
IGTI Fuels Report

Presented at
ASME Power & Energy Conference
June 28, 2017
Charlotte, NC

pete_baldwin@base-e.net
+1-781-721-6200 (o)
+1-617-306-7419 (m)



“Practical Strategies for Emerging Energy Technologies”

Primary Energy Consumption by Fuel - Mtoe

U.S. = 90.12 Quads

Million tonnes oil equivalent	2015							2016						Percent of 2016 Total	
	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renew - ables	Total	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renew - ables		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

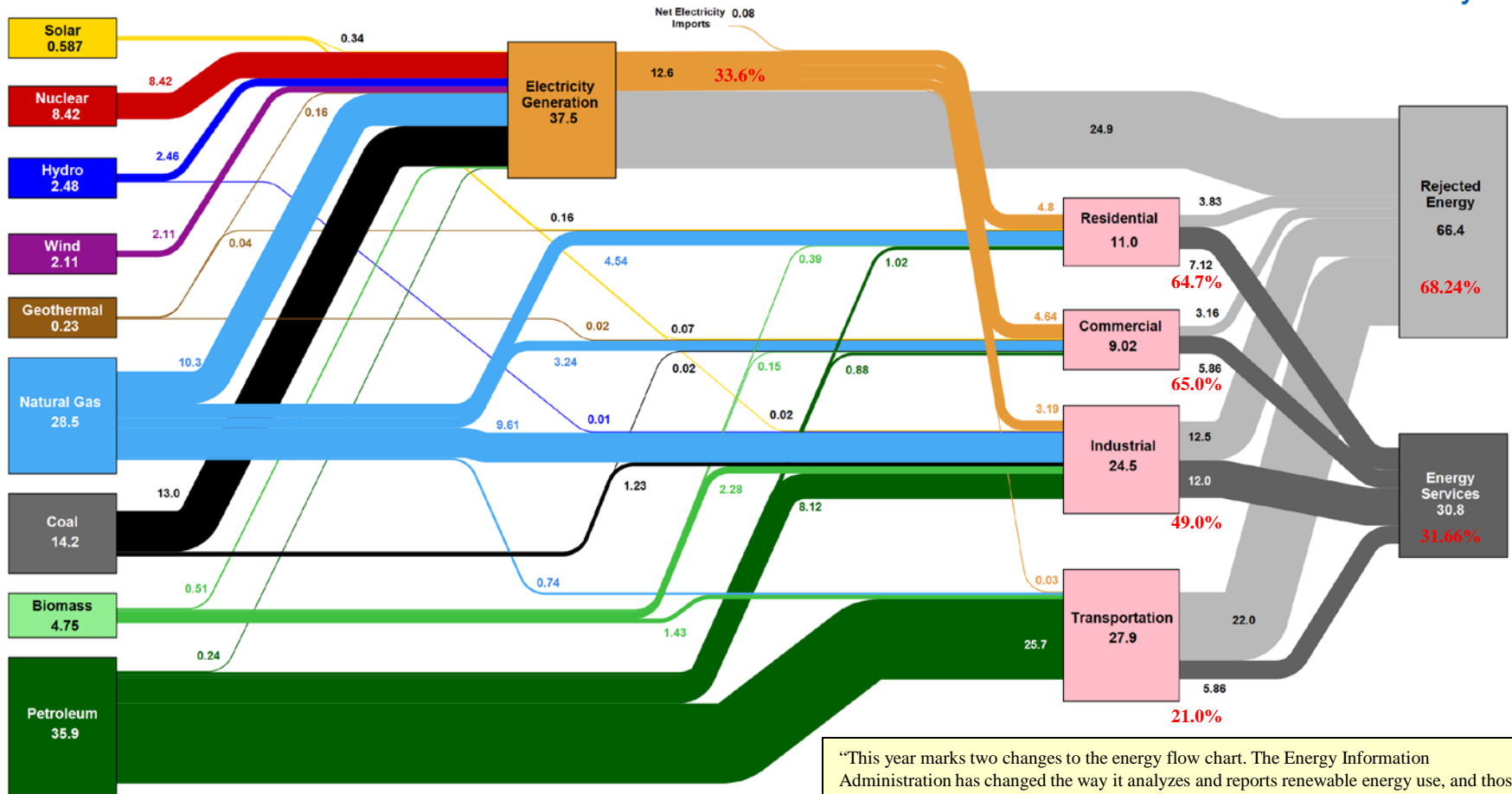
base_e

“Practical Strategies for Emerging Energy Technologies”

Source: BP Statistical Review of World Energy 2017

U.S. 2016 Energy Flow – 97.3Quads

Estimated U.S. Energy Consumption in 2016: 97.3 Quads



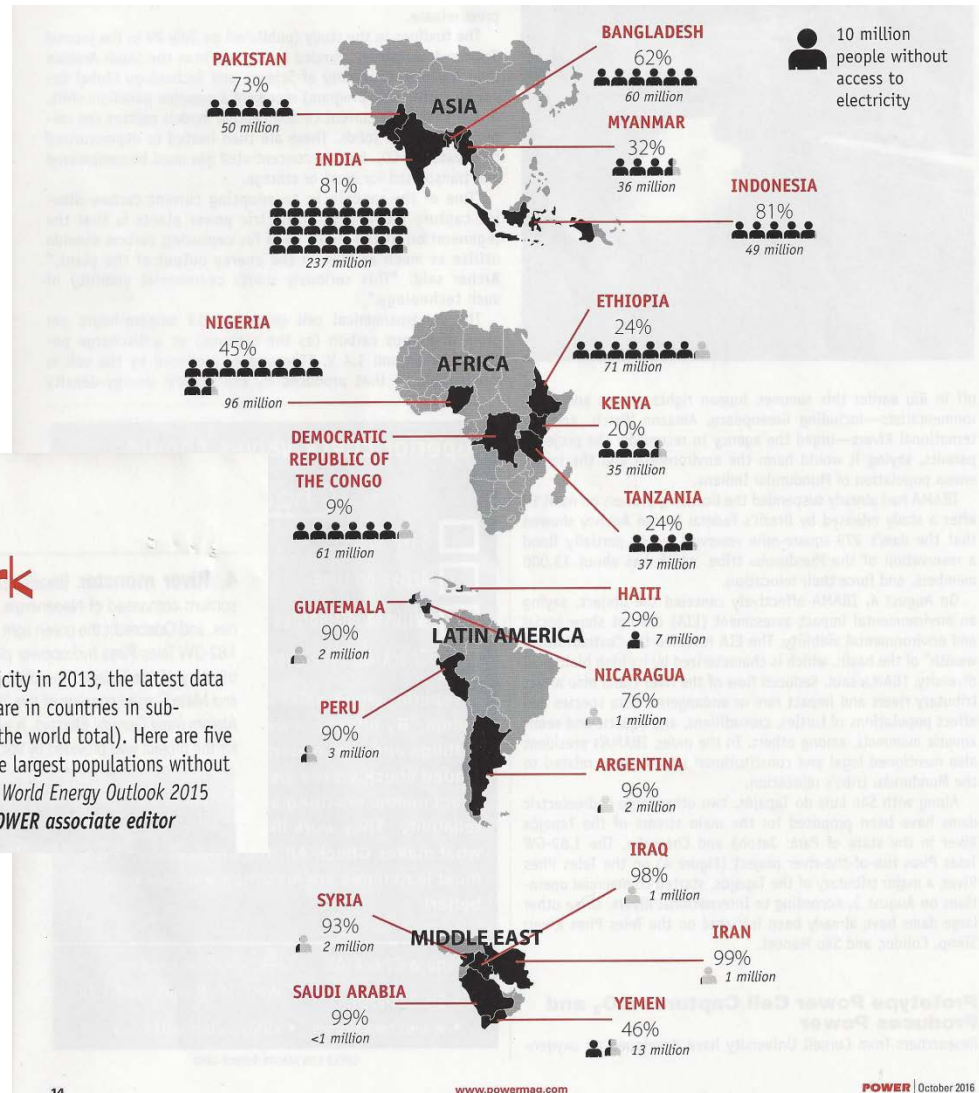
“This year marks two changes to the energy flow chart. The Energy Information Administration has changed the way it analyzes and reports renewable energy use, and those changes are reflected in the 2016 chart as well as a revision to the 2015 analysis. Additionally, the estimate of efficiency of the 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>



“Practical Strategies for Emerging Energy Technologies”

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

base_e

Worldwide CO₂ 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

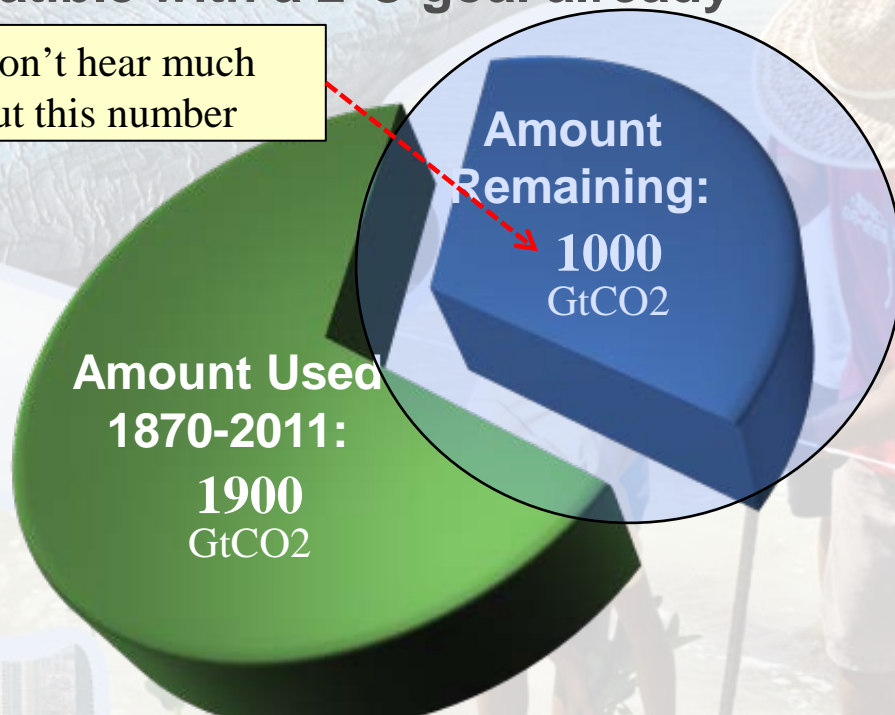
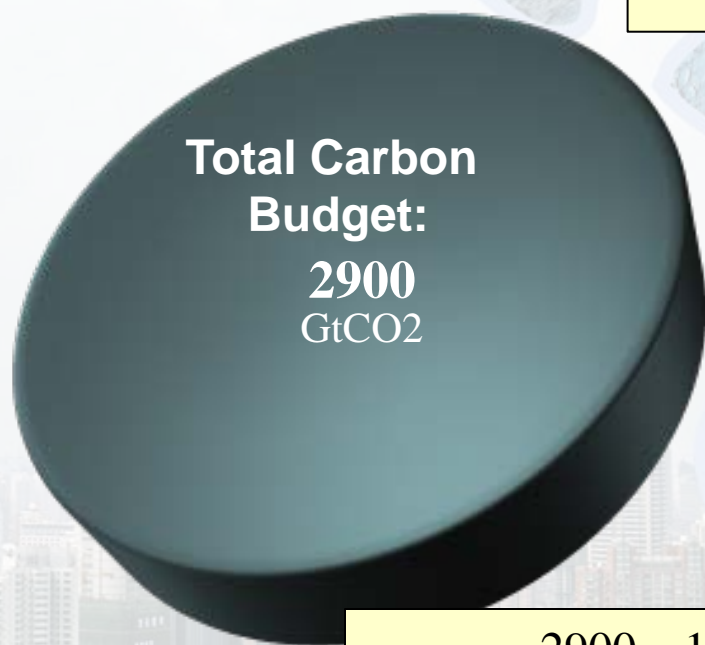
“Practical Strategies for Emerging Energy Technologies”

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



$$2900 - 1900 = 1000 \text{ GtCO}_2$$
$$1000 \text{ GtCO}_2 \div 33.5 = 29 \text{ Years is } 2040$$
$$1000 \text{ GtCO}_2 \div 43.2 = 23 \text{ Years is } 2034$$

AR5 WGI SPM

EIA Annual Energy Outlook 2017

Annual U.S. Emissions (Mmt CO2)

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

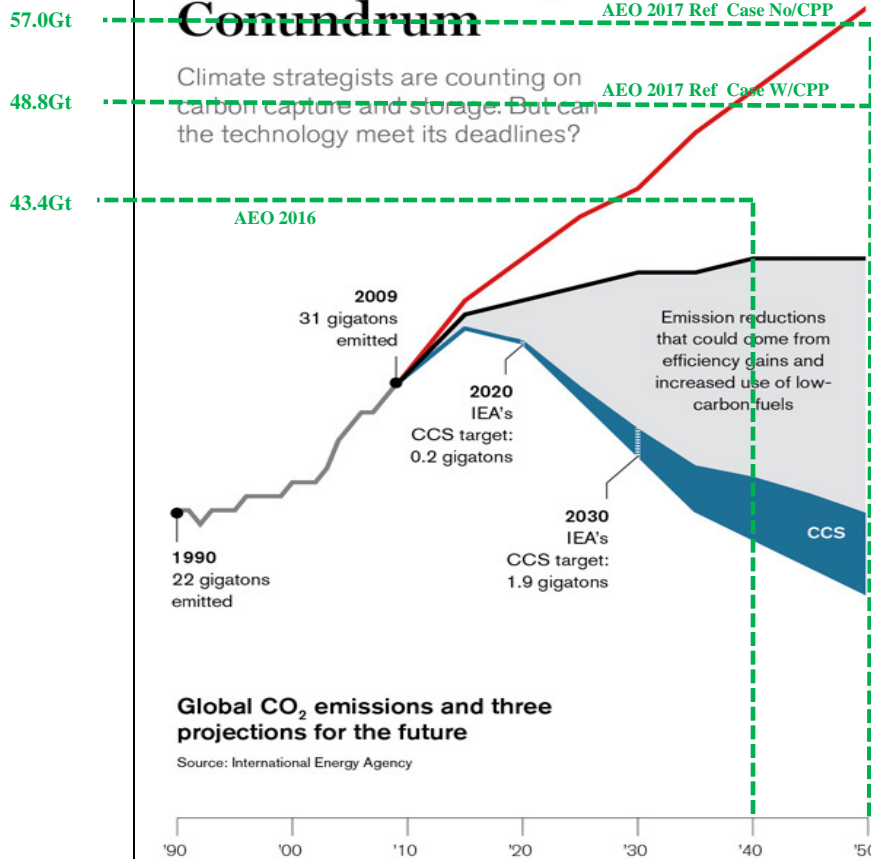
Worldwide Forecast with CPP = 48.8 Gt

Worldwide Forecast without CPP = 57.0 Gt

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

The Carbon Conundrum + AEO2017

The Carbon Capture Conundrum



Current trajectory
58 gigatons = 6°C

This projection assumes that essentially no action is taken to address climate change. Models predict a long-term global temperature rise of 6 °C in such a scenario.

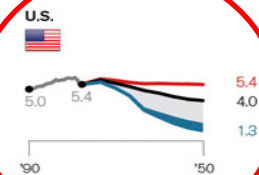
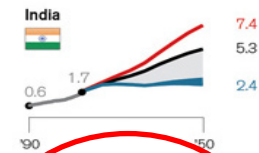
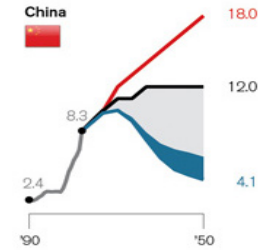
Global pledges
40 gigatons = 4°C

If countries make good on their pledges to reduce emissions, the projected trajectory is much less steep. Models suggest a long-term global temperature rise of 4 °C.

Target
16 gigatons

Models associate this trajectory with a long-term global temperature rise no higher than 2 °C. That has been a long-standing goal in climate change negotiations.

Scenarios and CCS targets for the three highest-emitting countries (in gigatons)



MIT Technology Review – Mike Orcott

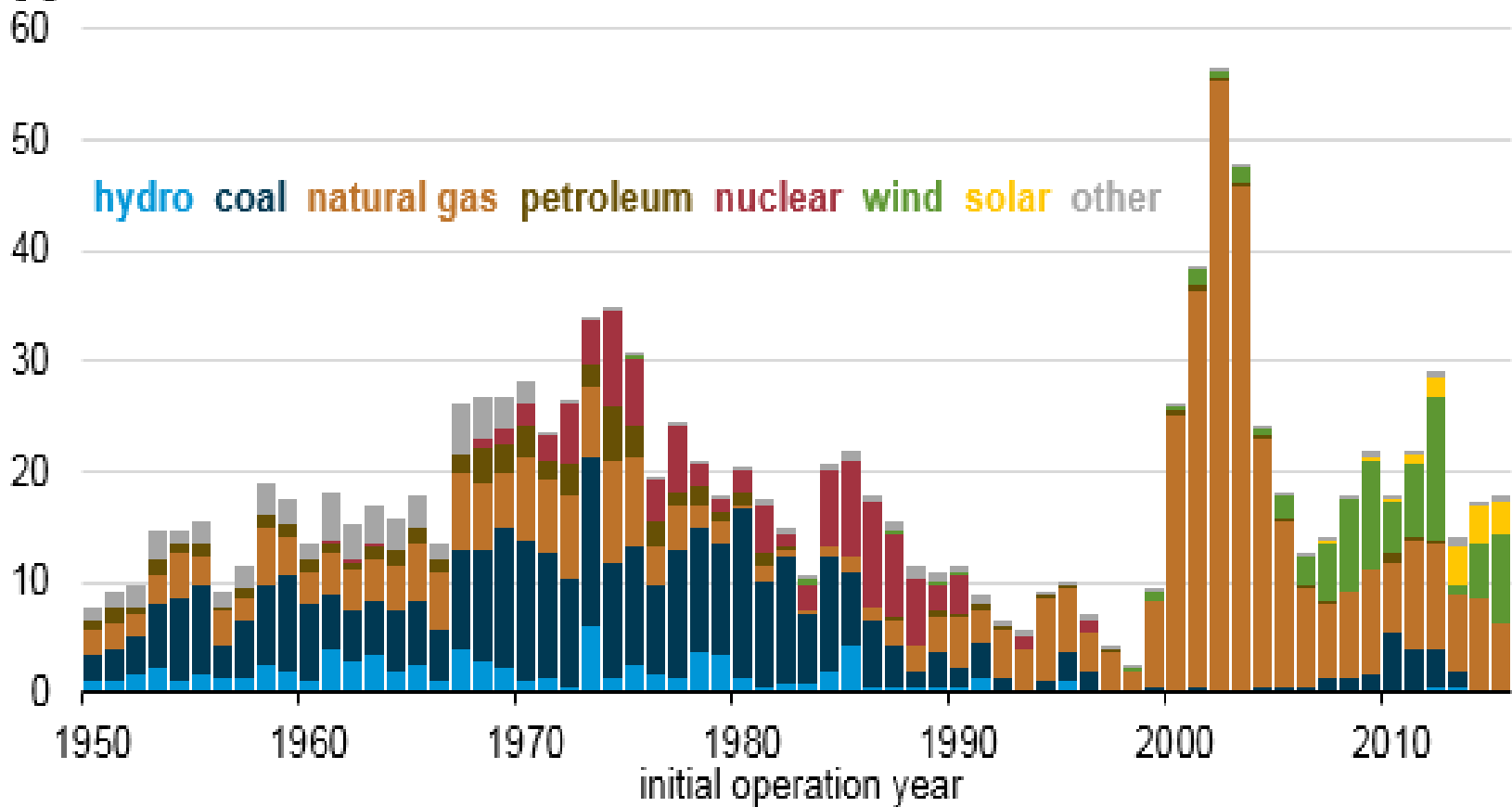
base_e

“Practical Strategies for Emerging Energy Technologies”

