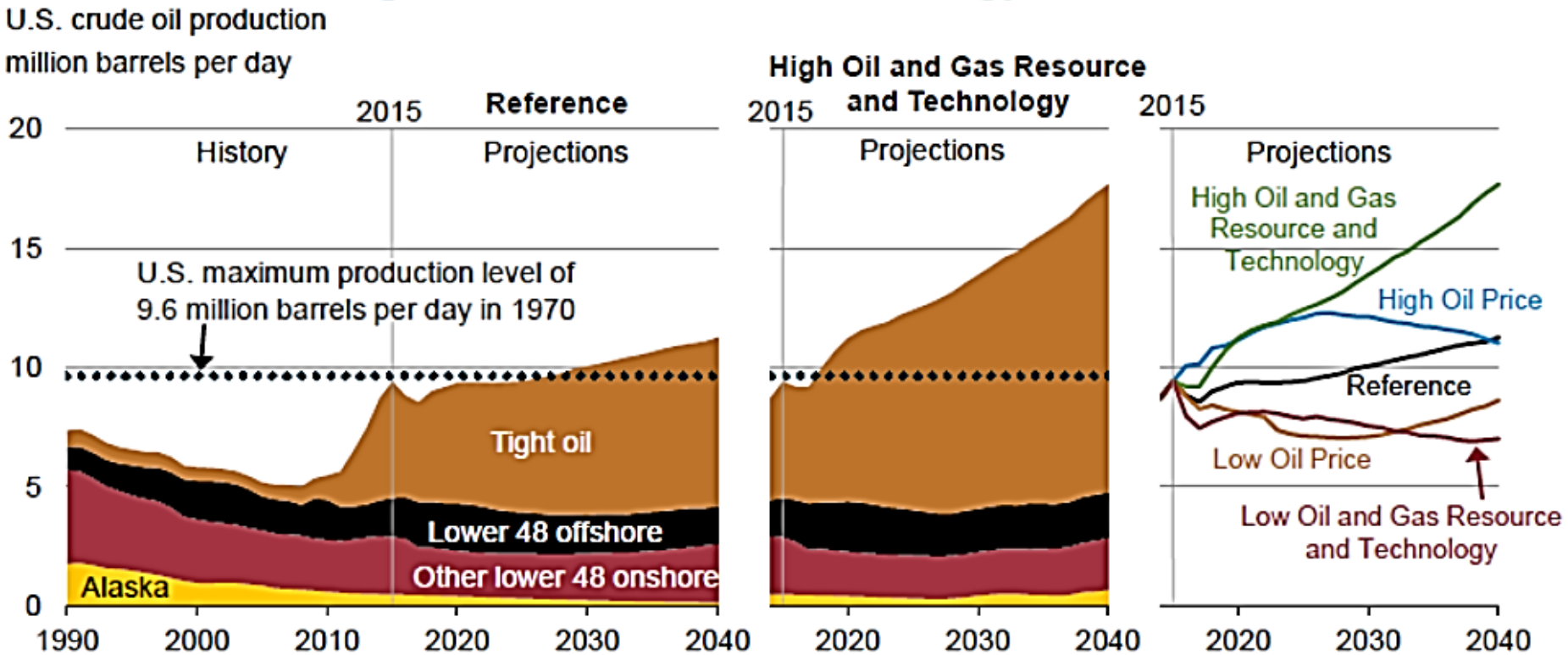
J. David Hughes, Drilling Deeper. A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil & Shale Gas Boom



"Shale gas production from the top seven plays will likely peak before 2020. Barring major new discoveries on the scale of the Marcellus, production will be far below the EIA's forecast by 2040. Shale gas production from the top seven plays will underperform the EIA's reference case forecast by 39% from 2014 to 2040, and more of this production will be front-loaded than the EIA estimates. By 2040, production rates from these plays will be about one-third that of the EIA forecast. Production from shale gas plays other than the top seven will need to be four times that estimated by the EIA in order to meet its reference case forecast".

Source: J. David Hughes, Post Carbon Institute

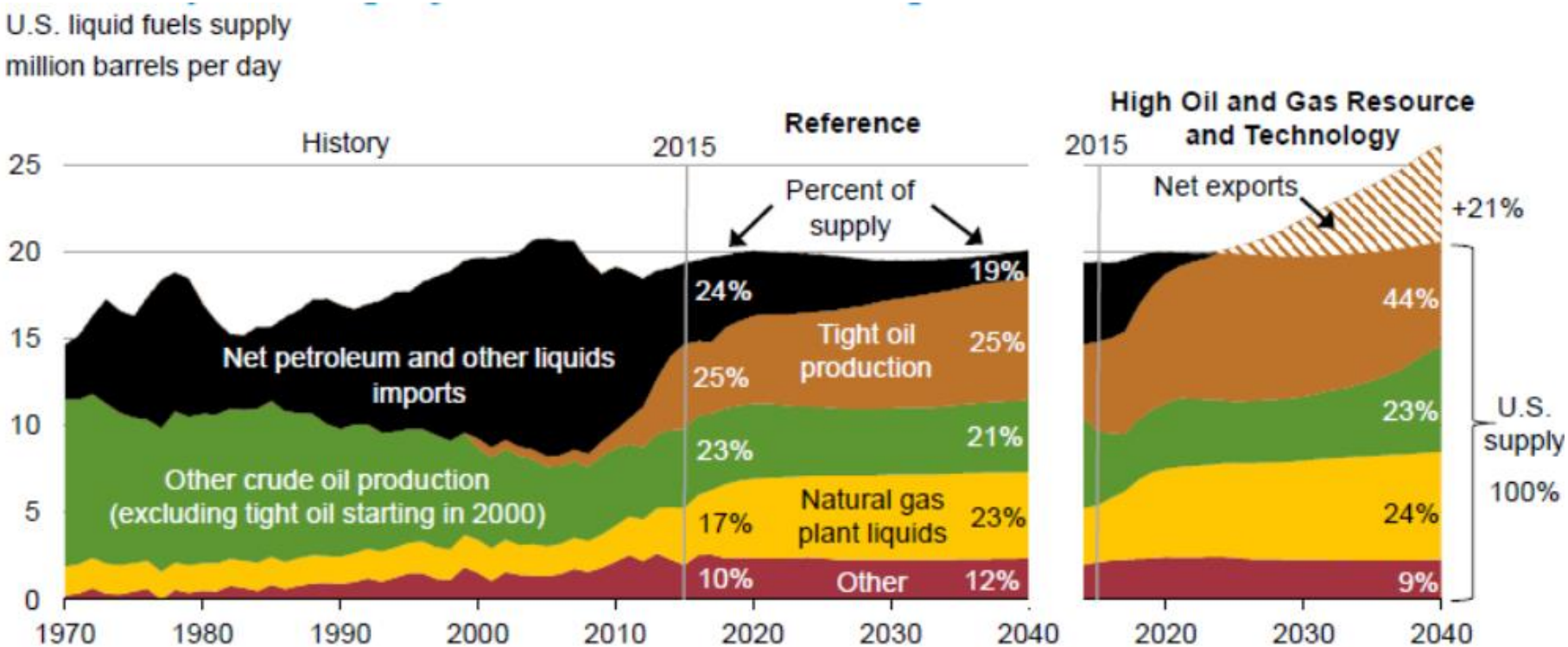
U.S. crude oil production rises above previous historical high before 2030; alternative price and resource/technology cases can differ



Source: EIA, Annual Energy Outlook 2016

Adam Sieminski, Johns Hopkins SAIS June 28, 2016

Combination of increased tight oil production and higher fuel efficiency drives projected decline in oil imports

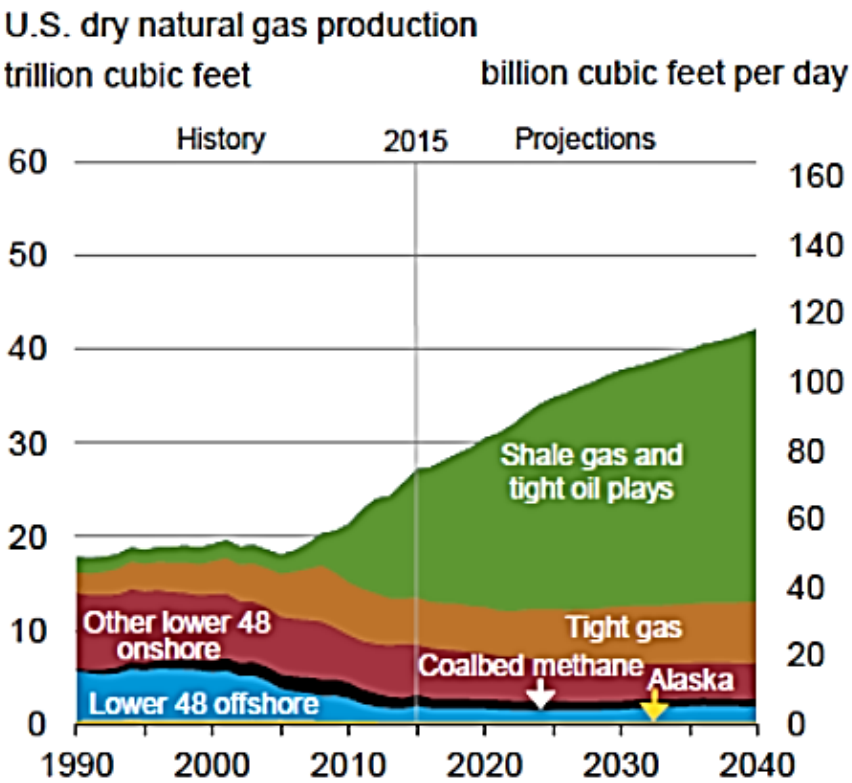


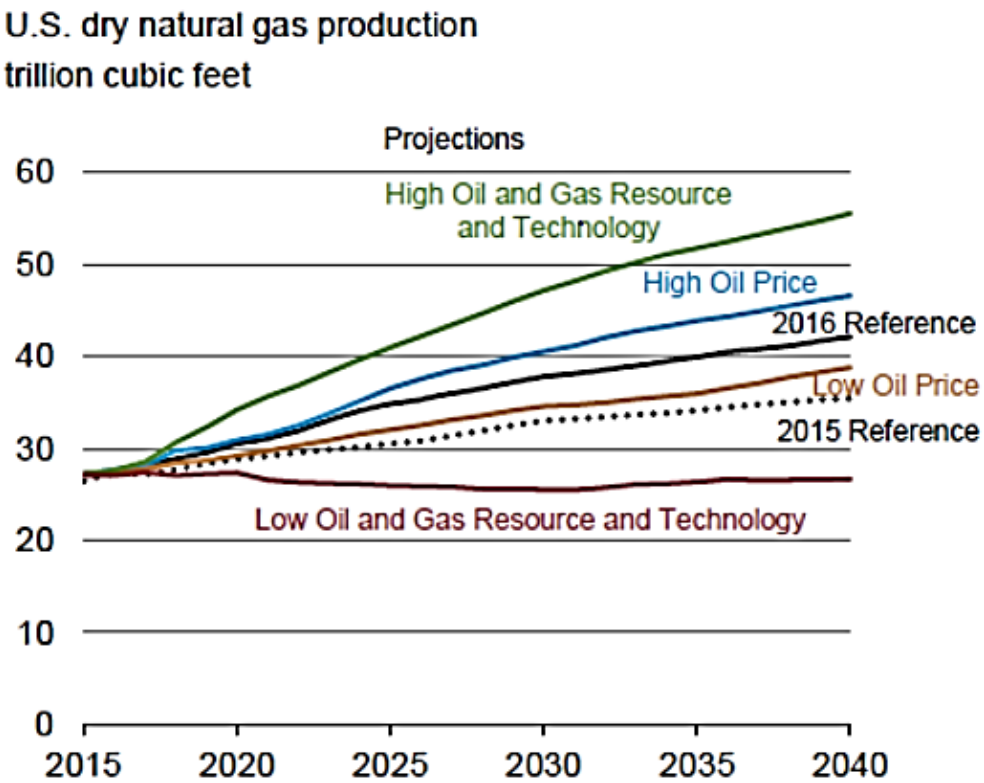
Note: "Other" includes refinery gain, biofuels production, all stock withdrawals, and other domestic sources of liquid fuels

Source: EIA, Annual Energy Outlook 2016

Adam Sieminski, Johns Hopkins SAIS June 28, 2016

U.S. natural gas production dominated by shale resources; alternative price and resource /technology assumptions could be quite different

