Electric Power Committee
Fuels Report 2018

Presented at

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base e

"Practical Strategies for Emerging Energy Technologies"

Acknowledgement to Author

- **Material presented created by Pete Baldwin:**
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  - –Past President of NREC*
    - –NREC Microturbine
    - –NREC Recuperator
  - –Ingersoll-Rand – 33 years
    - –International industry experiences (UK and Italy)
  - –Contributing Editor to Turbomachinery International
  - –Past Associate with IHS-CERA Distributed Energy Practise
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- **Presentation available for download at : http://www.base-e.net/articles.php**

*Northern Research & Engineering Corporation , now part of Concepts/NREC

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Basic Comparisons

	China	USA	India	Japan	Germany	Russia
Population - July 2014 est	1,379,302,771	326,525,791	1,281,935,911	126,451,398	80,594,017	142,257,519
Population Growth Rate	0.41%	0.81%	1.17%	-0.21%	-0.16%	-0.08%
Area - km^2	9,596,960	9,826,675	3,287,263	377,915	357,022	17,098,242
GDP - Purchasing Power Parity ($trillion)	23.1	19.4	9.4	5.4	4.2	4.0
Installed Generating Capacity GW	1,646	1,074	309	322	204	264
% of World at 6301GW	26%	17%	5%	5%	3%	4%
Electric Production TWh	6,142	4,088	1,289	976	559	1,008
Electric Consumption TWh	5,920	3,911	1,048	934	515	890
Aggregate Load Factor	42.6%	43.5%	47.6%	34.6%	31.3%	43.6%
Natural Gas Production - BCM	138.4	766.2	31.2	4.5	8.7	598.6
Natural Gas Consumption - BCM	210.3	773.2	102.3	123.6	79.2	418.9
Refined Petroleum Products Production - mmbbl/d	10.9	20.1	4.8	3.5	2.2	6.2
Refined Petroleum Products Consumption - mmbbl/d	11.8	19.7	4.1	4.0	2.4	3.6
Coal Production - Million Tonnes Oil Equivalent	1827.0	455.2	283.9	0.7	42.9	184.5
Coal Consumption - Million Tonnes Oil Equivalent	1920.4	396.3	407.2	119.4	78.3	88.7

Source: CIA World Factbook

CIA World Factbook

World Total Installed Electrical Generating Capacity **6301GW**

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PS… .Total Value of Outstanding Student Loans - $1.2 trillion
U.S. health care cost 2014 - $3.3 trillion
U.S. Household Debt 2017 - $13.2 trillion

Primary Energy Consumption by Fuel - Mtoe

U.S. = 91.86 Quads

Primary Energy: Consumption by fuel*

Million tonnes oil equivalent	2016 Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renew-ables	2016 Total	2017 Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renew-ables	2017 Total	Percent of 2017 Total
US	907.6	645.1	340.6	191.9	59.7	83.1	2228.0	913.3	635.8	332.1	191.7	67.1	94.8	**2234.9**	16.5%
Canada	107.0	94.1	18.9	21.8	87.6	9.6	339.0	108.6	99.5	18.6	21.9	89.8	10.3	**348.7**	2.6%
Mexico	90.1	79.0	12.4	2.4	6.9	4.1	194.9	86.8	75.3	13.1	2.5	7.2	4.4	**189.3**	1.4%
Total North America	**1104.6**	**818.2**	**371.9**	**216.1**	**154.2**	**96.8**	**2761.9**	**1108.6**	**810.7**	**363.8**	**216.1**	**164.1**	**109.5**	**2772.8**	20.5%
Brazil	135.7	32.4	15.9	3.6	86.2	19.1	293.0	135.6	33.0	16.5	3.6	83.6	22.2	**294.4**	2.2%
Total S. & Cent. America	**320.8**	**150.6**	**34.9**	**5.5**	**156.4**	**28.6**	**696.8**	**318.8**	**149.1**	**32.7**	**5.0**	**162.3**	**32.6**	**700.6**	5.2%
France	79.2	38.3	8.2	91.2	13.6	8.4	238.9	79.7	38.5	9.1	90.1	11.1	9.4	**237.9**	1.8%
Germany	117.3	73.0	75.8	19.2	4.6	38.3	328.2	119.8	77.5	71.3	17.2	4.5	44.8	**335.1**	2.5%
Italy	59.8	58.5	11.0	-	9.6	14.8	153.8	60.6	62.0	9.8	-	8.2	15.5	**156.0**	1.2%
Spain	64.2	25.0	10.5	13.3	8.2	15.4	136.7	64.8	27.5	13.4	13.1	4.2	15.7	138.8	1.0%
Turkey	47.1	38.2	38.5	-	15.2	5.4	144.4	48.8	44.4	44.6	-	13.2	6.6	157.7	1.2%
United Kingdom	76.3	69.6	11.2	16.2	1.2	17.6	192.2	76.3	67.7	9.0	15.9	1.3	21.0	191.3	1.4%
Total Europe	**719.3**	**434.7**	**295.1**	**195.2**	**146.1**	**144.2**	**1934.6**	**731.2**	**457.2**	**296.4**	**192.5**	**130.4**	**161.8**	**1969.5**	14.6%
Russian Federation	152.5	361.3	89.2	44.5	41.8	0.3	689.6	153.0	365.2	92.3	46.0	41.5	0.3	**698.3**	5.2%
Total CIS	**202.8**	**492.6**	**156.2**	**63.3**	**56.3**	**0.8**	**972.0**	**203.4**	**494.1**	**157.0**	**65.9**	**56.7**	**0.9**	**978.0**	7.2%
Iran	80.7	173.1	0.9	1.5	3.5	0.1	259.8	84.6	184.4	0.9	1.6	3.7	0.1	**275.4**	2.0%
Saudi Arabia	173.8	90.6	0.1	-	-	^	264.5	172.4	95.8	0.1	-	-	^	**268.3**	2.0%
United Arab Emirates	45.7	62.3	1.5	-	-	0.1	109.6	45.0	62.1	1.6	-	-	0.1	**108.7**	0.8%
Total Middle East	**416.0**	**437.6**	**9.1**	**1.5**	**4.6**	**1.0**	**869.7**	**420.0**	**461.3**	**8.5**	**1.6**	**4.5**	**1.4**	**897.2**	6.6%
South Africa	28.7	4.0	84.7	3.6	0.2	1.8	123.0	28.8	3.9	82.2	3.6	0.2	2.0	**120.6**	0.9%
Total Africa	**192.6**	**114.5**	**94.9**	**3.6**	**27.1**	**5.2**	**438.0**	**196.3**	**121.9**	**93.1**	**3.6**	**29.1**	**5.5**	**449.5**	3.3%
Australia	50.5	35.9	43.6	-	4.0	5.4	139.5	52.4	36.0	42.3	-	3.1	5.7	**139.4**	1.0%
China	587.2	180.1	1889.1	48.3	261.0	81.7	3047.2	608.4	206.7	1892.6	56.2	261.5	106.7	**3132.2**	23.2%
India	217.1	43.7	405.6	8.6	29.0	18.3	722.3	222.1	46.6	424.0	8.5	30.7	21.8	**753.7**	5.6%
Indonesia	74.2	32.9	53.4	-	4.4	2.6	167.4	77.3	33.7	57.2	-	4.2	2.9	**175.2**	1.3%
Japan	191.4	100.1	118.8	4.0	18.1	18.8	451.2	188.3	100.7	120.5	6.6	17.9	22.4	**456.4**	3.4%
South Korea	128.9	41.0	81.9	36.7	0.6	3.1	292.2	129.3	42.4	86.3	33.6	0.7	3.6	**295.9**	2.2%
Taiwan	48.6	17.2	38.6	7.2	1.5	1.0	114.0	49.2	19.1	39.4	5.1	1.2	1.2	**115.1**	0.9%
Thailand	62.1	43.5	17.7	-	0.8	2.8	126.9	63.9	43.1	18.3	-	1.1	3.4	**129.7**	1.0%
Total Asia Pacific	**1601.1**	**625.1**	**2744.0**	**106.0**	**368.5**	**140.8**	**5585.5**	**1643.4**	**661.8**	**2780.0**	**111.7**	**371.6**	**175.1**	**5743.6**	42.5%
Total World	**4557.3**	**3073.2**	**3706.0**	**591.2**	**913.3**	**417.4**	**13258.5**	**4621.9**	**3156.0**	**3731.5**	**596.4**	**918.6**	**486.8**	**13511.2**	
	34.4%	23.2%	28.0%	4.5%	6.9%	3.1%	100.0%	34.2%	23.4%	27.6%	4.4%	6.8%	3.6%	100.0%	100.0%

13,511.2 Mtoe = 555.4 Quads

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"Practical Strategies for Emerging Energy Technologies"

Source: BP Statistical Review of World Energy 2018

10 Trends Shaping the Power Industry - US

1. Focus on ***resilience***
2. Wholesale pricing reforms
3. States act on carbon, fuel mix
4. Environment regulations in flux
5. Pipeline politics heat up
6. Gas generation continues to rise
7. Renewable energy faces speed bumps
8. Storage becomes a mature power resource
9. DERs prove their system worth
10. State regulators push PBR – and the utility model begins to change

2017 was a whirlwind for the electric power sector.

The utility industry saw the death of two utility mega-projects, jaw-dropping prices for renewable energy and storage and a federal subsidy proposal that threatened to "blow up" the wholesale power markets.