Electric Generation Capacity Additions

Electric generation capacity additions by technology (1950-2015)

gigawatts



Coal-to-Gas Shift – nature.com

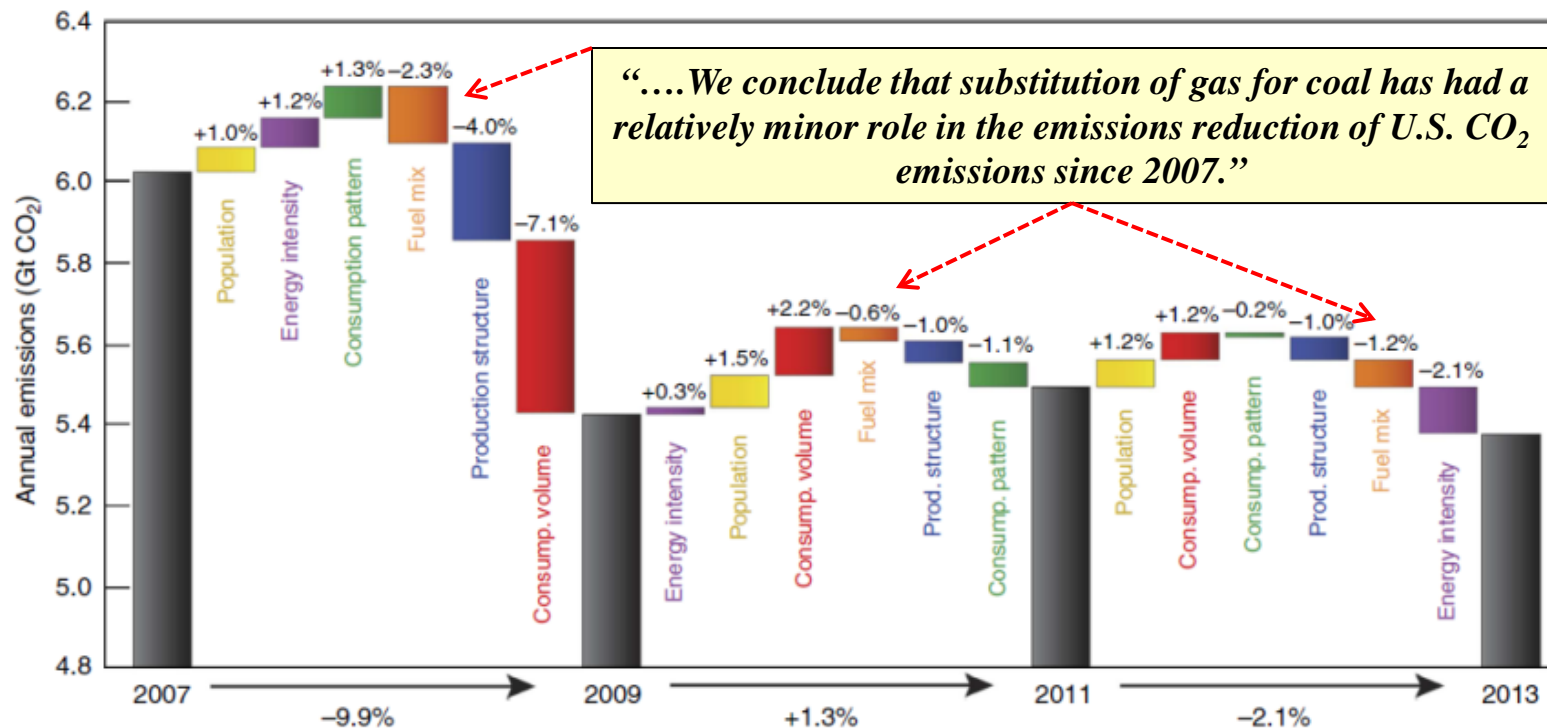


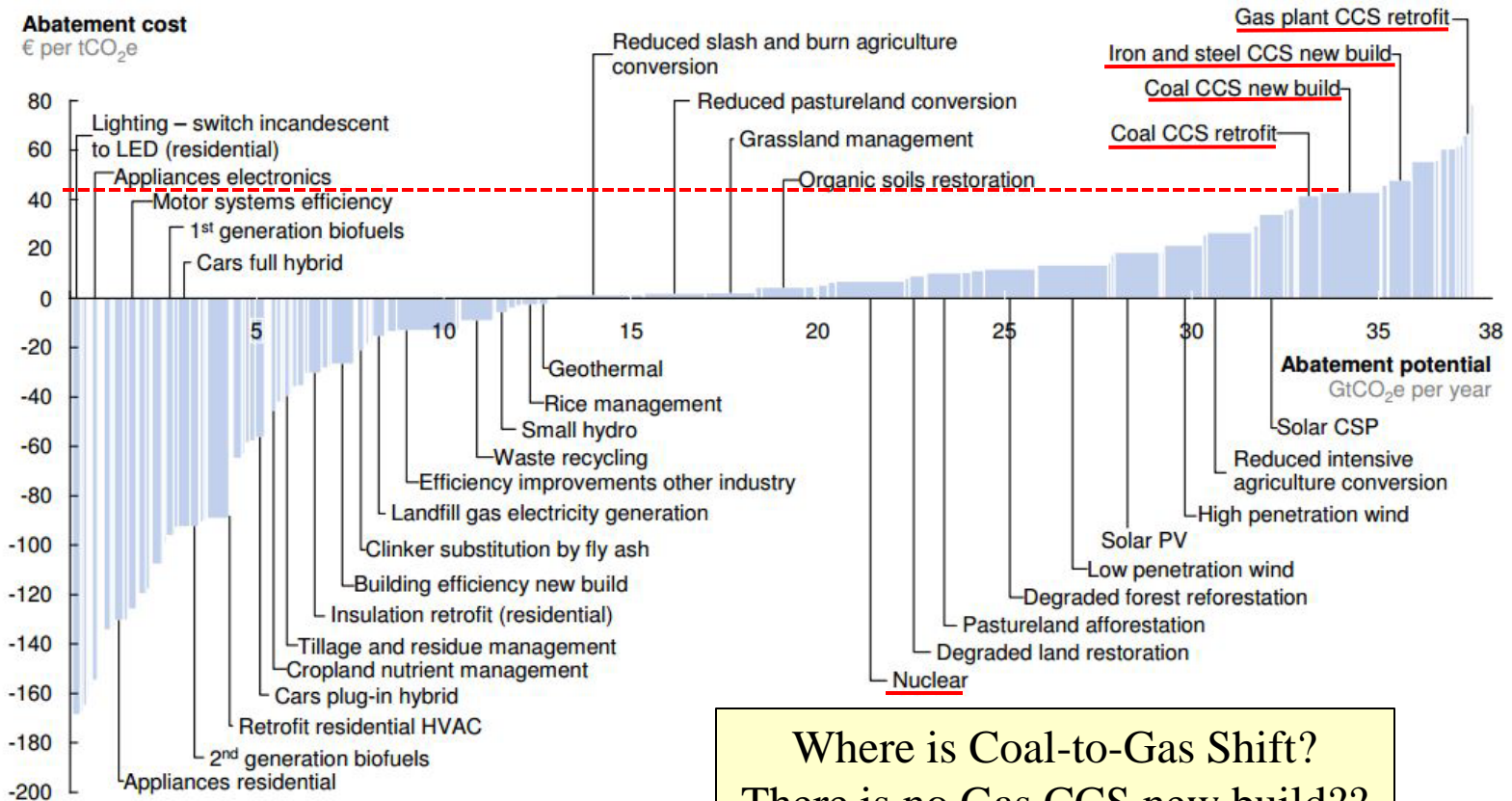
Figure 3 | Contributions of different factors to the decline in US CO₂ emissions 2007-2009 and 2009-2011 and 2011-2013. Between 2007 and 2009, decreases in the volume of goods and services consumed during the economic recession (red) was the primary contributor to the nearly 10% drop in emissions. But 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.

base_e

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

“Practical Strategies for Emerging Energy Technologies” <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??

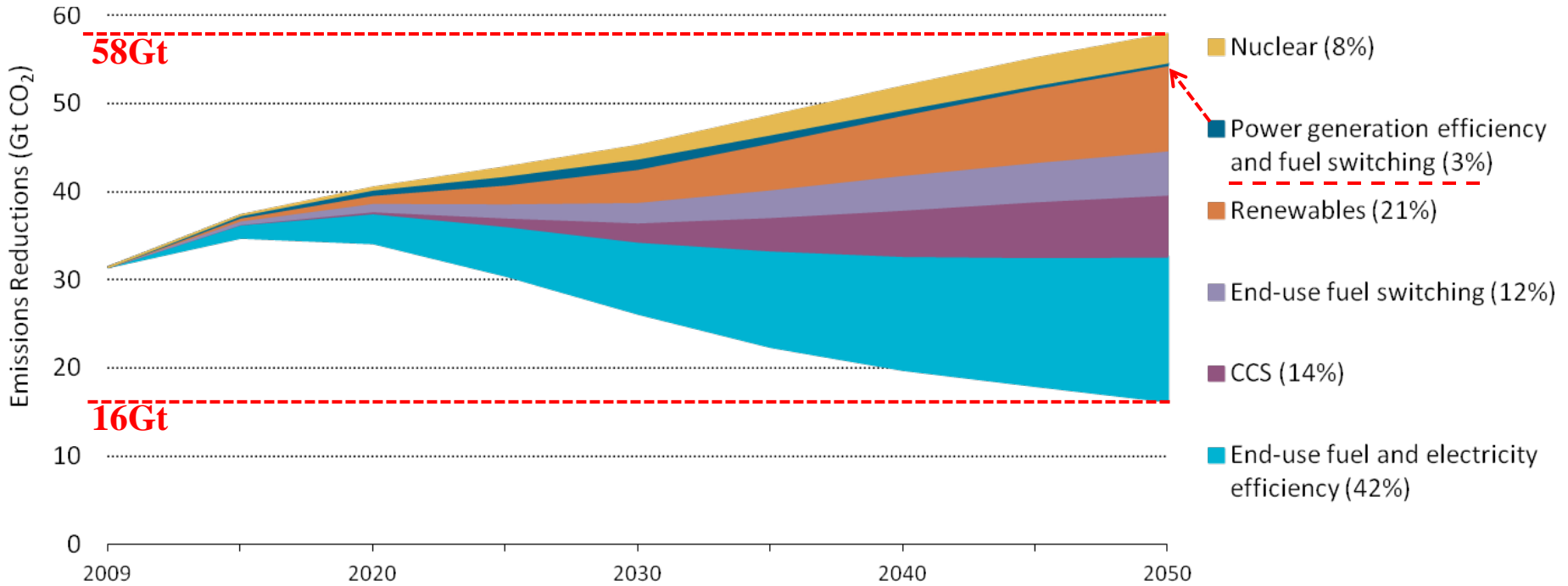
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: Global GHG Abatement Cost Curve v2.1



“Practical Strategies for Emerging Energy Technologies”

IEA Vision May 2013



Nuclear and CCS technologies currently on “life support”

**12th Annual CCUS Conference
Pittsburgh, 15 May 2013**

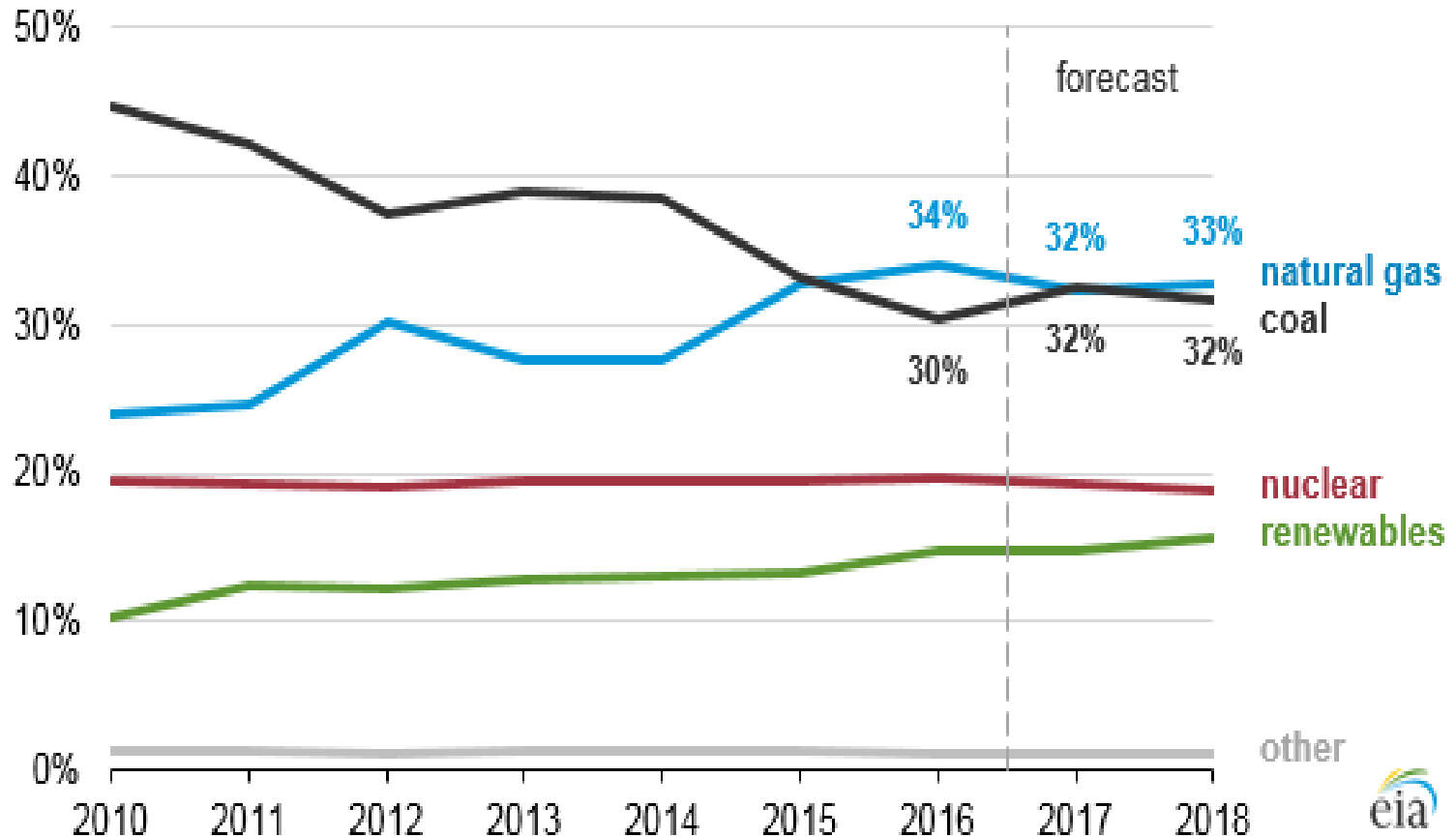
**Juho Lipponen
Head of Unit, Carbon Capture and
Storage
International Energy Agency**

base_e

“Practical Strategies for Emerging Energy Technologies”

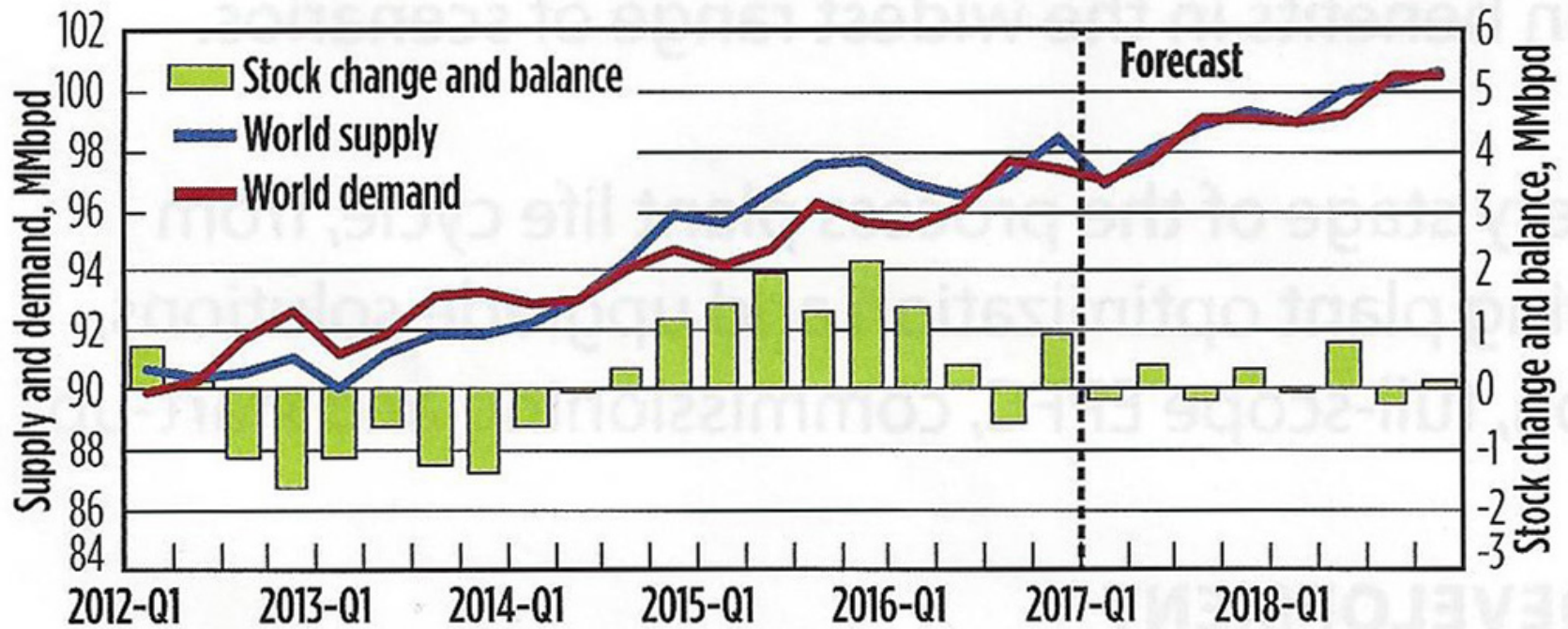
U.S. Power Generation Mix

Annual share of U.S. electricity generation by energy source



World Oil Supply/Demand Balance

World liquid fuel supply and demand, MMBpd



Source: EIA Short-Term Energy Outlook, March 2017

WW Oil Supply/Demand

	2016					2017				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
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.

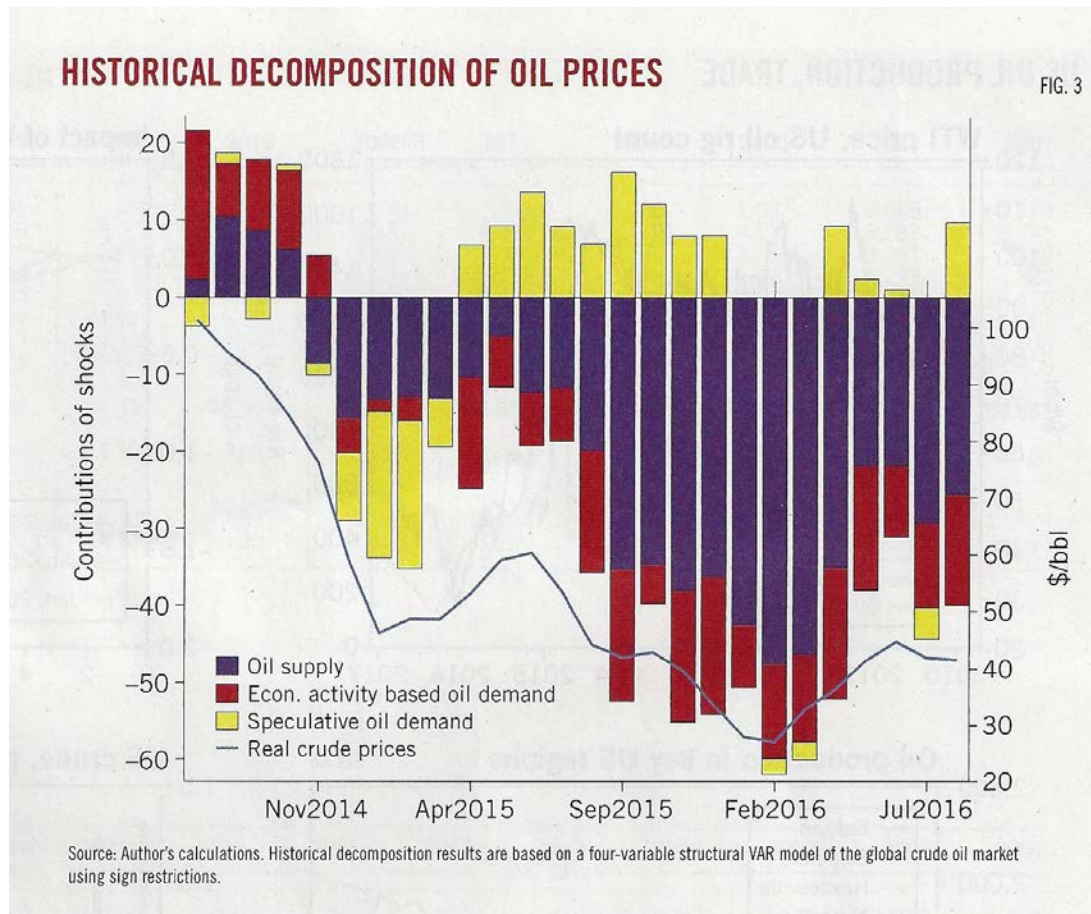
Source: International Energy Agency; OGI estimate of OPEC crude supply 4Q 2016 through 2017.

Source: O&G Journal January 2, 2017

base_e

“Practical Strategies for Emerging Energy Technologies”

Historical Decomposition of Oil Prices



Crude Oil Consumption – 96.6 MMbbl/d

Oil: Consumption*

Thousand barrels daily	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016	2005-15	Share 2016
													growth rate per annum		
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



“Practical Strategies for Emerging Energy Technologies”

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		Share 2016
													2016	2005-15	
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%

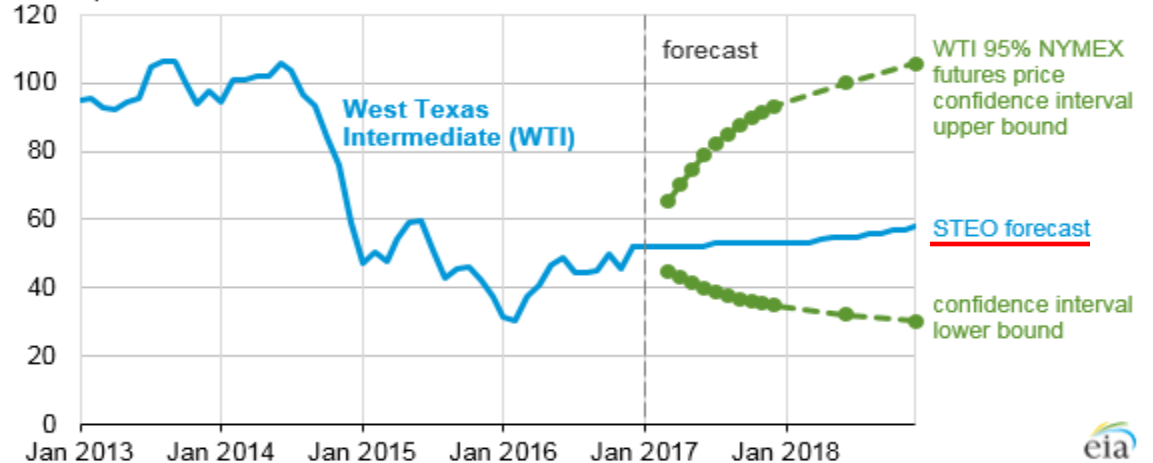
Source: BP Statistical Review of World Energy 2017

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



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	Grow th rate per annum 2016	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%

Coal Production – 3656.4 Mtoe

Coal: Production*

Million tonnes oil equivalent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016	2005-15	Share 2016
													2016	2005-15	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

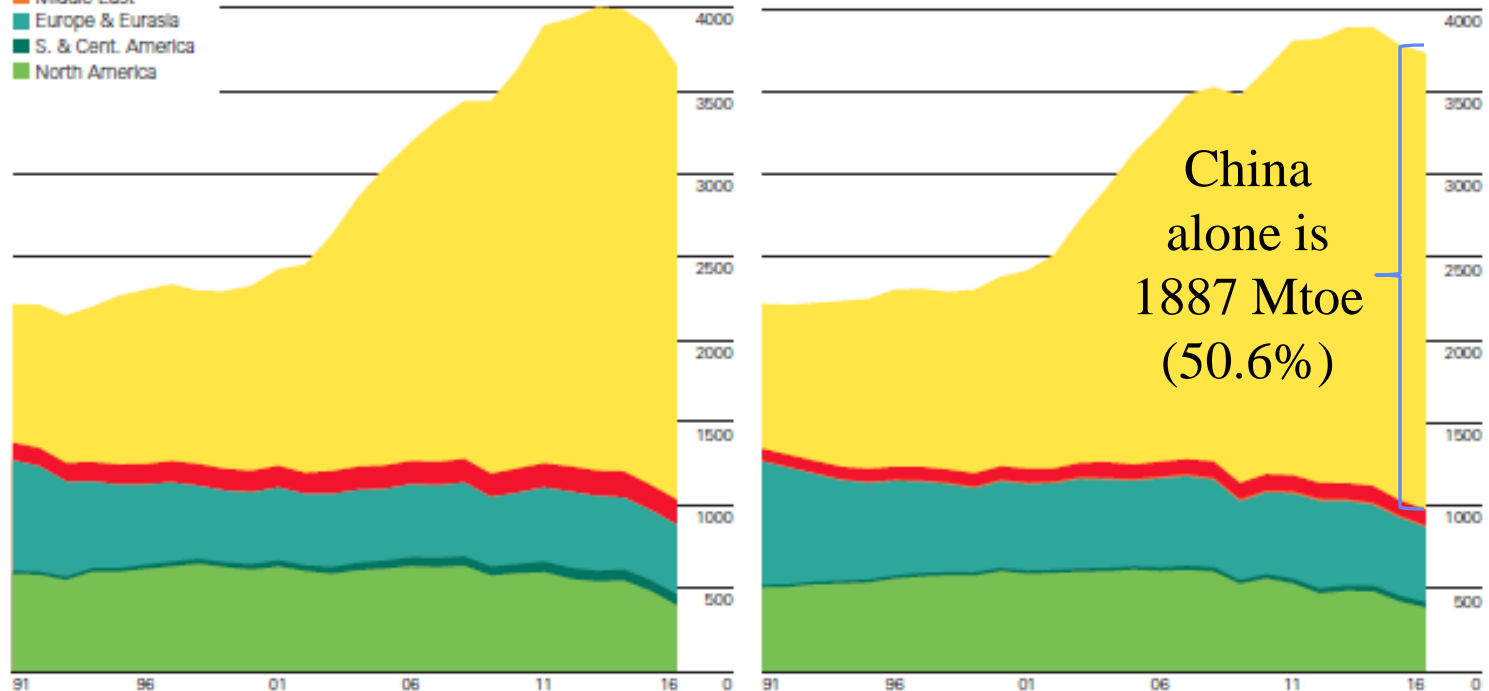
Production is ~70% bituminous/30% Lignite