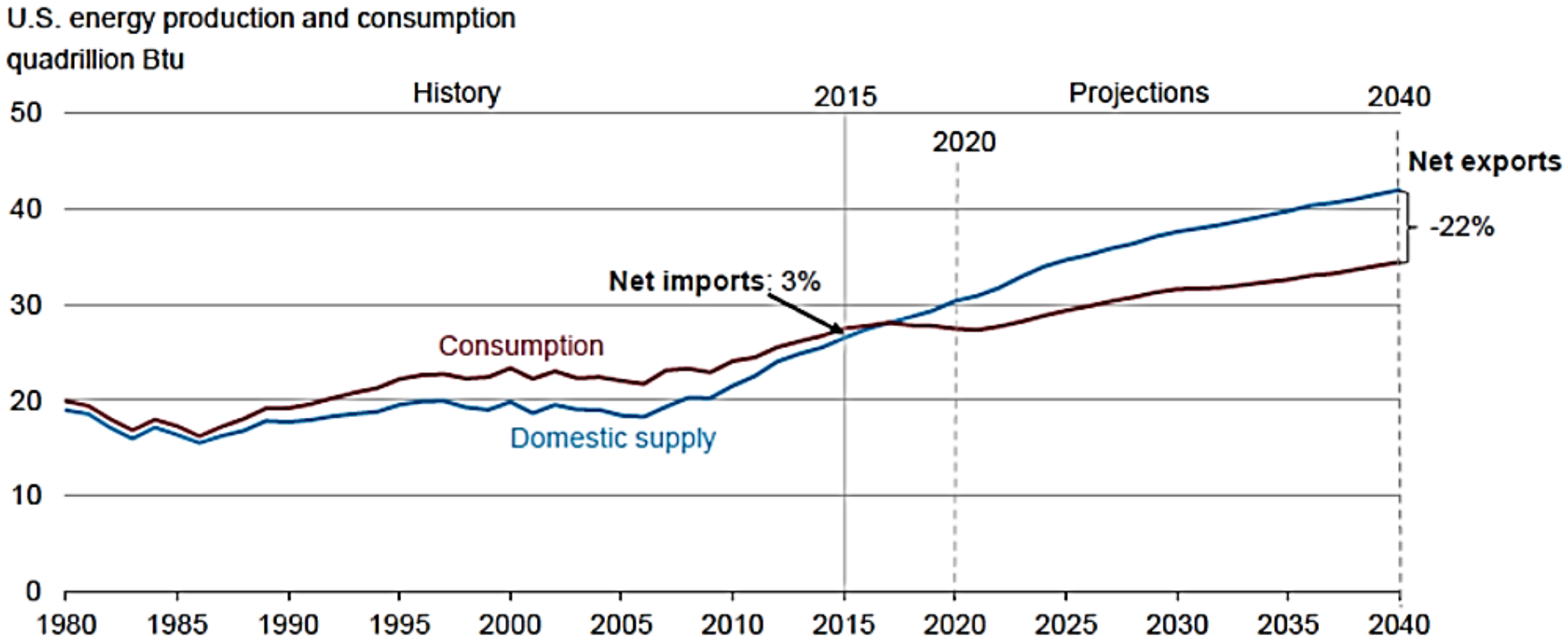




Source: EIA, Annual Energy Outlook 2016

Adam Sieminski, Johns Hopkins SAIS June 28, 2016

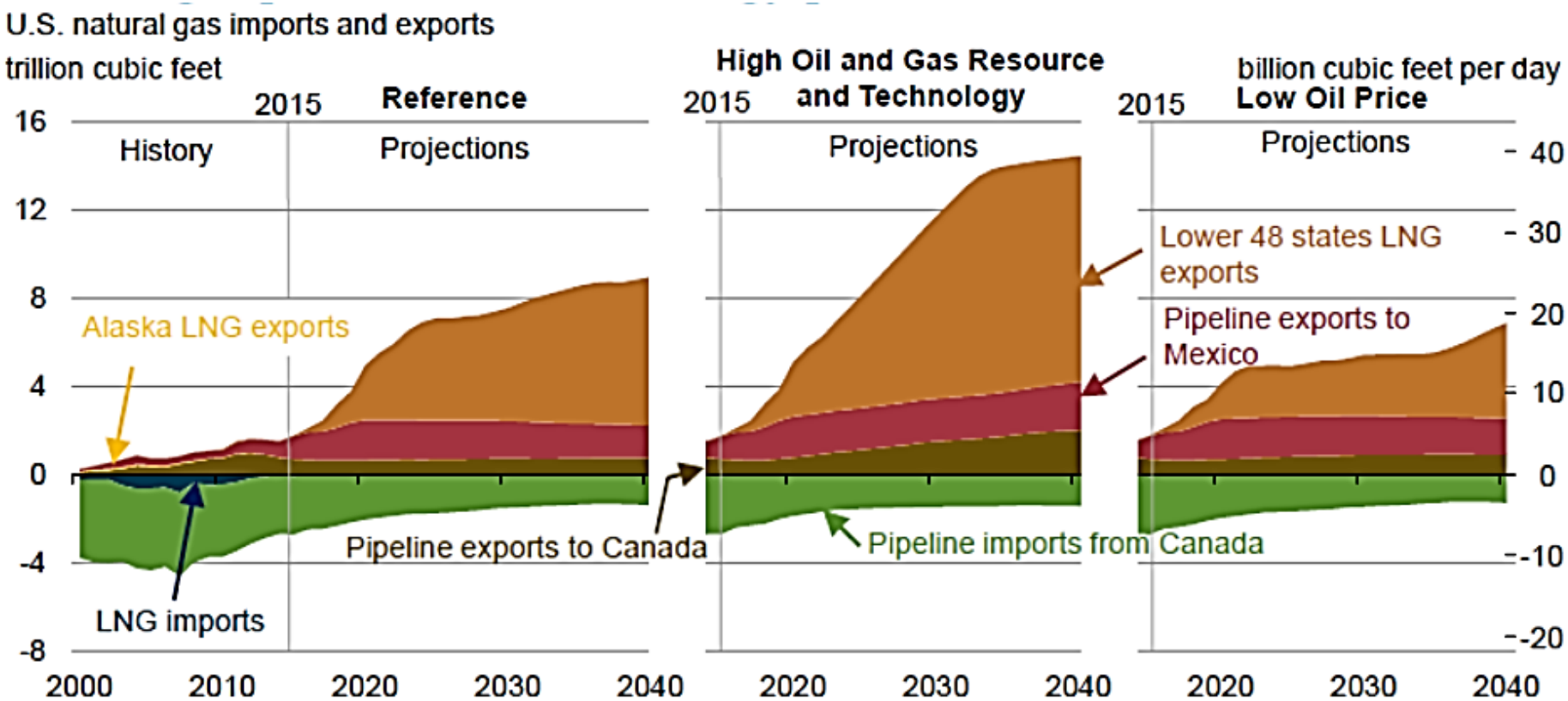
U.S. natural gas production will soon exceed consumption, making the United States a net exporter



Source: EIA, Annual Energy Outlook 2016

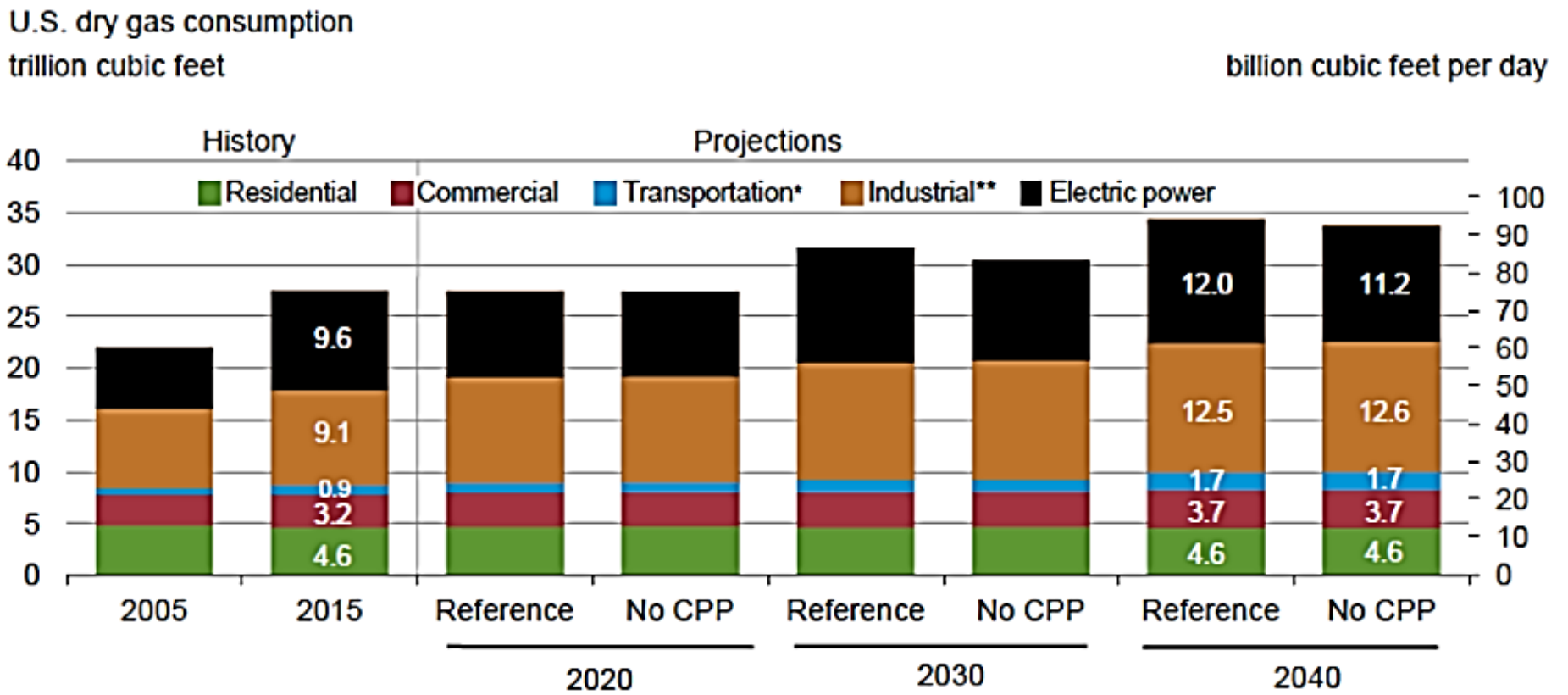
Adam Sieminski, Johns Hopkins SAIS June 28, 2016

Projected U.S. natural gas exports reflect the spread between domestic natural gas prices and world energy prices



Source: EIA, Annual Energy Outlook 2016

Natural gas consumption growth is led by electricity generation and industrial uses; natural gas use rises in all sectors except residential



Source: EIA, Annual Energy Outlook 2016

*Includes pipeline fuel
**Includes combined heat-and-power and lease, plant, and export liquefaction fuel

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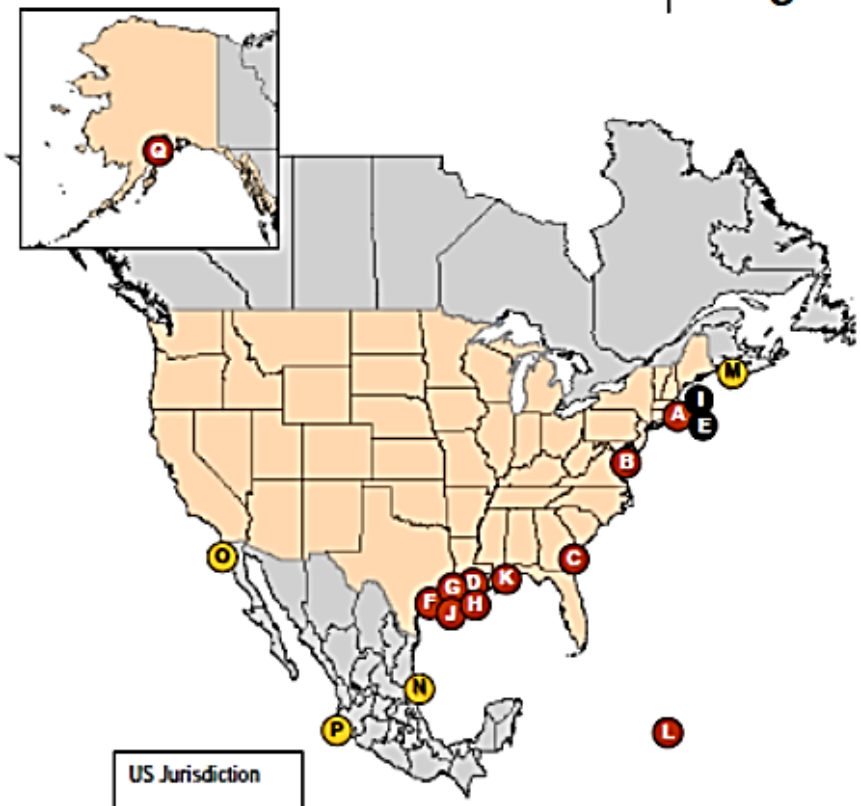
North American existing import/export LNG terminals

North American LNG Import/Export Terminals

Existing



As of July 11, 2016

★ Authorized to re-export delivered LNG

Import Terminals

U.S.

A. Everett, MA: 1.035 Bcfd (GDF SUEZ - DOMAC)
B. Cove Point, MD: 1.8 Bcfd (Dominion - Cove Point LNG)
C. Elba Island, GA: 1.6 Bcfd (El Paso - Southern LNG)
D. Lake Charles, LA: 2.1 Bcfd (Southern Union - Trunkline LNG)
E. Offshore Boston: 0.8 Bcfd (Excelerate Energy – Northeast Gateway)
F. Freeport, TX: 1.5 Bcfd (Cheniere/Freeport LNG Dev.) ★
G. Sabine, LA: 4.0 Bcfd (Cheniere/Sabine Pass LNG) ★
H. Hackberry, LA: 1.8 Bcfd (Sempra - Cameron LNG) ★
I. Offshore Boston, MA: 0.4 Bcfd (GDF SUEZ – Neptune LNG)
J. Sabine Pass, TX: 2.0 Bcfd (ExxonMobil – Golden Pass) (Phase I & II)
K. Pascagoula, MS: 1.5 Bcfd (El Paso/Crest/Sonangol - Gulf LNG Energy LLC)
L. Peñuelas, PR: 0.2 Bcfd (EcoElectrica)

Canada

M. Saint John, NB: 1.0 Bcfd (Repsol/Fort Reliance - Canaport LNG)

Mexico

N. Altamira, Tamulipas: 0.7 Bcfd (Shell/Total/Mitsui – Altamira LNG)
O. Baja California, MX: 1.0 Bcfd (Sempra – Energia Costa Azul)
P. Manzanillo, MX: 0.5 Bcfd (KMS GNL de Manzanillo)

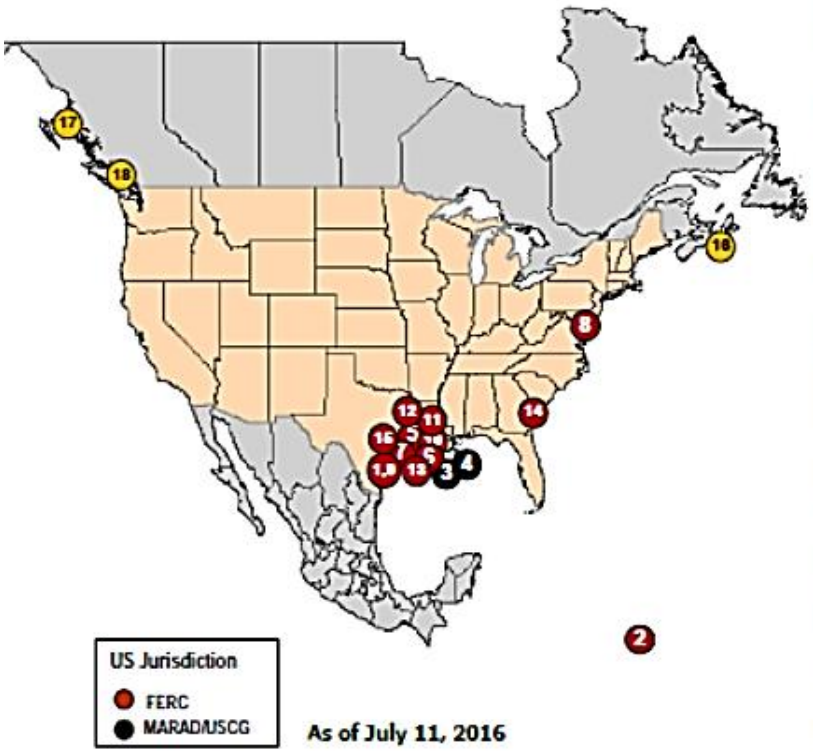
Export Terminals

U.S.

