IGTI Fuels Report

Presented at

ASME Power & Energy Conference

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BP “Six Megatrends”

1. **Energy transitions and the dominant fuel**
2. **Oil supply**
3. **Gas supply**
4. **Growth of renewables**
5. **Electrification**
6. **Changes in demand**

Primary Energy Consumption by Fuel - Mtoe

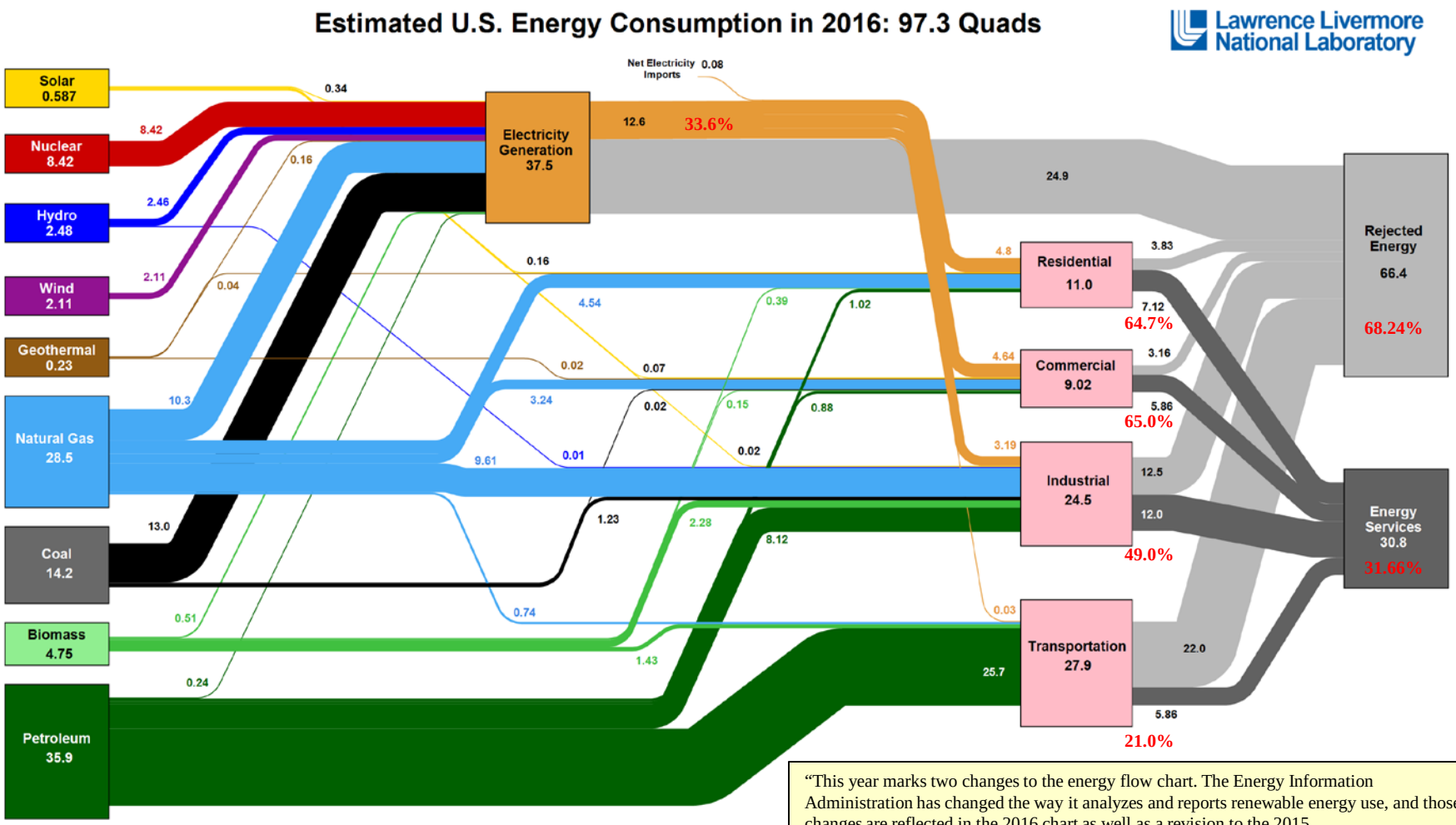
U.S. = 90.12 Quads

Million tonnes oil equivalent	2015 Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renew-ables	Total	2016 Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renew-ables	Total	Percent of 2016 Total
US	856.5	710.5	391.8	189.9	55.8	71.5	2275.9	863.1	716.3	358.4	191.8	59.2	83.8	**2272.7**	17.1%
Canada	99.1	92.2	19.6	22.8	85.4	8.5	327.7	100.9	89.9	18.7	23.2	87.8	9.2	**329.7**	2.5%
Mexico	84.4	78.4	12.7	2.6	7.0	3.7	188.8	82.8	80.6	9.8	2.4	6.8	4.1	**186.5**	1.4%
Total North America	**1040.0**	**881.2**	**424.2**	**215.3**	**148.2**	**83.6**	**2792.4**	**1046.9**	**886.8**	**386.9**	**217.4**	**153.9**	**97.1**	**2788.9**	21.0%
Brazil	146.6	37.5	17.7	3.3	81.4	16.0	302.6	138.8	32.9	16.5	3.6	86.9	19.0	**297.8**	2.2%
Total S. & Cent. America	**334.4**	**158.3**	**35.9**	**5.0**	**152.9**	**24.0**	**710.4**	**326.2**	**154.7**	**34.7**	**5.5**	**156.0**	**28.2**	**705.3**	5.3%
France	76.8	35.1	8.4	99.0	12.3	7.9	239.4	76.4	38.3	8.3	91.2	13.5	8.2	**235.9**	1.8%
Germany	110.0	66.2	78.5	20.8	4.3	38.1	317.8	113.0	72.4	75.3	19.1	4.8	37.9	**322.5**	2.4%
Italy	57.6	55.3	12.3	-	10.3	14.3	149.9	58.1	58.1	10.9	-	9.3	15.0	**151.3**	1.1%
Russian Federation	144.2	362.5	92.2	44.2	38.5	0.2	681.7	148.0	351.8	87.3	44.5	42.2	0.2	**673.9**	5.1%
Spain	61.2	24.6	13.7	13.0	6.3	15.6	134.4	62.5	25.2	10.4	13.3	8.1	15.5	**135.0**	1.0%
Turkey	38.9	39.2	34.7	-	15.2	3.9	131.9	41.2	37.9	38.4	-	15.2	5.2	**137.9**	1.0%
United Kingdom	71.8	61.3	23.0	15.9	1.4	17.5	190.9	73.1	69.0	11.0	16.2	1.2	17.5	**188.1**	1.4%
Total Europe & Eurasia	**865.9**	**909.2**	**471.3**	**263.9**	**194.7**	**141.6**	**2846.6**	**884.6**	**926.9**	**451.6**	**258.2**	**201.8**	**144.0**	**2867.1**	21.6%
Iran	84.5	171.7	1.6	0.8	4.1	0.1	262.8	83.8	180.7	1.7	1.4	2.9	0.1	**270.7**	2.0%
Saudi Arabia	166.6	94.0	0.1	-	-	^	260.8	167.9	98.4	0.1	-	-	^	**266.5**	2.0%
United Arab Emirates	40.9	66.4	1.3	-	-	0.1	108.6	43.5	69.0	1.3	-	-	0.1	**113.8**	0.9%
Total Middle East	**412.8**	**444.3**	**10.2**	**0.8**	**5.9**	**0.5**	**874.6**	**417.8**	**461.1**	**9.3**	**1.4**	**4.7**	**0.7**	**895.1**	6.7%
South Africa	27.9	4.6	83.4	2.8	0.2	1.4	120.1	26.9	4.6	85.1	3.6	0.2	1.8	**122.3**	0.9%
Total Africa	**182.1**	**122.2**	**95.3**	**2.8**	**26.9**	**4.2**	**433.5**	**185.4**	**124.3**	**95.9**	**3.6**	**25.8**	**5.0**	**440.1**	3.3%
Australia	47.9	38.6	44.1	-	3.2	4.8	138.5	47.8	37.0	43.8	-	4.0	5.4	**138.0**	1.0%
China	561.8	175.3	1913.6	38.6	252.2	64.4	3005.9	578.7	189.3	1887.6	48.2	263.1	86.1	**3053.0**	23.0%
India	195.8	41.2	396.6	8.7	30.2	12.7	685.1	212.7	45.1	411.9	8.6	29.1	16.5	**723.9**	5.5%
Indonesia	71.8	36.4	51.2	-	3.1	2.4	164.8	72.6	33.9	62.7	-	3.3	2.6	**175.0**	1.3%
Japan	189.0	102.1	119.9	1.0	19.0	14.8	445.8	184.3	100.1	119.9	4.0	18.1	18.8	**445.3**	3.4%
South Korea	113.8	39.3	85.5	37.3	0.5	3.9	280.2	122.1	40.9	81.6	36.7	0.6	4.3	**286.2**	2.2%
Taiwan	46.5	16.5	37.8	8.3	1.0	1.0	111.1	46.7	17.2	38.6	7.2	1.5	1.0	**112.1**	0.8%
Thailand	57.3	43.8	17.6	-	0.9	2.3	121.8	59.0	43.5	17.7	-	0.8	2.8	**123.8**	0.9%
Total Asia Pacific	**1505.8**	**631.6**	**2747.7**	**95.0**	**354.7**	**112.7**	**5447.4**	**1557.3**	**650.3**	**2753.6**	**105.9**	**368.1**	**144.5**	**5579.7**	42.0%
Total World	**4341.0**	**3146.7**	**3784.7**	**582.7**	**883.2**	**366.7**	**13105.0**	**4418.2**	**3204.1**	**3732.0**	**592.1**	**910.3**	**419.6**	**13276.3**	
	33.1%	24.0%	28.9%	4.4%	6.7%	2.8%	100.0%	33.3%	24.1%	28.1%	4.5%	6.9%	3.2%	100.0%	100.0%

13,276.3 Mtoe = 545.7 Quads

Source: BP Statistical Review of World Energy 2017

U.S. 2016 Energy Flow – 97.3Quads



"This year marks two changes to the energy flow chart. The Energy Information Administration has changed the way it analyzes and reports renewable energy use, and those changes are reflected in the 2016 chart as well as a revision to the 2015 analysis. Additionally, the estimate of efficiency of the industrial sector has been reduced from 80 percent to 49 percent to align with recent analysis at the DOE's Advanced Manufacturing Office. LLNL reports all year-over-year changes on a consistent basis with the new methodology."
https://energy.gov/eere/amo/energy-analysis-sector

Power – “Still in the Dark”

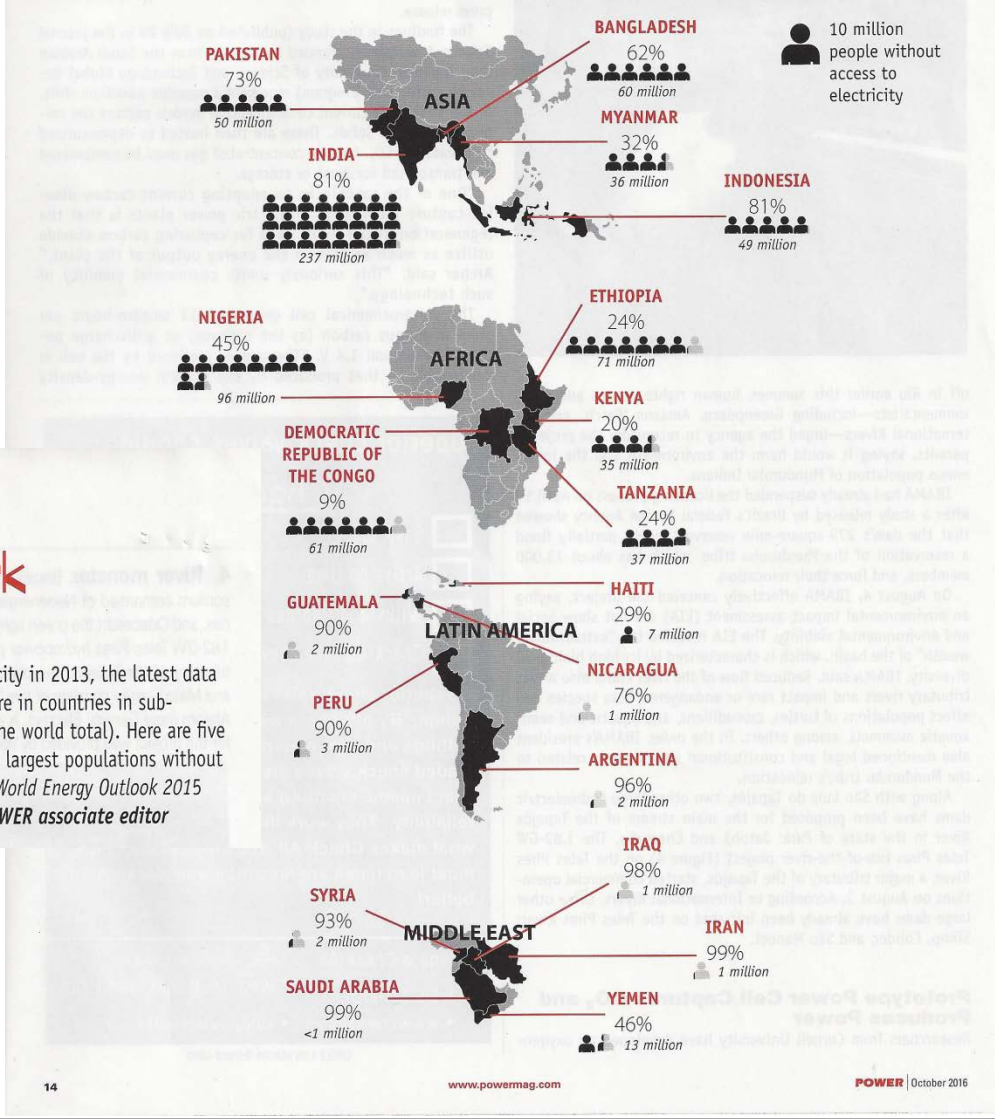
1.2 billion people
17% of Global
Population do not
have access to
electricity

GLOBAL MONITOR

THE BIG PICTURE: Still in the Dark

An estimated 1.2 billion people—17% of the global population—did not have access to electricity in 2013, the latest data from the International Energy Agency show. More than 95% of those living without electricity are in countries in sub-Saharan Africa and developing Asia, and they are predominantly in rural areas (around 80% of the world total). Here are five countries per region (developing Asia, Africa, Latin America, and the Middle East) that have the largest populations without access to electricity. Also noted is that country's national electrification rate (%). *Source: IEA, World Energy Outlook 2015*

—Copy and artwork by Sonal Patel, a POWER associate editor



Basic Comparisons

	China	USA	India	Japan	Germany	Russia
Population - July 2014 est	1,373,541,278	323,995,528	1,266,883,598	126,702,133	80,722,792	142,355,415
Population Growth Rate	0.45%	0.78%	1.22%	-0.16%	-0.17%	-0.04%
Area - km^2	9,596,960	9,826,675	3,287,263	377,915	357,022	17,098,242
GDP - Purchasing Power Parity ($trillion)	21.2	18.6	8.7	4.9	4.0	3.7
Installed Generating Capacity GW	1,505	1,075	311	313	198	248
% of World at 7089 GW	21%	15%	4%	4%	3%	3%
Electric Production TWh	5,388	4,103	1,218	980	591	1,064
Electric Consumption TWh	5,523	3,913	973	934	533	1,065
Aggregate Load Factor	40.9%	43.6%	44.7%	35.7%	34.1%	49.0%
Natural Gas Production - BCM	123.5	766.2	30.4	4.7	9.5	603.9
Natural Gas Consumption - BCM	181.1	773.2	52.1	131.3	79.2	453.3
Refined Petroleum Products Production - mmbbl/d	10.4	19.9	4.7	3.5	2.2	6.1
Refined Petroleum Products Consumption - mmbbl/d	11.1	19.5	3.7	4.1	2.4	3.7
Coal Production - Million Tonnes Oil Equivalent	1827.0	455.2	283.9	0.7	42.9	184.5
Coal Consumption - Million Tonnes Oil Equivalent	1920.4	396.3	407.2	119.4	78.3	88.7

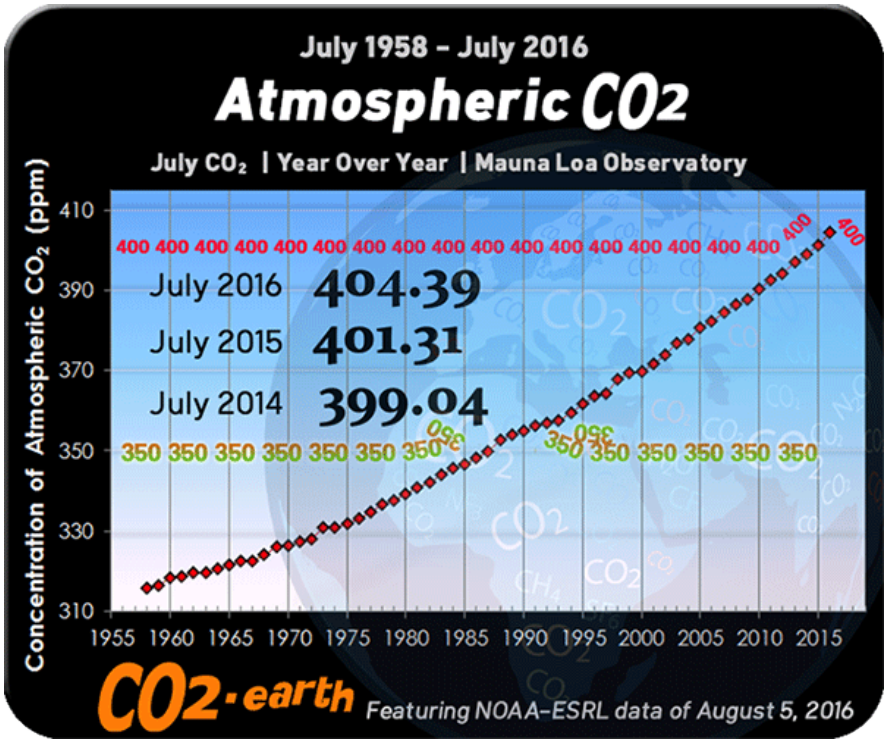
Source: CIA World Factbook

World Total Installed Electrical Generating Capacity 7,089 GW

Ps…….Total Value of Outstanding Student Loans - $1.4 trillion
U.S. health care cost 2014 - $3.2 trillion

Climate Change

What does "450 ppm(v) CO_2" Mean?



Gas	Ratio compared to Dry Air *(%)*		Molecular Mass *- M -* *(kg/kmol)*	Chemical Symbol
	By volume	By weight		
Oxygen	20.9500	23.2	32.00	O_2
Nitrogen	78.0900	75.47	28.02	N_2
Carbon Dioxide	0.0300	0.046	44.01	CO_2
Hydrogen	0.0001	~ 0	2.02	H_2
Argon	0.9330	1.28	39.94	Ar
Neon	0.0018	0.0012	20.18	Ne
Helium	0.0005	0.00007	4.00	He
Krypton	0.0001	0.0003	83.80	Kr
Xenon	$9\ 10^{-6}$	0.00004	131.29	Xe

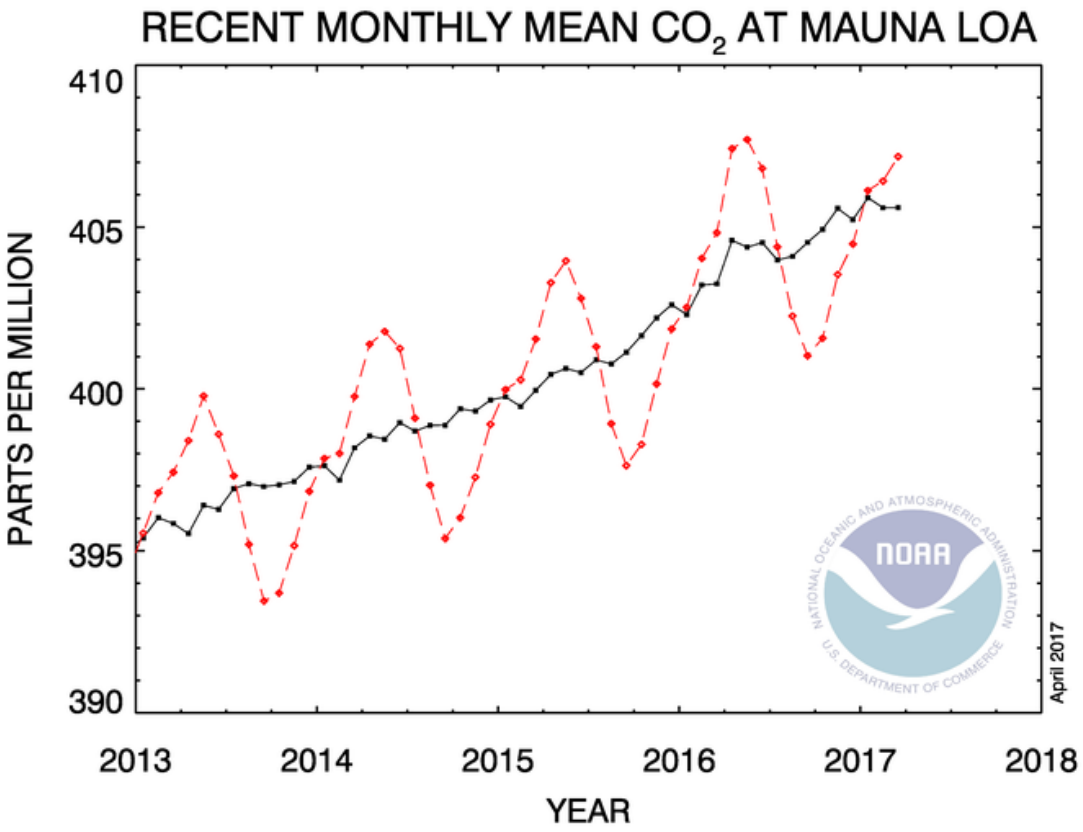
Standard assumptions on the chemical composition of Air

0.0300% = 300 ppm(v)

Value July 2016 at Mauna Loa was 404.30ppm(v)

Recent Monthly Mean CO_2 at Mauna Loa

March 2017: 407.18 ppm
March 2016: 404.83 ppm
Last updated: April 5, 2017



Worldwide CO_2 Emissions (Million metric tonnes)

CO2 Emissions (Million metric tonnes)

	2010	2011	2012	2013	2015	2020	2025	2030	2035	2040	Share 2015	Share 2040	Growth (2012-2040)
OECD													
OECD Americas	6502	6558	6343	6467	6478	6569	6620	6675	6769	6887	19.3%	15.9%	0.30%
United States	5458	5483	5272	5404	5428	5499	5511	5514	5521	5549	16.2%	12.8%	0.20%
Canada	547	562	563	561	557	557	577	587	621	647	1.7%	1.5%	0.50%
Mexico/Chile	498	513	508	501	492	513	533	573	628	690	1.5%	1.6%	1.10%
OECD Europe	4247	4193	4124	3997	4054	4096	4170	4252	4317	4415	12.1%	10.2%	0.20%
OECD Asia	2190	2270	2322	2317	2335	2361	2388	2407	2460	2513	7.0%	5.8%	0.30%
Japan	1169	1185	1247	1245	1215	1176	1175	1159	1144	1111	3.6%	2.6%	-0.40%
South Korea	577	642	639	641	685	734	742	761	803	850	2.0%	2.0%	1.00%
Australia/New Zealand	444	442	436	431	435	451	470	487	513	552	1.3%	1.3%	0.80%
Total OECD	**12939**	**13021**	**12790**	**12781**	**12867**	**13026**	**13178**	**13334**	**13547**	**13815**	38.4%	32.0%	0.30%
Non-OECD													
Non-OECD Europe and Eurasia	2717	2845	2938	2922	2832	2914	3038	3128	3198	3170	8.4%	7.3%	0.30%
Russia	1665	1695	1795	1818	1762	1814	1862	1897	1924	1864	5.3%	4.3%	0.10%
Other	1051	1150	1143	1105	1070	1100	1176	1231	1275	1306	3.2%	3.0%	0.50%
Non-OECD Asia	11005	11785	12195	12615	13201	14456	15505	16386	17482	18682	39.4%	43.2%	1.50%
China	7383	8119	8378	8760	9125	9861	10371	10636	10878	11051	27.2%	25.6%	1.00%
India	1624	1663	1778	1804	1932	2143	2394	2693	3161	3732	5.8%	8.6%	2.70%
Other	1998	2003	2038	2051	2144	2452	2740	3057	3443	3898	6.4%	9.0%	2.30%
Middle East	1732	1828	1894	1949	2090	2399	2608	2887	3171	3446	6.2%	8.0%	2.20%
Africa	1133	1120	1184	1187	1267	1438	1594	1760	1973	2239	3.8%	5.2%	2.30%
Central and South America	1215	1242	1271	1279	1282	1398	1509	1608	1725	1865	3.8%	4.3%	1.40%
Brazil	459	475	501	498	503	549	599	650	704	764	1.5%	1.8%	1.50%
Other	755	767	769	782	779	849	910	958	1021	1101	2.3%	2.5%	1.30%
Total Non-OECD	**17801**	**18818**	**19481**	**19952**	**20671**	**22605**	**24254**	**25769**	**27549**	**29402**	61.6%	68.0%	1.50%
Total World	**30741**	**31839**	**32271**	**32733**	**33538**	**35631**	**37432**	**39103**	**41096**	**43217**	100.0%	100.0%	**1.00%**

33.5 Gt **43.2 Gt**

base e®

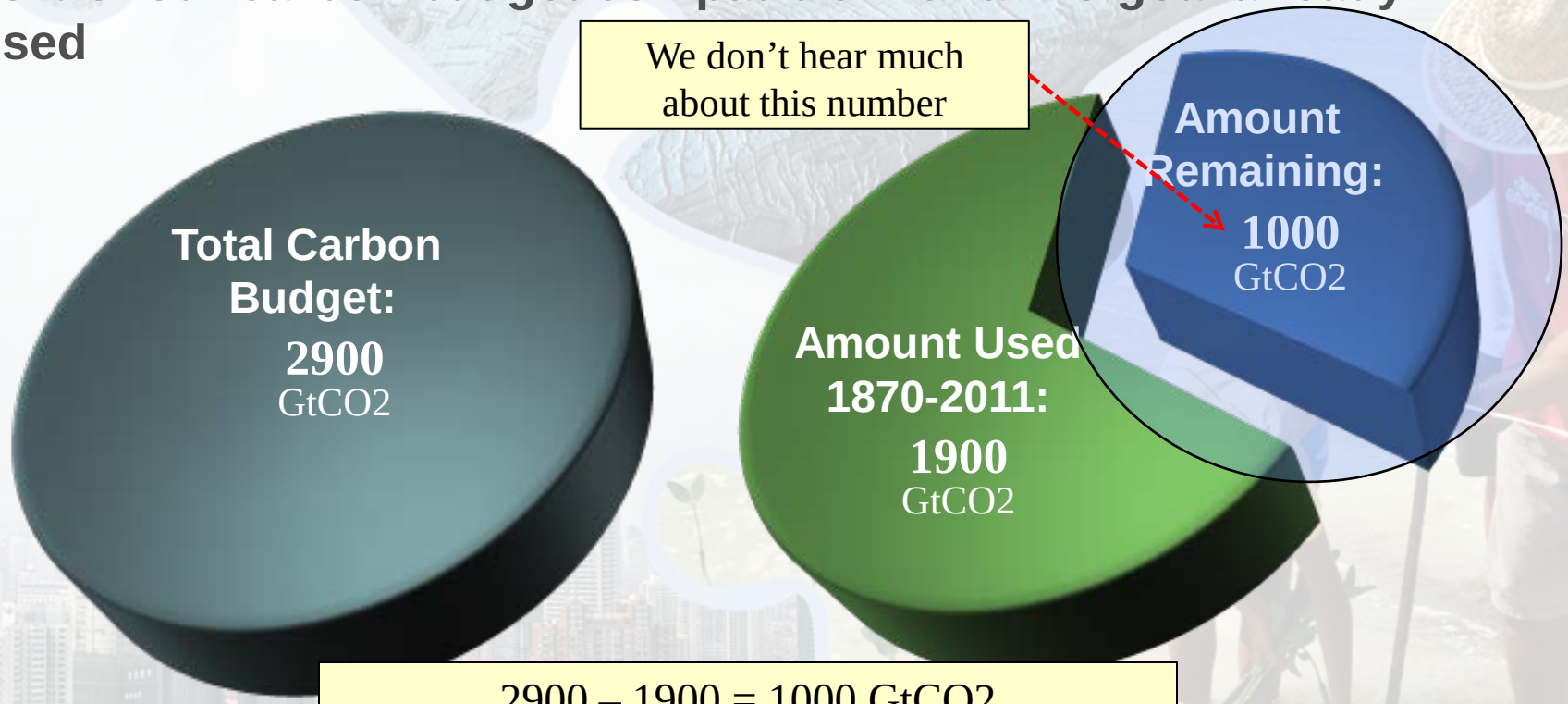
"Practical Strategies for Emerging Energy Technologies"

EIA AEO2016 Reference Case September 2016

The window for action is rapidly closing

65% of our carbon budget compatible with a 2°C goal already used

We don't hear much about this number



AR5 WGI SPM

2900 – 1900 = 1000 GtCO2
1000GtCO2 ÷ 33.5 = 29 Years is 2040
1000GtCO2 ÷ 43.2 = 23 Years is 2034

EIA Annual Energy Outlook 2017

Annual U.S. Emissions (Mmt CO2)

	Case ID	2015	2020	2025	2030	2035	2040	2045	2050
Total Electric Power	Ref Case without CPP	1918.5	1835.9	1849.8	1885.5	1906.6	1940.6	1979.1	2018.7
U.S. Energy-Related		5259.1	5287.8	5267.6	5210.5	5208.2	5297.2	5419.4	5565.4
Electric Power	High Economic Growth	1918.5	1846.3	1661.1	1541.5	1539.4	1544.0	1552.0	1561.2
U.S. Energy-Related		5259.1	5328.6	5118.9	4947.7	5000.6	5128.3	5292.9	5481.3
Electric Power	Low Oil Price	1918.5	1824.0	1661.8	1540.1	1540.3	1536.6	1541.7	1553.6
U.S. Energy-Related		5259.1	5336.6	5154.6	4979.4	5018.5	5101.0	5225.0	5380.9
Electric Power	High O&G Res & Tech	1918.5	1743.3	1616.2	1532.7	1528.3	1523.9	1523.0	1551.3
U.S. Energy-Related		5259.1	5216.1	5079.2	4929.0	4928.2	4981.9	5073.9	5217.2
Electric Power	Ref Case with CPP	1918.5	1820.5	1658.9	1537.0	1532.0	1530.8	1536.3	1546.8
U.S. Energy-Related		5259.1	5271.7	5068.6	4850.9	4827.1	4878.4	4968.3	5084.2
Electric Power	High Oil Price	1918.5	1678.1	1641.2	1533.6	1528.8	1531.1	1537.0	1545.1
U.S. Energy-Related		5259.1	5044.7	4960.2	4806.1	4819.9	4880.4	4918.8	5018.5
Electric Power	Low O&G Res & Tech	1918.5	1870.2	1660.0	1528.4	1531.5	1522.0	1510.2	1505.0
U.S. Energy-Related		5259.1	5303.8	4982.2	4710.9	4685.3	4704.0	4777.5	4862.6
Electric Power	Low Economic Growth	1918.5	1787.9	1644.2	1530.2	1531.3	1534.3	1537.9	1539.9
U.S. Energy-Related		5259.1	5203.1	4964.9	4708.8	4639.7	4616.4	4624.4	4647.5

No impact for Coal-to-Gas shift after 2030
CPP contributes 400-500 Mmt

EIA Annual Energy Outlook 2017

- The Impact of the Clean Power Plan is 400-500 Mmt

	Case ID	2015	2020	2025	2030	2035	2040	2045	2050
Impact of CPP	Electric Power	0.0	15.4	190.9	348.5	374.6	409.8	442.8	471.9
Impact of CPP	U.S. Energy Related	0.0	16.1	199.0	359.6	381.1	418.8	451.0	481.2

- The U.S. would represent 10.4% or 11.4% of worldwide CO2 emission, depending on whether CPP is in or is out of the plan.

	Case ID	2015	2020	2025	2030	2035	2040	2045	2050
WW Emissions AEO2016	U.S. Energy Related	33.5	35.6	37.432	39.1	41.1	43.2		
U.S. % of WW	without CPP	15.7%	14.8%	14.1%	13.3%	12.7%	12.3%	11.8%	11.4%
U.S. % of WW	With CPP	15.7%	14.8%	13.5%	12.4%	11.7%	11.3%	10.8%	10.4%

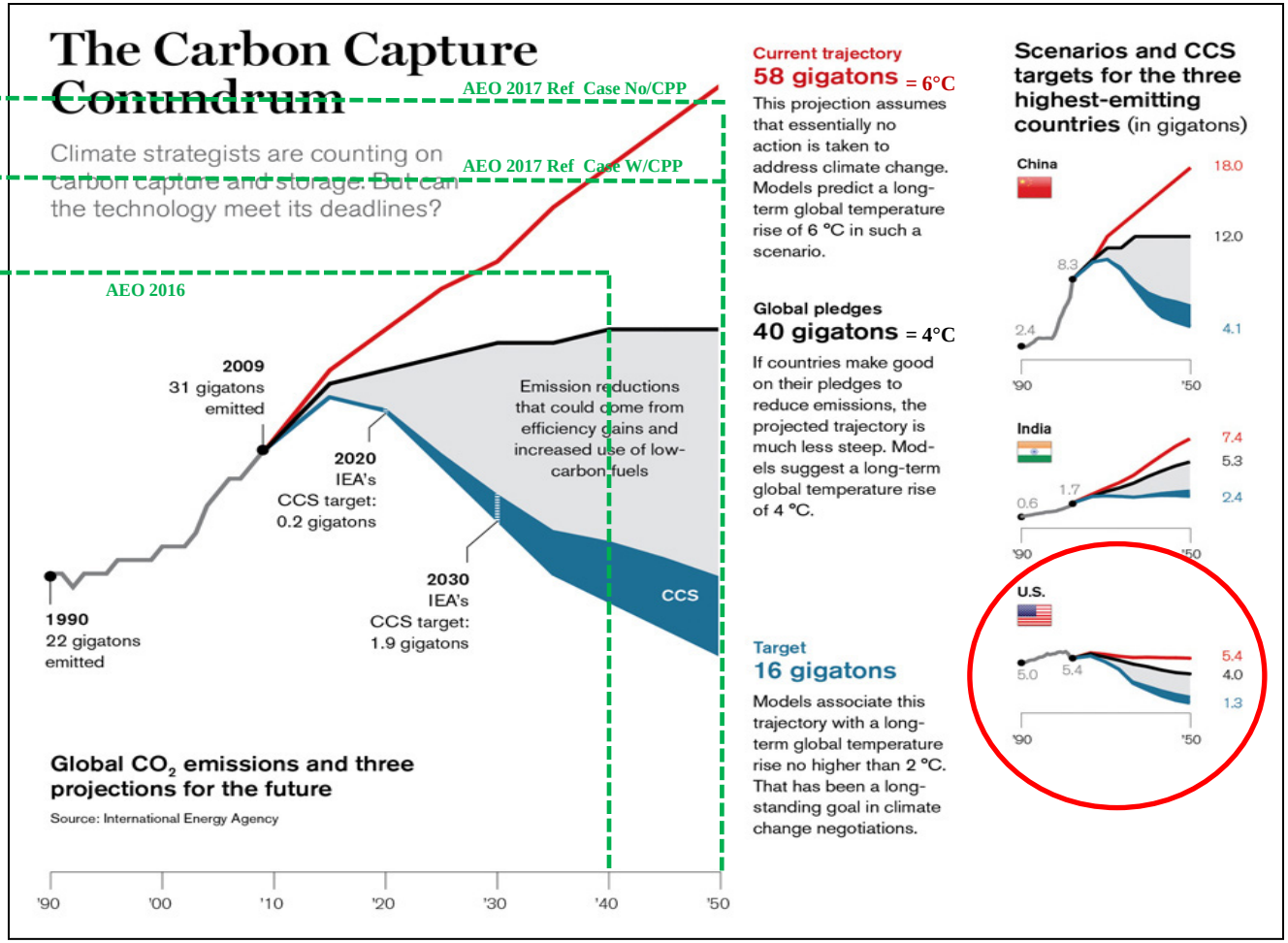
- The AEO2017 Reference Case Worldwide in 2050:

  Worldwide Forecast with CPP = 48.8 Gt

  Worldwide Forecast without CPP = 57.0 Gt

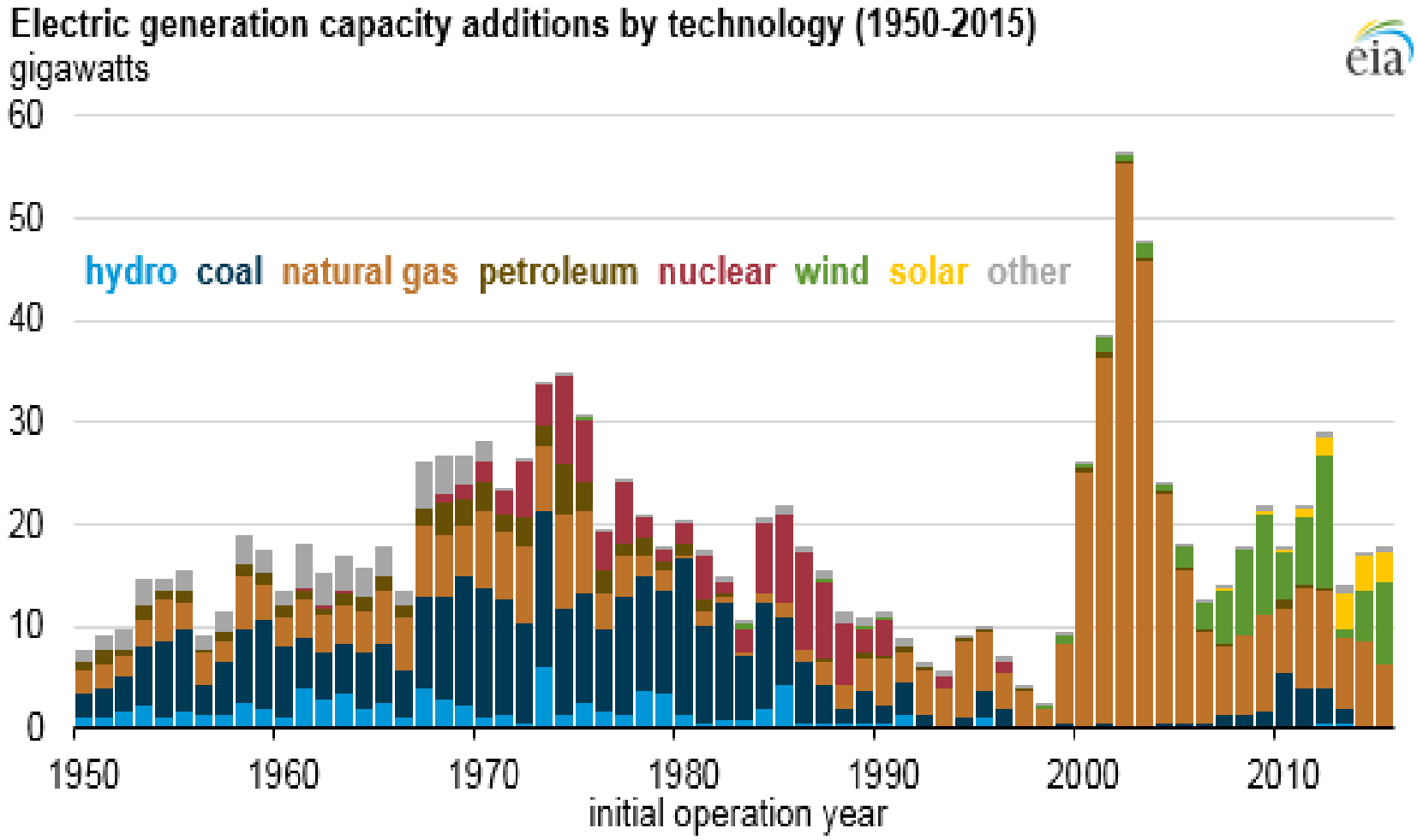
The World reaches the cumulative 2900Gt, 2C/450 ppm in ~2037/38

The Carbon Conundrum + AEO2017

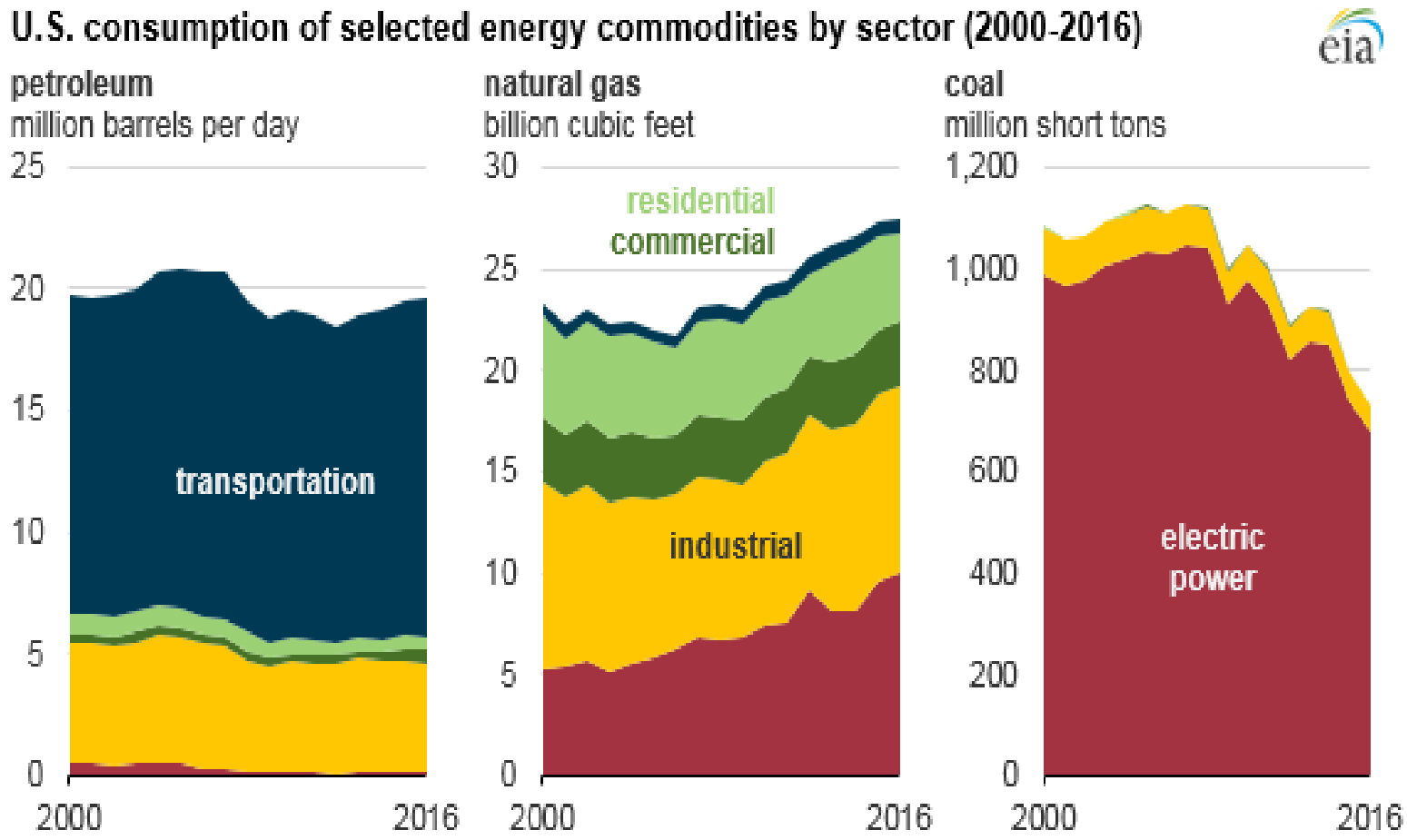


MIT Technology Review – Mike Orcott

Electric Generation Capacity Additions



U.S. Energy Consumption by Sector

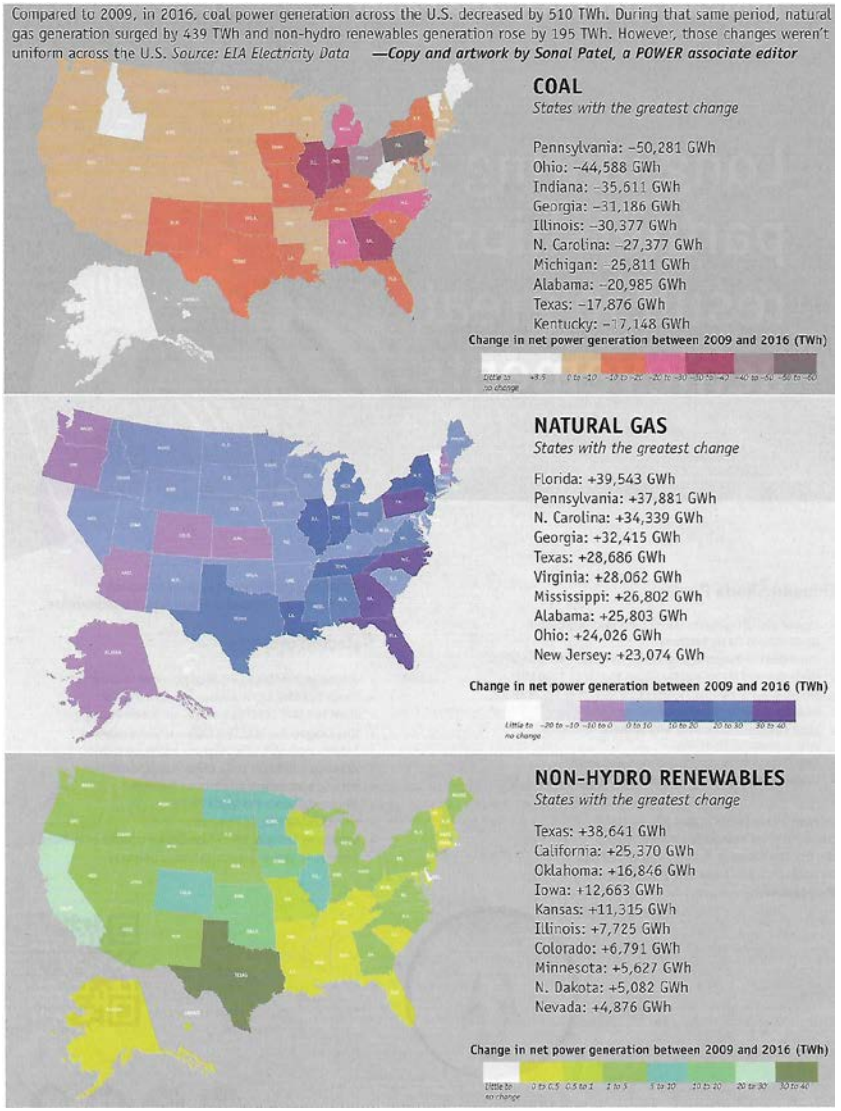


The Gas Bridge has already been built

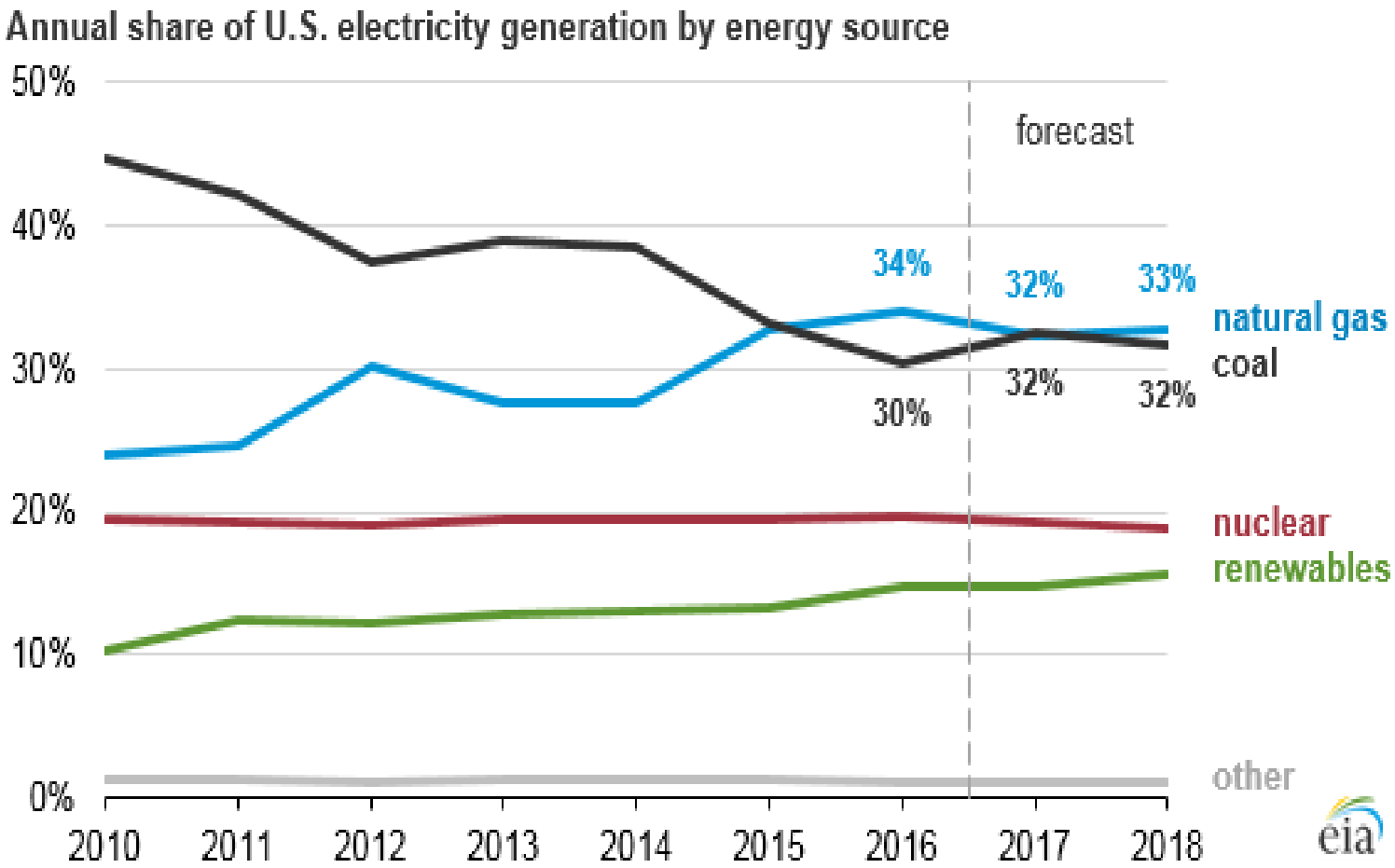
The Big Picture: Generation Transition

2016 vs. 2009

- Coal – 510TWh
- Natural Gas +439 TWh
- Non-hydro Renewables +195 TWh



U.S. Power Generation Mix



Coal-to-Gas Shift – nature.com

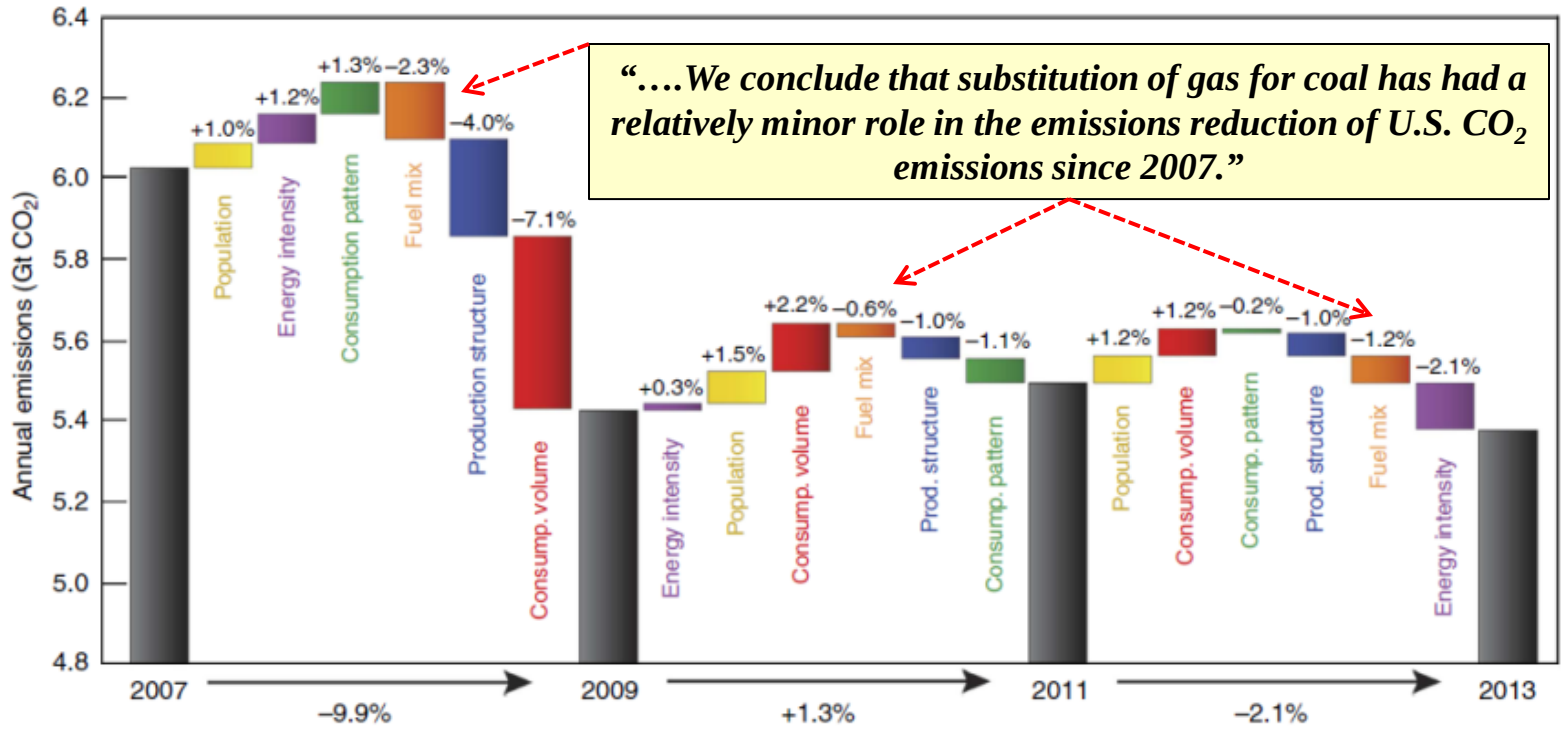
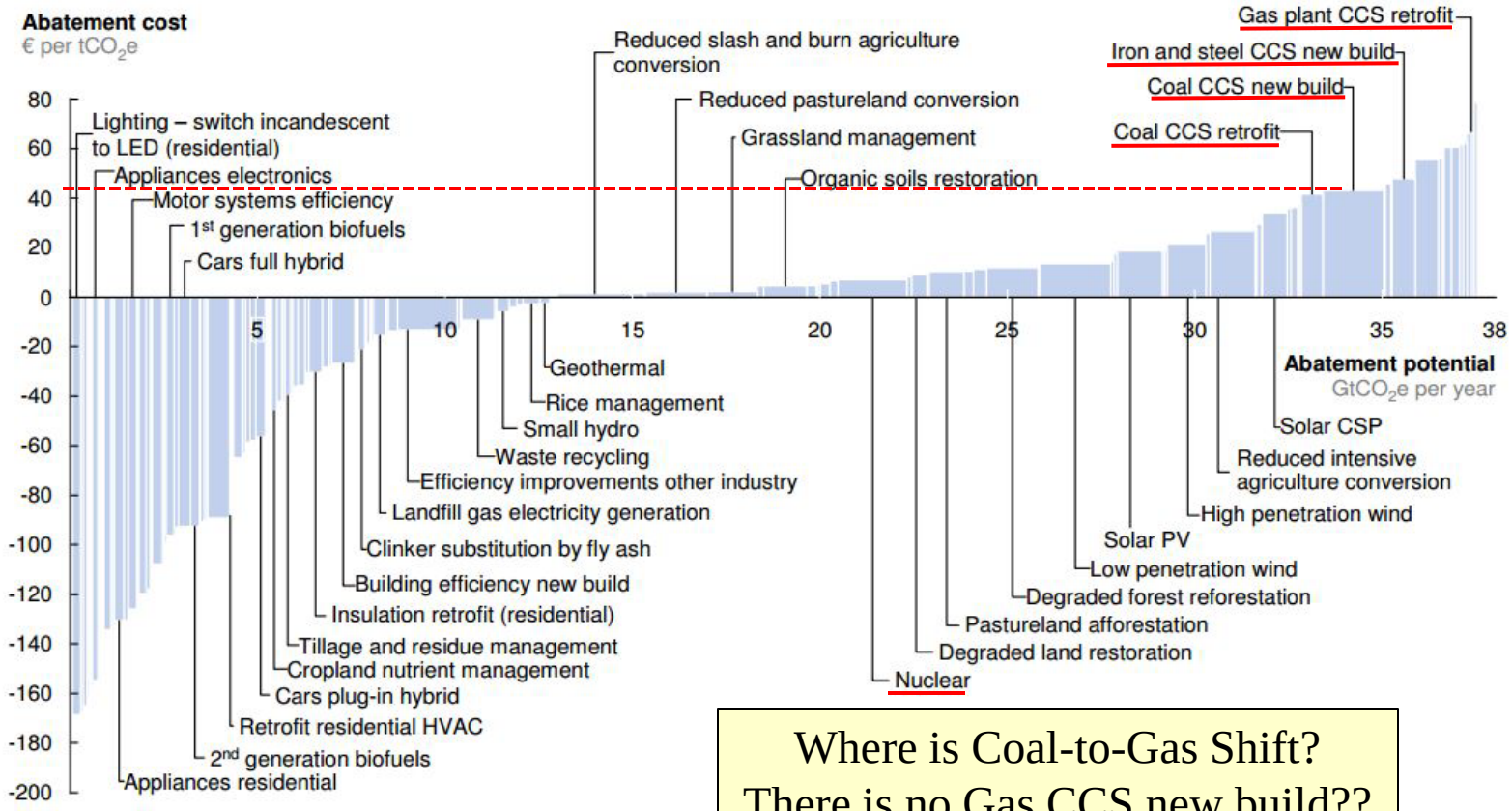


Figure 3 | Contributions of different factors to the decline in US CO_2 emissions 2007–2009 and 2009–2011 and 2011–2013. Between 2007 and 2009, decreases in the volume of goods and services consumed during the economic recession (red) was the primary contributor to the nearly 10% drop in emissions. But between 2009 and 2011, consumption (consump.) volume rebounded, population grew and the energy intensity of output increased, driving up emissions by 1.3% against modest decreases in the carbon intensity of the fuel mix and shifts in production structure and consumption patterns. Between 2011 and 2013, increases in population and consumption volume again pushed emissions upward, but overall emissions decreased by 2.1% due to further changes in production (prod.) structure, consumption patterns, decreasing use of coal and decreases in energy intensity of output. Not shown here, emissions increased by 1.7% between 2012 and 2013, driven primarily by increases in consumption volume.