Coal - Regional Consumption - Mtoe

Coal: Production by region
Million tonnes oil equivalent

- Asia Pacific
- Africa
- Middle East
- Europe & Eurasia
- S. & Cent. America
- North America



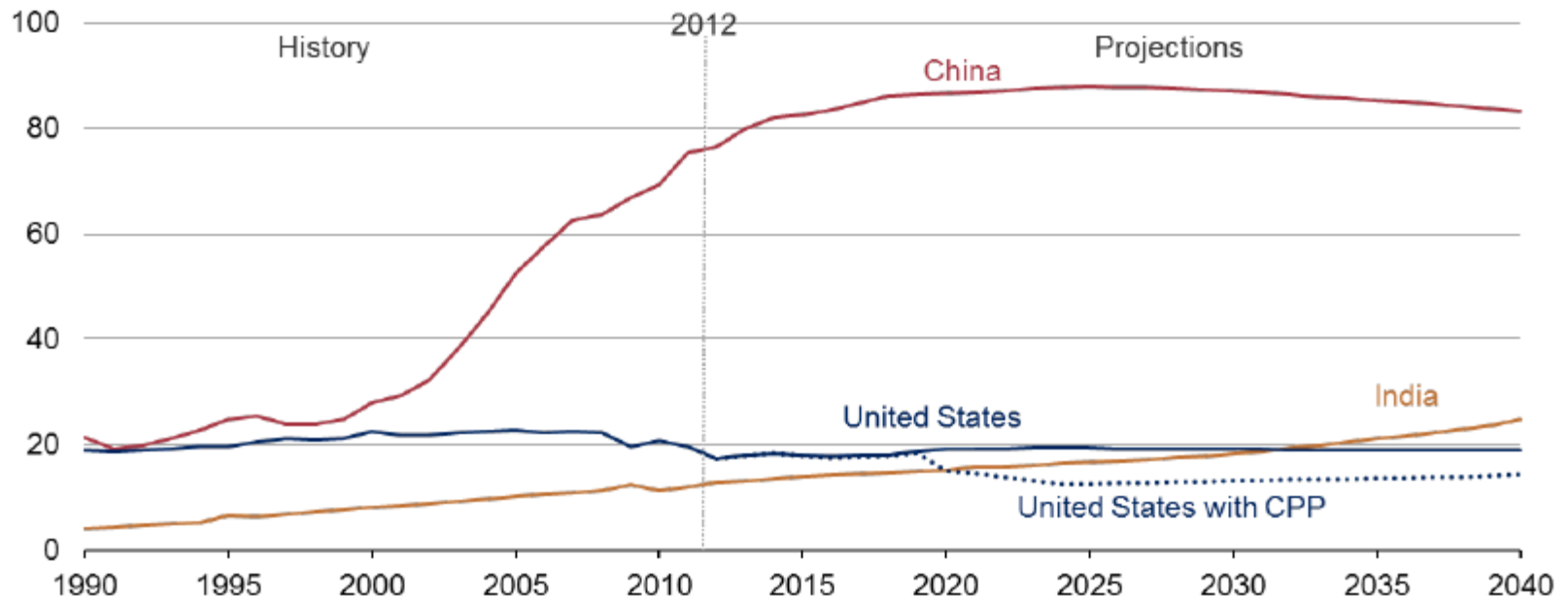
China gets most of its coal from Indonesia and Australia. The tighter regulations on coal consumption and imports could mean India may be able to surpass China as the world's largest coal importer in 2015.

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 8.8% fall), China (-26 mtoe, -1.6%) and the United Kingdom (-12 mtoe, -52.5%).

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)



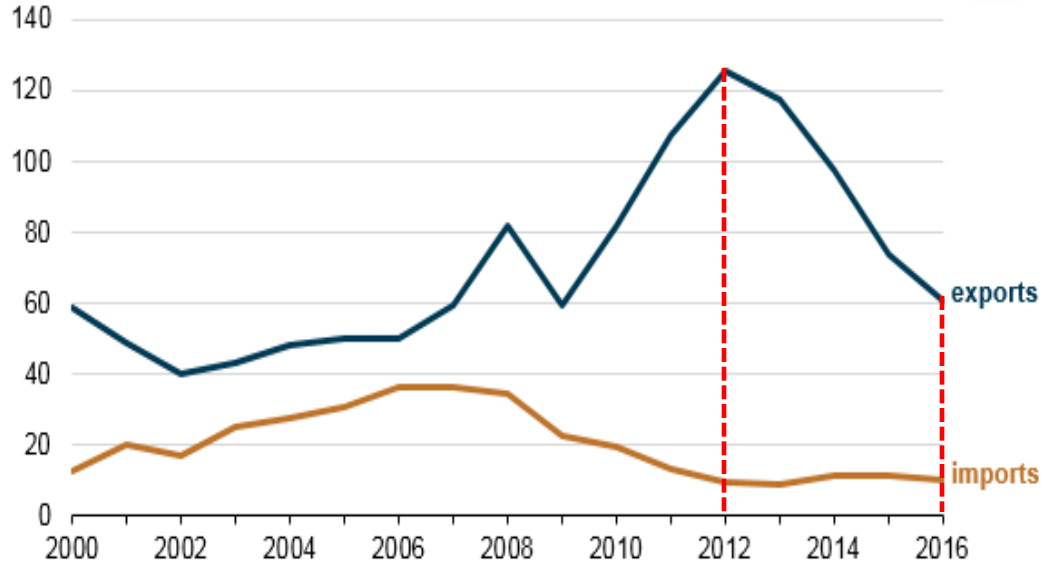
Adam Sieminski, Center for Strategic and International Studies
May 11, 2016

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.

Annual U.S. coal exports and imports (2000-16)

million short tons



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-owned ¹	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)		% production from companies recently in bankruptcy*
	Total	From mines of 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.

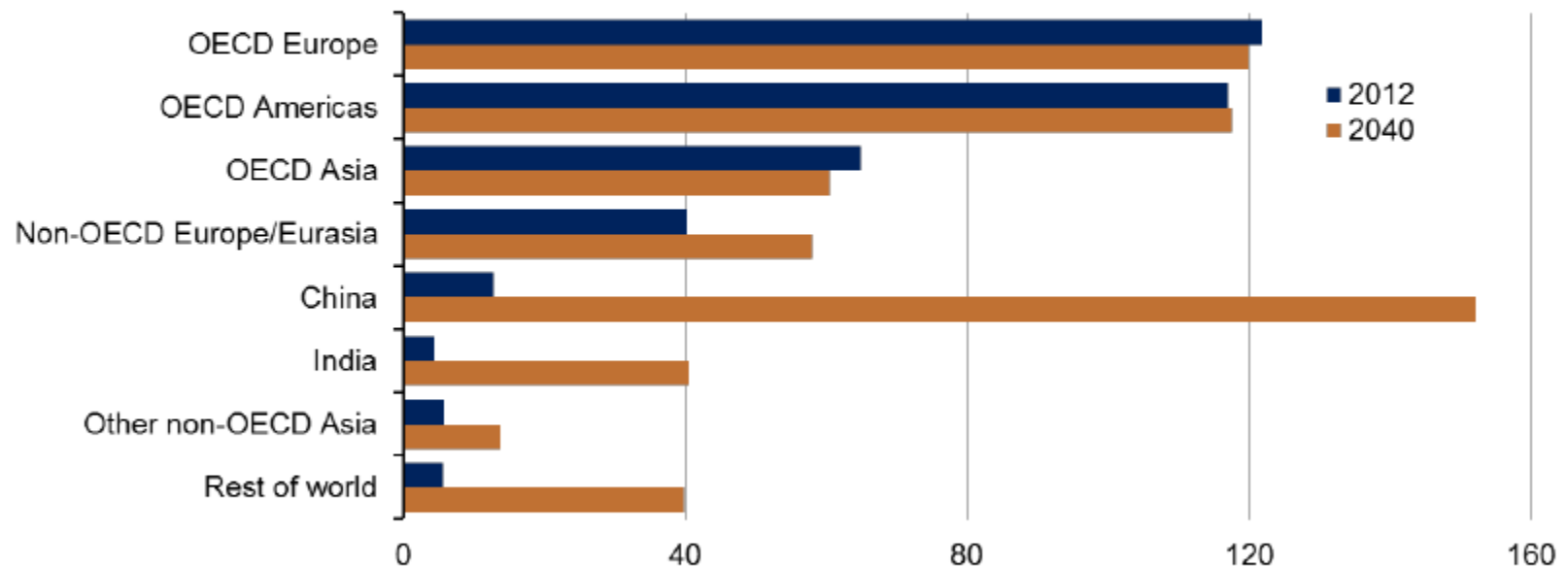
Source: S&P Global Market Intelligence



Nuclear 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



Adam Sieminski, Center for Strategic and International Studies
May 11, 2016

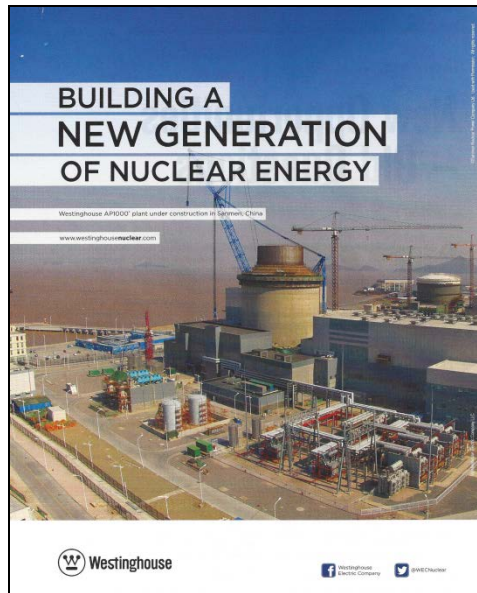
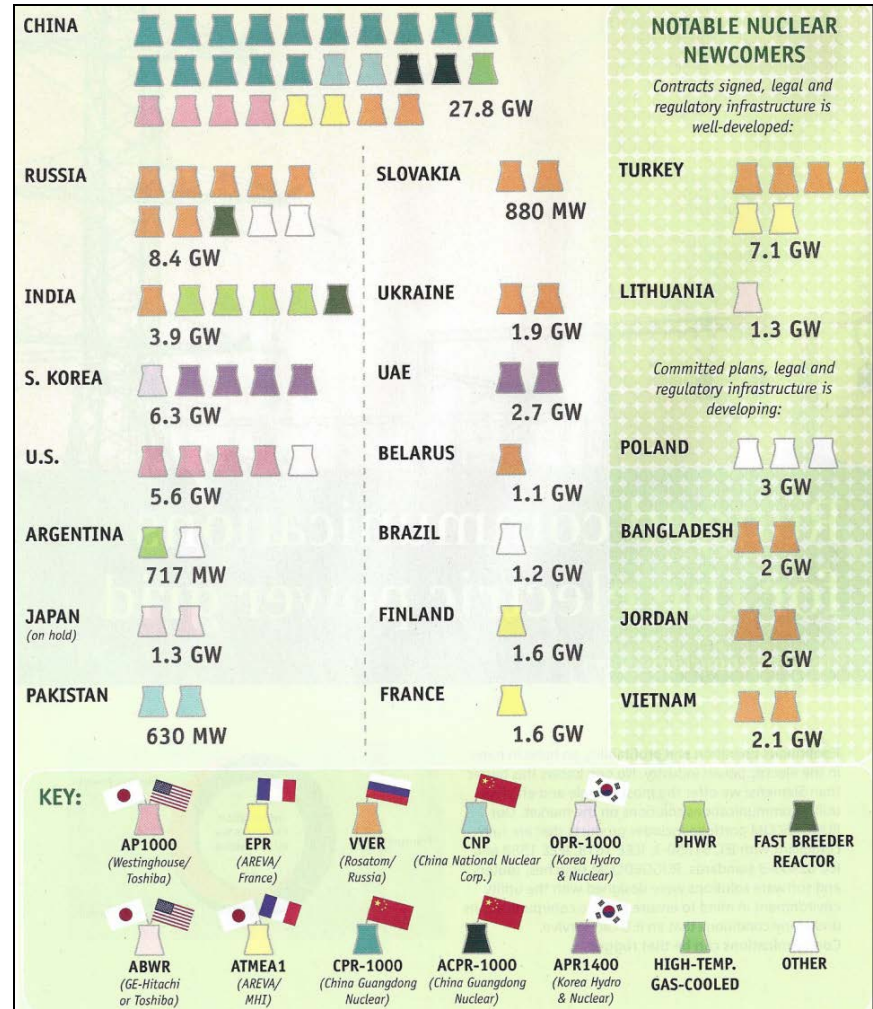
30

base_e

“Practical Strategies for Emerging Energy Technologies”

“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



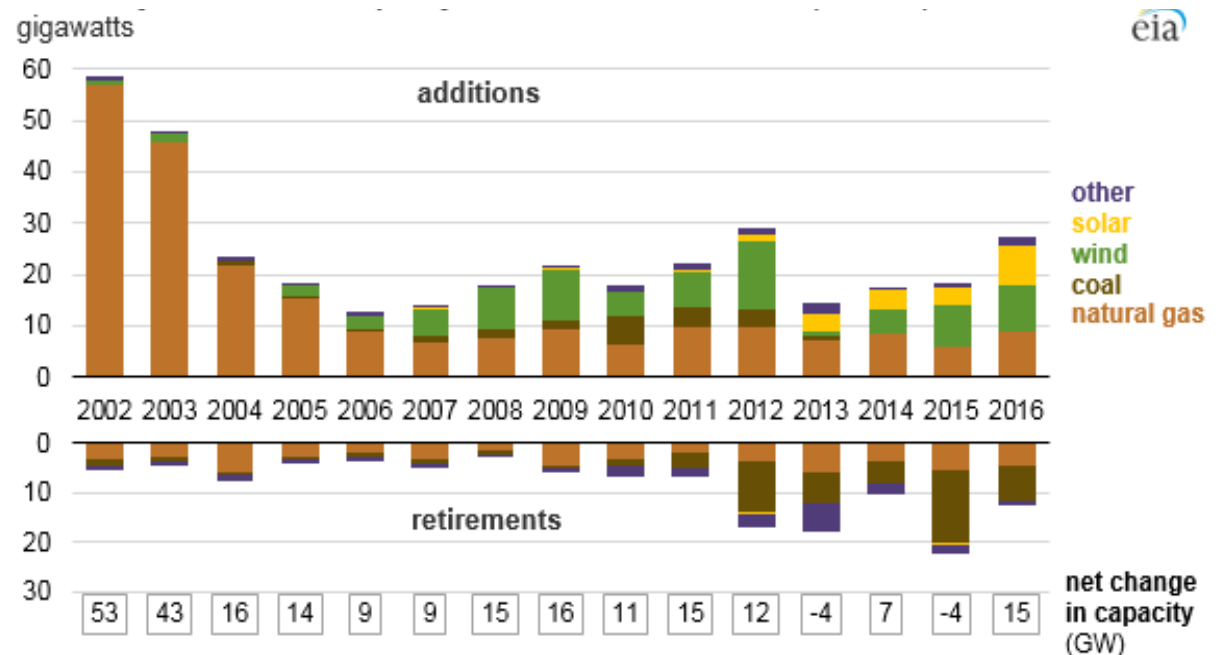
Installed Generating Capacity (2012) = 5,550 GW

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.

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)

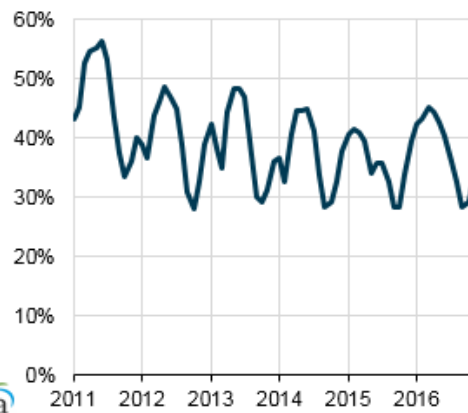


U.S. Hydro Capacity is Very Old

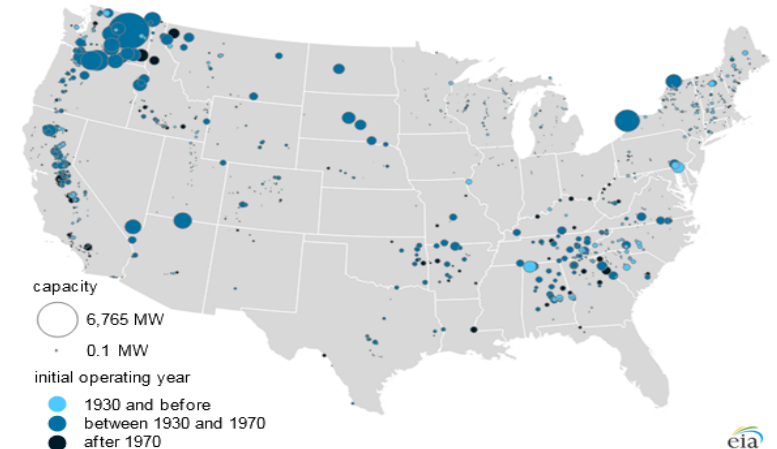
Conventional hydroelectric net generation
million megawatthours



Conventional hydroelectric capacity factors
percent



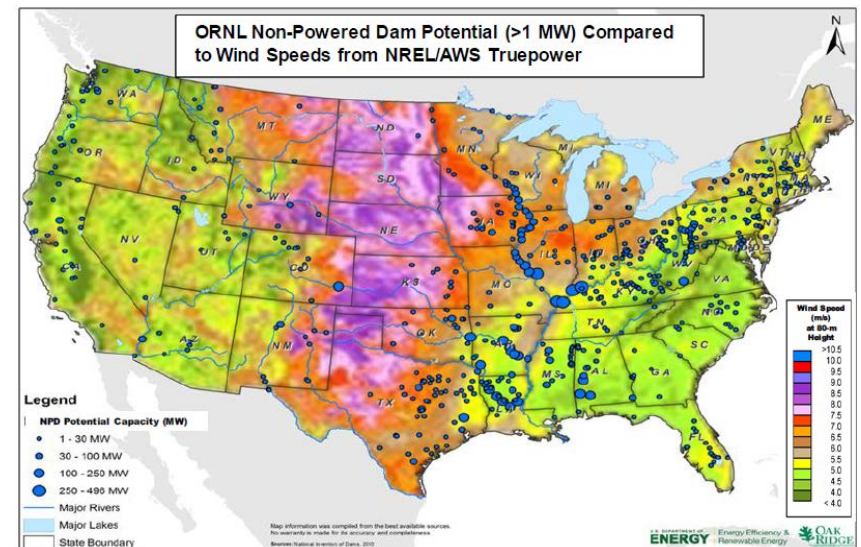
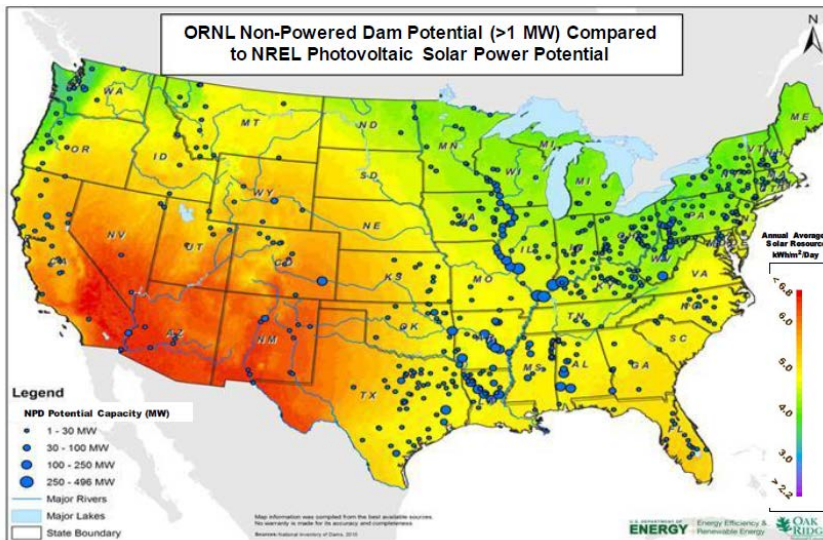
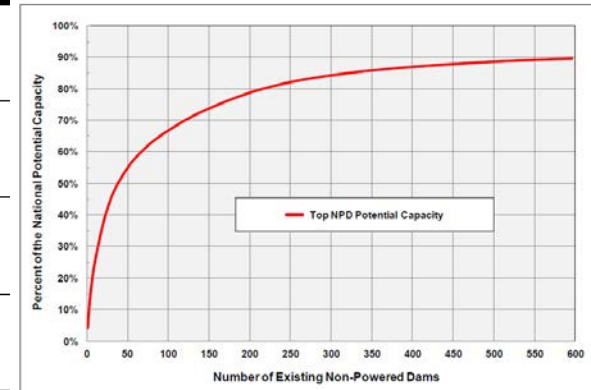
Distribution of conventional hydroelectric plants in the Lower 48 states



- 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%.