Q. Kenai, AK: 0.2 Bcfd (ConocoPhillips)
G. Sabine, LA: 0.7 Bcfd (Cheniere/Sabine Pass LNG – Train 1)

North American approved import/export LNG terminals

North American LNG Import/Export Terminals
Approved



Import Terminals

U.S.

APPROVED - UNDER CONSTRUCTION - FERC
1. Corpus Christi, TX: 0.4 Bcfd (Cheniere – Corpus Christi LNG) (CP12-507)

APPROVED – NOT UNDER CONSTRUCTION - FERC
2. Salinas, PR: 0.6 Bcfd (Aguirre Offshore GasPort, LLC) (CP13-193)

APPROVED - NOT UNDER CONSTRUCTION - MARAD/Coast Guard
3. Gulf of Mexico: 1.0 Bcfd (Main Pass McMoRan Exp.)
4. Gulf of Mexico: 1.4 Bcfd (TORP Technology-Bienville LNG)

Export Terminals

U.S.

APPROVED - UNDER CONSTRUCTION - FERC
5. Sabine, LA: 2.1 Bcfd (Cheniere/Sabine Pass LNG) (CP11-72 & CP14-12)
6. Hackberry, LA: 2.1 Bcfd (Sempra–Cameron LNG) (CP13-25)
7. Freeport, TX: 1.8 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction) (CP12-509)
8. Cove Point, MD: 0.82 Bcfd (Dominion–Cove Point LNG) (CP13-113)
9. Corpus Christi, TX: 2.14 Bcfd (Cheniere – Corpus Christi LNG) (CP12-507)
10. Sabine Pass, LA: 1.40 Bcfd (Sabine Pass Liquefaction) (CP13-552) ★

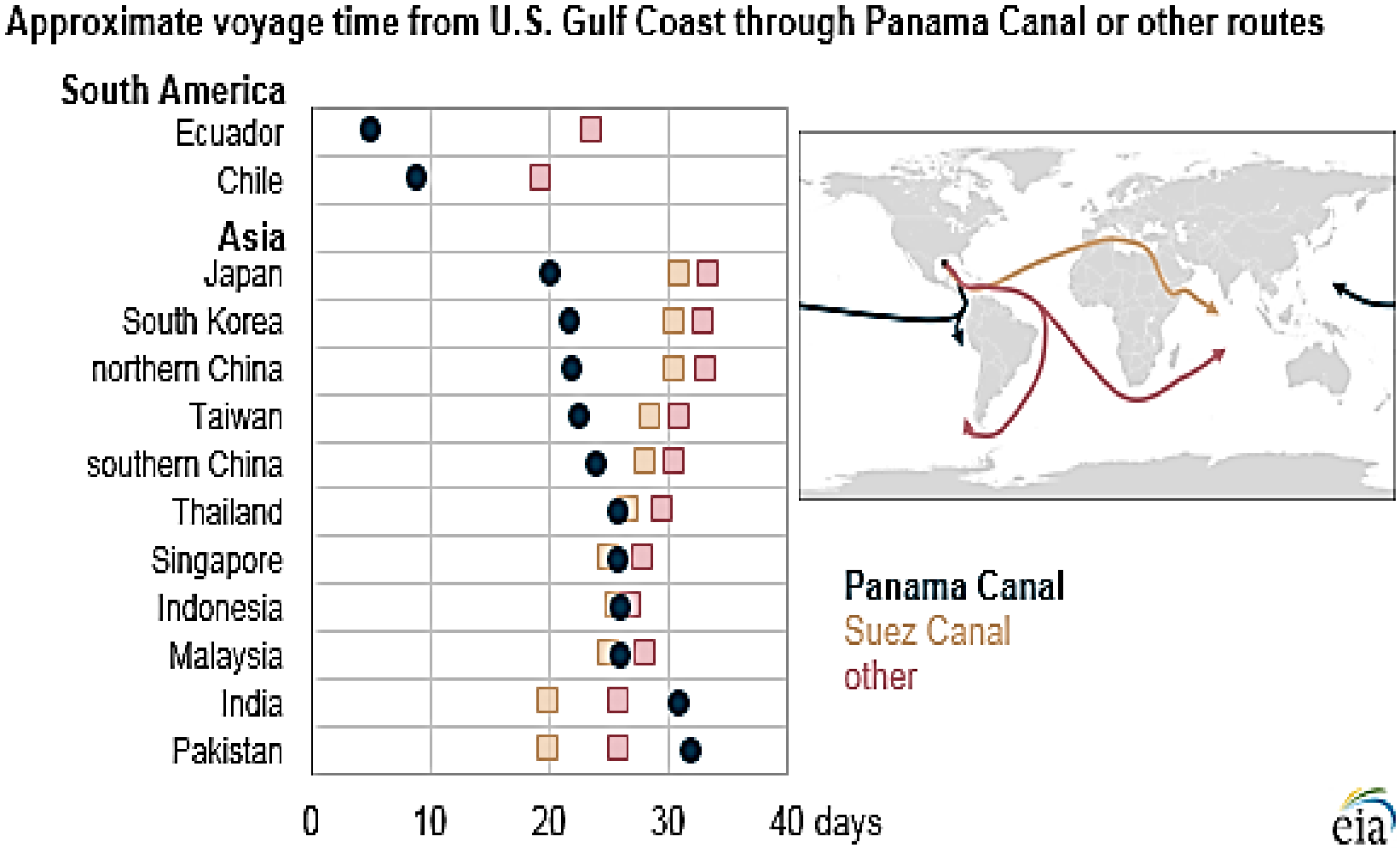
APPROVED – NOT UNDER CONSTRUCTION - FERC
11. Lake Charles, LA: 2.2 Bcfd (Southern Union – Lake Charles LNG) (CP14-120)
12. Lake Charles, LA: 1.08 Bcfd (Magnolia LNG) (CP14-347)
13. Hackberry, LA: 1.41 Bcfd (Sempra - Cameron LNG) (CP15-560)
14. Elba Island, GA: 0.35 Bcfd (Southern LNG Company) (CP14-103)
15. Freeport, TX: 0.34 Bcfd (Freeport LNG Dev) (CP15-518)

Canada

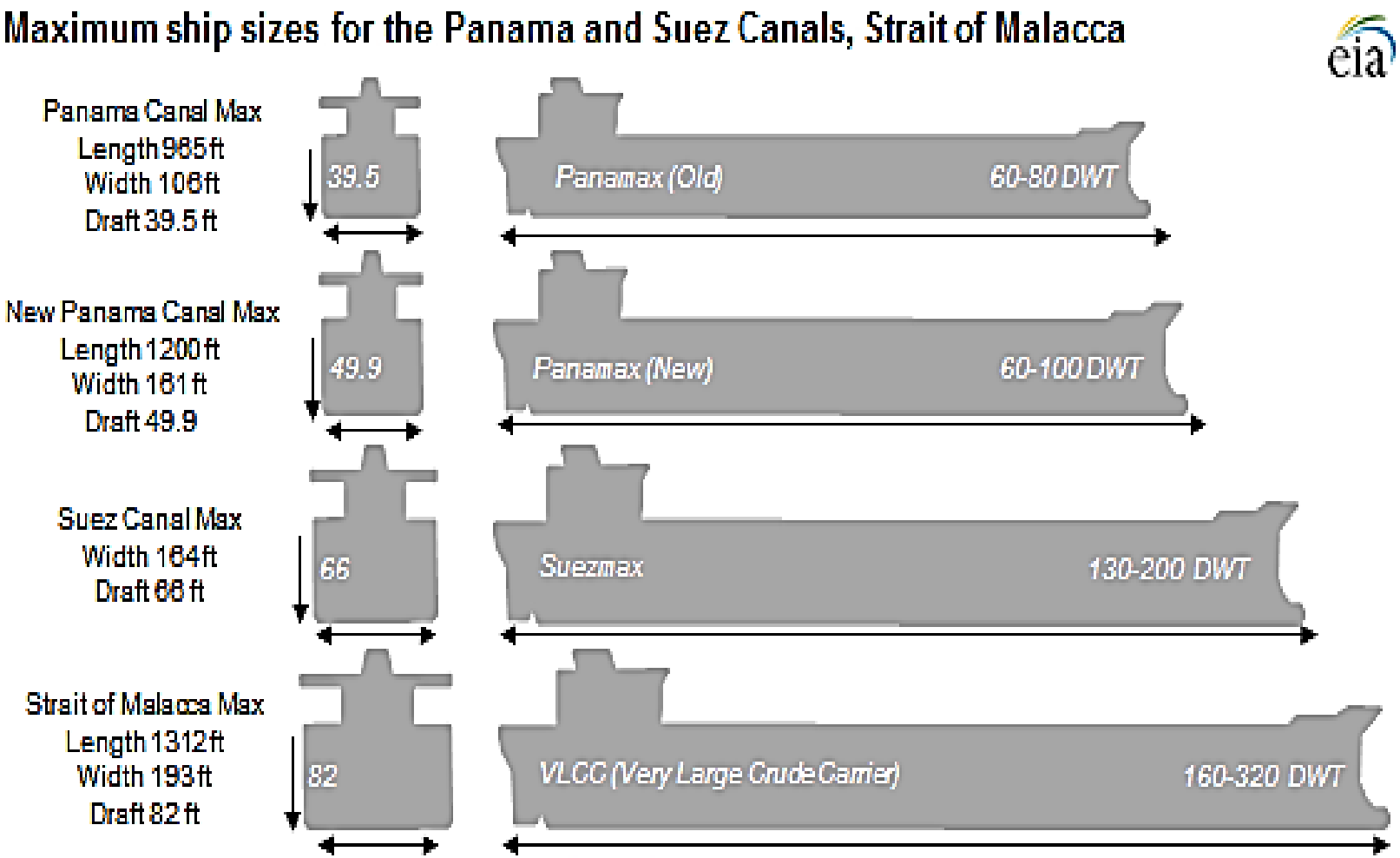
APPROVED – NOT UNDER CONSTRUCTION
16. Port Hawkesbury, NS: 0.5 Bcfd (Bear Head LNG)
17. Kitimat, BC: 3.23 Bcfd (LNG Canada)
18. Squamish, BC: 0.29 Bcfd (Woodfibre LNG Ltd)

★ Trains 5 & 6 with Train 5 under construction

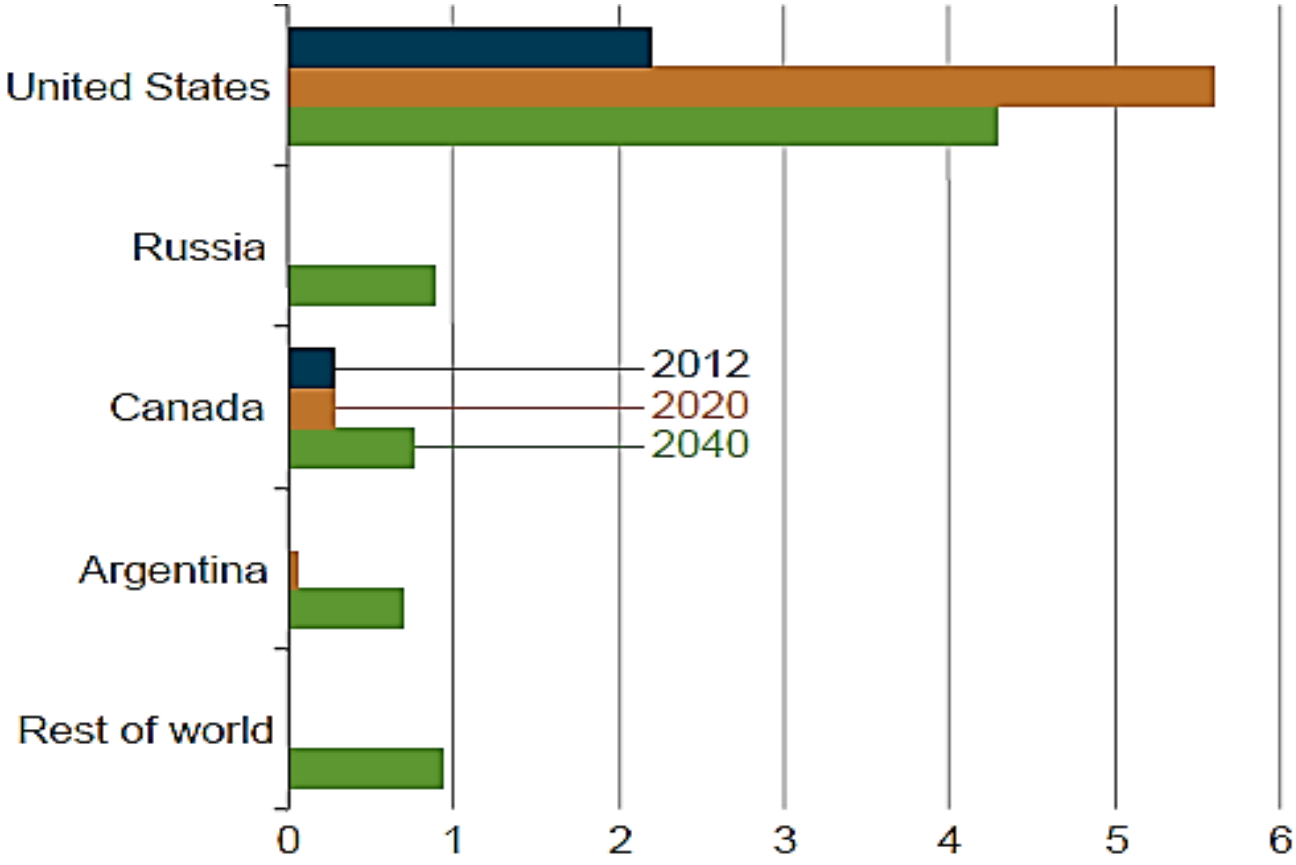
Expanded Panama Canal reduces travel time for shipments of U.S. LNG to Asian markets