"The new EPA Clean Power Plan is largely built on fuel switching and renewables deployment"

http://www.nature.com/ncomms/2015/150721/ncomms8714/full/ncomms8714.html

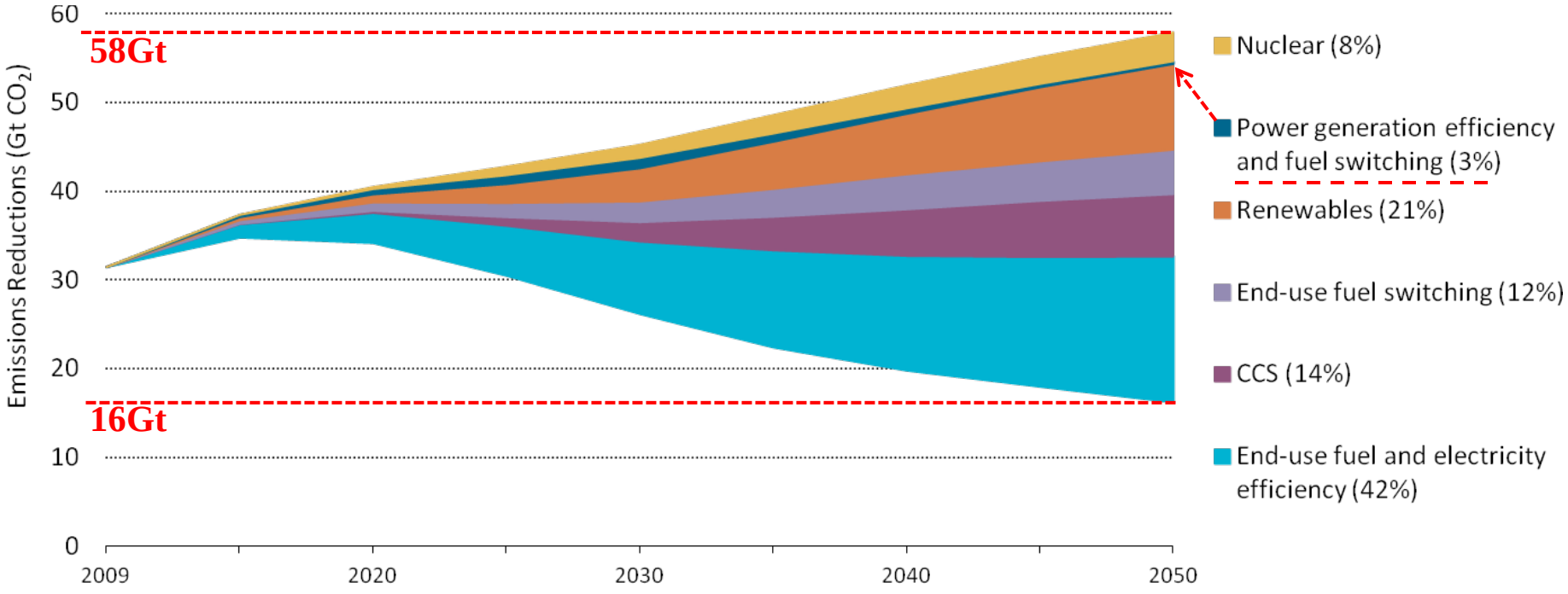
McKinsey Global GHG Cost Curve V2.1



Where is Coal-to-Gas Shift?
There is no Gas CCS new build??

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

IEA Vision May 2013



Nuclear and CCS technologies currently on "life support"

12th Annual CCUS Conference
Pittsburgh, 15 May 2013

Juho Lipponen
Head of Unit, Carbon Capture and Storage
International Energy Agency

Oil

Crude Oil Consumption – 96.6 MMbbl/d

Oil: Consumption*

Thousand barrels daily	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	20802	20687	20680	19490	18771	19180	18882	18490	18961	19106	19531	**19631**	0.5%	-0.6%	20.3%
Canada	2278	2275	2342	2295	2173	2305	2380	2340	2383	2372	2299	**2343**	1.9%	0.1%	2.4%
Mexico	2030	2019	2067	2054	1996	2014	2043	2063	2020	1943	1923	**1869**	-2.8%	-0.5%	1.9%
Total North America	**25110**	**24982**	**25089**	**23840**	**22940**	**23499**	**23305**	**22894**	**23364**	**23421**	**23753**	**23843**	**0.4%**	**-0.6%**	**24.7%**
Brazil	2123	2155	2313	2485	2502	2721	2839	2901	3110	3239	3170	**3018**	-4.8%	4.1%	3.1%
Total S. & Cent. America	**5373**	**5554**	**5831**	**6100**	**6094**	**6424**	**6666**	**6826**	**7073**	**7171**	**7139**	**6976**	**-2.3%**	**2.9%**	**7.2%**
France	1946	1942	1911	1889	1822	1763	1730	1676	1664	1616	1616	**1602**	-0.9%	-1.8%	1.7%
Germany	2592	2609	2380	2502	2409	2445	2369	2356	2408	2348	2340	**2394**	2.3%	-1.0%	2.5%
Italy	1798	1791	1740	1661	1563	1532	1475	1346	1260	1184	1222	**1232**	0.9%	-3.8%	1.3%
Russian Federation	2647	2762	2780	2861	2775	2878	3074	3119	3135	3299	3137	**3203**	2.1%	1.7%	3.3%
Spain	1593	1592	1613	1558	1473	1446	1378	1291	1195	1191	1237	**1268**	2.5%	-2.5%	1.3%
United Kingdom	1828	1813	1752	1720	1646	1623	1590	1533	1518	1511	1565	**1597**	2.1%	-1.5%	1.7%
Total Europe & Eurasia	**20229**	**20452**	**20202**	**20110**	**19300**	**19244**	**19064**	**18594**	**18370**	**18287**	**18450**	**18793**	**1.9%**	**-0.9%**	**19.5%**
Iran	1699	1851	1879	1954	1950	1817	1844	1854	2014	1961	1850	**1848**	-0.1%	0.9%	1.9%
Saudi Arabia	2203	2274	2407	2622	2914	3218	3295	3462	3470	3726	3868	**3906**	1.0%	5.8%	4.0%
Total Middle East	**6510**	**6726**	**6949**	**7418**	**7779**	**8102**	**8382**	**8760**	**8950**	**9180**	**9300**	**9431**	**1.4%**	**3.6%**	**9.8%**
Total Africa	**2900**	**2912**	**3042**	**3203**	**3316**	**3483**	**3393**	**3571**	**3720**	**3771**	**3866**	**3937**	**1.8%**	**2.9%**	**4.1%**
Australia	870	936	935	944	950	957	1006	1036	1046	1045	1039	**1036**	-0.3%	1.8%	1.1%
China	6900	7432	7808	7941	8278	9436	9796	10230	10734	11209	11986	**12381**	3.3%	5.7%	12.8%
India	2606	2737	2941	3077	3237	3319	3488	3685	3727	3849	4164	**4489**	7.8%	4.8%	4.6%
Indonesia	1303	1244	1318	1287	1317	1411	1589	1625	1639	1663	1592	**1615**	1.4%	2.0%	1.7%
Japan	5354	5174	5013	4846	4387	4442	4442	4702	4516	4303	4139	**4037**	-2.5%	-2.5%	4.2%
Singapore	796	848	921	973	1049	1157	1208	1202	1225	1268	1336	**1382**	3.4%	5.3%	1.4%
South Korea	2312	2320	2399	2308	2339	2370	2394	2458	2455	2454	2577	**2763**	7.2%	1.1%	2.9%
Taiwan	1052	1051	1110	1005	1020	1045	983	983	1010	1032	1040	**1046**	0.6%	-0.1%	1.1%
Thailand	1015	996	1030	1018	1065	1122	1185	1250	1298	1311	1355	**1382**	2.0%	2.9%	1.4%
Total Asia Pacific	**24556**	**25152**	**26047**	**25907**	**26262**	**27969**	**28920**	**30031**	**30636**	**31195**	**32494**	**33577**	**3.3%**	**2.8%**	**34.8%**
Total World	**84678**	**85777**	**87161**	**86578**	**85691**	**88722**	**89729**	**90675**	**92114**	**93025**	**95003**	**96558**	**1.6%**	**1.2%**	**100.0%**

+1,555 MMbbl/d

Source: BP Statistical Review of World Energy 2017

Crude Oil Production – 92.2 MMbbl/d

Oil: Production*

Thousand barrels daily	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	6900	6825	6860	6784	7263	7549	7862	8894	10073	11779	12757	**12354**	-3.2%	6.3%	13.4%
Canada	3041	3208	3290	3207	3202	3332	3515	3740	4000	4271	4389	**4460**	1.6%	3.7%	4.8%
Mexico	3766	3689	3479	3165	2978	2959	2940	2911	2875	2784	2587	**2456**	-5.1%	-3.7%	2.7%
Total North America	**13706**	**13722**	**13628**	**13156**	**13444**	**13841**	**14317**	**15545**	**16948**	**18833**	**19733**	**19270**	**-2.3%**	**3.7%**	**20.9%**
Brazil	1706	1806	1831	1897	2029	2137	2179	2145	2110	2341	2525	**2605**	3.2%	4.0%	2.8%
Colombia	526	529	531	588	671	786	915	944	1004	990	1006	**924**	-8.1%	6.7%	1.0%
Venezuela	3302	3340	3233	3222	3042	2842	2755	2704	2680	2692	2644	**2410**	-8.9%	-2.2%	2.6%
Total S. & Cent. America	**7341**	**7498**	**7334**	**7430**	**7384**	**7404**	**7436**	**7376**	**7407**	**7659**	**7761**	**7474**	**-3.7%**	**0.6%**	**8.1%**
Azerbaijan	445	646	856	895	1014	1023	919	872	877	849	840	**826**	-1.6%	6.6%	0.9%
Kazakhstan	1295	1370	1415	1485	1609	1676	1684	1664	1737	1710	1695	**1672**	-1.4%	2.7%	1.8%
Norway	2961	2772	2551	2466	2349	2136	2040	1917	1838	1889	1948	**1995**	2.4%	-4.1%	2.2%
Russian Federation	9598	9819	10044	9951	10140	10367	10519	10642	10780	10838	10981	**11227**	2.2%	1.4%	12.2%
United Kingdom	1834	1659	1651	1549	1469	1356	1112	946	864	852	963	**1013**	5.1%	-6.2%	1.1%
Total Europe & Eurasia	**17516**	**17582**	**17795**	**17574**	**17754**	**17694**	**17387**	**17127**	**17174**	**17206**	**17479**	**17716**	**1.4%**	**♦**	**19.2%**
Iran	4218	4293	4359	4421	4292	4417	4465	3819	3615	3725	3897	**4600**	18.0%	-0.8%	5.0%
Iraq	1833	1999	2143	2428	2452	2490	2801	3116	3141	3285	4031	**4465**	10.8%	8.2%	4.8%
Kuwait	2668	2735	2660	2784	2498	2560	2913	3169	3129	3101	3068	**3151**	2.7%	1.4%	3.4%
Oman	774	738	710	757	813	865	885	918	942	943	981	**1004**	2.4%	2.4%	1.1%
Qatar	1151	1241	1267	1438	1421	1638	1834	1931	1906	1886	1890	**1899**	0.5%	5.1%	2.1%
Saudi Arabia	10931	10671	10268	10663	9663	10075	11144	11635	11393	11505	11986	**12349**	3.0%	0.9%	13.4%
United Arab Emirates	2919	3098	3002	3027	2725	2895	3320	3401	3627	3674	3928	**4073**	3.7%	3.0%	4.4%
Total Middle East	**25549**	**25765**	**25348**	**26430**	**24765**	**25822**	**28136**	**28518**	**28213**	**28515**	**30065**	**31789**	**5.7%**	**1.6%**	**34.5%**
Algeria	1990	1979	1992	1969	1775	1689	1642	1537	1485	1589	1558	**1579**	1.4%	-2.4%	1.7%
Angola	1282	1432	1699	1916	1804	1863	1726	1784	1799	1712	1826	**1807**	-1.1%	3.6%	2.0%
Egypt	672	679	698	715	730	725	714	715	710	714	726	**691**	-4.8%	0.8%	0.8%
Nigeria	2527	2433	2314	2109	2185	2471	2408	2370	2270	2347	2329	**2053**	-11.9%	-0.8%	2.2%
Total Africa	**9816**	**10014**	**10268**	**10218**	**9838**	**10065**	**8464**	**9247**	**8612**	**8307**	**8297**	**7892**	**-4.9%**	**-1.7%**	**8.6%**
China	3642	3711	3742	3814	3805	4077	4074	4155	4216	4246	4309	**3999**	-7.2%	1.7%	4.3%
India	737	760	768	803	816	882	916	906	906	887	876	**856**	-2.3%	1.7%	0.9%
Indonesia	1096	1018	972	1006	994	1003	952	918	882	852	841	**881**	4.8%	-2.6%	1.0%
Malaysia	757	713	742	741	701	717	650	654	621	645	699	**705**	0.9%	-0.8%	0.8%
Total Asia Pacific	**7981**	**7938**	**7962**	**8086**	**8038**	**8426**	**8285**	**8372**	**8252**	**8307**	**8369**	**8010**	**-4.3%**	**0.5%**	**8.7%**
Total World	**81908**	**82519**	**82334**	**82894**	**81222**	**83251**	**84026**	**86183**	**86606**	**88826**	**91704**	**92150**	**0.5%**	**1.1%**	**100.0%**
OPEC	35101	35574	35269	36303	33997	35086	35988	37480	36561	36573	38133	**39358**	3.2%	0.8%	**42.7%**
CIS	11794	12281	12761	12783	13215	13496	13544	13597	13810	13810	13932	**14141**	1.5%	1.7%	**15.3%**

Source: BP Statistical Review of World Energy 2017

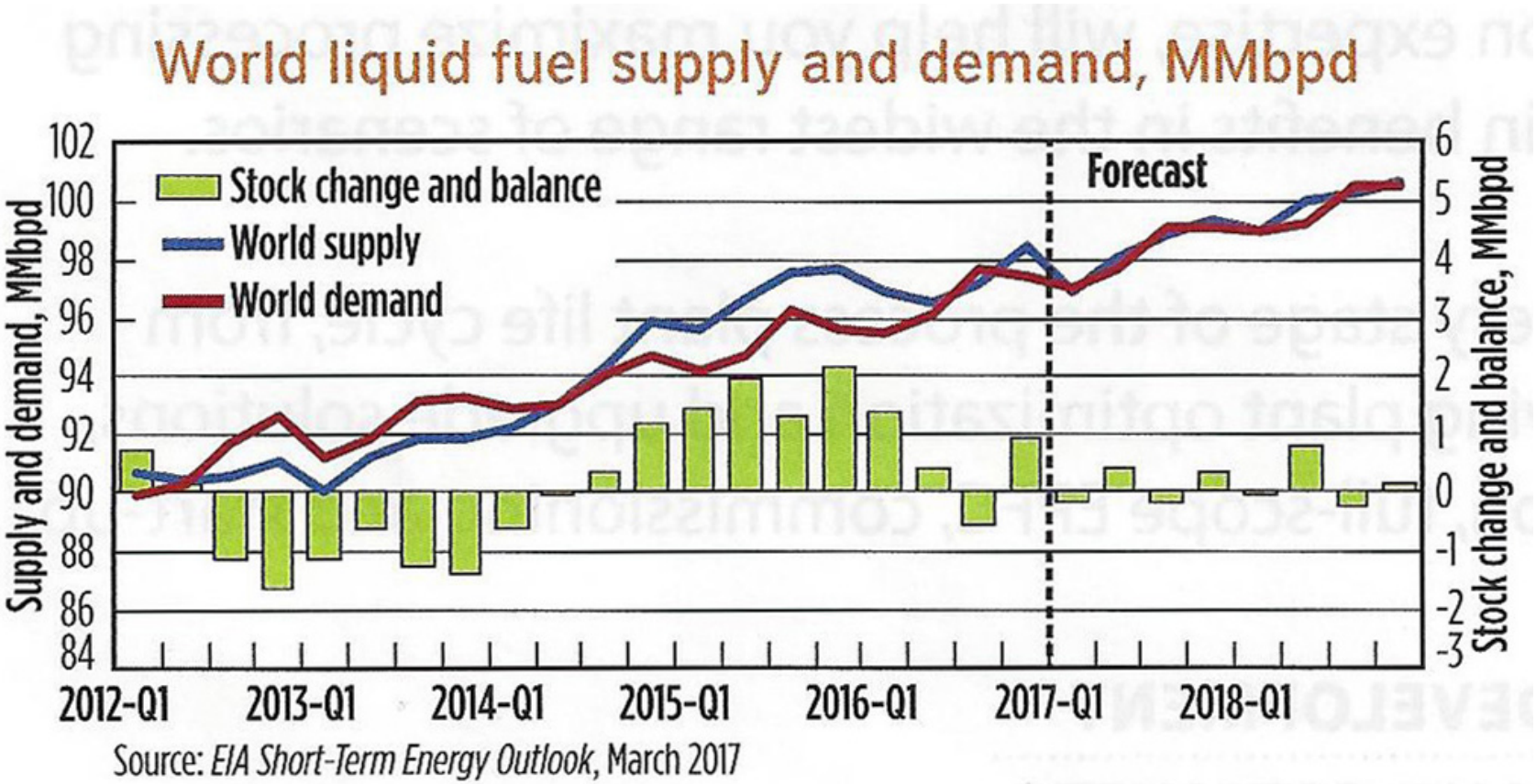
WW Oil Supply/Demand

	2016 1st Qtr.	2016 2nd Qtr.	2016 3rd Qtr.	2016 4th Qtr.	2016 Year	2017 1st Qtr.	2017 2nd Qtr.	2017 3rd Qtr.	2017 4th Qtr.	2017 Year
	Million b/d									
DEMAND										
OECD										
Americas	24.5	24.4	25.0	24.6	24.6	24.5	24.5	24.9	24.6	24.6
Europe	13.6	13.9	14.4	13.7	13.9	13.7	14.0	14.3	13.7	13.9
Asia Pacific	8.5	7.6	7.8	8.2	8.1	8.6	7.6	7.7	8.2	8.0
Total OECD	**46.7**	**46.0**	**47.2**	**46.5**	**46.6**	**46.8**	**46.1**	**46.1**	**46.4**	**46.6**
Non-OECD										
FSU	4.6	4.6	4.9	5.0	4.8	4.7	4.8	5.1	5.0	4.9
Europe	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
China	11.7	12.0	11.7	12.0	11.9	11.9	12.1	12.2	12.4	12.2
Other Asia	13.1	13.1	12.8	13.4	13.1	13.6	13.7	13.4	13.9	13.7
Latin America	6.5	6.8	6.9	6.8	6.8	6.5	6.7	6.8	6.8	6.7
Middle East	7.9	8.5	8.8	8.4	8.4	8.2	8.6	8.9	8.5	8.6
Africa	4.2	4.2	4.1	4.3	4.2	4.3	4.4	4.2	4.4	4.3
Total Non-OECD	**48.7**	**49.8**	**49.8**	**50.5**	**49.7**	**50.0**	**51.0**	**51.4**	**51.8**	**51.0**
Total Demand	**95.4**	**95.8**	**97.1**	**96.9**	**96.3**	**96.8**	**97.1**	**98.3**	**98.2**	**97.6**
Supply										
OECD										
Americas	19.9	19.0	19.4	19.4	19.4	19.5	19.4	19.5	19.5	19.5
Europe	3.6	3.4	3.3	3.4	3.5	3.4	3.4	3.3	3.4	3.4
Asia Pacific	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5	0.5
Total OECD	**24.0**	**22.8**	**23.1**	**23.3**	**23.3**	**23.4**	**23.3**	**23.3**	**23.4**	**23.3**
Non-OECD										
FSU	14.3	14.0	14.0	14.5	14.2	14.3	14.2	14.3	14.5	14.4
Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
China	4.2	4.1	3.9	3.8	4.0	3.8	3.8	3.7	3.7	3.8
Other Asia	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6
Latin America	4.4	4.4	4.6	4.6	4.5	4.6	4.7	4.7	4.7	4.7
Middle East	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.2
Africa	2.0	1.9	2.0	2.1	2.0	2.1	2.1	2.1	2.1	2.1
Total Non-OECD	**29.0**	**28.6**	**28.6**	**29.1**	**26.8**	**28.8**	**28.7**	**28.9**	**29.1**	**28.9**
Processing gains	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Global biofuels	1.9	2.4	2.8	2.4	2.4	2.0	2.5	2.9	2.5	2.5
Total Non-OPEC	**57.1**	**56.1**	**56.8**	**57.0**	**56.8**	**56.5**	**56.8**	**57.4**	**57.3**	**57.0**
OPEC										
Crude	32.8	33.1	33.6	34.1	33.4	32.7	32.7	32.7	32.7	32.7
NGL	6.7	6.8	6.9	6.9	6.8	7.0	7.0	7.0	7.0	7.0
Total OPEC	**39.6**	**39.9**	**40.5**	**41.0**	**40.2**	**39.7**	**39.7**	**39.7**	**39.7**	**39.7**
Total supply	**96.7**	**96.0**	**97.3**	**98.0**	**97.0**	**96.2**	**96.5**	**97.1**	**97.0**	**96.7**
Stock change	1.3	0.2	0.2	1.1	0.7	(0.6)	(0.6)	(1.2)	(1.2)	(0.9)

Totals may not add due to rounding.
Source: International Energy Agency; OGJ estimate of OPEC crude supply 4Q 2016 through 2017.

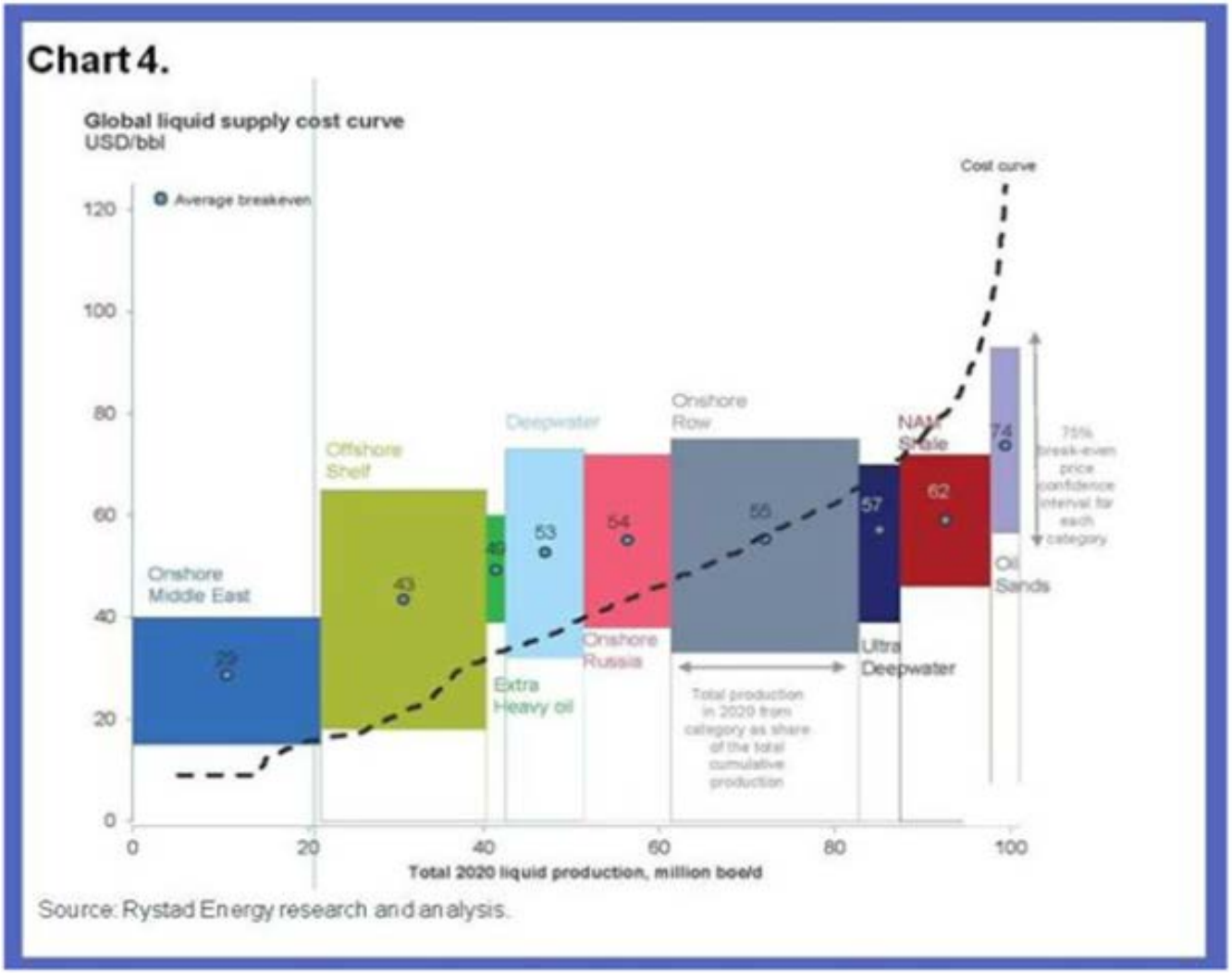
Source: O&G Journal January 2, 2017

World Oil Supply/Demand Balance



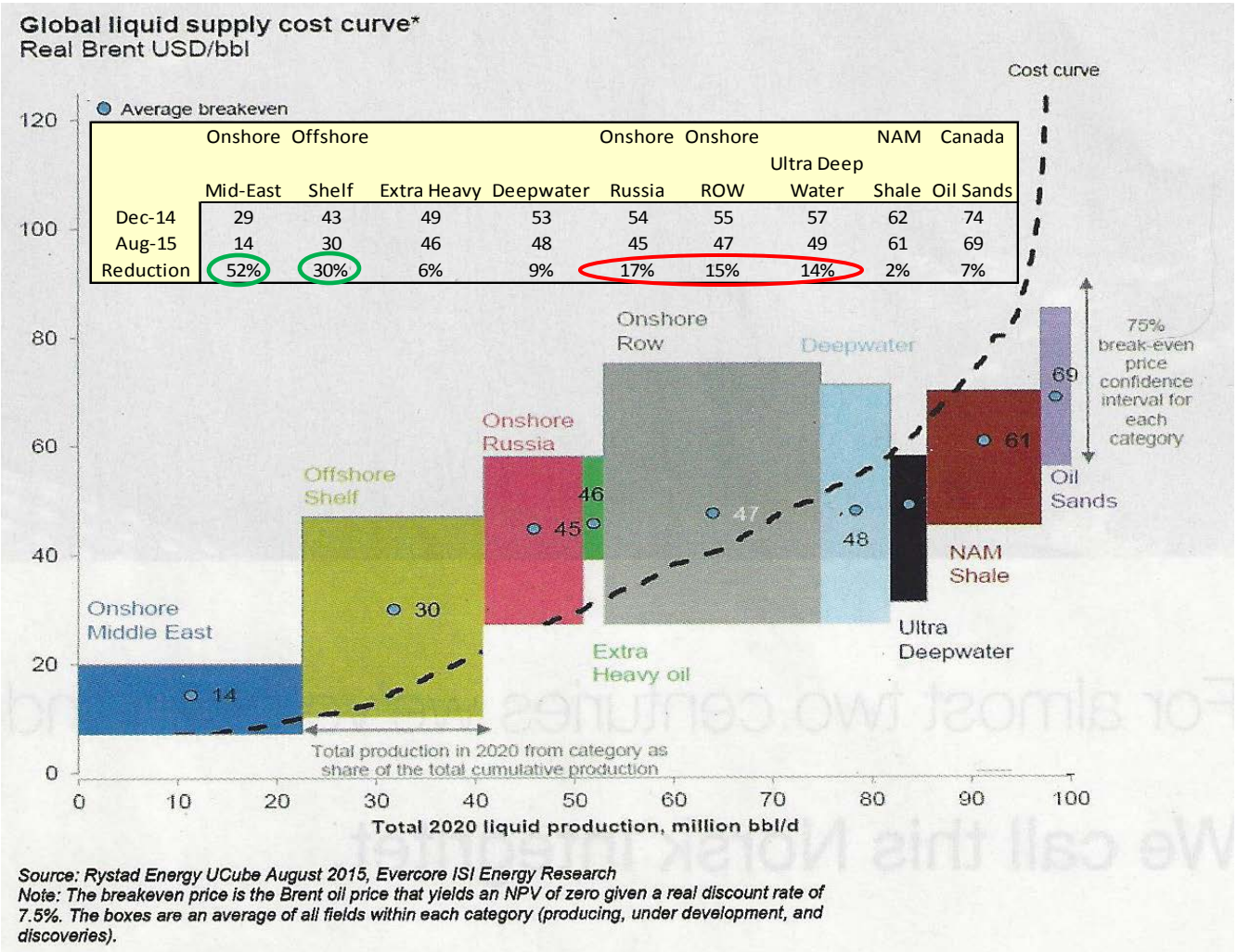
Source: Hydrocarbon Processing June 2017

Global Liquid Supply Cost Curve December 2014



Source: Rabah Arezki, Oliver Blanchard, IMF blog Dec. 22, 2014

Global Liquid Supply Cost Curve August 2015

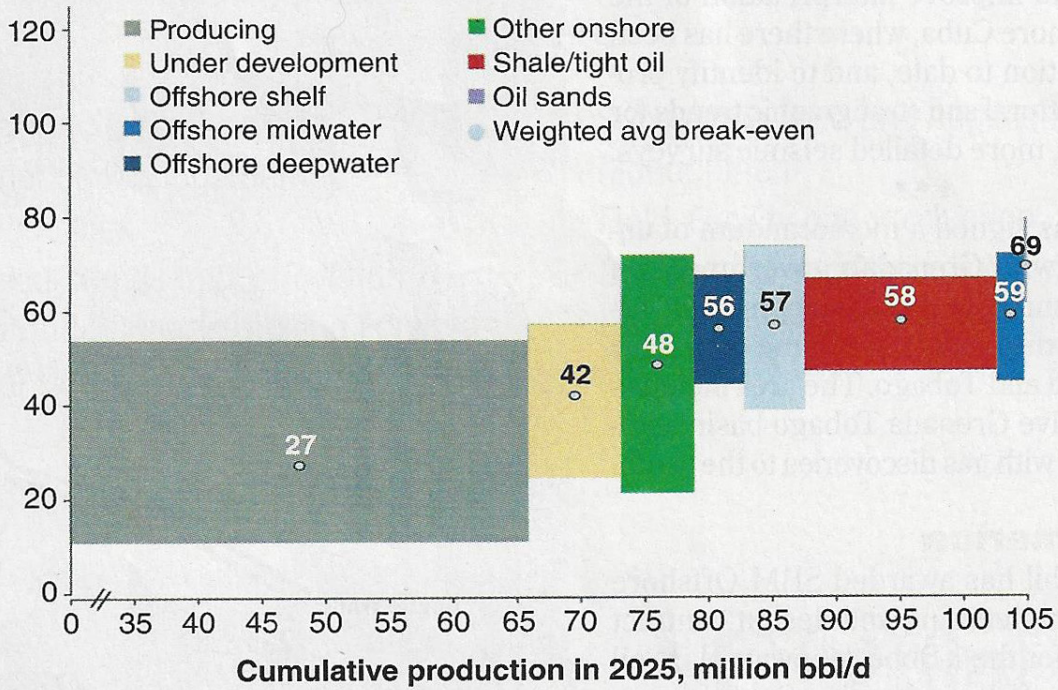


Source: Rystad Energy UCube August 2015, Evercore ISI Energy Research
Note: The breakeven price is the Brent oil price that yields an NPV of zero given a real discount rate of 7.5%. The boxes are an average of all fields within each category (producing, under development, and discoveries).

Source: Rystad Energy UCube through Offshore January 2016

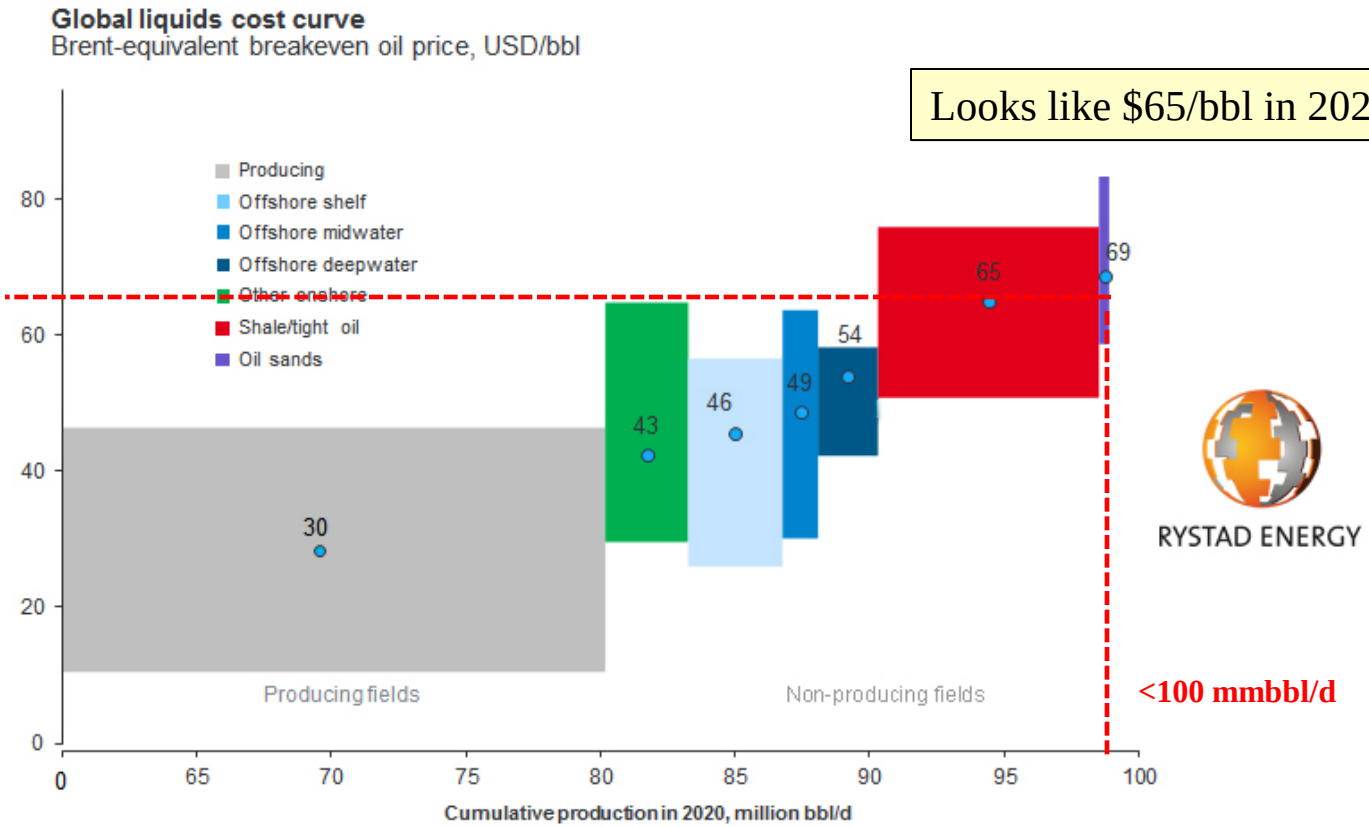
Rystad Liquids Cost Curve January 2017

Source: IHS RigPoint Notes: Rig types included are jackups, semis, and drillships.



Source: Rystad Energy research and analysis, UCube January 2017

Global Liquid Supply Cost Curve 2020 Forecast

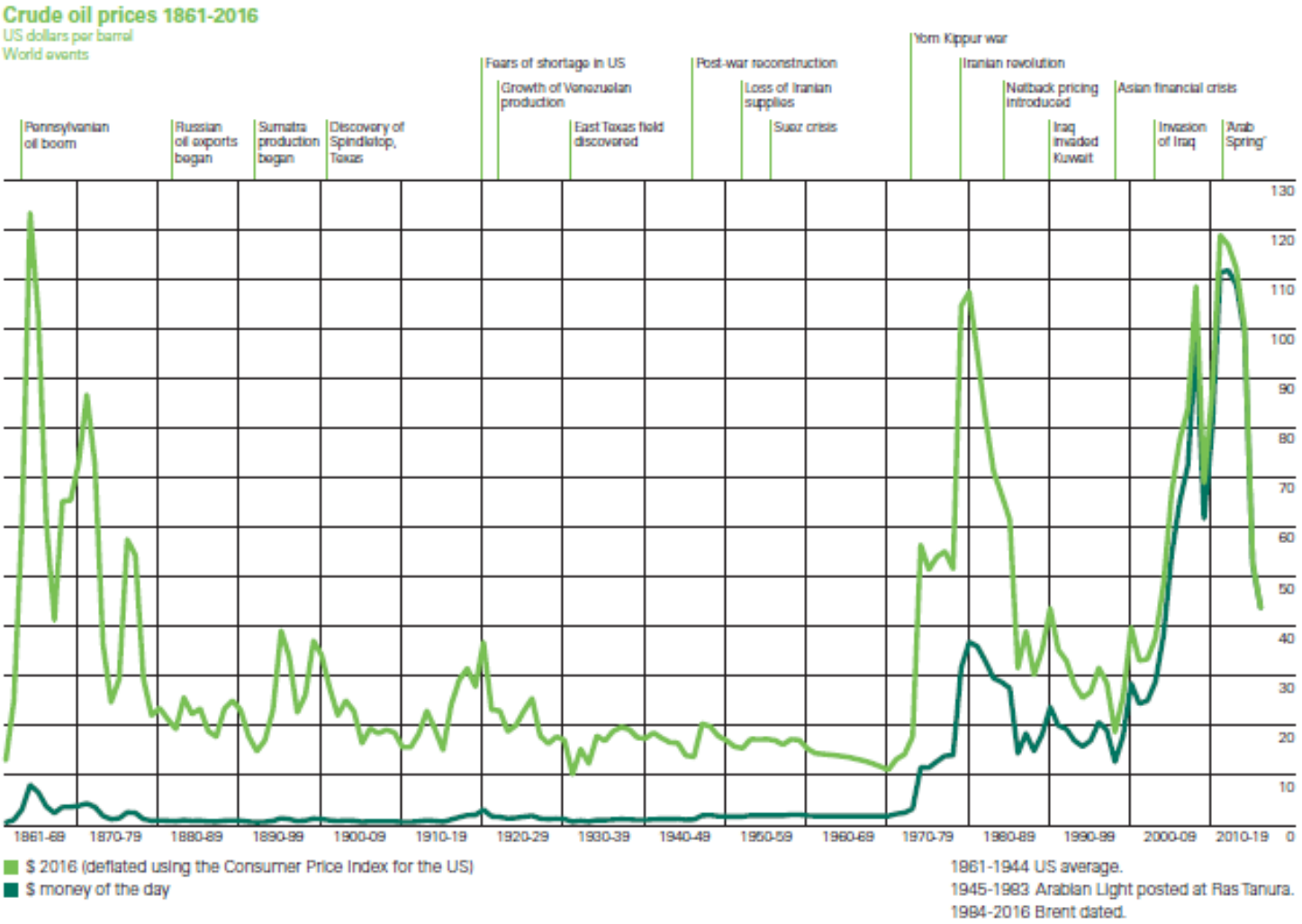


Producing fields are the cheapest supply source, as opposed to the most expensive – non producing oil sands – with 69 USD/bbl. The producing fields' low breakeven price is due to past capex that we consider as sunk, cheap Middle East and shale production. Non-producing shale and oil sands are the marginal sources of supply in 2020, with high drilling/completion costs for the former and high capex/opex for the latter.

Rystad Energy's liquids cost curve is made up of nearly 20,000 unique assets by considering each asset's breakeven oil price and potential production in 2020. The breakeven price is the Brent oil price at which NPV equals zero, considering all future cash flows using a real discount rate of 7.5%.

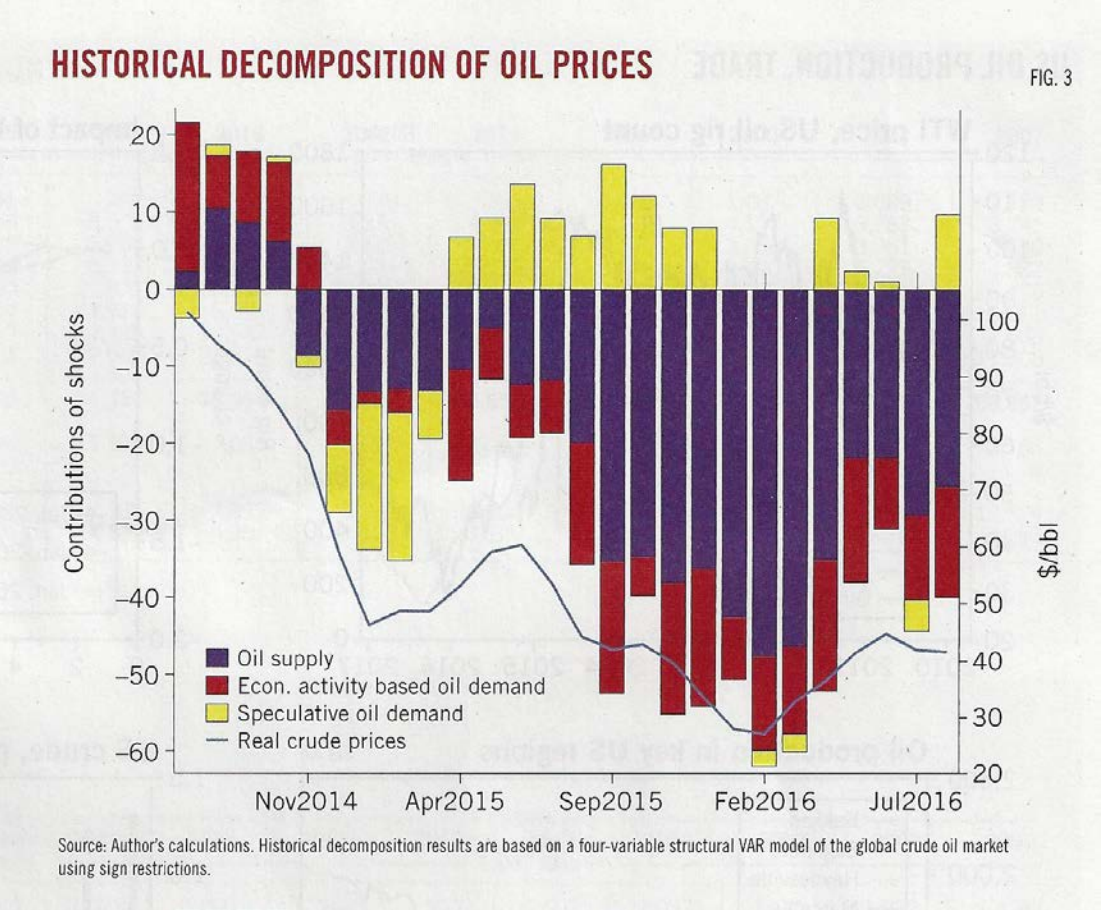
Source: **Rystad Energy** research and analysis; UCube March 2016

Crude Oil Prices - $/bbl



Source: BP Statistical Review of World Energy 2017

Historical Decomposition of Oil Prices

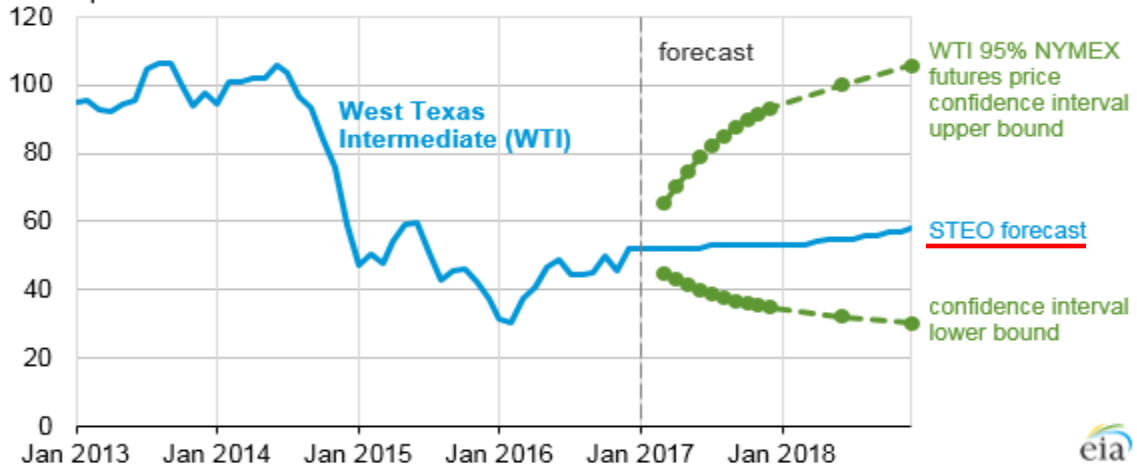


Oil & Gas Journal January 2,

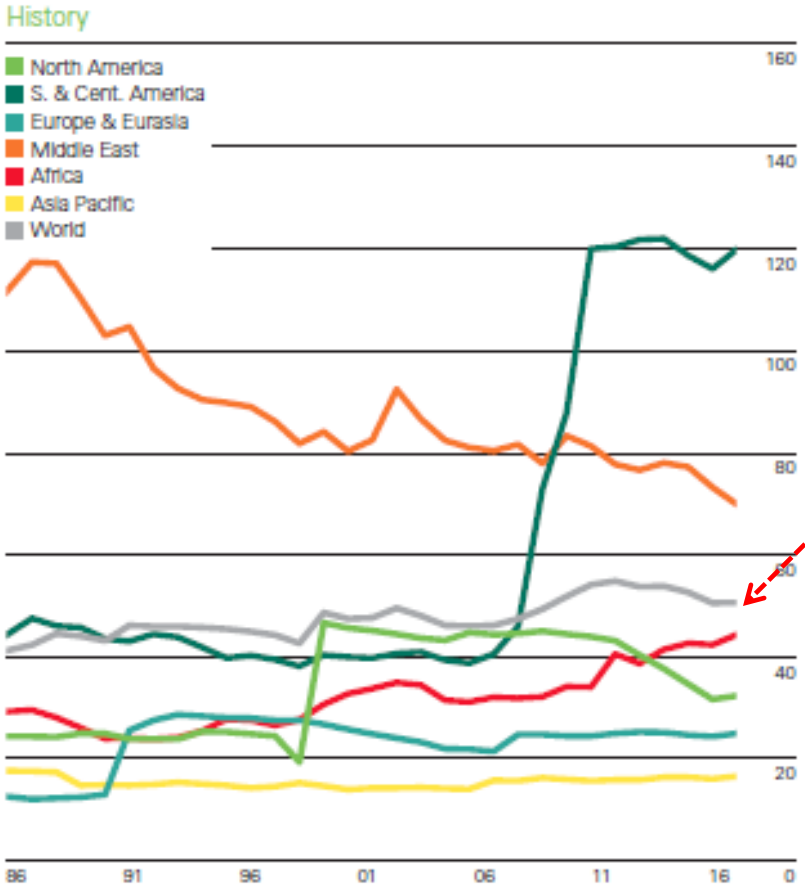
EIA Crude Price Forecast January 12, 2017

Monthly West Texas Intermediate and Brent crude oil prices (2013-18)
dollars per barrel

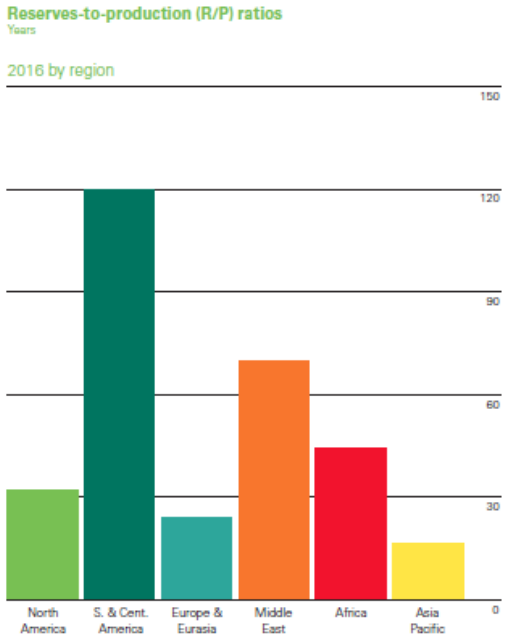
West Texas Intermediate crude oil price and NYMEX confidence intervals (2013-18)
dollars per barrel

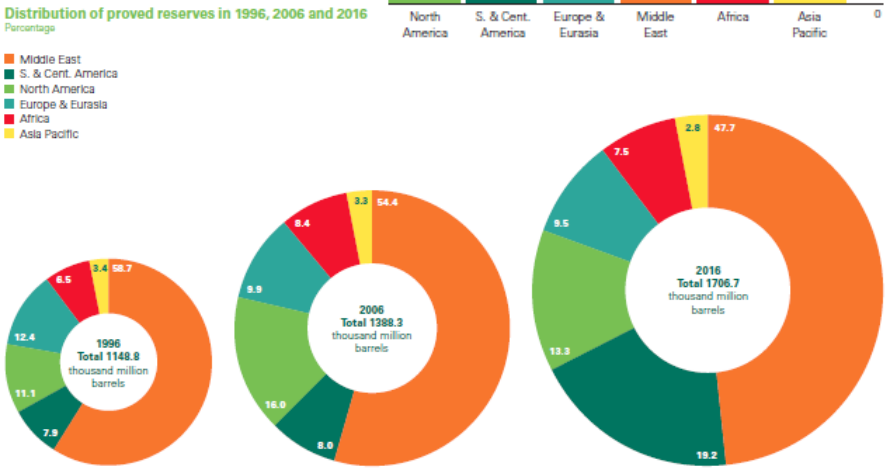


Crude Oil to Production Ratio - 2017



World 50 Year Supply





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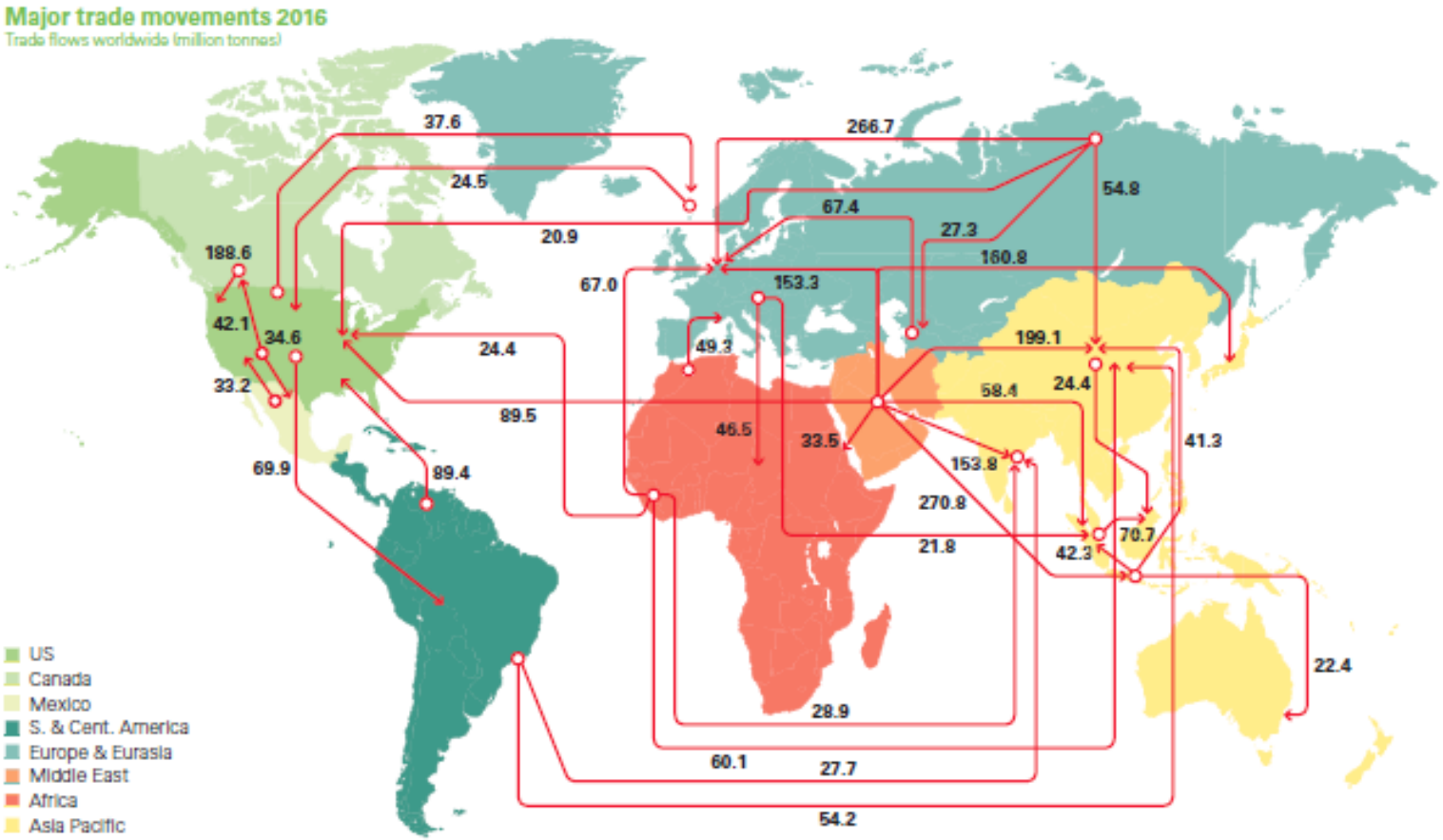
Source: BP Statistical Review of World Energy 2017