12GW Complimentary Non-Power Dams (NPD)

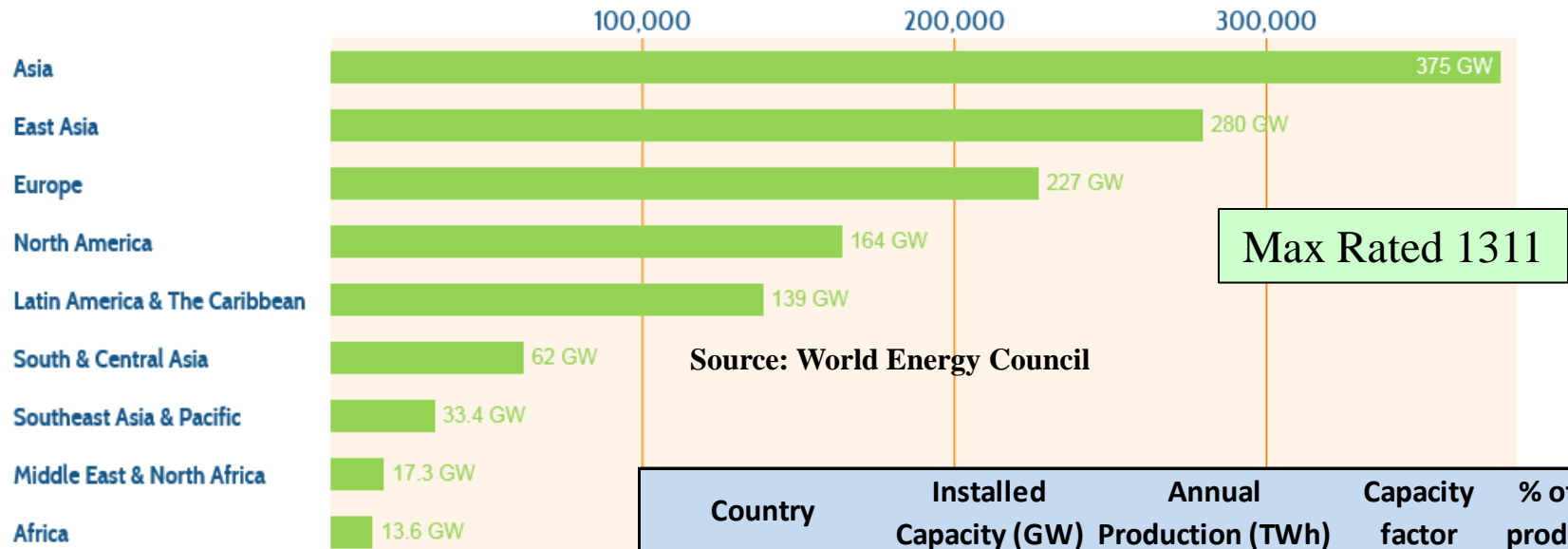
Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (TWh/yr)	Hydrologic Regions (HUC02)	Potential Capacity (MW)	Potential Generation (MWh/yr)
1 New England	243	1.110	10 Missouri	258	0.865
2 Mid-Atlantic	479	1.997	11 Arkansas-White-Red	1898	5.960
3 South Atlantic-Gulf	1618	3.778	12 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”

World Hydroelectric Capacity – 936 GW



China Three Gorges – 18GW

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	

base_e

“Practical Strategies for Emerging Energy Technologies”

World Total Hydro 3884.6 TWh = 16.5%

2014 World Electricity Production = 23,537 TWh

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
												2014 over	share
												2013	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



“Practical Strategies for Emerging Energy Technologies”

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

base_e

“Practical Strategies for Emerging Energy Technologies”

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

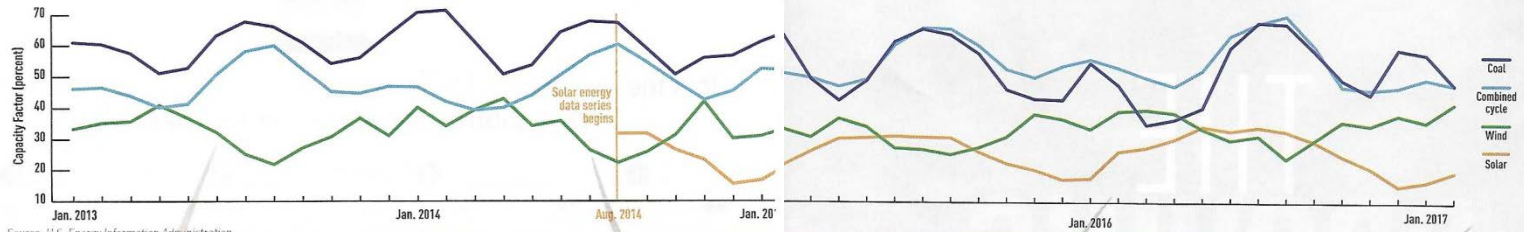
in the capacity factor figures for coal and gas generation. As recently as 2014, the annual capacity factor for coal plants was over 60 percent and reached nearly 72 percent in February 2014. Since then, however, the need for coal power has been eroded by both renewables and gas-fired plants. In March 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**

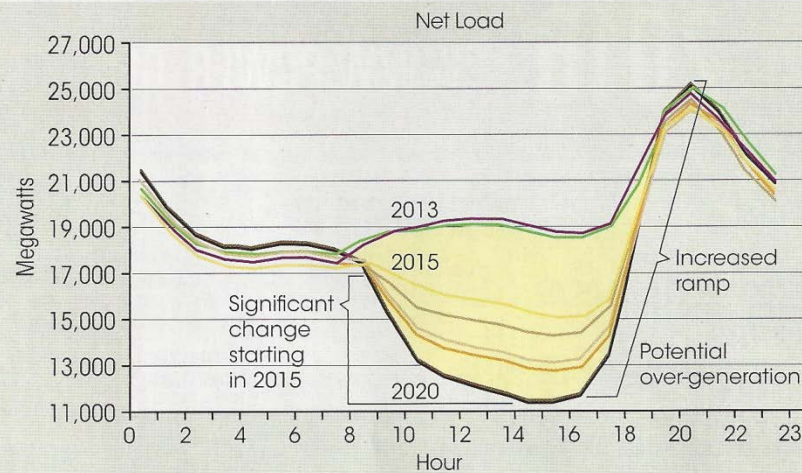
JEFFREY WINTERS

CAPACITY FACTORS FOR SELECTED UTILITY-SCALE GENERATORS



Dealing with an even “Bigger” Duck

California Duck Renewable Generation 1



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.

The Duck Pond of Non-Renewable Generation 2

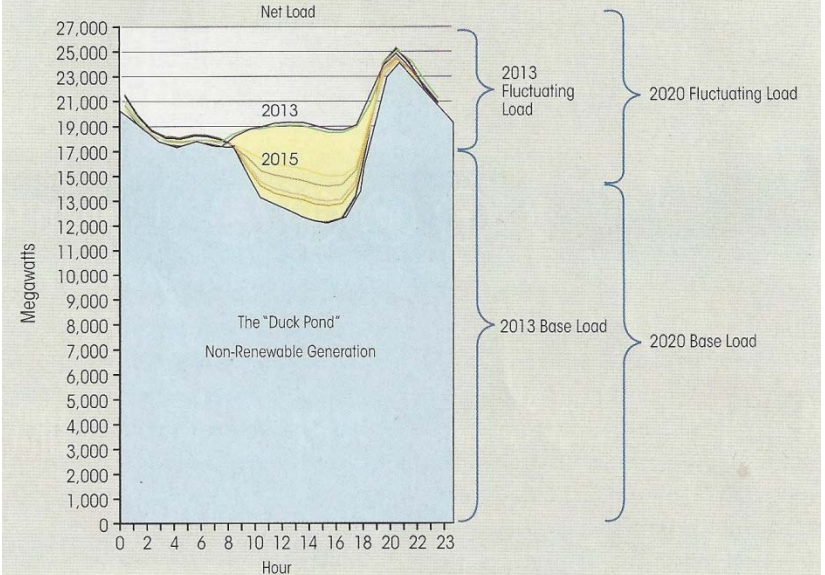


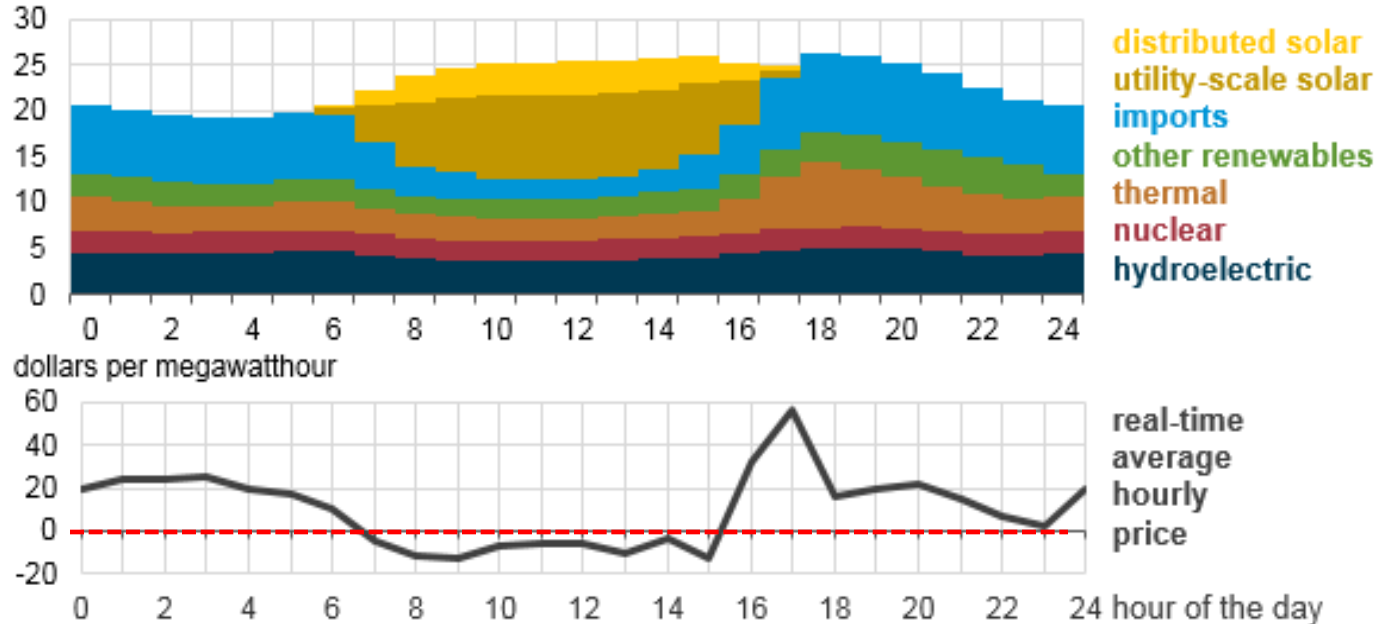
Figure 2 is an expansion of Figure 1, showing the amount of generation under the duck.

California Net Generation March 11, 2017

- 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

California Independent System Operator net generation, March 11, 2017
gigawatthours



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."

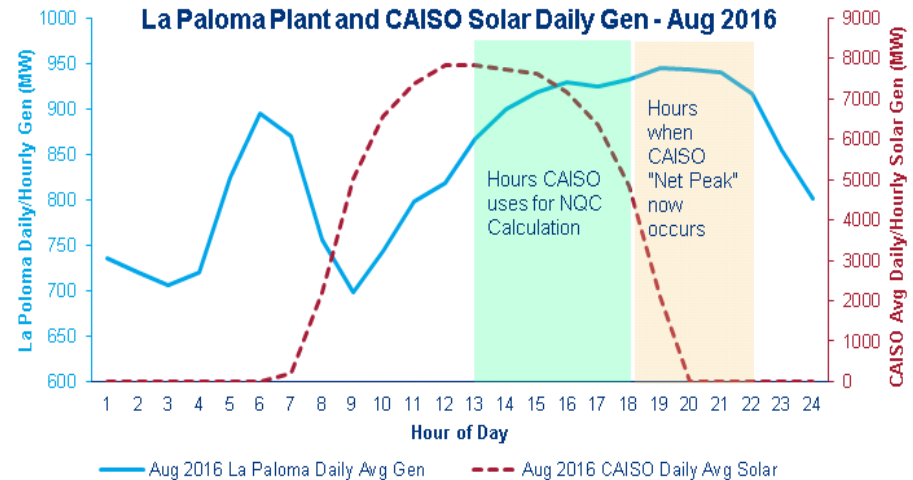
La Paloma is owned by Rockland Capital LLC, one of several California plant owners that has asked the state for help in offsetting losses, arguing that it is in the state's interest to support the natural gas plants because they provide stability and reliability to the power grid.

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.

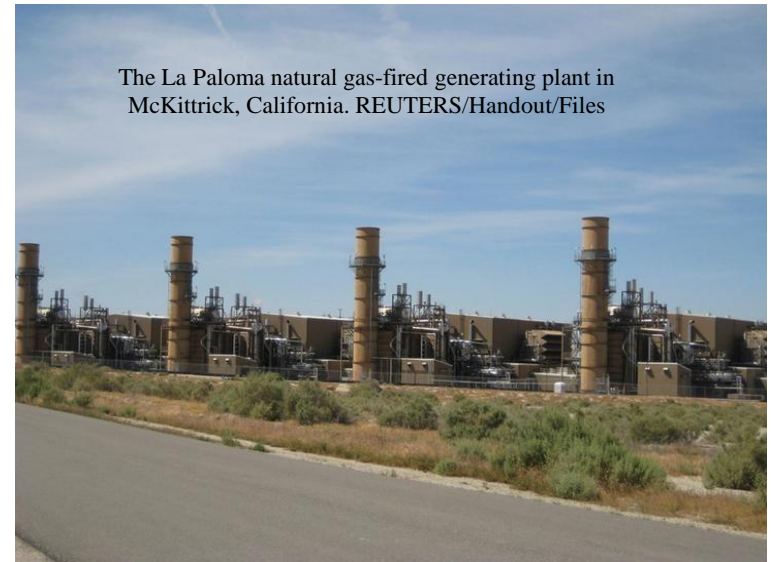
In its court filing, La Paloma said it had decided that Chapter 11 was in the best interests of the company and its creditors and stakeholders, following consultation with financial and legal advisers.

The company listed Bank of America Corp (BAC.N) and SunTrust Bank [STIHC.B.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



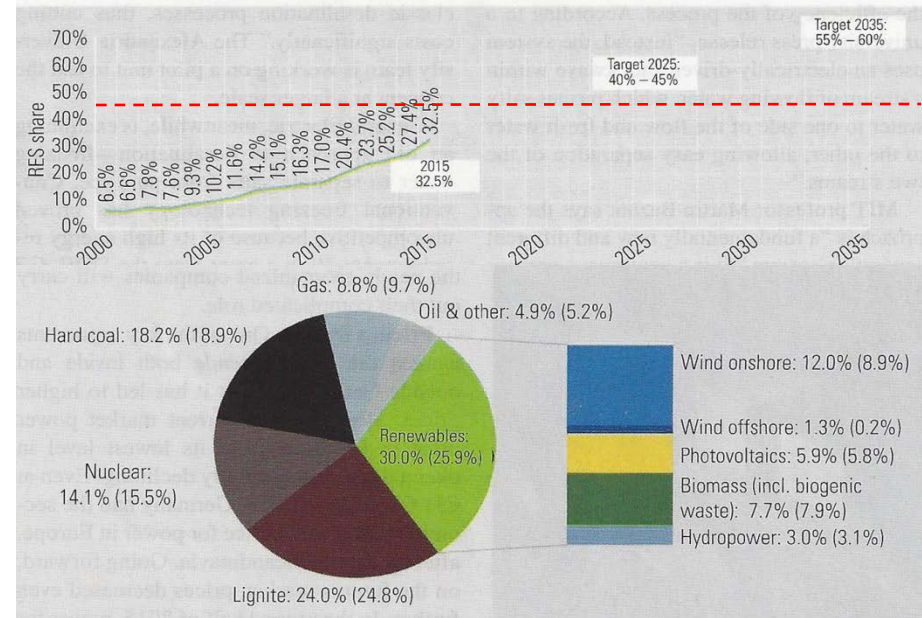
<http://www.reuters.com/article/us-la-paloma-bankruptcy-idUSKBN13V2PY>

“Practical Strategies for Emerging Energy Technologies”

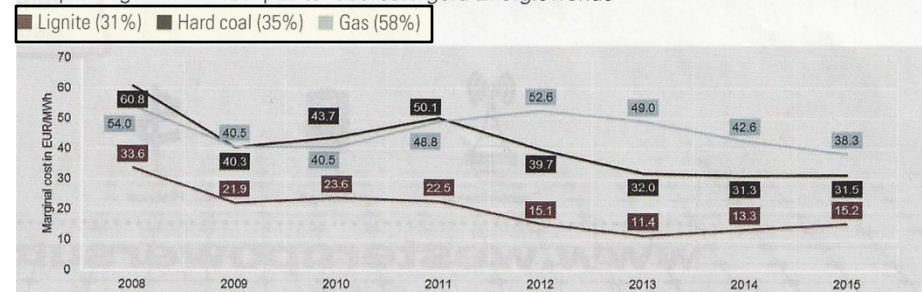
Germany Energiewende

- **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*

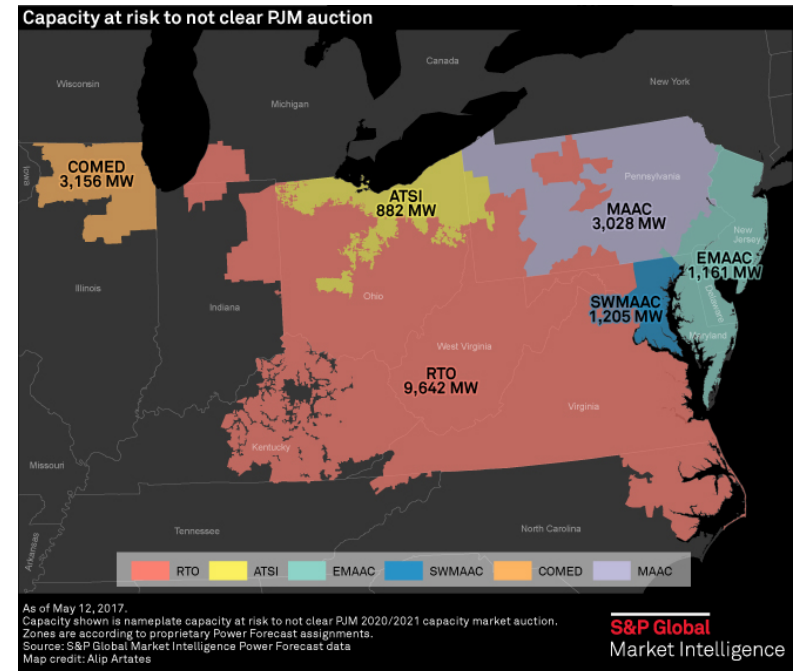


3. Marginal costs for new gas and old coal power plants 2008–2015. Despite lower prices for natural gas and slightly higher CO₂ prices, new gas plants cannot compete against old coal plants. *Source: Agora Energiewende*



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

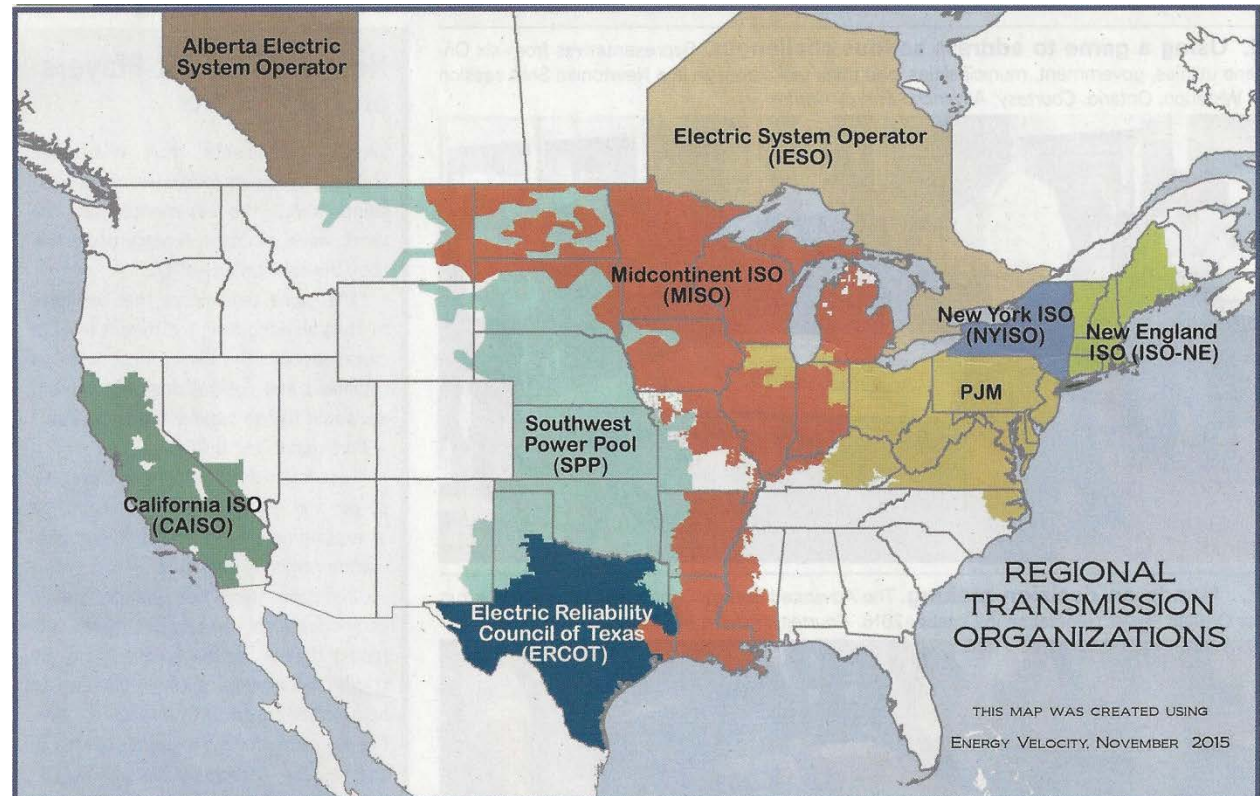
As of May 12, 2017.
Capacity shown is nameplate capacity at risk to not clear PJM 2020/2021 capacity market auction.
Source: S&P Global Market Intelligence Power Forecast data

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



base_e

“Practical Strategies for Emerging Energy Technologies”

Natural Gas Production – 3551.6BCM

Natural Gas: Production*

Billion cubic metres												Growth rate per annum		Share 2016	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016		2005-15
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%

Natural Gas Demand – 3542.9 BCM

Natural Gas: Consumption in billion cubic metres*

Billion cubic metres													Growth rate per annum		Share
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016	2005-15	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%

Natural Gas Reserves & R/P – 2016

Natural gas Total proved reserves	at end 1996	at end 2006	at end 2015	at end 2016			
	Trillion cubic metres	Trillion cubic metres	Trillion cubic metres	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



Natural Gas Prices – March 2013

LNG LANDED PRICES: MARCH 2013*



*Estimated \$/MMbtu. Revised Feb. 7, 2013.
Source: FERC, Market Oversight, Waterborne Energy Inc., Houston

FIG. 1

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

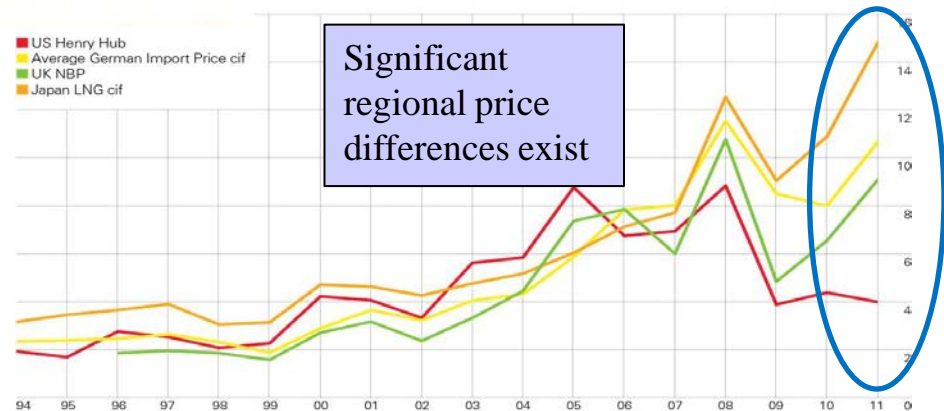
Supply:

North America

- Significant shale resource
- Significant associated gas production

Australia & East Africa

- Project cost/timing uncertainties



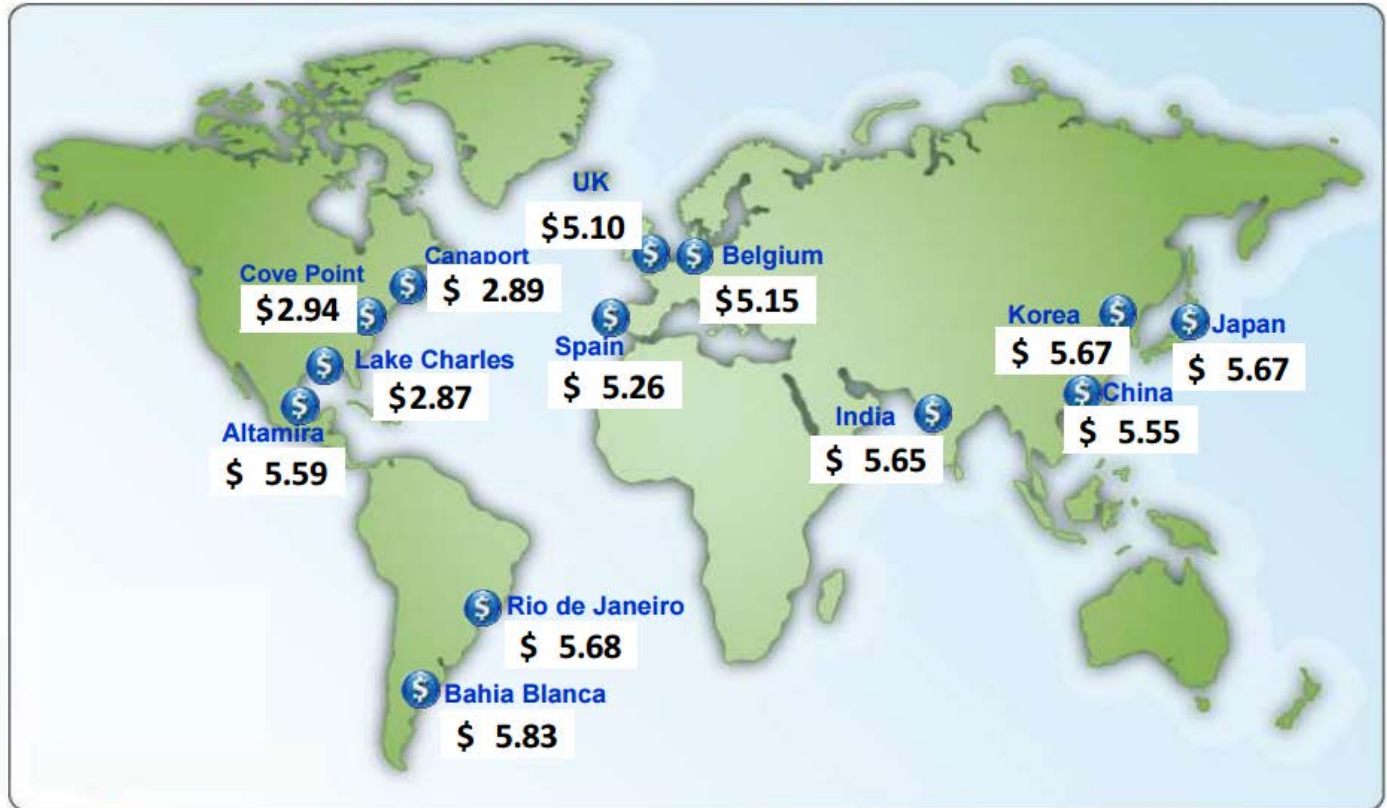
Significant regional price differences exist

LNG Landed Prices – March 2017

National Natural Gas Market Overview: World LNG Landed Prices

Federal Energy Regulatory Commission • Market Oversight • www.ferc.gov/oversight

World LNG Estimated Landed Prices: Mar-17



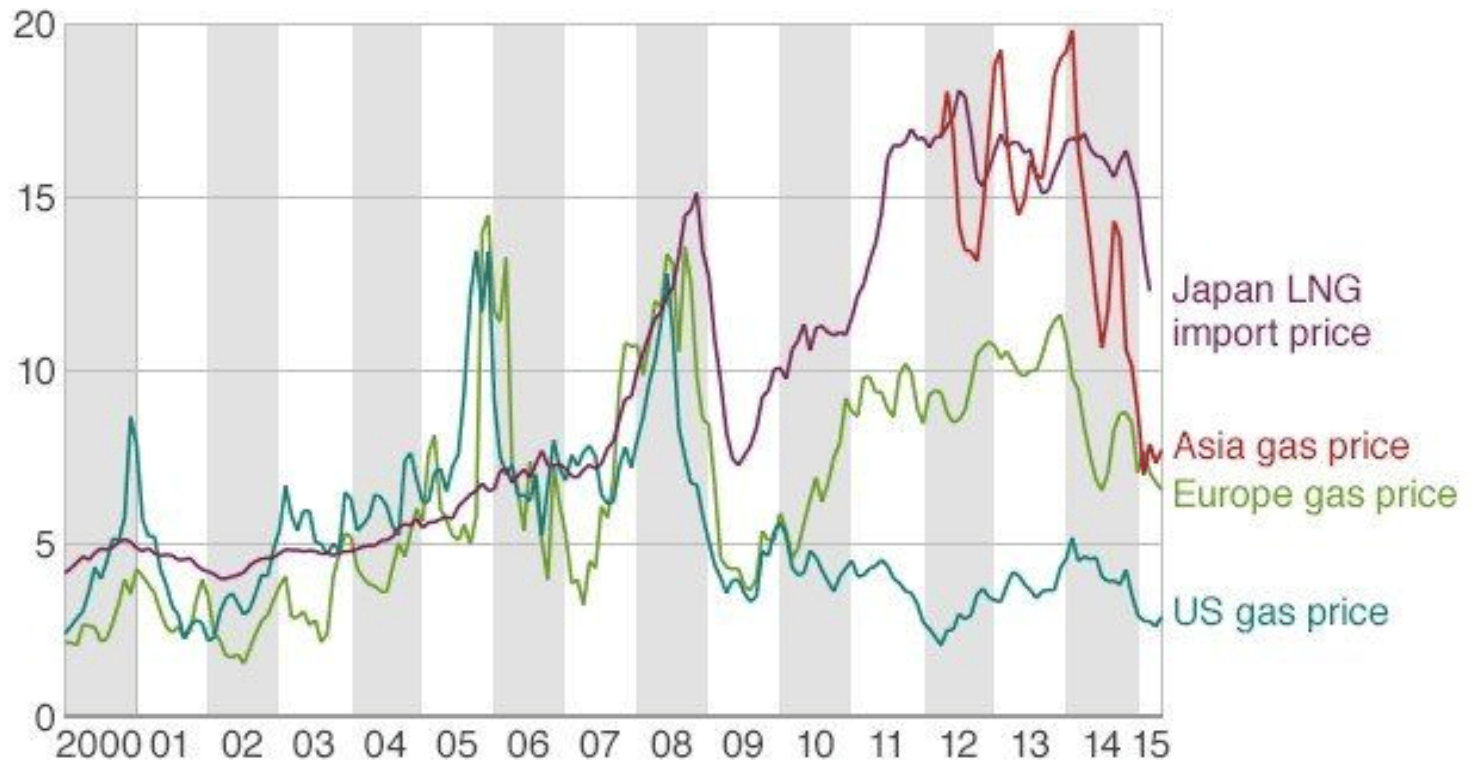
Source: *Waterborne Energy, Inc.* Data in \$US/MMBtu. Landed prices are based on a netback calculation.
Note: Includes information and Data supplied by IHS Global Inc. and its affiliates ("IHS"); Copyright (publication year) all rights reserved.
Prices are the monthly average of the weekly landed prices for the listed month.

Updated: Apr-17

Natural Gas Prices

Global gas prices, 2000-2015

\$ Million metric British units



January 2017 Short-Term Energy Outlook

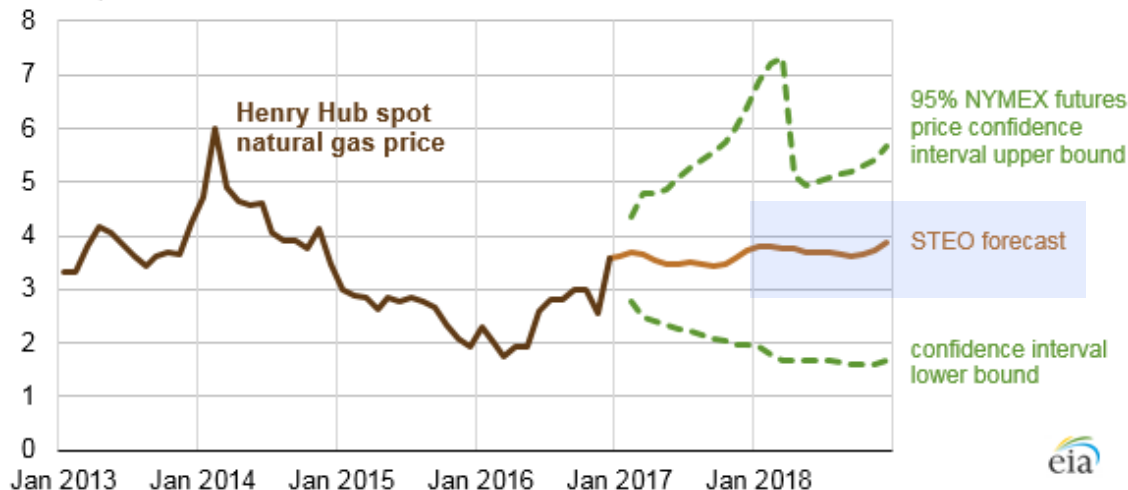
- EIA Henry Hub natural gas spot price forecast

- 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.

Henry Hub natural gas price and NYMEX confidence intervals (2013-18)
dollars per million British thermal units



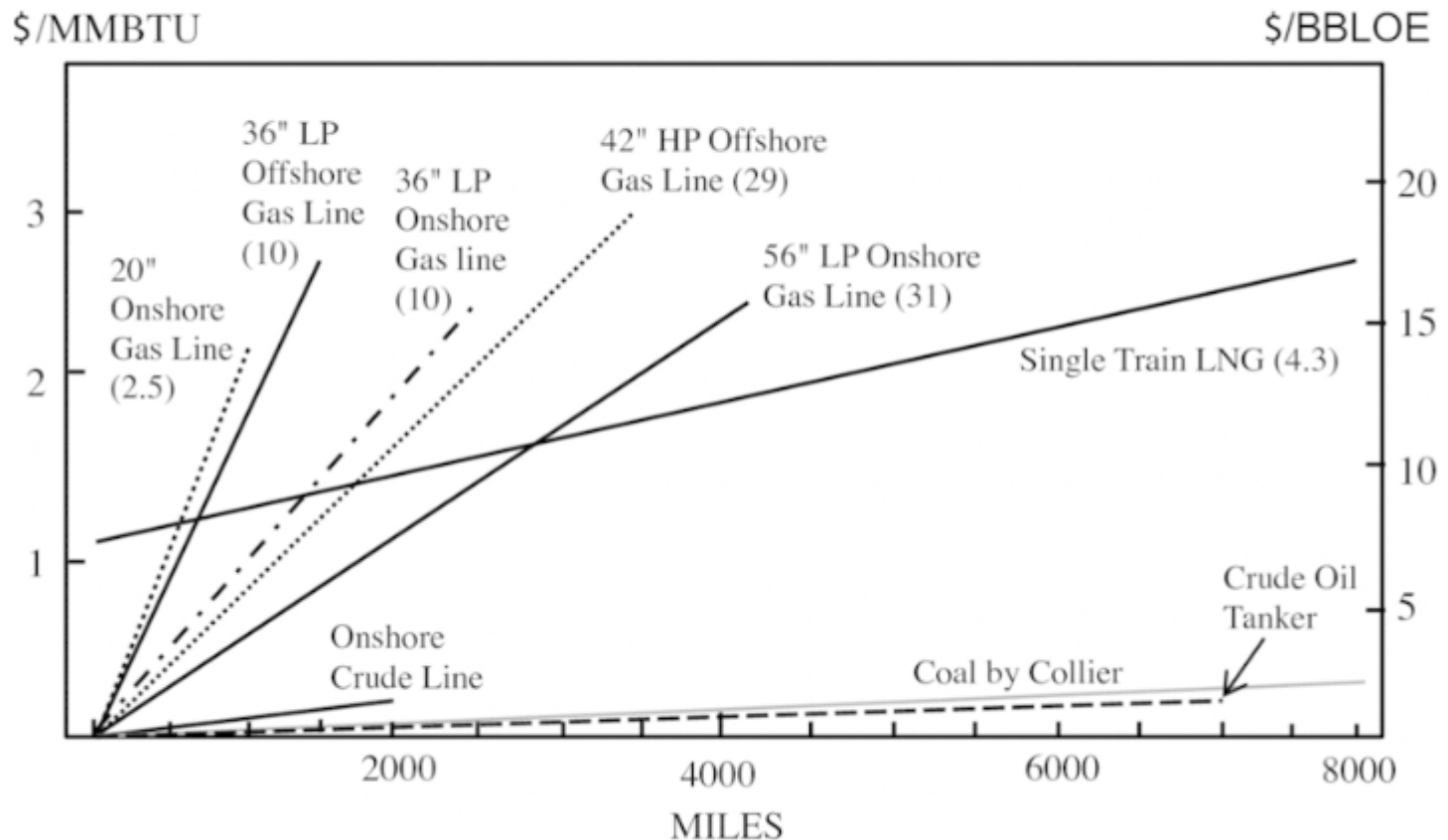
Getting Gas to Market

base_e

“Practical Strategies for Emerging Energy Technologies”

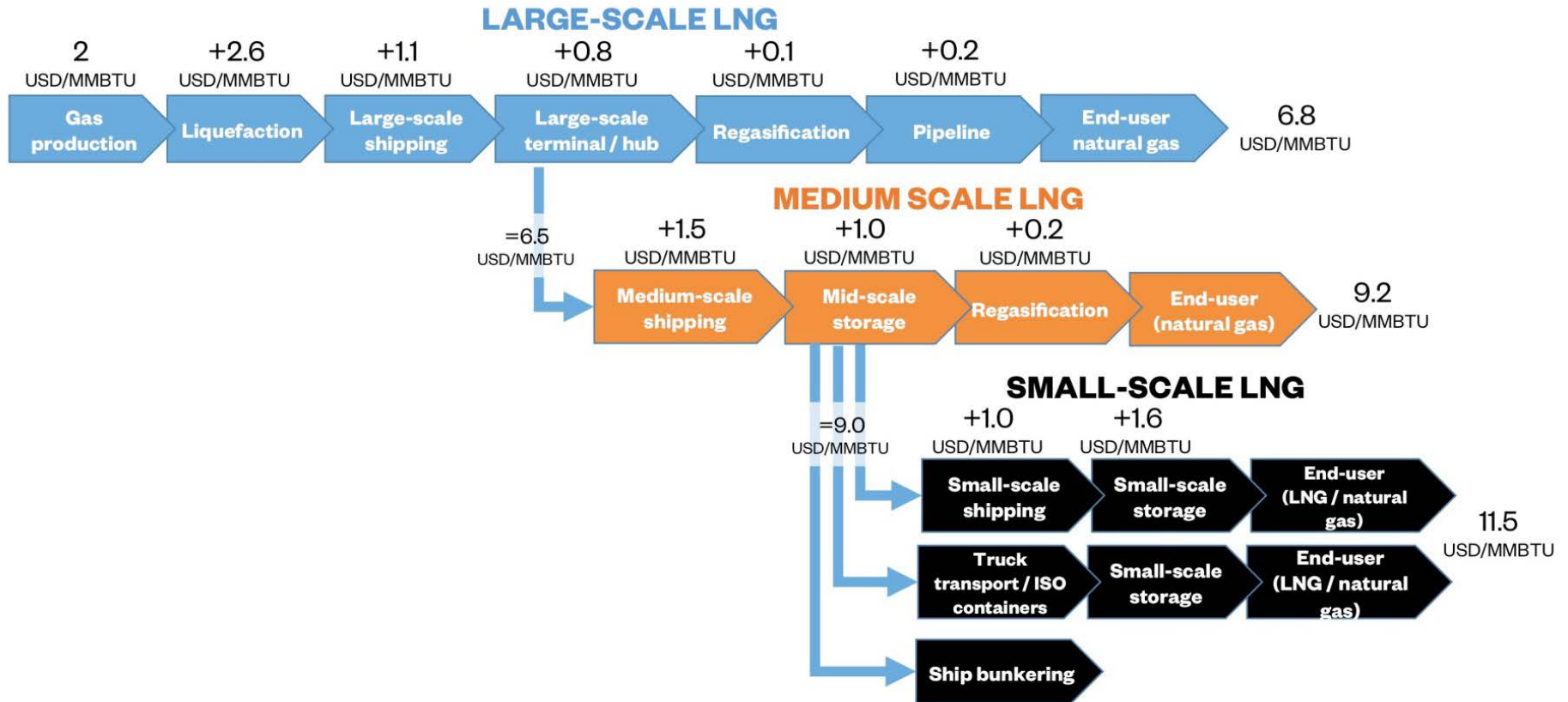
Jensen 2004 Break-even Points

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

LNG Value Chain



Wärtsilä Technical Journal October 20, 2016

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
Norway	†	-	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
8.1	-†	11.3	3.7
2.7	-†	8.1	†
8.6	-†	-†	-
-	-	-	-†
-†	-†	-†	0.9
0.5	2.8	-	0.9
-†	-	-†	-
3.7	0.2	-†	-
4.5	-†	5.3	-†
-†	-	0.1	0.4
-†	0.1	0.1	-†
-†	†	†	-
5.2	-†	-†	0.3
5.5	1.3	1.2	-†
-†	-	11.7	-†
-†	-	-	-
0.9	-	1.7	-
-	-	-†	2.7
-†	3.9	-†	-†
-	-	10.8	-†
-†	6.5	-†	-†
1.9	0.1	-	18.7
4.5	8.5	-	-
-	-†	-	-
-	-	-†	0.5
-	0.2	-	-†
-†	8.8	1.4	-†
28.5	21.1	28.5	21.1

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

base_e

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

Source: BP Statistical Review of World Energy 2017

“Practical Strategies for Emerging Energy Technologies”

Changing LNG Contract Terms

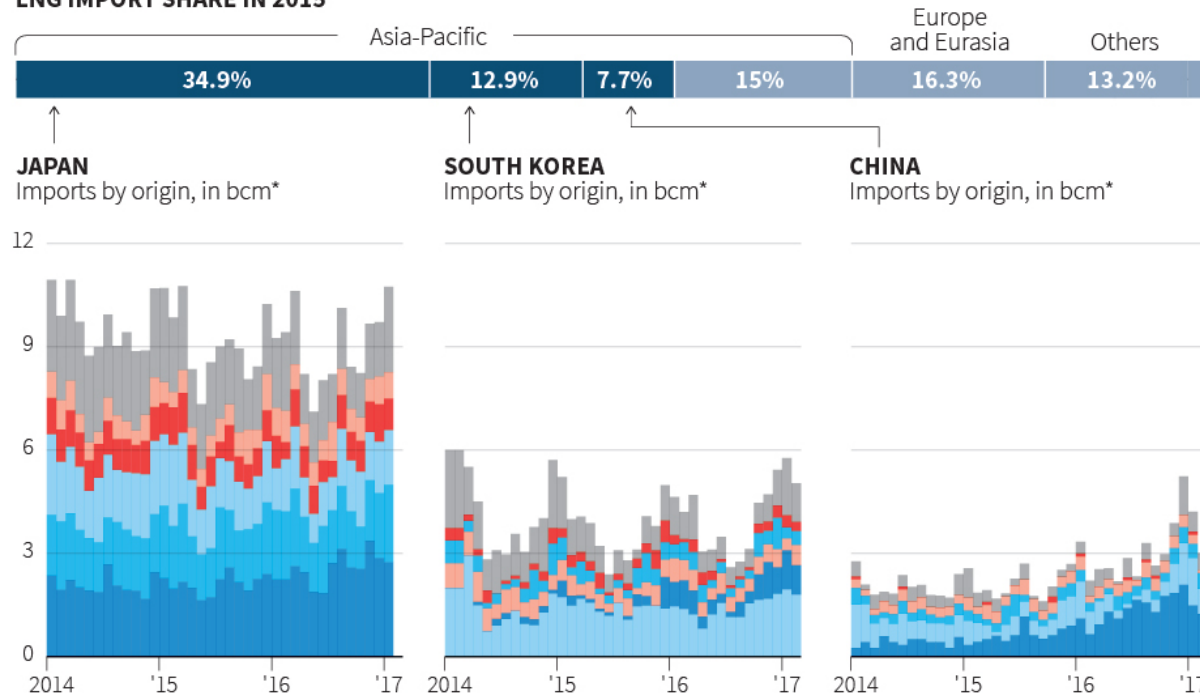
Top Asian LNG buyers form alliance

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.