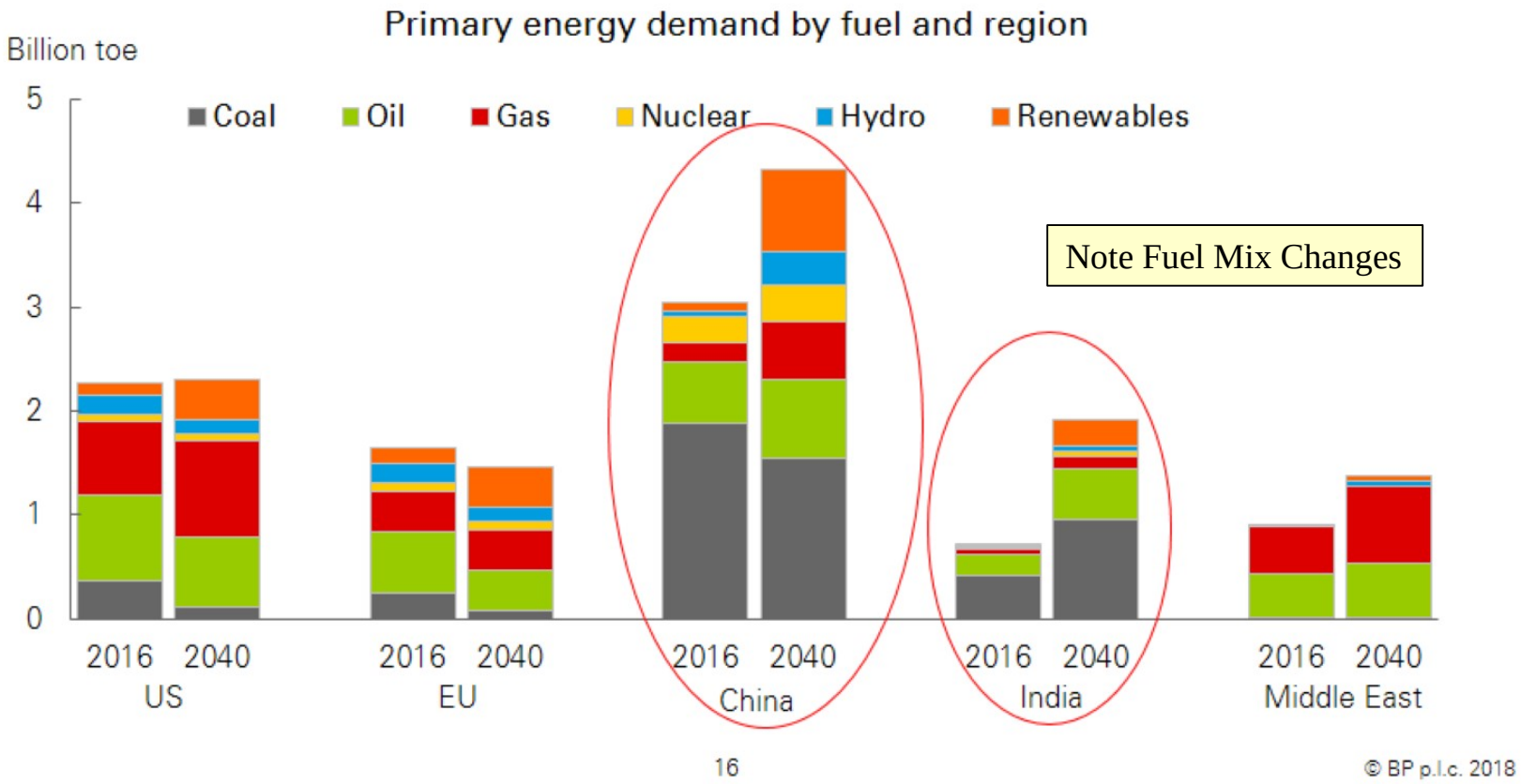
And that was just the second half of the year.

2018 promises to be no different. From EPA speeding through a Clean Power Plan replacement to FERC's "truncated" resilience docket and the first federal pipeline policy review since 1999, the sector's plate is full even before state and local issues come into play.

Rocky Mountain Institute
Gavin Bade@GavinBade

BP 2018 Primary Energy Demand by Fuel & Region

Energy mix by region



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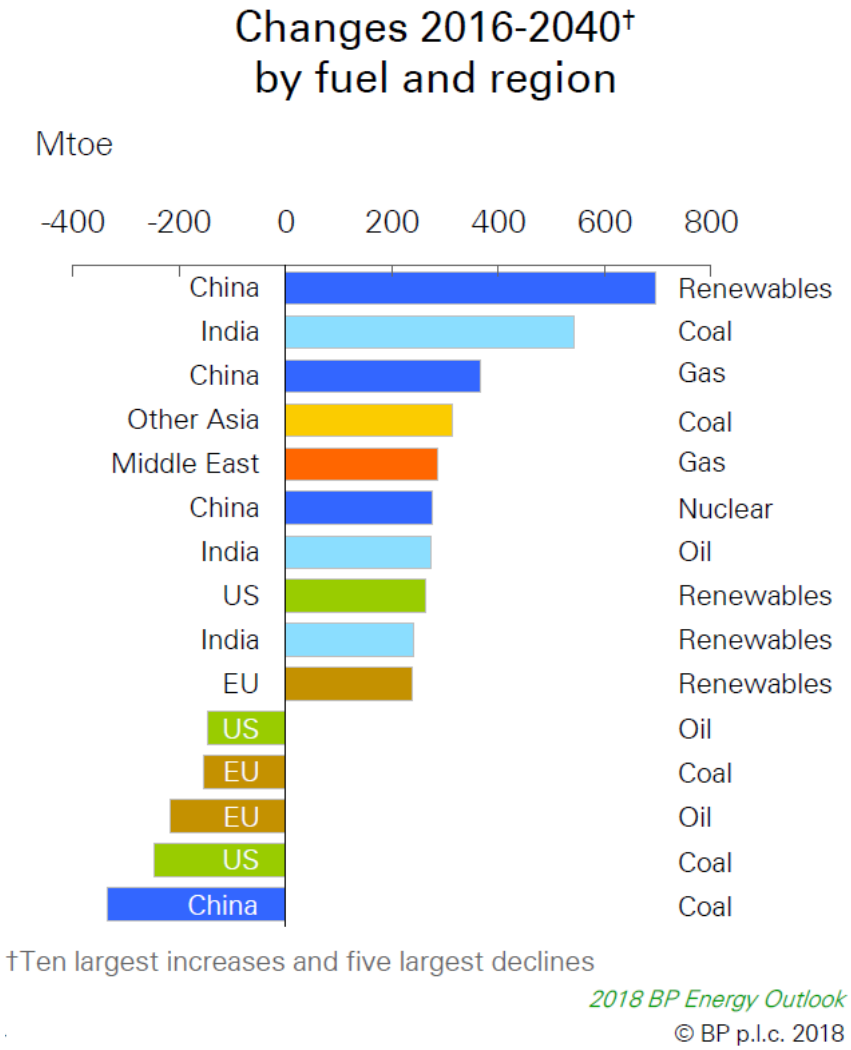
Fuel Mix Changes