Crude Oil Trade Movements -2016



Total Trade 65.5 MMbbl/d is approximately 2/3rd of consumption

Source: BP Statistical Review of World Energy 2017

Coal

Coal Consumption – 3732.0 Mtoe

- Coal consumption declined by 1.7% in 2016
- India grew by 3.6%
- China declined by 1.6%
- Asia represents 73.8% of 2016

Coal: Consumption*

Million tonnes oil equivalent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	574.5	565.7	573.3	564.2	496.2	525.0	495.4	437.9	454.6	453.5	391.8	**358.4**	-8.8%	-3.8%	9.6%
Canada	30.1	29.2	30.3	29.4	23.5	24.8	21.8	21.0	20.8	19.7	19.6	**18.7**	-5.2%	-4.2%	0.5%
Total North America	**616.0**	**607.1**	**614.9**	**603.7**	**530.0**	**562.5**	**531.9**	**471.8**	**488.1**	**486.0**	**424.2**	**386.9**	**-9.0%**	**-3.7%**	**10.4%**
Brazil	13.0	12.8	13.6	13.8	11.1	14.5	15.4	15.3	16.5	17.5	17.7	**16.5**	-6.8%	3.1%	0.4%
Total S. & Cent. America	**21.2**	**24.3**	**25.7**	**28.0**	**23.2**	**28.1**	**30.2**	**31.7**	**34.2**	**36.1**	**35.9**	**34.7**	**-3.7%**	**5.4%**	**0.9%**
Czech Republic	20.2	21.0	21.4	19.7	17.7	18.8	18.4	17.4	17.2	16.0	16.6	**16.9**	1.7%	-2.0%	0.5%
Germany	81.3	84.5	86.7	80.1	71.7	77.1	78.3	80.5	82.8	79.6	78.5	**75.3**	-4.3%	-0.4%	2.0%
Kazakhstan	26.9	28.3	31.1	33.8	30.9	33.4	36.3	36.5	36.3	41.0	35.8	**35.6**	-0.8%	2.9%	1.0%
Poland	55.1	57.4	55.9	55.2	51.8	55.1	55.0	51.2	53.4	49.4	48.7	**48.8**	♦	-1.2%	1.3%
Russian Federation	94.6	97.0	93.9	100.7	92.2	90.5	94.0	98.4	90.5	87.6	92.2	**87.3**	-5.5%	-0.3%	2.3%
Turkey	22.2	26.2	29.5	29.6	30.9	31.4	33.9	36.5	31.6	36.1	34.7	**38.4**	10.3%	4.6%	1.0%
Ukraine	37.5	39.8	39.8	41.8	35.9	38.3	41.5	42.5	41.6	35.6	27.3	**31.5**	14.9%	-3.1%	0.8%
United Kingdom	37.4	40.9	38.4	35.6	29.8	30.9	31.4	39.0	36.8	29.7	23.0	**11.0**	-52.5%	-4.7%	0.3%
Total Europe & Eurasia	**515.2**	**536.3**	**540.2**	**528.3**	**475.8**	**492.5**	**514.9**	**528.1**	**508.1**	**487.3**	**471.3**	**451.6**	**-4.5%**	**-0.9%**	**12.1%**
Total Middle East	**9.8**	**9.8**	**9.9**	**9.7**	**9.9**	**10.1**	**11.2**	**12.3**	**10.9**	**10.8**	**10.2**	**9.3**	**-9.5%**	**0.4%**	**0.2%**
South Africa	80.0	81.5	83.7	93.3	93.8	92.8	90.5	88.3	88.6	89.8	83.4	**85.1**	1.8%	0.4%	2.3%
Total Africa	**89.3**	**90.6**	**92.1**	**101.5**	**101.0**	**100.1**	**98.5**	**96.1**	**97.5**	**102.3**	**95.3**	**95.9**	**0.4%**	**0.7%**	**2.6%**
Australia	51.7	53.1	52.7	54.9	53.1	49.4	48.1	45.1	43.0	42.6	44.1	**43.8**	-0.9%	-1.6%	1.2%
China	1324.6	1454.7	1584.2	1609.3	1685.8	1748.9	1903.9	1927.8	1969.1	1954.5	1913.6	**1887.6**	-1.6%	3.7%	50.6%
India	211.3	219.4	240.1	259.3	280.8	290.4	304.8	330.0	352.8	387.5	396.6	**411.9**	3.6%	6.5%	11.0%
Indonesia	24.4	28.9	36.2	31.5	33.2	39.5	46.9	53.0	57.0	45.1	51.2	**62.7**	22.2%	7.7%	1.7%
Japan	114.0	112.3	117.7	120.3	101.6	115.7	109.6	115.8	121.2	119.1	119.9	**119.9**	-0.2%	0.5%	3.2%
Malaysia	6.9	7.3	8.8	9.8	10.6	14.8	14.8	15.9	15.1	15.4	16.9	**19.9**	17.6%	9.4%	0.5%
Philippines	4.6	5.0	5.4	6.4	6.1	7.0	7.7	8.1	10.0	10.6	11.6	**13.5**	16.0%	9.7%	0.4%
South Korea	54.8	54.8	59.7	66.1	68.6	75.9	83.6	81.0	81.9	84.6	85.5	**81.6**	-4.8%	4.6%	2.2%
Taiwan	35.3	37.0	38.8	37.0	35.2	37.6	38.9	38.0	38.6	39.0	37.8	**38.6**	1.7%	0.7%	1.0%
Thailand	11.6	12.4	14.0	15.1	15.1	15.5	15.8	16.5	16.3	17.9	17.6	**17.7**	0.7%	4.3%	0.5%
Vietnam	9.0	5.3	5.8	11.4	10.7	14.0	16.5	15.0	15.8	18.9	22.3	**21.3**	-4.4%	9.5%	0.6%
Other Asia Pacific	21.3	21.9	18.8	20.6	20.9	20.4	16.5	17.2	13.8	16.0	16.9	**20.6**	21.3%	-2.3%	0.6%
Total Asia Pacific	**1882.8**	**2025.7**	**2197.4**	**2257.3**	**2336.3**	**2442.3**	**2620.6**	**2677.4**	**2748.3**	**2767.0**	**2747.7**	**2753.6**	**-0.1%**	**3.9%**	**73.8%**
Total World	**3134.3**	**3293.9**	**3480.2**	**3528.4**	**3476.1**	**3635.6**	**3807.2**	**3817.3**	**3887.0**	**3889.4**	**3784.7**	**3732.0**	**-1.7%**	**1.9%**	**100.0%**

Source: BP Statistical Review of World Energy 2017

Coal Production – 3656.4 Mtoe

Coal: Production*

Million tonnes oil equivalent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	580.2	595.1	587.7	596.7	540.8	551.2	556.1	517.8	500.9	507.7	449.3	**364.8**	-19.0%	-2.5%	10.0%
Canada	35.3	34.8	35.7	35.6	33.1	35.4	35.5	35.6	36.4	35.6	31.9	**31.4**	-1.8%	-1.0%	0.9%
Total North America	**621.6**	**636.7**	**630.7**	**639.2**	**580.0**	**594.0**	**600.9**	**560.9**	**544.5**	**550.5**	**488.1**	**400.7**	**-18.1%**	**-2.4%**	**11.0%**
Colombia	41.2	45.7	48.2	50.7	50.2	51.3	59.2	61.5	59.0	61.1	59.0	**62.5**	5.5%	3.7%	1.7%
Total S. & Cent. America	**49.6**	**53.9**	**56.2**	**57.7**	**55.3**	**55.9**	**63.9**	**66.3**	**65.3**	**67.5**	**64.9**	**67.6**	**3.9%**	**2.7%**	**1.8%**
Czech Republic	23.6	23.9	23.8	22.8	20.9	20.7	20.9	20.1	17.7	16.8	16.8	**16.3**	-3.4%	-3.3%	0.4%
Germany	56.6	53.3	54.4	50.1	46.4	45.9	46.7	47.8	45.1	44.1	42.9	**39.9**	-7.2%	-2.7%	1.1%
Kazakhstan	37.3	41.4	42.2	47.9	43.4	47.5	49.8	51.6	51.4	48.9	46.2	**44.1**	-4.9%	2.2%	1.2%
Poland	69.4	68.0	62.5	60.9	56.4	55.4	55.7	57.8	57.2	54.0	53.0	**52.3**	-1.5%	-2.7%	1.4%
Russian Federation	135.6	141.0	143.5	149.0	141.7	151.0	157.6	168.3	173.1	176.6	186.4	**192.8**	3.1%	3.2%	5.3%
Turkey	11.2	13.2	14.8	16.7	17.4	17.5	17.9	17.0	15.5	16.4	12.8	**15.2**	18.7%	1.3%	0.4%
Ukraine	34.9	35.7	34.0	34.4	31.8	31.8	36.3	38.0	36.6	25.9	16.4	**17.1**	4.3%	-7.3%	0.5%
Total Europe & Eurasia	**431.9**	**440.4**	**438.0**	**443.9**	**418.8**	**429.3**	**446.9**	**459.4**	**450.9**	**433.2**	**422.5**	**419.4**	**-1.0%**	**-0.2%**	**11.5%**
Total Middle East	**1.0**	**1.0**	**1.1**	**1.0**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.6**	**0.7**	**0.7**	**-**	**-3.3%**	**♦**
South Africa	138.4	138.3	138.4	141.0	139.7	144.1	143.2	146.6	145.3	148.2	142.9	**142.4**	-0.6%	0.3%	3.9%
Total Africa	**141.5**	**140.5**	**140.5**	**142.7**	**141.5**	**146.8**	**146.0**	**152.0**	**152.3**	**157.5**	**151.7**	**150.5**	**-1.0%**	**0.7%**	**4.1%**
Australia	215.1	220.4	227.0	234.2	242.5	250.6	245.1	265.9	285.8	305.7	305.8	**299.3**	-2.4%	3.6%	8.2%
China	1241.7	1328.4	1439.3	1491.8	1537.9	1665.3	1851.7	1873.5	1894.6	1864.2	1825.6	**1685.7**	-7.9%	3.9%	46.1%
India	189.9	198.2	210.3	227.5	246.0	252.4	250.8	255.0	255.7	269.5	280.9	**288.5**	2.4%	4.0%	7.9%
Indonesia	90.0	114.2	127.8	141.6	151.0	162.1	208.2	227.4	279.7	269.9	272.0	**255.7**	-6.2%	11.7%	7.0%
Mongolia	3.7	4.1	4.8	5.2	8.2	15.2	19.9	18.1	18.0	14.8	14.5	**22.8**	57.0%	14.8%	0.6%
Vietnam	19.1	21.7	23.8	22.3	24.7	25.1	26.1	23.6	23.0	23.0	23.2	**22.0**	-5.4%	2.0%	0.6%
Total Asia Pacific	**1794.3**	**1922.2**	**2065.5**	**2156.2**	**2244.8**	**2406.7**	**2638.8**	**2699.7**	**2792.5**	**2783.1**	**2759.4**	**2617.4**	**-5.4%**	**4.4%**	**71.6%**
Total World	**3039.9**	**3194.7**	**3331.9**	**3440.8**	**3441.1**	**3633.3**	**3897.3**	**3938.9**	**4006.1**	**3992.4**	**3887.3**	**3656.4**	**-6.2%**	**2.5%**	**100.0%**

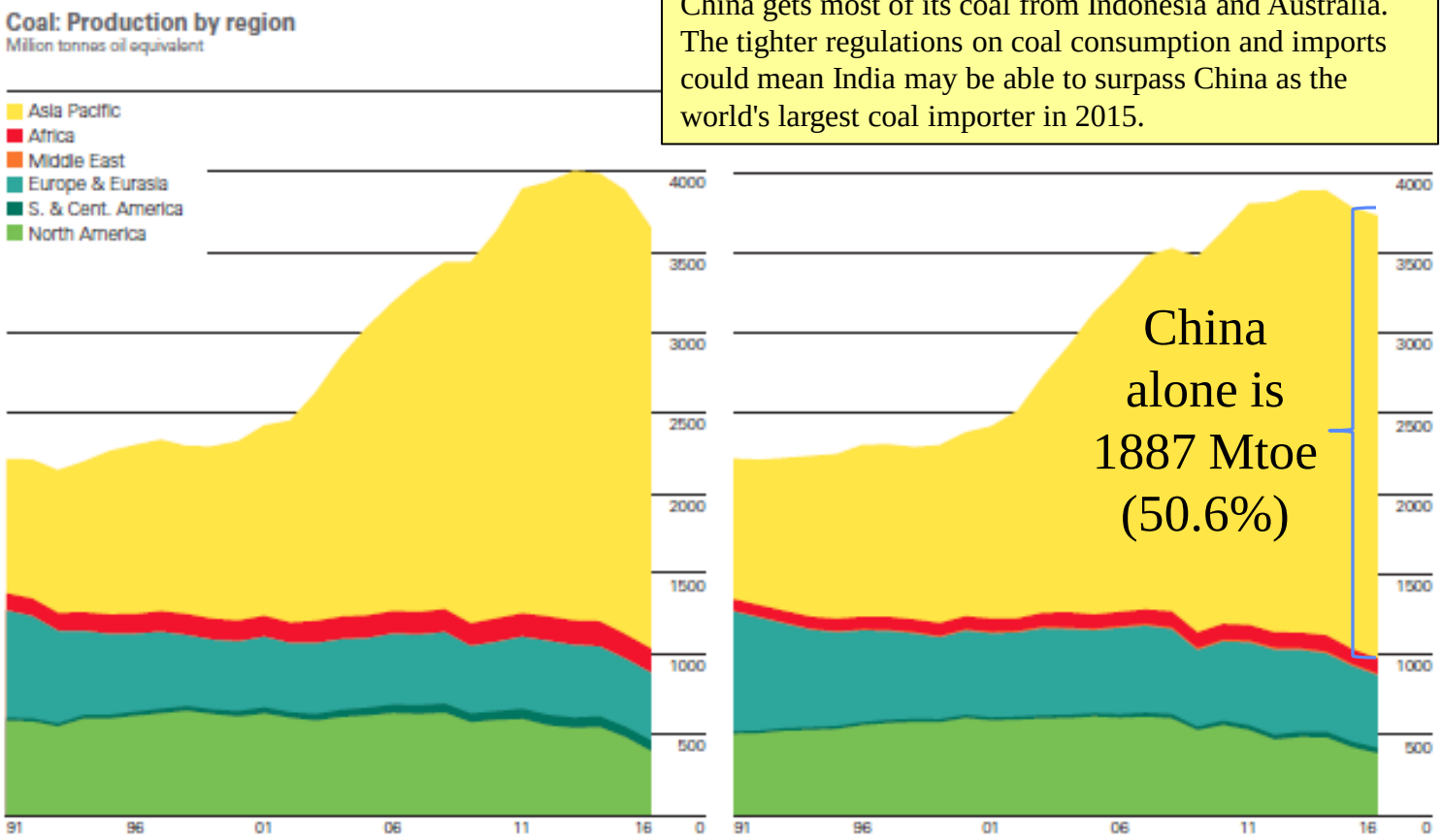
Calorific equivalents
One tonne of oil equivalent equals approximately:
Solid fuels 1.5 tonnes of hard coal
3 tonnes of lignite

Production is ~70% bituminous/30% Lignite

Source: BP Statistical Review of World Energy 2017

Coal - Regional Consumption - Mtoe

China gets most of its coal from Indonesia and Australia. The tighter regulations on coal consumption and imports could mean India may be able to surpass China as the world's largest coal importer in 2015.



World coal production fell by 6.2%, or 231 million tonnes of oil equivalent (mtoe) in 2016, the largest decline on record. China's production fell by 7.9% or 140 mtoe – also a record decline – while US production fell by 19% or 85 mtoe. Global coal consumption fell by 1.7%, the second successive decline. The largest decreases were seen in the US (-33 mtoe, an 8.9% fall), China (-26 mtoe, -1.6%) and the United Kingdom (-12 mtoe, -52.5%).

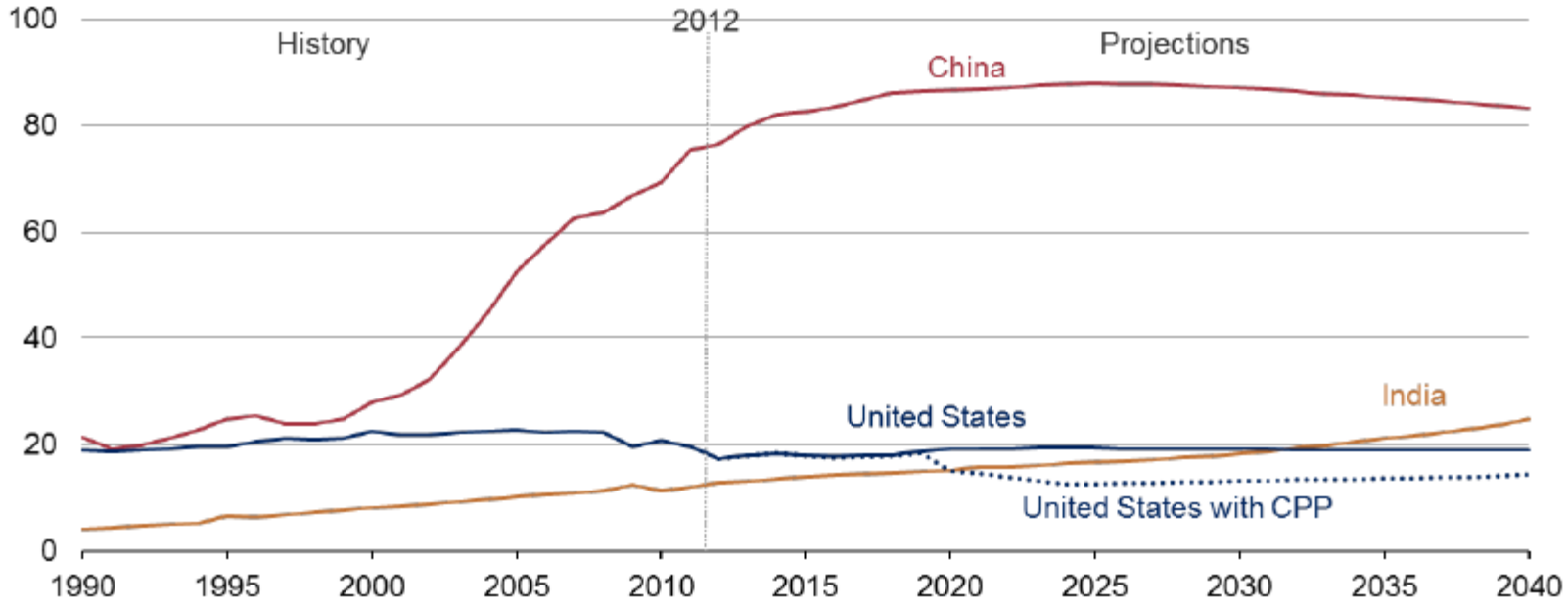
Source: BP Statistical Review of World Energy 2017

India Coal

Of the world's three largest coal consumers, only India is projected to continue to increase throughout the projection

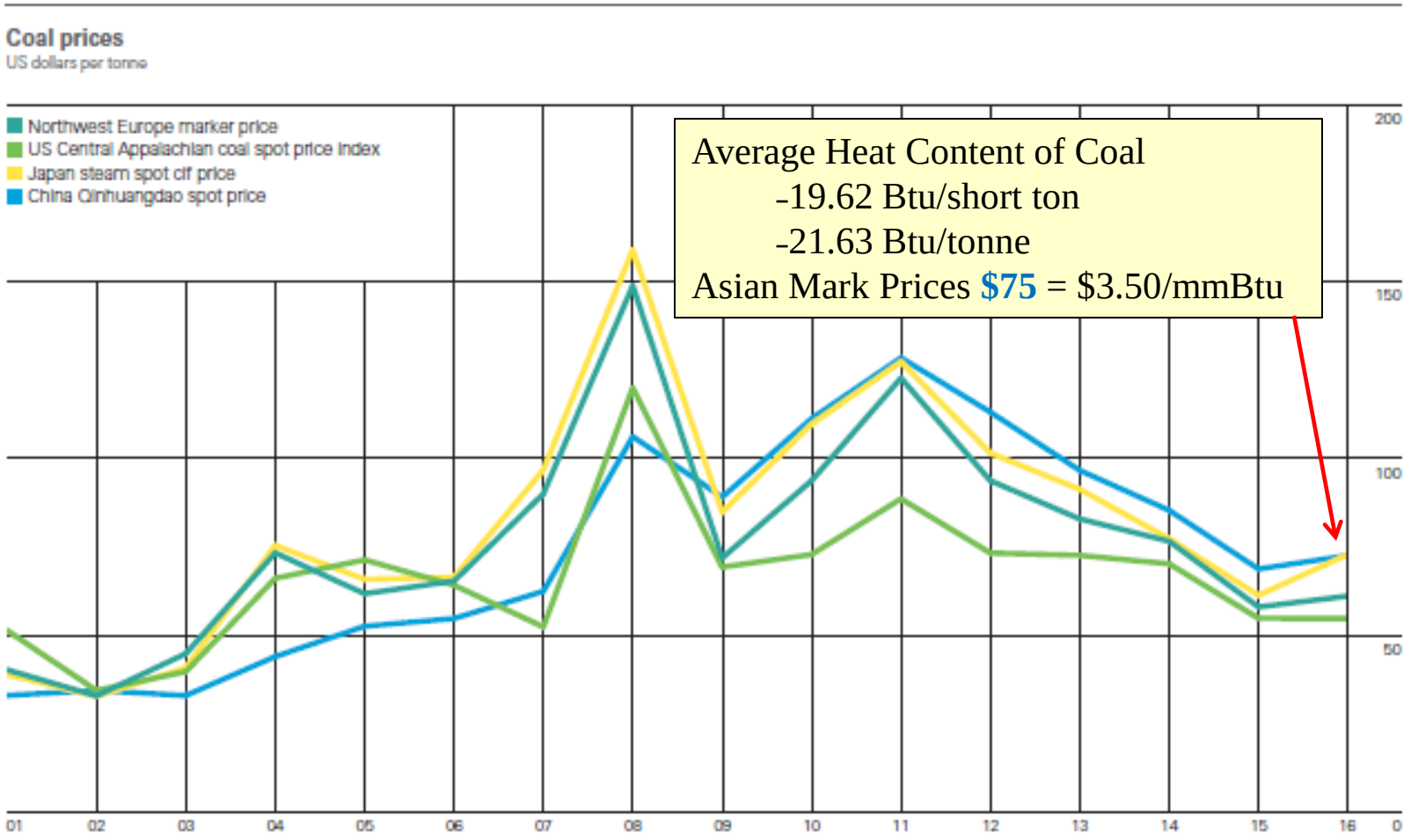
coal consumption in the US, China, and India

quadrillion Btu

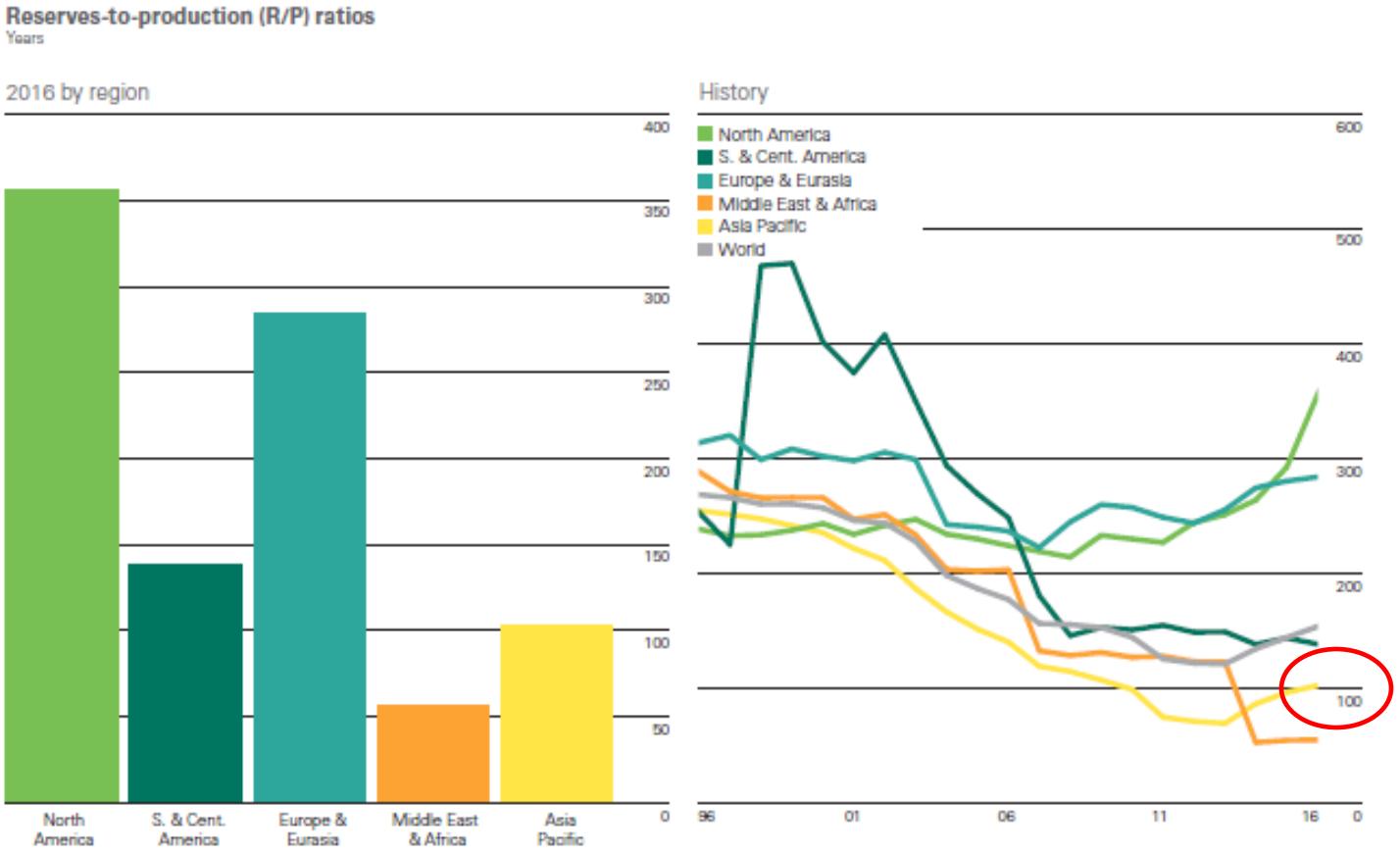


Source: EIA, International Energy Outlook 2016 and EIA, Analysis of the Impacts of the Clean Power Plan (May 2015)

Coal Prices


Coal prices
US dollars per tonne
Northwest Europe marker price
US Central Appalachian coal spot price index
Japan steam spot cif price
China Qinhuangdao spot price
200
150
100
50
0
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
Average Heat Content of Coal
-19.62 Btu/short ton
-21.63 Btu/tonne
Asian Mark Prices $75 = $3.50/mmBtu

Coal Reserves to Production Ratio - 2016



World proved coal reserves are currently sufficient to meet 153 years of global production, roughly three times the R/P ratio for oil and gas. By region, Asia Pacific holds the most proved reserves (46.5% of total), with China accounting for 21.4% of the global total. The US remains the largest reserve holder (22.1% of total).

Source: BP Statistical Review of World Energy 7

Coal Reserves to Production Ratio - 2016

Coal:
Total proved reserves at end 2016

Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of Total	R/P ratio
US	221400	30182	**251582**	22.1%	381
Canada	4346	2236	**6582**	0.6%	109
Total North America	**226906**	**32469**	**259375**	**22.8%**	356
Brazil	1547	5049	**6596**	0.6%	*
Colombia	4881	-	**4881**	0.4%	54
Total S. & Cent. America	**8943**	**5073**	**14016**	**1.2%**	138
Germany	12	36200	**36212**	3.2%	206
Kazakhstan	25605	-	**25605**	2.2%	250
Poland	18700	5461	**24161**	2.1%	184
Russian Federation	69634	90730	**160364**	14.1%	417
Serbia	402	7112	**7514**	0.7%	196
Turkey	378	10975	**11353**	1.0%	163
Ukraine	32039	2336	**34375**	3.0%	*
Other Europe & Eurasia	2618	5172	**7790**	0.7%	201
Total Europe & Eurasia	**153283**	**168841**	**322124**	**28.3%**	284
South Africa	9893	-	**9893**	0.9%	39
Total Middle East & Africa	**14354**	**66**	**14420**	**1.3%**	54
Australia	68310	76508	**144818**	12.7%	294
China	230004	14006	**244010**	21.4%	72
India	89782	4987	**94769**	8.3%	137
Indonesia	17326	8247	**25573**	2.2%	59
New Zealand	825	6750	**7575**	0.7%	*
Total Asia Pacific	**412728**	**116668**	**529396**	**46.5%**	102
Total World	**816214**	**323117**	**1139331**	**100.0%**	**153**

There's a lot of it except in China!

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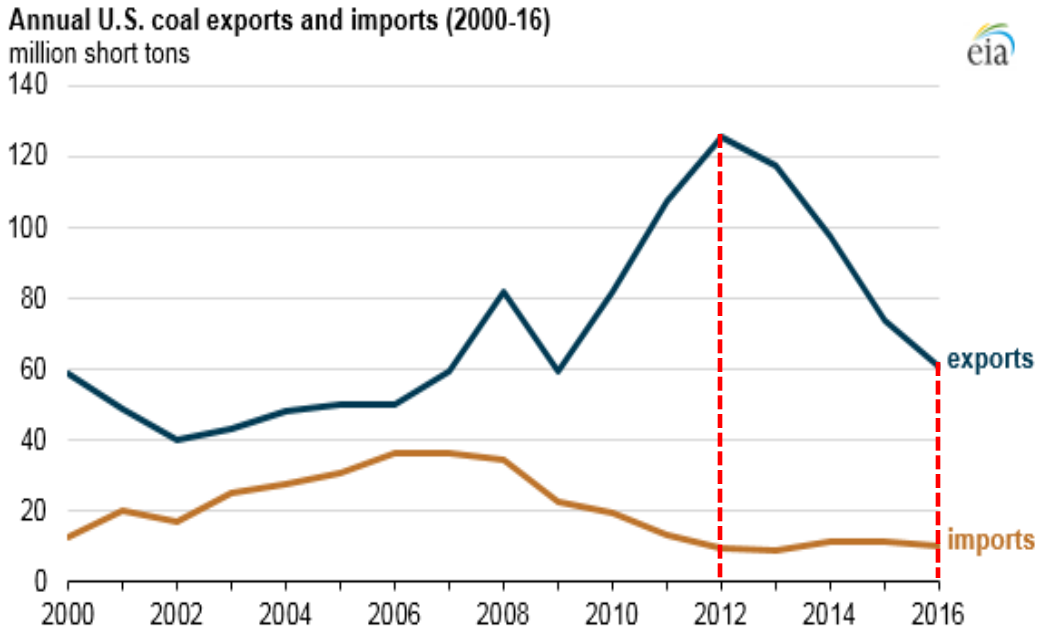
Source: BP Statistical Review of World Energy 2017

Coal Exports

- The United States remained a net exporter of coal in 2016
  - Exporting 60.3 million short tons = $3.316 billion
  - Importing 9.8 million short tons = $0.539 billion
  - Net =$2.777 billion
- U.S. coal exports fell for the fourth consecutive year, down 13.7 MMst from 2015, with 2016 exports less than half of the record volume of coal exported in 2012 (125.7 MMst).
- Nearly 80% of the coal exported by the United States in 2016 went to 10 countries.
- Declining exports to 9 of those 10 countries accounted for two-thirds of the total drop in U.S. exports.



Coal Company Bankruptcies

Largest mines owned by companies recently in bankruptcy

Mine name*	Ultimate owner	Coal produced (tons) 2015	Q4'14	Q4'15
North Antelope Rochelle	Peabody Energy Corp.	109,343,913	30,671,497	28,153,722
Black Thunder	Arch Coal Inc.	99,450,689	26,506,223	22,502,481
Eagle Butte	Alpha Natural Resources Inc.	19,649,723	5,210,041	4,873,247
Belle Ayr	Alpha Natural Resources Inc.	18,318,629	4,625,701	3,775,390
Rawhide	Peabody Energy Corp.	15,167,996	3,959,328	3,784,091
Caballo	Peabody Energy Corp.	11,402,062	2,239,334	2,794,723
Bear Run	Peabody Energy Corp.	7,878,025	2,145,839	1,739,479
Coal Creek	Arch Coal Inc.	7,840,491	2,412,109	2,200,692
Cumberland	Alpha Natural Resources Inc.	7,490,061	2,008,118	2,086,848
El Segundo	Peabody Energy Corp.	7,476,237	2,173,207	1,866,494
Kayenta	Peabody Energy Corp.	6,804,555	2,071,901	1,375,829
Lively Grove	Multi-owned1	5,953,533	1,187,294	1,281,696
West Elk	Arch Coal Inc.	5,074,821	1,668,373	854,076
Foidel Creek	Peabody Energy Corp.	4,122,448	1,200,546	1,186,340
Leer	Arch Coal Inc.	3,383,885	898,667	655,893
Prairie Eagle - Underground	Arch Coal Inc.; CBR Investments LLC	3,353,038	879,050	769,690
No. 7	Walter Energy	3,035,681	1,110,442	362,666
Francisco Underground Pit	Peabody Energy Corp.	2,935,577	810,675	704,954
No. 4	Walter Energy	2,416,556	720,849	316,649
Coal-Mac Inc. Holden No. 22 Surface	Arch Coal Inc.	2,259,286	628,888	504,244
Viper	Arch Coal Inc.	2,155,473	467,453	491,455
Somerville Central	Peabody Energy Corp.	2,143,884	470,800	490,245
Wild Boar	Peabody Energy Corp.	2,041,888	544,416	509,813
Wildcat Hills - Underground	Peabody Energy Corp.	2,026,081	538,322	447,865
Mountaineer II	Arch Coal Inc.	1,923,968	560,493	373,767

As of March 1, 2016.
Includes coal production for bankrupt coal companies as operator, owner and ultimate owner of mines that have filed bankruptcy since 2012.
* Mines in bankruptcy are defined as mines owned by companies in bankruptcy since 2012 as tracked by S&P Global Market Intelligence compared to ownership and production data from the U.S. Mine Safety and Health Administration as of the end of the fourth quarter of 2015. Some mines may have since been transferred to solvent companies and some companies may have since emerged from bankruptcy.
1 Peabody Energy Corp.; Northern Illinois Municipal; Kentucky Muni Power Agency; Southern Illinois Power Coop; Prairie Power Inc.; MJMEUC; Indiana Municipal Power Agency; Illinois Municipal Elec Agency; American Mun Power Inc.
Source: S&P Global Market Intelligence

Source: SNL April 13, 2016

- 44.3% of the coal produced in the U.S. came from a company that has filed for bankruptcy court protection since 2012.
- More than 69% of the coal produced in the Powder River Basin came from coal companies recently filing bankruptcy.
- Three of every four tons mined in Wyoming came from a coal company on the bankruptcy list.
- 28.9% of coal from the Illinois Basin comes from a coal company recently filing for bankruptcy court protections.

Q4'15 coal production by major coal basins

Coal basin	Coal produced (tons) Total	From mines of companies recently in bankruptcy*	% production from companies recently in bankruptcy*
Powder River Basin	98,013,293	68,084,346	69.46
Illinois Basin	26,410,510	7,628,394	28.88
Northern Appalachia	27,356,159	3,772,808	13.79
Central Appalachia	18,699,925	6,364,752	34.04
Entire U.S.	207,355,826	91,946,261	44.34

As of March 1, 2016.
Includes coal production for bankrupt coal companies as operator, owner and ultimate owner of mines that have filed bankruptcy since 2012.
* Mines in bankruptcy are defined as mines owned by companies in bankruptcy since 2012 as tracked by S&P Global Market Intelligence compared to ownership and production data from the U.S. Mine Safety and Health Administration as of the end of the fourth quarter of 2015. Some mines may have since been transferred to solvent companies and some companies may have since emerged from bankruptcy.
Source: S&P Global Market Intelligence

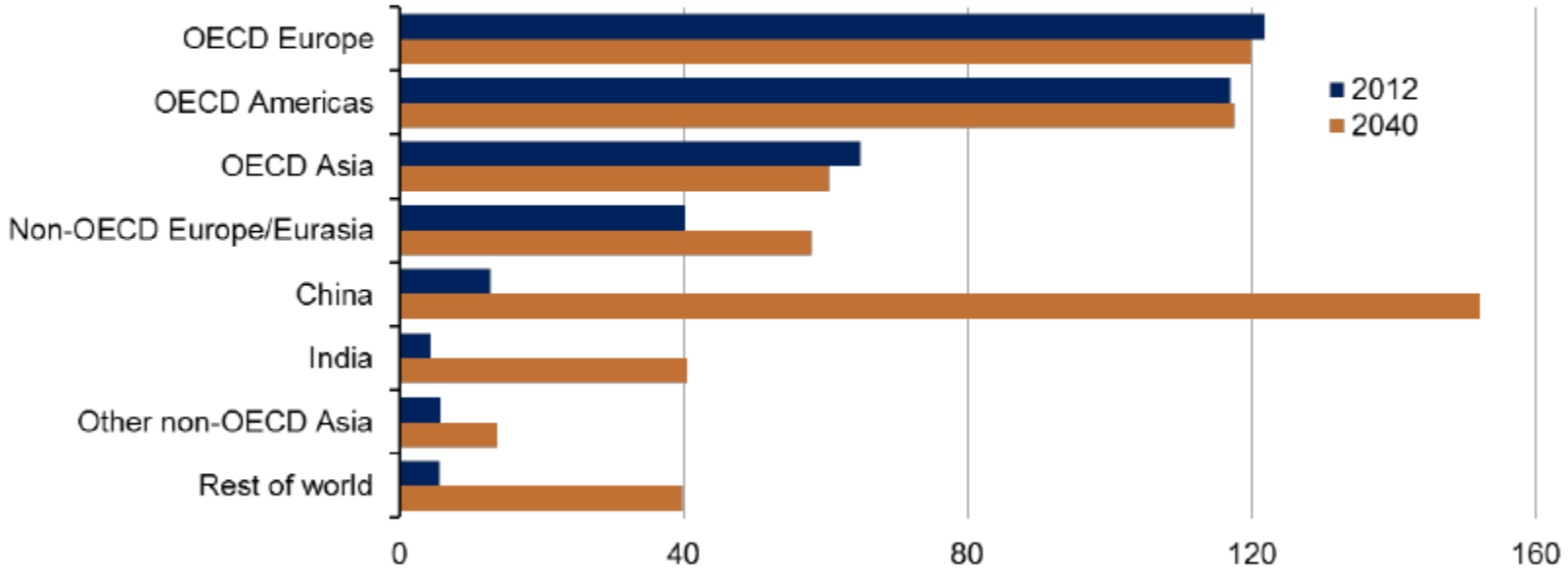
Nuclear

Nuclear Power Growth

Virtually all of the growth in nuclear power will occur in the non-OECD regions; China accounts for 61% of world nuclear capacity growth

world installed nuclear capacity by region

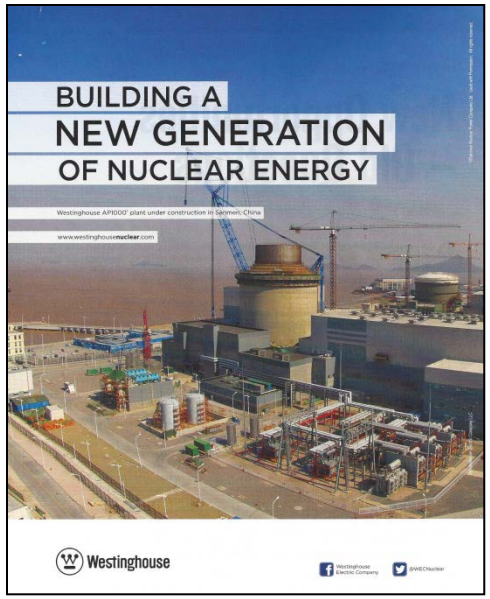
gigawatts



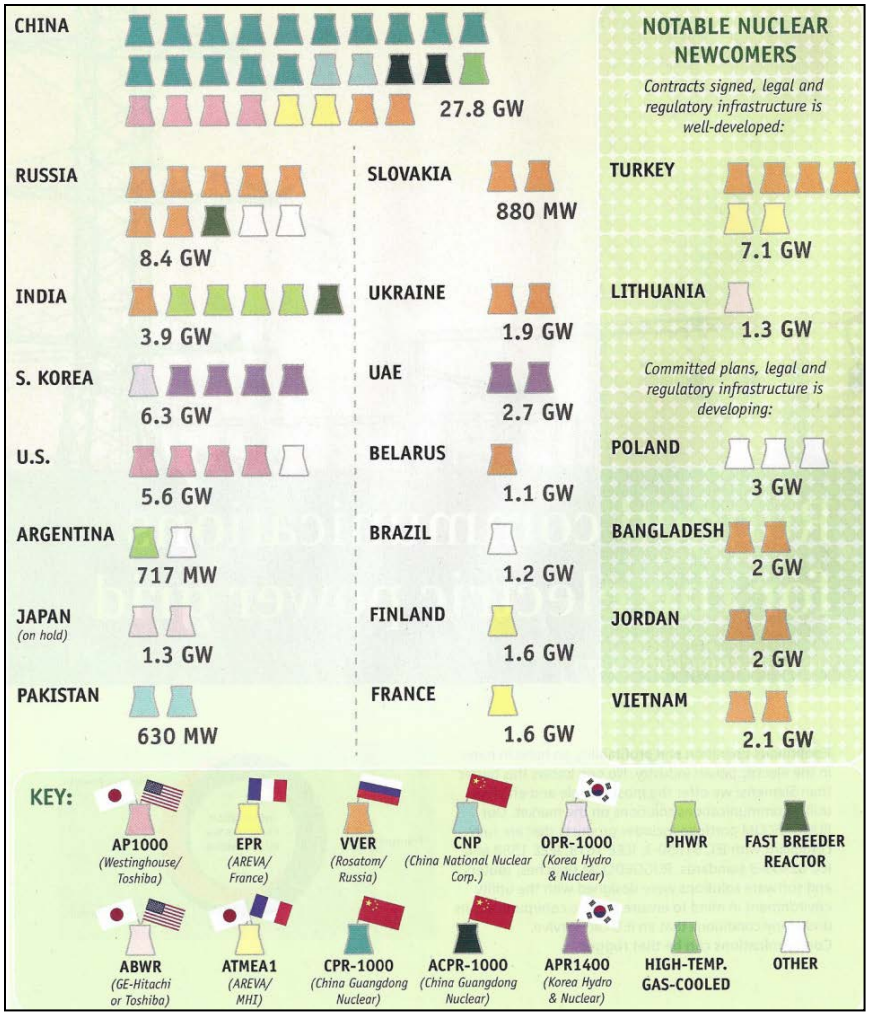
Source: EIA, International Energy Outlook 2016

“The Big Picture: Next-Gen Nuclear”

- Compliments of Power magazine April 2014
- 72 mostly advanced nuclear reactions under construction
- A total of 68GW (12% of installed base)
- China represents 40% of the total
- France will cap nuclear capacity at the current 63.2GW, forcing closures w/capacity additions
  - Currently at 75% share of generation
  - Goal is 50% by 2025



Westinghouse AP1000® plant under construction in Sanmen, China



Installed Generating Capacity (2012) = 5,550 GW

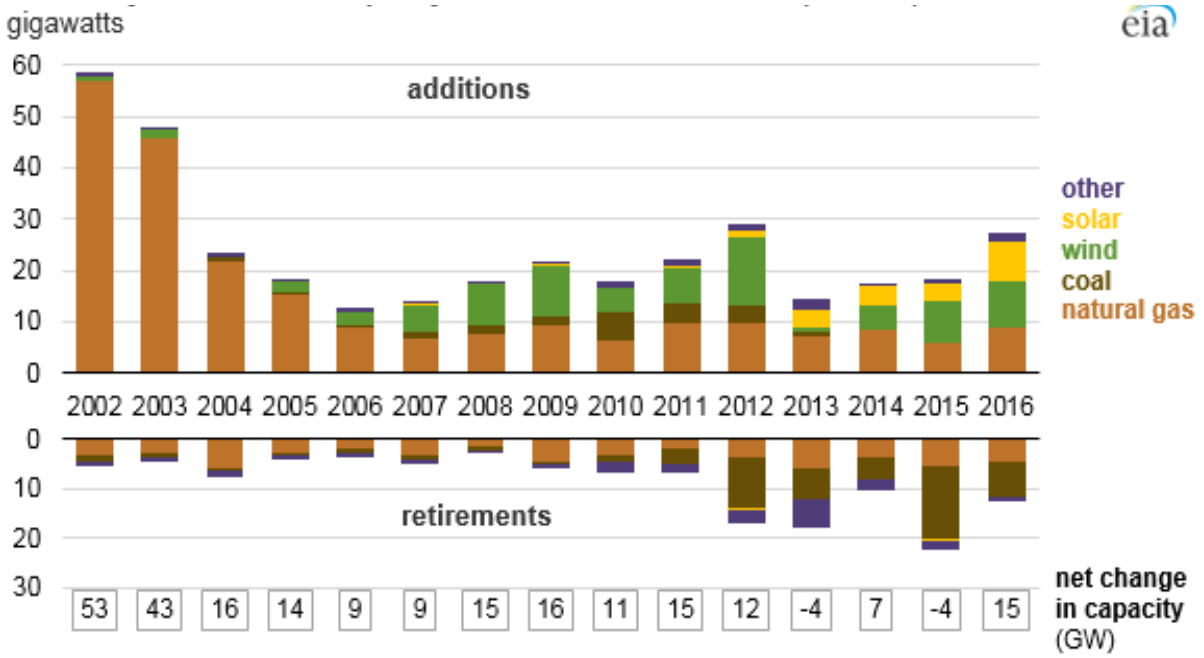
French - Nuclear

- France's outlook for nuclear sector in the next 10 years will be decisive for the country's capacity to meet its climate and energy goals, and – at the same time -- maintain electricity security
- Cut the share of nuclear power from 78% of electricity produced today to 50% by 2025, while also reducing greenhouse gas emissions by 40% in 2030
- The IEA report highlights five avenues to accelerate the energy transition and guide energy investment:
  - Track progress along robust scenarios
  - Continue with clear and long-term carbon pricing instruments
  - Take timely decisions on the safe and long-term operation of the nuclear reactors
  - Further reduce barriers to renewable deployment
  - Strengthen efforts towards market opening, competition and consumer choice.
- France's Transition Act is a first-class energy and climate framework, based on:
  - A low-carbon strategy, carbon budgets, and the related investment planning
  - France leads on carbon pricing with a long-term carbon price trajectory set by law up to 2030."
- France's nuclear fleet is the world's second-largest, and has reached a 30-year average lifetime
  - For now, no decision has been taken in favor of long-term operation pending safety reviews.

Renewables

U.S Utility-Scale Capacity Additions & Retirements

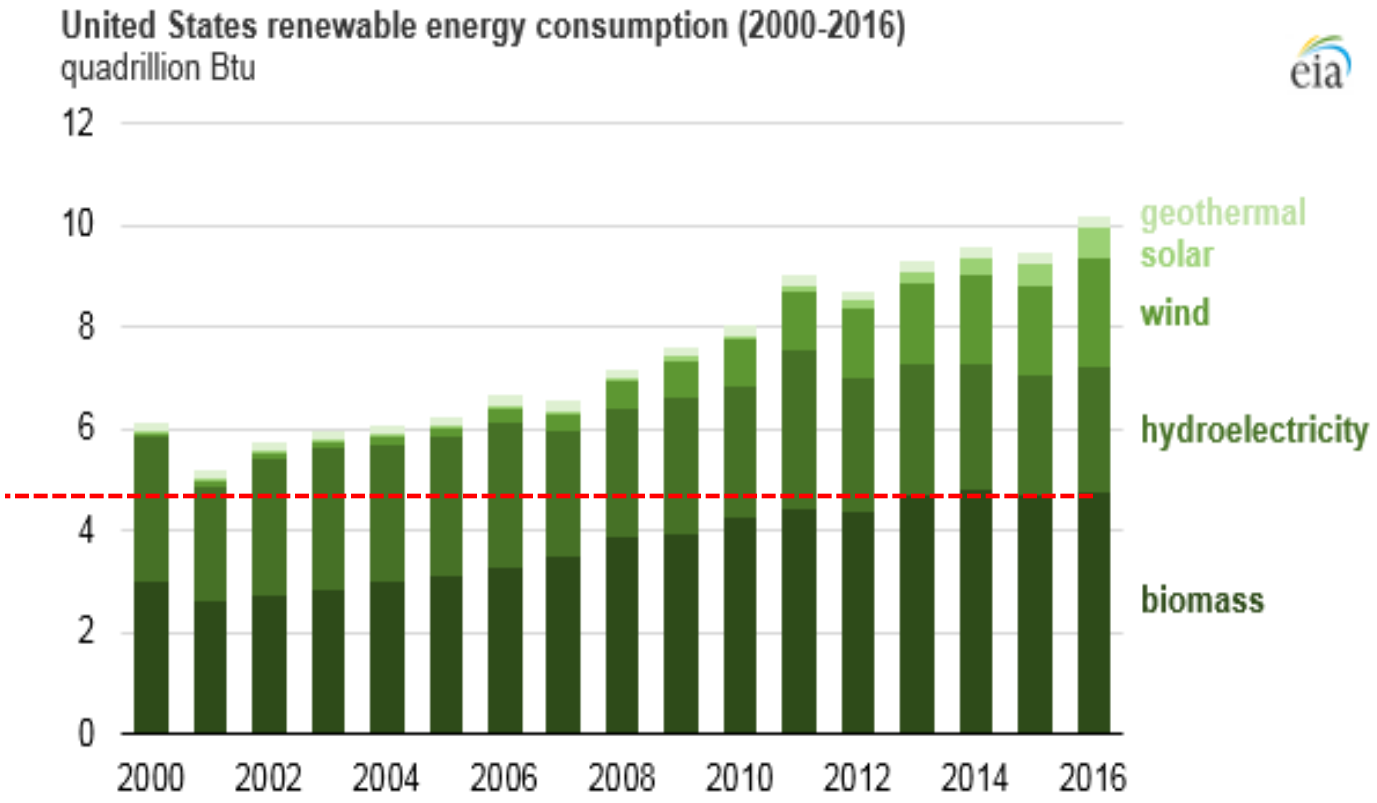
- **27+ gigawatts (GW) of electricity generating capacity added in 2016**
  - These additions more than offset the retirement of roughly 12 GW of capacity,
  - Net capacity gain of nearly 15 GW
- **228 GW of natural gas capacity added in the past 15 years**
  - 2002 through 2006, natural gas made up most of the capacity additions in each year
- **More recently, renewable technologies, primarily wind and solar, were larger share of additions**
- **2016 total utility-scale capacity additions**
  - 32% were wind (8.7 GW)
  - 28.5% solar (7.7 GW)
  - 33.3% natural gas (9.0 GW)



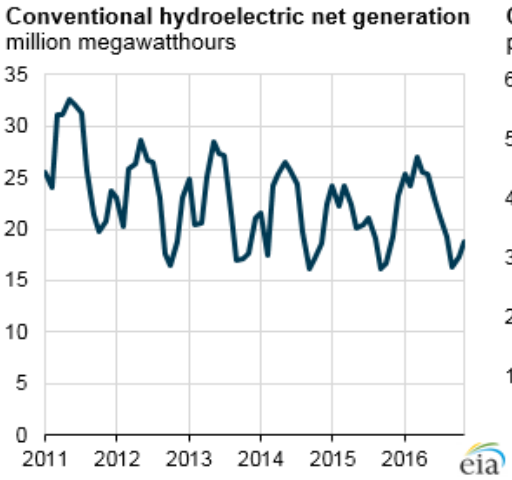
U.S. Renewable Energy Generation

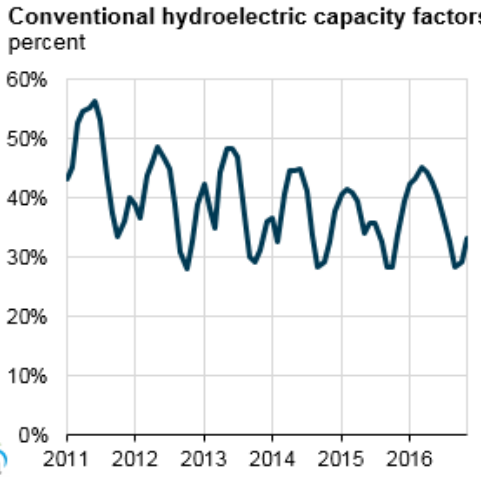
"BP Energy use by Fuel" (Slide 2) 59.2 + 83.8 =143.0 Mtoe =	5.67 Quads
Biomass in LLNL Energy Flow (Slide 10)	4.75 Quads
	10.42 Quads
This chart	10.20 Quads

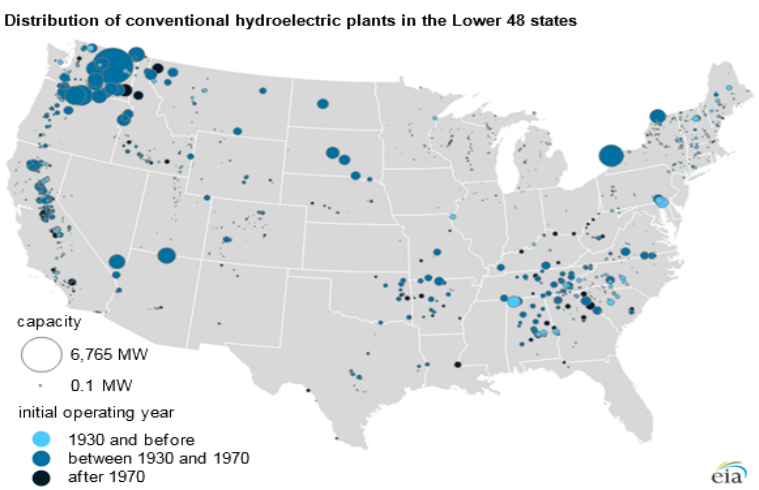
Biomass is missing from "BP Energy use by Fuel" Data



U.S. Hydro Capacity is Very Old

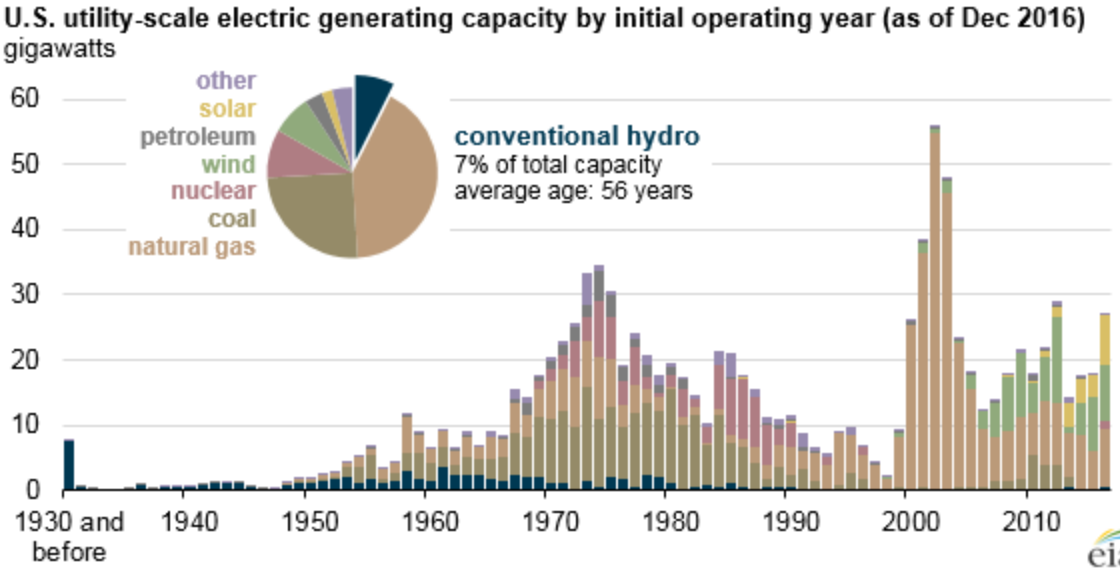




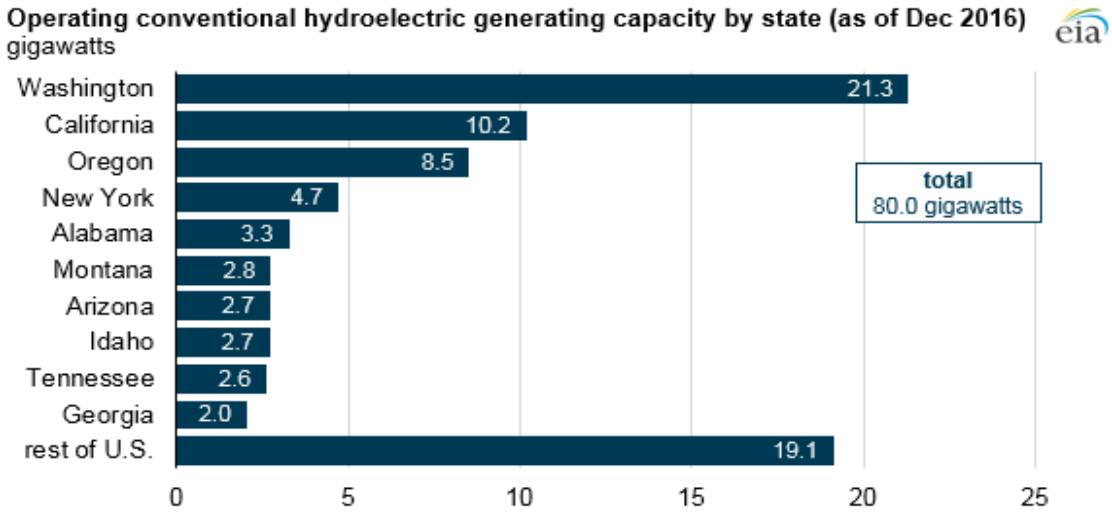


- Conventional hydroelectric generators account for 7% of the operating electricity generating capacity in the United States and about 6% to 7% of U.S. electricity generation each year.
- Hydropower plants account for 99% of all currently operating capacity built before 1930
- The 50 oldest electric generating plants in the United States are all hydroelectric generators; each has been in service since 1908.
- Many reservoirs must balance power output with competing water demand for irrigation, municipal, industrial, and other needs, as well as concerns with fish migration.
- As a result, hydroelectric facilities often do not run at full output. U.S. hydroelectric capacity factors, which measure actual output as a percent of total capacity, average between 30% and 40%.