LNG origin:

- Others
- Russia
- Indonesia
- Qatar
- Malaysia
- Australia

LNG IMPORT SHARE IN 2015



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

Sources: Thomson Reuters; British Petroleum

C. Inton, 23/03/2017

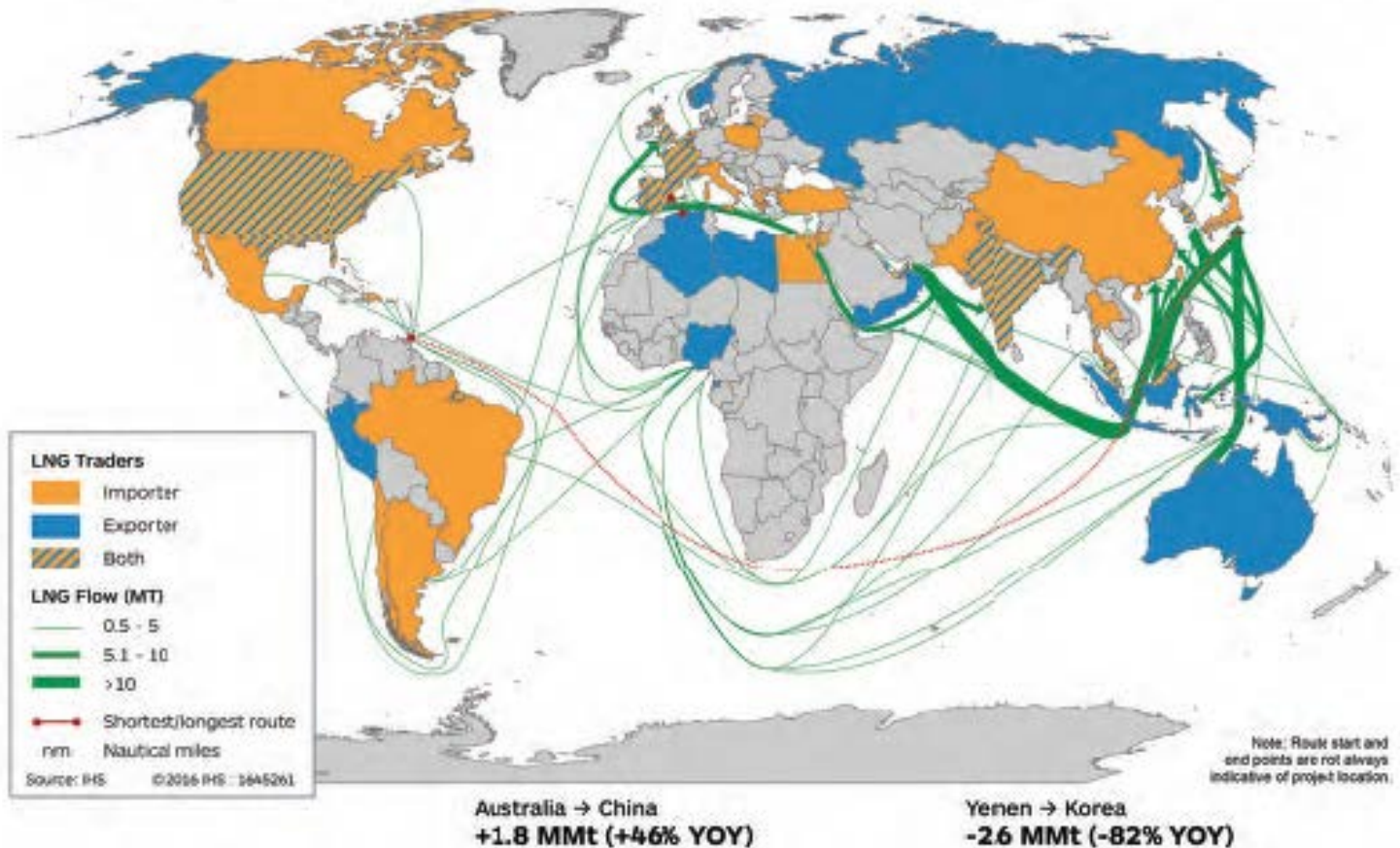
Major LNG Shipping Routes

Figure 5.7: Major LNG Shipping Routes, 2015

Shortest LNG voyage length in 2015:
111 nm (Algeria to Spain)

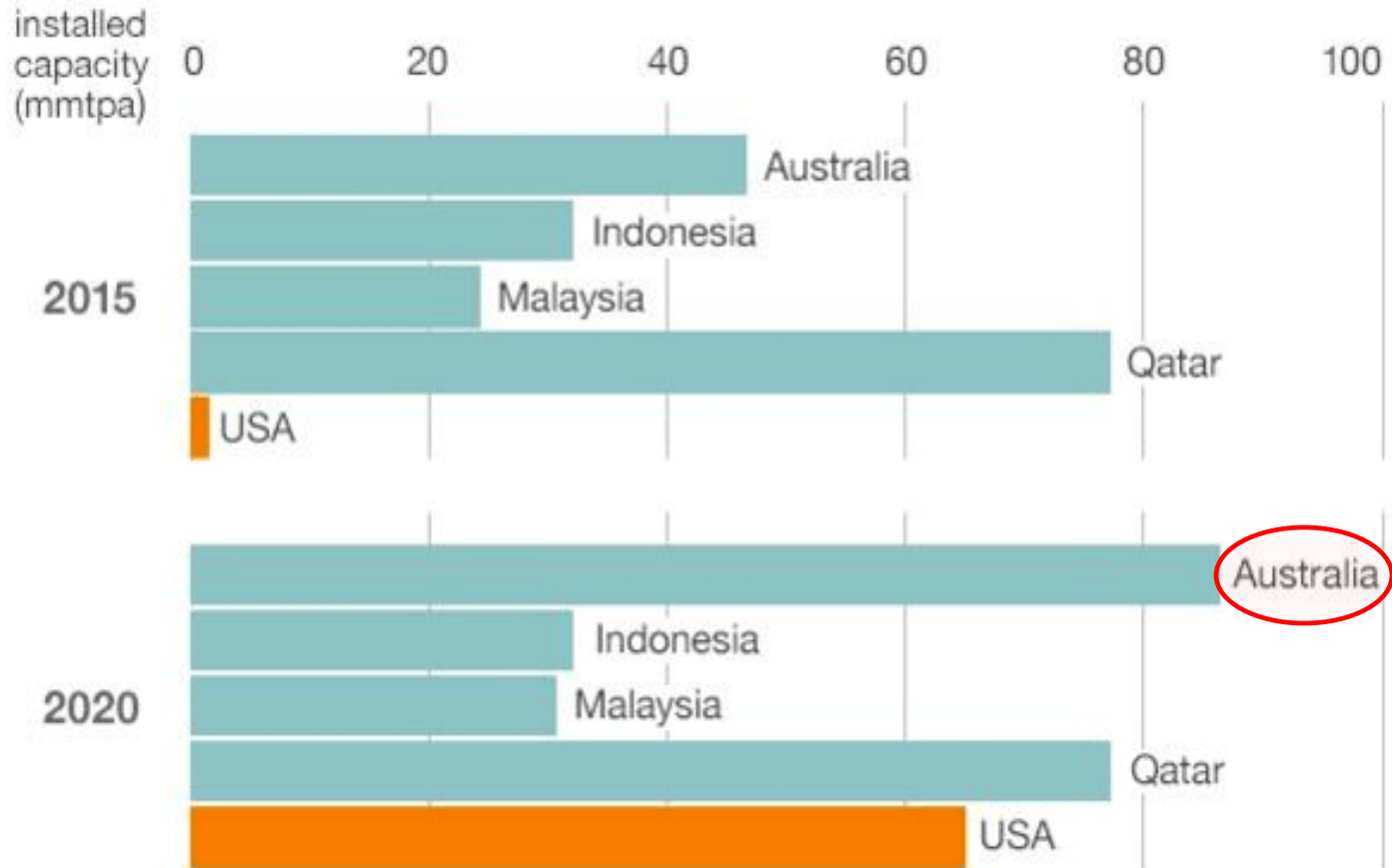
Average LNG voyage length
in 2015: 7,640 nm

Longest LNG voyage length in 2015:
13,809 nm (Trinidad to Japan)



Top LNG Producers

World's top LNG producers



Source: Poyry Management Consulting

Nord Stream 2

- 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.

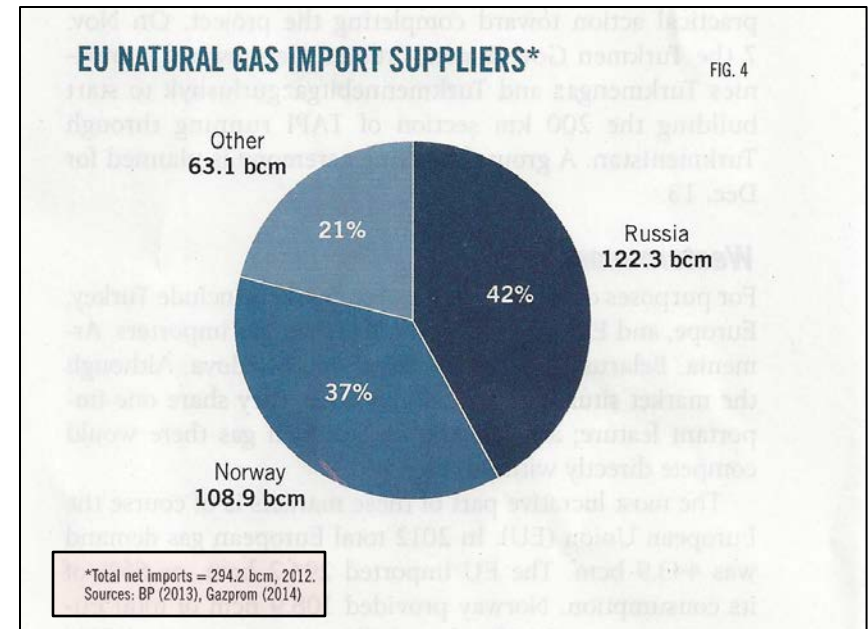
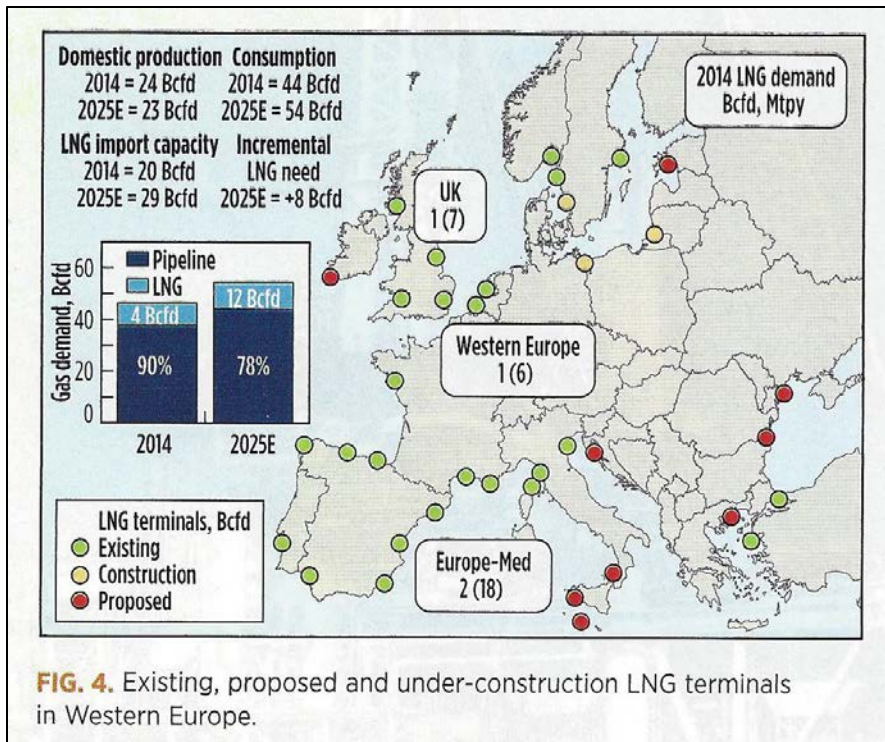


SCP-TANAP-TAP Pipeline

- **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 Caucasus Pipeline
- TANAP - Trans-Anatolian Natural Gas Pipeline
- TAP – Trans Adriatic Pipeline

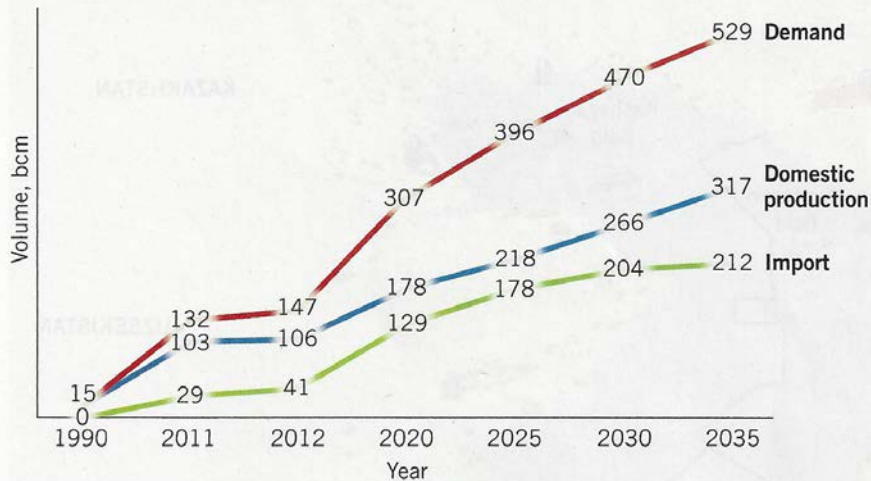


EU LNG Imports



China Natural Gas

NATURAL GAS IN CHINA

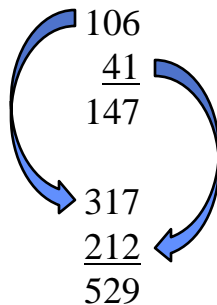


Sources: IEA (2013), BP (2013)

- 147 in 2012
- Domestic production
- Imported

3x @ 3.5% pa

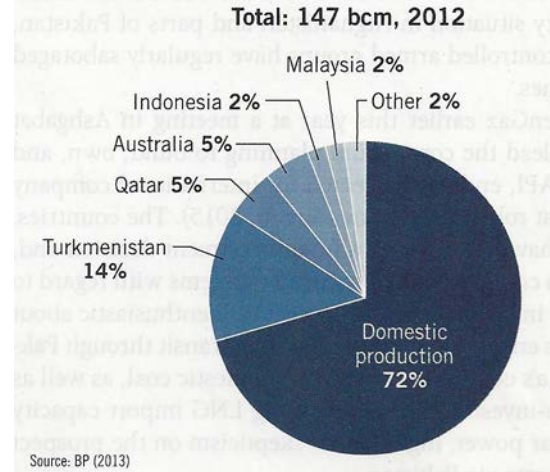
- 529 in 2035
- Domestic production
- Imported



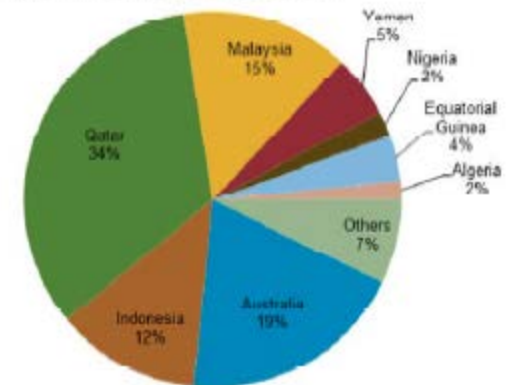
5x @ 12.8% pa

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

SOURCES, CONSUMED NATURAL GAS IN CHINA



China LNG import sources, 2014



Source: IHS Energy.
Others: Angola, Brunei, Egypt, Norway, Oman, Papua New Guinea, Russia, Trinidad & Tobago, and re-exports from Spain and South Korea.

base_e

“Practical Strategies for Emerging Energy Technologies”

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

China forecast:

2015 - 230 BCM (15.6%/year)

2020 - 375 BCM (12.6%/year)

- 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

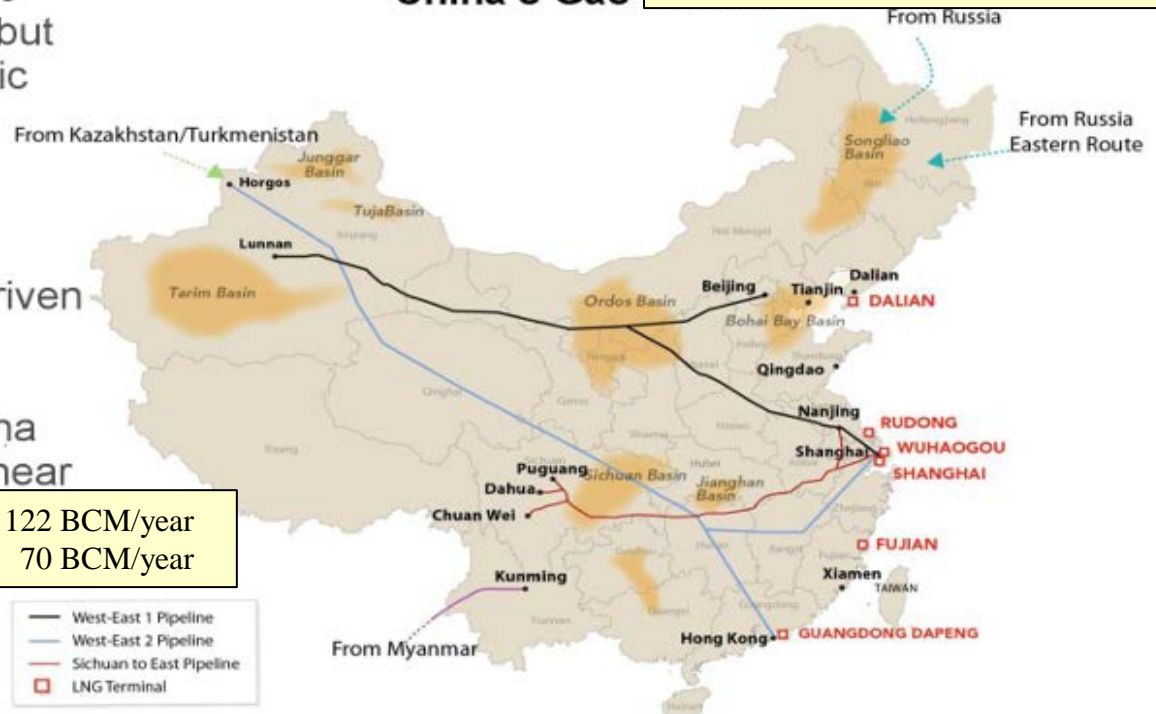
- Pipeline imports into China are projected to grow to near 4.3 tcf a year

4.3 tcf/year = 122 BCM/year

2.4 tcf/year = 70 BCM/year

- Domestic production will remain the major gas source

China's Gas



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

Russian Gas - 607 BCM Production

44,600 BCM Reserves
Reserves/Production Ratio - 73.5

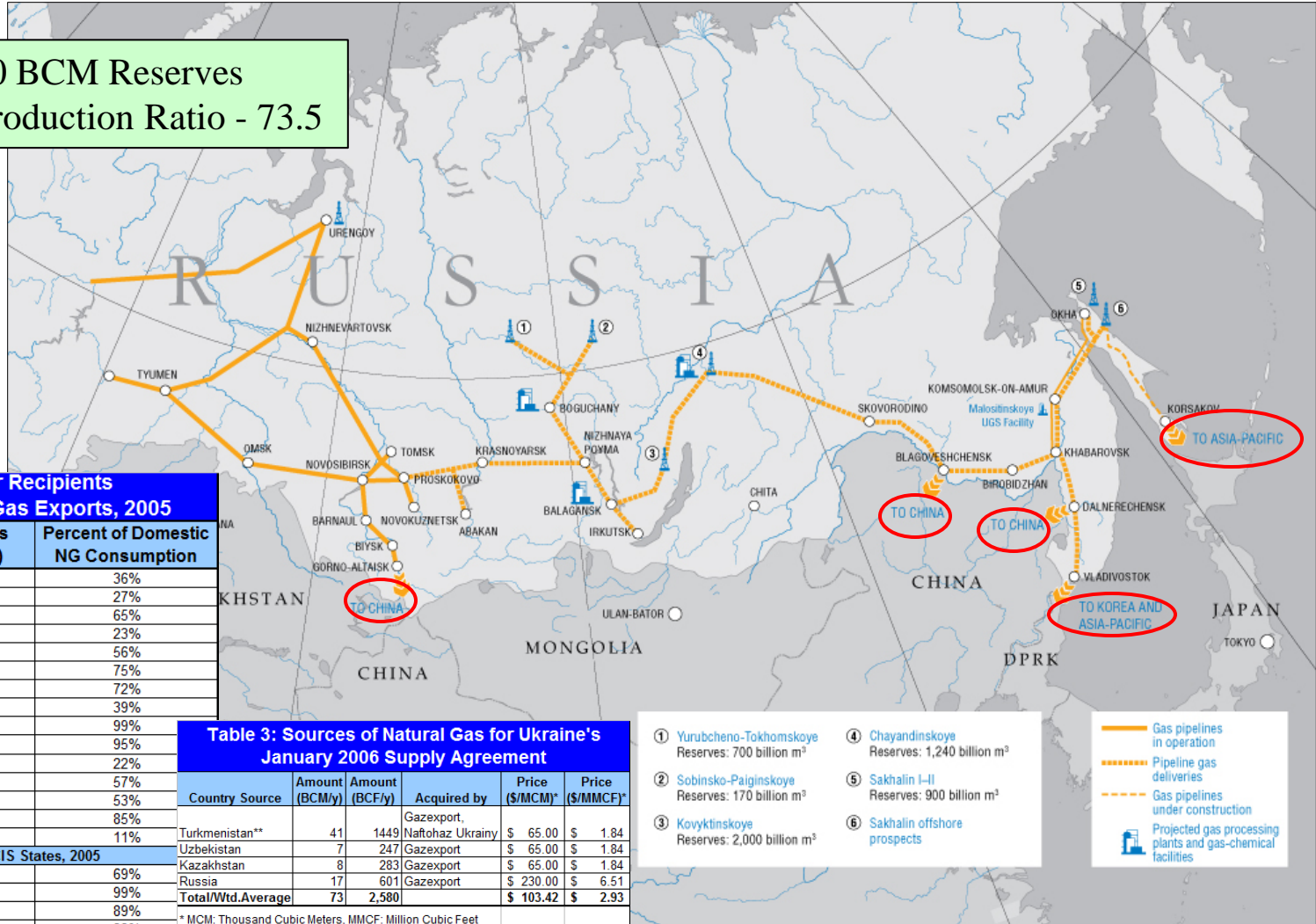


Table 2: Major Recipients of Russian Natural Gas Exports, 2005

Rank	Country	Imports (bcfy)	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%	

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/mcm 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

- ① Yurubcheno-Tokhomskoye Reserves: 700 billion m³
- ② Sobinsko-Paiginskoye Reserves: 170 billion m³
- ③ Kovyktinskoye Reserves: 2,000 billion m³
- ④ Chayandinskoye Reserves: 1,240 billion m³
- ⑤ Sakhalin I-II Reserves: 900 billion m³
- ⑥ Sakhalin offshore prospects

— Gas pipelines in operation
- - - Pipeline gas deliveries
- - - Gas pipelines under construction
 Projected gas processing plants and gas-chemical facilities

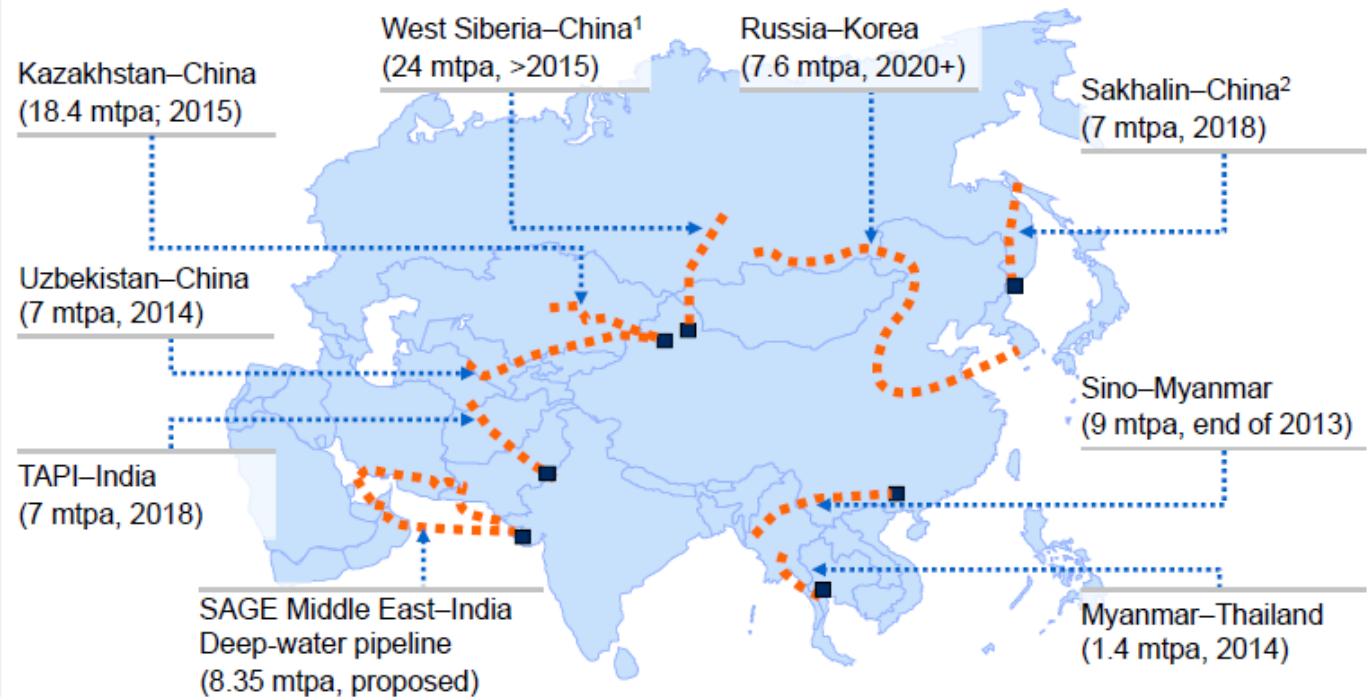
Sources: Domestic Consumption: EIA International Energy Annual, 2005; Imports: Cedigaz 2006 and BP Statistical Review 2007.