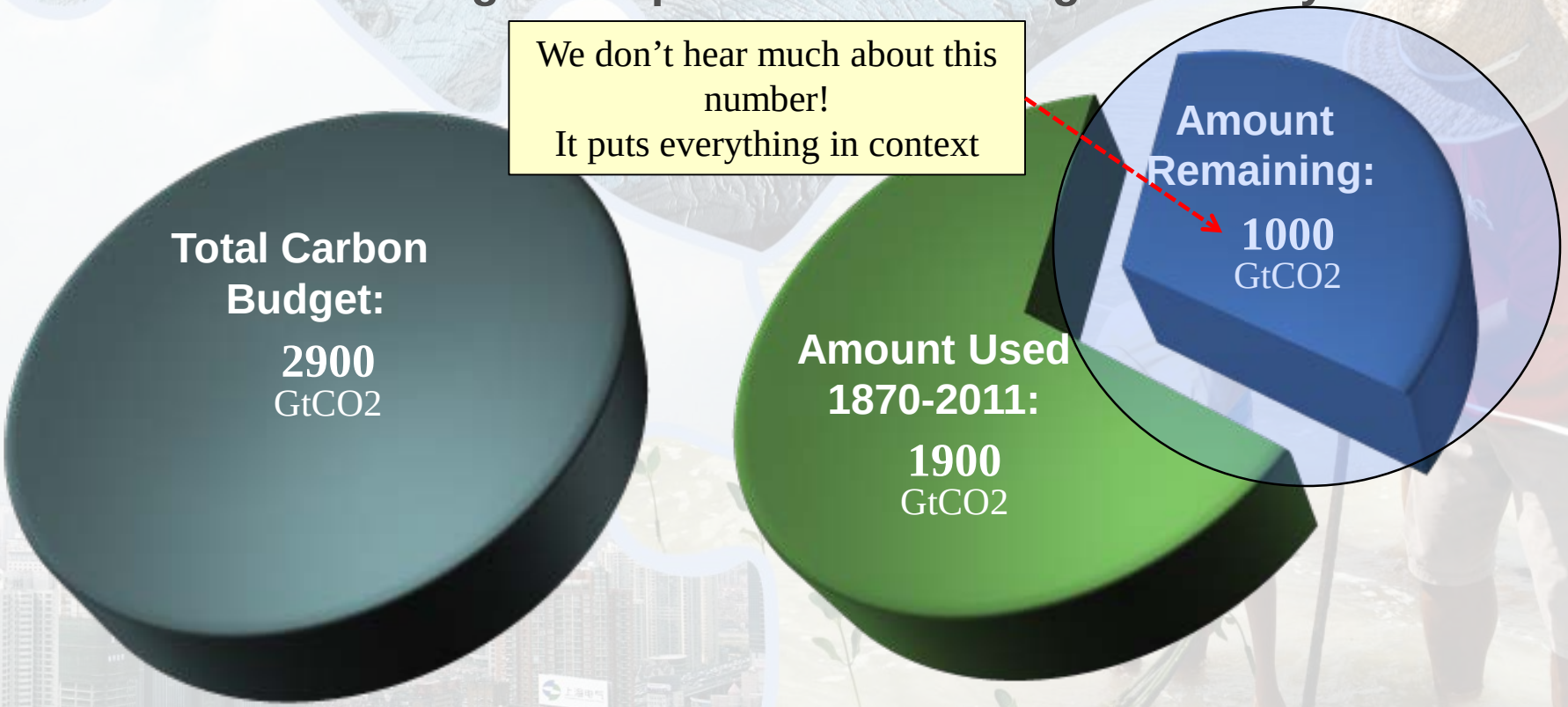


Climate Change

The window for action is rapidly closing

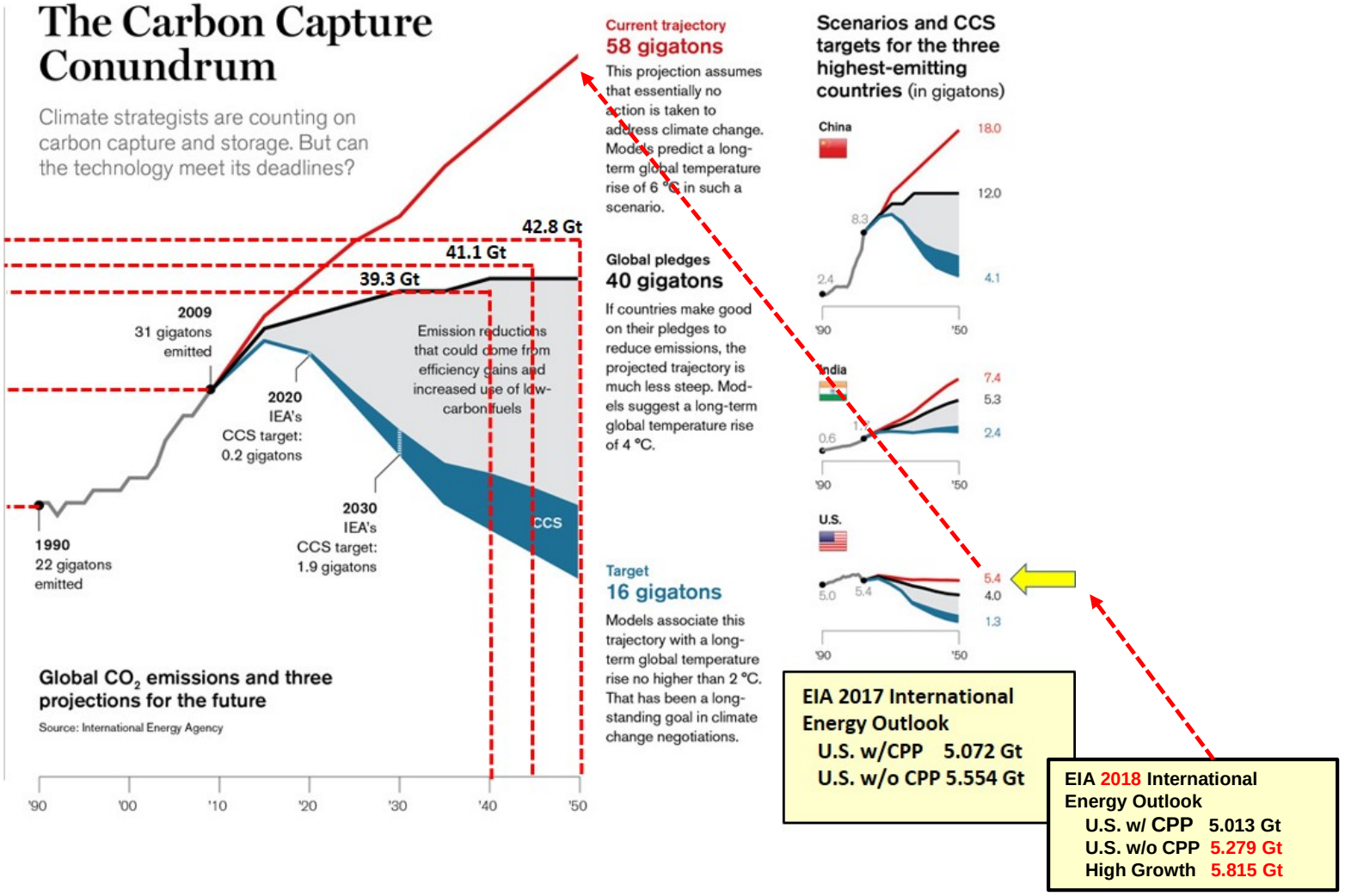
65% of our carbon budget compatible with a 2°C goal already used

We don't hear much about this number!
It puts everything in context



AR5 WGI SPM

EIA Annual Energy Outlook 2018



EIA 2017 International Energy Outlook
- U.S. w/CPP 5.072 Gt
- U.S. w/o CPP 5.554 Gt

EIA 2018 International Energy Outlook
- U.S. w/ CPP 5.013 Gt
- U.S. w/o CPP 5.279 Gt
- High Growth 5.815 Gt

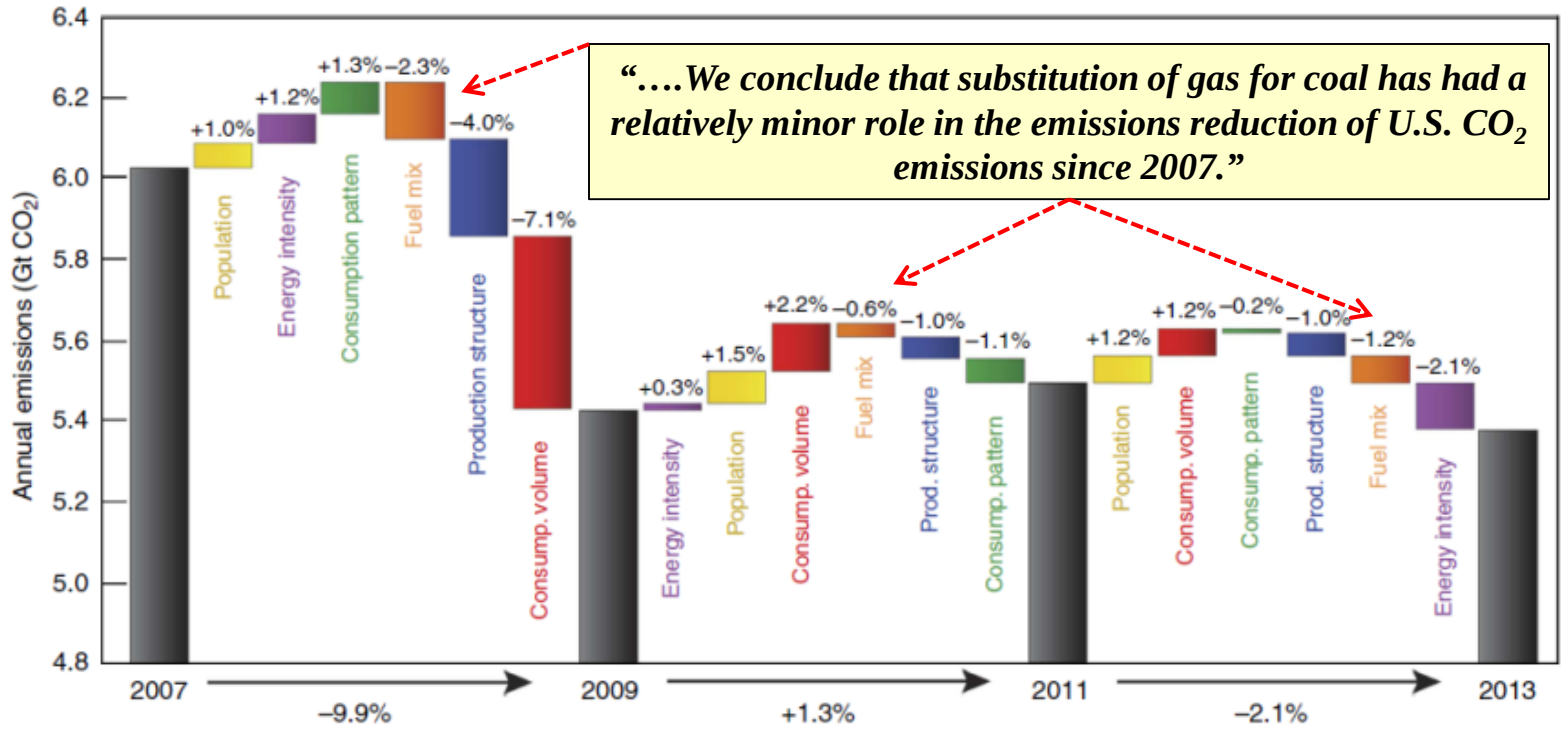
EIA Annual Energy Outlook 2018 – US portion 1,300

Energy-Related Carbon Dioxide Emissions by Sector and Source (MMmt)	2016	2020	2025	2030	2035	2040	2045	2050	Growth (2017-2050)
High economic growth	5174	5207	5138	5170	5225	5372	5568	5814	0.40%
Low oil price	5174	5170	5163	5156	5165	5234	5365	5521	0.20%
High economic growth with Clean Power Plan	5174	5204	5041	4927	4943	5057	5234	5424	0.20%
High oil and gas resource and technology	5174	5132	4999	5014	5020	5069	5152	5307	0.10%
Reference case	5174	5187	5079	5053	5024	5080	5159	5279	0.10%
Low oil and gas resource and technology	5174	5300	5114	4984	4954	4968	5030	5103	0.00%
High oil price	5174	5141	4926	4937	4950	4950	4987	5061	-0.10%
Reference case with Clean Power Plan	5174	5179	4997	4840	4822	4852	4915	5013	-0.10%
Low economic growth	5174	5110	4919	4856	4780	4743	4728	4742	-0.20%
Low economic growth with Clean Power Plan	5174	5115	4861	4697	4611	4586	4561	4562	-0.40%
CPP Impact Ref Case	0	24	43	87	121	205	319	266	
Energy-Related Carbon Dioxide Emissions Intensity by Sector and Source (MMmtCO2/capita)									
Reference case	16.0	15.5	14.7	14.1	13.6	13.4	13.3	13.3	-0.50%
Reference case with Clean Power Plan	16.0	15.5	14.4	13.5	13.0	12.8	12.6	12.6	-0.70%
Real Gross Domestic Product ($billion)									
Reference case	16716	18335	20221	22421	24802	27356	30204	33205	2.00%
Reference case with Clean Power Plan	16716	18319	20195	22380	24775	27341	30177	33161	2.00%
Population (millions)									
Reference case	323.7	333.8	346.6	358.6	369.5	379.4	388.6	397.5	0.60%
Reference case with Clean Power Plan	323.7	333.8	346.6	358.6	369.5	379.4	388.6	397.5	0.60%

Not much

Coal has to capture, Gas does not, and makes Nuc and CCS costly, both of which we need

Coal-to-Gas Shift – nature.com



"….We conclude that substitution of gas for coal has had a relatively minor role in the emissions reduction of U.S. CO_2 emissions since 2007."

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

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

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

US - 45Q Tax Credit (Price on Carbon)

- The 45Q CCUS tax credit was originally passed in 2008 and provided $10/metric ton for CO_2 used for EOR and $20/metric ton for CO_2 injected into saline storage
- The reformed 45Q tax credit provides:
  - **$35/metric ton CO2 for beneficial use, including EOR**
  - **$50/metric ton CO2 for saline aquifer storage**
  - 12-year window for receiving tax credits
  - Construction must begin by Jan 1, 2024
  - Minimum capture rate: 500,000 metric tons per year for power plants and 100,000 tpy for industry.
  - Transferrable, which means that non-profits such as cooperatives can use the tax credit.
- Not all power companies pay enough in taxes to directly use the tax credits that would be generated.
- Due to the recent US tax legislation, overall national and corporate tax rates are lower, resulting in fewer opportunities use and/or monetize the 45Q credits.
- Providing new, tangible examples that CCUS is real and provides substantial emission reductions from multiple industries.
- These projects may result in the states, US federal government, and possibly even inter-governmental (for example, the US and Canada) developing standards for CO_2 storage monitoring, verification, and well-closure rules. This would represent a major advancement for CCUS.
- They will lead to real infrastructure investments, including pipelines, which is especially important for CO_2 transport.