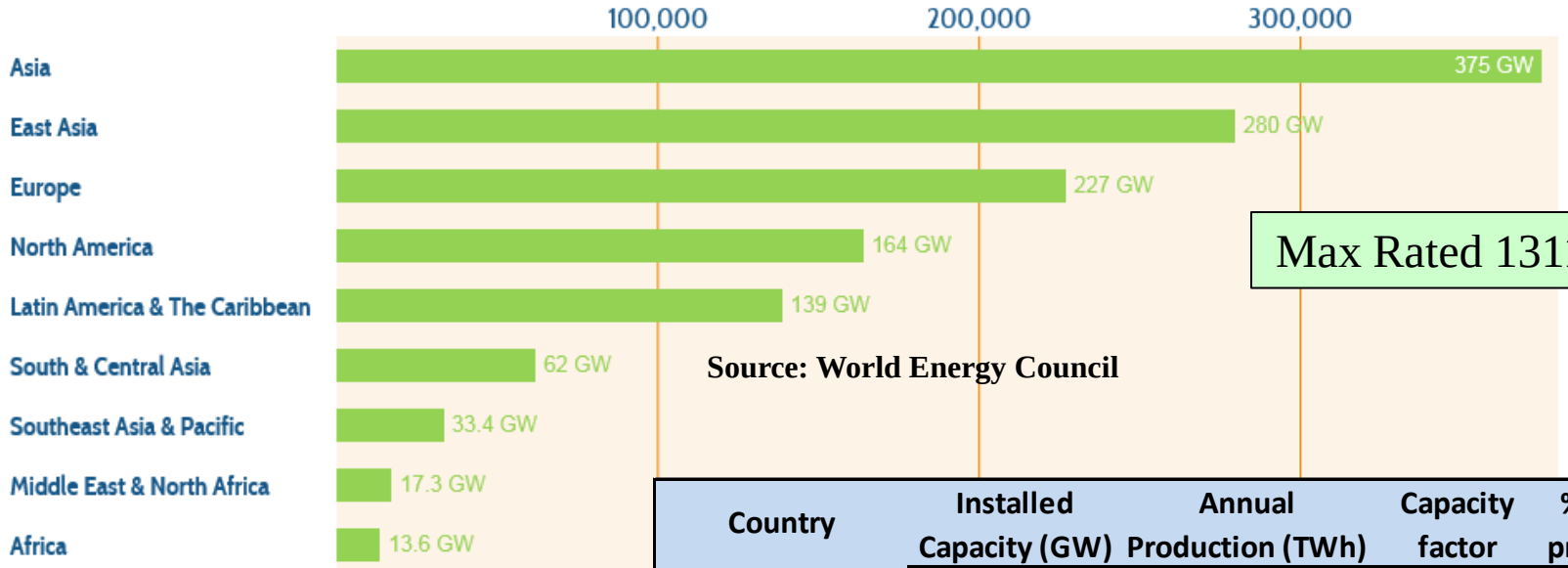
U.S. Hydro



Hydroelectric generators are among the United States' oldest power plants



World Hydroelectric Capacity – 936 GW



Source: World Energy Council

Max Rated 1311

Country	Installed Capacity (GW)	Annual Production (TWh)	Capacity factor	% of total production
China	196.8	652.1	0.37	22.3
Canada	89.0	369.5	0.59	61.1
Brazil	69.1	363.8	0.56	85.6
United States	79.5	250.6	0.42	5.7
Russia	45.0	167.0	0.42	17.6
Norway	27.5	140.5	0.49	98.3
India	33.6	115.6	0.43	15.8
Venezuela	14.6	86.0	0.67	69.2
Japan	27.2	69.2	0.37	7.2
Sweden	16.2	65.5	0.46	44.3
Total	598.5	2279.7	0.435	

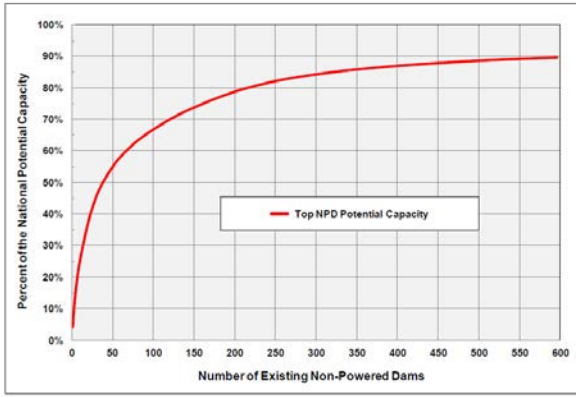
China Three Gorges – 18GW

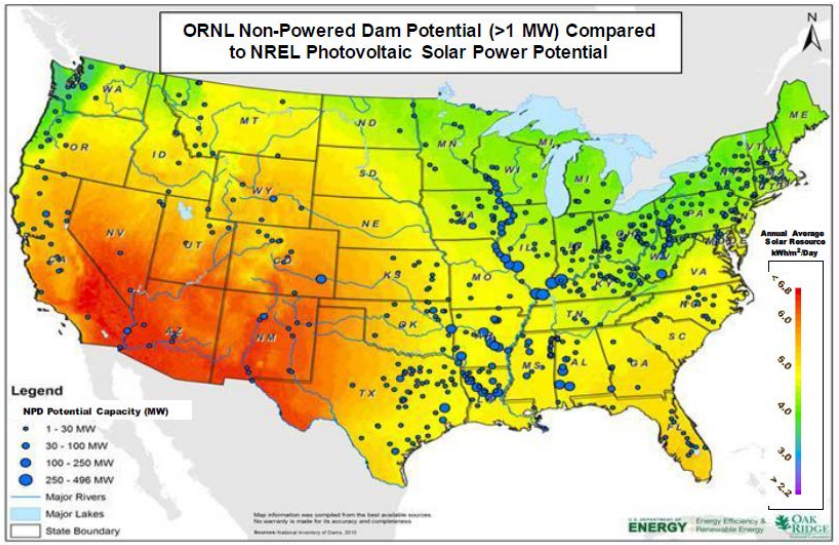
World Total Hydro 3884.6 TWh = 16.5%

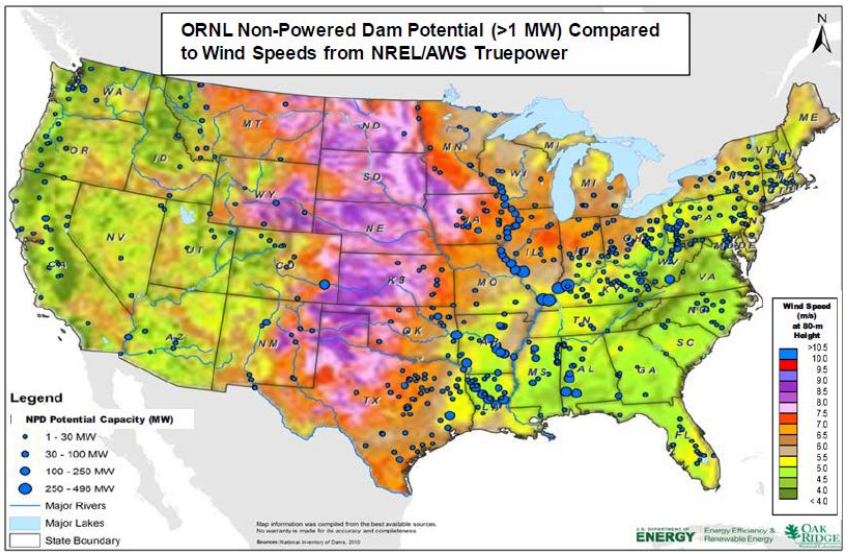
2014 World Electricity Production = 23,537 TWh

12GW Complimentary Non-Power Dams (NPD)

Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (TWh/yr)	Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (MWh/yr)
1 New England	243	1.110	10 Missouri	258	0.865
2 Mid-Atlantic	479	1.997	11 Arkansas-White-Red	1898	5.960
3 South Atlantic-Gulf	1618	3.778	12 Texas-Gulf	608	1.308
4 Great Lakes	156	0.903	13 Rio Grande	98	0.241
5 Ohio	3236	13.603	14 Upper Colorado	53	0.145
6 Tennessee	53	0.197	15 Lower Colorado	124	0.370
7 Upper Mississippi	2027	9.943	16 Great Basin	29	0.080
8 Lower Mississippi	743	2.802	17 Pacific Northwest	225	0.871
9 Souris-Red-Rainy	58	0.239	18 California	156	0.586







base e

"Practical Strategies for Emerging Energy Technologies"

Cumulative Geothermal Installed Capacity – 12.6GW

Cumulative installed geothermal power capacity*

Megawatts	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	**2014**	Change 2014 over 2013	2014 share of total
China	28	28	28	28	24	24	24	24	24	27	**27**	0.0%	0.2%
Costa Rica	163	163	163	163	163	166	166	208	208	208	**208**	0.0%	1.7%
El Salvador	151	151	195	195	204	204	204	204	204	204	**204**	0.0%	1.6%
Iceland	202	202	312	485	576	576	575	665	665	665	**665**	0.0%	5.3%
Indonesia	807	850	850	980	1052	1189	1193	1209	1339	1339	**1401**	4.6%	11.1%
Italy	791	791	811	811	811	843	883	883	875	876	**916**	4.6%	7.3%
Japan	535	534	534	532	532	500	502	502	502	503	**539**	7.2%	4.3%
Kenya	167	167	167	170	174	174	209	212	217	253	**590**	133.7%	4.7%
Mexico	960	960	960	960	965	965	965	887	812	834	**834**	0.0%	6.6%
New Zealand	370	425	425	443	585	625	723	723	723	971	**971**	0.0%	7.7%
Philippines	1932	1978	1978	1958	1958	1953	1966	1783	1848	1868	**1917**	2.6%	15.2%
Russia (Kamchatka)	79	79	79	82	82	82	82	82	82	82	**82**	0.0%	0.7%
Turkey	20	20	28	28	35	82	94	114	114	226	**368**	62.6%	2.9%
US	2866	2893	2940	3037	3163	3289	3308	3318	3450	3524	**3525**	0.0%	28.0%
Total World	**9225**	**9396**	**9655**	**10121**	**10575**	**10928**	**11152**	**11071**	**11397**	**11917**	**12594**	**5.7%**	**100.0%**

Sources: International Geothermal Association, ThinkGeoEnergy, and national sources

Wind Installed Capacity & Load Factors (2012)

Top windpower electricity producing countries in 2012 (TWh)

Country	Windpower Production	% of World Total	Nameplate GW	Nameplate TWh	Load Factor
United States	140.9	26.40%	60.0	526	26.8%
China	118.1	22.10%	75.3	660	17.9%
Spain	49.1	9.20%	22.8	200	24.6%
Germany	46.0	8.60%	31.3	274	16.8%
India	30.0	5.60%	18.4	161	18.6%
United Kingdom	19.6	3.70%	8.4	74	26.6%
France	14.9	2.80%	7.6	67	22.4%
Italy	13.4	2.00%	8.1	71	18.9%
Canada	11.8	2.20%	6.2	54	21.7%
Denmark	10.3	1.90%	4.2	36	28.3%
Rest of World	80.2	15.00%	40.9	358	22.4%
World Total	534.3	100.00%	283.1	2480	21.5%

2.3%

2014 World Electricity Production = 23,537 TWh

Source: Global Wind Report – Annual Market Update 2014, GWEC

Average Load Factor is 21.5%

- High 28.3% - Denmark
  26.8% - USA
  17.9% - China
- Low 16.8% - Germany

Changing Load Factors

BY THE NUMBERS:
NEW FACTORING ON CAPACITY

Renewables and baseload are starting to converge.

It was Charles Dudley Warner, not his more famous friend, Mark Twain, who first quipped, "Everybody complains about the weather, but nobody does anything about it." These days, that isn't necessarily true: Engineers are harnessing the weather—specifically sunshine and wind—and using it to generate power to put on the grid.

Michael Liebreich, chairman of the advisory board at Bloomberg New Energy Finance, pointed out at a talk in April that the effects of these weather-based renewable energy sources are becoming increasingly felt in power markets. Internationally, renewable energy (excluding hydropower) has grown to 25 to 30 percent in Germany, Italy, Spain, and the United Kingdom. As recently as 2006, renewables accounted for around 2 percent in the U.K. and 9 percent in Germany.

In the United States, Liebreich said, non-hydro renewable grid penetration is 30 percent or more in states as varied as Idaho, California, Iowa, and Maine.

In addition to the weather, engineers have long complained about the low capacity factor inherent in solar and wind power. What about at night when the wind doesn't blow?

Beginning in 2015, the U.S. Energy Information Administration began publishing data about the capacity factors of various generating technologies in its *Electric Power Monthly*, with the data itself dating back to 2013. The capacity factors for utility-scale solar photovoltaic panels are about what one would expect, around 26 percent annually, with summer months reaching as high as 35 percent before dipping into the mid-teens in mid-winter. Wind does better—and in some blustery months wind produced 40 percent or more of nameplate capacity across all U.S. turbines—but the average over the whole year is steadily around 33 percent.

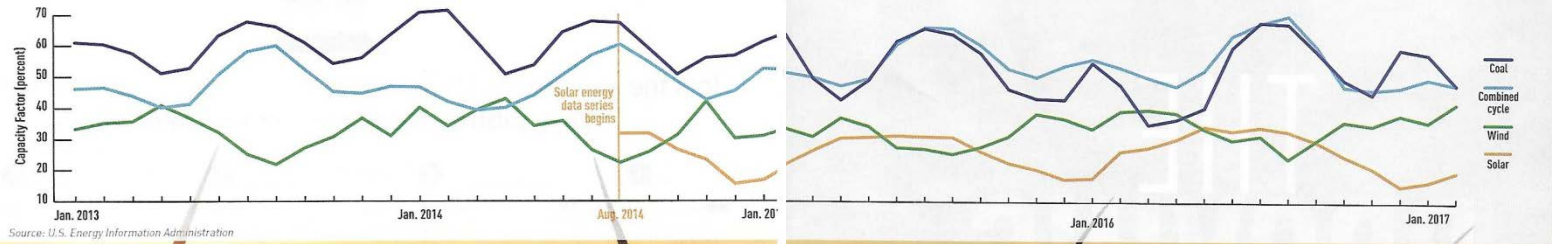
Even if only a fraction of the nameplate solar or wind capacity is available over a given day or month, grid managers are becoming more sophisticated in their forecasting—and the actual capacity has increased so much—that less traditional baseload power is needed. That's reflected in the capacity factor figures for coal and gas generation. As recently as 2014, the annual capacity factor for coal plants was over 60 percent and reached nearly 72 percent in February 2014. Since then, however, the need for coal power has been eroded by both renewables and gas-fired plants. In March 2016, for instance, coal plants produced only 35.6 percent of their nameplate capacity, a far smaller capacity factor than wind produced that month.

Meanwhile, gas-fired generation—both peaking plants as well as combined-cycle gas turbines—were being relied upon to fill the gaps, and their capacity factors were increasing as a result.

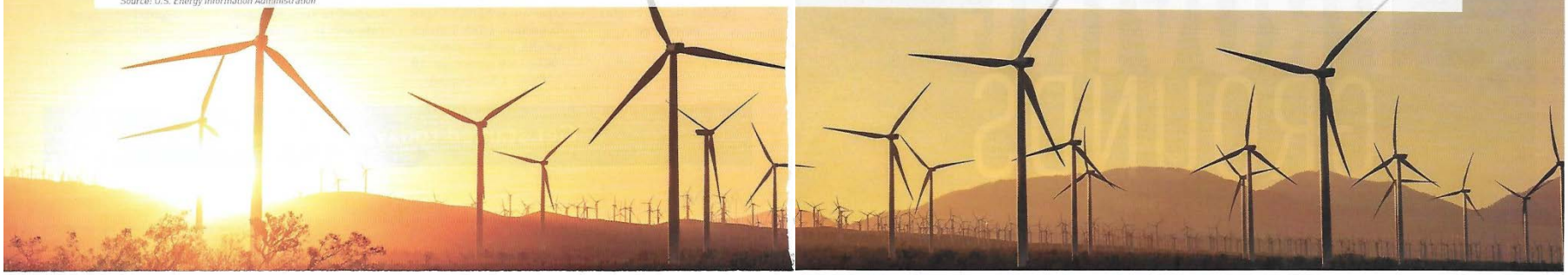
According to Bloomberg's Liebreich, as the price of renewables continues to fall, this "base cost power" will replace baseload power as the driver of the energy system. If that happens, it will make talk about the weather far more important than idle chatter. ME

JEFFREY WINTERS

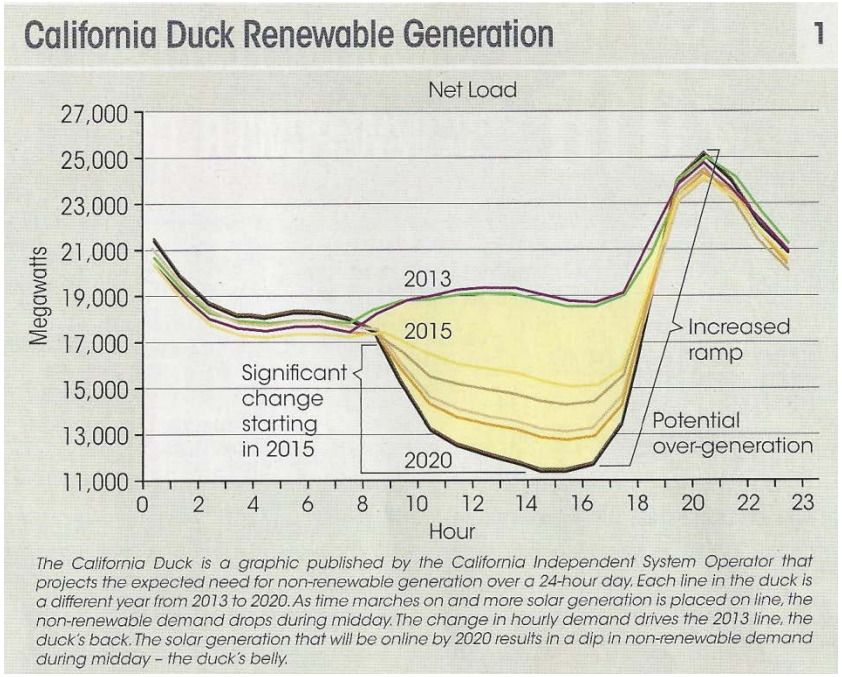
CAPACITY FACTORS FOR SELECTED UTILITY-SCALE GENERATORS



Source: U.S. Energy Information Administration



Dealing with an even “Bigger” Duck



The California Duck is a graphic published by the California Independent System Operator that projects the expected need for non-renewable generation over a 24-hour day. Each line in the duck is a different year from 2013 to 2020. As time marches on and more solar generation is placed on line, the non-renewable demand drops during midday. The change in hourly demand drives the 2013 line, the duck's back. The solar generation that will be online by 2020 results in a dip in non-renewable demand during midday – the duck's belly.

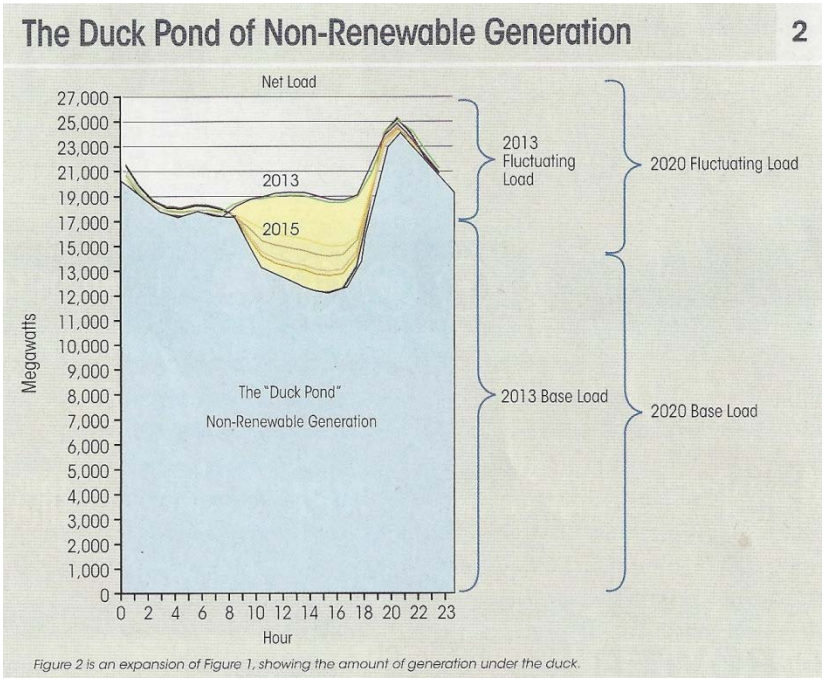


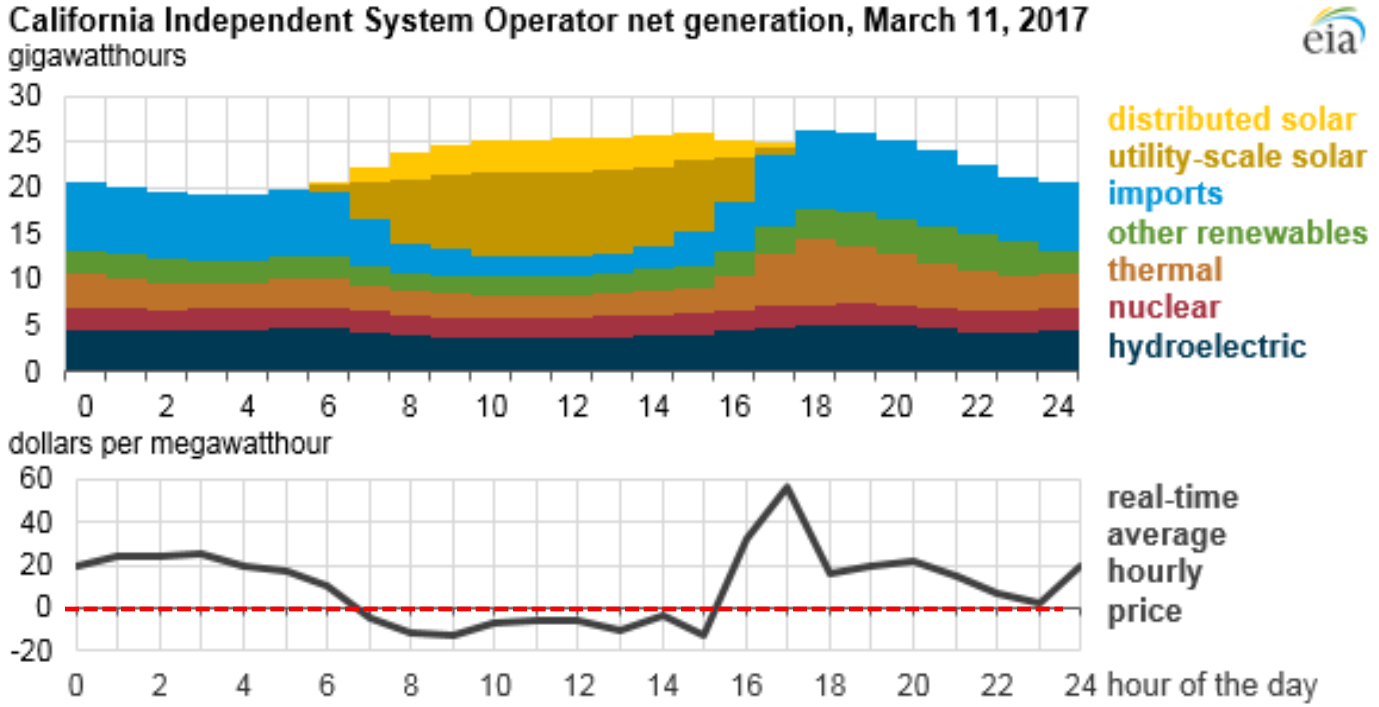
Figure 2 is an expansion of Figure 1, showing the amount of generation under the duck.

Source: Bonnie Marini – Siemens Energy
Through Power Engineering

California Net Generation March 11, 20117

- Solar energy accounted for nearly 40 percent of all grid power produced between 11 a.m. and 2 p.m.
- Nearly 50 percent growth in utility-scale solar capacity installed over the last year
- EIA estimated the total solar share of gross demand likely exceeded 50 percent during mid-day hours.
- Prices on the CASIO power exchange has been driven to much lower levels, sometimes negative.
- These lower prices have yet to be passed on to consumers, as California customers pay prices that are among the highest in the nation.

By Editors of Power Engineering



La Paloma Plant Going Bankrupt

A natural gas-fired power plant in California that earlier this year warned it might need to shut down filed for bankruptcy protection on Tuesday, blaming "inhospitable" regulations and a shift toward renewable energy for power generation.

La Paloma Generating Co LLC [CMENGL.UL], a 1,200 megawatt combined cycle plant about 110 miles northwest of Los Angeles, filed for U.S. Chapter 11 bankruptcy in Delaware on Tuesday, citing $524 million of debt.

In its filing, La Paloma said market factors including slower-than-expected growth in electricity demand and a rise in renewable generation resources in California were "exacerbated by an inhospitable regulatory environment."

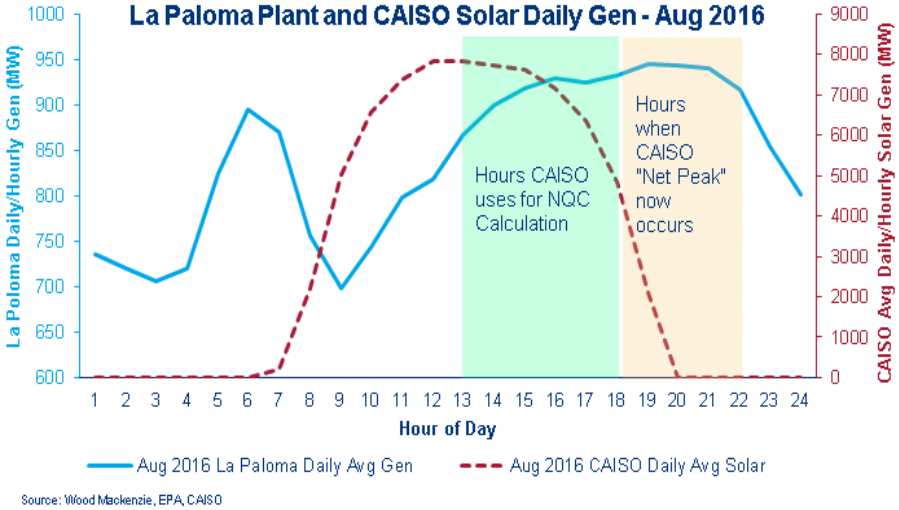
La Paloma is owned by Rockland Capital LLC, one of several California plant owners that has asked the state for help in offsetting losses, arguing that it is in the state's interest to support the natural gas plants because they provide stability and reliability to the power grid.

An unexpected combination of oversupply of natural gas and a boom in solar and other renewable energy has depressed power prices and threatened the viability of natural gas plants that sell power into California's electricity market.

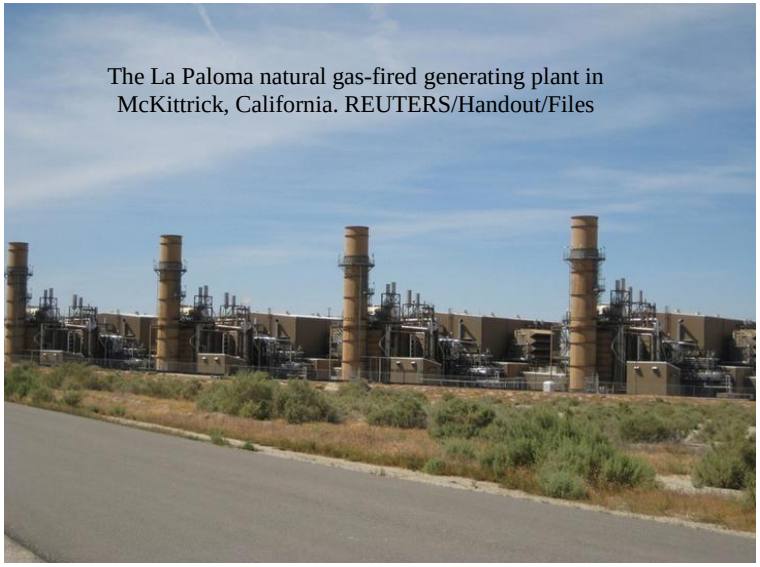
In its court filing, La Paloma said it had decided that Chapter 11 was in the best interests of the company and its creditors and stakeholders, following consultation with financial and legal advisers.

The company listed Bank of America Corp (BAC.N) and SunTrust Bank [STIHCB.UL] as its lenders. It has trade debt with a number of organizations including Alstom Power Inc, the West Kern Water District and Pacific Gas & Electric Co (PCG_pa.A).

(Reporting by Tracy Rucinski; Eiting by Steve Orlofsky)



Source: Wood Mackenzie, EPA, CAISO



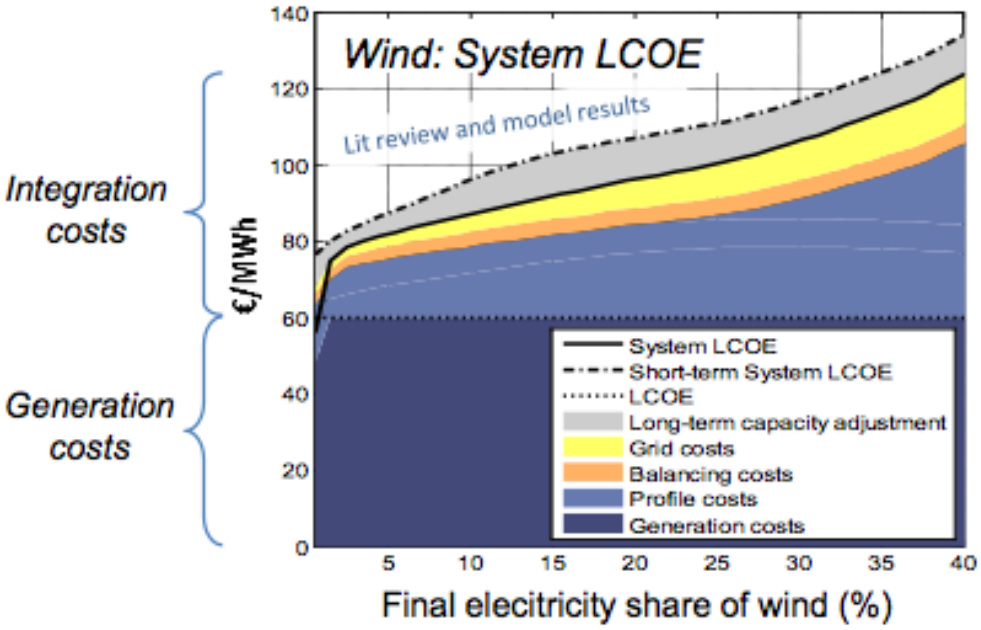
The La Paloma natural gas-fired generating plant in McKittrick, California. REUTERS/Handout/Files

http://www.reuters.com/article/us-la-paloma-bankruptcy-idUSKBN13V2PY

Wind Integration Costs

- Integration includes:
  - Fluctuating output profile costs
  - Output uncertainties balancing costs
  - Grid costs

At higher penetration, integration costs for wind exceed generation costs.



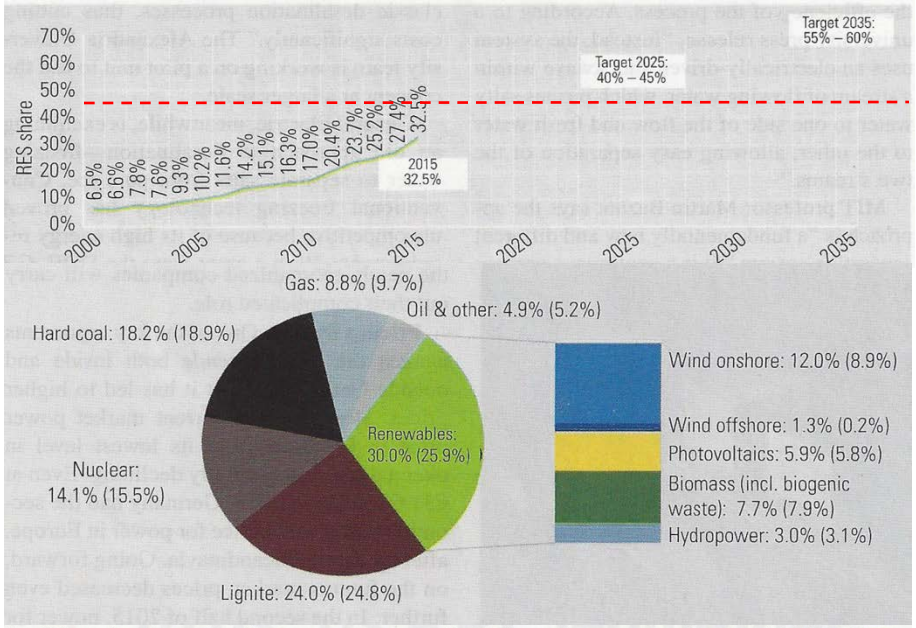
Source: System LCOE: What are the costs of variable renewables? Falko Ueckerdt, Lion Hirth, Gunnar Luderer, Ottmar Edenhofer Paris, June 20, 2013 32th International Energy Workshop

As presented by John Thompson Clean Air Task Force CCS – Pittsburgh 2104

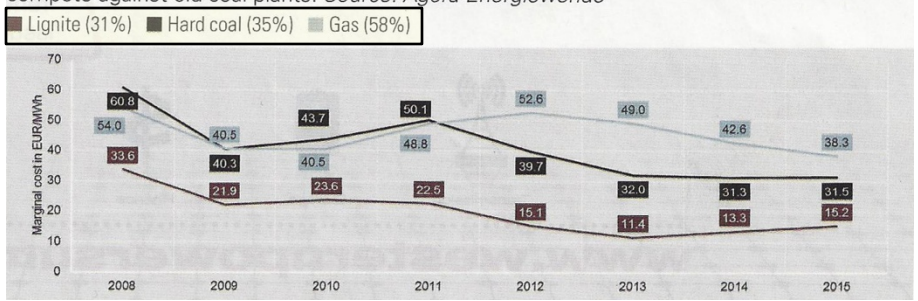
Germany Energiewende

- **Energiewende at a new turning point**
- **No more than** 45% renewable energy by 2025
- Goal for completing underground transmission lines for wind in the north to industry in the south by 2022
- Rapidly decreasing load factors are killing financial returns of old-line power producers
- Conventional utilities restructuring into:
  - Legacy assets
  - Renewables
- RWE mothballed a brand new billion-euro Westfalen-D coal-fired plant
  - Damaged at start-up
  - Decision not to correct error, but to de-construct plant
- E.ON applied to shutter two new gas-fired unit in 2015 as unprofitable
- Merit Order Dispatch Consequences
  - First determined based on fuel input cost
  - However, all renewable energy must be absorbed first
  - Dispatch order is solar, wind, hydro, biomass, nuclear, lignite, hard coal, and then natural gas.
  - Germany burns imported hard coal, generating excess capacity, export that capacity elsewhere in Europe
  - New gas plants cannot compete

1. The path to more renewables in Germany. Renewable energy sources (RES) already supply about a third of the country's electricity. *Source: Agora Energiewende; data from AG Energiebilanzen 2015*



3. Marginal costs for new gas and old coal power plants 2008–2015. Despite lower prices for natural gas and slightly higher CO_2 prices, new gas plants cannot compete against old coal plants. *Source: Agora Energiewende*



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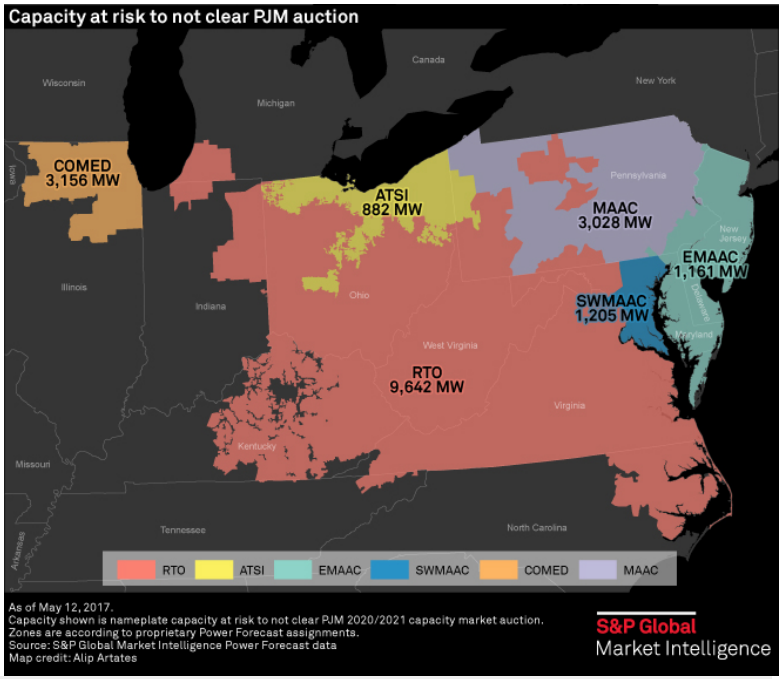
German States to Put Brakes On Green Energy

The German chancellor, Angela Merkel, has hammered out a deal with state premiers on the latest reform to Germany's renewable energy law aimed at curbing the costs and controlling the speed of the roll-out of green power sources.

- Generous green subsidies have led to a boom in renewable energy
- That rapid expansion has pushed up electricity costs and placed a strain on its grid.
  - Cap the expansion of onshore wind power at 2.8 GW in capacity per year
  - Limited of new capacity will be permitted in north Germany to avoid overburdening the grid
- The latest reforms are aimed at slowing the growth in renewables, which accounted for around a third of Germany's electricity last year, up from 28% in 2014.
- The government will have to put the brakes on growth to avoid overshooting production target of 40-45% renewables of total electricity by 2025
- One of the biggest sticking points in the talks was a plan to limit the amount of onshore wind, with critics saying this would endanger Germany's long-term energy goals and put jobs in the sector at risk.
- The government and states failed to agree on upper limits for biomass, which is important in the southern state of Bavaria, but are expected to be able to clear up this point.
- The draft law is due to come into force at the start of 2017.

19GW at Risk Not to Clear 2020/2021 Auction

- The PJM Interconnection 2020/2021 Base Residual Auction
- An S&P Global Market Intelligence analysis data shows that 19,073 MW of capacity is at risk to not clear the auction.
  - S&P Global Market Intelligence identified generating units in PJM with the highest heat rates
  - The 25 gas- and coal-fired units, all with an operating capacity greater than 100 MW
  - And, no approved retirement date through 2021
  - Have a technology type of steam turbine.
- The plants also have an average age of 52 years, which is just over the average age of a coal unit retirement of 51 years seen from 2000 to 2016.
- These 25 units represent 5,853 MW of capacity, which generated over 7 million MWh in 2016 at an average capacity factor of 14%.



Capacity at risk to not clear PJM auction by fuel type

Fuel type: Technology type	At risk capacity (MW)
Coal: Steam turbine	10,550
Gas: Steam turbine	2,980
Oil: Steam turbine	2,654
Nuclear	2,646
Oil: Internal combustion	133
Gas: Internal combustion	111
Total	**19,073**

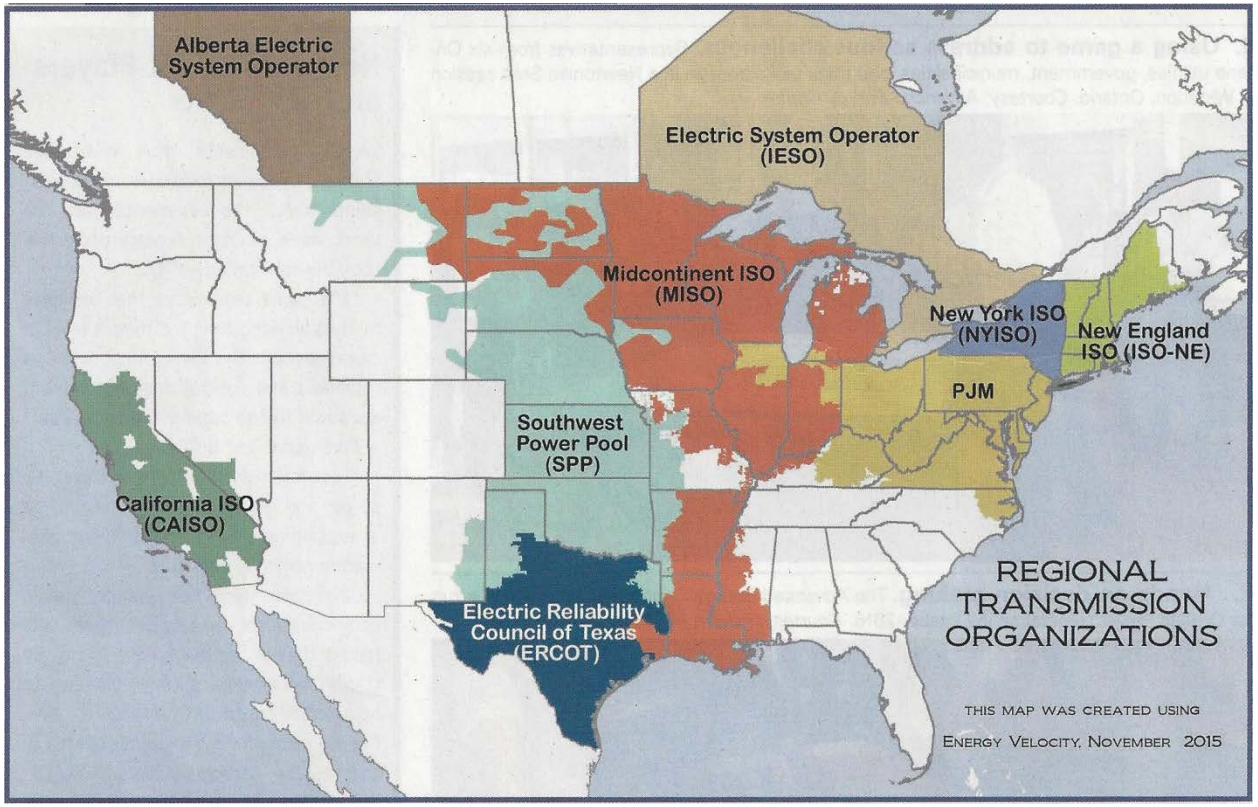
As of May 12, 2017.
Capacity shown is nameplate capacity at risk to not clear PJM 2020/2021 capacity market auction.
Source: S&P Global Market Intelligence Power Forecast data

U.S. Electric Market in Transition

The U.S. market for electricity is trifurcated. More than half the country is served by competitive generators bidding against each other in wholesale markets. Almost half is served by conventional state-regulated, vertically integrated utilities controlling generation and transmission. The rest, a much smaller portion, consists of government-owned and customer-owned utilities, some of which are generators and most of which serve retail customers. All categories are in transition.