Pipelines to China & India

S4 Transnational gas pipelines into China and India are progressing

..... Cross border gas pipe planned or under construction (capacity, start date)

Transnational pipelines in Asia



Asian gas grid, connecting Iran, Myanmar, Bangladesh, India, China and Pakistan, is under discussion

¹ Project currently on hold

² Sakhalin-China pipe is confirmed and under construction

SOURCE: International Energy Agency; OGJ; literature search; FACTS

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 Bm³, but it has declined over the past few years, settling at 29.2 Bm³ 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.



Australia Supply Strategy

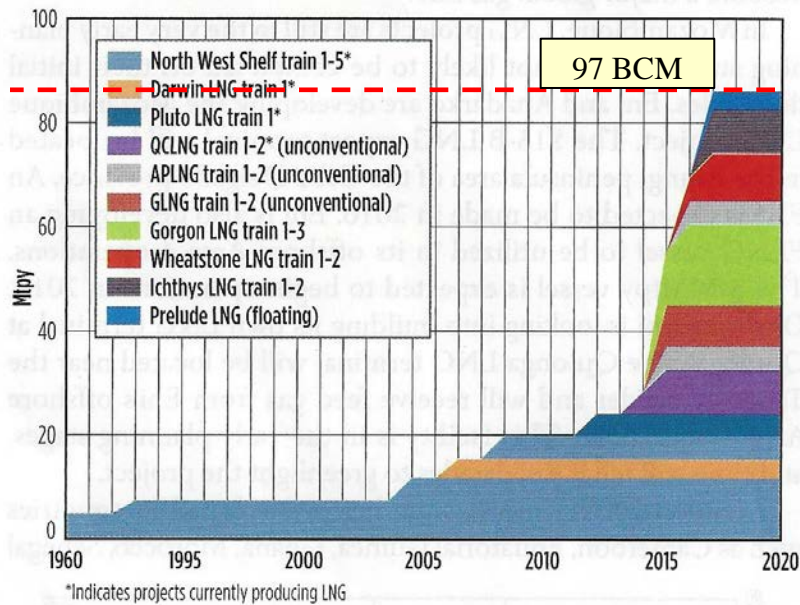
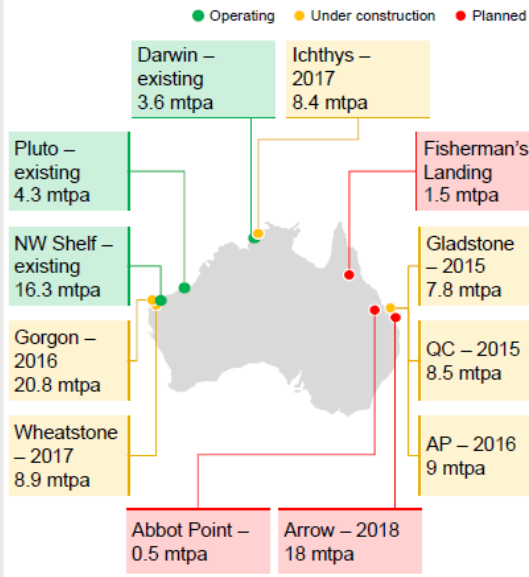


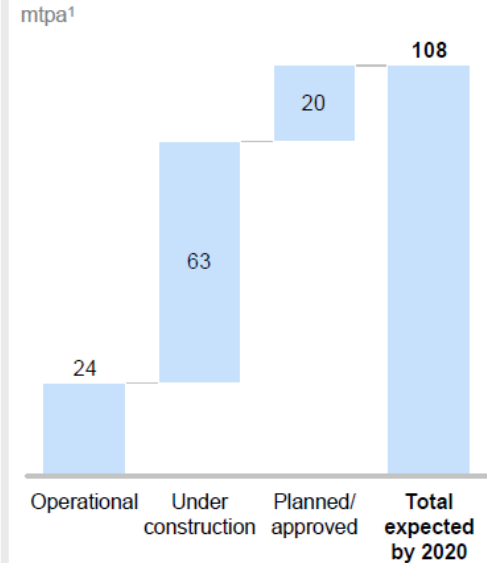
FIG. 2. Australian liquefaction capacity. Source: Australian Department of Industry and Reserve Bank of Australia.

S2 Australian supply projects are progressing

Map of onshore Australian LNG projects¹



Project status

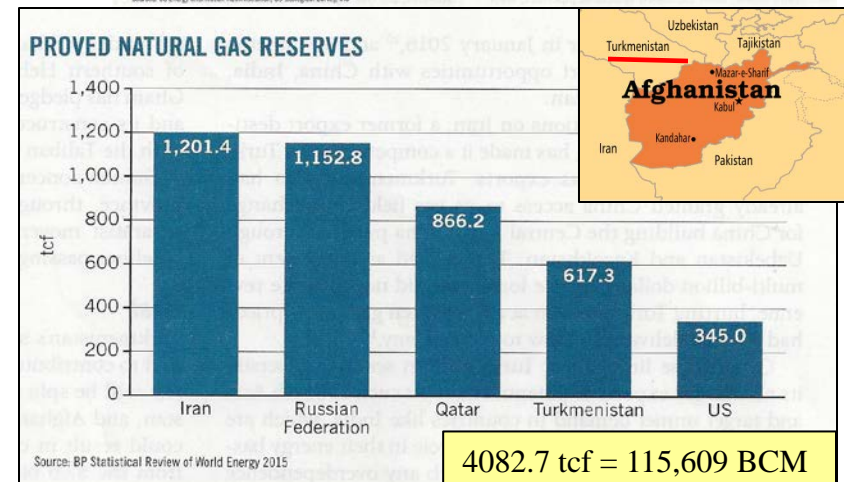
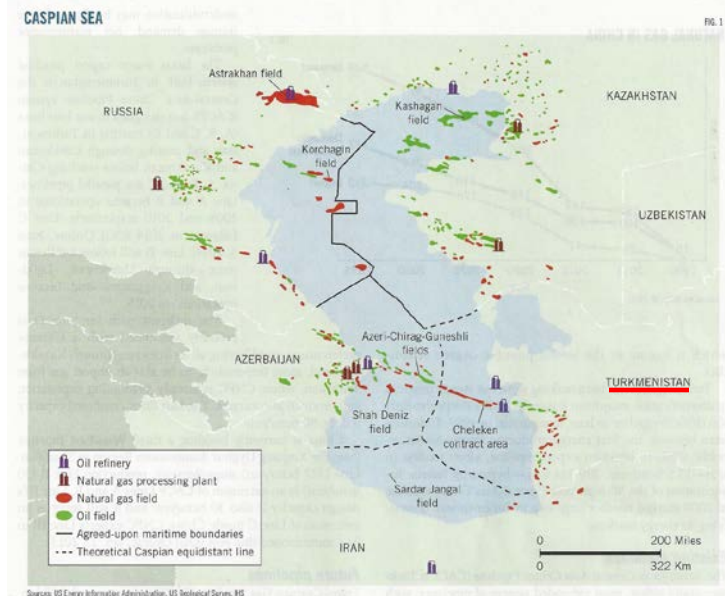


¹ Excludes 5 FLNG projects of total 18.1 mtpa (Prelude, Greater Sunrise, Bonaparte, Scarborough and Tassie)

SOURCE: Enerdata; literature search; McKinsey analysis

Turkmenistan – Serving Eurasia?

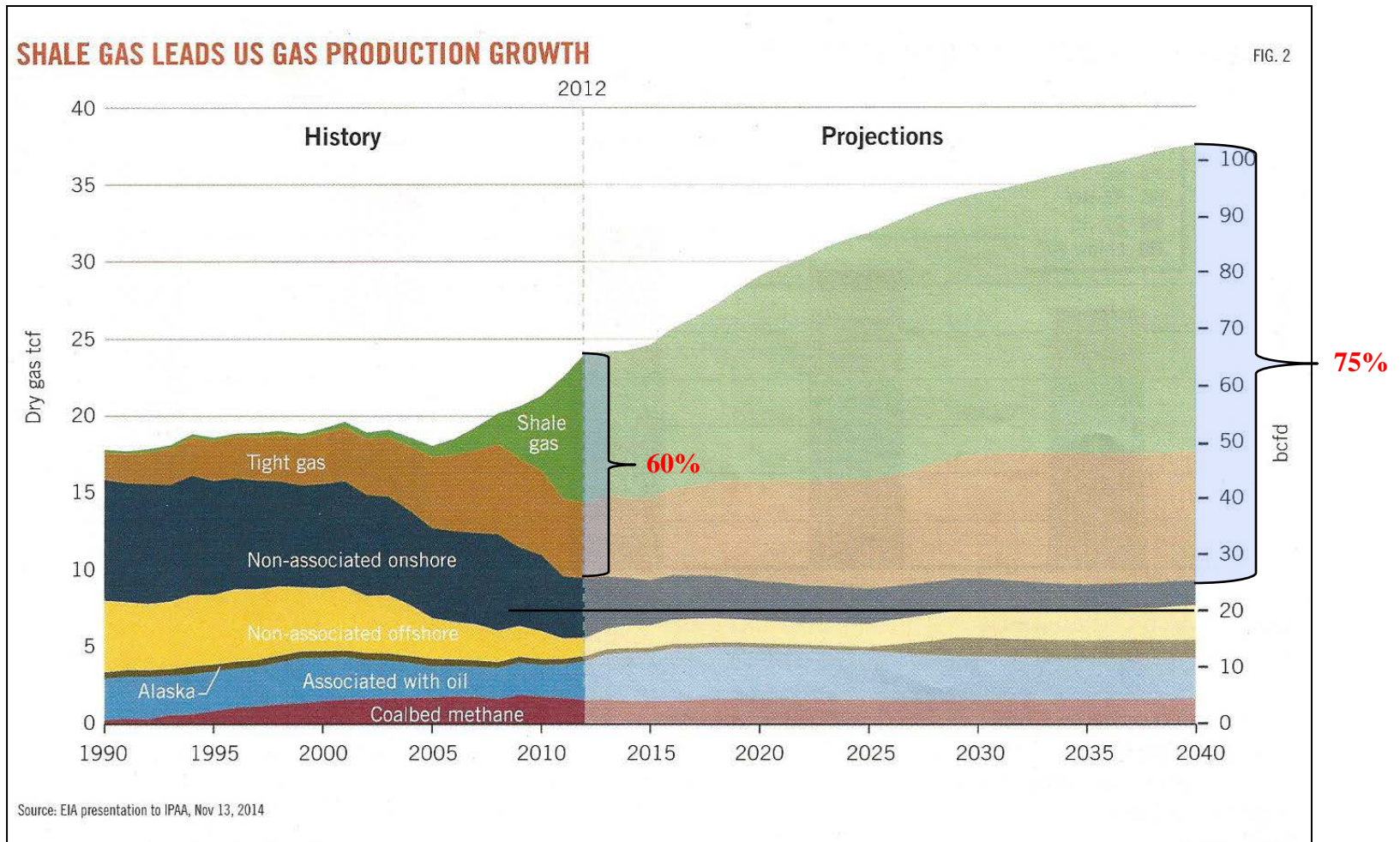
- 17,500 BCM proven natural gas reserves
- 9.3% of world total
- Russian Gas Pipeline Access/Use
 - 1989 – 81 BCM
 - 1998 – 12 BCM
- 74% in Galkynysh field near Afghan border
- China National Petroleum Corp. (CNPC)
 - CNPC controls 82% of Proven gas reserves
 - Produced 13 BCM (20%) in 2012
 - Export 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



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



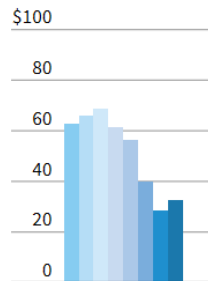
Reuters Break-even Shale Price

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.

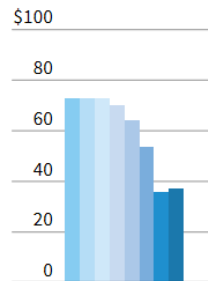
PRICE PER BARREL

■ 2010 ■ 2011 ■ 2012 ■ 2013
■ 2014 ■ 2015 ■ 2016 ■ 2017*

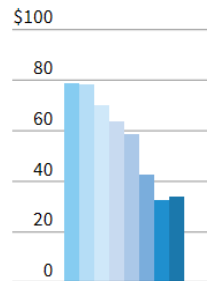
BAKKEN



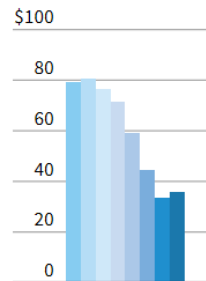
EAGLE FORD



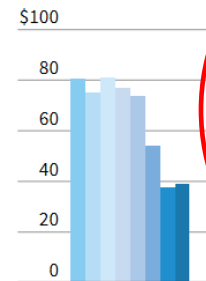
NIOBRARA



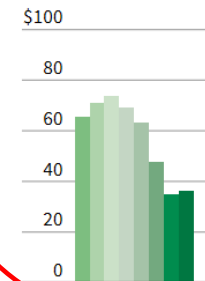
DELAWARE BASIN



MIDLAND BASIN



U.S. SHALE AVERAGE



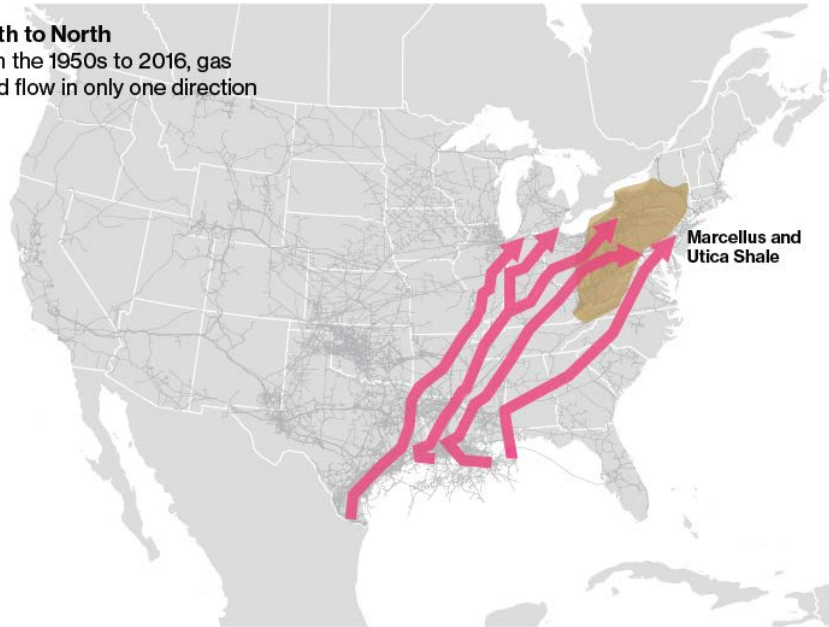
•Estimated
 •Source Rystad Energy

- 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?

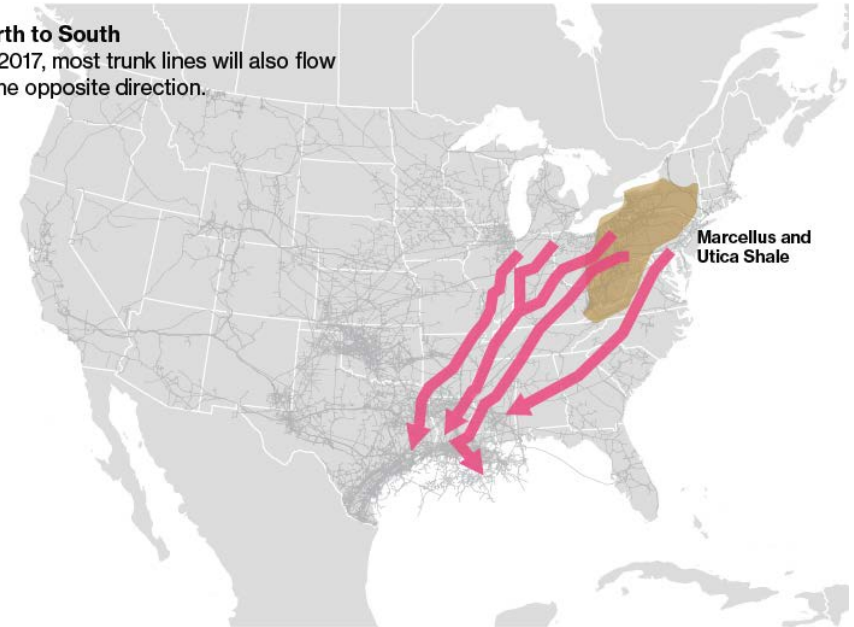
South to North

From the 1950s to 2016, gas could flow in only one direction



North to South

By 2017, most trunk lines will also flow in the opposite direction.



- 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

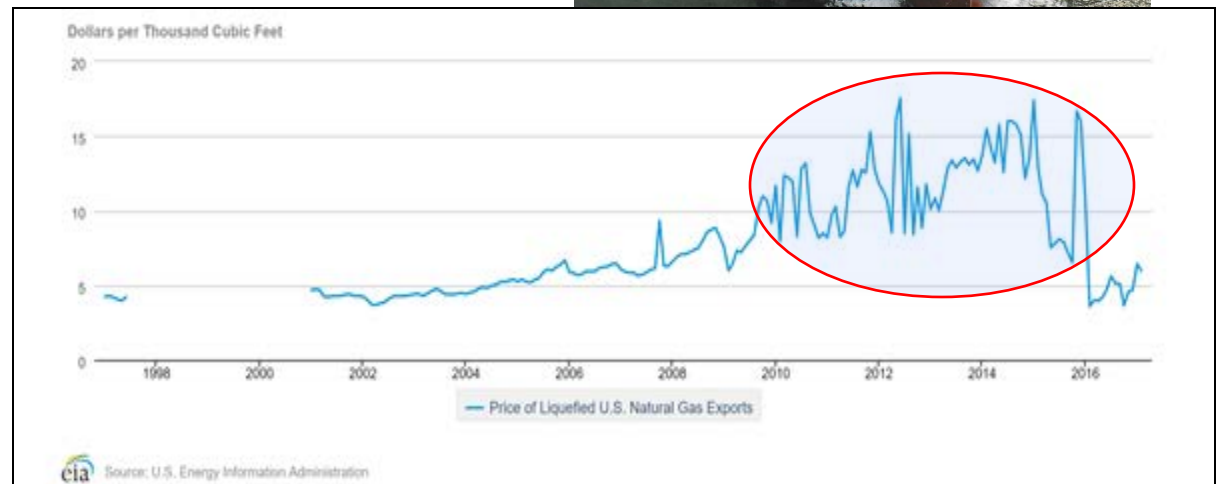
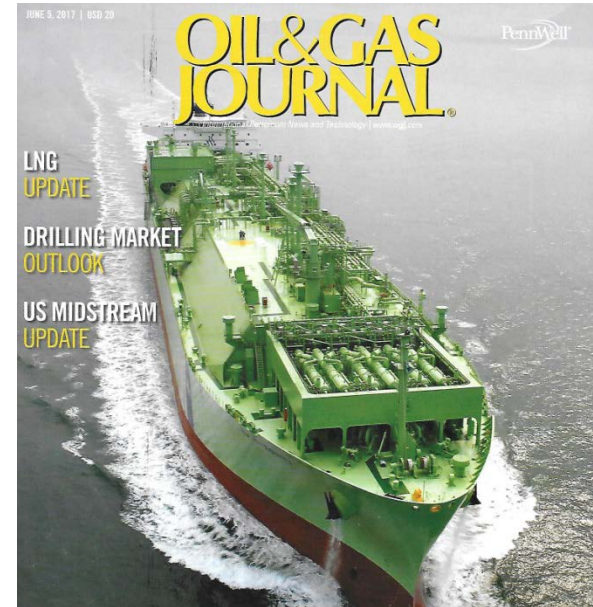
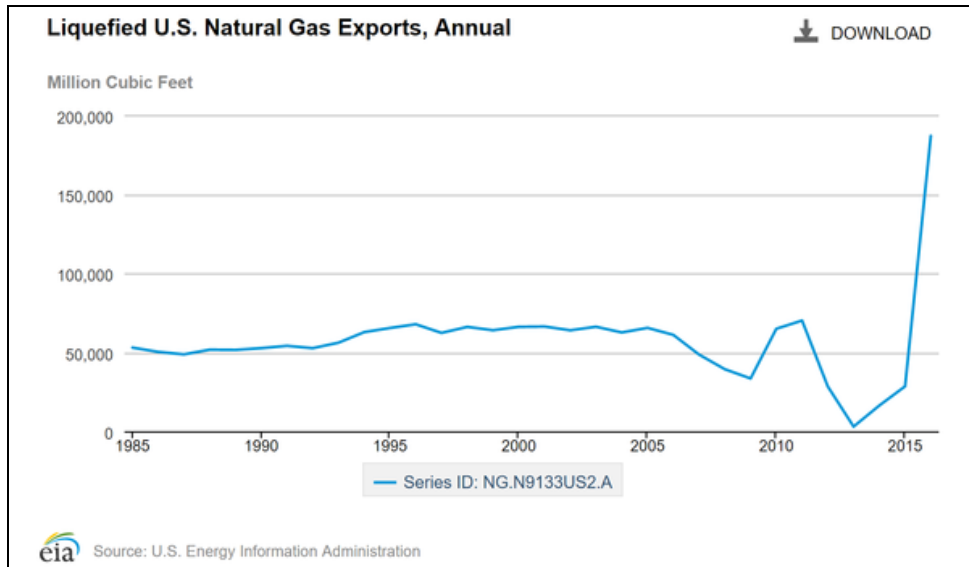
Sources: Data compiled by Bloomberg, U.S. Energy Information Administration, Cheniere, LNG shipment data compiled by Bloomberg via IHS and Genscape data, as of Nov. 16.