Holly Krutka
Peabody Energy
April 19, 2018

Oil

Crude Oil Consumption – 98.2 MMbbl/d

Oil: Consumption*

Thousand barrels daily	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	Growth rate per annum 2017	Growth rate per annum 2006-16	Share 2017
US	20680	19490	18771	19180	18882	18490	18961	19106	19531	19687	**19880**	1.0%	-0.5%	20.2%
Canada	2342	2297	2174	2306	2381	2342	2383	2399	2348	2401	**2428**	1.2%	0.5%	2.5%
Mexico	2089	2080	2021	2040	2065	2083	2034	1960	1939	1977	**1910**	-3.4%	-0.2%	1.9%
Total North America	**25111**	**23868**	**22967**	**23526**	**23329**	**22915**	**23379**	**23465**	**23818**	**24065**	**24219**	0.6%	-0.4%	24.7%
Brazil	2308	2481	2498	2716	2839	2915	3124	3242	3181	3013	**3017**	0.1%	3.4%	3.1%
Total S. & Cent. America	**5742**	**6032**	**6006**	**6334**	**6570**	**6742**	**6987**	**7058**	**7021**	**6811**	**6794**	-0.2%	2.2%	6.9%
France	1911	1889	1822	1763	1730	1676	1664	1616	1615	1600	**1615**	1.0%	-1.9%	1.6%
Germany	2380	2502	2409	2445	2369	2356	2408	2348	2340	2378	**2447**	2.9%	-0.9%	2.5%
Italy	1740	1661	1563	1532	1475	1346	1260	1184	1222	1228	**1247**	1.6%	-3.7%	1.3%
Spain	1613	1558	1473	1446	1378	1291	1195	1191	1237	1280	**1293**	1.1%	-2.2%	1.3%
United Kingdom	1752	1720	1646	1623	1590	1533	1518	1518	1561	1592	**1598**	0.3%	-1.3%	1.6%
Total Europe	**16356**	**16227**	**15537**	**15418**	**14975**	**14443**	**14263**	**14049**	**14413**	**14696**	**14980**	1.9%	-1.2%	15.3%
Russian Federation	2780	2861	2775	2878	3074	3119	3135	3301	3162	3193	**3224**	1.0%	1.5%	3.3%
Total CIS	**3844**	**3900**	**3768**	**3834**	**4118**	**4206**	**4176**	**4323**	**4162**	**4243**	**4282**	0.9%	1.1%	4.4%
Iran	1838	1925	1919	1791	1826	1849	2011	1953	1766	1722	**1816**	5.4%	-0.4%	1.8%
Saudi Arabia	2407	2622	2914	3206	3294	3461	3451	3753	3875	3939	**3918**	-0.5%	5.6%	4.0%
Total Middle East	**6970**	**7385**	**7724**	**7973**	**8271**	**8595**	**8870**	**9032**	**9029**	**9161**	**9290**	1.4%	3.1%	9.5%
Total Africa	**3040**	**3201**	**3325**	**3482**	**3388**	**3569**	**3724**	**3785**	**3877**	**3950**	**4047**	**2.5%**	**3.1%**	**4.1%**
Australia	935	944	950	957	1001	1025	1034	1046	1030	1041	**1079**	3.6%	1.1%	1.1%
China	7808	7941	8278	9436	9796	10230	10734	11209	11986	12302	**12799**	4.0%	5.2%	13.0%
India	2941	3077	3237	3319	3488	3685	3727	3849	4164	4560	**4690**	2.9%	5.2%	4.8%
Indonesia	1318	1287	1317	1411	1589	1640	1663	1681	1564	1580	**1652**	4.5%	2.4%	1.7%
Japan	5013	4847	4390	4442	4442	4702	4516	4303	4151	4031	**3988**	-1.1%	-2.5%	4.1%
Singapore	921	973	1049	1157	1208	1202	1225	1268	1338	1381	**1430**	3.5%	5.0%	1.5%
South Korea	2399	2308	2339	2370	2394	2458	2455	2454	2577	2771	**2796**	0.9%	1.8%	2.8%
Taiwan	1110	1005	1020	1045	983	983	1010	1040	1037	1043	**1051**	0.8%	-0.1%	1.1%
Thailand	1030	1018	1076	1122	1185	1250	1299	1310	1354	1377	**1423**	3.4%	3.3%	1.4%
Total Asia Pacific	**26041**	**25901**	**26260**	**27967**	**28911**	**30038**	**30689**	**31274**	**32521**	**33562**	**34574**	3.0%	2.9%	35.2%
Total World	**87105**	**86515**	**85587**	**88535**	**89561**	**90509**	**92088**	**92986**	**94843**	**96488**	**98186**	**1.8%**	**1.2%**	**100.0%**

+1,698 MMbbl/d

Source: BP Statistical Review of World Energy 2018

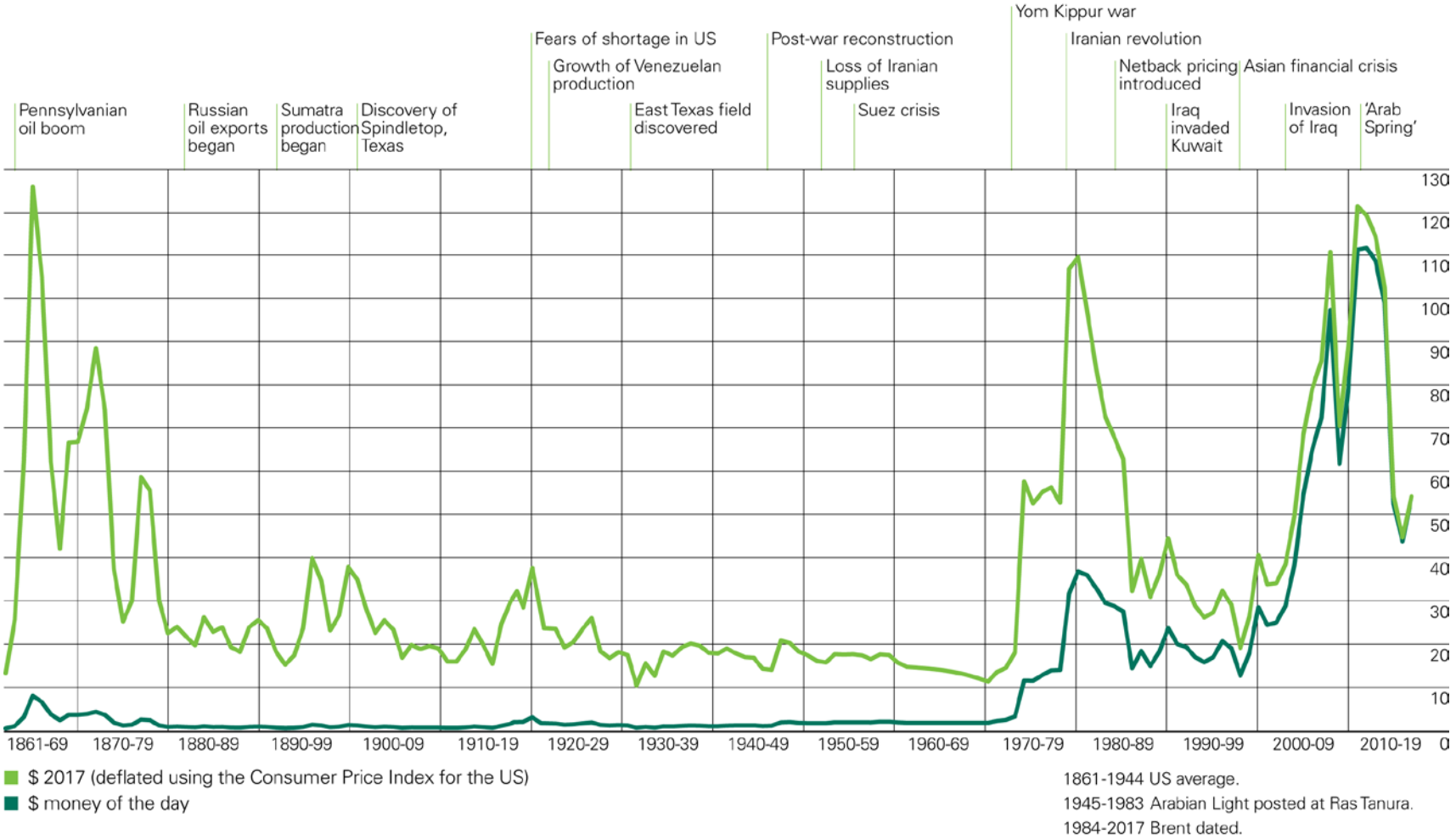
Crude Oil Production – 92.6 MMbbl/d

Oil: Production*

Thousand barrels daily	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	Growth rate per annum 2017	2006-16	Share 2017
US	6860	6784	7263	7549	7859	8904	10071	11768	12750	12366	**13057**	5.6%	6.1%	14.1%
Canada	3290	3207	3202	3332	3515	3740	4000	4271	4389	4470	**4831**	8.1%	3.4%	5.2%
Mexico	3479	3165	2978	2959	2940	2911	2875	2784	2587	2456	**2224**	-9.4%	-4.0%	2.4%
Total North America	**13628**	**13156**	**13444**	**13841**	**14314**	**15555**	**16946**	**18823**	**19726**	**19292**	**20112**	**4.3%**	**3.5%**	**21.7%**
Brazil	1831	1897	2029	2137	2179	2145	2110	2341	2525	2608	**2734**	4.8%	3.7%	3.0%
Colombia	531	588	671	786	915	944	1004	990	1006	886	**851**	-3.9%	5.3%	0.9%
Venezuela	3237	3228	3038	2842	2755	2704	2680	2692	2631	2387	**2110**	-11.6%	-3.3%	2.3%
Total S. & Cent. America	**7344**	**7439**	**7385**	**7410**	**7449**	**7373**	**7403**	**7663**	**7759**	**7418**	**7182**	**-3.2%**	**-0.1%**	**7.8%**
Norway	2551	2466	2349	2137	2039	1917	1838	1889	1946	1995	**1969**	-1.3%	-3.2%	2.1%
United Kingdom	1651	1549	1469	1356	1112	946	864	852	963	1013	**999**	-1.3%	-4.8%	1.1%
Total Europe	**5032**	**4790**	**4539**	**4198**	**3835**	**3523**	**3356**	**3390**	**3538**	**3566**	**3519**	**-1.3%**	**-3.9%**	**3.8%**
Azerbaijan	876	916	1027	1037	932	882	888	861	851	838	**795**	-5.1%	2.6%	0.9%
Kazakhstan	1415	1485	1609	1676	1684	1664	1737	1710	1695	1655	**1835**	10.8%	1.9%	2.0%
Russian Federation	10062	9969	10157	10383	10538	10660	10809	10860	11009	11269	**11257**	-0.1%	1.4%	12.2%
Total CIS	**12795**	**12825**	**13232**	**13502**	**13557**	**13609**	**13834**	**13830**	**13966**	**14162**	**14288**	**0.9%**	**1.4%**	**15.4%**
Iran	4359	4421	4292	4430	4472	3820	3617	3724	3862	4602	**4982**	8.2%	0.7%	5.4%
Iraq	2143	2428	2446	2469	2773	3079	3103	3239	3986	4423	**4520**	2.2%	8.3%	4.9%
Kuwait	2660	2784	2499	2560	2913	3169	3129	3101	3065	3145	**3025**	-3.8%	1.4%	3.3%
Oman	710	757	813	865	885	918	942	943	981	1004	**971**	-3.4%	3.1%	1.0%
Qatar	1267	1438	1421	1638	1834	1939	2002	1985	1958	1970	**1916**	-2.7%	4.7%	2.1%
Saudi Arabia	10268	10663	9663	10075	11144	11635	11393	11505	11994	12402	**11951**	-3.6%	1.5%	12.9%
United Arab Emirates	3094	3113	2783	2915	3285	3430	3543	3599	3873	4020	**3935**	-2.1%	2.5%	4.2%
Total Middle East	**25440**	**26517**	**24818**	**25834**	**28082**	**28523**	**28194**	**28496**	**30023**	**31849**	**31597**	**-0.8%**	**2.1%**	**34.1%**
Algeria	1992	1969	1775	1689	1642	1537	1485	1589	1558	1577	**1540**	-2.3%	-2.2%	1.7%
Angola	1656	1876	1754	1812	1670	1734	1748	1668	1772	1755	**1674**	-4.6%	2.3%	1.8%
Egypt	698	715	730	725	714	715	710	714	726	691	**660**	-4.5%	0.2%	0.7%
Libya	1820	1820	1652	1659	479	1509	989	498	432	426	**865**	102.9%	-13.5%	0.9%
Nigeria	2208	2174	2212	2534	2463	2413	2280	2278	2204	1903	**1988**	4.5%	-2.2%	2.1%
Total Africa	**10139**	**10263**	**9838**	**10104**	**8494**	**9264**	**8580**	**8191**	**8130**	**7687**	**8072**	**5.0%**	**-2.5%**	**8.7%**
China	3742	3814	3805	4077	4074	4155	4216	4246	4309	3999	**3846**	-3.8%	0.8%	4.2%
India	768	803	816	882	916	906	906	887	876	856	**865**	1.1%	1.2%	0.9%
Indonesia	972	1006	994	1003	952	918	882	852	841	882	**949**	7.6%	-1.4%	1.0%
Malaysia	730	731	691	726	660	662	626	650	698	704	**697**	-1.0%	0.1%	0.8%
Total Asia Pacific	**7951**	**8076**	**8028**	**8436**	**8296**	**8382**	**8257**	**8327**	**8405**	**8050**	**7879**	**-2.1%**	**0.2%**	**8.5%**
Total World	**82330**	**83067**	**81284**	**83325**	**84027**	**86229**	**86570**	**88721**	**91547**	**92023**	**92649**	**0.7%**	**1.1%**	**100.0%**
of which: OECD	19136	18426	18436	18534	18566	19487	20626	22571	23571	23139	**23901**	3.3%	1.8%	25.8%
OPEC	35835	37029	34596	35665	36478	38034	37004	36945	38362	39601	**39436**	-0.4%	0.9%	42.6%