Kennedy Maize

Power: January 2107



Natural Gas
Supply and Demand Balancing

Natural Gas Production – 3551.6BCM

Natural Gas: Production*

Billion cubic metres	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	511.1	524.0	545.6	570.8	584.0	603.6	648.5	680.5	685.4	733.1	766.2	**749.2**	-2.5%	4.1%	21.1%
Canada	170.7	171.7	165.5	159.3	147.6	144.5	144.4	141.1	141.4	147.2	149.1	**152.0**	1.7%	-1.3%	4.3%
Total North America	**734.1**	**753.0**	**764.6**	**783.5**	**790.9**	**805.7**	**851.2**	**878.9**	**885.0**	**937.3**	**969.4**	**948.4**	**-2.4%**	**2.8%**	**26.7%**
Argentina	45.6	46.1	44.8	44.1	41.4	40.1	38.8	37.7	35.5	35.5	36.5	**38.3**	4.6%	-2.2%	1.1%
Trinidad & Tobago	33.0	40.1	42.2	42.0	43.6	44.8	43.1	42.7	42.8	42.1	39.6	**34.5**	-13.2%	1.8%	1.0%
Venezuela	27.4	31.5	36.2	32.8	31.0	30.6	27.6	29.5	28.4	28.6	32.4	**34.3**	5.5%	1.7%	1.0%
Total S. & Cent. America	**140.5**	**154.1**	**162.1**	**163.0**	**157.8**	**166.2**	**166.9**	**173.4**	**175.6**	**176.9**	**178.0**	**177.0**	**-0.8%**	**2.4%**	**5.0%**
Netherlands	62.5	61.5	60.5	66.5	62.7	70.5	64.1	63.8	68.6	57.9	43.3	**40.2**	-7.6%	-3.6%	1.1%
Norway	85.8	88.7	90.3	100.1	104.4	107.3	101.3	114.7	108.7	108.8	117.2	**116.6**	-0.7%	3.2%	3.3%
Russian Federation	580.1	595.2	592.0	601.7	527.7	588.9	607.0	592.3	604.7	581.7	575.1	**579.4**	0.5%	-0.1%	16.3%
Turkmenistan	57.0	60.4	65.4	66.1	36.4	42.4	59.5	62.3	62.3	67.1	69.6	**66.8**	-4.3%	2.0%	1.9%
United Kingdom	88.2	80.0	72.1	69.6	59.7	57.1	45.2	38.9	36.5	36.8	39.6	**41.0**	3.3%	-7.7%	1.2%
Uzbekistan	54.0	56.6	58.2	57.8	55.6	54.4	57.0	56.9	56.9	57.3	57.7	**62.8**	8.4%	0.7%	1.8%
Total Europe & Eurasia	**1026.7**	**1042.2**	**1037.8**	**1066.7**	**947.9**	**1021.1**	**1032.5**	**1025.5**	**1032.7**	**1003.2**	**995.4**	**1000.1**	**0.2%**	**-0.3%**	**28.2%**
Iran	102.3	111.5	124.9	130.8	143.7	152.4	159.9	166.2	166.8	185.8	189.4	**202.4**	6.6%	6.4%	5.7%
Oman	22.1	25.8	26.1	26.0	27.0	29.3	30.9	32.2	34.8	33.3	34.7	**35.4**	1.7%	4.6%	1.0%
Qatar	45.8	50.7	63.2	77.0	89.3	131.2	145.3	157.0	177.6	174.1	178.5	**181.2**	1.3%	14.6%	5.1%
Saudi Arabia	71.2	73.5	74.4	80.4	78.5	87.7	92.3	99.3	100.0	102.4	104.5	**109.4**	4.4%	3.9%	3.1%
United Arab Emirates	47.8	48.8	50.3	50.2	48.8	51.3	52.3	54.3	54.6	54.2	60.2	**61.9**	2.5%	2.3%	1.7%
Total Middle East	**321.1**	**343.6**	**371.9**	**400.7**	**422.2**	**495.4**	**528.8**	**554.7**	**587.2**	**602.6**	**615.9**	**637.8**	**3.3%**	**6.7%**	**18.0%**
Algeria	88.2	84.5	84.8	85.8	79.6	80.4	82.7	81.5	82.4	83.3	84.6	**91.3**	7.6%	-0.4%	2.6%
Egypt	42.5	54.7	55.7	59.0	62.7	61.3	61.4	60.9	56.1	48.8	44.3	**41.8**	-5.7%	0.4%	1.2%
Nigeria	25.0	29.6	36.9	36.2	26.0	37.3	40.6	43.3	36.2	45.0	50.1	**44.9**	-10.6%	7.2%	1.3%
Total Africa	**177.0**	**192.6**	**203.4**	**212.0**	**199.7**	**213.2**	**209.4**	**214.4**	**206.3**	**207.1**	**210.0**	**208.3**	**-1.1%**	**1.7%**	**5.9%**
Australia	36.8	39.2	41.2	40.4	45.9	50.4	53.2	56.9	59.0	63.6	72.6	**91.2**	25.2%	7.0%	2.6%
China	51.0	60.6	71.6	83.1	88.2	99.1	109.0	111.8	122.2	131.6	136.1	**138.4**	1.4%	10.3%	3.9%
India	29.6	29.3	30.1	30.5	37.6	49.3	44.5	38.9	32.1	30.5	29.3	**27.6**	-6.0%	-0.1%	0.8%
Indonesia	75.1	74.3	71.5	73.7	76.9	85.7	81.5	77.1	76.5	75.3	75.0	**69.7**	-7.4%	♦	2.0%
Malaysia	63.9	62.7	61.5	63.8	61.1	56.2	62.2	61.5	67.3	68.4	71.2	**73.8**	3.4%	1.1%	2.1%
Pakistan	39.1	39.9	40.5	41.4	41.6	42.3	42.3	43.8	42.6	41.9	42.0	**41.5**	-1.3%	0.7%	1.2%
Thailand	23.4	24.0	25.7	28.5	30.6	35.8	36.6	41.0	41.3	41.6	39.3	**38.6**	-2.2%	5.3%	1.1%
Total Asia Pacific	**374.5**	**391.3**	**407.8**	**428.3**	**450.3**	**490.6**	**501.4**	**505.4**	**517.0**	**538.8**	**561.9**	**579.9**	**2.9%**	**4.1%**	**16.3%**
Total World	**2774.0**	**2876.7**	**2947.5**	**3054.2**	**2968.8**	**3192.2**	**3290.2**	**3352.3**	**3403.9**	**3465.9**	**3530.6**	**3551.6**	**0.3%**	**2.4%**	**100.0%**

Source: BP Statistical Review of World Energy 2017

Natural Gas Demand – 3542.9 BCM

Natural Gas: Consumption in billion cubic metres*

Billion cubic metres	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**2016**	Growth rate per annum 2016	Growth rate per annum 2005-15	Share 2016
US	623.4	614.4	654.2	659.1	648.7	682.1	693.1	723.2	740.6	753.0	773.2	**778.6**	0.4%	2.2%	22.0%
Canada	97.8	96.9	96.2	96.1	94.9	95.0	100.9	100.2	103.9	104.2	102.5	**99.9**	-2.8%	0.5%	2.8%
Mexico	60.9	66.6	63.4	66.3	72.2	72.5	76.6	79.9	83.3	86.8	87.1	**89.5**	2.5%	3.6%	2.5%
Total North America	**782.1**	**778.0**	**813.8**	**821.5**	**815.9**	**849.6**	**870.6**	**903.3**	**927.8**	**944.1**	**962.8**	**968.0**	**0.3%**	**2.1%**	**27.3%**
Argentina	40.4	41.8	43.9	44.4	42.1	43.3	45.1	46.7	46.7	47.2	48.2	**49.6**	2.7%	1.8%	1.4%
Brazil	19.6	20.6	21.2	24.9	20.1	26.8	26.7	31.7	37.3	39.5	41.7	**36.6**	-12.5%	7.9%	1.0%
Venezuela	27.4	31.5	36.2	34.3	32.3	32.2	29.7	31.4	30.5	30.7	34.5	**35.6**	2.7%	2.3%	1.0%
Total S. & Cent. America	**123.4**	**135.5**	**142.6**	**143.4**	**136.7**	**150.2**	**150.5**	**159.6**	**165.2**	**168.9**	**175.8**	**171.9**	**-2.5%**	**3.6%**	**4.9%**
France	45.6	44.0	42.8	44.3	42.7	47.3	41.1	42.5	43.1	36.2	38.9	**42.6**	9.0%	-1.6%	1.2%
Germany	86.3	87.9	84.7	85.5	80.7	84.1	77.3	77.5	81.2	70.6	73.5	**80.5**	9.2%	-1.6%	2.3%
Italy	79.1	77.4	77.3	77.2	71.0	75.6	70.9	68.2	63.8	56.3	61.4	**64.5**	4.7%	-2.5%	1.8%
Netherlands	39.6	38.0	36.9	38.5	38.9	43.6	38.1	36.0	36.5	31.8	31.5	**33.6**	6.4%	-2.3%	0.9%
Russian Federation	394.0	415.0	422.0	416.0	389.6	414.1	424.6	416.2	413.5	409.7	402.8	**390.9**	-3.2%	0.2%	11.0%
Turkey	26.9	30.5	36.1	37.5	35.7	39.0	40.9	41.4	42.0	44.6	43.6	**42.1**	-3.7%	5.0%	1.2%
United Kingdom	94.9	90.0	91.0	93.8	87.0	94.2	78.1	73.9	73.0	66.7	68.1	**76.7**	12.2%	-3.3%	2.2%
Uzbekistan	42.7	41.9	45.9	48.7	39.9	40.8	47.6	47.2	46.8	48.8	50.2	**51.4**	2.0%	1.6%	1.4%
Total Europe & Eurasia	**1092.2**	**1114.8**	**1123.8**	**1132.2**	**1041.3**	**1118.4**	**1092.8**	**1074.0**	**1054.4**	**1005.6**	**1010.2**	**1029.9**	**1.7%**	**-0.8%**	**29.1%**
Iran	102.7	112.0	125.5	133.2	142.7	152.9	162.2	161.5	162.9	183.7	190.8	**200.8**	5.0%	6.4%	5.7%
Qatar	18.6	19.2	23.5	19.3	20.8	29.8	19.6	23.4	37.9	36.4	43.9	**41.7**	-5.4%	9.0%	1.2%
Saudi Arabia	71.2	73.5	74.4	80.4	78.5	87.7	92.3	99.3	100.0	102.4	104.5	**109.4**	4.4%	3.9%	3.1%
United Arab Emirates	42.1	43.4	49.2	59.5	59.1	60.8	63.2	65.6	66.9	65.9	73.8	**76.6**	3.6%	5.8%	2.2%
Total Middle East	**279.2**	**296.3**	**321.7**	**347.3**	**359.1**	**396.5**	**403.4**	**415.0**	**440.3**	**460.8**	**493.6**	**512.3**	**3.5%**	**5.9%**	**14.5%**
Algeria	23.2	23.7	24.3	25.4	27.2	26.3	27.8	31.0	33.4	37.5	39.4	**40.0**	1.2%	5.4%	1.1%
Egypt	31.6	36.5	38.4	40.8	42.5	45.1	49.6	52.6	51.4	48.0	47.8	**51.3**	7.0%	4.2%	1.4%
Total Africa	**85.0**	**89.6**	**96.7**	**100.7**	**99.5**	**106.4**	**113.3**	**120.6**	**123.2**	**127.0**	**135.8**	**138.2**	**1.4%**	**4.8%**	**3.9%**
Australia	22.5	25.1	28.1	27.9	29.1	31.1	33.7	33.8	35.5	38.3	42.9	**41.1**	-4.4%	6.6%	1.2%
China	48.2	59.3	73.0	84.1	92.6	111.2	137.1	150.9	171.9	188.4	194.8	**210.3**	7.7%	15.0%	5.9%
India	35.7	37.3	40.3	41.5	50.7	60.3	61.1	71.1	49.3	48.8	45.7	**50.1**	9.2%	2.5%	1.4%
Indonesia	35.9	36.6	34.1	39.1	41.5	43.4	42.1	42.2	40.8	40.9	40.4	**37.7**	-7.0%	1.2%	1.1%
Japan	78.6	83.7	90.2	93.7	87.4	94.5	105.5	116.9	116.9	118.0	113.4	**111.2**	-2.2%	3.7%	3.1%
Malaysia	34.9	35.3	35.5	39.2	35.4	29.6	34.8	35.5	40.3	42.2	41.8	**43.0**	2.7%	1.8%	1.2%
Pakistan	39.1	39.9	40.5	41.4	41.6	42.3	42.3	43.8	42.6	41.9	43.5	**45.5**	4.2%	1.1%	1.3%
South Korea	30.4	32.0	34.7	35.7	33.9	43.0	46.3	50.2	52.5	47.8	43.6	**45.5**	4.0%	3.7%	1.3%
Thailand	30.6	31.5	33.6	35.3	36.4	41.3	42.3	46.5	46.7	47.7	48.7	**48.3**	-1.0%	4.7%	1.4%
Total Asia Pacific	**406.5**	**436.5**	**468.7**	**499.8**	**513.3**	**566.4**	**615.4**	**665.1**	**672.9**	**694.4**	**701.8**	**722.5**	**2.7%**	**5.6%**	**20.4%**
Total World	**2768.4**	**2850.6**	**2967.3**	**3044.9**	**2965.9**	**3187.6**	**3245.9**	**3337.7**	**3383.8**	**3400.8**	**3480.1**	**3542.9**	**1.5%**	**2.3%**	**100.0%**

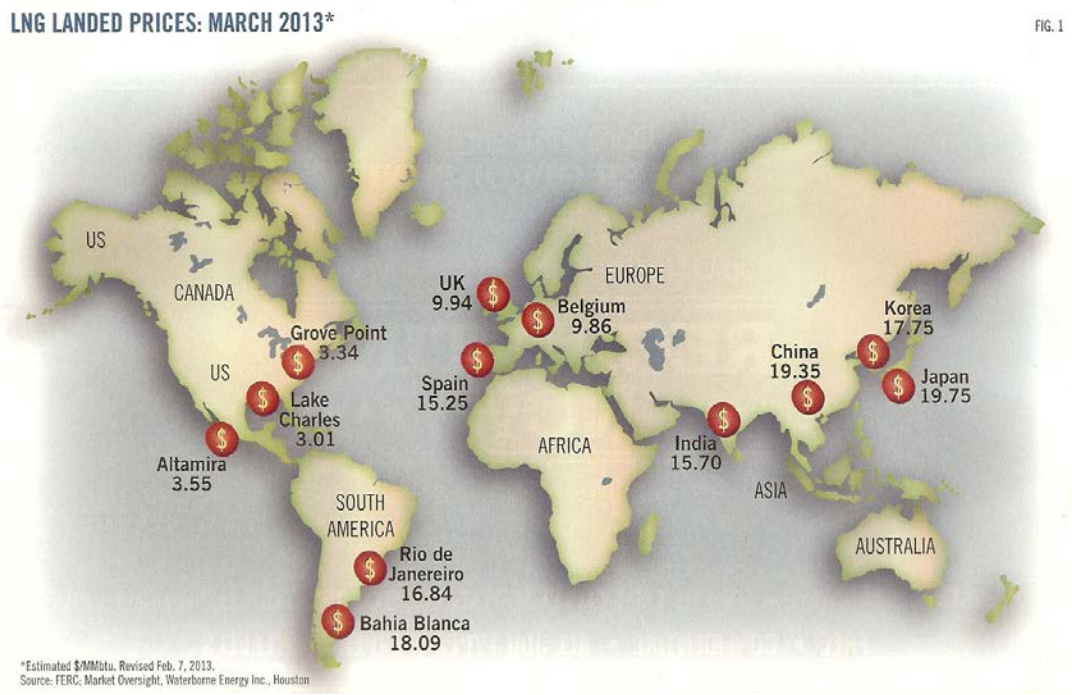
Source: BP Statistical Review of World Energy 2017

Natural Gas Reserves & R/P – 2016

Natural gas Total proved reserves	at end 1996 Trillion cubic metres	at end 2006 Trillion cubic metres	at end 2015 Trillion cubic metres	at end 2016 Trillion cubic metres	 Trillion cubic feet	 Share of total	 R/P ratio
US	4.7	6.0	8.7	**8.7**	**307.7**	4.7%	11.6
Canada	1.9	1.6	2.2	**2.2**	**76.7**	1.2%	14.3
Total North America	**8.5**	**8.0**	**11.1**	**11.1**	**393.0**	**6.0%**	**11.7**
Venezuela	4.1	4.7	5.7	**5.7**	**201.3**	3.1%	166.3
Total S. & Cent. America	**6.0**	**7.2**	**7.7**	**7.6**	**268.0**	**4.1%**	**42.9**
Azerbaijan	n/a	0.9	1.1	**1.1**	**40.6**	0.6%	65.8
Norway	1.5	2.3	1.9	**1.8**	**62.3**	0.9%	15.1
Russian Federation	30.9	31.2	32.3	**32.3**	**1139.6**	17.3%	55.7
Turkmenistan	n/a	2.3	17.5	**17.5**	**617.3**	9.4%	261.7
Total Europe & Eurasia	**39.8**	**42.8**	**56.8**	**56.7**	**2002.0**	**30.4%**	**56.7**
Iran	23.0	26.9	33.5	**33.5**	**1183.0**	18.0%	165.5
Iraq	3.4	3.2	3.7	**3.7**	**130.5**	2.0%	*
Kuwait	1.5	1.8	1.8	**1.8**	**63.0**	1.0%	104.2
Qatar	8.5	25.5	24.3	**24.3**	**858.1**	13.0%	134.1
Saudi Arabia	5.7	7.1	8.4	**8.4**	**297.6**	4.5%	77.0
United Arab Emirates	5.8	6.4	6.1	**6.1**	**215.1**	3.3%	98.5
Total Middle East	**49.2**	**72.6**	**79.4**	**79.4**	**2803.2**	**42.5%**	**124.5**
Algeria	3.7	4.5	4.5	**4.5**	**159.1**	2.4%	49.3
Egypt	0.8	2.0	1.8	**1.8**	**65.2**	1.0%	44.1
Libya	1.3	1.4	1.5	**1.5**	**53.1**	0.8%	149.2
Nigeria	3.5	5.2	5.3	**5.3**	**186.6**	2.8%	117.7
Total Africa	**10.2**	**14.4**	**14.2**	**14.3**	**503.3**	**7.6%**	**68.4**
Australia	1.3	2.3	3.5	**3.5**	**122.6**	1.9%	38.1
China	1.2	1.7	4.8	**5.4**	**189.5**	2.9%	38.8
India	0.6	1.1	1.3	**1.2**	**43.3**	0.7%	44.4
Indonesia	2.0	2.6	2.8	**2.9**	**101.2**	1.5%	41.1
Malaysia	2.4	2.5	1.2	**1.2**	**41.3**	0.6%	15.8
Myanmar	0.3	0.5	0.5	**1.2**	**42.0**	0.6%	63.0
Total Asia Pacific	**9.9**	**13.2**	**16.2**	**17.5**	**619.3**	**9.4%**	**30.2**
Total World	**123.5**	**158.2**	**185.4**	**186.6**	**6588.8**	**100.0%**	**52.5**

Source: BP Statistical Review of World Energy 2017

Natural Gas Prices – March 2013



Demand:

Japan

- Fukushima = Japan 36% WW LNG
- Oil-price-linked formula

China

- Demand Growth
- Oil-price-linked formula

Europe

- Concern over Russian dependency
- Oil-price-linked formula
- UK declining indigenous supply

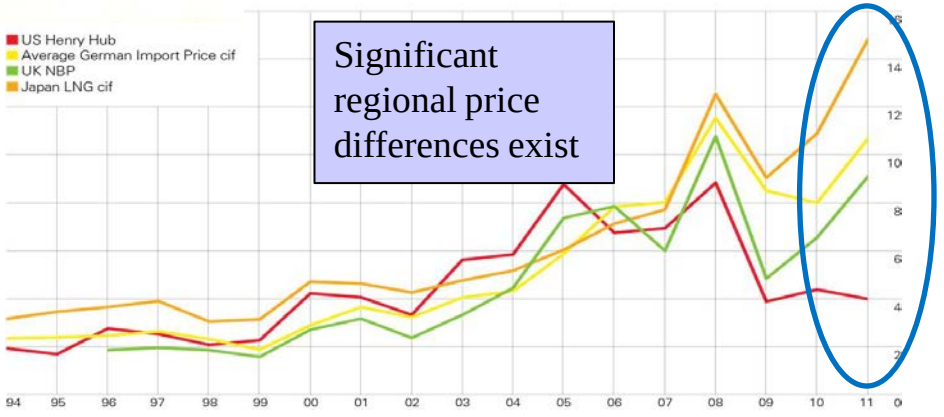
Supply:

North America

- Significant shale resource
- Significant associated gas production

Australia & East Africa

- Project cost/timing uncertainties



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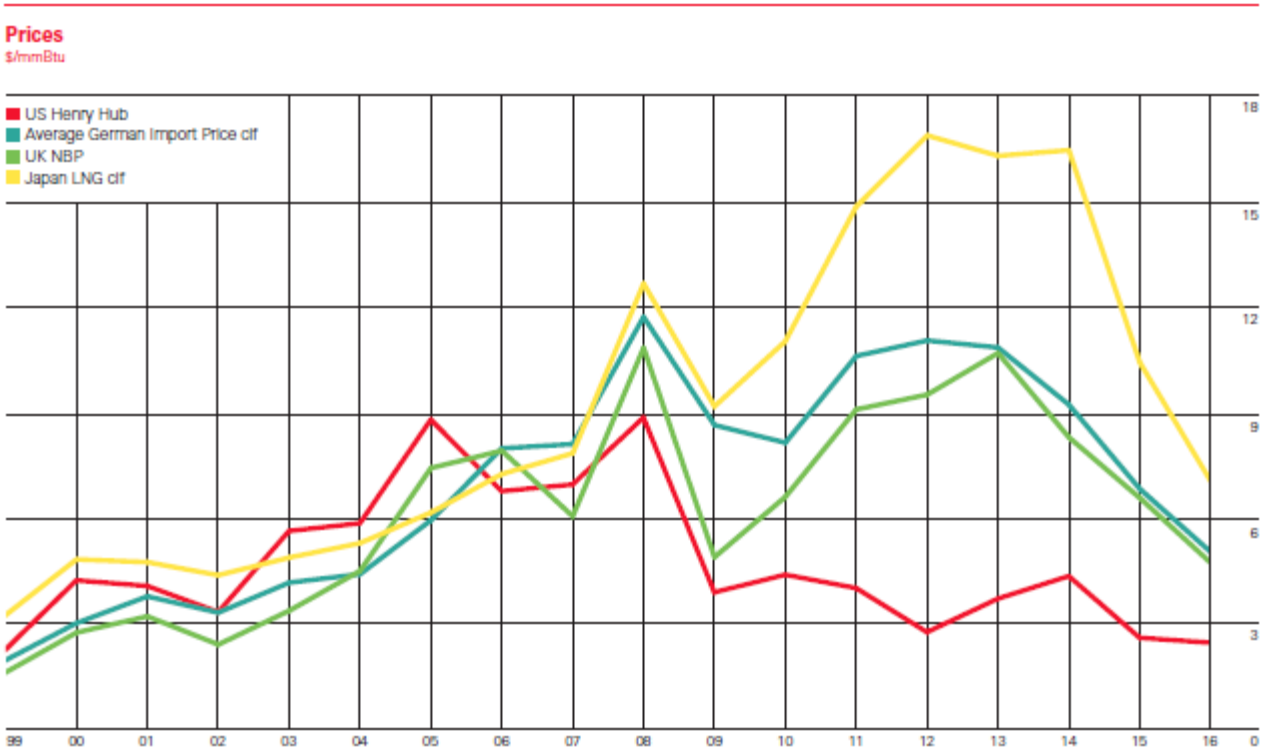
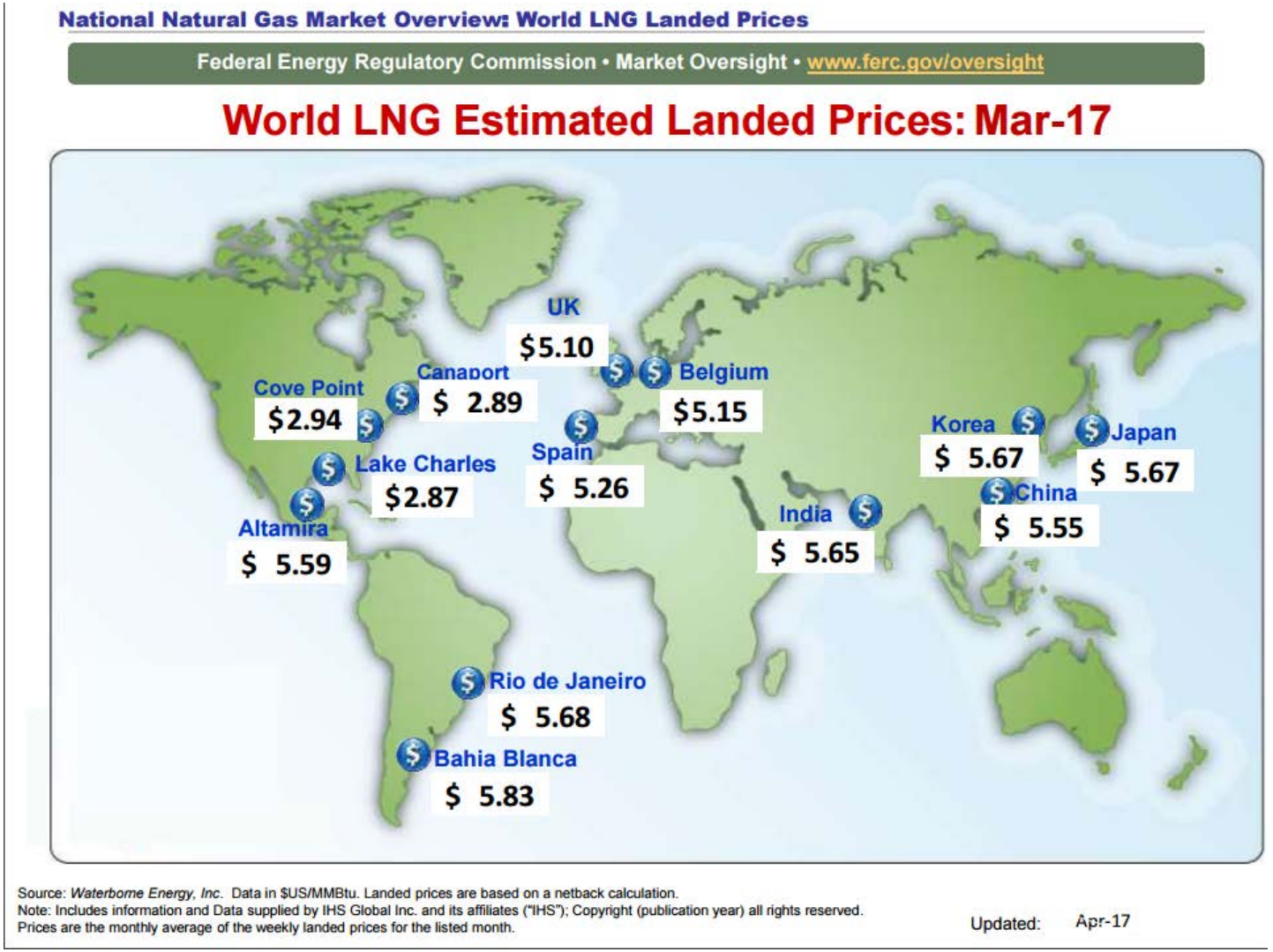
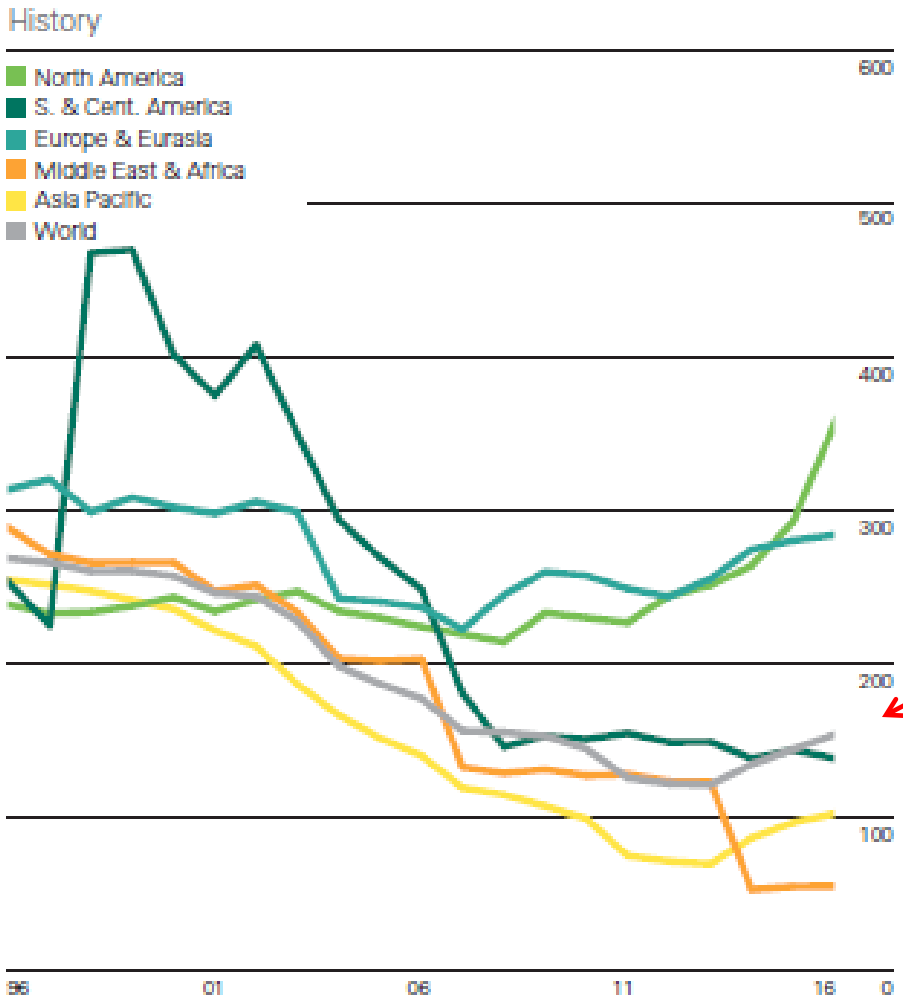


Source: BP Statistical Review of World Energy 2017

LNG Landed Prices – March 2017



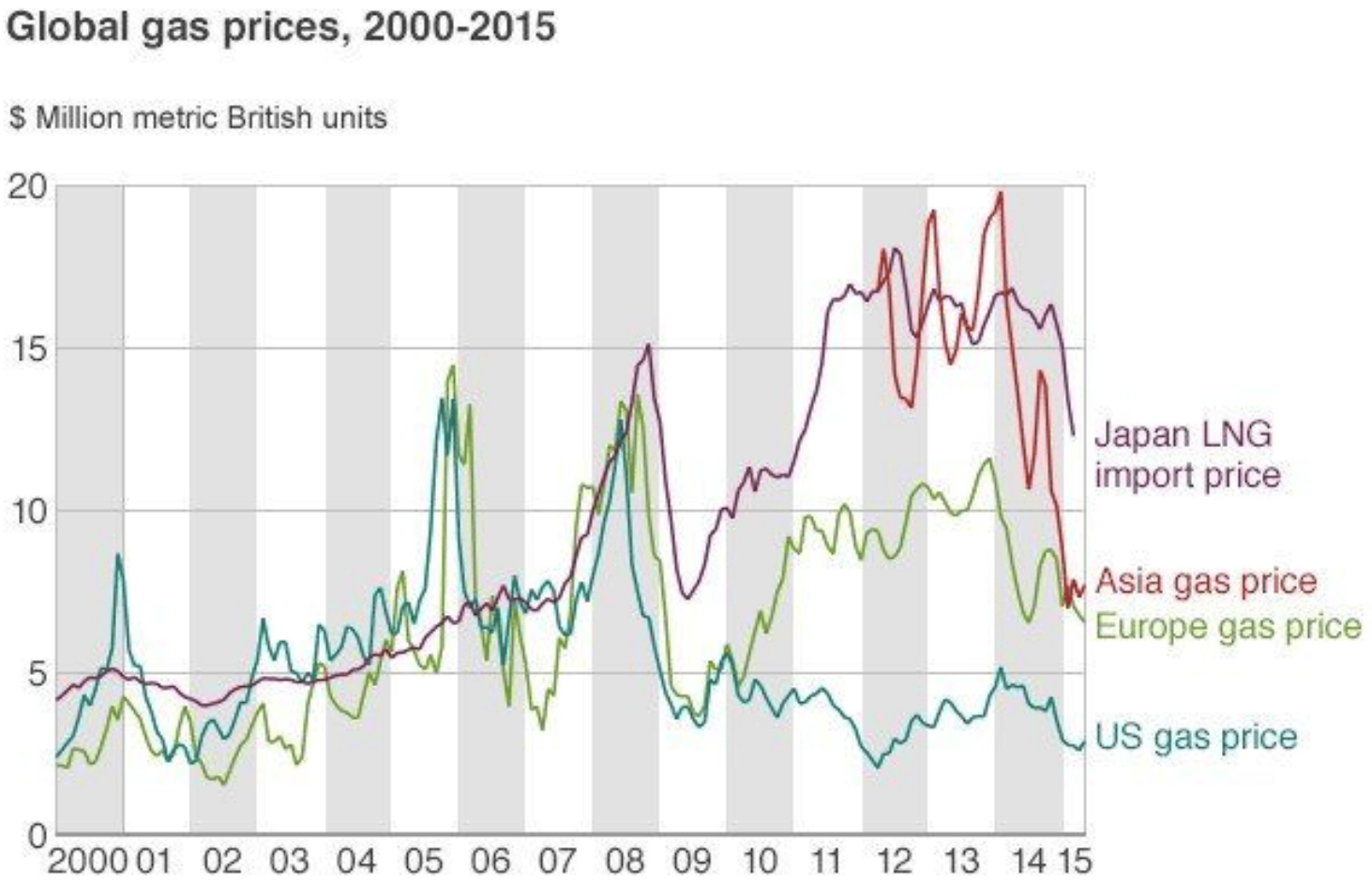
Natural Gas Reserves to Production Ratio -2016



150 Year Supply Worldwide

Source: BP Statistical Review of World Energy 2017

Natural Gas Prices



Source: Bloomberg, Argus LNG

BBC

Prices

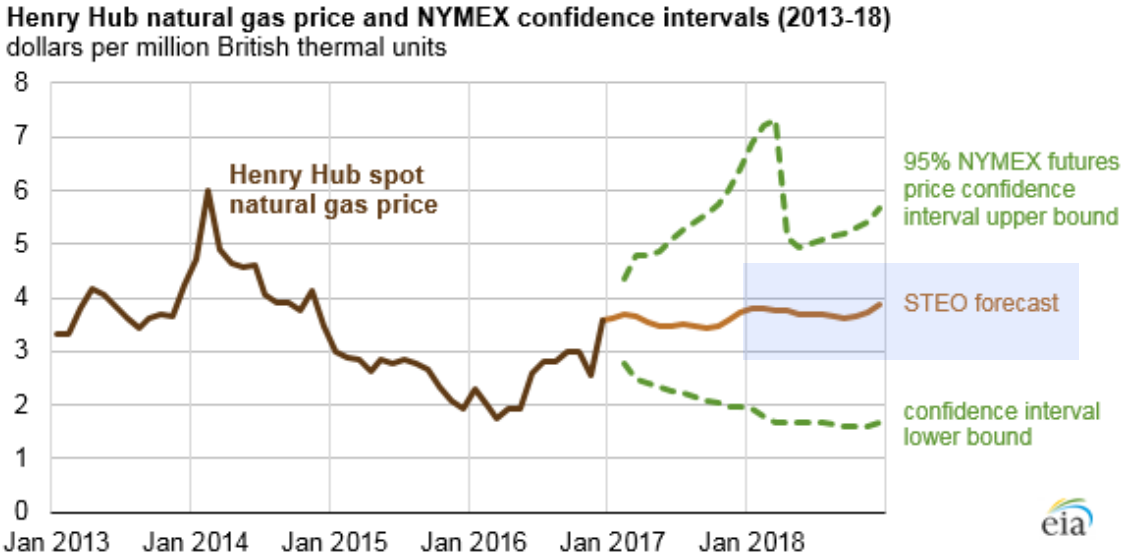
US dollars per million Btu	LNG Japan cif	Natural gas: Average German Import Price*	Natural gas: UK (Heren NBP Index)†	Natural gas: US Henry Hub‡	Natural gas: Canada (Alberta)‡	Crude oil OECD countries cif
1986	4.10	3.93	–	–	–	2.57
1987	3.35	2.55	–	–	–	3.09
1988	3.34	2.22	–	–	–	2.56
1989	3.28	2.00	–	1.70	–	3.01
1990	3.64	2.78	–	1.64	1.05	3.82
1991	3.99	3.23	–	1.49	0.89	3.33
1992	3.62	2.70	–	1.77	0.98	3.19
1993	3.52	2.51	–	2.12	1.69	2.82
1994	3.18	2.35	–	1.92	1.45	2.70
1995	3.46	2.43	–	1.69	0.99	2.96
1996	3.66	2.50	1.87	2.76	1.12	3.54
1997	3.91	2.66	1.96	2.53	1.36	3.29
1998	3.05	2.33	1.86	2.08	1.42	2.16
1999	3.14	1.86	1.58	2.27	2.00	2.98
2000	4.72	2.91	2.71	4.23	3.75	4.83
2001	4.64	3.67	3.17	4.07	3.61	4.08
2002	4.27	3.21	2.37	3.33	2.57	4.17
2003	4.77	4.06	3.33	5.63	4.83	4.89
2004	5.18	4.30	4.46	5.85	5.03	6.27
2005	6.05	5.83	7.38	8.79	7.25	8.74
2006	7.14	7.87	7.87	6.76	5.83	10.66
2007	7.73	7.99	6.01	6.95	6.17	11.95
2008	12.55	11.60	10.79	8.85	7.99	16.76
2009	9.06	8.53	4.85	3.99	3.38	10.41
2010	10.91	8.03	6.56	4.39	3.69	13.47
2011	14.73	10.49	9.04	4.01	3.47	18.56
2012	16.75	10.93	9.46	2.76	2.27	18.82
2013	16.17	10.73	10.64	3.71	2.93	18.25
2014	16.33	9.11	8.25	4.35	3.97	16.80
2015	10.31	6.72	6.53	2.60	2.01	9.77
2016	6.94	4.93	4.69	2.46	1.55	7.04

*Source: 1986-1990 German Federal Statistical Office, 1991-2016 German Federal Office of Economics and Export Control (BAFA).
†Source: ICIS Heren Energy Ltd.
‡Source: Energy Intelligence Group, *Natural Gas Week*.
Note: cif = cost+insurance+freight (average prices).

Source: BP Statistical Review of World Energy 2017

January 2017 Short-Term Energy Outlook

- **EIA Henry Hub natural gas spot price forecast**
  - 2016 average $2.51/mmBtu.
  - 2017 (e) $3.55/mmBtu
  - 2018 (e) $3.73/mmBtu
- **United States is expected to become a net exporter of natural gas on an annual basis in 2018.**
  - Export growth in 2017 largely reflects additional capacity coming online at Cheniere's Sabine Pass liquefied natural gas (LNG) liquefaction plant in Louisiana.
  - The 2018 growth is driven by the expected start of Cove Point LNG in Maryland in December 2017 and new projects at Cameron LNG and Freeport LNG on the U.S. Gulf Coast during the second half of 2018.
  - A small increase in pipeline exports to Mexico is expected in both years.



LNG - 2025

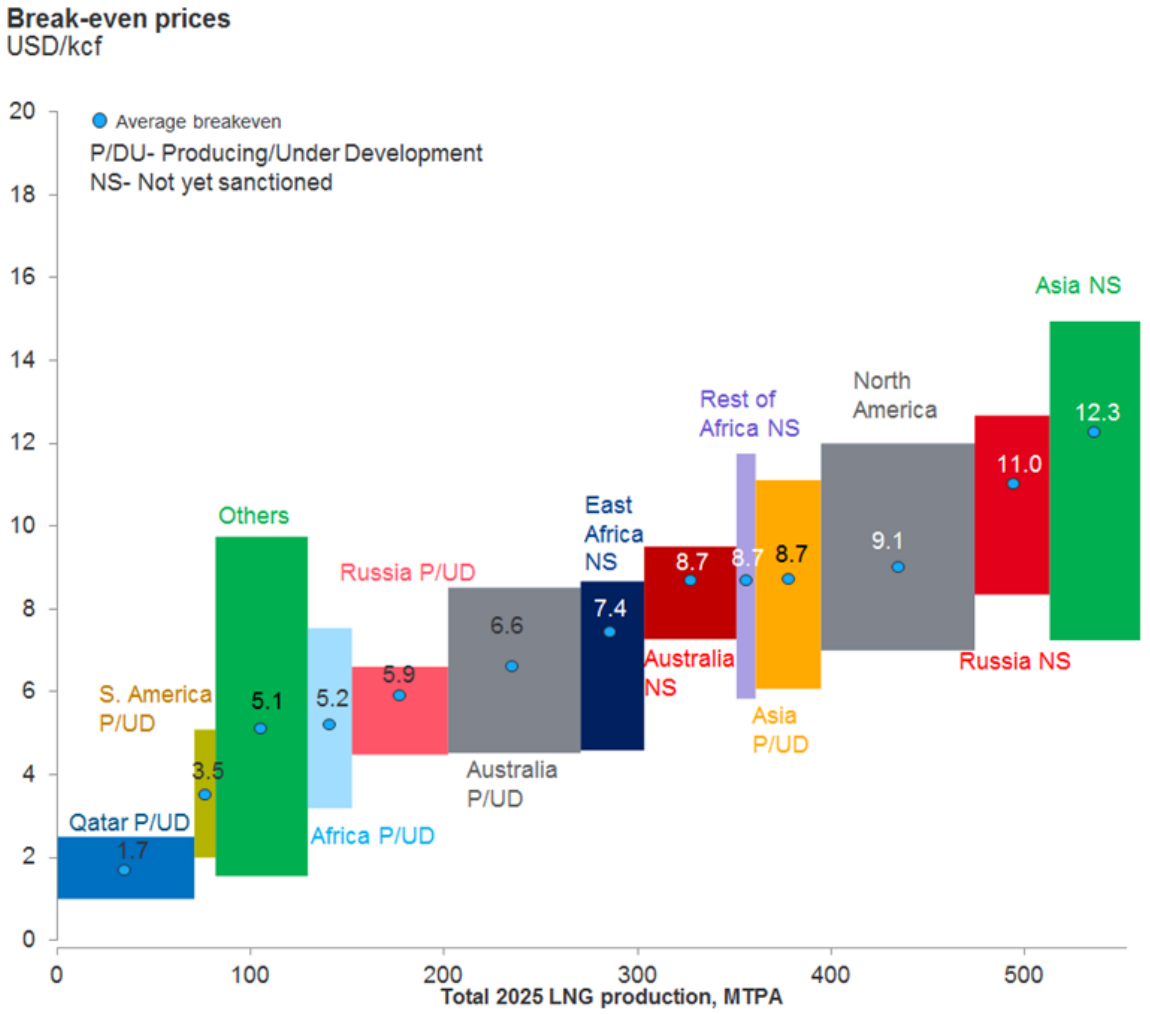


Figure 4: Global LNG Cost of supply curve for differences sources (Source: UCube from Rystad Energy)

U. S. Dry Gas Supply Curve

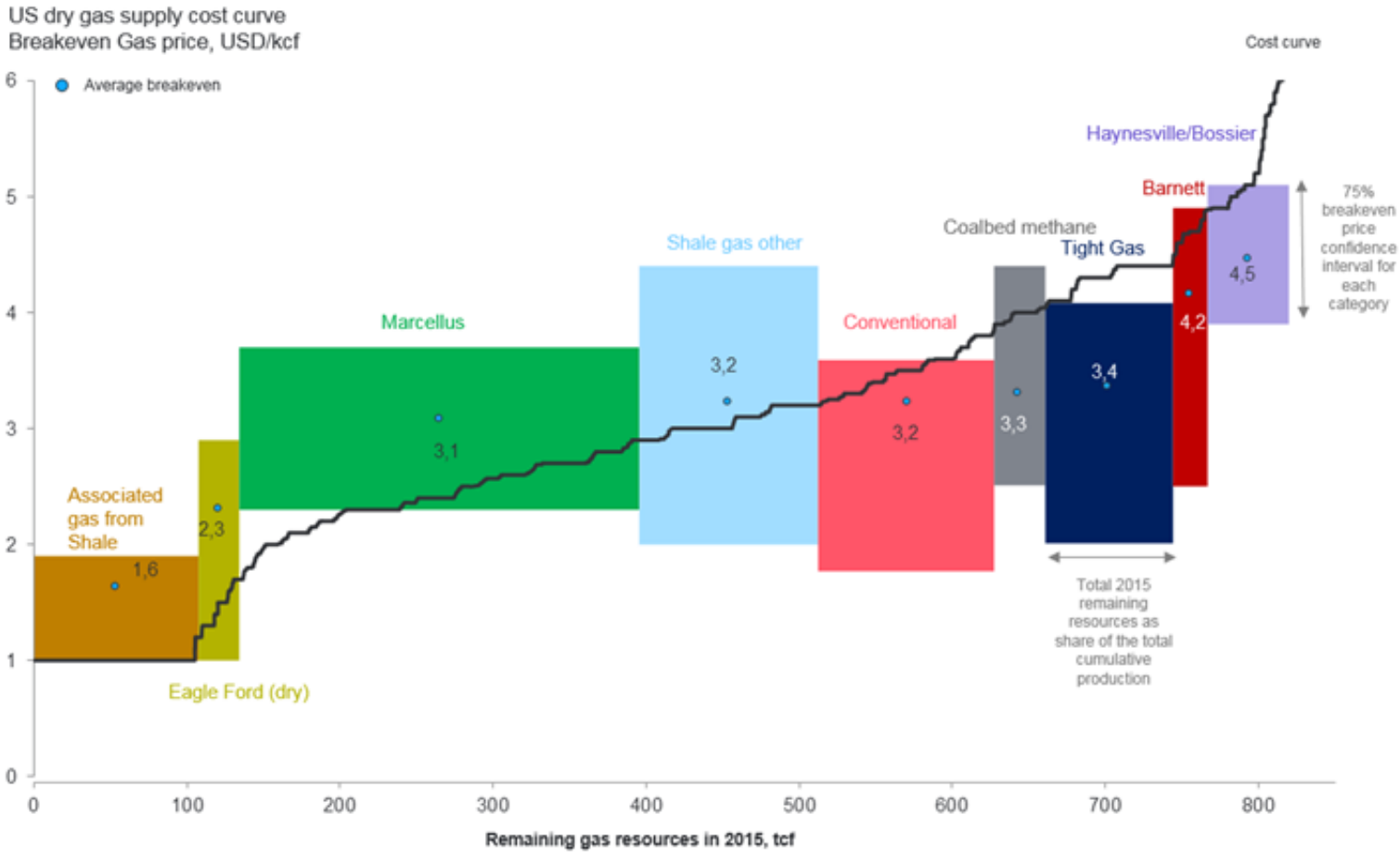
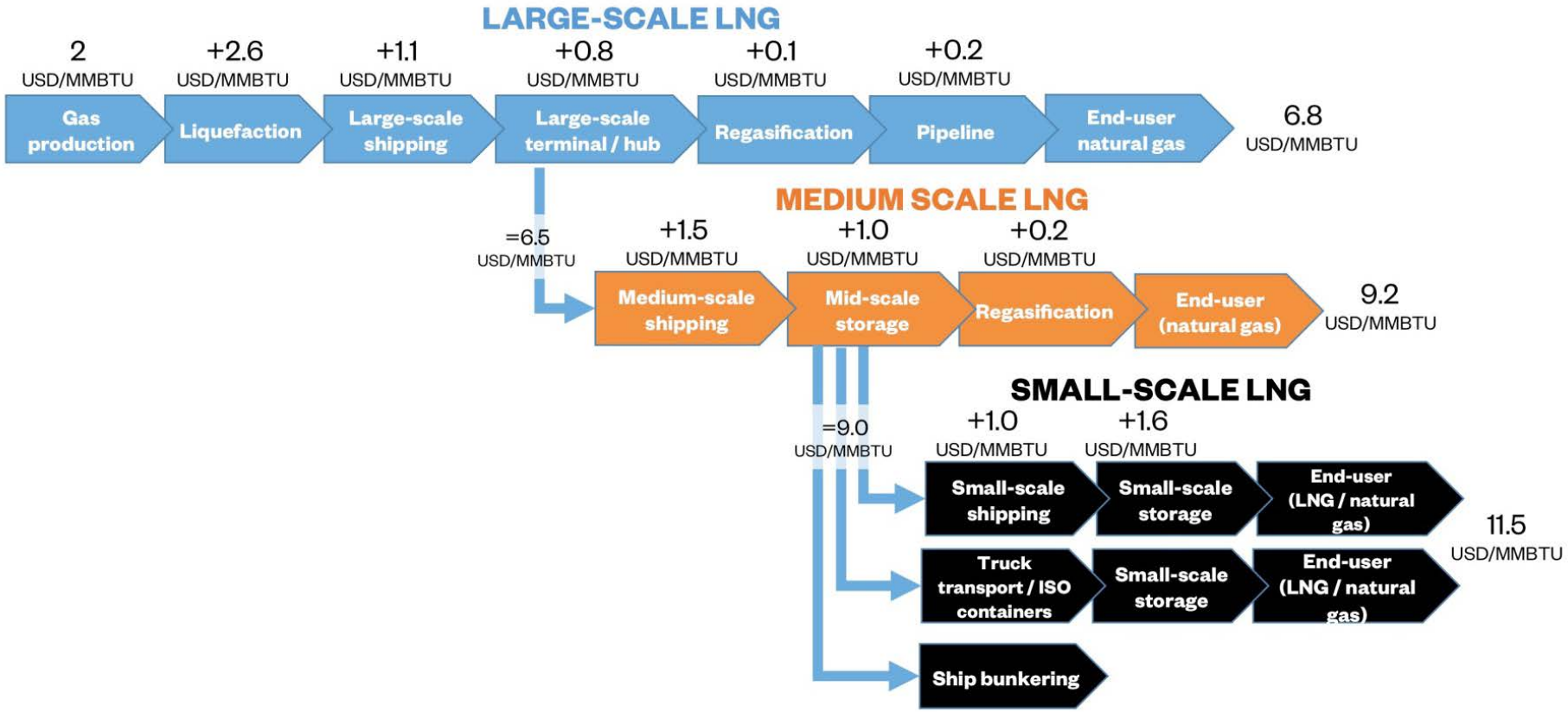


Figure 3: US dry gas supply curve, based on 2015 remaining resources. Source Rystad Energy UCube and analysis

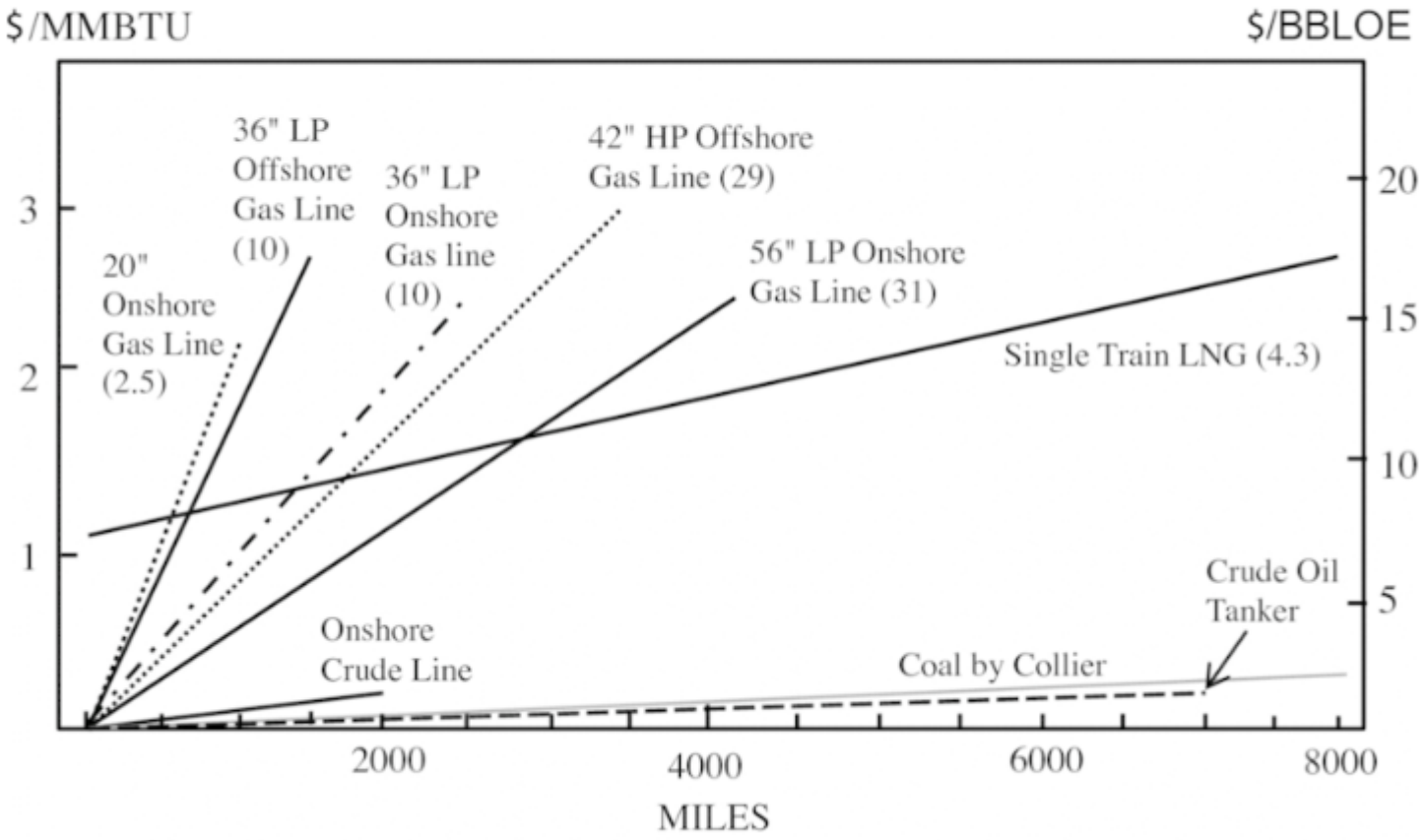
LNG Value Chain



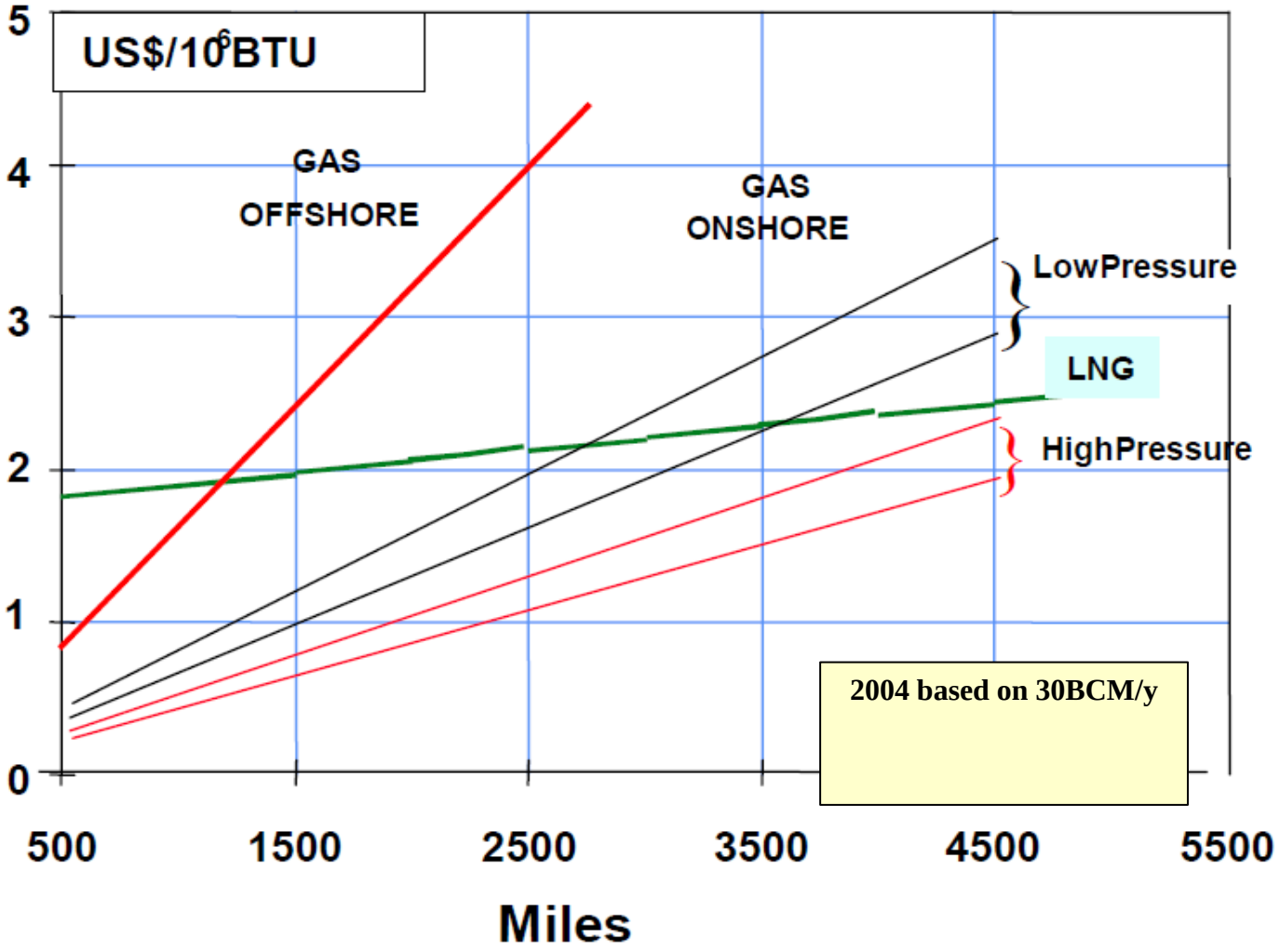
Wärtsilä Technical Journal October 20, 2016

Jensen 2004 Break-even Points

Figure 1 Break-even points. Source of data: [6]6. Jensen , J. 2004. The Development of a Global LNG Market. Is it Likely? If So, When?, Oxford: Oxford Institute for Energy Studies. View all references.



Note: Figures in brackets show gas delivery capability in BCM


US$/10⁶BTU
GAS
OFFSHORE
GAS
ONSHORE
LowPressure
LNG
HighPressure
2004 based on 30BCM/y
5
4
3
2
1
0
500
1500
2500
3500
4500
5500
Miles

Natural Gas Trade – 1034.5 BCM

Pipeline trade grew 4.0%
LNG trade grew 6.5%
Consumption grew 1.5%

Gas Trade in 2015 and 2016 in billion cubic metres

Billion cubic metres	2015				2016			
	Pipeline imports	LNG imports	Pipeline exports	LNG exports	Pipeline imports	LNG imports	Pipeline exports	LNG exports
US	74.4	2.6	49.1	0.7	82.5	2.5	60.3	4.4
Canada	19.2	0.6	74.3	†	21.9	0.3	82.4	†
Mexico	29.9	7.3	†	-	38.4	5.9	†	-
Trinidad and Tobago	-	-	-	16.9	-	-	-	14.3
Other S. & Cent. America	19.9	19.8	19.9	5.1	16.8	15.5	16.8	6.1
France	31.8	6.8	-	0.6	32.3	9.7	-	1.5
Germany	102.3	-	32.7	-	99.3	-	19.3	-
Italy	55.7	5.4	0.2	-	59.4	5.7	-	-
Netherlands	33.6	2.1	47.1	1.3	38.0	1.5	52.3	0.7
Norw ay	†	-	109.6	5.9	†	-	109.8	6.3
Spain	15.2	13.1	0.5	1.8	15.0	13.2	0.6	0.2
Turkey	38.4	7.7	0.6	-	37.4	7.7	0.6	-
United Kingdom	29.0	13.1	13.4	0.3	34.1	10.5	10.0	0.5
Other Europe	94.7	6.9	13.8	1.5	100.2	8.2	15.0	1.3
Russian Federation	21.8	-	179.1	14.0	21.7	-	190.8	14.0
Ukraine	17.3	-	-	-	11.1	-	-	-
Other CIS	27.0	-	72.3	-	27.9	-	74.0	-
Qatar	-	-	20.0	101.8	-	-	20.0	104.4
Other Middle East	29.6	10.2	8.4	18.8	26.9	14.2	8.4	18.1
Algeria	-	-	26.3	16.6	-	-	37.1	15.9
Other Africa	9.0	3.7	11.0	30.0	8.8	10.2	8.5	29.6
Australia	6.4	-	-	38.1	8.3	0.1	-	56.8
China	33.6	25.8	-	-	38.0	34.3	-	-
Japan	-	110.7	-	-	-	108.5	-	-
Indonesia	-	-	9.3	20.7	-	-	8.8	21.2
South Korea	-	43.8	-	0.2	-	43.9	-	0.1
Other Asia Pacific	20.3	46.0	21.4	51.4	19.3	54.8	22.7	51.1
Total World	**709.0**	**325.5**	**709.0**	**325.5**	**737.5**	**346.6**	**737.5**	**346.6**

BCM Change 2016 vs. 2015

	Imports		exports	
	Pipeline imports	LNG imports	Pipeline exports	LNG exports
US	8.1	-†	11.3	3.7
Canada	2.7	-†	8.1	†
Mexico	8.6	-†	-†	-
Trinidad and Tobago	-	-	-	-†
Other S. & Cent. America	-†	-†	-†	0.9
France	0.5	2.8	-	0.9
Germany	-†	-	-†	-
Italy	3.7	0.2	-†	-
Netherlands	4.5	-†	5.3	-†
Norw ay	-†	-	0.1	0.4
Spain	-†	0.1	0.1	-†
Turkey	-†	†	†	-
United Kingdom	5.2	-†	-†	0.3
Other Europe	5.5	1.3	1.2	-†
Russian Federation	-†	-	11.7	-†
Ukraine	-†	-	-	-
Other CIS	0.9	-	1.7	-
Qatar	-	-	-†	2.7
Other Middle East	-†	3.9	-†	-†
Algeria	-	-	10.8	-†
Other Africa	-†	6.5	-†	-†
Australia	1.9	0.1	-	18.7
China	4.5	8.5	-	-
Japan	-	-†	-	-
Indonesia	-	-	-†	0.5
South Korea	-	0.2	-	-†
Other Asia Pacific	-†	8.8	1.4	-†
Total World	**28.5**	**21.1**	**28.5**	**21.1**

† Less than 0.05. Source: Includes data from FGE MENAgas service, GIIGNL, IHS Waterborne, PIRA Energy Group, Wood Mackenzie.