By [Dave Merrill](#) Dave Merrill and Christine Buurma
November 30, 2016

base_e

“Practical Strategies for Emerging Energy Technologies”

U.S. LNG Exports



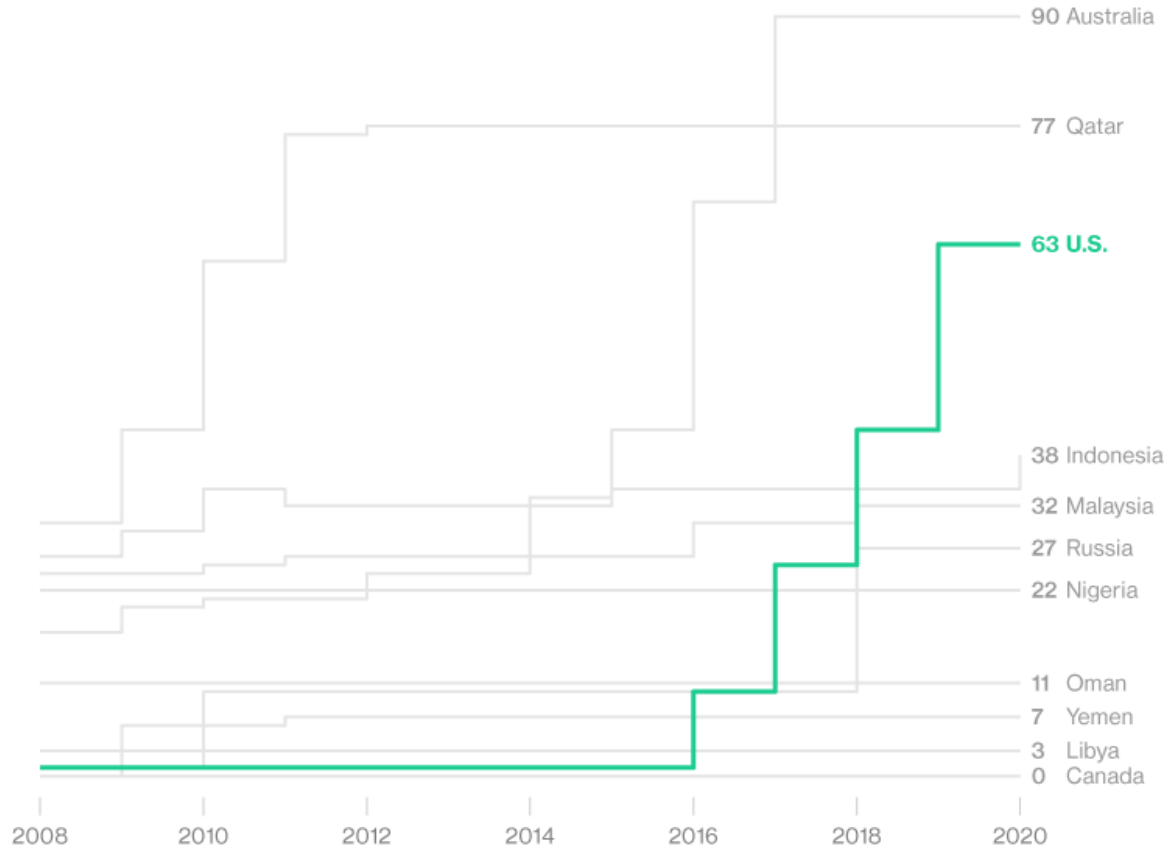
base_e

“Practical Strategies for Emerging Energy Technologies”

Gas Exports Terminals

A new natural gas leader

The U.S. is building more gas export terminals than any other nation



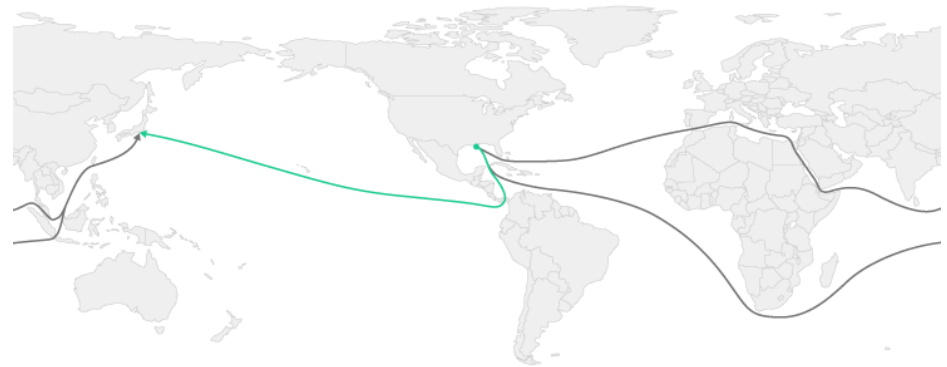
Source: Energy Aspects

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



Expanded canal opens Asia market to U.S. shale gas
Canal route shortens trip by one-third



Shipping times from the U.S. Gulf to northeast Asia



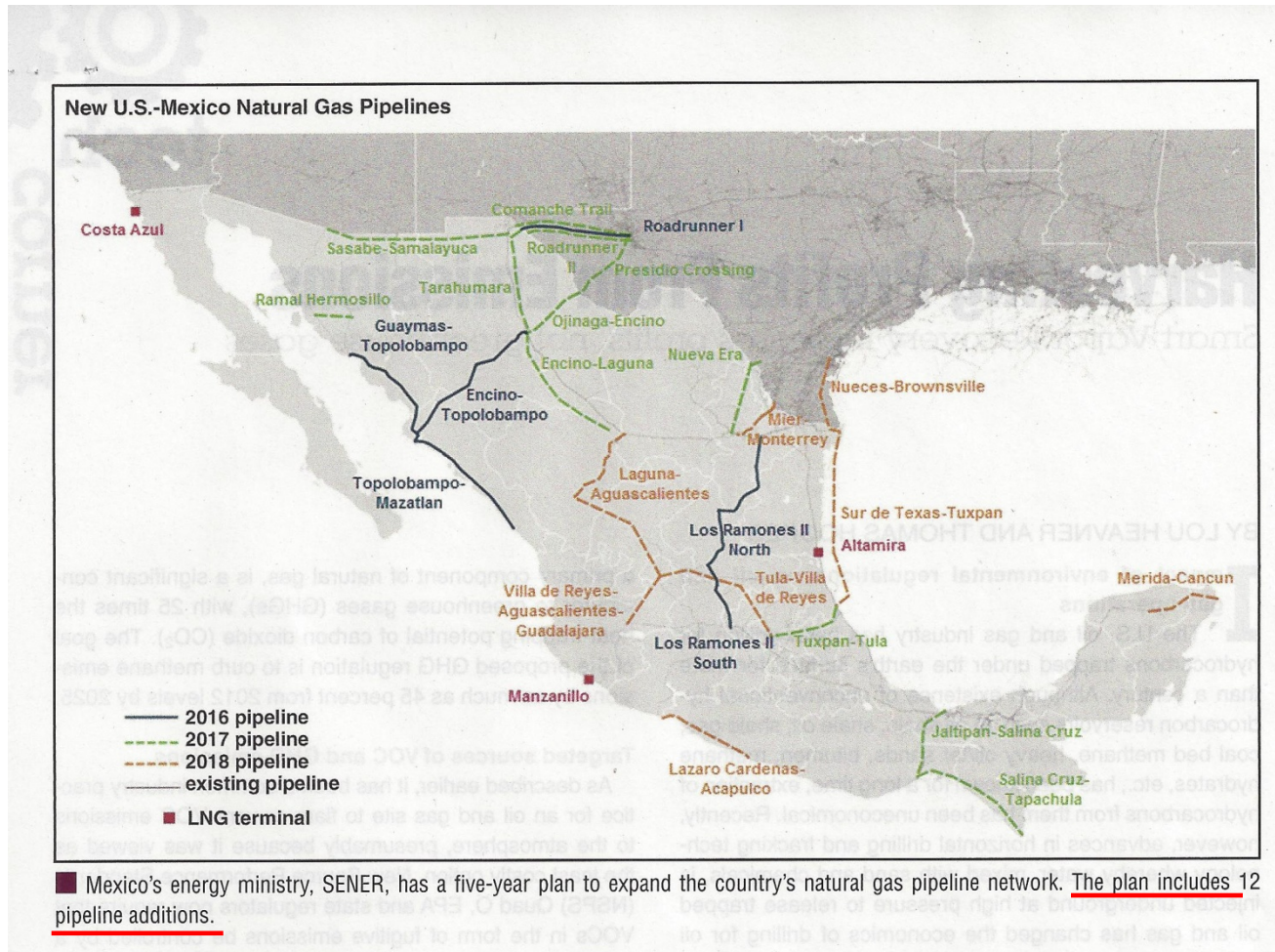
Source: Panama Canal Authority

base_e

“Practical Strategies for Emerging Energy Technologies”

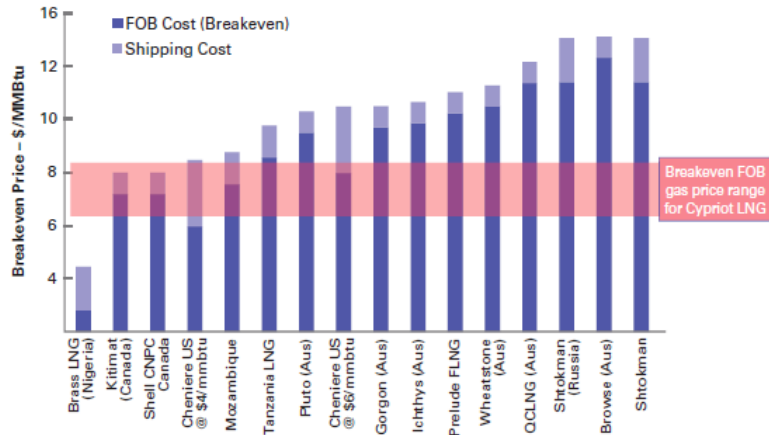
Source: Alex Nussbaum and Naureen Malik May 2016

Gas to Mexico



Cyprus

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



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

Potential 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

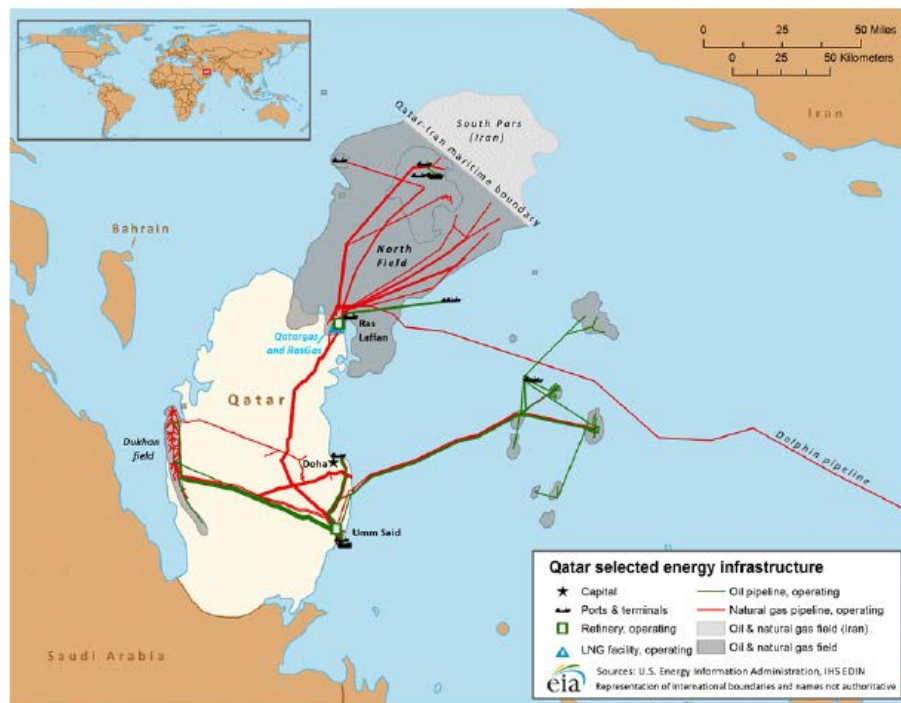
- The discovery of fields called Leviathan and Tamar, said to hold 25 trillion to 30 trillion cubic feet of natural gas came in 2010
- A partnership led by Noble Energy, a Houston-based company, and the Delek Group, an Israeli firm, has developed wells in Tamar; the first supplies reached domestic markets 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)



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

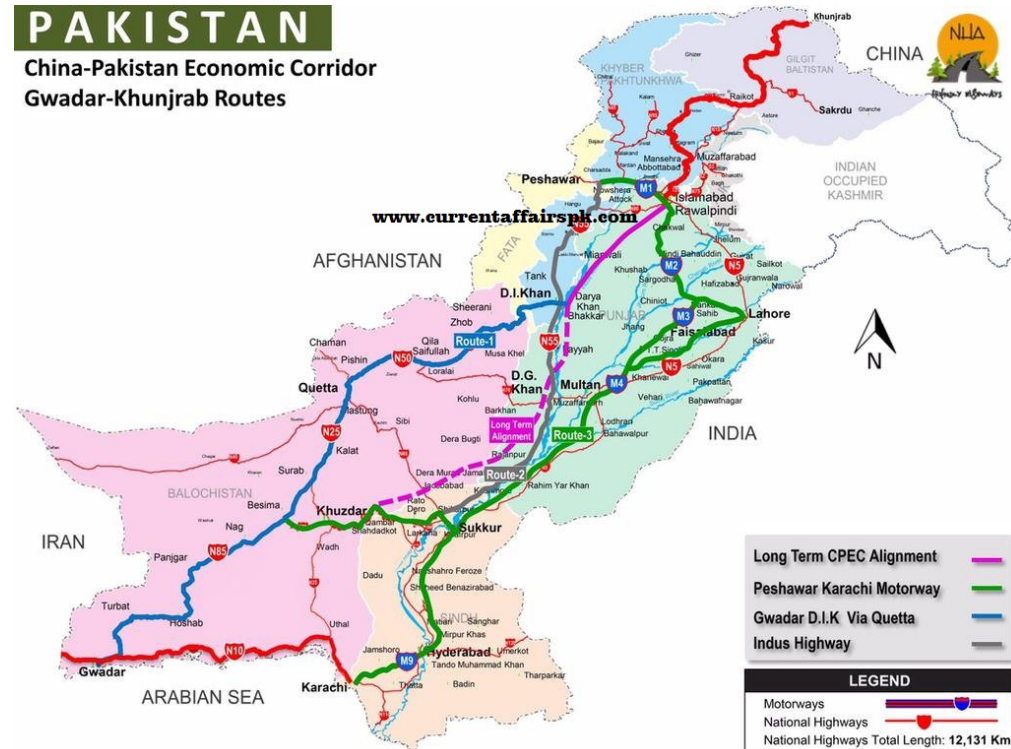


The New “Silk Roads”



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

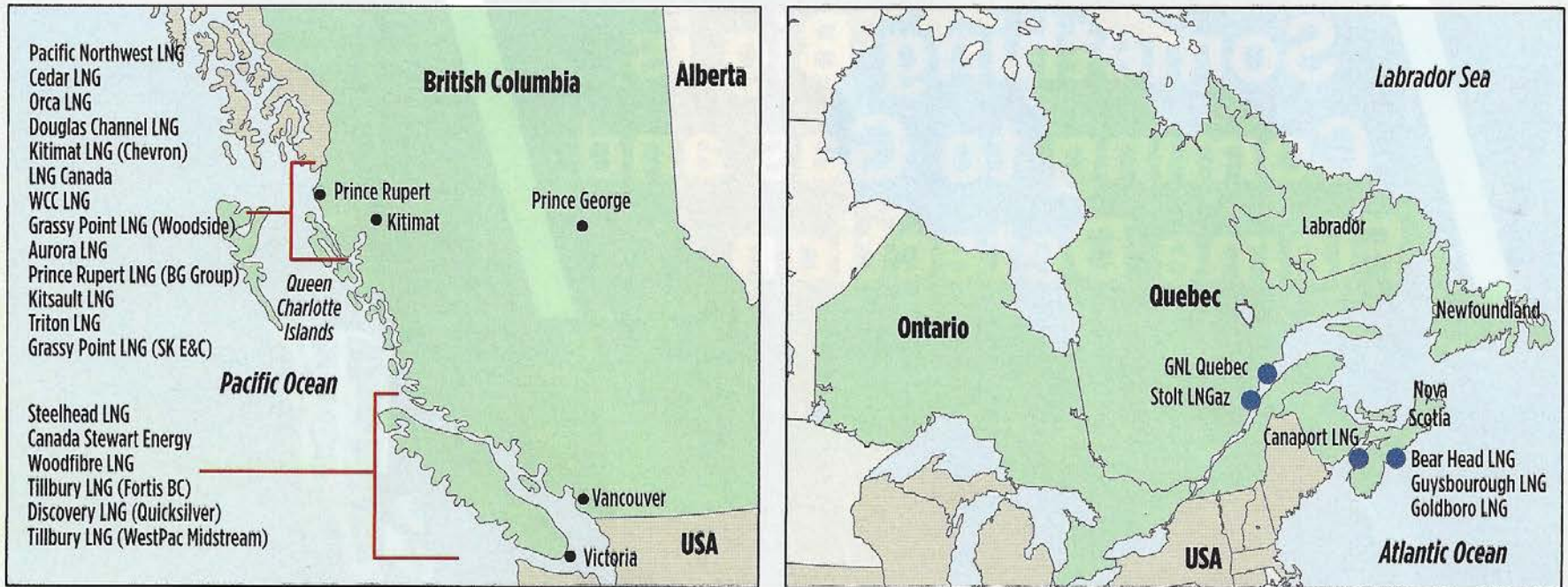


FIG. 3. Canada has announced a multitude of LNG export projects on its west and east coasts.

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 liquids (NGPL) extraction and fractionation facility near Chicago
- 2020

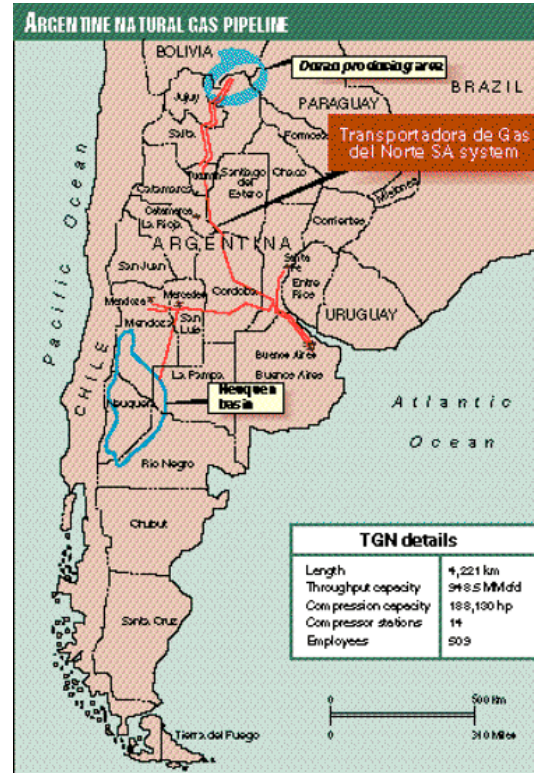
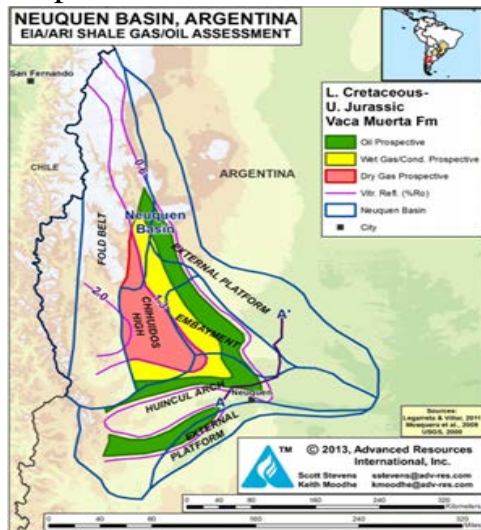
Alliance pipeline system



- 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

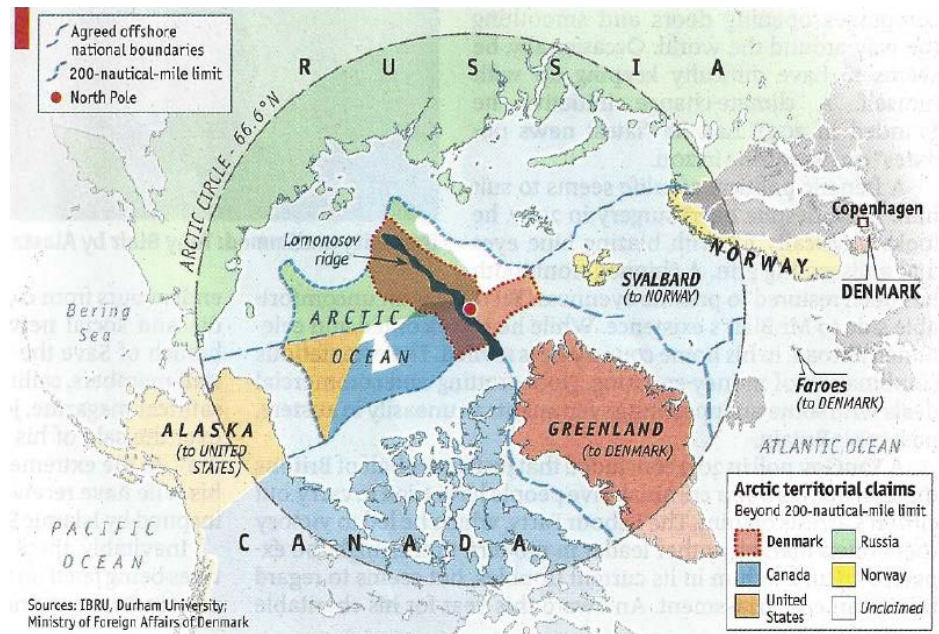
Argentina Shale Gas

- 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.



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



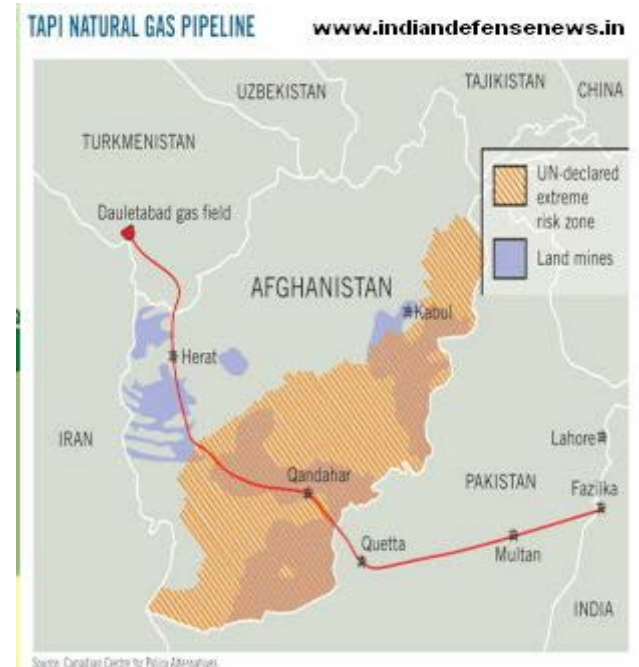
The Economist 2014

- 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.

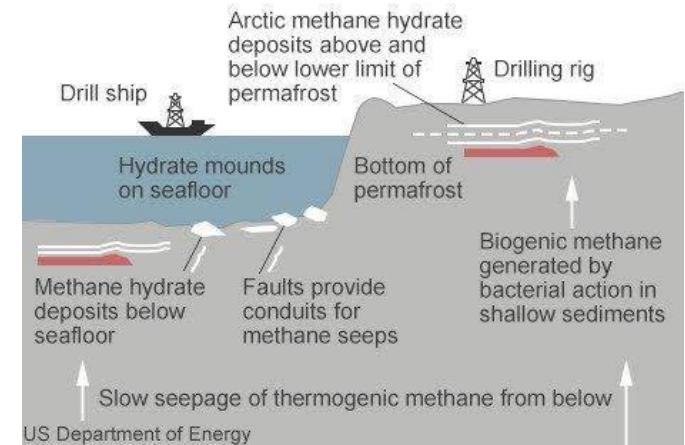


Methane Hydrates – 280,000 to 2,800,000 BCM?

- 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



How methane hydrates are formed



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

base_e

“Practical Strategies for Emerging Energy Technologies”

Pete Baldwin
781-721-6200 (o)
617-306-7419 (c)
pete_baldwin@base-e.net

base_e

“Practical Strategies for Emerging Energy Technologies”