Panama Canal expansion will allow transit of larger ships with greater volumes

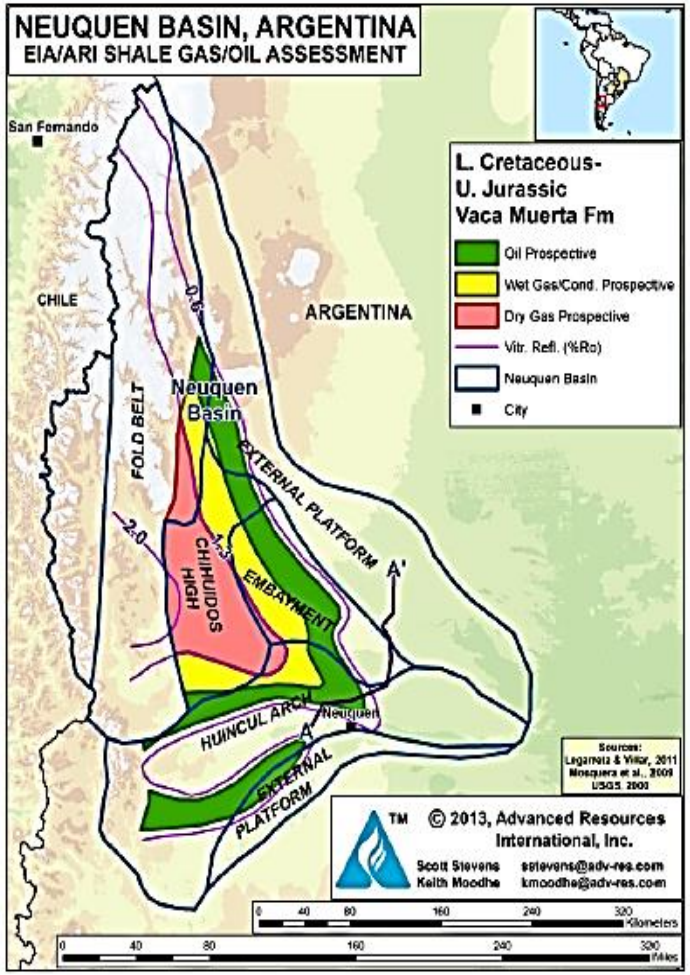


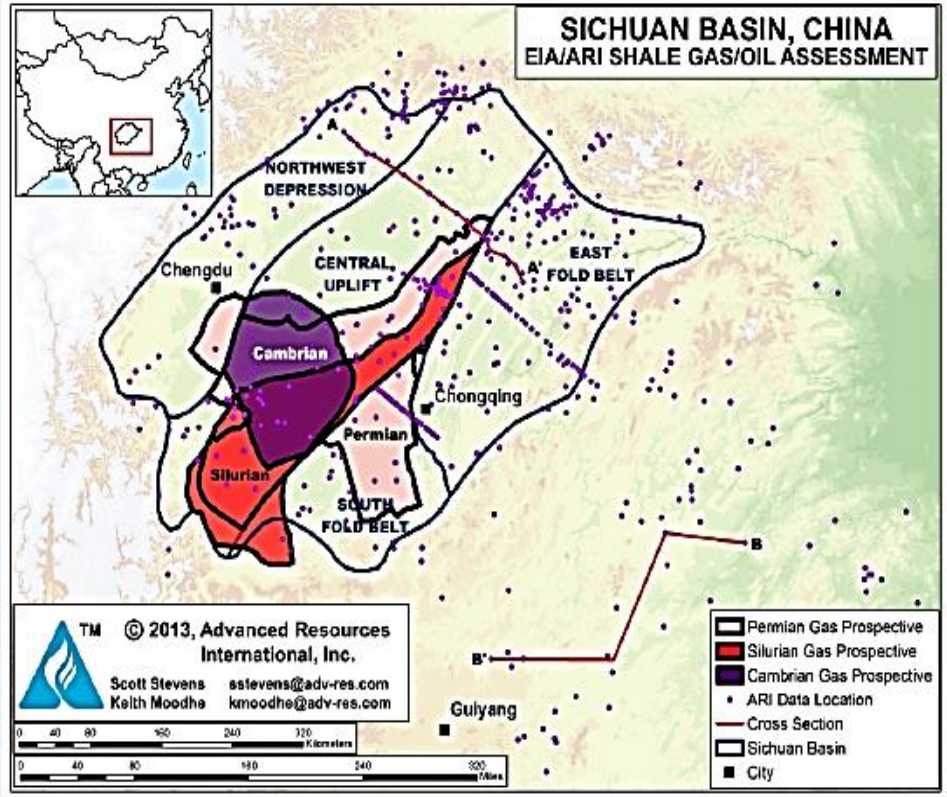
World tight oil production in the IEO2016 Reference case, 2012, 2020, and 2040 (million barrels per day)



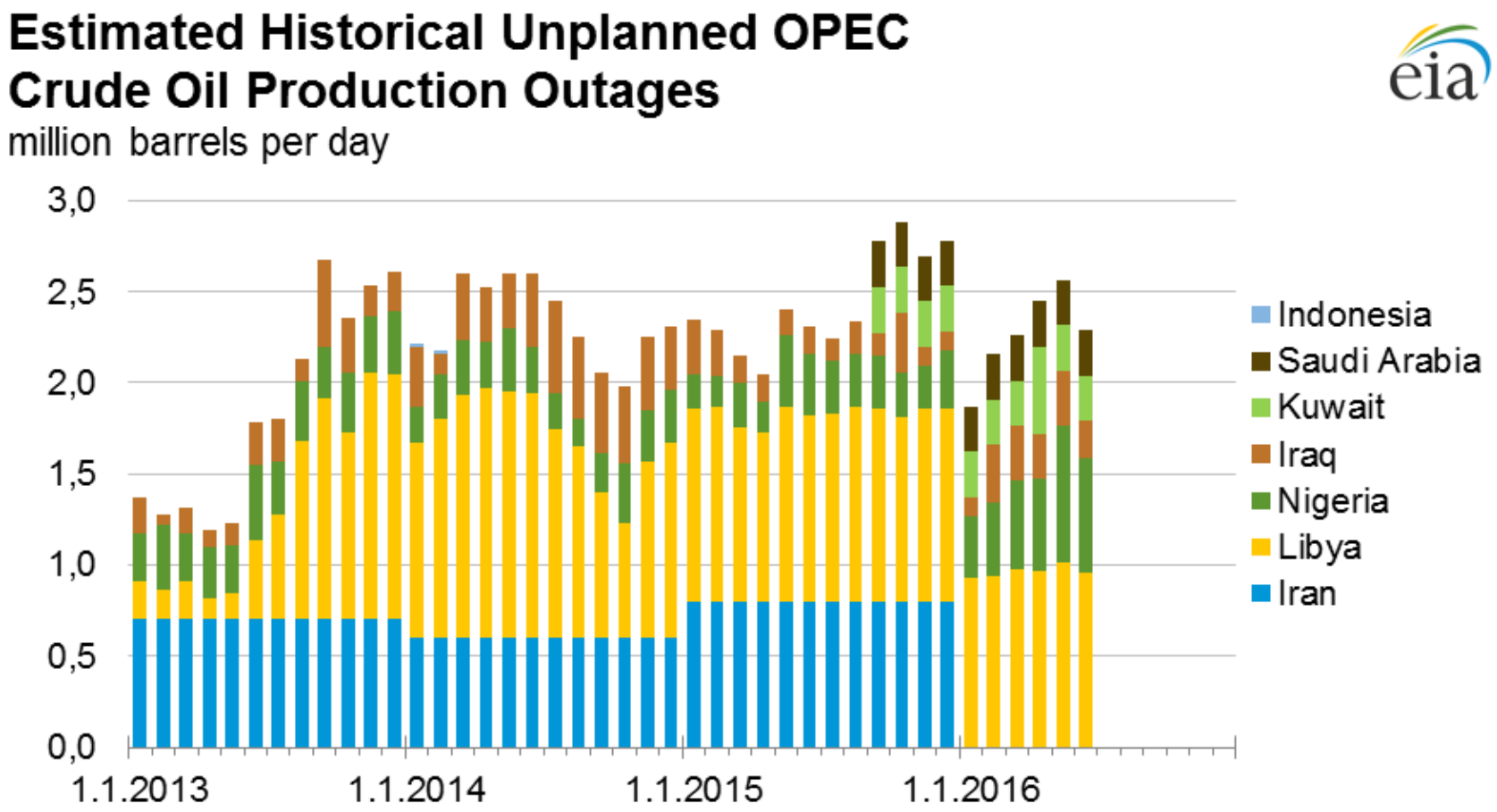
Source: EIA International Energy Outlook 2016 Reference case

EIA/ARI assessments of shale gas and tight oil resources in Argentina's Nequen Basin and China's Sichuan Basin



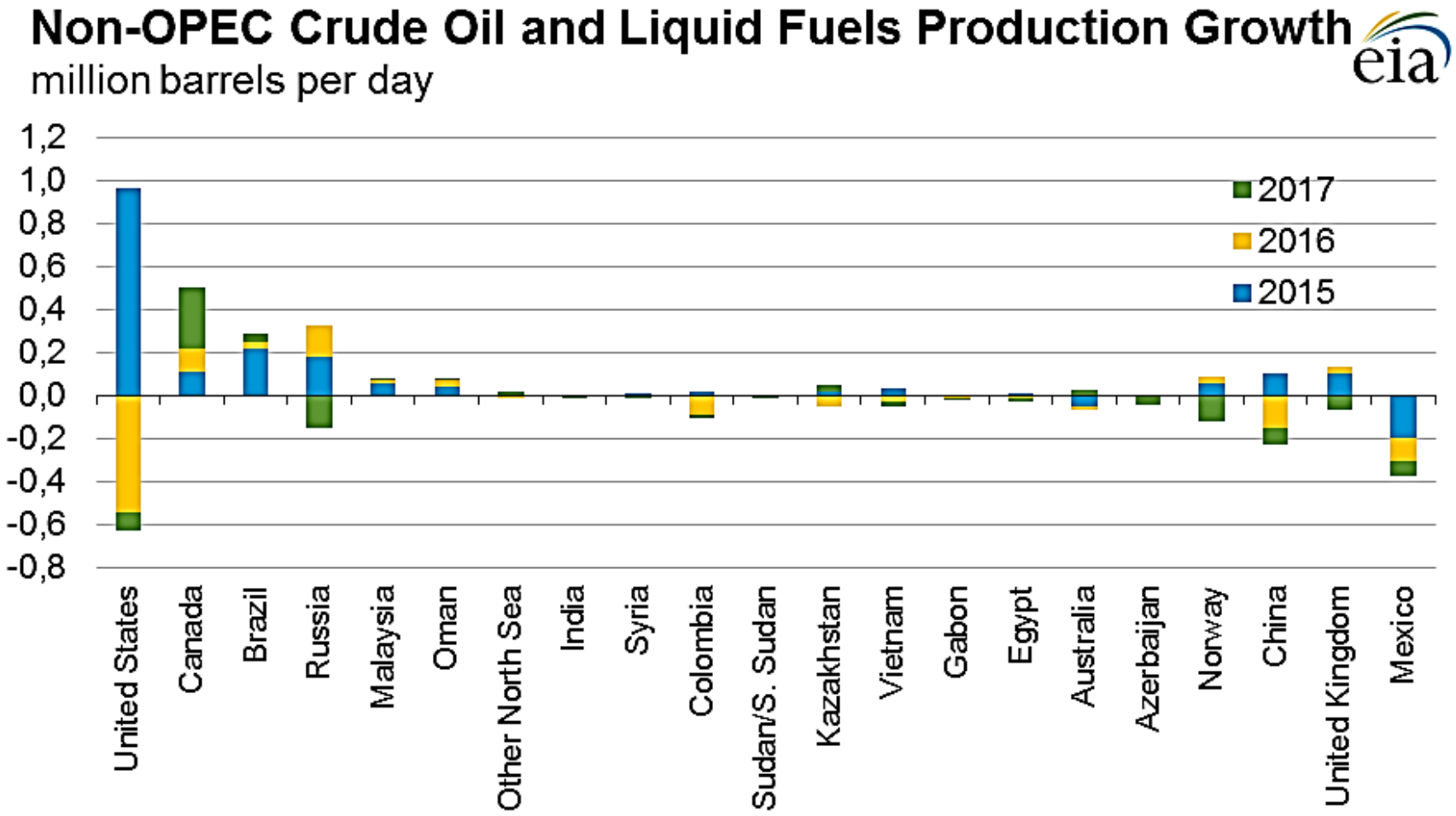


Estimated Historical Unplanned OPEC Crude Oil Production Outages



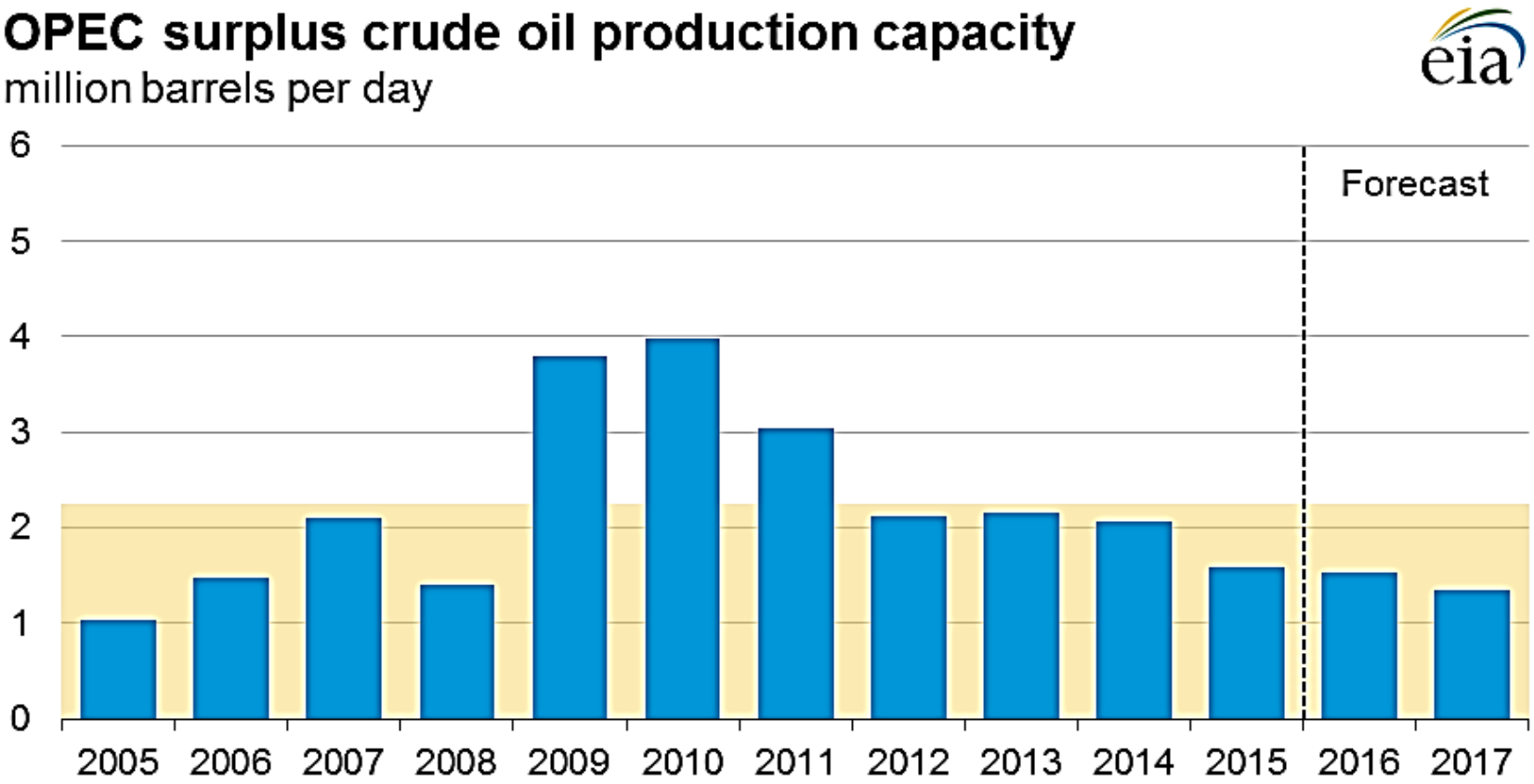
Source: Short-Term Energy Outlook, July 2016.