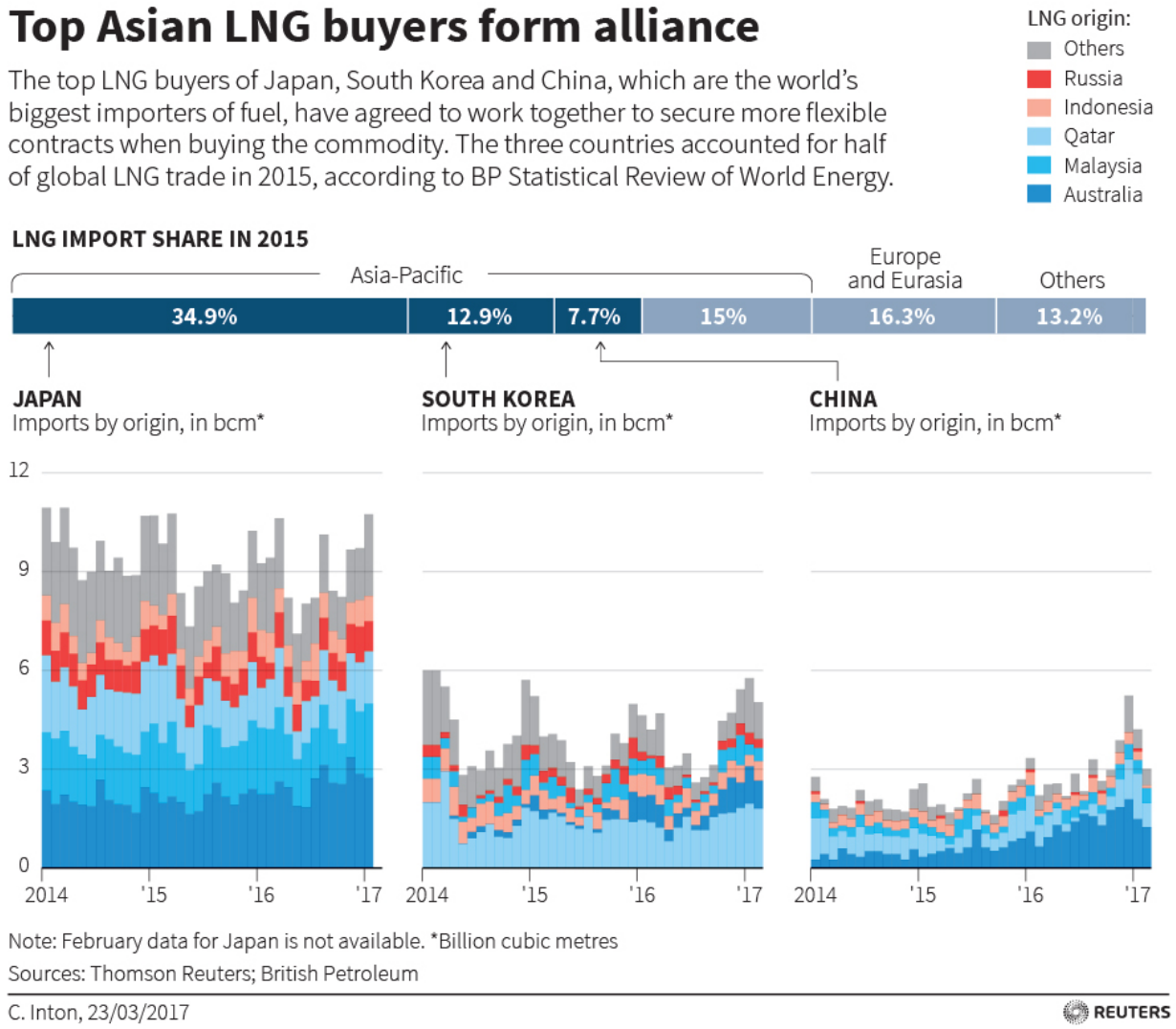
Trade represents approximately 30% of the consumption
Japan & Korea represent almost half of all LNG Imports

Source: BP Statistical Review of World Energy 2017

Changing LNG Contract Terms

Top Asian LNG buyers form alliance

The top LNG buyers of Japan, South Korea and China, which are the world's biggest importers of fuel, have agreed to work together to secure more flexible contracts when buying the commodity. The three countries accounted for half of global LNG trade in 2015, according to BP Statistical Review of World Energy.



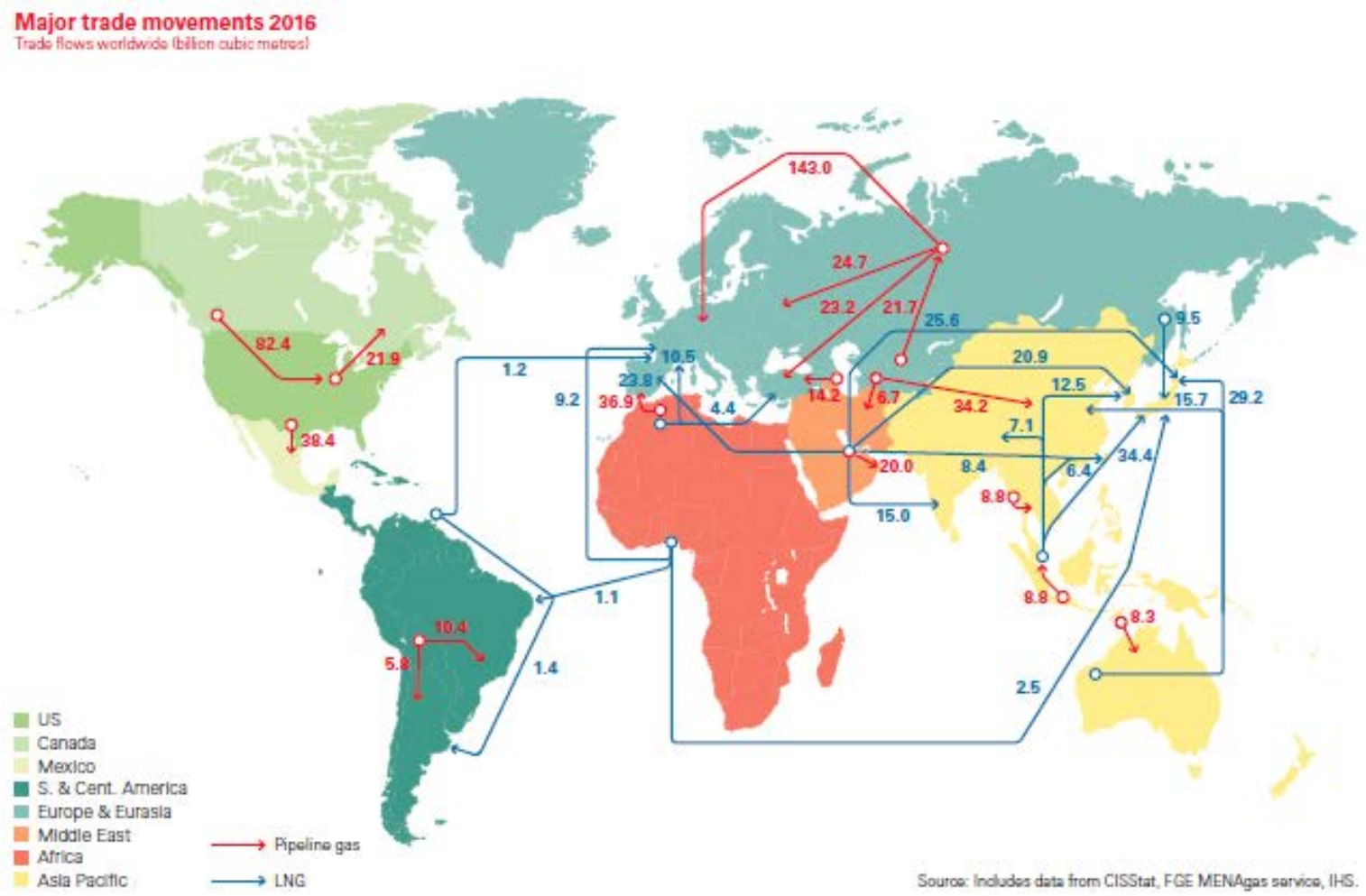
Note: February data for Japan is not available. *Billion cubic metres

Sources: Thomson Reuters; British Petroleum

C. Inton, 23/03/2017

REUTERS

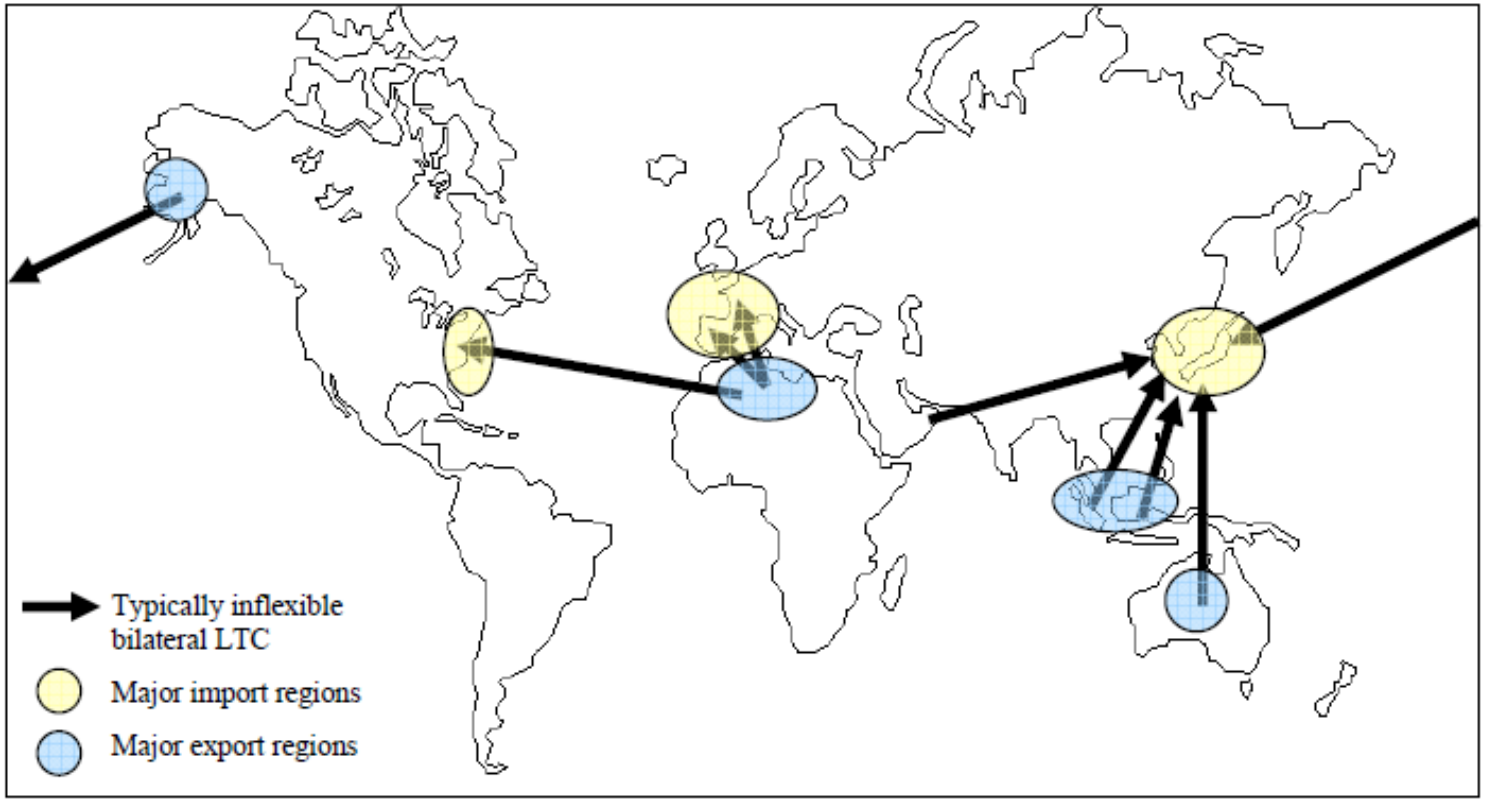
Major Natural Gas Trade Movements BCM - 2016



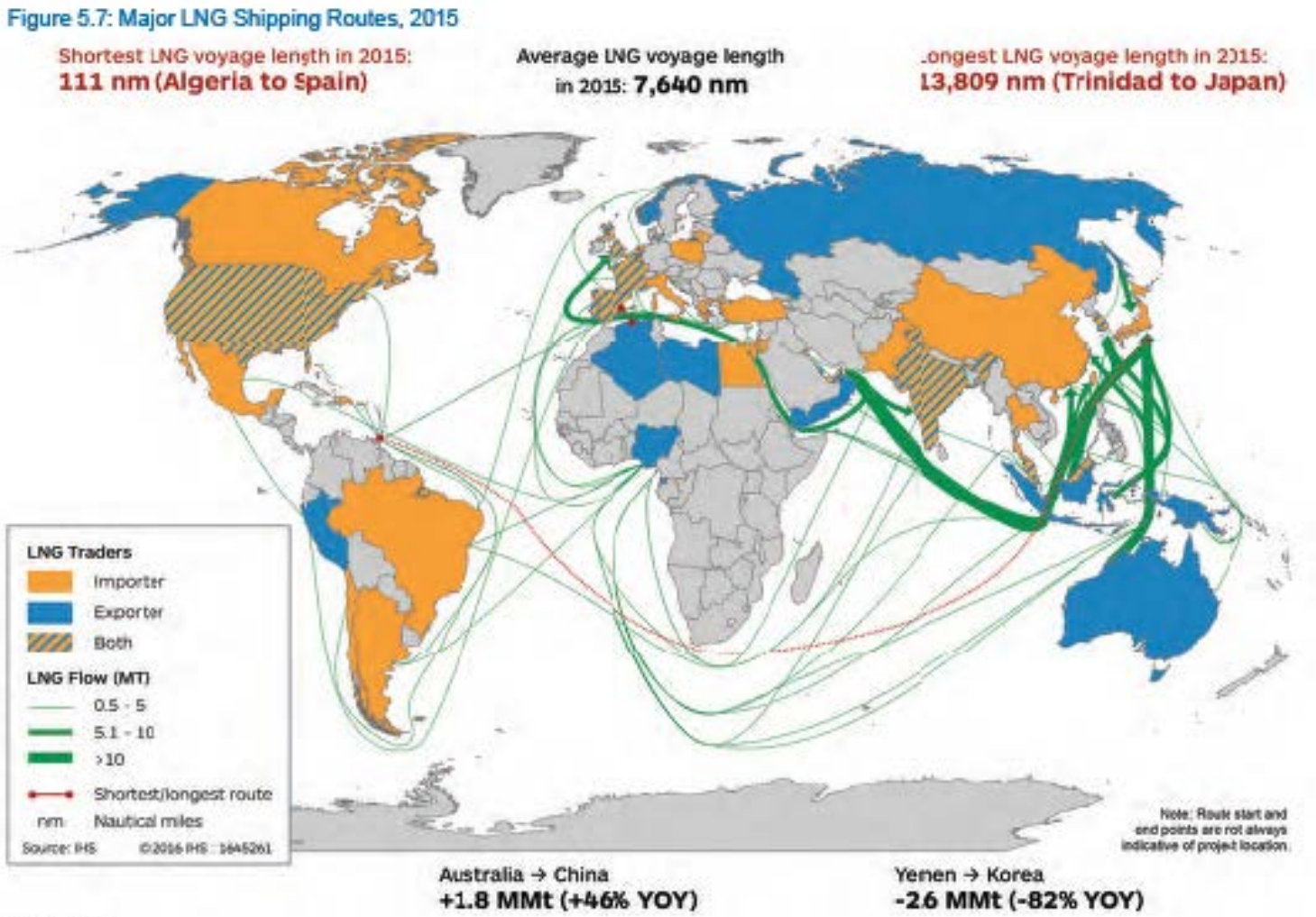
Source: BP Statistical Review of World Energy 2017

“Old World of LNG”

Figure 5: „Old world of LNG“ – bilateral relationships



Major LNG Shipping Routes



Source: IHS.

World Oil Choke Points

Table 1. Volume of crude oil and petroleum products transported through world chokepoints, 2009-13

Location	2009	2010	2011	2012	2013
Strait of Hormuz	15.7	15.9	17.0	16.9	17.0
Strait of Malacca	13.5	14.5	14.6	15.1	15.2
Suez Canal and SUMED Pipeline	3.0	3.1	3.8	4.5	4.6
Bab el-Mandab	2.9	2.7	3.4	3.7	3.8
Danish Straits	3.0	3.2	3.3	3.1	3.3
Turkish Straits	2.8	2.8	3.0	2.9	2.9
Panama Canal	0.8	0.7	0.8	0.8	0.8
World maritime oil trade	53.9	55.5	55.6	56.7	56.5
World total oil supply	84.9	87.5	87.8	89.7	90.1

- 36% of World Oil Supply
- 57% of World Maritime Oil Trade

Figure 2. Map of the Strait of Hormuz

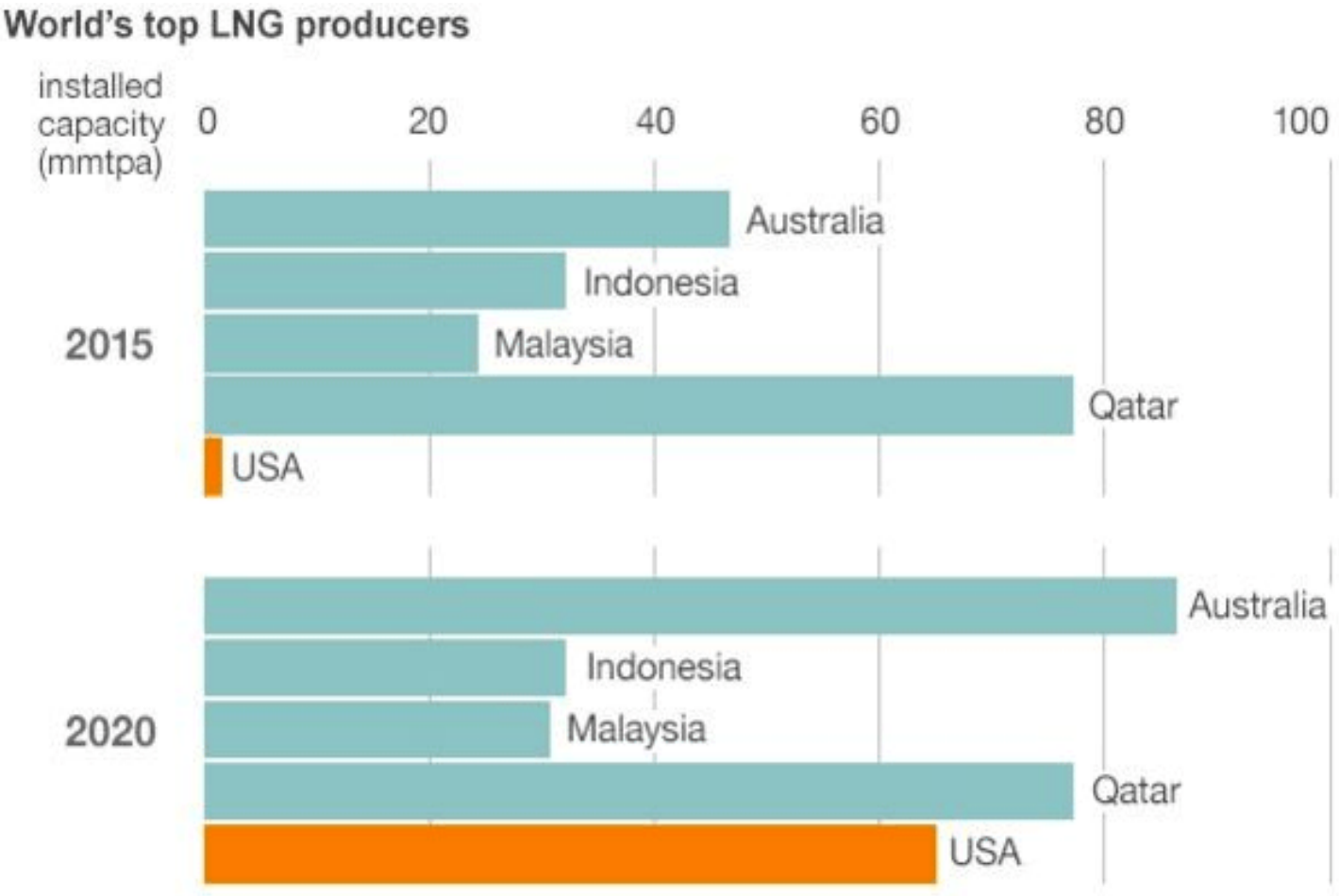
Source: U.S. Government (See full map for alternate routes)

Figure 3. Map of the Strait of Malacca

Source: CIA Factbook (See closer view of Strait of Malacca)

Gas to Market(s)

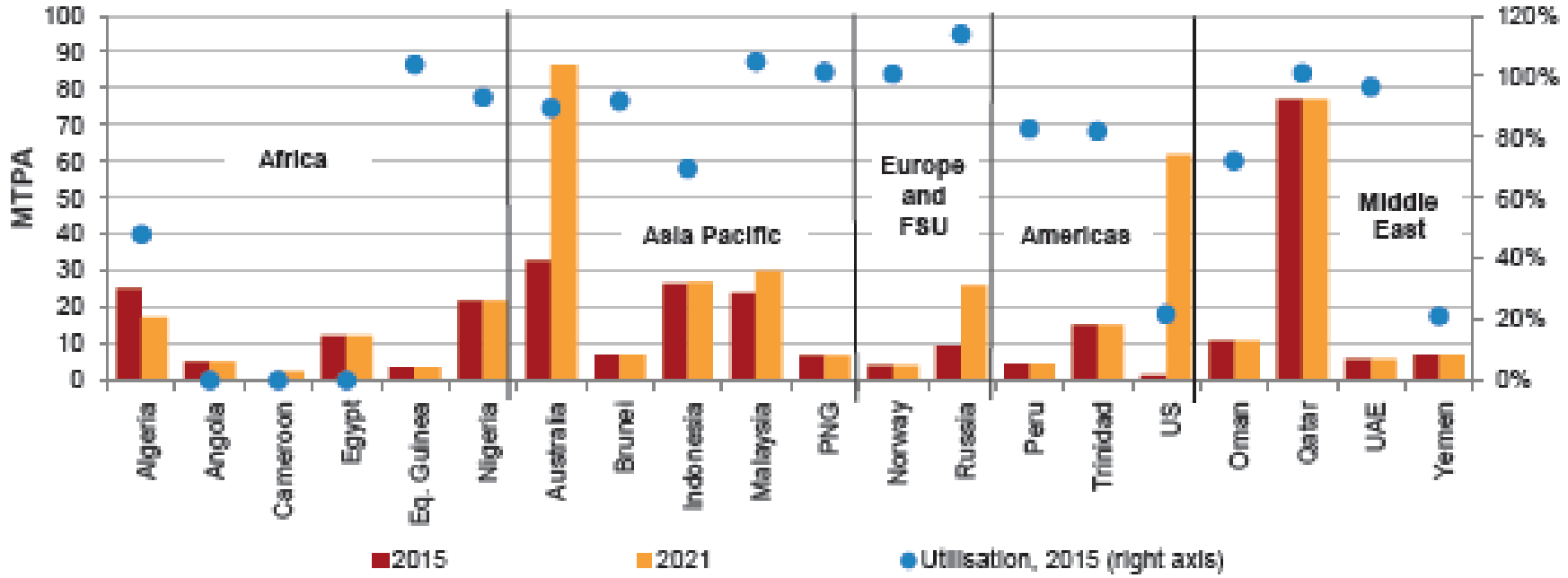
Top LNG Producers



Source: Poyry Management Consulting

LNG Capacity by Country 2015 & 2021

Figure 4.4: Nominal Liquefaction Capacity by Country in 2015 and 2021



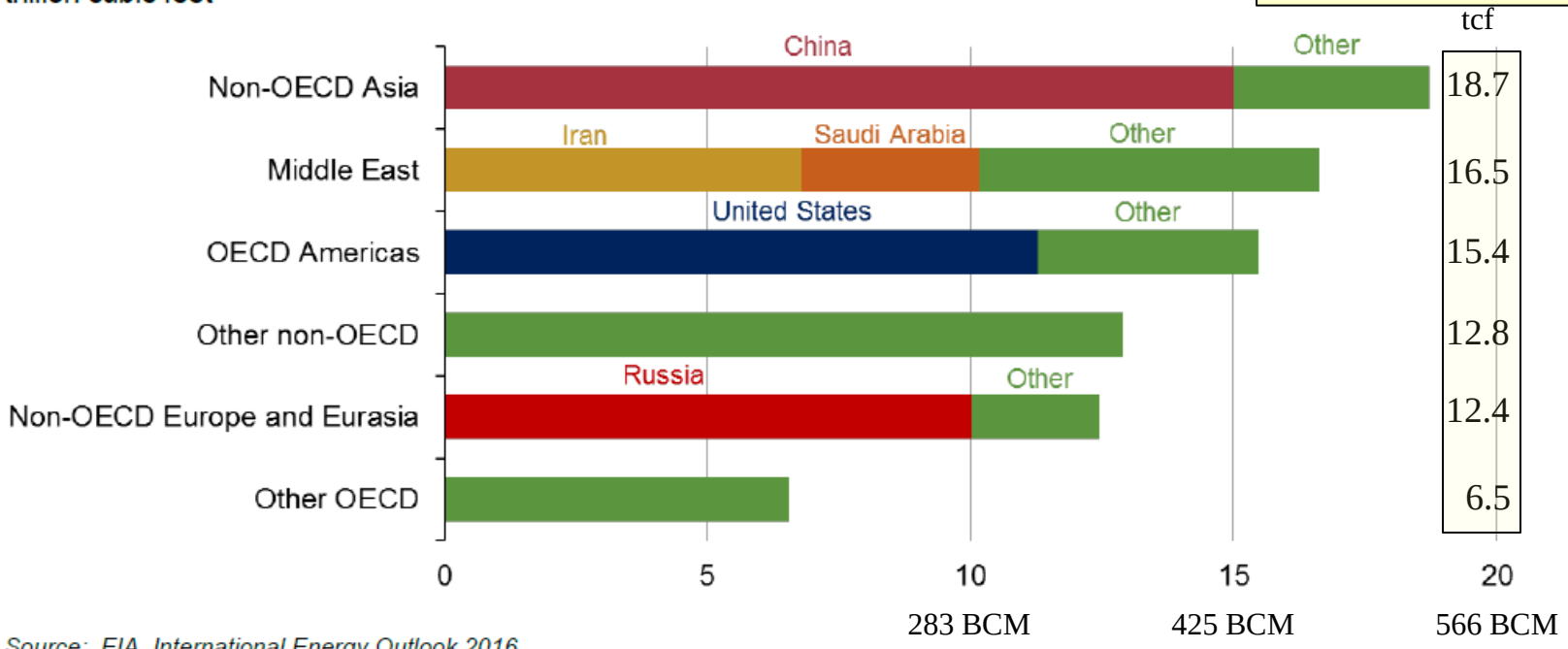
Sources: IHS, Company Announcements

World Change in Gas Production – 2012-2040

Non-OECD Asia, Middle East, and OECD Americas account for the largest increases in natural gas production

world change in natural gas production, 2012–40
trillion cubic feet

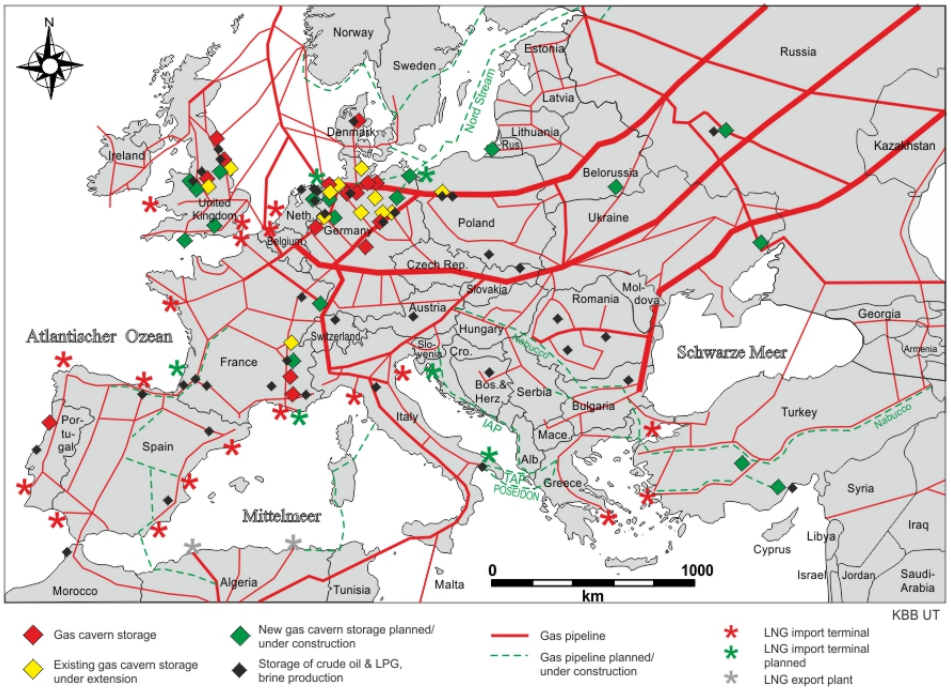
+82.3 tcf = 2330 BCM



Source: EIA, International Energy Outlook 2016

Gas to Europe - 1101 BCM Demand

- Europe/Eurasia Pipeline Imports - 470 BCM
  - Russia 208
  - Norway 93
  - The Netherlands 50
  - Algeria 33
- Europe/Eurasia LNG Imports - 91 BCM
  - Qatar 43
  - Algeria 16
  - Nigeria 16

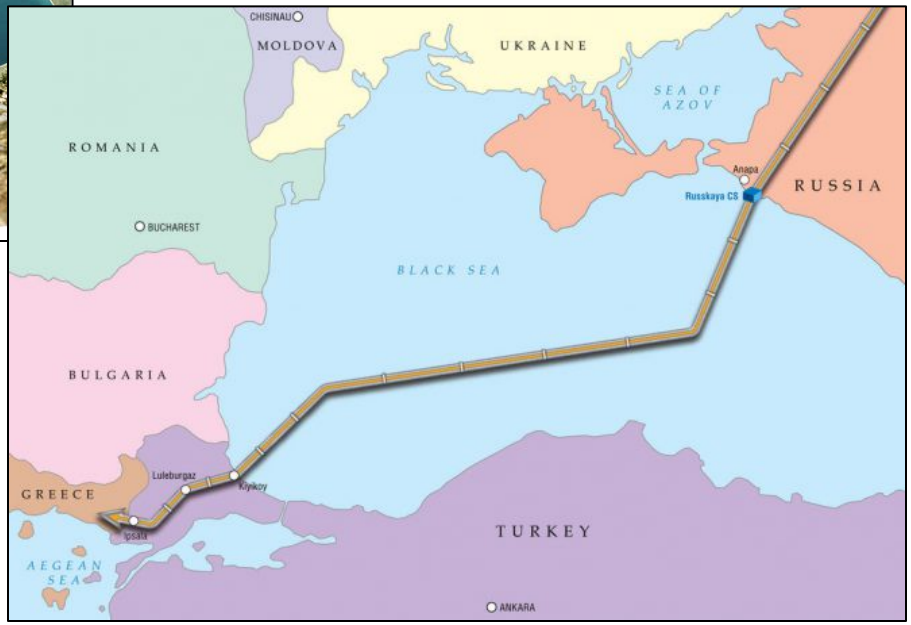


Nord Stream

- The total capacity of two strings of Nord Stream 2 is 55 billion cubic meters of gas per year
- The aggregated design capacity of Nord Stream and Nord Stream 2 is therefore 110 billion cubic meters of gas per year
- Nord Stream 2 will be put into operation before late 2019

TurkStream

- TurkStream is a new export gas pipeline stretching from Russia to Turkey across the Black Sea.
- The first string of the pipeline is intended for Turkish consumers, while the second string will deliver gas to southern and southeastern Europe.
- When fully operational, TurkStream will deliver 31.5 billion cubic meters of natural gas annually.



SCP-TANAP-TAP Pipeline

- **The planned capacity of the natural gas pipeline**
  - 2018 16 BCM (0.6 tcf) per year at initial stage
  - 2023 23 BCM(0.8 tcf) by
  - 2026 31 BCM(1.1 tcf)
  - final stage 60 BCM(2.1 tcf) if be able to transport additional gas supplies from Azerbaijan
- SCP – South Caucuses Pipeline
- TANAP - Trans-Anatolian Natural Gas Pipeline
- TAP – Trans Adriatic Pipeline

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EU LNG Imports

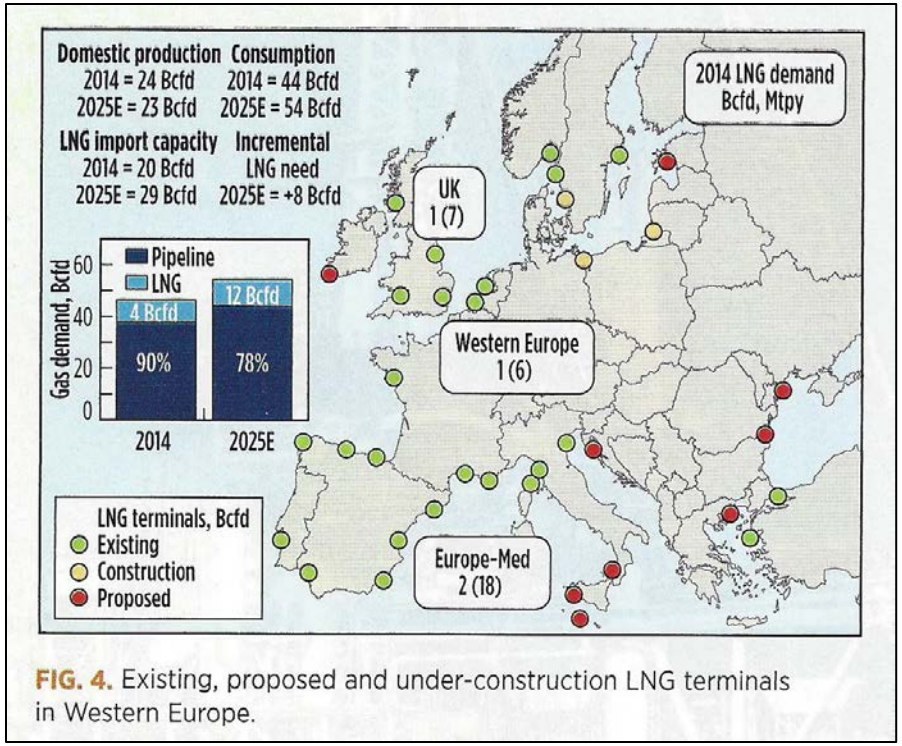
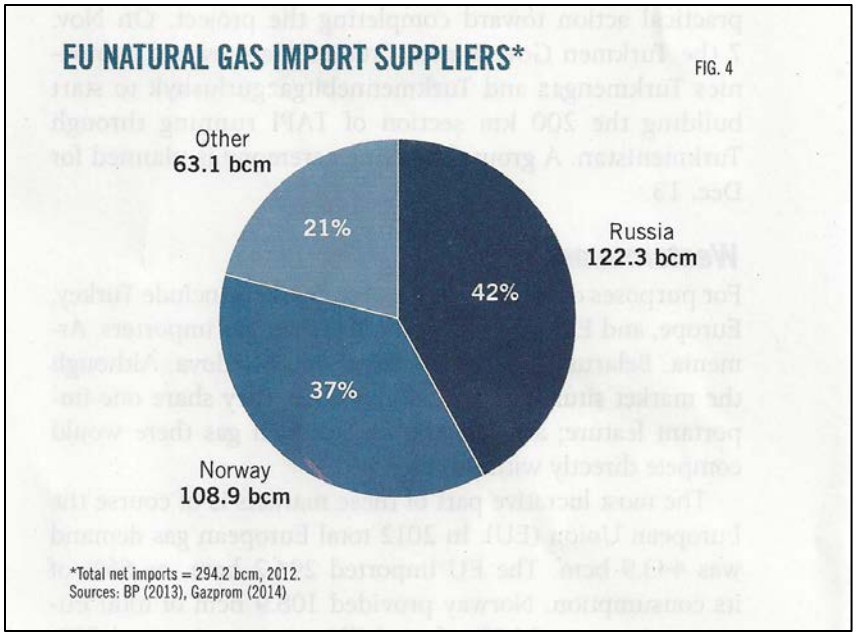
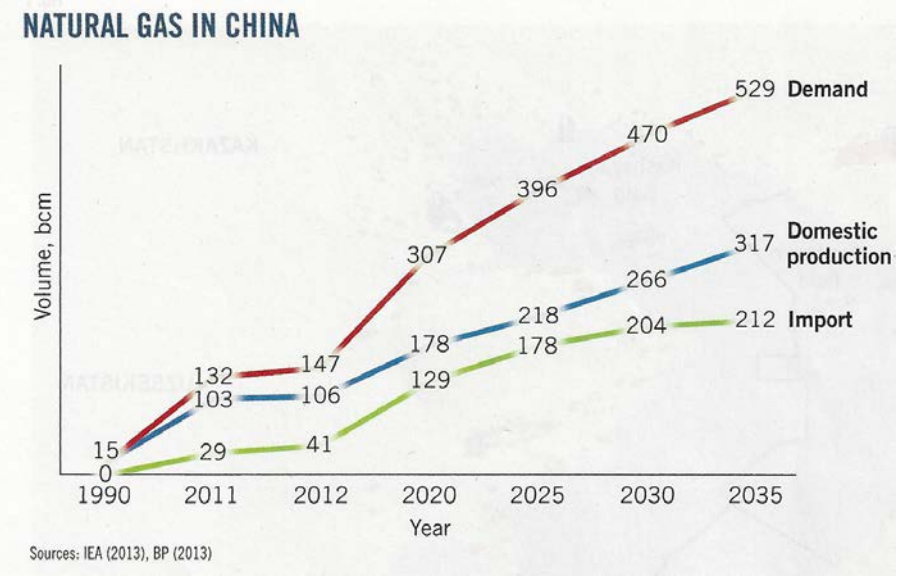
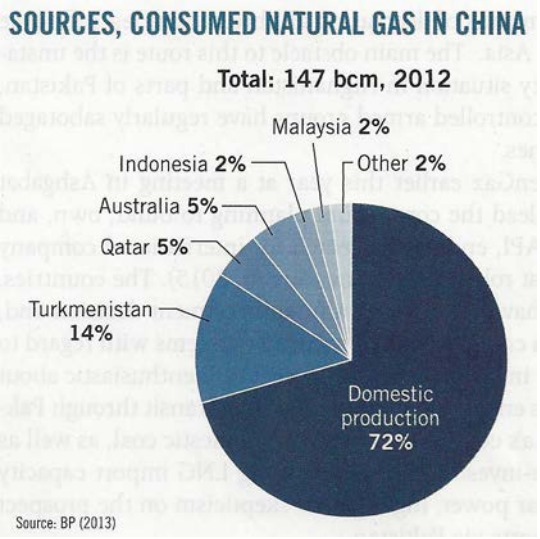


FIG. 4. Existing, proposed and under-construction LNG terminals in Western Europe.



China Natural Gas





- 147 in 2012
  - Domestic production
  - Imported

3x @3.5% pa

106
41
147

5x @ 12.8% pa

317
212
529

- 529 in 2035
  - Domestic production
  - Imported

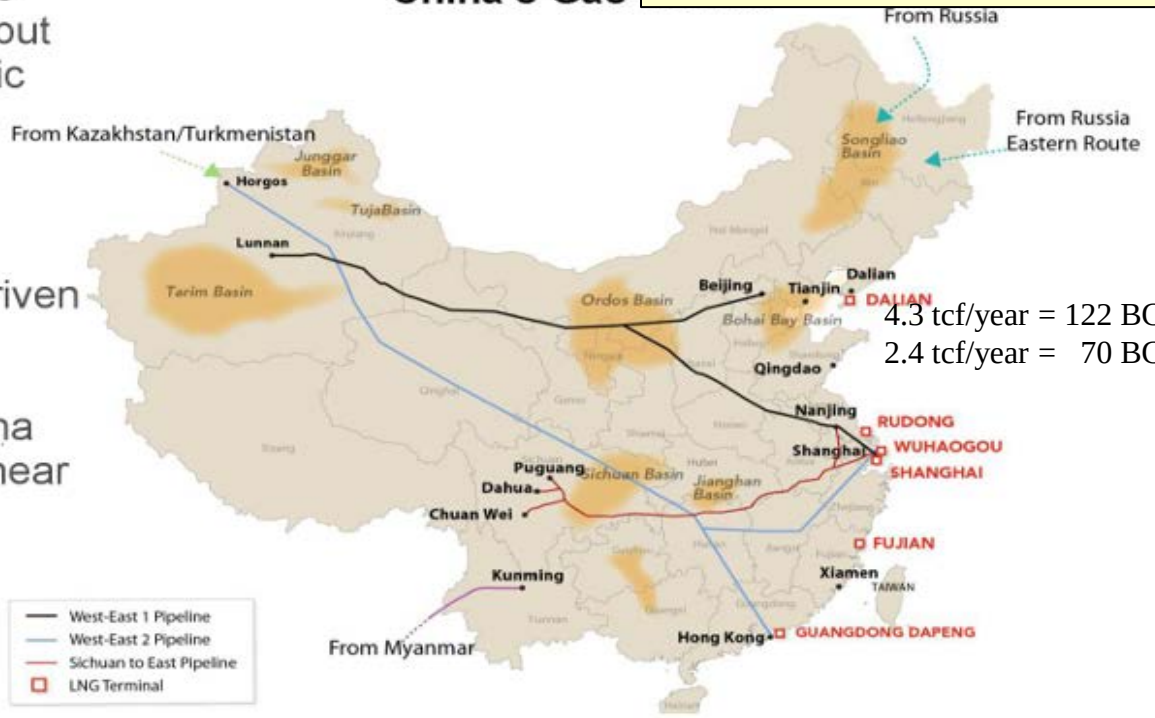
$(529/147)^{1/33}$ = 4.0% per year

China: World's Second Largest Importer by 2025

Over 2.4 tcf per year of LNG demand, growing at a fast pace with high uncertainty

- LNG demand expected to grow near 15% per year but is dependent on economic growth, domestic gas production and pipeline imports
- Chinese LNG demand driven by GDP growth
- Pipeline imports into China are projected to grow to near 4.3 tcf a year
- Domestic production will remain the major gas source

China forecast:
2015 - 230 BCM (15.6%/year)
2020 - 375 BCM (12.6%/year)



4.3 tcf/year = 122 BCM/year
2.4 tcf/year = 70 BCM/year

China has built LNG import terminals along its eastern coast and pipelines to move natural gas from Central Asia suppliers to serve its population centers

Source: Poten & Partners

Russia

- Gazprom has long been the dominant supplier of natural gas to Europe
  - Last year, it supplied 31% of the Continent's gas needs.
  - Europe accounts for the vast bulk of Gazprom's profits
- Gazprom holds the world's largest natural gas reserves
  - It has most of the spare capacity in the marketplace, about 100 billion cubic meters
  - That's equivalent to 25% of its output and about 3% of global production.
- Gazprom is one of the world's lowest-cost gas producers.
  - the cost for Gazprom to deliver natural gas to Germany is $3.5 per million British thermal unit (BTU).
  - For LNG exported from the U.S., the breakeven point will be around $4.3 per million BTU even at the current low gas prices.
- The U.S. LNG industry will have the capacity to export about 3.8 billion cubic feet of natural gas per year by 2018
- Australia will be No. 1 in LNG, with the U.S. at No. 2
- Over the next five years, Wood Mackenzie estimates over 130 million metric tons of gas supplies will come online
- Gazprom is defending Europe with everything it has. And it's expanding into Asia
  - Beginning in 2019, it will be sending natural gas through pipelines to China.

Russian Gas - 607 BCM Production

44,600 BCM Reserves
Reserves/Production Ratio - 73.5

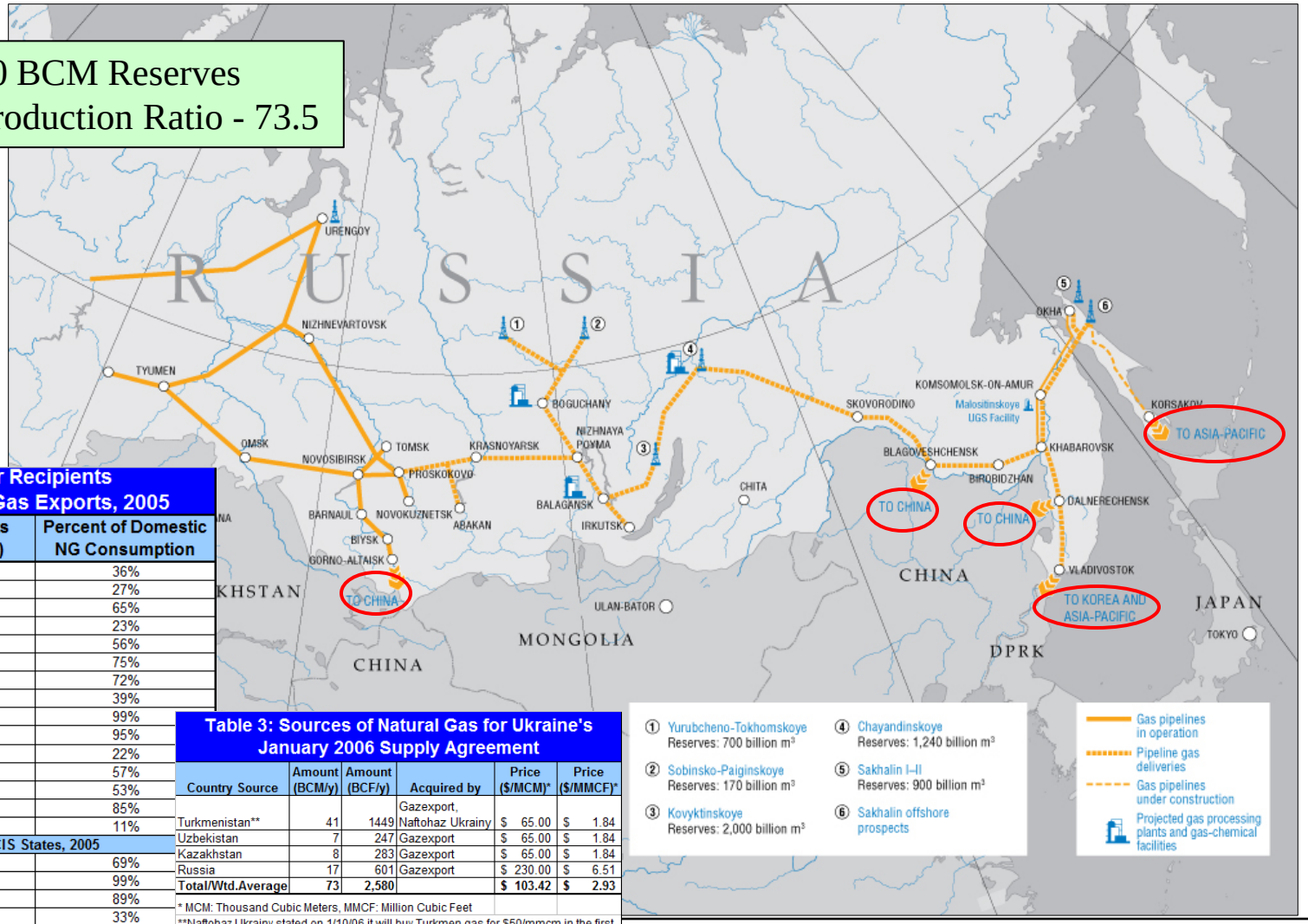


Table 2: Major Recipients of Russian Natural Gas Exports, 2005

Rank	Country	Imports (bcf/y)	Percent of Domestic NG Consumption
1	Germany	1,291	36%
2	Italy	824	27%
3	Turkey	630	65%
4	France	406	23%
5	Hungary	294	56%
6	Czech Republic	252	75%
7	Austria	246	72%
8	Poland	226	39%
9	Slovakia	226	99%
10	Finland	148	95%
11	Romania	140	22%
12	Fmr Yugoslavia	134	57%
13	Bulgaria	101	53%
14	Greece	85	85%
15	Switzerland	13	11%
	Sales to Baltic & CIS States, 2005		
	Ukraine	2,113	69%
	Belarus	710	99%
	Baltic States	205	89%
	Azerbaijan	120	33%
	Georgia	46	88%

Sources: Domestic Consumption: EIA International Energy Annual, 2005; Imports: Cedigaz 2006 and BP Statistical Review 2007.

Table 3: Sources of Natural Gas for Ukraine's January 2006 Supply Agreement

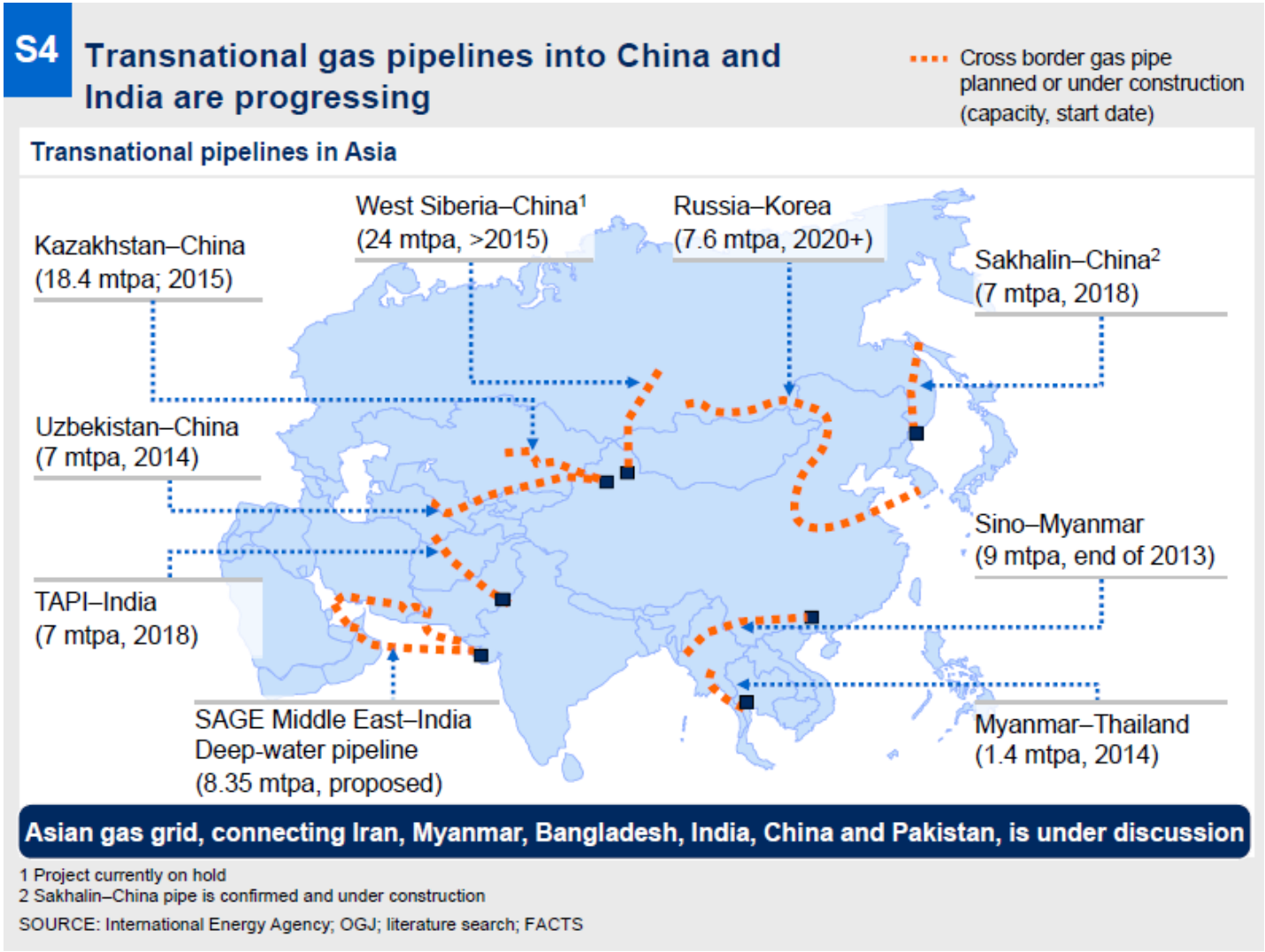
Country Source	Amount (BCM/y)	Amount (BCF/y)	Acquired by	Price ($/MCM)*	Price ($/MMCF)*
Turkmenistan**	41	1449	Gazexport, Naftohaz Ukrainy	$ 65.00	$ 1.84
Uzbekistan	7	247	Gazexport	$ 65.00	$ 1.84
Kazakhstan	8	283	Gazexport	$ 65.00	$ 1.84
Russia	17	601	Gazexport	$ 230.00	$ 6.51
Total/Wtd.Average	**73**	**2,580**		**$ 103.42**	**$ 2.93**

* MCM: Thousand Cubic Meters, MMCF: Million Cubic Feet

**Naftohaz Ukrainy stated on 1/10/06 it will buy Turkmen gas for $50/mmcm in the first half of 2006 and $60 during the second half, but the final agreement's price was higher. Using the lower price for Turkmen gas, the wtd. average price is $97.8/MCM.

Source: Russian Energy Monthly, January 2006

Pipelines to China & India



India Natural Gas

- **India plans to dramatically increase its LNG import capacity**
  - Indian gas production meets nearly half of domestic demand
  - The country's domestic natural gas production peaked in 2010 at 44.5 Bm^3, but it has declined over the past few years, settling at 29.2 Bm^3 in 2015
  - India must rely on imports to satisfy demand
- **India is expanding import capacity at its LNG terminals, as well as building grassroots facilities and utilizing floating storage and regasification unit (FSRU) vessels**
  - The country has four operational LNG import terminals with a combined installed capacity of 25 MMtpy
  - India's Ministry of Petroleum and Natural Gas announced that LNG import capacity will increase from 25 MMtpy to 50 Mmtpy
  - Nearly 80% of these new LNG supplies will come from Australia and the US.
- **India is also planning to utilize LNG as a bunker fuel and transportation fuel.**
  - The country has plans to build four LNG barges along the Ganges River.
  - These barges will provide waterway transport vessels with cleaner-burning LNG, as opposed to diesel fuel.
- **India is also promoting the use of LNG-fueled vehicles to curb emissions and mitigate its dependence on oil imports**
  - India's Petronet is heavily involved in promoting LNG as a transportation fuel
  - Plan includes LNG to be used in vehicles, water vessels and trains
  - Petronet is also in talks with major Indian fuel retailers to install LNG pumps at their fuel locations.
- **LNG-fueled vehicles, in combination with new Bharat Stage 6 fuel regulations, could have a dramatic impact on vehicle emissions in the country**
  - Air pollution has become such a crucial issue that New Delhi and other cities are requiring drivers to use their vehicles only every other day
  - The government is investing in the construction of compressed natural gas (CNG) fueling stations in the hope that citizens will switch to the cheaper, more fuel-efficient transportation option.