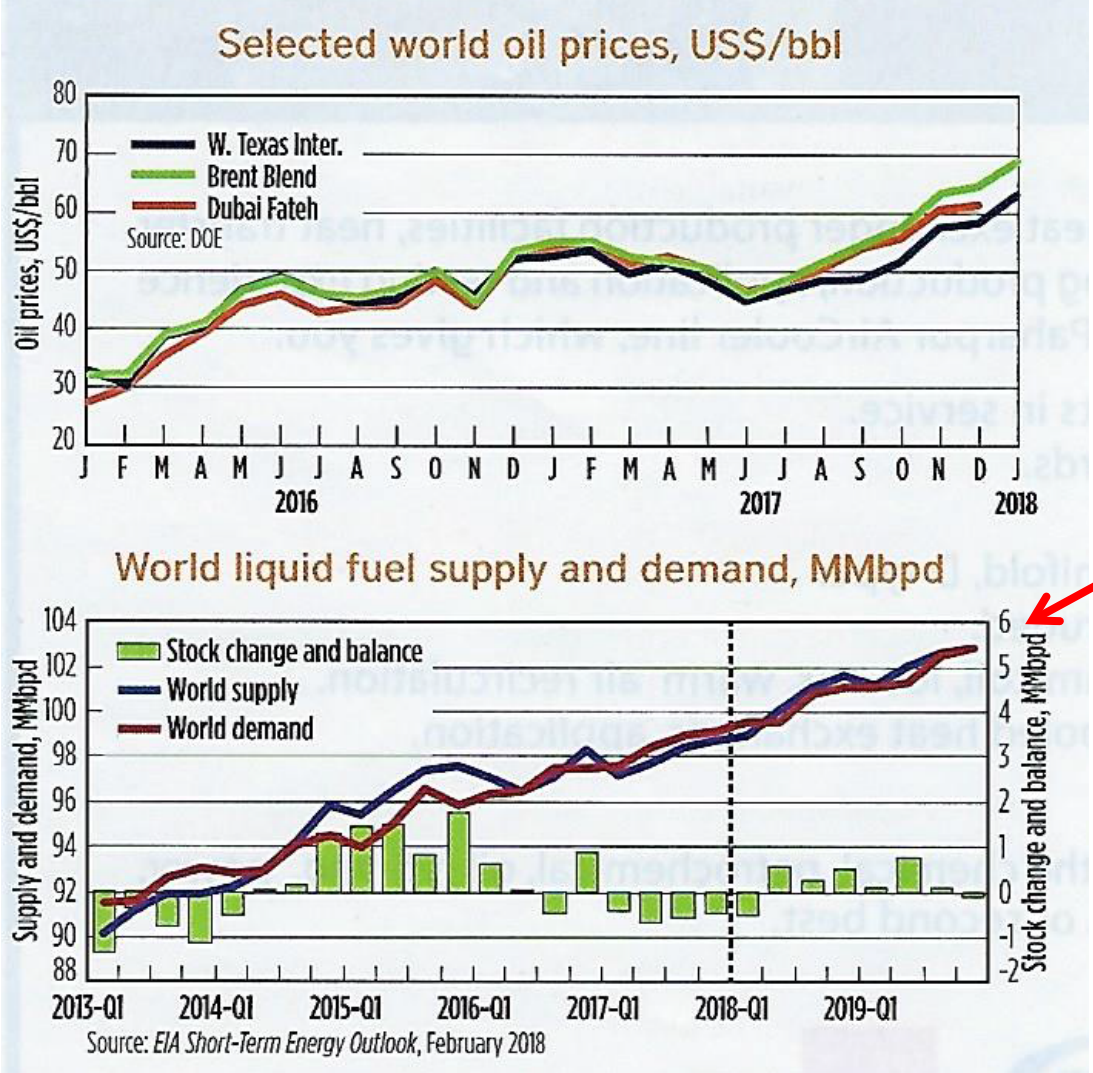
Source: BP Statistical Review of World Energy 2018

Crude Oil Prices - $/bbl



Source: BP Statistical Review of World Energy 2018

World Oil Supply/Demand Balance, MMbpd



Coming into Balance

Source: Hydrocarbon Processing March 2018

Iran Deal Effect

- HOUSTON, May 9 (Reuters) - U.S. shale producers will **not** boost output to offset any global oil squeeze after President Donald Trump abandoned the Iran nuclear deal, one of the industry's most prominent executives said on Wednesday.

- The withdrawal, alongside Trump's decision to impose the "highest level" of sanctions on Iran, sent Brent and U.S. benchmark oil prices up more than 3 percent on Wednesday.

- **Iran**, the third-largest oil producer in the Organization of the Petroleum Exporting Countries, pumps **3.8 million barrels per day (bpd).**

- **U.S. shale producers**, which in the past year have increased output by nearly 2 million bpd, to about 7 million bpd, **are not likely to act to fill that void** should Iranian exports slip, said Mark Papa, chief executive of Centennial Resource Development Inc.

- "I don't think it's going to change what U.S. producers do at all," Papa told Reuters in Houston after a meeting with the board of directors of national oil company Saudi Aramco, which is holding a regularly scheduled gathering this week in Houston.

- Many U.S. shale producers have set their 2018 spending budgets and are wary of boosting spending to pump more as their shareholders call for **higher dividends and share buyback**s.

WTI Crude May 25, 2018

The oil price rebound reflects not only tighter market conditions, as strong demand and OPEC cuts have succeeded in drawing down excess inventories, but also heightened geopolitical risks.

These include:

- The possibility of renewed oil supply disruptions in Libya and Nigeria;
- Rapidly falling oil production in Venezuela;
- Recent missile strikes against Syria and missile attacks from Yemen targeting cities and oil facilities in Saudi Arabia;
- Upcoming elections in Iraq;
- The prospect that President Trump may cancel the Iran nuclear deal in mid-May;
- Not to mention fears of a trade war.