Non-OPEC Crude Oil and Liquid Fuels Production Growth



Source: Short-Term Energy Outlook, July 2016.

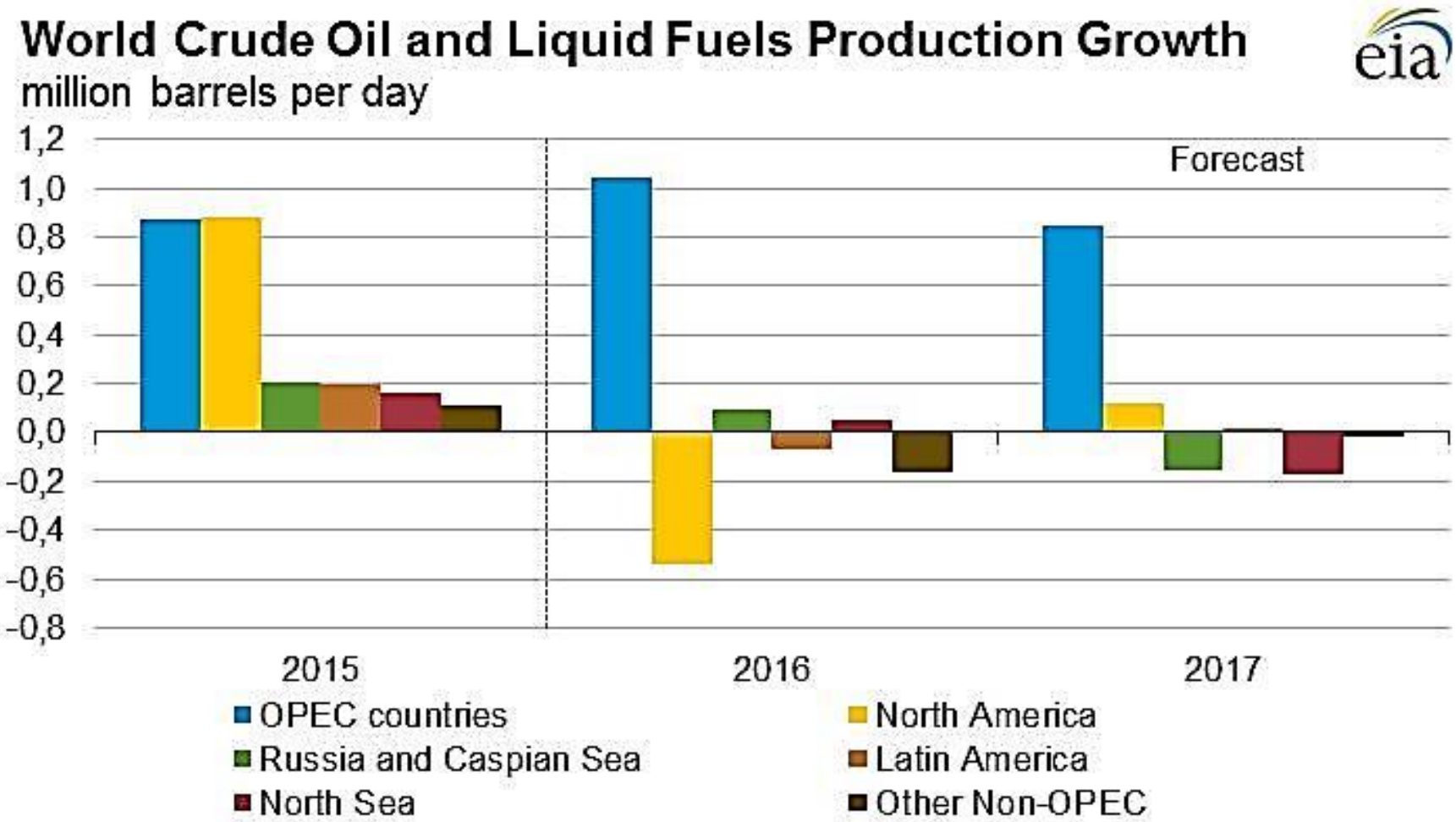
OPEC surplus crude oil production capacity



Note: Shaded area represents 2005-2015 average (2.3 million barrels per day).

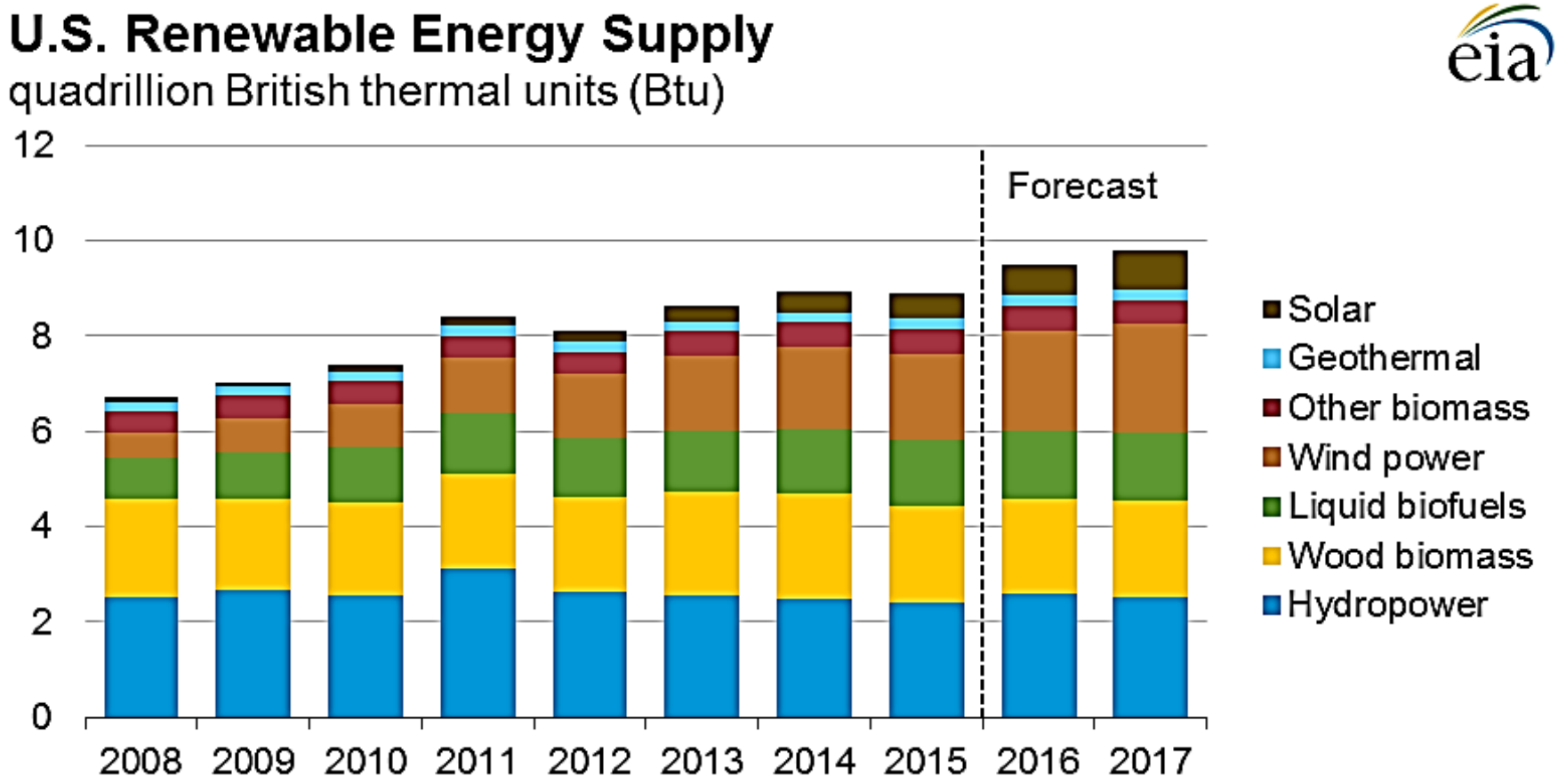
Source: Short-Term Energy Outlook, July 2016.

World Crude Oil and Liquid Fuels Production Growth



Source: Short-Term Energy Outlook, July 2016.

U.S. Renewable Energy Supply



Note: Hydropower excludes pumped storage generation. Liquid biofuels include ethanol and biodiesel. Other biomass includes municipal waste from biogenic sources, landfill gas, and other non-wood waste.

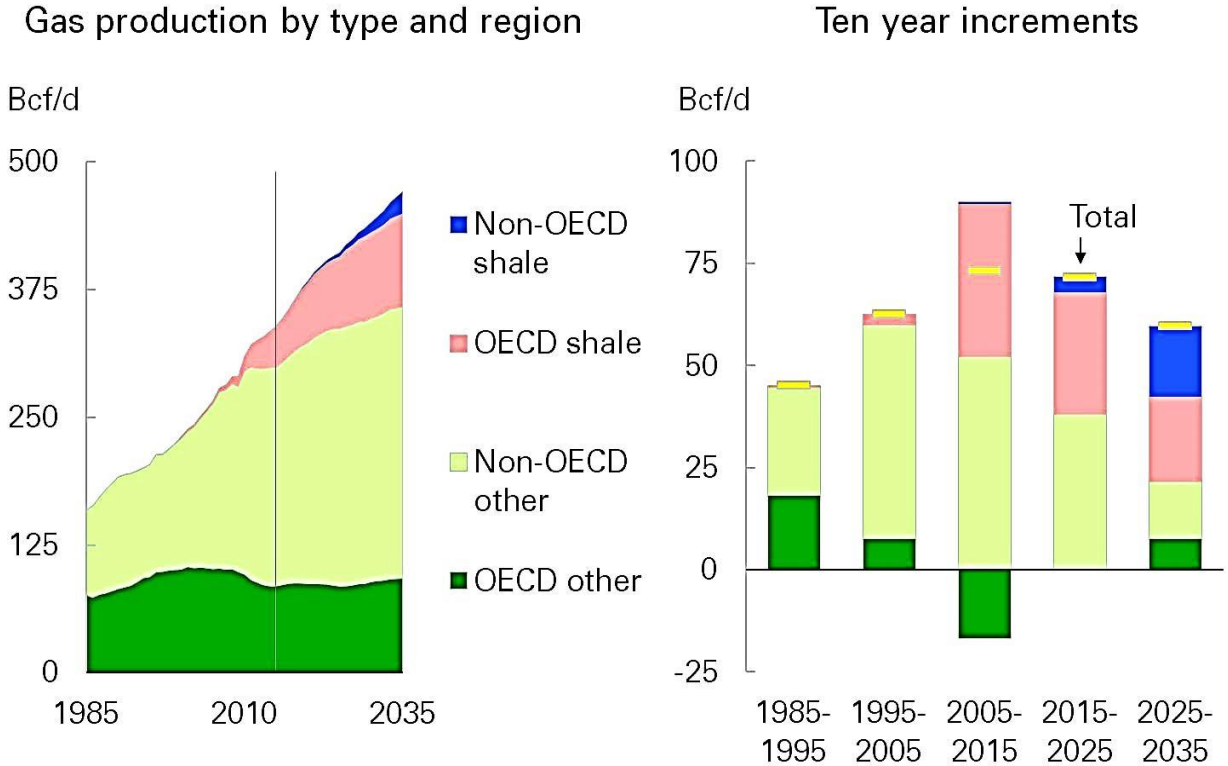
Source: Short-Term Energy Outlook, July 2016.