India – Gas Supply

TABLE 1. India's LNG import capacity, MMtpy, 2014–2022

Location	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dahej	10	12.5	15	15	15	15	15	15	15
Hazira	5	5	5	10	10	10	10	10	10
Dabhol	5	5	5	5	5	5	5	5	5
Kochi	5	5	5	5	10	10	10	10	10
Ennore	0	0	5	5	5	5	5	5	5
Mundra	0	0	5	5	10	10	10	10	10
Kakinada (FSRU)	0	2.5	5	5	5	5	5	5	5
Gangavaram	0	3	3	3	3	3	3	3	3
East Coast terminal (1)	0	0	0	2.5	2.5	5	5	5	5
West Coast terminal (1)	0	0	0	0	2.5	5	5	5	5
Total	**25**	**33**	**48**	**55.5**	**68**	**73**	**73**	**73**	**73**

Source: Petroleum & Natural Gas Regulatory Board of India

INDIA'S GAS SUPPLY

	2012-13	2016-17	2021-22	2026-27	2029-30
			MMscmd		
Domestic sources	101.1	156.7	182.0	211.0	230.0
LNG imports	44.6	143.0	188.0	214.0	214.0
Cross border pipeline imports*	—	—	30.0	30.0	30.0
Total	**145.7**	**299.7**	**400.0**	**455.0**	**474.0**

*TAPI pipeline projected commissioning 2017-18
Source: "Vision 2030 – Natural Gas

53	110	146	166	173 BCM

Australia Supply Strategy

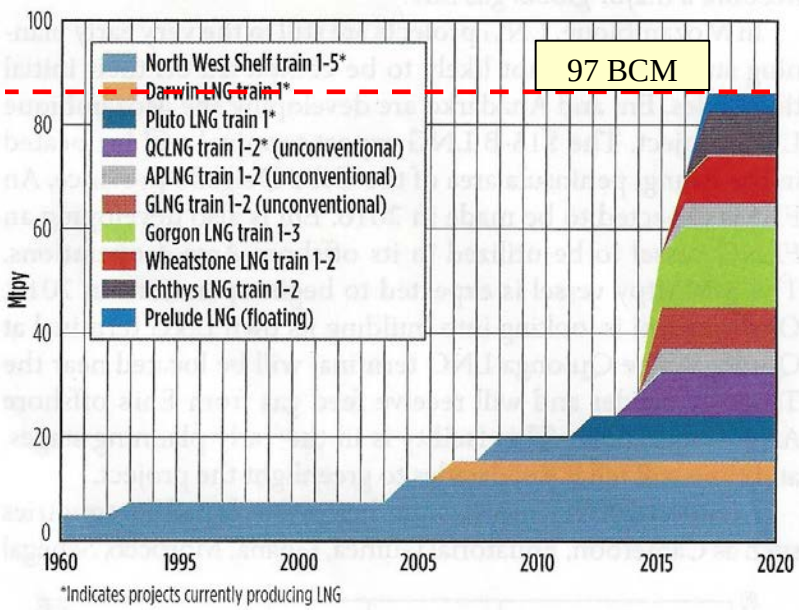
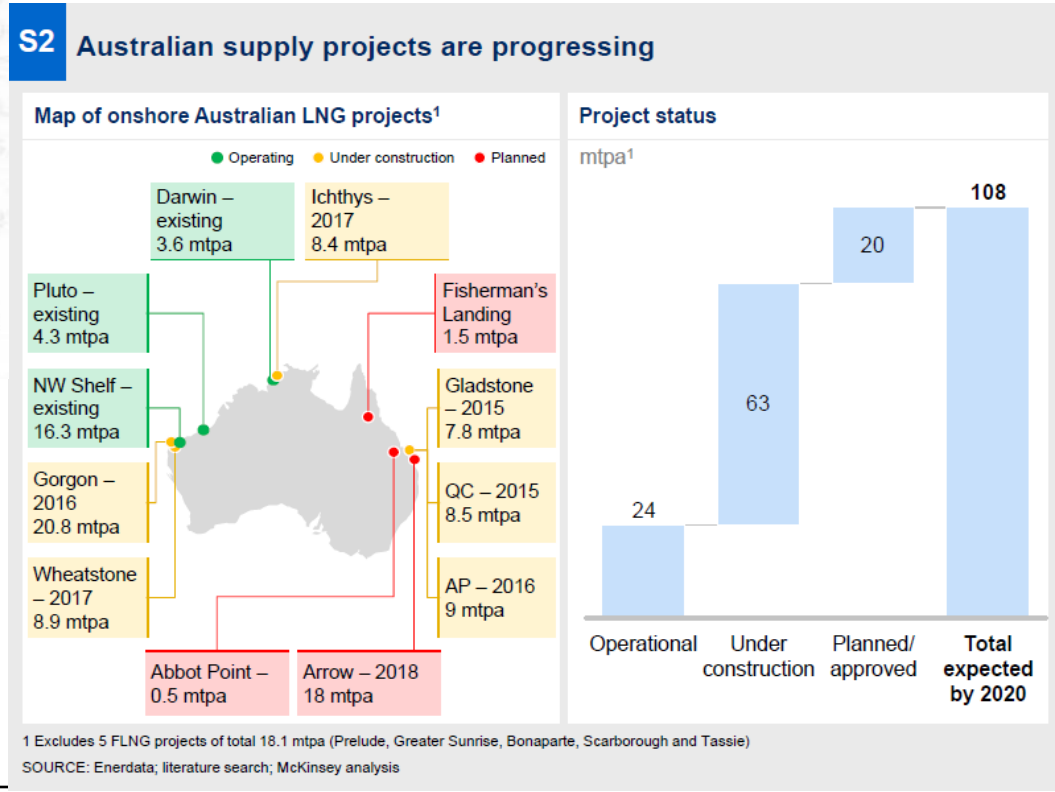
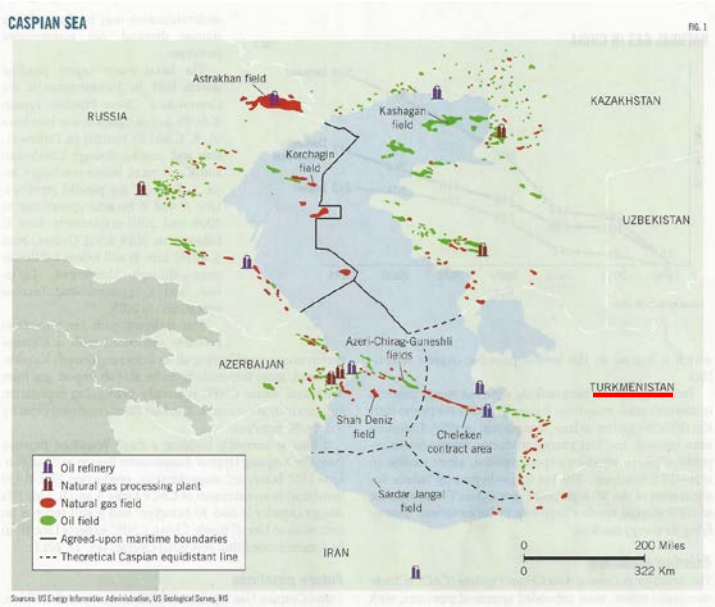


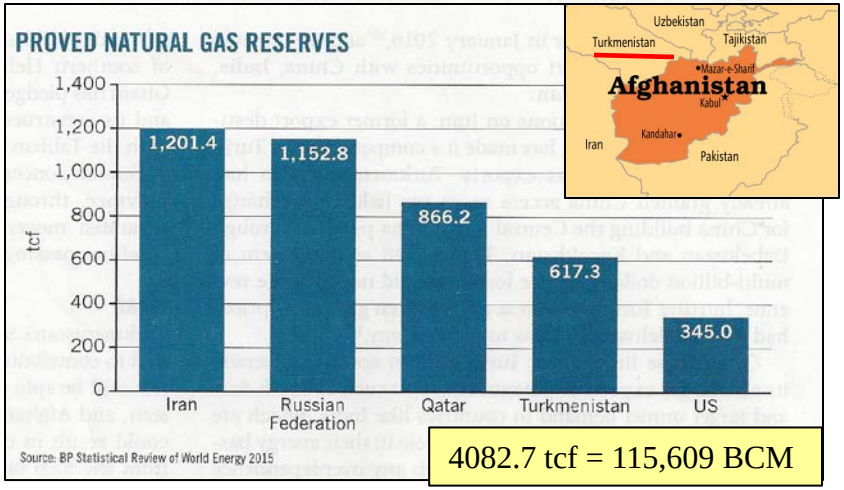
FIG. 2. Australian liquefaction capacity. Source: Australian Department of Industry and Reserve Bank of Australia.



Turkmenistan – Serving Eurasia?

- 17,500 BCM proven natural gas reserves
- 9.3% of world total
- Russian Gas Pipeline Access/Use
  - 1989 – 81 BCM
  - 1998 – 12 BCM
- 74% in Galkynysh field near Afghan border
- China National Petroleum Corp. (CNPC)
  - CNPC controls 82% of Proven gas reserves
  - Produced 13 BCM (20%) in 2012
  - Export 30 BCM/year for 30 years
  - Expected to bring annual gas deliveries to 65 BCM/year
- Turkmengaz largest producer
  - Produced 51 BCM (80%) in 2012
- Does not directly border with Europe, China, or India and depends on transiting thru other countries.
- Trans-Caspian Gas Pipeline (300km) proposed but far from guaranteed





4082.7 tcf = 115,609 BCM

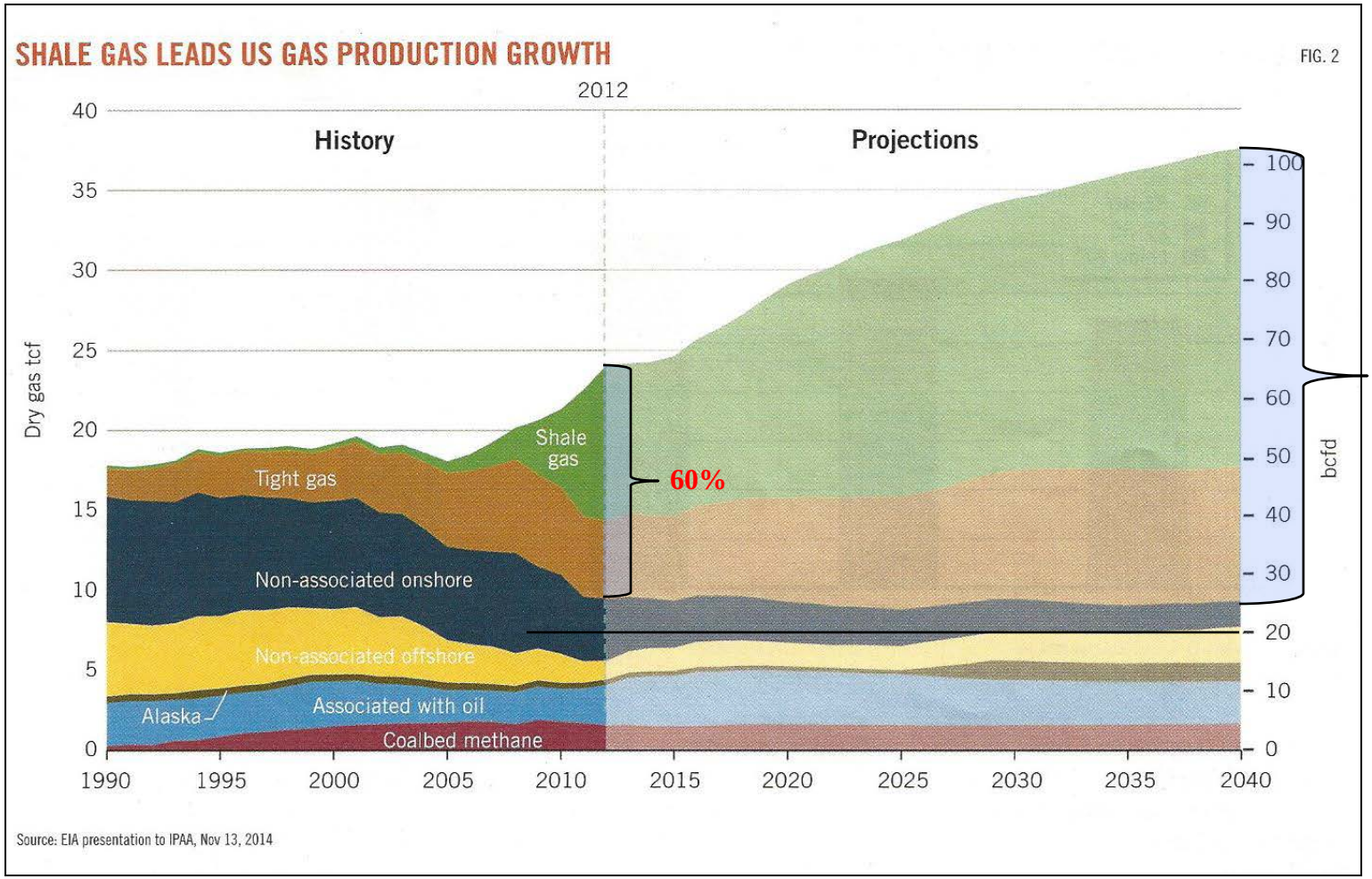
"Practical Strategies for Emerging Energy Technologies"

Source: O&G Journal December 7, 2015

Other Issues & Countries to Watch

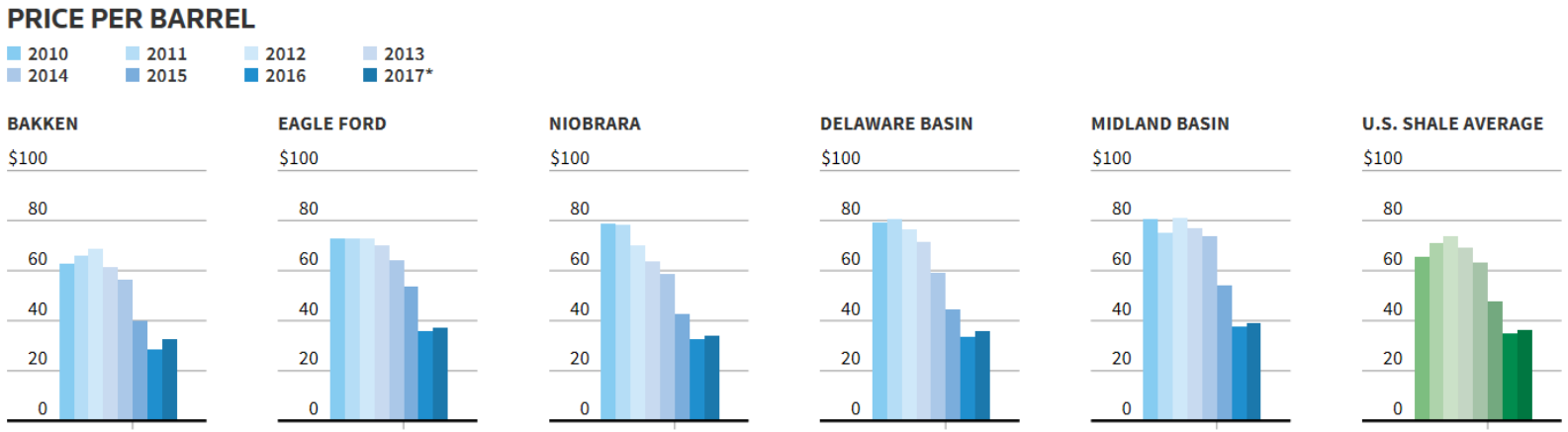
- LNG Supply Demand Balancing
- North American Shale
- Panama Canal
- Mexico
- East Mediterranean Resource
- Qatar
- China-Pakistan Economic Corridor
- Canadian Resources
- Arctic
- Turkmenistan–Afghanistan–Pakistan–India Pipeline (TAPI)
- Argentina
- Methane Hydrates

U.S. Shale Gas


SHALE GAS LEADS US GAS PRODUCTION GROWTH
FIG. 2
2012
History
Projections
Dry gas tcf
bcfd
Shale gas
Tight gas
Non-associated onshore
Non-associated offshore
Alaska
Associated with oil
Coalbed methane
60%
75%
40
35
30
25
20
15
10
5
0
100
90
80
70
60
50
40
30
20
10
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Source: EIA presentation to IPAA, Nov 13, 2014

Reuters Break-even Shale Price

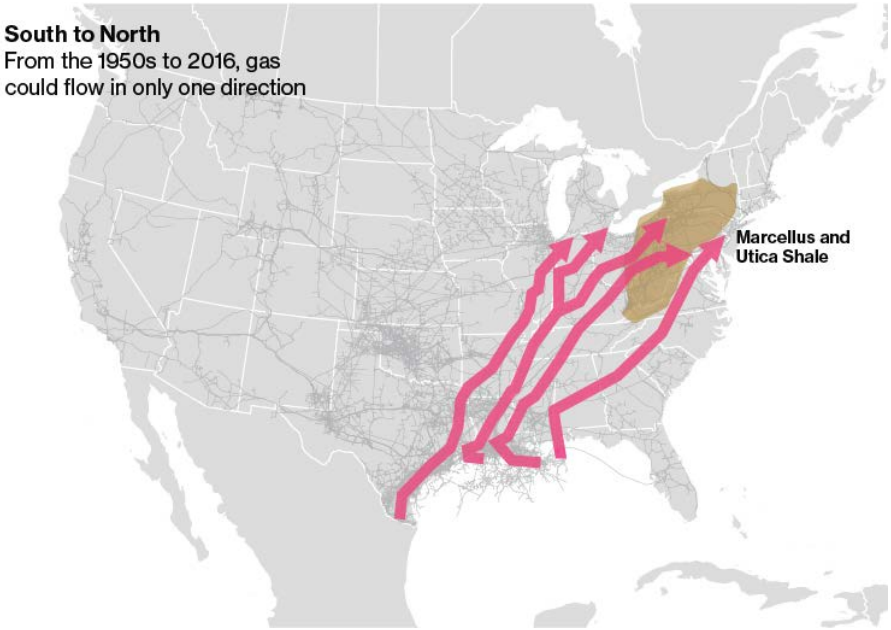
U.S. shale producers' break-even price per barrel is projected to rise in 2017 for first time in five years. The wellhead price required to generate a profit is about half of what it was in 2010.

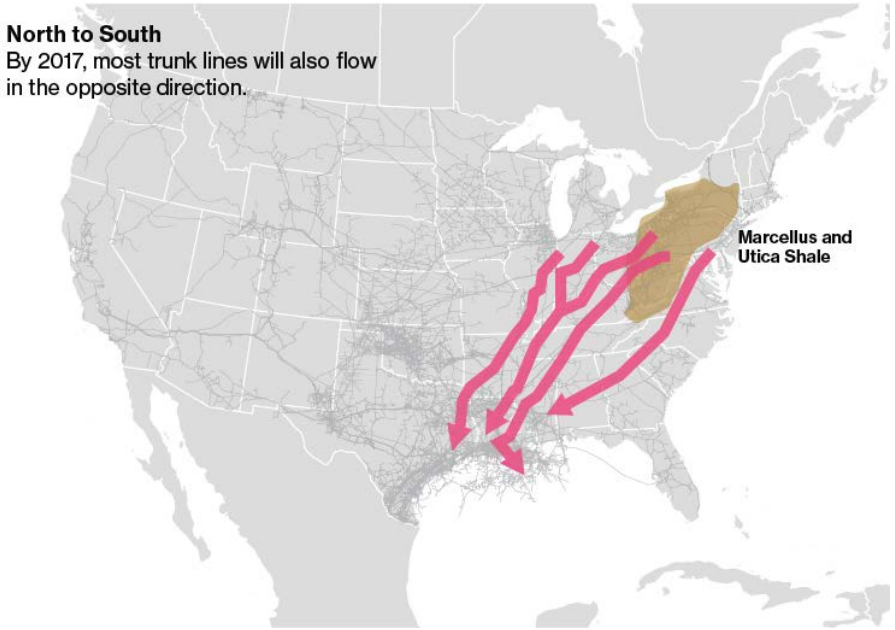


•Estimated
•Source Rystad Energy

- Drilling innovations over the past decade have generated a dizzying reduction in the cost of pumping oil from shale formations across the United States
- The first time since 2012, shale producers will see a rise in break-even production costs this year
- The per-barrel costs will rise an average of $1.60 across the shale patch to $36.50
- The wellhead price required to generate a profit is about half of what it was in 2010

Can the U.S. Become an Energy Superpower in 2017?





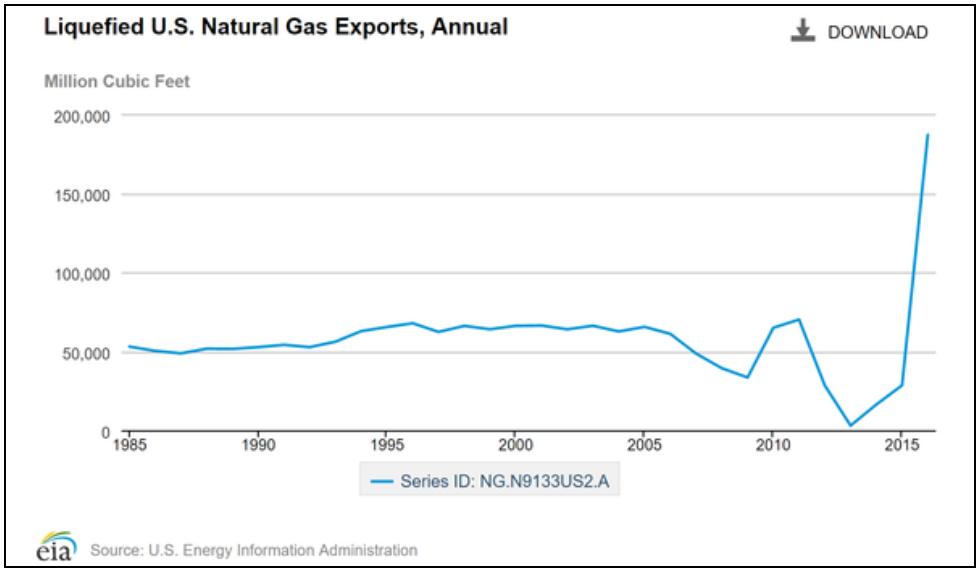
- America's frackers are pulling 18 billion cubic feet of gas per day from the Marcellus shale formation in the eastern U.S
- More than any other domestic shale deposit
- U.S. pipeline system was designed only to move gas from the Gulf Coast to cities in the Northeast—not the reverse

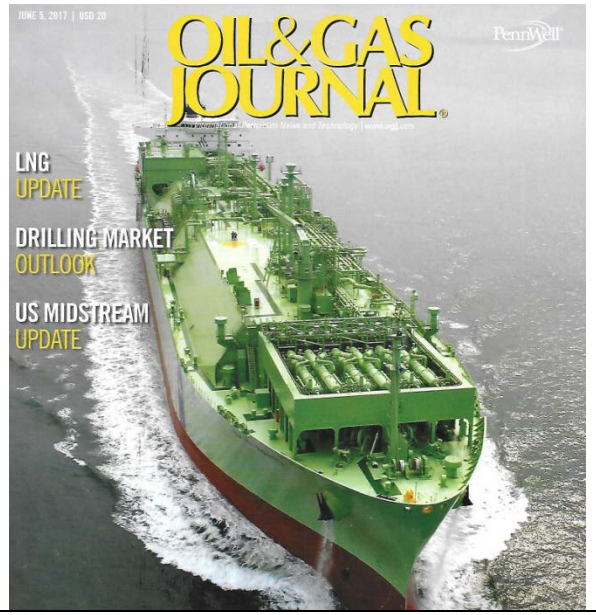
- Export terminals are being built on the Gulf Coast
- Pipelines are being re-engineered to flow south
- Thousands of miles of bidirectional pipelines are slated to be online in 2017

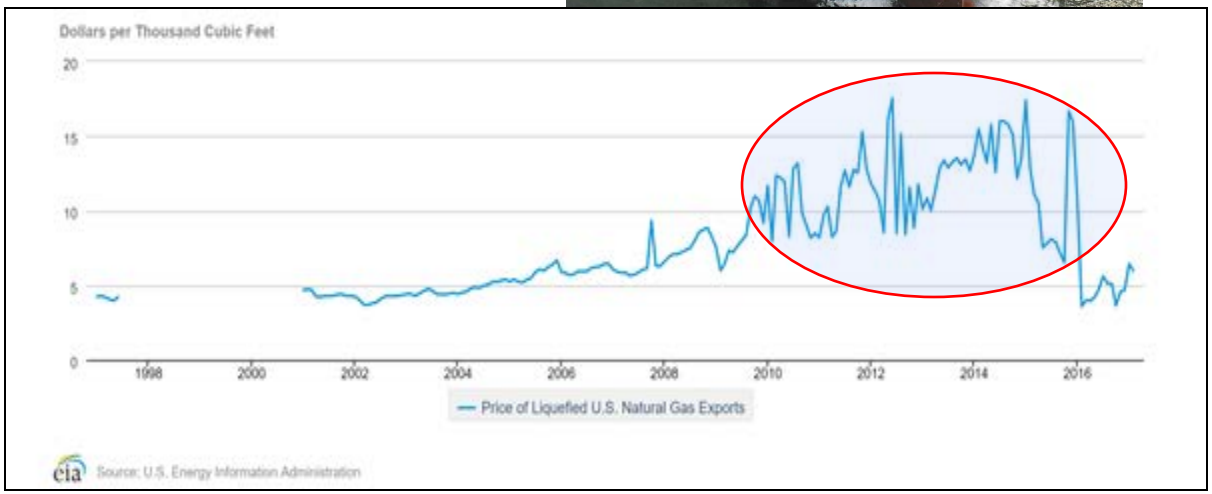
Sources: Data compiled by Bloomberg, U.S. Energy Information Administration, Cheniere, LNG shipment data compiled by Bloomberg via IHS and Genscape data, as of Nov. 16.

By Dave MerrillDave Merrill and Christine Buurma
November 30, 2016

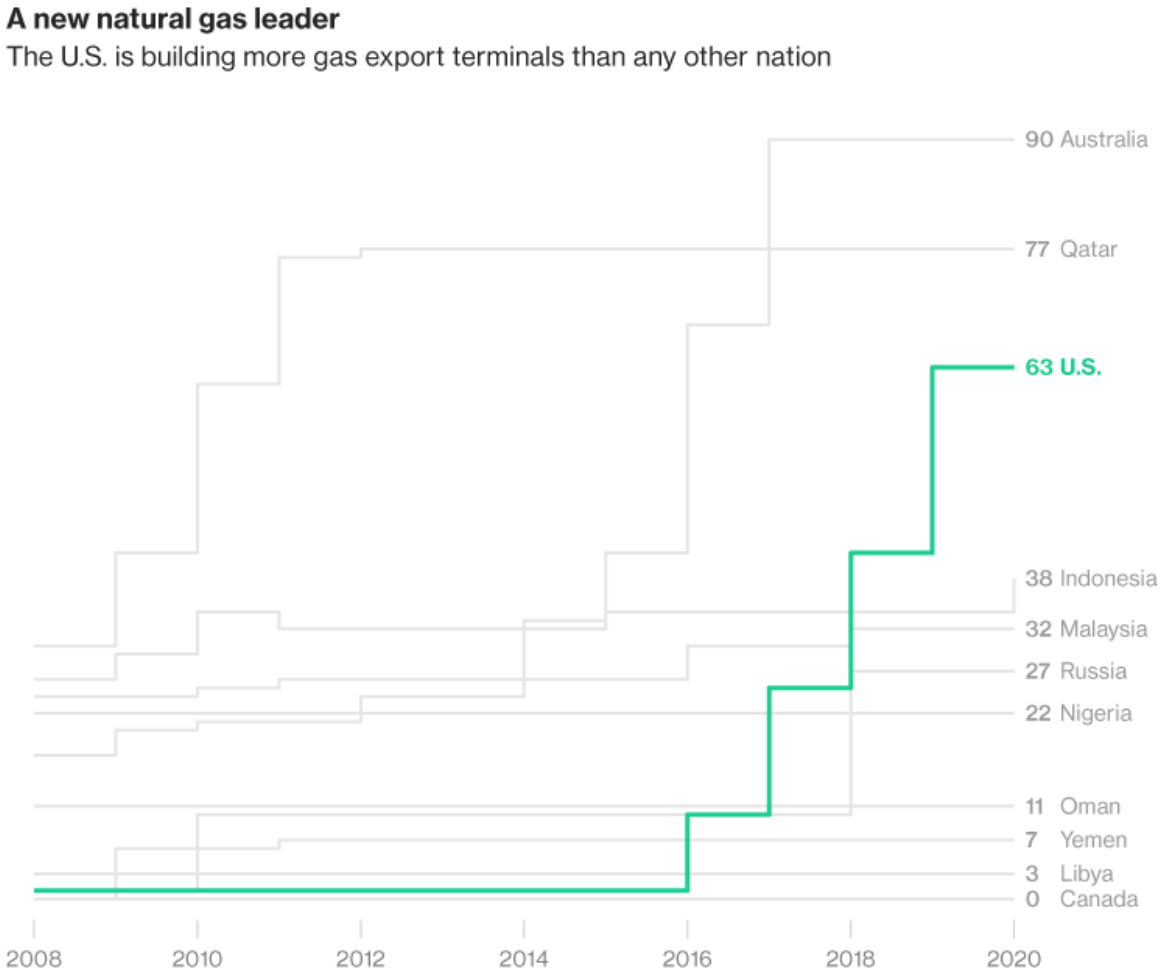
U.S. LNG Exports





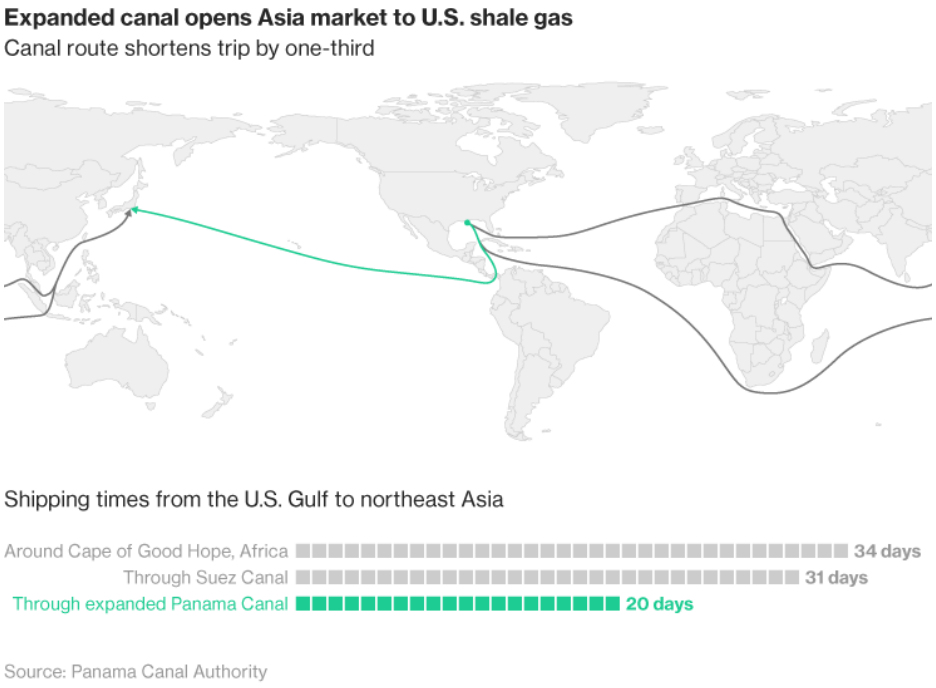


Gas Exports Terminals



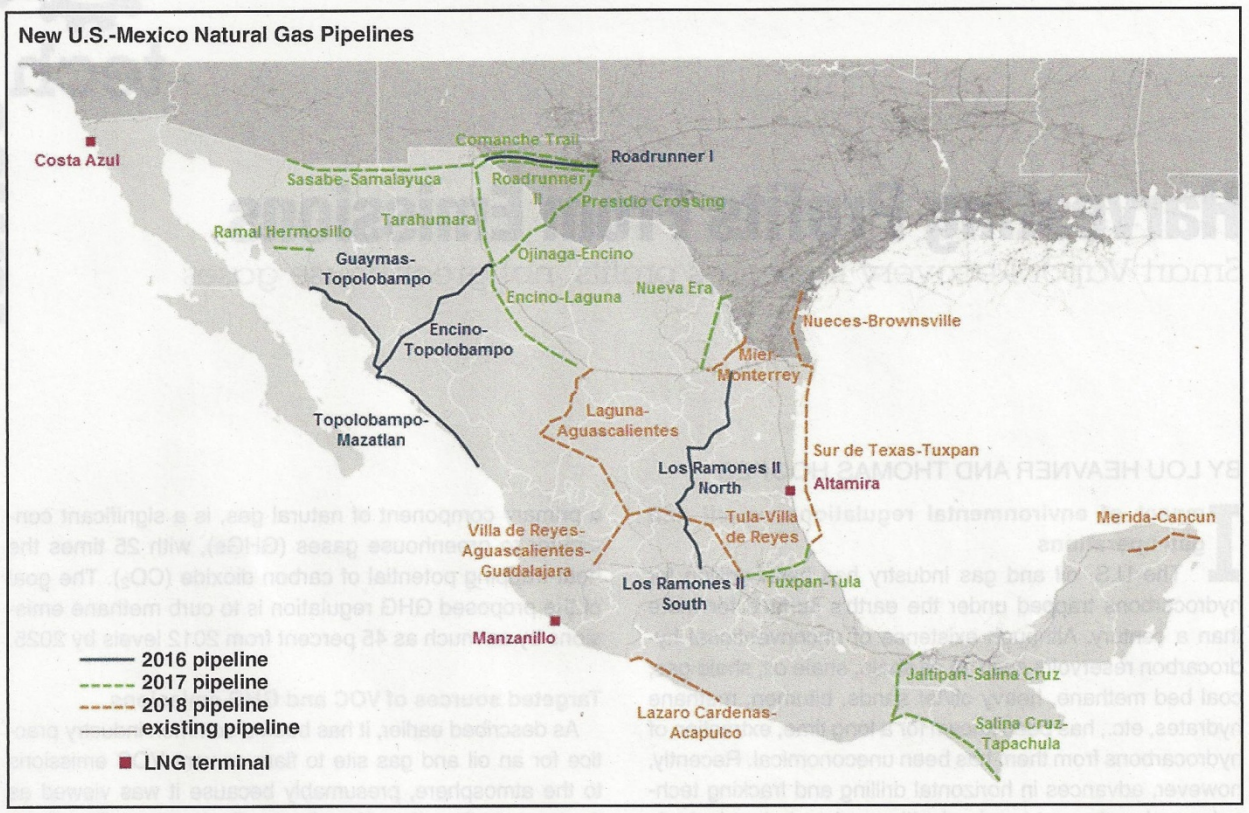
The New Panama Canal

- **Current locks are too small for most natural-gas carriers**
  - 90 percent of the world fleet will be able to use the new canal
  - Able to accommodate the kind of tankers that transport liquefied natural gas
  - Shaving eleven days and a third of the cost off the typical round trip to the Far East
- **Nine years of construction work, at a cost of more than $5 billion**
  - A third set of locks and deeper navigation channels
  - Crucial improvements that will double the isthmus's capacity for carrying cargo between the Atlantic and Pacific oceans.
- **The debut coincides with a surge in U.S. natural-gas production**
  - Markets from Chile to China will also become more accessible for oil drillers across the Americas



Source: Alex Nussbaum and Naureen Malik May 2016

Gas to Mexico

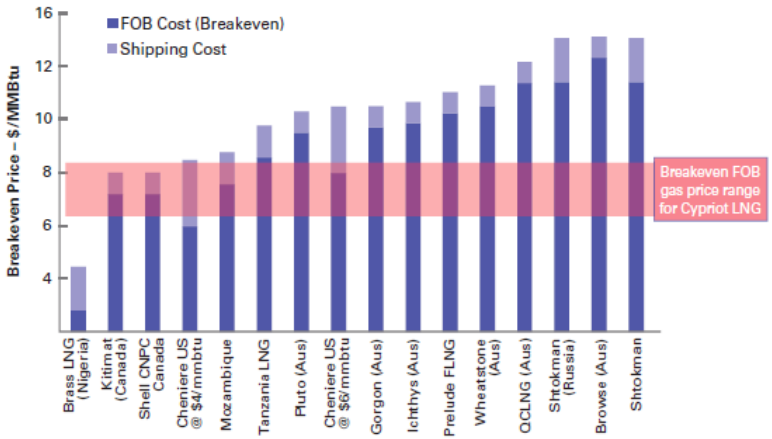


Mexico's energy ministry, SENER, has a five-year plan to expand the country's natural gas pipeline network. The plan includes 12 pipeline additions.

Source: CompressorTech2 May 2017

Cyprus

Figure 15 – Estimated Breakeven Gas Prices for Set of Major Contemporary LNG Projects



Source: Deutsche Bank (2012) and author's calculations.

otential Route for a Pipeline from Cyprus to Greece and Onward to Italy and Bulgaria

This report has focused on the BEP as a measure of the value of the project. A comparison of BEP with a realized (or expected) natural gas price provides guidance for undertaking the project. According to BP (BP, 2013), in 2011 average natural gas prices were $4.01/MMBtu in the United States (Henry Hub), $9.04/MMBtu in the United Kingdom (Heren NBP Index), $10.48/MMBtu in Germany (average German import cif – cost + insurance + freight), and $14.73/MMBtu in Japan (Japan cif). These prices are subject to variation and, as any option for Cyprus natural gas will take some time to develop, the projections for gas prices in 2020 also can be considered. IEA (2012) projects Europe's import prices to be $11.50/MMBtu and Japan's import prices to be $14.30/MMBtu (both prices are in real terms — in 2011 US dollars).

According to the analysis in this report, in the base cases, BEP prices are $9.75/MMBtu for the Cyprus LNG option to the European markets, $10.25/MMBtu for the Cyprus LNG option to the Asian markets, and $10.32/MMBtu for the Cyprus offshore pipeline option to the European markets.

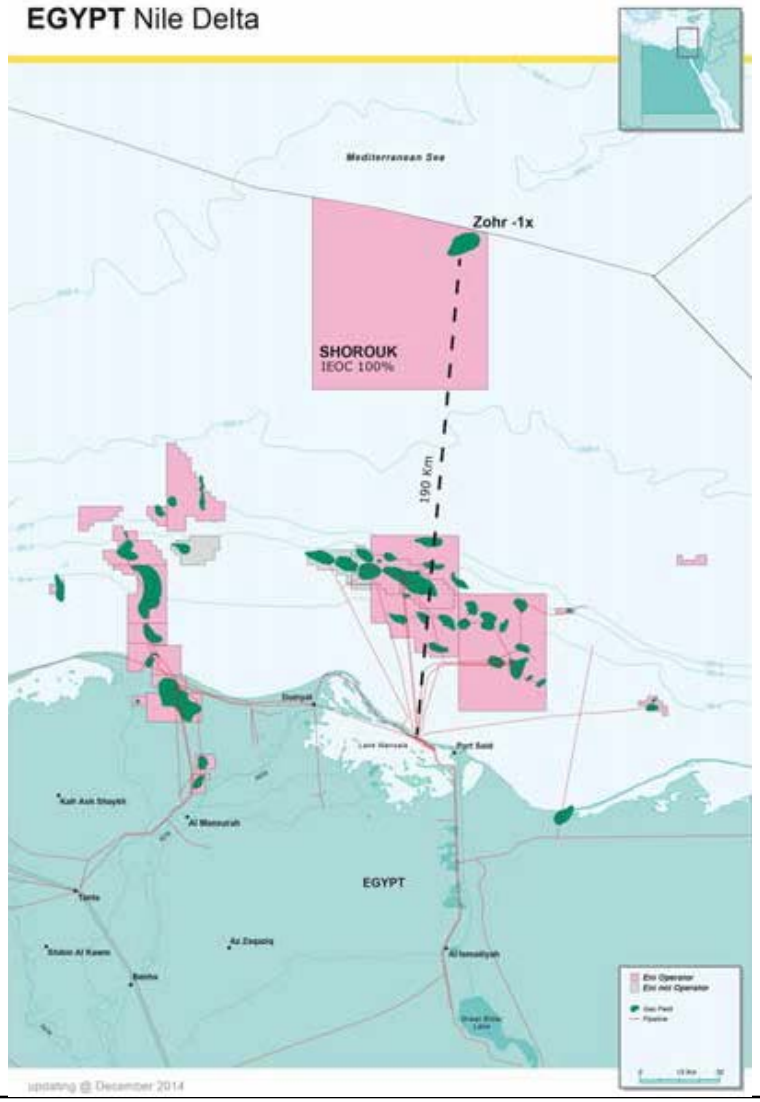
Israel

- The discovery of fields called Leviathan and Tamar, said to hold 25 trillion to 30 trillion cubic feet of natural gas came in 2010
- A partnership led by Noble Energy, a Houston-based company, and the Delek Group, an Israeli firm, has developed wells in Tamar; the first supplies reached domestic markets in 2013.
- After years of delay, Israel is, finally pushing ahead with an ambitious strategy to tap offshore reserves that could transform its economy and, it hopes, its place in a historically hostile region.
- Israeli gas now produces more than half the country's electricity and the influx of natural gas translated to an additional 2 percent of gross domestic product
- Leviathan, which is more than twice the size of Tamar, has yet to be developed
- Estimated at 16 trillion cubic feet (450 BCM)

By Peter Baker New York Times January 14, 2017

Egypt

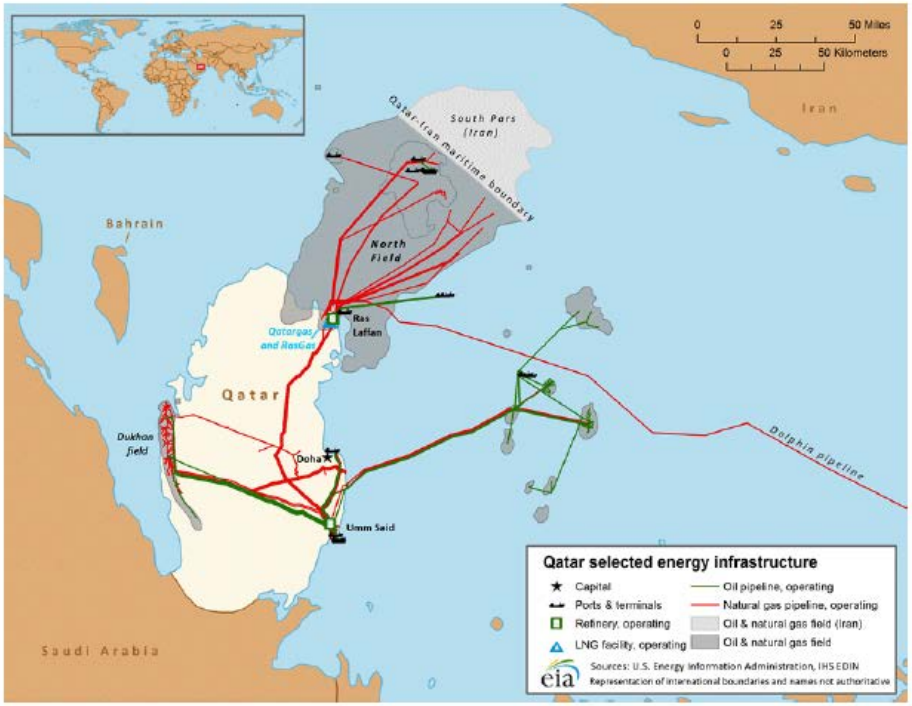
- The discovery of a huge natural gas deposit in Egyptian waters has boosted hopes of other such finds in the eastern Mediterranean
- Eni SpA "milestone" discovery of Zohr, estimated to hold 30 trillion cubic feet of gas (850 BCM), has reinvigorated the interest of other major oil and gas companies in the region.
- Bertelli said an alternative option for export purposes is to build pipelines linking east Mediterranean gas fields with Turkey and Europe.
- Zohr Gas field is located within the 3,752km² Shorouk Block, within the Egyptian Exclusive Economic Zone (EEZ), in the Mediterranean Sea
- The field is situated more than 150km from the coast.
- The deepwater gas field is expected to start production in 2017 and reach full production capacity in 2019.



Qatar

- RasGas
  - JV ExxonMobil
  - Qatar Petroleum (state owned)
- Long-term LNG Contracts w/Petronet (India)
  - 5.0 MMtpa = 240 Bcf = 6.72 BCM
  - 2.5 MMtpa = 120 Bcf = 3.36 BCM
  - $12-13/MMBtu reduced to $6-7/Mmbtu
- New Contract Terms
  - Reduced 60 month moving average
  - Slope-to-crude (percent indexation to crude)
- Qatari Asian contracts 2Tcf = 56.3 BCM
- Qatari LNG Exports
  - India – 14.1%
  - Japan – 19.6%
  - South Korea – 15.0%
  - China – 6.6%

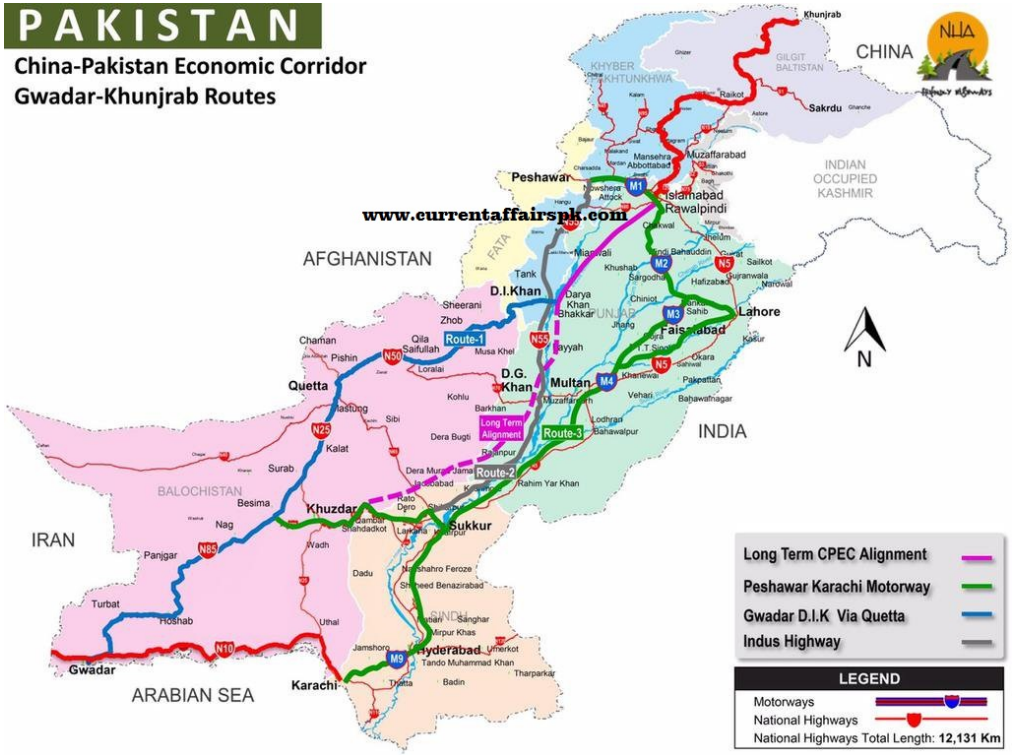
Qatar selected energy infrastructure



The New "Silk Roads"

China-Pakistan Economic Corridor

- The project includes coal-fired, solar and wind power stations and a network of highways running 3,000 kilometers down the length of the country, from the freezing passes of the Karakoram Highway to the Arabian Sea.
- Frequent power blackouts have driven traditional industries like textiles to countries such as Bangladesh and Vietnam.
- Of the $46 billion planned investment in the China-Pakistan Economic Corridor, $35 billion is earmarked for energy.
- For China, CPEC offers a shorter route to the Indian Ocean, without going through the congested and strategically sensitive Strait of Malacca.
- It strengthens the bond with Pakistan, an ally that bridges South Asia and the Middle East. And it gives China a port in the Indian Ocean that could one day become a naval base.



- For Pakistan, it brings soft loans to build power stations, roads and a deep-sea port and free-trade zone modeled on

Canadian Oil Sands

- Canadian Natural purchased the oil sands business of Royal Dutch Shell PLC and Marathon Oil Corp. in February, boosting its overall production to one million barrels a day.
  - It's one of a handful of Canadian operators that took advantage of the foreign selloff to grow their oil sands holdings.
  - Statoil ASA, Murphy Oil Corp. and ConocoPhillips have also exited, while other international companies have cut spending on their oil sands plays.
  - Suncor is integrating its operations with those of Syncrude and looking at all aspects to reduce costs, from greater automation to changing how it uses suppliers.
  - If oil prices stay in the US$50 a barrel range, Suncor would generate a lot of free cash flow after completing its Fort Hills oil sands and Hebron offshore oil projects and would look at further dividend increases
- Before the oil crash, the oil sands struggled
  - Rising costs due to competition for staff and services
  - The international spotlight attracted capital, but also negative attention that delayed pipeline approvals and fuelled concern about high greenhouse gas emissions.
  - Differentials — the discount applied to heavy oil — have shrunk amid higher demand for Canadian production by refineries in the U.S. Gulf because of the continuing decline in imports from Mexico and Venezuela, Rogers said.

Canada LNG

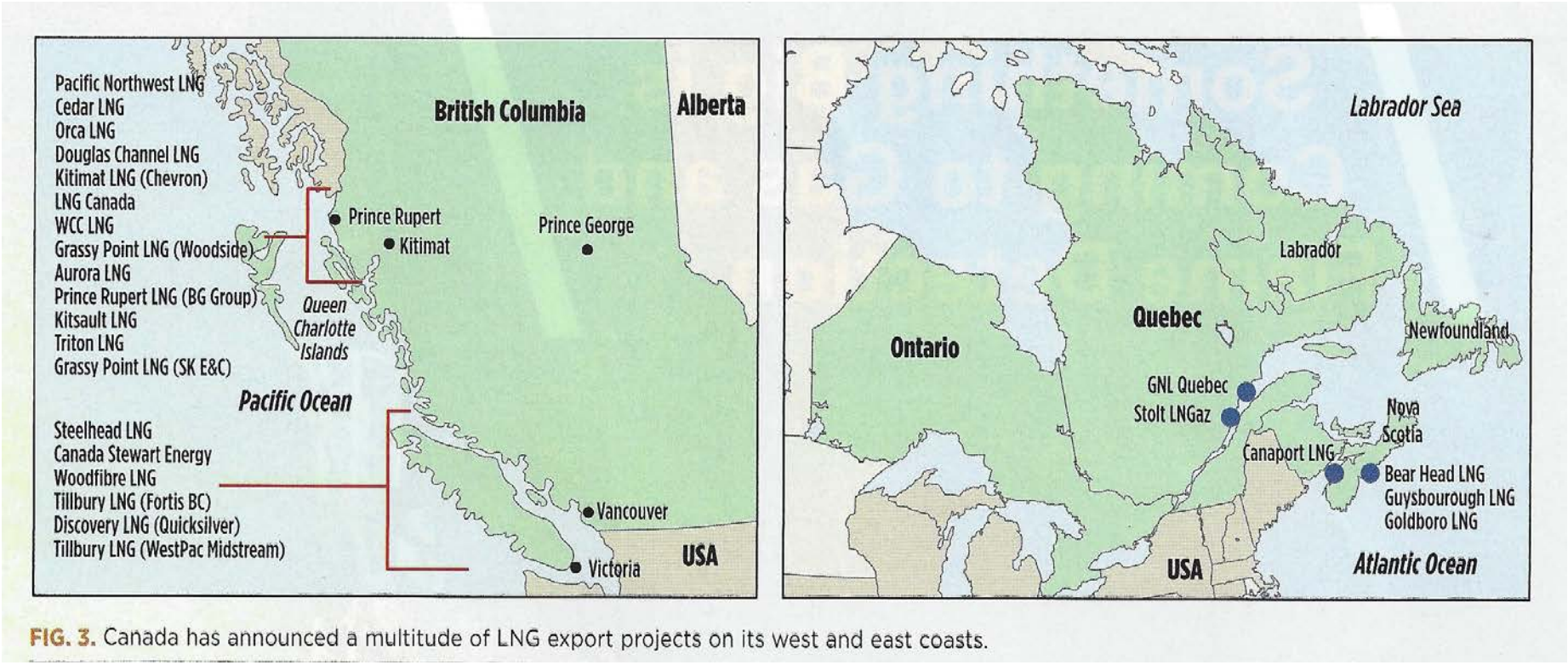


FIG. 3. Canada has announced a multitude of LNG export projects on its west and east coasts.

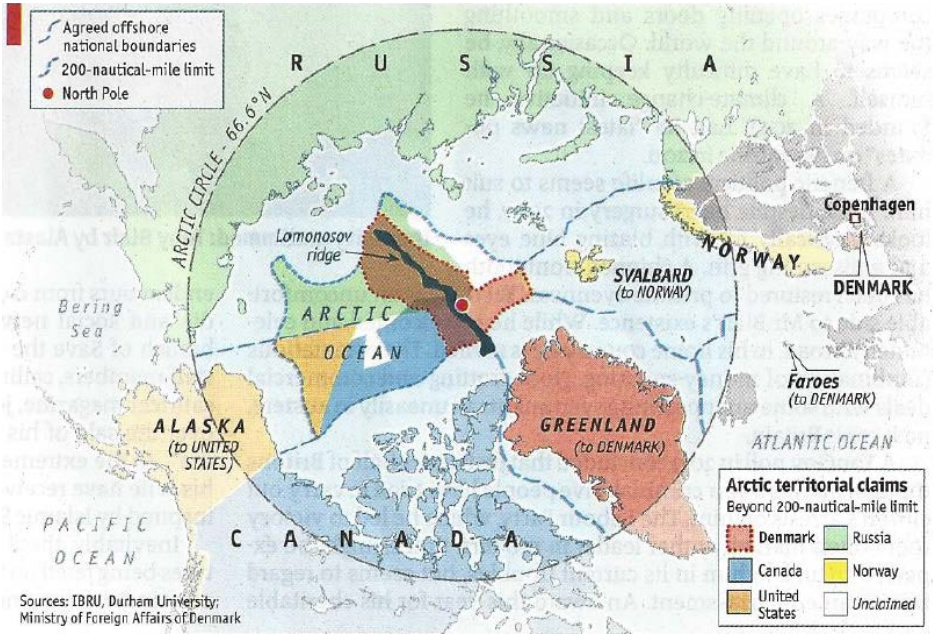
Canada Wet Gas Alliance Pipeline

- The Alliance pipeline is unique because it carries unprocessed natural gas
  - Unprocessed, or wet, natural gas contains ethane, propane, butanes, and natural gasoline, as well as methane, the primary component of natural gas
  - Alliance is the only pipeline of its kind that transports wet natural gas prior to processing over long distances at high pressure
  - It accomplishes this feat by modulating pipeline pressure up to nearly 2,000 psig to ensure that the mix of methane and NGPL does not separate while in the pipeline
- The Alliance pipeline currently has the capacity to carry up to 1.6 billion cubic feet per day (Bcf/d) of wet natural gas from production sites in Alberta and British Columbia along 2,391 miles of pipeline to the Aux Sable natural gas plant liquids (NGPL) extraction and fractionation facility near Chicago
- 2020

- The expansion would add up to 0.5 Bcf/d of capacity, for a total throughput of more than 2.0 Bcf/d (20BCM/y), potentially starting November 2020

Arctic Oil & Gas

- Estimated 13% (90 billion barrels) of the world's undiscovered conventional oil
- 30% of its undiscovered conventional natural gas
- Costs to develop reserves in the region can be 50-100% more than similar projects undertaken in Texas.
- Profitable development challenging due to the following factors:
  - Equipment needs to be specially designed to withstand the frigid temperatures.
  - On Arctic lands, poor soil conditions
  - Long supply lines
  - Natural gas hydrates can pose operational problems
  - Natural gas development could be impeded by the low market value of natural gas relative to that of oil. and higher transportation costs
  - Environmental issues include the preservation of animal and plant species unique to the Arctic
  - The adequacy of existing technology to manage offshore oil spills in an arctic environment

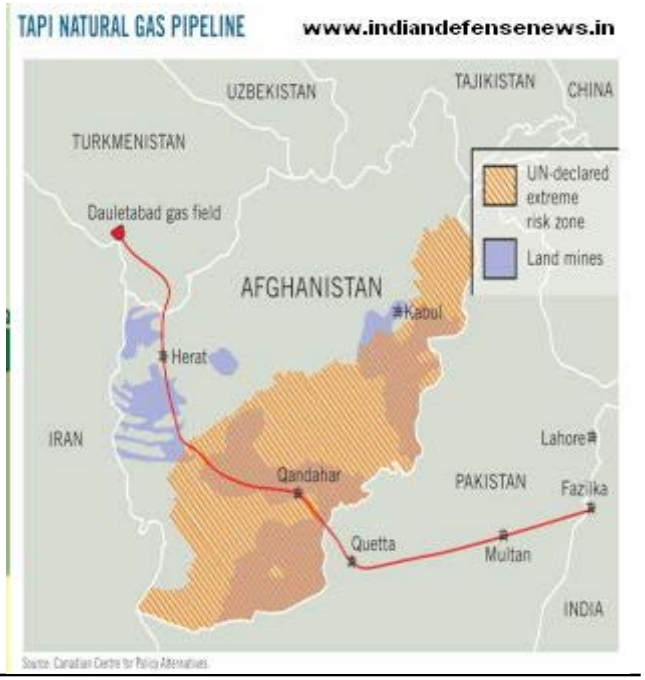


The Economist 2014

  - Overlapping and disputed claims of economic sovereignty.
    - Exclusive Economic Zone (EEZ)- countries have exclusive rights to seabed resources up to 200 miles
    - Beyond the EEZ, assessments of "natural prolongation" of the continental shelf may influence countries' seabed boundaries.