JASON BORDOFF, OPINION CONTRIBUTOR — 04/25/18

https://oilprice.com/oil-price-charts

Natural Gas
Supply and Demand Balancing

Natural Gas Production – 3680.4BCM

Natural Gas: Production*

Billion cubic metres	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	Growth rate per annum 2017	Growth rate per annum 2006-16	Share 2017
US	521.9	546.1	557.6	575.2	617.4	649.1	655.7	704.7	740.3	729.3	**734.5**	1.0%	3.8%	20.0%
Canada	174.7	166.5	155.0	149.6	151.1	150.3	151.9	159.1	160.9	171.6	**176.3**	3.0%	-0.4%	4.8%
Total North America	**743.4**	**759.8**	**765.2**	**775.9**	**820.5**	**850.3**	**860.1**	**915.1**	**949.2**	**944.6**	**951.5**	**1.0%**	**2.6%**	**25.9%**
Argentina	43.6	42.8	40.3	39.0	37.7	36.7	34.6	34.5	35.5	37.3	**37.1**	-0.1%	-1.8%	1.0%
Trinidad & Tobago	41.0	40.8	42.4	43.5	41.9	41.5	41.7	40.9	38.5	33.5	**33.8**	1.2%	-1.5%	0.9%
Venezuela	37.2	33.4	31.8	30.5	30.2	31.9	30.6	31.8	36.1	38.0	**37.4**	-1.3%	0.9%	1.0%
Total S. & Cent. America	**160.7**	**161.5**	**156.3**	**163.8**	**167.5**	**173.8**	**176.9**	**179.1**	**180.9**	**178.8**	**179.0**	**0.4%**	**1.4%**	**4.9%**
Netherlands	63.3	69.6	65.6	73.8	67.1	66.8	71.8	60.6	45.4	42.0	**36.6**	-12.6%	-4.2%	1.0%
Norway	89.6	99.4	103.6	106.4	100.5	113.9	107.9	108.0	116.2	115.8	**123.2**	6.7%	2.8%	3.3%
United Kingdom	75.5	72.8	61.2	57.9	46.1	39.2	37.0	37.4	40.7	41.8	**41.9**	0.6%	-6.7%	1.1%
Total Europe	**287.6**	**299.0**	**283.5**	**289.5**	**262.9**	**266.5**	**259.4**	**246.7**	**241.7**	**238.6**	**241.9**	**1.7%**	**-2.3%**	**6.6%**
Russian Federation	601.6	611.5	536.2	598.4	616.8	601.9	614.5	591.2	584.4	589.3	**635.6**	8.2%	-0.3%	17.3%
Turkmenistan	68.4	69.1	38.0	44.3	62.3	65.1	65.2	70.2	72.8	66.9	**62.0**	-7.1%	0.6%	1.7%
Uzbekistan	60.9	60.4	58.1	56.9	53.9	53.9	53.9	54.2	54.6	53.1	**53.4**	0.8%	-1.1%	1.5%
Total CIS	**777.4**	**795.7**	**687.8**	**755.9**	**788.9**	**777.1**	**792.8**	**776.1**	**771.6**	**769.8**	**815.5**	**6.2%**	**♦**	**22.2%**
Iran	123.1	128.9	141.6	150.1	157.5	163.7	164.3	183.1	191.4	203.2	**223.9**	10.5%	6.3%	6.1%
Qatar	65.4	79.7	92.4	123.9	150.4	162.5	167.7	169.1	175.2	177.0	**175.7**	-0.5%	12.9%	4.8%
Saudi Arabia	70.7	76.4	74.5	83.3	87.6	94.4	95.0	97.3	99.2	105.3	**111.4**	6.1%	4.2%	3.0%
United Arab Emirates	49.0	49.0	47.6	50.0	51.0	52.9	53.2	52.9	58.7	59.6	**60.4**	1.8%	2.3%	1.6%
Total Middle East	**367.7**	**397.6**	**419.6**	**481.6**	**526.4**	**552.2**	**569.1**	**589.9**	**608.4**	**630.8**	**659.9**	**4.9%**	**6.5%**	**17.9%**
Algeria	81.6	82.6	76.6	77.4	79.6	78.4	79.3	80.2	81.4	91.4	**91.2**	0.1%	1.2%	2.5%
Egypt	53.6	56.8	60.3	59.0	59.1	58.6	54.0	47.0	42.6	40.3	**49.0**	22.1%	-2.6%	1.3%
Nigeria	35.0	34.4	24.7	35.5	38.6	41.1	34.4	42.8	47.6	42.6	**47.2**	11.0%	4.3%	1.3%
Total Africa	**197.4**	**205.5**	**192.8**	**206.1**	**202.6**	**207.8**	**198.3**	**200.6**	**203.6**	**207.0**	**225.0**	**9.0%**	**1.1%**	**6.1%**
Australia	42.8	41.7	46.7	54.0	55.7	59.5	61.8	66.6	76.0	96.4	**113.5**	18.0%	9.0%	3.1%
China	69.8	80.9	85.9	96.5	106.2	111.5	121.8	131.2	135.7	137.9	**149.2**	8.5%	8.9%	4.1%
Indonesia	72.6	74.8	78.0	87.0	82.7	78.3	77.6	76.4	76.2	70.7	**68.0**	-3.6%	-0.6%	1.8%
Malaysia	67.6	69.2	66.9	67.6	67.0	69.3	72.9	72.0	73.9	75.6	**78.4**	4.1%	1.0%	2.1%
Total Asia Pacific	**407.1**	**426.4**	**447.5**	**496.5**	**500.1**	**509.4**	**519.6**	**539.4**	**564.0**	**580.3**	**607.5**	**5.0%**	**4.0%**	**16.5%**
Total World	**2941.3**	**3045.4**	**2952.8**	**3169.3**	**3269.0**	**3337.1**	**3376.2**	**3446.9**	**3519.4**	**3549.8**	**3680.4**	**4.0%**	**2.2%**	**100.0%**

Source: BP Statistical Review of World Energy 2018

Natural Gas Demand – 3670.4 BCM

Natural Gas: Consumption*

Billion cubic metres	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	Growth rate per annum 2017	Growth rate per annum 2006-16	Share 2017
US	624.1	628.9	617.6	648.2	658.2	688.1	707.0	722.3	743.6	750.3	**739.5**	-1.2%	2.5%	20.1%
Canada	90.9	89.3	86.6	88.7	95.6	92.8	98.0	103.2	102.9	109.5	**115.7**	6.0%	2.5%	3.2%
Mexico	57.0	60.0	65.2	66.0	70.8	73.7	78.5	80.1	78.0	91.8	**87.6**	-4.4%	4.7%	2.4%
Total North America	**772.1**	**778.2**	**769.4**	**803.0**	**824.6**	**854.6**	**883.6**	**905.6**	**924.5**	**951.6**	**942.8**	**-0.7%**	**2.7%**	**25.7%**
Argentina	42.7	43.2	41.0	42.2	44.0	45.7	45.8	46.2	46.7	48.3	**48.5**	0.5%	1.7%	1.3%
Brazil	22.2	26.1	21.0	28.0	28.0	33.1	39.0	41.3	43.7	37.7	**38.3**	1.9%	5.8%	1.0%
Venezuela	37.3	35.1	33.2	32.2	32.6	34.0	32.9	32.9	36.5	38.3	**37.6**	-1.5%	0.9%	1.0%
Total S. & Cent. America	**143.1**	**143.5**	**136.6**	**150.1**	**153.1**	**162.2**	**168.7**	**172.2**	**178.6**	**175.1**	**173.4**	**-0.7%**	**2.3%**	**4.7%**
France	44.7	46.4	44.7	49.6	43.0	44.5	45.2	37.9	40.8	44.6	**44.7**	0.7%	-0.3%	1.2%
Germany	88.6	89.5	84.4	88.1	80.9	81.1	85.0	73.9	77.0	84.9	**90.2**	6.5%	-0.8%	2.5%
Italy	81.5	81.4	74.9	79.7	74.8	71.9	67.2	59.4	64.8	68.0	**72.1**	6.3%	-1.7%	2.0%
Netherlands	38.6	40.3	40.7	45.6	39.8	37.7	38.2	33.3	32.9	34.5	**36.1**	4.7%	-1.4%	1.0%
Turkey	33.9	35.3	33.7	35.8	41.8	43.3	44.0	46.6	46.0	44.4	**51.7**	16.6%	4.3%	1.4%
United Kingdom	95.3	97.9	91.2	98.5	81.9	76.9	76.3	70.1	71.8	81.0	**78.8**	-2.4%	-1.5%	2.1%
Total Europe	**550.7**	**563.1**	**527.9**	**567.7**	**523.3**	**512.3**	**506.2**	**458.9**	**475.8**	**505.6**	**531.7**	**5.5%**	**-0.9%**	**14.5%**
Russian Federation	428.8	422.7	399.5	422.6	435.6	429.6	423.0	423.6	409.6	420.2	**424.8**	1.4%	♦	11.6%
Uzbekistan	48.0	50.9	41.7	42.7	44.1	43.7	43.3	45.3	48.6	41.6	**41.6**	0.3%	-0.5%	1.1%
Total CIS	**609.9**	**605.4**	**551.8**	**588.7**	**606.2**	**600.5**	**583.1**	**582.7**	**568.4**	**572.9**	**574.6**	**0.6%**	**-0.4%**	**15.7%**
Iran	123.6	131.2	140.6	150.6	159.8	159.1	160.4	180.9	191.9	201.4	**214.4**	6.8%	6.2%	5.8%
Qatar	24.0	19.3	19.6	24.7	27.3	33.7	35.0	38.8	44.1	43.1	**47.4**	10.3%	8.3%	1.3%
Saudi Arabia	70.7	76.4	74.5	83.3	87.6	94.4	95.0	97.3	99.2	105.3	**111.4**	6.1%	4.2%	3.0%
United Arab Emirates	47.9	58.0	57.6	59.3	61.6	63.9	64.4	63.4	71.0	72.5	**72.2**	-0.2%	5.5%	2.0%
Total Middle East	**315.8**	**341.0**	**351.3**	**385.6**	**403.6**	**417.6**	**429.0**	**455.0**	**487.2**	**508.9**	**536.5**	**5.7%**	**5.9%**	**14.6%**
Algeria	23.4	24.4	26.2	25.3	26.8	29.9	32.1	36.1	37.9	38.6	**38.9**	1.0%	5.4%	1.1%
Egypt	36.9	39.3	40.9	43.4	47.8	50.6	49.5	46.2	46.0	49.4	**56.0**	13.7%	3.5%	1.5%
Total Africa	**94.6**	**98.6**	**97.2**	**102.5**	**108.3**	**116.2**	**116.6**	**122.1**	**129.6**	**133.2**	**141.8**	**6.8%**	**4.3%**	**3.9%**
Australia	29.0	28.5	29.1	33.8	35.3	35.4	37.2	40.1	42.1	41.7	**41.9**	0.6%	4.9%	1.1%
China	71.1	81.9	90.2	108.9	135.2	150.9	171.9	188.4	194.7	209.4	**240.4**	15.1%	13.7%	6.6%
India	38.8	40.0	48.3	59.5	61.3	56.7	49.8	49.6	46.4	50.8	**54.2**	6.9%	3.5%	1.5%
Indonesia	34.6	39.7	42.1	44.0	42.7	42.9	41.4	41.5	41.0	38.3	**39.2**	2.6%	0.3%	1.1%
Japan	94.4	98.1	91.5	98.9	110.4	122.4	122.3	120.5	118.7	116.4	**117.1**	0.8%	2.9%	3.2%
Malaysia	40.4	43.5	40.0	39.8	38.3	42.0	44.6	44.7	43.9	41.9	**42.8**	2.4%	0.5%	1.2%
Pakistan	33.8	34.6	34.7	35.3	35.3	36.6	35.6	35.0	36.5	38.3	**40.7**	6.7%	1.4%	1.1%
South Korea	36.3	37.3	35.5	45.0	48.4	52.5	55.0	50.0	45.6	47.6	**49.4**	3.9%	3.6%	1.3%
Thailand	35.2	36.9	38.1	43.2	44.3	48.6	48.9	49.9	51.0	50.6	**50.1**	-0.7%	4.4%	1.4%
Total Asia Pacific	**472.0**	**502.3**	**513.5**	**578.3**	**621.9**	**663.6**	**684.3**	**702.2**	**710.1**	**727.0**	**769.6**	**6.2%**	**5.2%**	**21.0%**
Total World	**2958.0**	**3032.1**	**2947.8**	**3175.9**	**3241.0**	**3327.1**	**3371.5**	**3398.7**	**3474.2**	**3574.2**	**3670.4**	**3.0%**	**2.3%**	**100.0%**