Global supplies of natural gas grow robustly underpinned by increases in shale gas around the world

Base case: Fuel by fuel detail

bp

Global supplies of natural gas grow robustly…

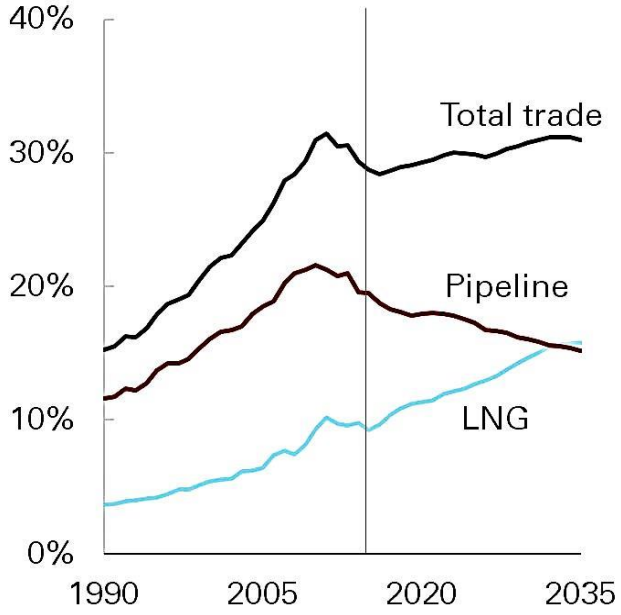


Trade in gas grows broadly in line with global consumption with LNG playing an increasingly important role

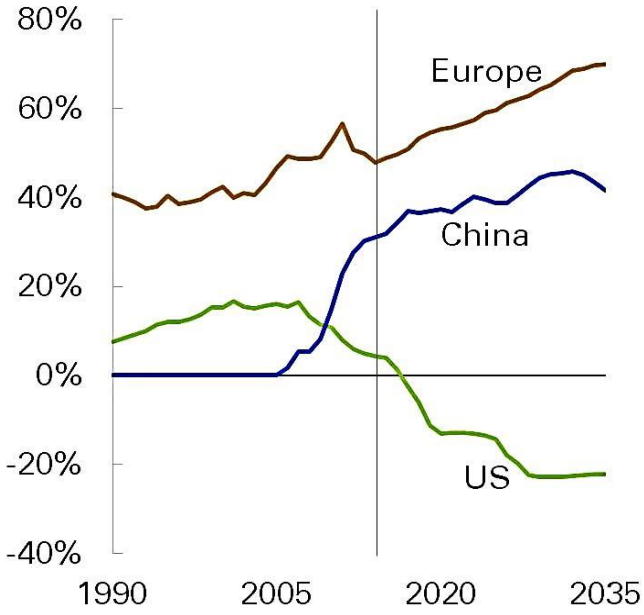
Base case: Fuel by fuel detail

Trade in gas grows broadly in line with global consumption…

Trade as share of global consumption



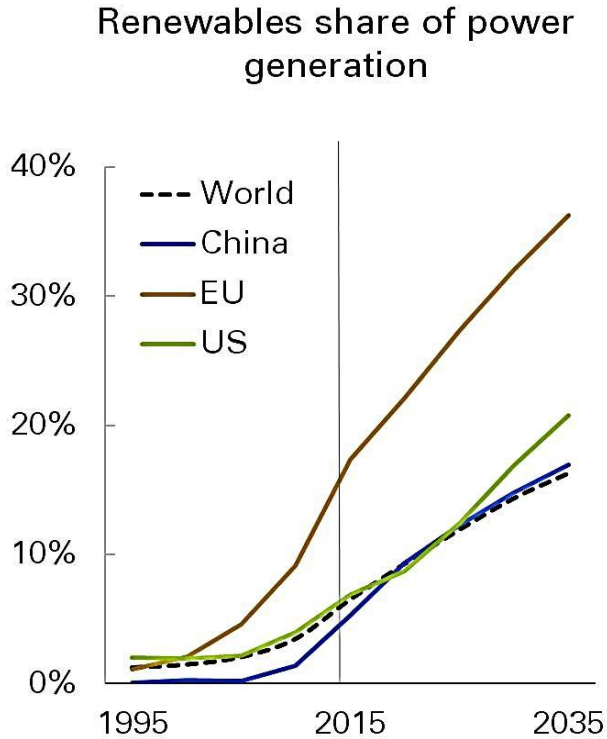
Imports as share of consumption

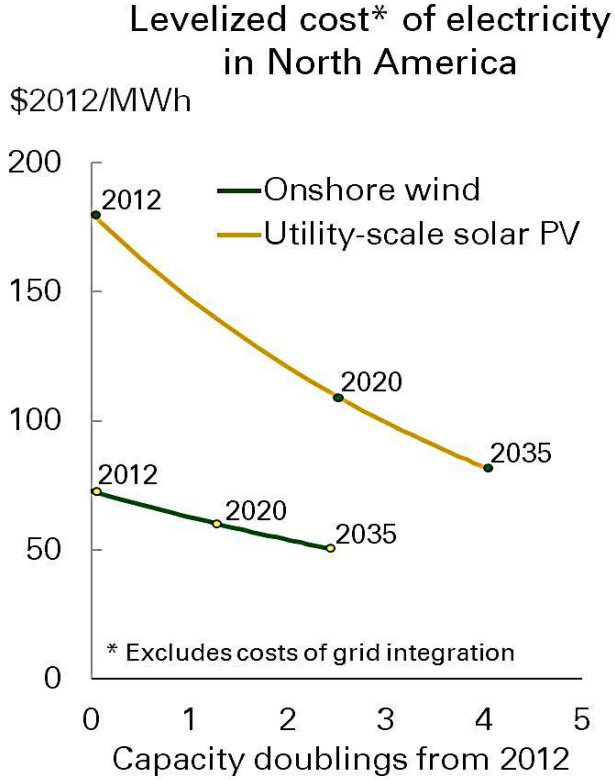


Renewables continue to grow rapidly supported by significant cost reductions

Base case: Fuel by fuel detail

Renewables continue to grow rapidly…

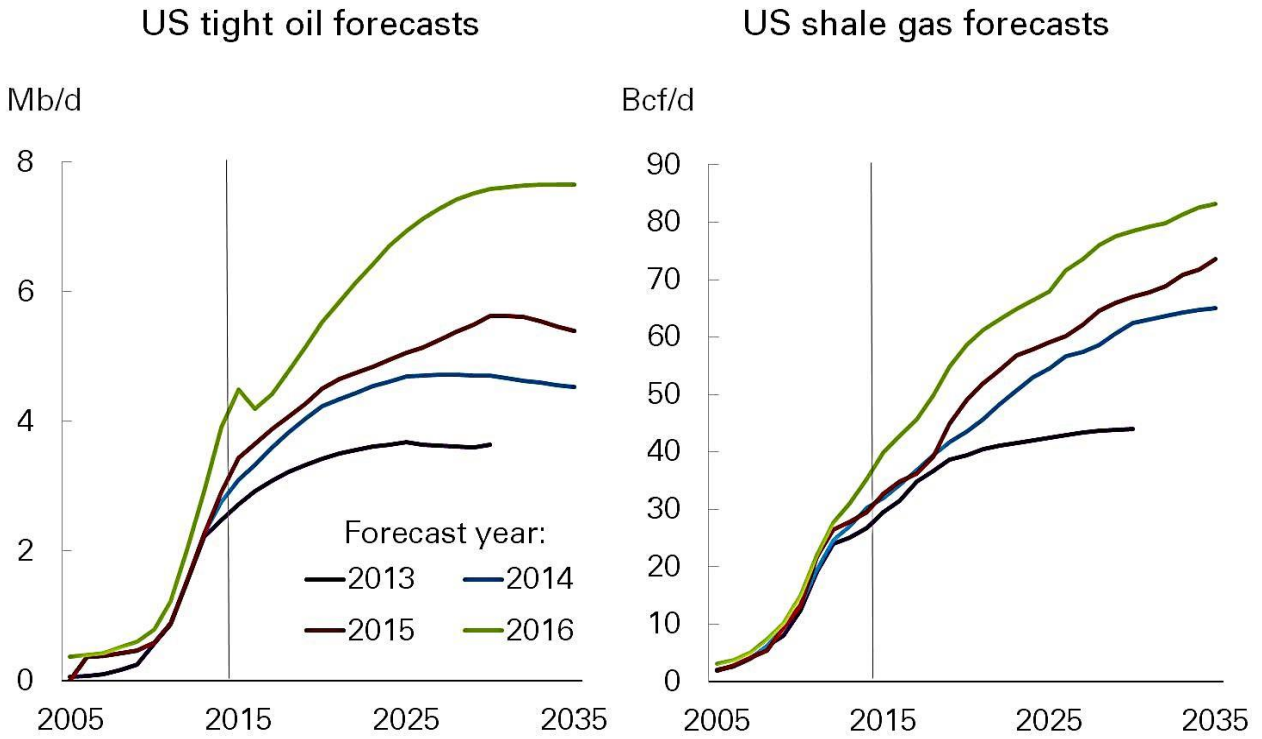




The outlook for US shale has been revised up repeatedly as technology and productivity gains unlock new resources

Key issues: What have we learned about US shale?

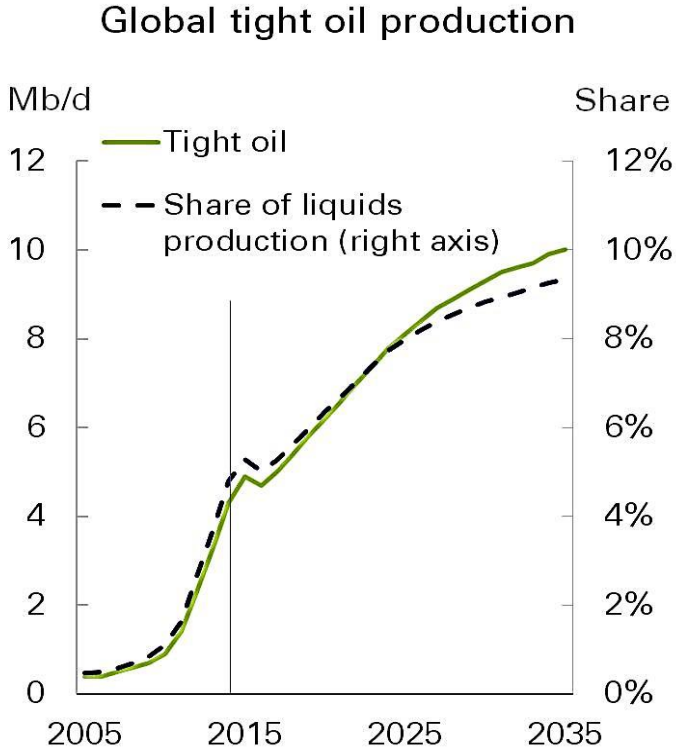
The outlook for US shale has been revised up repeatedly…

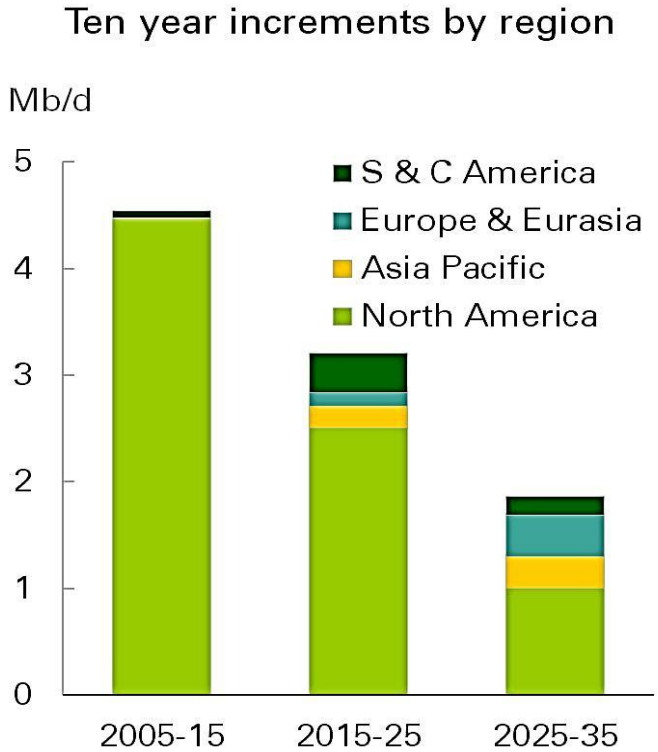


The global growth in tight oil slows as North American gradually moderates

Key issues: What have we learned about US shale?

The global growth in tight oil slows…

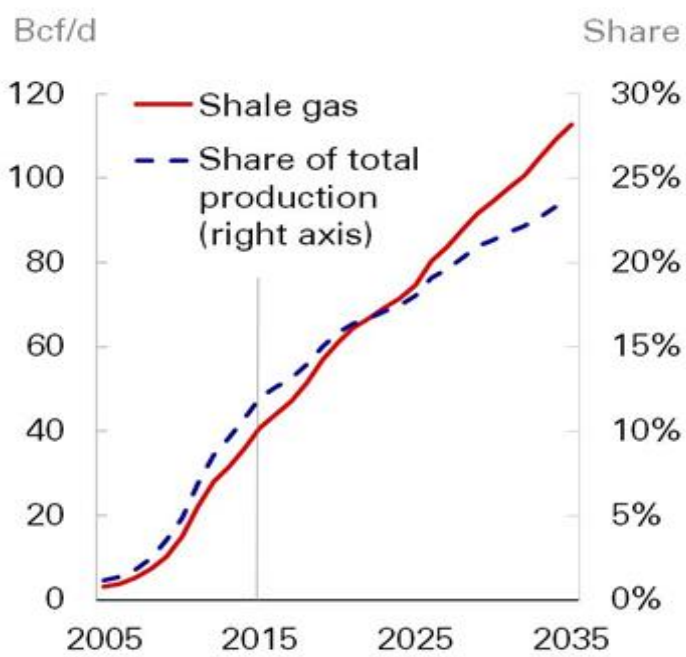


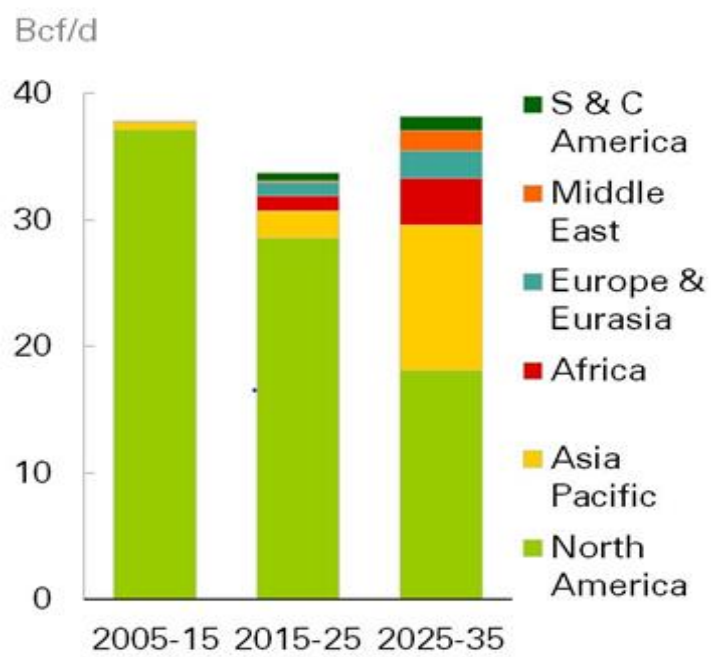


Shale gas production continues to expand rapidly helped by increasing production outside North America

Key issues: What have we learned about US shale?