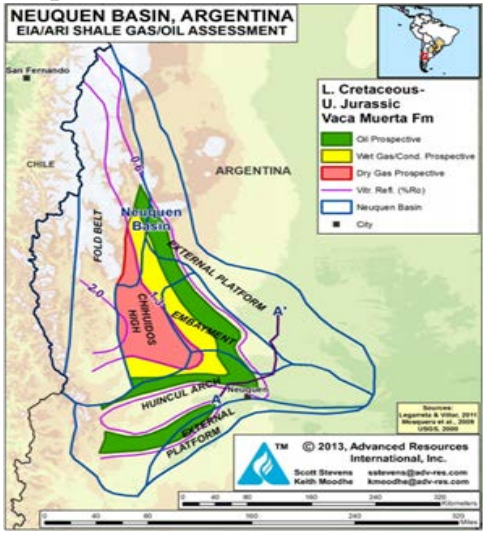
TAPI Natural Gas Pipeline

- **Turkmenistan–Afghanistan–Pakistan–India Pipeline (TAPI)**
  - A natural gas pipeline being developed by the Asian Development Bank.
  - The pipeline will transport Caspian Sea natural gas from Turkmenistan through Afghanistan into Pakistan and then to India.
    - Progress, but future uncertain
    - Construction on the project started in Turkmenistan on December 13th, 2015.
    - The pipeline is expected to be operational by 2019.
  - The abbreviation TAPI comes from the first letters of those countries
  - Proponents of the project see it as a modern continuation of the Silk Road.



Argentina Shale Gas

- EIA recent update of global shale resources ranked Argentina's potential second in the world
  - 802 TCF/22,700 BCM
- Argentina rates their shale prospects at:
  - 1181 TCF/33,400 BCM
- Vaca Muerta's geologic properties have been compared to the Eagle Ford in terms of its depth, thickness, pressure, and mineral composition.

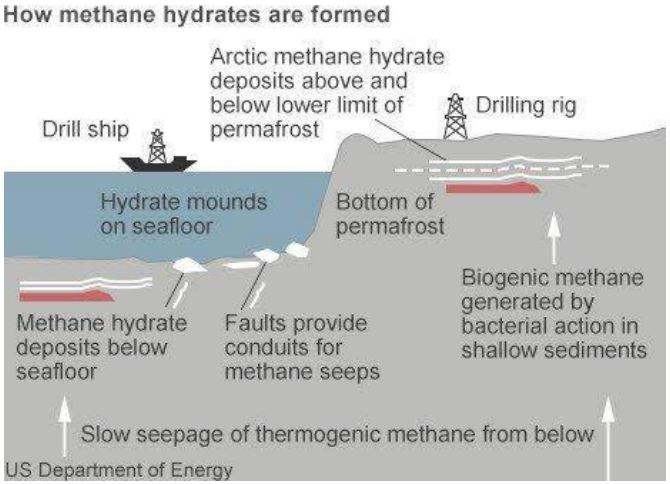


Methane Hydrates – 280,000 to 2,800,000 BCM?

- **For the first time, China has extracted gas from methane Hydrates under the South China Sea**
- Considered key to (their?) future global energy supply
- Officially known as methane clathrates, or hydrates
- Methane hydrates, also called "flammable ice", hold vast reserves of natural gas
- Many countries including the US and Japan are working on how to tap those reserves
- Mining and extracting are extremely difficult
  - They are formed at very low temperatures and under high pressure
  - They can be found in sediments under the ocean floor as well as underneath permafrost on land.

• Methane hydrates could be key to future energy needs

Likely the world's last great source of carbon-based fuel



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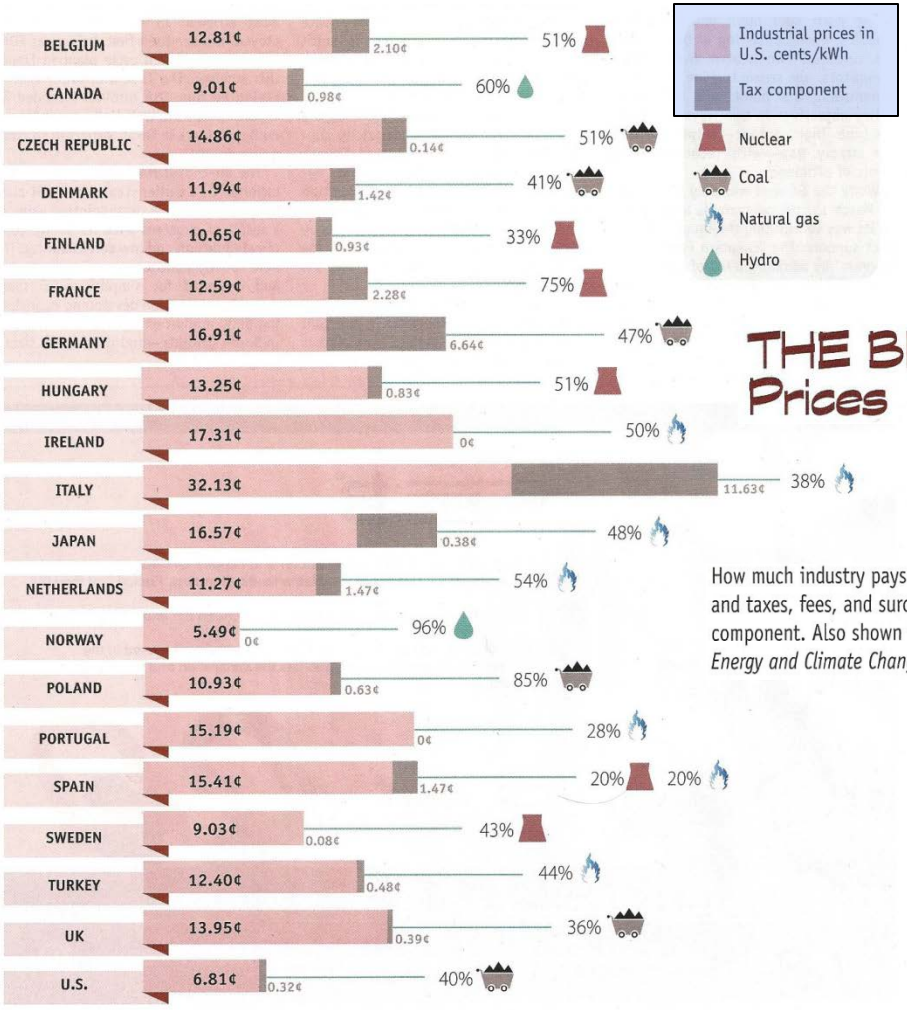
Stray Data

The Big Picture: World Industrial Power Prices



THE BIG PICTURE: World Industrial Power Prices

How much industry pays for power varies tremendously by country, owing to variations in generation costs, network costs, and taxes, fees, and surcharges. This comparison shows average industrial electricity prices in 2013, with each nation's tax component. Also shown is the fuel source that dominated each nation's power mix in 2013. *Source: UK Department of Energy and Climate Change, Eurostat, International Energy Agency* ***—Copy and artwork by Sonal Patel, associate editor***

AEO2017 Cost & Performance New Generating Tech

Technology	First Available Year[1]	Size (MW)	Lead time (years)	Base Overnight Cost in 2015 (2015 $/kW)	Project Contin-gency Factor[2]	Techno-logical Optimism Factor[3]	Total Overnight Cost in 2015[4,10] (2015 $/kW)	Variable O&M[5] (2015 $/MWh)	Fixed O&M (2015 $/ kW/yr.)	Heatrate[6] in 2015 (Btu/ kWh)	nth-of-a-kind Heatrate (Btu/ kWh)
Coal with 30% carbon sequestration (CCS)	2019	650	4	4,649	1.07	1.03	5,098	6.95	68.49	9,750	9,221
Conv Gas/Oil Comb Cycle	2018	702	3	911	1.05	1.00	956	3.42	10.76	6,600	6,350
Adv Gas/Oil Comb Cycle (CC)	2018	429	3	1,000	1.08	1.00	1,080	1.96	9.78	6,300	6,200
Adv CC with CCS	2018	340	3	1,898	1.08	1.04	2,132	6.97	32.69	7,525	7,493
Conv Comb Turbine[7]	2017	100	2	1,026	1.05	1.00	1,077	3.42	17.12	9,960	9,600
Adv Comb Turbine	2017	237	2	632	1.05	1.00	664	10.47	6.65	9,800	8,550
Fuel Cells	2018	10	3	6,217	1.05	1.10	7,181	44.21	0.00	9,500	6,960
Adv Nuclear	2022	2,234	6	5,288	1.10	1.05	6,108	2.25	98.11	10,449	10,449
Distributed Generation-Base	2018	2	3	1,448	1.05	1.00	1,520	7.98	17.94	9,004	8,900
Distributed Generation - Peak	2017	1	2	1,739	1.05	1.00	1,826	7.98	17.94	10,002	9,880
Biomass	2019	50	4	3,498	1.07	1.01	3,765	5.41	108.63	13,500	13,500
Geothermal[8,9]	2019	50	4	2,559	1.05	1.00	2,687	0.00	116.12	9,541	9,541
MSW - Landfill	2018	50	3	7,954	1.07	1.00	8,511	9.00	403.97	14,360	18,000
Conventional Hydropower[9]	2019	500	4	2,191	1.10	1.00	2,411	2.62	14.70	9,541	9,541
Wind[10]	2018	100	3	1,536	1.07	1.00	1,644	0.00	45.98	9,541	9,541
Wind Offshore	2019	400	4	4,605	1.10	1.25	6,331	0.00	76.10	9,541	9,541
Solar Thermal[8]	2018	100	3	3,895	1.07	1.00	4,168	0.00	69.17	9,541	9,541
Photovoltaic[8,11]	2017	150	2	2,362	1.05	1.00	2,480	0.00	21.33	9,541	9,541

BP Conversion Factors

Approximate conversion factors

Crude oil*

From	To				
	tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

*Based on worldwide average gravity.

Products

	To convert			
	barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied petroleum gas (LPG)	0.086	11.60	0.542	1.844
Gasoline	0.120	8.35	0.753	1.328
Kerosene	0.127	7.88	0.798	1.253
Gas oil/diesel	0.134	7.46	0.843	1.186
Residual fuel oil	0.157	6.35	0.991	1.010
Product basket	0.125	7.98	0.788	1.269

Natural gas (NG) and liquefied natural gas (LNG)

From	To					
	billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

Units

1 metric tonne	= 2204.62lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187kJ = 3.968Btu
1 kilojoule (kJ)	= 0.239kcal = 0.948Btu
1 British thermal unit (Btu)	= 0.252kcal = 1.055kJ
1 kilowatt-hour (kWh)	= 860kcal = 3600kJ = 3412Btu

Calorific equivalents

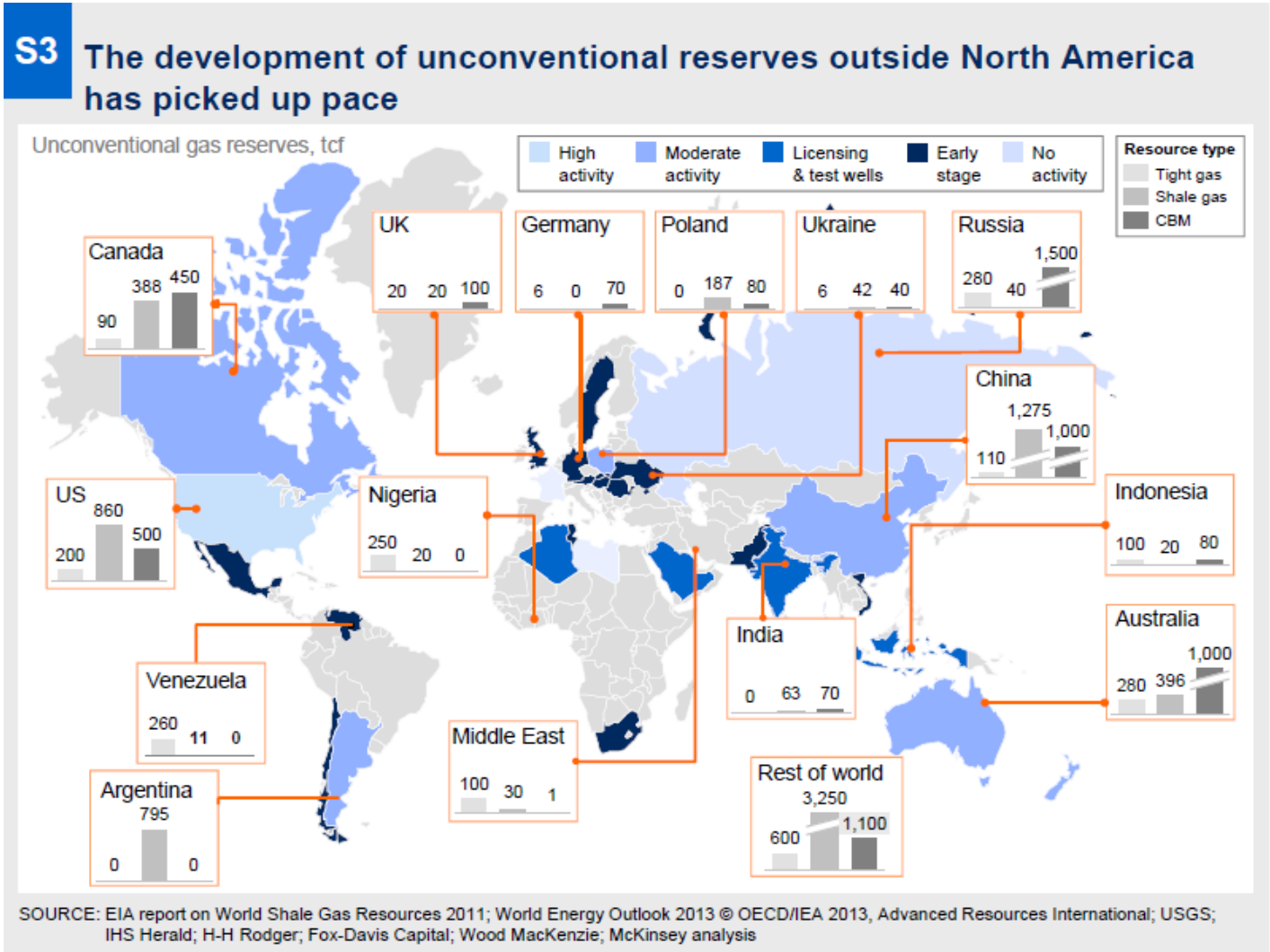
One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural gas and liquefied natural gas table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil
1 barrel of biodiesel = 0.88 barrel of oil

Unconventional Resources

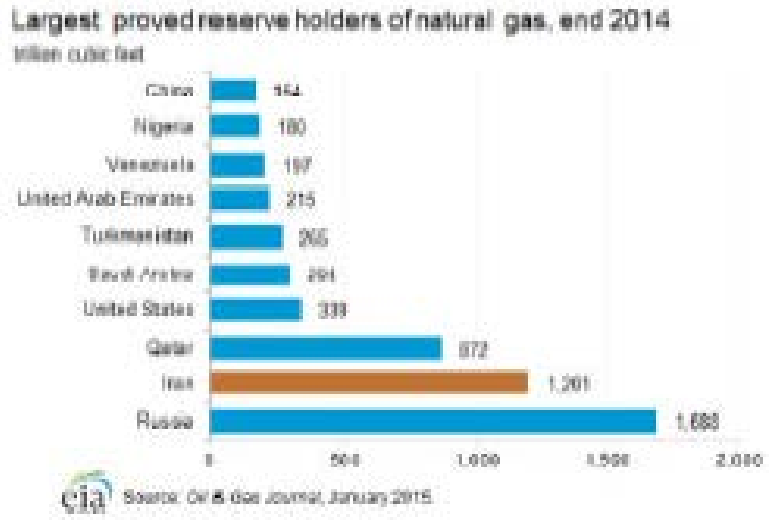


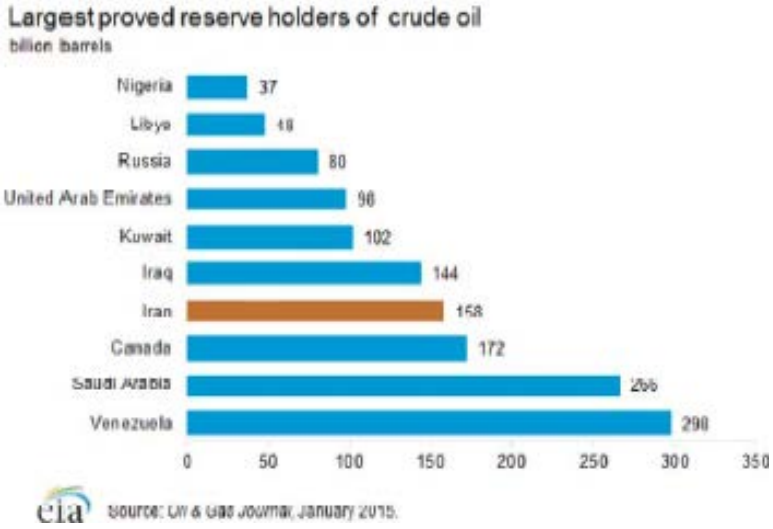
Iran

- Iran holds the world's fourth-largest proved crude oil reserves and the world's second-largest natural gas reserves
- Iran Petroleum Ministry reserves 1201tcf/33,988 BCM
- Iran may have more success with LNG rather than pipeline to Europe
- Target export of 11 MMtpy (15.2 BCM)
- LNG Foreign investment opportunities
  - LNG Plant near Tombak 25 MMtpy/35 BCM
  - Kish Island recoverable reserves 63.6 tcf/1,800 BCM

Source: U.S. Energy Information Administration, IHS EDIN

Source: U.S. Energy Information Administration, IHS EDIN

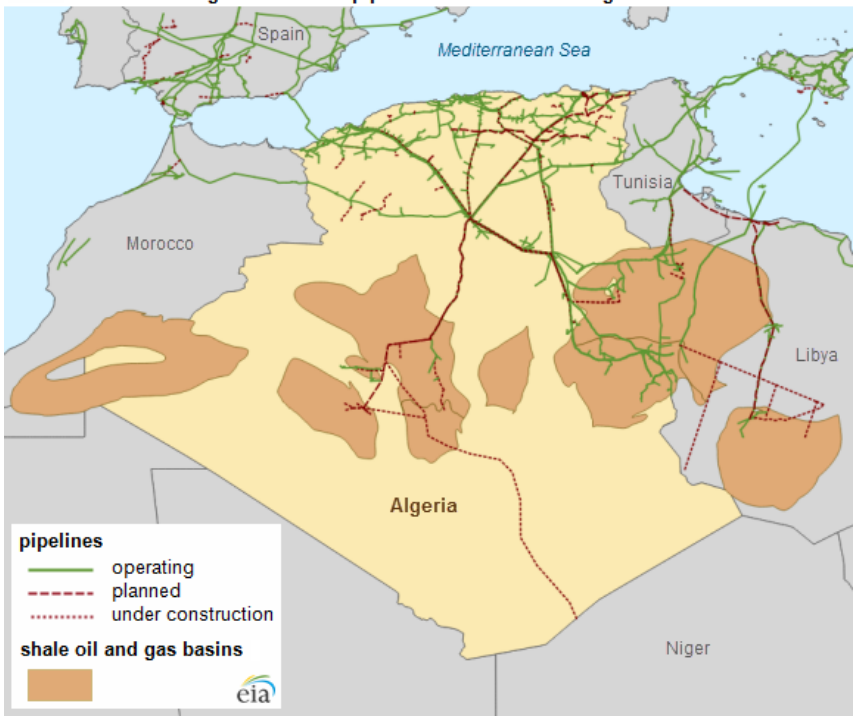




Algeria

- Sonatrach announced plans to spend $64 billion, or 70% of its total investment program from 2015 to 2018, in upstream activities to reverse the decline in crude oil and natural gas production in Algeria
- Sonatrach set a target to increase gross hydrocarbon output:
  - 1,429 million barrels of oil equivalent (MMBOE) in 2014 to 1,649 MMBOE by 2019
  - 535 to 616 MMBOE of oil
  - 894 to 1,034 MMBOE of natural gas
- Declining production has led the Algerian government to amend its law regarding foreign investment in hydrocarbons in an attempt to attract the investment and technology improvements needed to help stop production declines

Shale oil and natural gas basins and pipeline infrastructure in Algeria



Saudi Arabia

- Plans to spend $150B per year to become the global leader in refining and petrochemical production
- Including $70-80B of overseas downstream acquisitions
- Seeks to boost ties with China & Korea
- Satisfy domestic transport fuel and chemical demand, domestically
- Increase refined product export to Europe
- Worldwide target of 8-10 MMbpd
- Will add 1.2 MMbpd of new Middle Eastern refining capacity by 2018
- Double gas output by 2030
- Invest $190B in power generation

TABLE 1. HPI facilities in Saudi Arabia

Refinery/plant	Capacity	Unit	Description	Location	Products
Jiddah refinery	100,000	bpd	May close by 2022 due to age and environmental concerns	Jiddah	LPG, unleaded gasoline, diesel, asphalt, naphtha, kerosine, jet fuel
Ras Tanura refinery	550,000	bpd	Will be upgraded to produce low-sulfur fuels	Ras Tanura	LPG, gasoline, diesel, jet fuel, fuel oil, asphalt
Riyadh refinery	120,000	bpd	Will be upgraded to produce low-sulfur fuels	Riyadh	Gasoline, diesel, asphalt, sulfur
Yanbu refinery	225,000	bpd	Mainly serves the domestic market	Yanbu	LPG, gasoline, jet fuel, diesel, fuel oil
SAMREF (Saudi Aramco Mobil Refinery Co.)	400,000	bpd	Completed clean fuels upgrade project in 4Q 2014	Yanbu	Gasoline, jet fuel, diesel, marine fuel oil, propane, sulfur
LUBEREF (Saudi Aramco Lubricating Oil Refining Co.)	4 million	bpy	The sole in-Kingdom producer of lubricating base oils	Jiddah and Yanbu	Base oils
SASREF (Saudi Aramco Shell Refinery Co.)	305,000	bpd	Produces petroleum products and chemical plant feedstocks, primarily for sale in markets outside Saudi Arabia	Jubail	LPG, sulfur, benzene, naphtha, kerosine, gasoil, fuel oil
Petro Rabigh complex (Saudi Aramco/Sumitomo Chemical Co. JV)	400,000	bpd	Will be upgraded to produce low-sulfur fuels	Rabigh	Polyethylene, polypropylene, monoethylene, glycol, LPG, naphtha, gasoline, gasoil, fuel oil, kerosine
Jazan refinery (under construction)	400,000	bpd	Estimated completion date is 2017	Jazan	Gasoline, ultra-low-sulfur diesel, fuel oil
SATORP refinery (Saudi Aramco Total Refining and Petrochemical Co.)	400,000	bpd	Completed in 2014	Jubail	Gasoline, diesel, jet fuel, petroleum coke, fuel oil, liquid sulfur, aromatics
Sadara Chemical Co. complex (Saudi Aramco/ Dow Chemical Co. JV)	3 million	tpy	Estimated completion date is 2016	Jubail	Amines, glycol ethers, isocyanates, polyether polyols, polyethylene, polyolefin elastomers, propylene glycol
YASREF (Yanbu Aramco Sinopec Refining Co.)	400,000	bpd	Completed in 2014	Yanbu	LPG, gasoline, jet fuel, diesel, fuel oil

Source: Hydrocarbon Processing November 2015

Hydrocarbon Processing Worldwide Refining

TABLE 1. Refining capacity by region, MMbpd, 2007–2015*

	2007	2009	2011	2012	2013	2014	2015
US	17.59	17.58	17.32	17.82	17.93	17.89	18.32
North America	20.96	21.02	20.97	21.48	21.5	21.46	21.88
Central and South America	6.53	6.31	6.45	5.82	5.92	6.07	6.22
Brazil	1.96	1.99	2.01	2	2.09	2.24	2.28
Europe	24.55	24.4	24.24	23.55	23.64	23.63	23.64
Russia	5.48	5.44	5.73	5.84	6.25	6.35	6.43
Middle East	7.56	7.99	8.1	8.23	8.4	9.34	9.34
Africa	3.03	3.08	3.26	3.47	3.57	3.59	3.59
Asia-Pacific	26.1	27.77	29.09	30.59	32.04	32.68	32.55
China	8.75	9.48	10.83	11.93	13.3	14.11	14.26
India	2.98	3.57	3.8	4.28	4.32	4.32	4.31
World total	**88.75**	**90.57**	**92.11**	**93.13**	**95.07**	**96.77**	**97.23**
OECD	45.51	45.5	44.96	44.81	44.31	43.91	44.12
Non-OECD	43.24	45.07	27.15	48.32	50.75	52.86	53.11

*Note: Numbers may not equal due to rounding. Source: BP's *Statistical Review of World Energy 2016*.

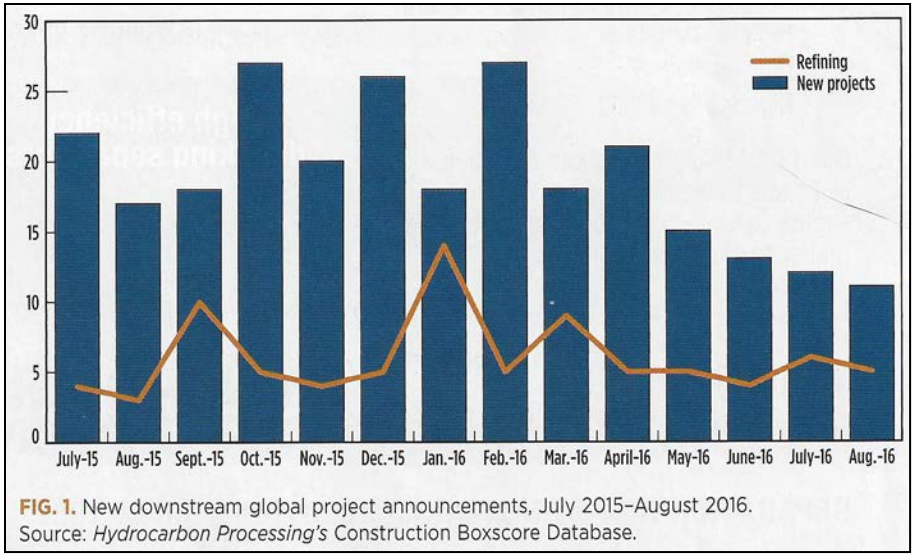
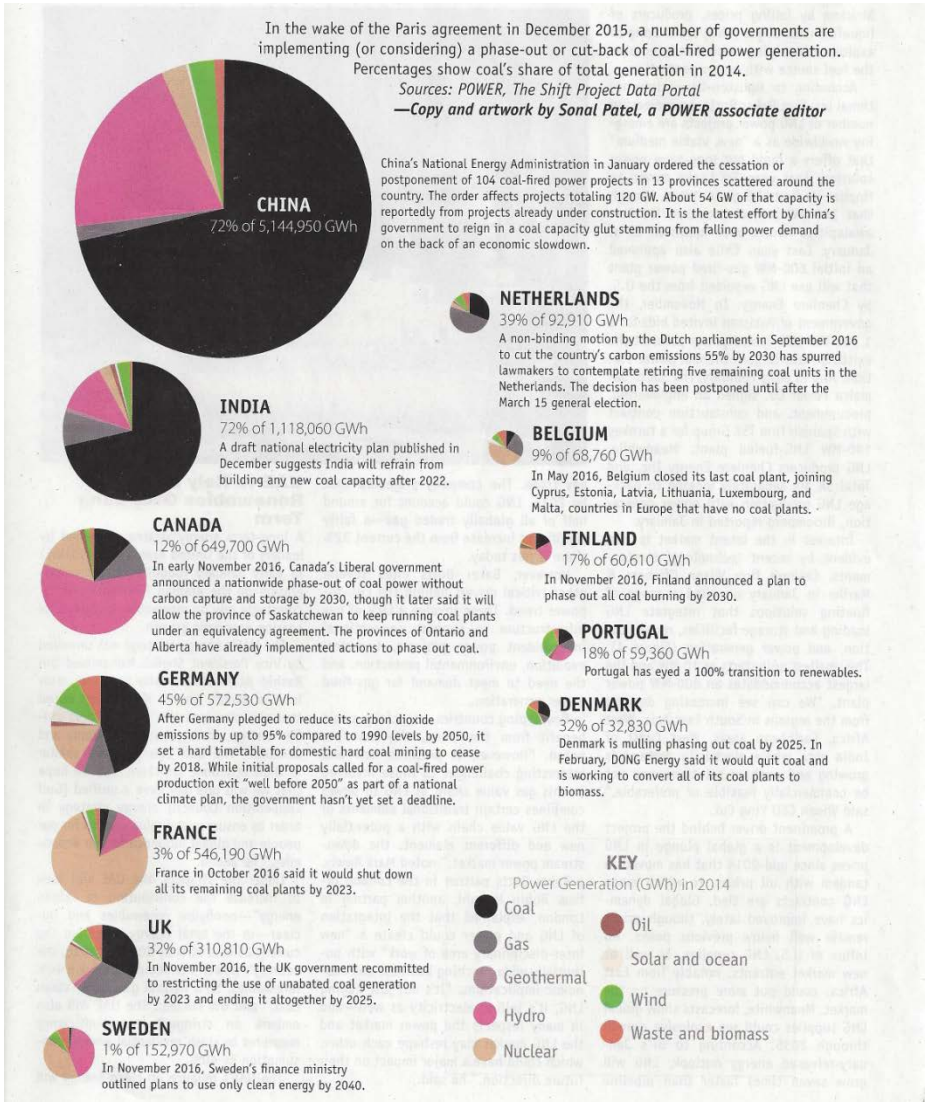
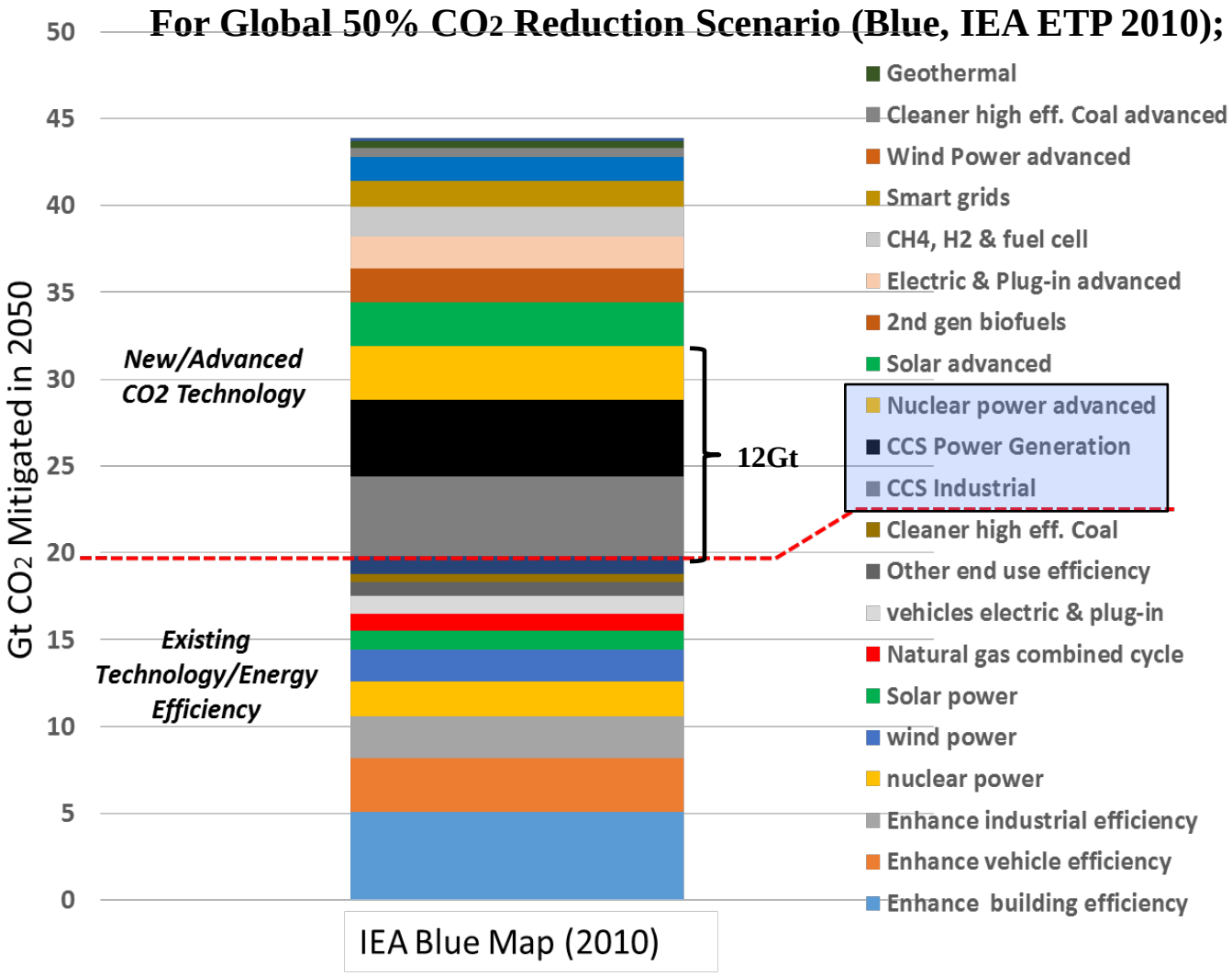


FIG. 1. New downstream global project announcements, July 2015–August 2016. Source: *Hydrocarbon Processing's* Construction Boxscore Database.

Power Big Picture: Shunning Coal



New & Advanced Technologies Needed



Source: DOE SCO2 Conference 2014, as presented by EPA

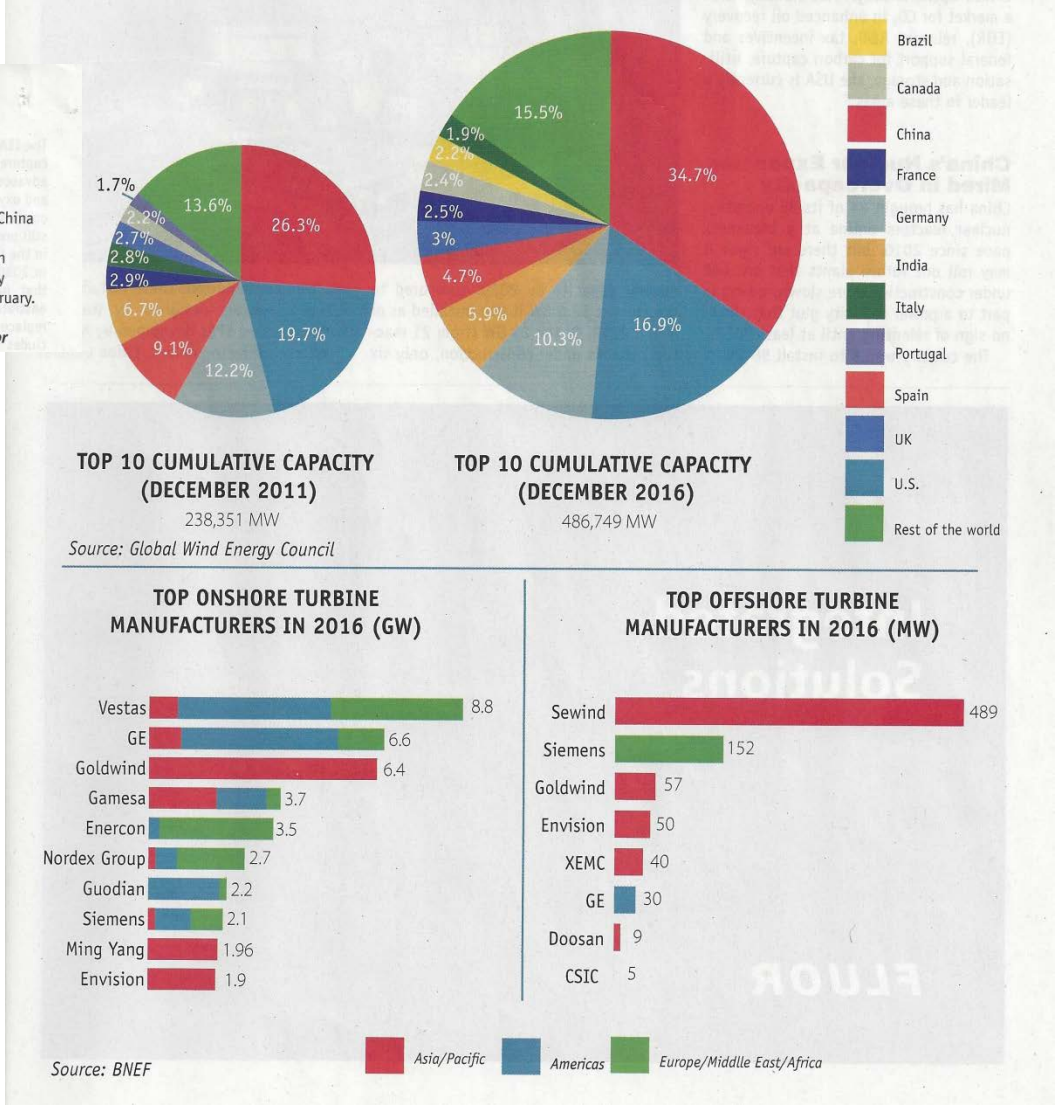
Power: “Prevailing Winds”

GLOBAL MONITOR

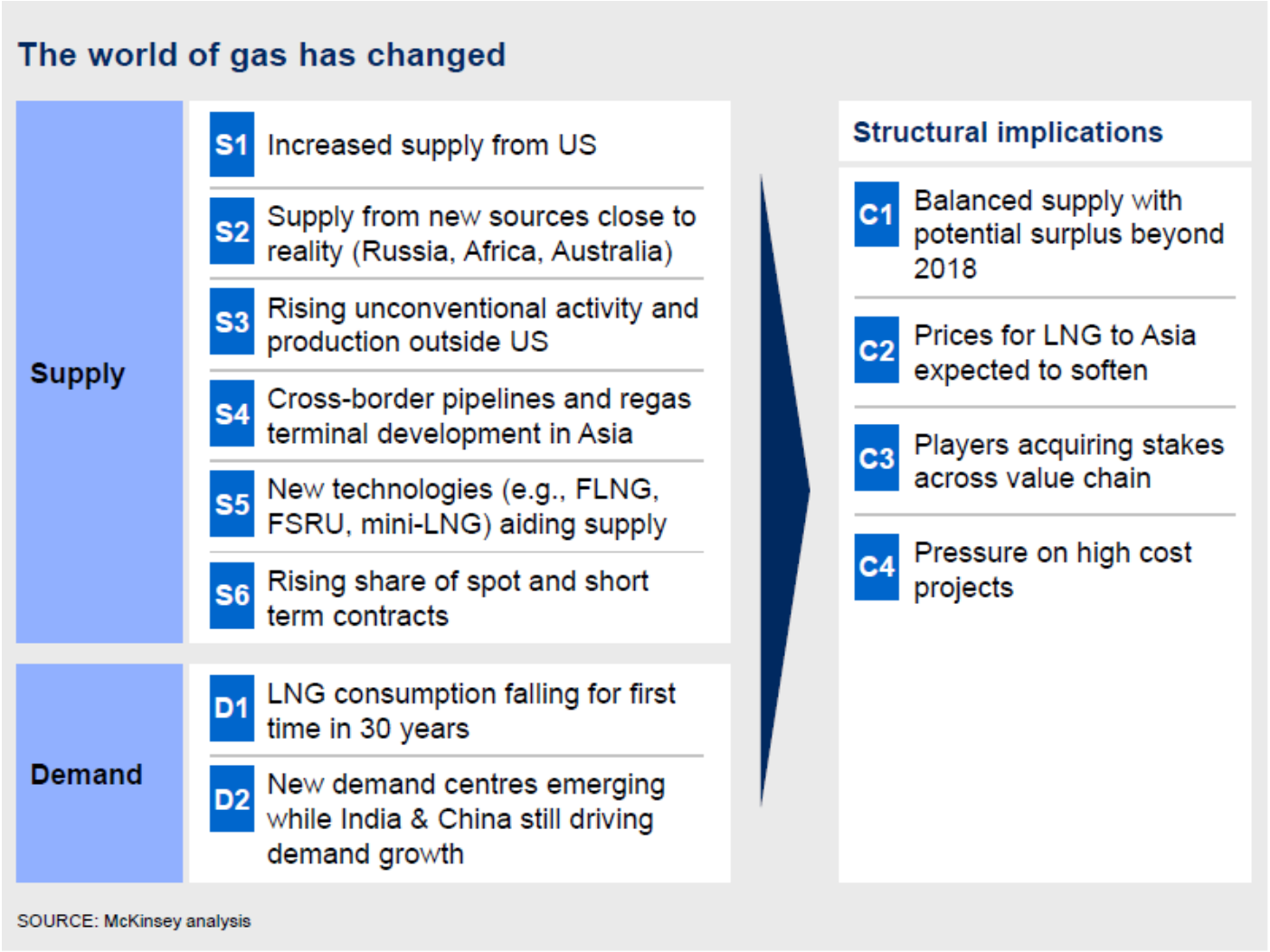
THE BIG PICTURE: Prevailing Winds

Total global installed capacity of wind power surged to nearly 487 GW at the end of 2016. Over the past five years, China has taken an ever-larger share of the market, dominating onshore and offshore installations in 2016. Chinese wind turbine manufacturers have also made big gains in market share in a sector increasingly characterized by mergers. In 2016, a “strong breakaway group” of three companies emerged within the world’s wind turbine market, “with a fairly tight field following,” noted David Hostert, head of wind research for Bloomberg New Energy Finance (BNEF), in February. Siemens Wind and Gamesa, which are in the process of merging, will join the “big four” dominant group, he said.

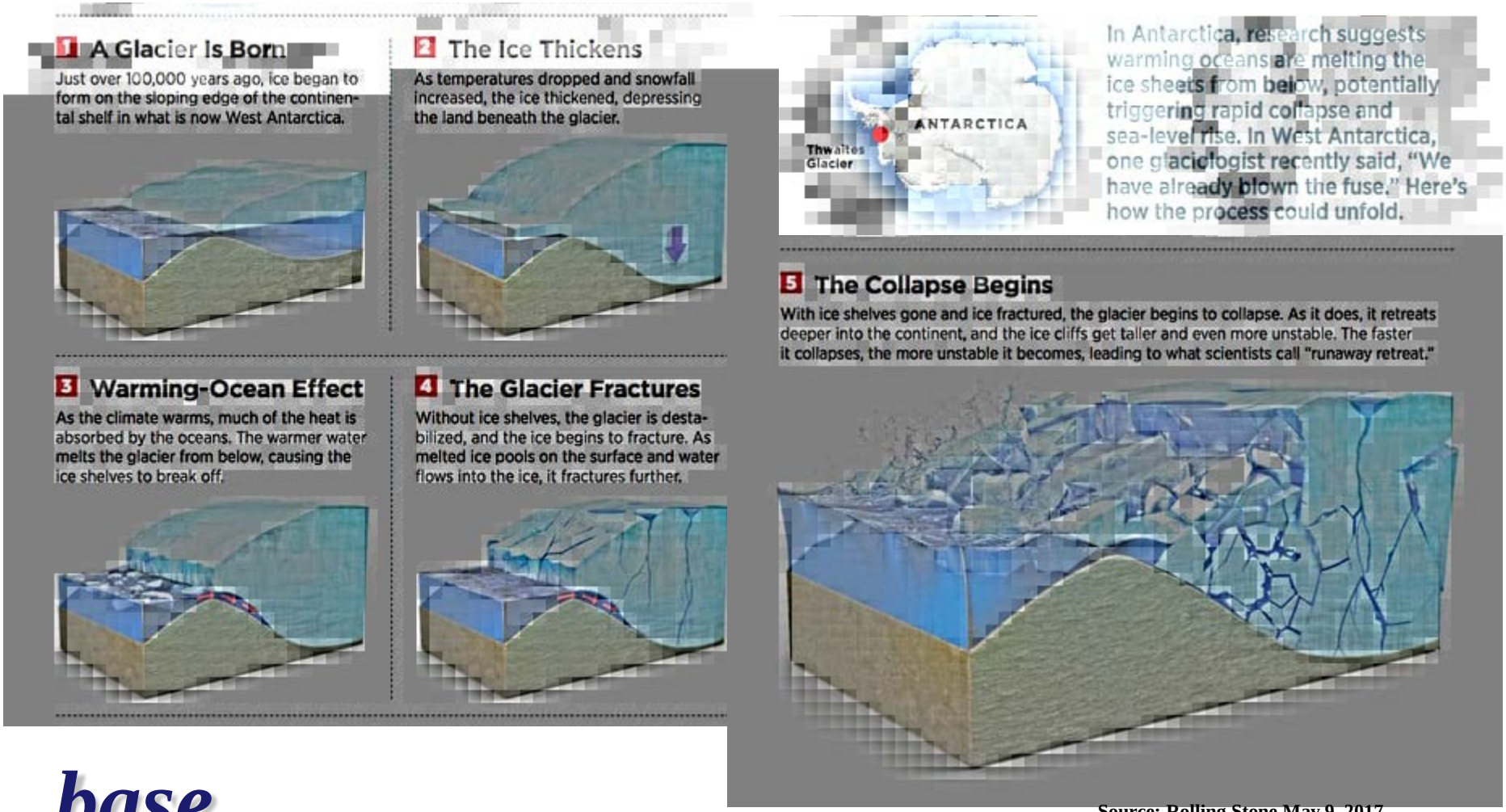
—Copy and artwork by Sonal Patel, a POWER associate editor



The World of Gas has Changed



The Ice Apocalypse



Source: Rolling Stone May 9, 2017

Saudi Arabia's Oil Ministry - OPEC April 12, 2017

OPEC 24th Forum on Fundamentals of the Oil and Gas Industry in Kuwait

- A stable oil price of ~$60/bbl over the next three years, rising gradually over the next 10 years to $70-80/bbl, will cause supply and demand to be roughly balanced
- Oil price of $70-80/bbl was "ideal in terms of the increasing production cost″
- Would result in higher investments in the oil and energy sectors ensuring market balance.
- Annual demand growth of "anywhere from 1.0-1.5 mmbbl/d" would boost current global demand by 10mm bbl/d to 108mm bbl/d.
- The most important factor promoting this would be global economic growth of 3-4%, with an even higher rate in developing countries
- Downplayed the importance of US shale oil
  - "is not a primary source of energy“
  - Contributes only 5% of global oil output
  - Even if prices were to rise to $100/bbl, shale output would rise from its current level of 4.5mm bbl/d to 10mm bbl/d over the coming decade, comprising "only 10% of total oil output”

Goldman Sachs

- A looming recovery in U.S. output on the back of higher oil prices combined with an avalanche of new conventional projects will create a substantial surplus by 2019
- Most forecasters including OPEC and the International Energy Agency underestimated shale's decline during the oil price collapse and its production increases as prices recovered.
- Predicts the coming two years will see a huge burst of development, complicating OPEC's efforts to rebalance the market and ease a global glut with the help of output cuts.
- "This long lead-time wave of projects and a short-cycle revival, led by U.S. shale, could create a material oversupply in 2018-19,
- New projects and rising shale output could add 1 million barrels per day (bpd) to global supply by 2018-2019.
- The forecast contrasts with those of consultancy Wood Mackenzie, which foresees a supply gap of 20 million bpd by 2025, and Goldman's rival Morgan Stanley, which believes a surge in U.S. production this year will not derail the rebalancing.
- "OPEC has successfully constrained output, and although drilling activity in U.S. shale is picking up rapidly, this will probably not come quick enough to prevent a period of sizeable inventory draws late this year
- "By 2020, we estimate that (around) 1.5 million bpd of demand will need to come from projects that have not been sanctioned yet, but that have break-even oil prices of $70-75 a barrel," the bank said.
- Goldman stands by its prediction that supply and demand will fall into and line this year, even though global crude inventories in developed economies alone top 3 billion barrels, some 300 million barrels above the five-year average that OPEC is targeting with its supply cuts.

Other Opinions

The Organization of the Petroleum Exporting Countries and some of its biggest rivals including Russia, agreed in late 2016 to cut output jointly by 1.8 million bpd for the first half of this year to tackle the overhang.

UBS, meanwhile, sees a potential 4 million bpd hole by 2020, even though a higher crude price this year has prompted some companies to bring forward their exploration and development plans. "Beyond 2017, the impact of a collapse in longer-cycle conventional investment over 2014-16 begins to be felt. 2015 saw just six major upstream projects totaling (some) 0.6 million bpd ... versus the 3-4 million bpd average, and 2016 has seen just one major liquids project sanctioned," UBS strategist Jon Rigby said.

Bank of America-Merrill Lynch points out that along with the collapse in spending, the global rig count, a measure of production activity, shows no sign of picking up outside the United States.

According to oil services company **Baker Hughes**, the number of non-U.S. oil rigs has risen by just 29 since hitting an 11-year low of 666 in November last year, compared with a rise of 346 in U.S. rigs in just 10 months.

Speaking at the **S&P Platts** London Oil & Energy Forum on Monday, **PIRA Energy's** Gary Ross said the bull market for oil is about to return, potentially sending prices as high as $60 a barrel in the coming weeks. Ross is frequently bullish on oil prices. In 2015, for example, he forecast that oil could jump to $75 in 2016. Prices did almost exactly the opposite, hitting multiyear lows in February 2016, before ending the year on a more upbeat note following OPEC's output deal.

Dave Ernsberger, global head of energy pricing at Platts, said **Platts Analytics** projected Brent could rise to $65-$70 a barrel by December this year.

Conference delegates had a more muted outlook on the oil price, however. In a poll asking "what price will front-month ICE Brent futures be trading this time next year," 48% of respondents chose the $55-$65 bracket.

Gas Bridge to Renewables Already Built

- For the U.S. to reach its climate goals, the deadline for constructing the last gas-fired power plant is coming up shortly — if not already past
- Gas has a significant near-term role in reducing dependence on coal-fired power and helping the transition to intermittent renewable sources. But, to reduce greenhouse gas emissions to a target of 80% below 1990 levels by 2050, the nation must ultimately eliminate almost all use of fossil fuels, including natural gas
- "A power plant on the drawing boards today could still be operational in 2050 and well beyond. With each passing year, the likely life span of new natural gas power plants moves further beyond 2050 ".
- **The U.S. EPA's Clean Power Plan might do more harm than good** because substituting gas-fired power for coal capacity is one of the options for complying with the rules requirements. Rather, lawmakers should consider setting a final date beyond which no new natural gas power plants can be approved, Weissman advised.
- To make that possible while maintaining grid reliability, policymakers would have to require strategic adoption of renewable power, trying to match the types and locations for maximum impact.
- Lawmakers and regulators would also need to deploy a wide range of demand-response tools, focus on energy efficiency measures and better structure regional power markets to manage shifting demand.
- Almost 237 GW of gas-fired generation capacity was added between 2000 and 2010, making up 81% of all the generation capacity added in that decade. This momentum could increasingly complicate efforts to cut back on gas use.
- **"As more people and institutions invest in natural gas, political pressure to sustain its use grows. It will become more and more difficult to achieve long-range greenhouse gas reduction goals". "Natural gas cannot play a long-term role in creating our desired carbon-constrained future, as its benefits are not enough to support our carbon reduction goals"**

Steve Weissman – Senior Policy Advisor, Center for Sustainable Energy

Source: Sarah Smith SNL Thursday, March 31, 2016 12:56 PM ET

CO_2 Emission from Electric Power

Electric power sector carbon dioxide emissions, 1990, 2005, 2008, and 2009

	1990	2005	2008	2009
Estimated emissions (million metric tons)	1,831.0	2,416.9	2,373.7	2,160.3
Change from 1990 (million metric tons)		585.8	542.7	329.3
(percent)		*32.0%*	*29.6%*	*18.0%*
Average annual change from 1990 *(percent)*		*1.9%*	*1.5%*	*0.9%*
Change from 2005 (million metric tons)			-43.1	-256.5
(percent)			*-1.8%*	*-10.6%*
Change from 2008 (million metric tons)				-213.4
(percent)				*-9.0%*

Figure 15. U.S. electric power sector energy sales and losses and carbon dioxide emissions from primary fuel combustion, 1990-2009

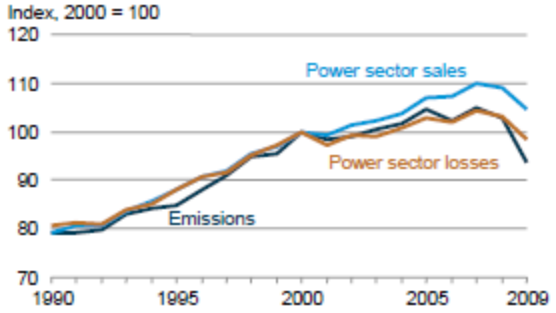


Table 12. U.S. carbon dioxide emissions from electric power sector energy consumption, 1990-2009 (million metric tons carbon dioxide)

Fuel	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009
Petroleum										
Residual fuel oil	91.6	44.6	68.6	68.5	69.3	69.1	28.4	31.3	18.9	14.3
Distillate fuel oil	7.1	7.9	12.8	11.8	8.1	8.4	5.4	6.5	5.3	5.1
Petroleum coke	3.1	8.2	10.1	17.8	22.7	24.9	21.8	17.5	15.7	14.2
Petroleum subtotal	*101.8*	*60.7*	*91.5*	*98.1*	*100.1*	*102.3*	*55.6*	*55.3*	*40.0*	*33.6*
Coal	1,547.6	1,660.7	1,927.4	1,931.0	1,943.1	1,983.8	1,953.7	1,987.3	1,959.4	1,742.2
Natural gas	175.5	228.2	280.9	278.3	296.8	319.1	338.2	371.7	362.3	372.6
Municipal solid waste[a]	5.8	10.0	10.1	11.4	11.2	11.2	11.5	11.3	11.6	11.8
Geothermal	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total	1,831.0	1,960.1	2,310.2	2,319.2	2,351.5	2,416.9	2,359.5	2,425.9	2,373.7	2,160.3

[a]Emissions from nonbiogenic sources, including fuels derived from recycled tires.
Notes: Emissions for total fuel consumption are allocated to end-use sectors in proportion to electricity sales. Totals may not equal sum of components due to independent rounding.

38.5% from Fossil Fuel PowerGen

2,302.9 total in 2005

base e

"Practical Strategies for Emerging Energy Technologies"

2005 @ 2416 Mt is benchmark for CPP
Was 2,416 x 0.68 = 1643 mmt