Source: BP Statistical Review of World Energy 2018

Natural Gas Reserves & R/P – 2017

Natural gas Total proved reserves	at end 1997 Trillion cubic metres	at end 2007 Trillion cubic metres	at end 2016 Trillion cubic metres	 Trillion cubic metres	at end 2017 Trillion cubic feet	 Share of total	 R/P ratio
US	4.5	6.4	8.7	**8.7**	**308.5**	4.5%	11.9
Canada	1.7	1.6	2.0	**1.9**	**66.5**	1.0%	10.7
Total North America	**8.0**	**8.4**	**10.9**	**10.8**	**381.9**	**5.6%**	**11.4**
Venezuela	4.6	5.4	6.4	**6.4**	**225.0**	3.3%	170.2
Total S. & Cent. America	**6.6**	**7.8**	**8.3**	**8.2**	**290.3**	**4.2%**	**45.9**
Norway	1.2	2.3	1.8	**1.7**	**60.6**	0.9%	13.9
Total Europe	4.9	5.0	3.0	**3.0**	**104.5**	**1.5%**	**12.2**
Azerbaijan	0.7	1.0	1.3	**1.3**	**46.6**	0.7%	74.4
Kazakhstan	1.5	1.5	1.1	**1.1**	**40.4**	0.6%	42.2
Russian Federation	33.6	33.9	34.8	**35.0**	**1234.9**	18.1%	55.0
Turkmenistan	2.6	2.6	19.5	**19.5**	**688.1**	10.1%	314.1
Ukraine	0.7	0.8	1.1	**1.1**	**37.1**	0.5%	54.0
Uzbekistan	1.2	1.3	1.2	**1.2**	**42.7**	0.6%	22.7
Total CIS	**40.3**	**41.2**	**59.0**	**59.2**	**2091.1**	**30.6%**	**72.6**
Iran	22.7	27.7	33.2	**33.2**	**1173.0**	17.2%	148.4
Iraq	3.0	3.0	3.5	**3.5**	**123.9**	1.8%	337.7
Kuwait	1.4	1.7	1.7	**1.7**	**59.9**	0.9%	97.6
Qatar	8.8	26.4	24.9	**24.9**	**879.9**	12.9%	141.8
Saudi Arabia	5.6	6.9	8.0	**8.0**	**283.8**	4.2%	72.1
United Arab Emirates	5.9	6.3	5.9	**5.9**	**209.7**	3.1%	98.2
Total Middle East	**48.6**	**73.6**	**78.8**	**79.1**	**2794.2**	**40.9%**	**119.9**
Algeria	3.9	4.3	4.3	**4.3**	**153.1**	2.2%	47.5
Egypt	0.9	2.0	1.8	**1.8**	**62.8**	0.9%	36.3
Libya	1.2	1.5	1.4	**1.4**	**50.5**	0.7%	124.0
Nigeria	3.3	5.0	5.2	**5.2**	**183.7**	2.7%	110.2
Other Africa	0.8	1.2	1.1	**1.1**	**37.8**	0.6%	41.1
Total Africa	**10.2**	**14.0**	**13.8**	**13.8**	**487.8**	**7.1%**	**61.4**
Australia	1.2	1.8	3.6	**3.6**	**128.3**	1.9%	32.0
China	1.2	2.3	5.5	**5.5**	**193.5**	2.8%	36.7
India	0.7	1.0	1.2	**1.2**	**43.8**	0.6%	43.6
Indonesia	2.2	3.0	2.9	**2.9**	**102.9**	1.5%	42.9
Malaysia	2.2	2.4	2.7	**2.7**	**96.6**	1.4%	34.9
Myanmar	0.3	0.5	1.2	**1.2**	**41.3**	0.6%	65.0
Total Asia Pacific	**9.4**	**13.6**	**19.2**	**19.3**	**681.8**	**10.0%**	**31.8**
Total World	**128.1**	**163.5**	**193.1**	**193.5**	**6831.7**	**100.0%**	**52.6**

Source: BP Statistical Review of World Energy 2018

Natural Gas Prices – March 2013

Demand:

Japan

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

China

- Demand Growth
- Oil-price-linked formula

Europe

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

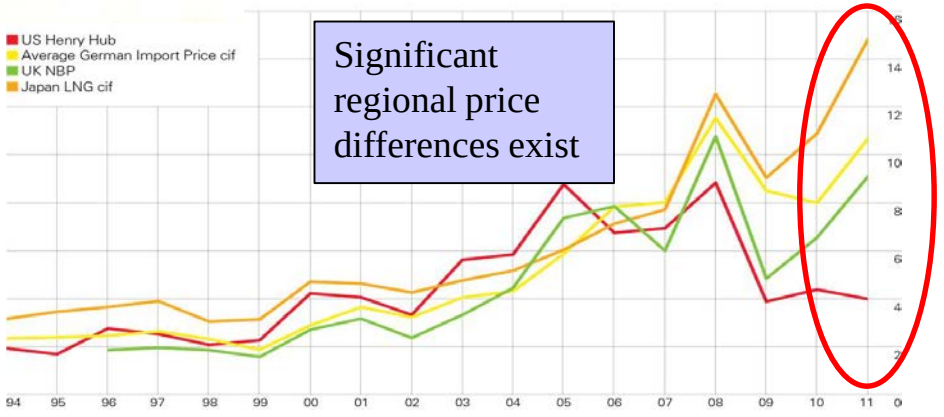
Supply:

North America

- Significant shale resource
- Significant associated gas production

Australia & East Africa

- Project cost/timing uncertainties



World LNG Estimated Landed Prices January 2018

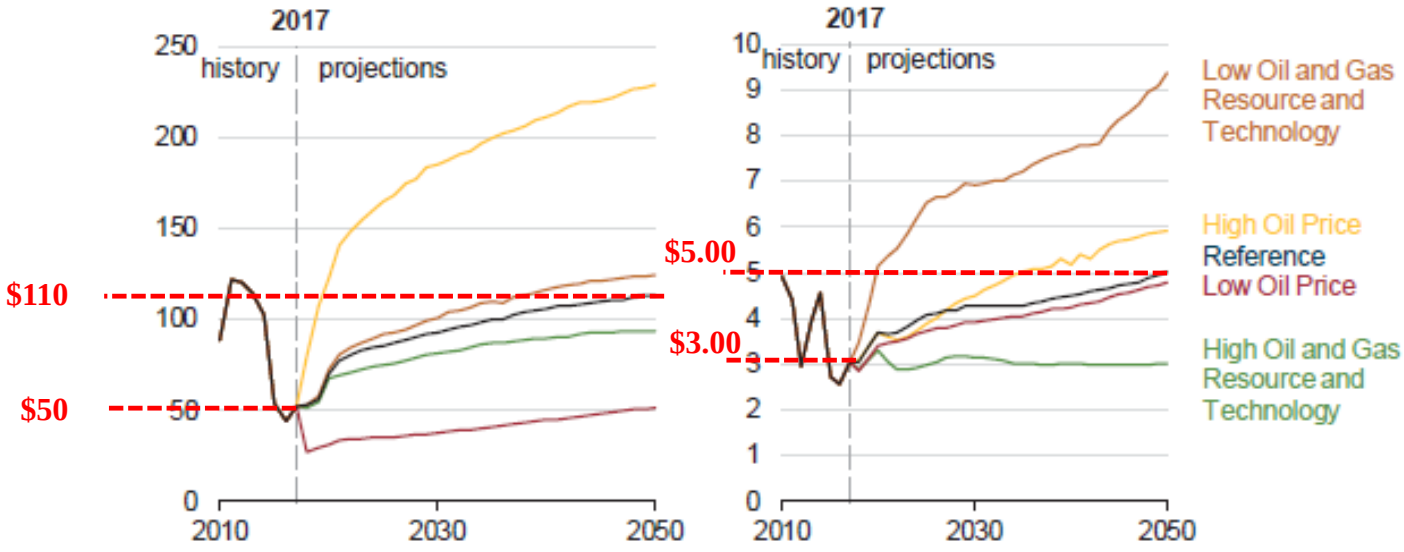
Source: *Waterborne Energy, Inc.* Data in $US/MMBtu.
Note: Includes information and Data supplied by IHS Global Inc. and its affiliates ("IHS"); Copyright (publication year) all rights reserved. Prices are the monthly average of the weekly landed prices for the listed month. Landed prices are based on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

Updated: Feb-18

Natural Gas Prices $/mmBtu

Oil & Natural Gas Prices

Assumptions about the size of U.S. resources and the improvement in technology affect domestic oil and natural gas prices—



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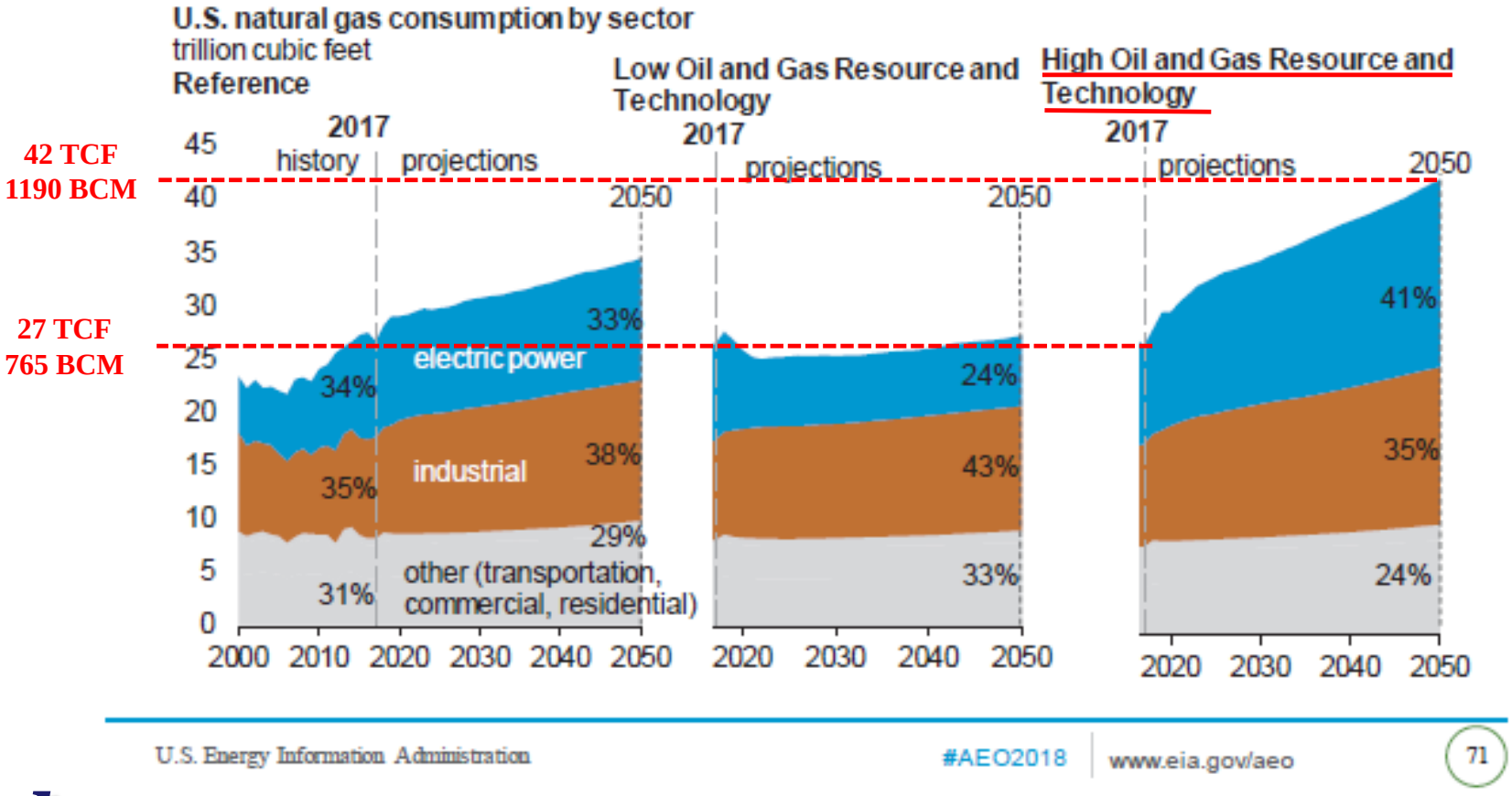
EIA AEO2018 Natural Gas Consumption