Shale gas production continues to expand rapidly…



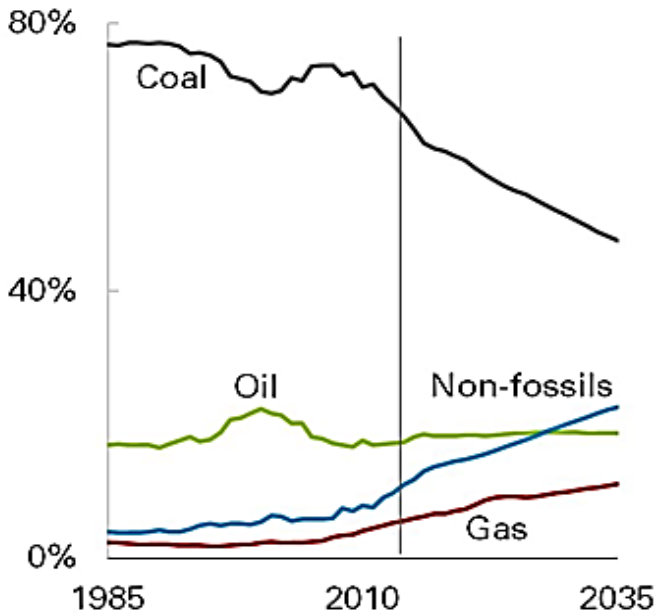


China fuel mix is likely to change significantly as China reduces its reliance on coal

Key issues: China's changing energy needs

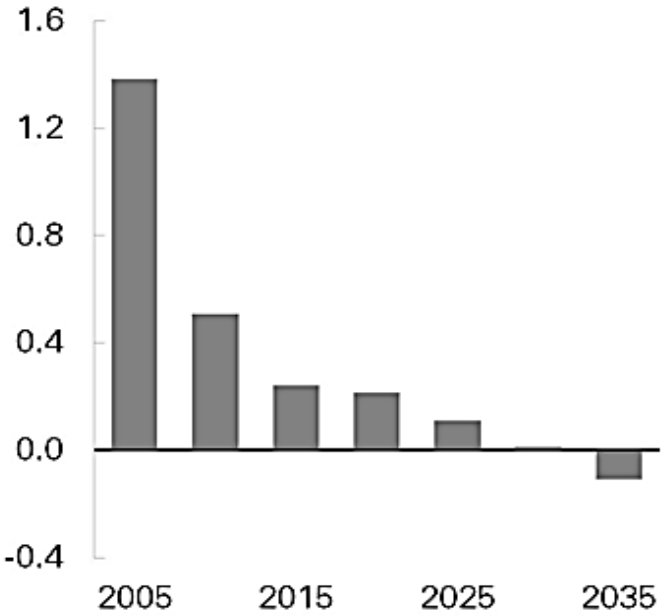
China's fuel mix is also likely to change significantly…

Shares of primary energy in China



Ratio of coal demand growth to GDP growth

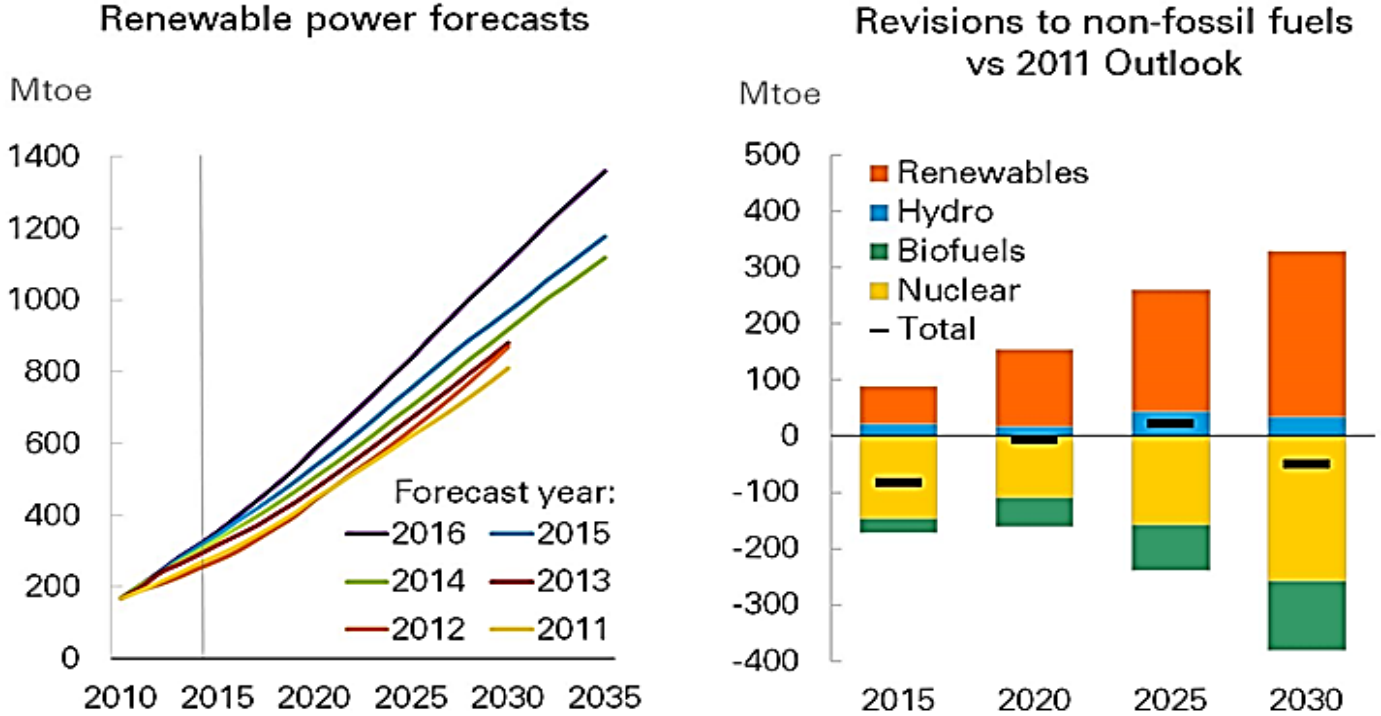
Average ratio during previous five years



Renewables have been revised up repeatedly while other non-fossil fuels have been revised doun

Base case: Main changes

Renewables have been revised up repeatedly...

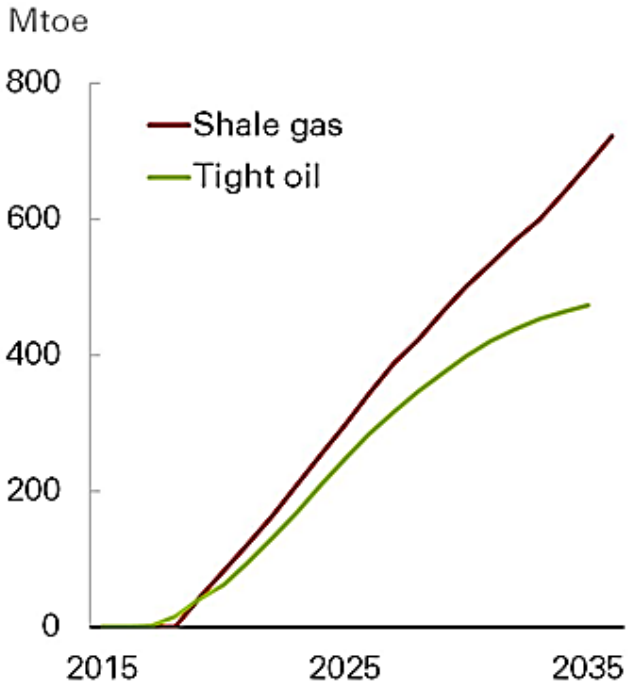


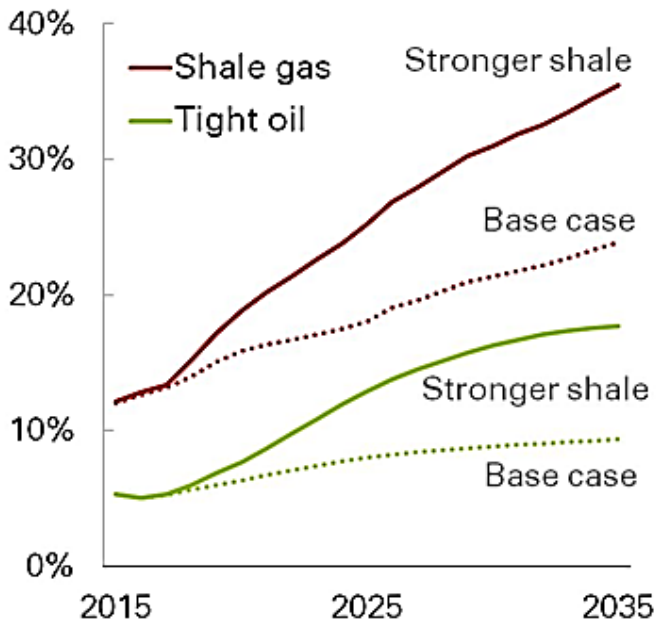
Note: Projected growth from each Outlook applied to latest 2010 data

Tight oil and shale gas having even greater potential has significant implications for global energy supplies

Stronger shale

Case 3: Tight oil and shale gas having even greater potential…

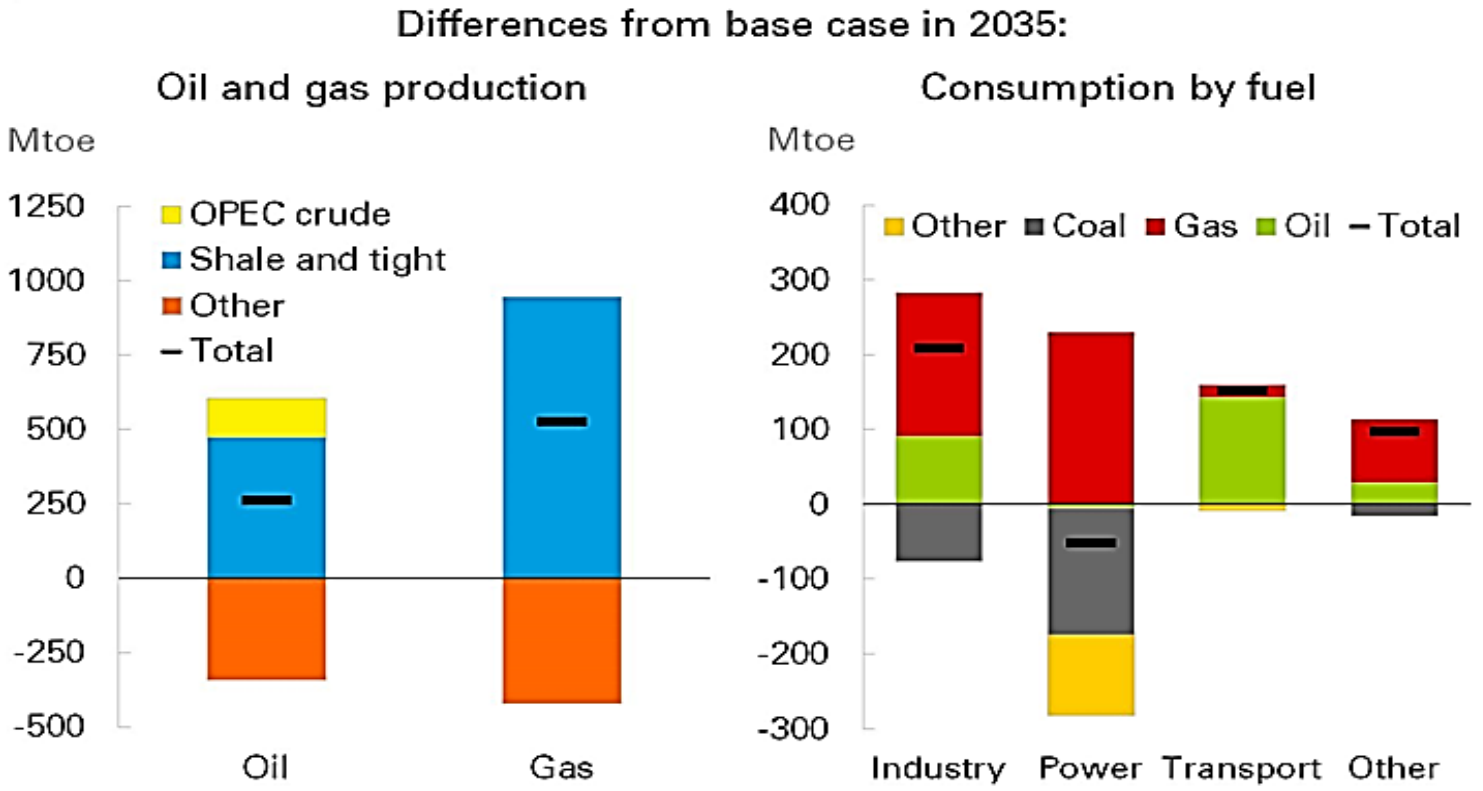




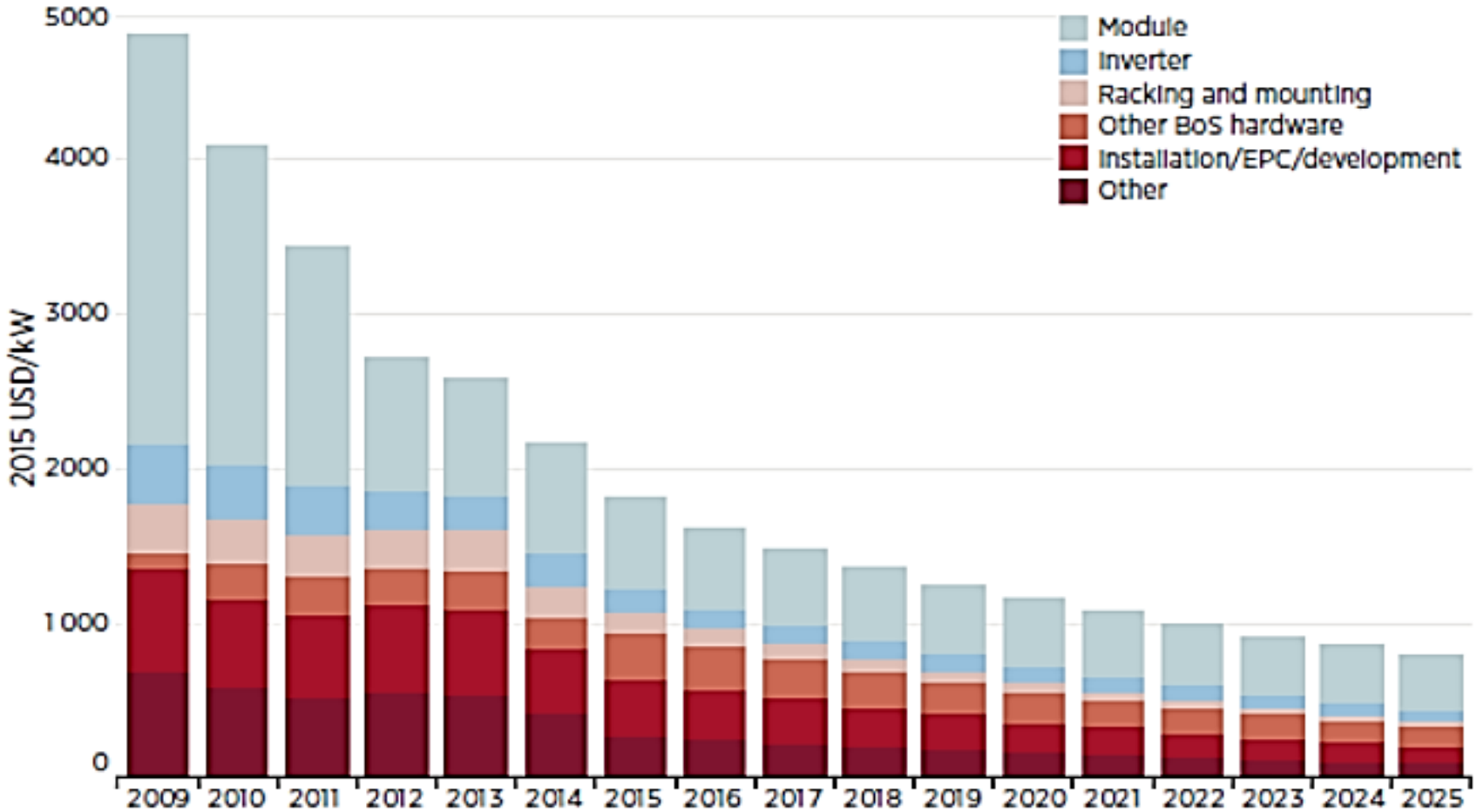
Higher shale output crows out conventional production and other fuels

Stronger shale

Higher shale output crowds out conventional production...

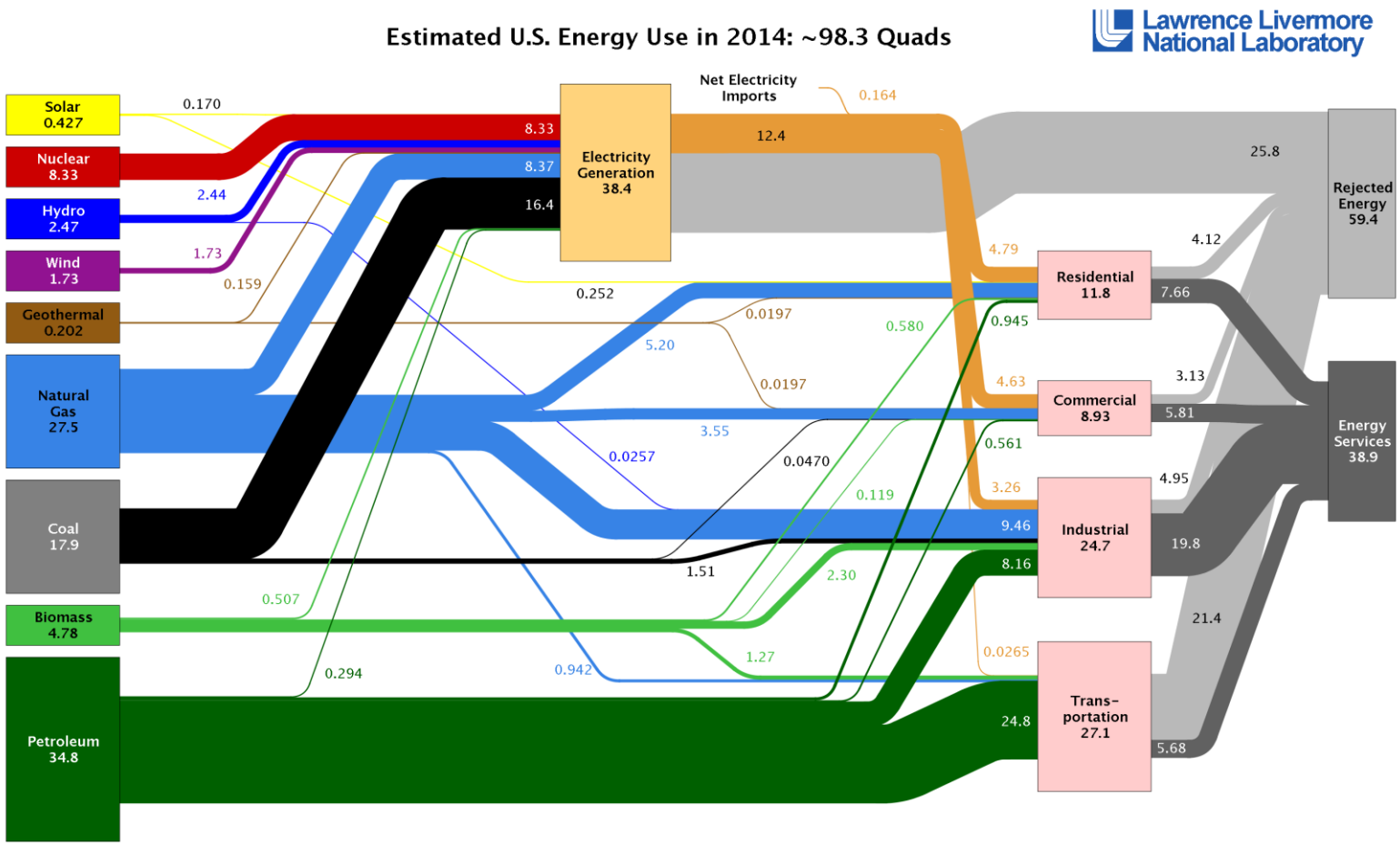


Global weighted average utility-scale solar PV total installed costs, 2009-2025



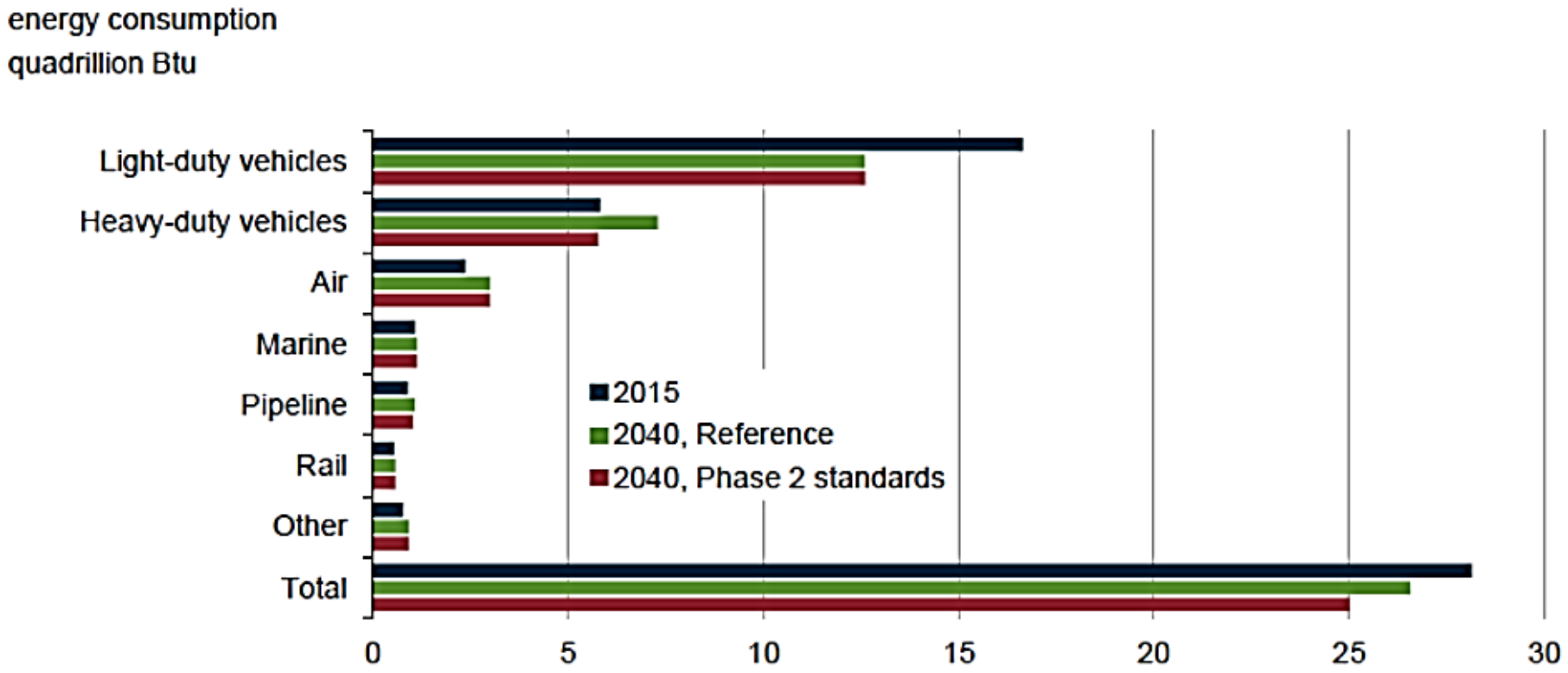
IRENA
International Renewable Energy Agency

U.S. Energy Mix



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Light-duty vehicle share of energy consumption declines because of new vehicle fuel economy standards



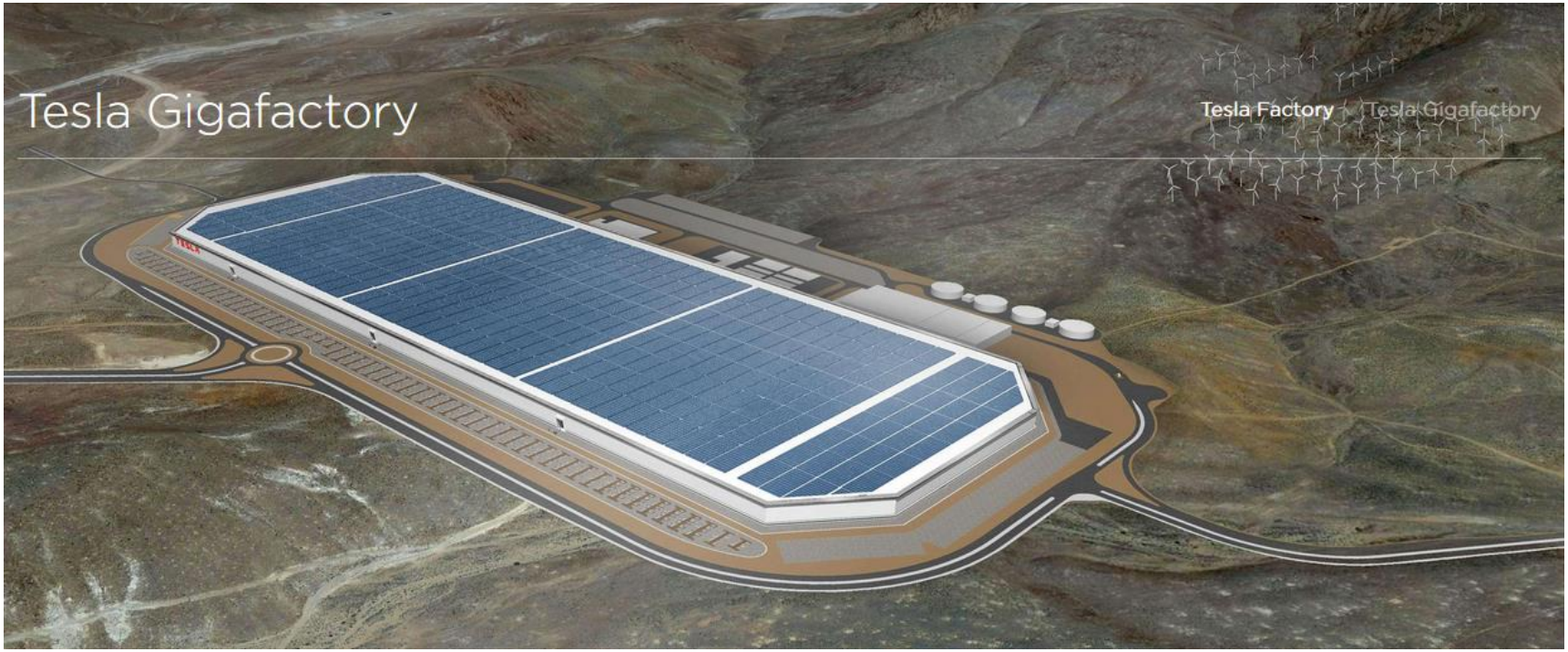
Source: EIA, Annual Energy Outlook 2016

Adam Sieminski, Johns Hopkins SAIS June 28, 2016

Elon Musk is changing energy paradigm

Each Powerwall has a 7 kWh energy storage capacity, sufficient to power most homes during the evening using electricity generated by solar panels during the day. Multiple batteries may be installed together for homes with greater energy needs. A 10 kWh weekly cycle version is available for backup applications.

The Future is Coming



By 2020, the Gigafactory will reach full capacity and produce more lithium ion batteries annually than were produced worldwide in 2013. In cooperation with Panasonic and other strategic partners, the Gigafactory will produce batteries for significantly less cost using economies of scale, innovative manufacturing, reduction of waste, and the simple optimization of locating most manufacturing process under one roof. We expect to drive down the per kilowatt hour (kWh) cost of our battery pack by more than 30 percent. The Gigafactory will also be powered by renewable energy sources, with the goal of achieving net zero energy.

Thank You for Attention!