Natural gas supply assumptions that affect prices result in significant changes in natural gas consumption—



Coal

Coal Production – 3768.6 Mtoe

Coal: Production*

Million tonnes oil equivalent	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	**2017**	Growth rate per annum 2017	Growth rate per annum 2006-16	Share 2017
US	558.3	566.9	513.7	523.7	528.3	491.9	475.8	482.3	426.9	348.3	**371.3**	6.9%	-4.7%	9.9%
Canada	35.7	35.6	33.1	35.4	35.5	35.5	36.1	35.9	32.3	31.8	**31.1**	-2.0%	-0.9%	0.8%
Total North America	**601.3**	**609.4**	**552.9**	**566.4**	**573.1**	**534.9**	**519.1**	**525.5**	**466.1**	**386.2**	**407.9**	**5.9%**	**-4.4%**	**10.8%**
Colombia	48.0	50.5	50.0	51.1	58.9	61.2	58.7	60.8	58.8	62.2	**61.4**	-0.9%	3.2%	1.6%
Total S. & Cent. America	**55.9**	**57.5**	**55.1**	**55.7**	**63.6**	**65.9**	**65.0**	**67.8**	**64.4**	**67.8**	**66.8**	**-1.3%**	**2.4%**	**1.8%**
Czech Republic	23.8	22.8	20.9	20.8	21.0	20.3	17.8	17.0	17.1	16.1	**15.4**	-3.8%	-3.9%	0.4%
Germany	54.4	50.1	46.4	45.9	46.7	47.8	45.1	44.1	42.8	39.8	**39.6**	-0.3%	-2.9%	1.0%
Poland	62.5	60.9	56.4	55.4	55.7	57.8	57.2	54.0	53.0	52.1	**49.6**	-4.4%	-2.6%	1.3%
Turkey	14.8	16.7	17.4	17.5	17.9	17.0	15.5	16.4	12.8	15.5	**20.8**	34.8%	1.6%	0.6%
Total Europe	**216.6**	**211.0**	**200.1**	**197.4**	**201.4**	**199.2**	**187.5**	**179.0**	**171.2**	**161.3**	**164.6**	**2.3%**	**-3.1%**	**4.4%**
Kazakhstan	42.2	47.9	43.4	47.5	49.8	51.6	51.4	48.9	46.2	44.3	**47.9**	8.5%	0.7%	1.3%
Russian Federation	143.5	149.0	141.7	151.0	157.6	168.3	173.1	176.6	186.4	194.0	**206.3**	6.7%	3.2%	5.5%
Ukraine	34.0	34.4	31.8	31.8	36.3	38.0	36.6	25.9	16.4	17.1	**14.4**	-15.6%	-7.1%	0.4%
Total CIS	**221.5**	**233.0**	**218.8**	**232.0**	**245.7**	**260.3**	**263.5**	**254.0**	**251.5**	**258.1**	**271.8**	**5.6%**	**1.6%**	**7.2%**
Total Middle East	**1.1**	**1.0**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.8**	**0.8**	**-**	**-2.9%**	**♦**
South Africa	138.4	141.0	139.7	144.1	143.2	146.6	145.3	148.2	142.9	142.4	**143.0**	0.7%	0.3%	3.8%
Total Africa	**140.5**	**142.7**	**141.5**	**146.8**	**146.0**	**151.9**	**152.4**	**157.7**	**151.6**	**149.6**	**154.5**	**3.6%**	**0.6%**	**4.1%**
Australia	227.0	234.2	242.5	250.6	245.1	265.9	285.8	305.9	306.4	307.7	**297.4**	-3.1%	3.4%	7.9%
China	1439.3	1491.8	1537.9	1665.3	1851.7	1873.5	1894.6	1864.2	1825.6	1691.4	**1747.2**	3.6%	2.4%	46.4%
India	210.3	227.5	246.0	252.4	250.8	255.0	255.7	269.5	281.0	284.9	**294.2**	3.5%	3.7%	7.8%
Indonesia	127.8	141.6	151.0	162.1	208.2	227.4	279.7	269.9	272.0	268.8	**271.6**	1.3%	8.9%	7.2%
Mongolia	4.8	5.2	8.2	15.2	19.9	17.9	18.0	15.2	14.3	21.5	**30.3**	41.4%	18.2%	0.8%
Vietnam	23.8	22.3	24.7	25.1	26.1	23.6	23.0	23.0	23.3	21.6	**21.3**	-0.9%	-0.1%	0.6%
Total Asia Pacific	**2065.5**	**2156.2**	**2240.5**	**2402.6**	**2636.0**	**2697.0**	**2790.6**	**2781.7**	**2756.7**	**2639.6**	**2702.3**	**2.7%**	**3.2%**	**71.7%**
Total World	**3302.4**	**3410.8**	**3409.6**	**3601.6**	**3866.6**	**3909.8**	**3978.9**	**3966.4**	**3862.1**	**3663.5**	**3768.6**	**3.2%**	**1.5%**	**100.0%**

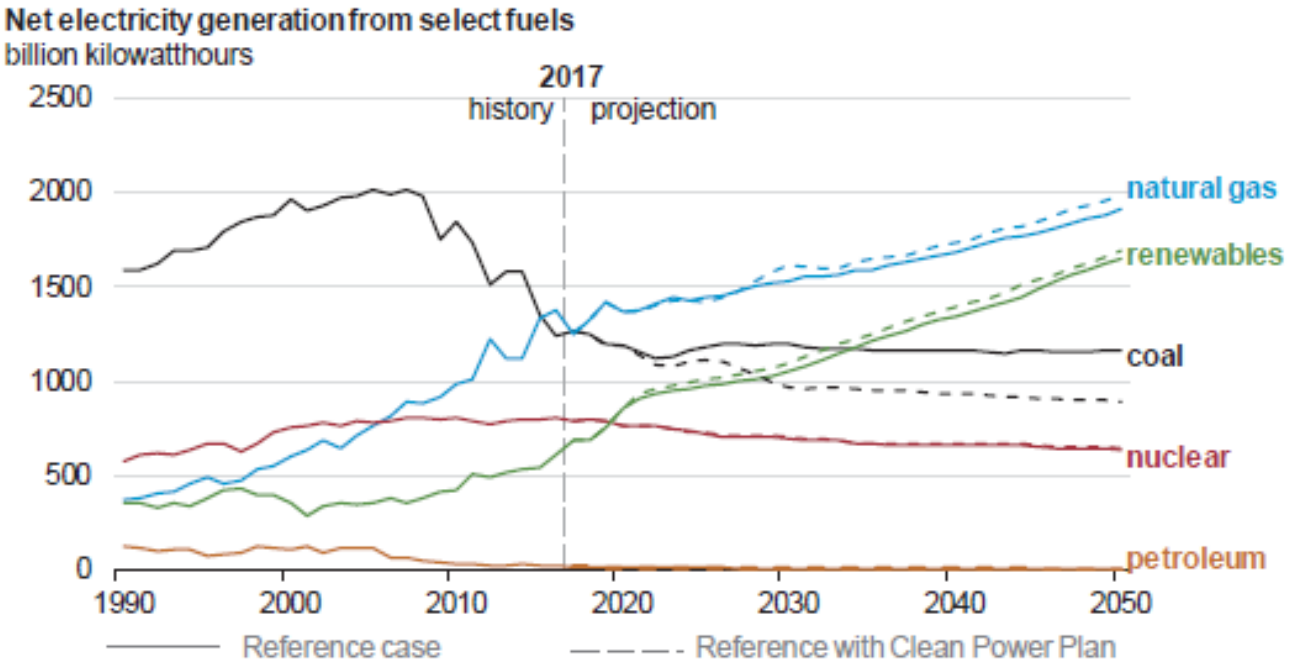
Calorific equivalents
One tonne of oil equivalent equals approximately:
Solid fuels 1.5 tonnes of hard coal
3 tonnes of lignite

Production is ~70% bituminous/30% Lignite

Source: BP Statistical Review of World Energy 2018

EIA AEO2018 Impact of Clean Power Plan

Coal-fired electricity generation remains at a higher level in the Reference case than in the Clean Power Plan case—



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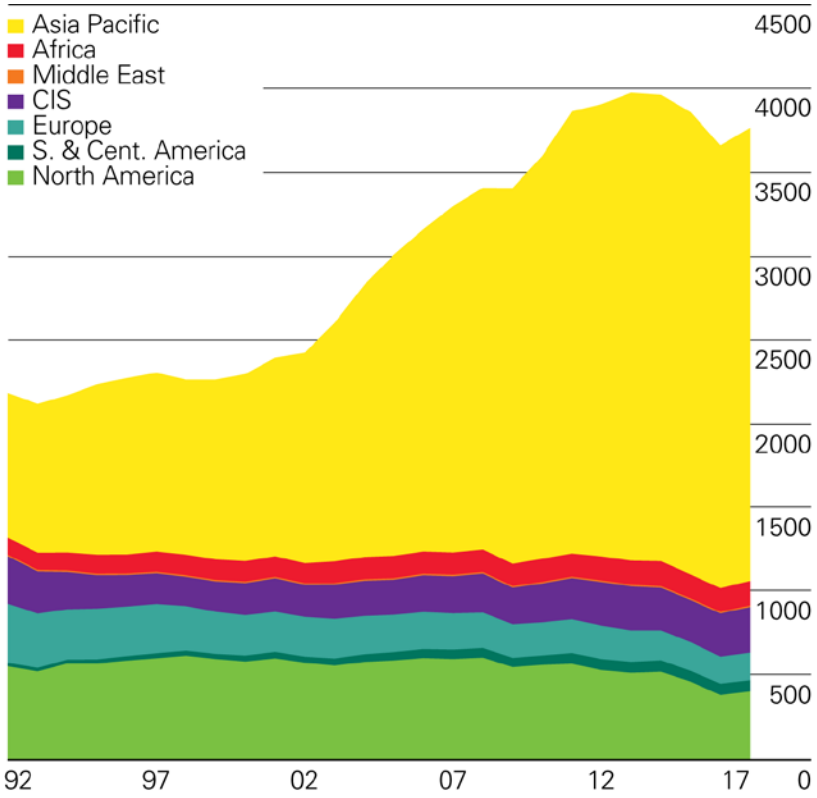
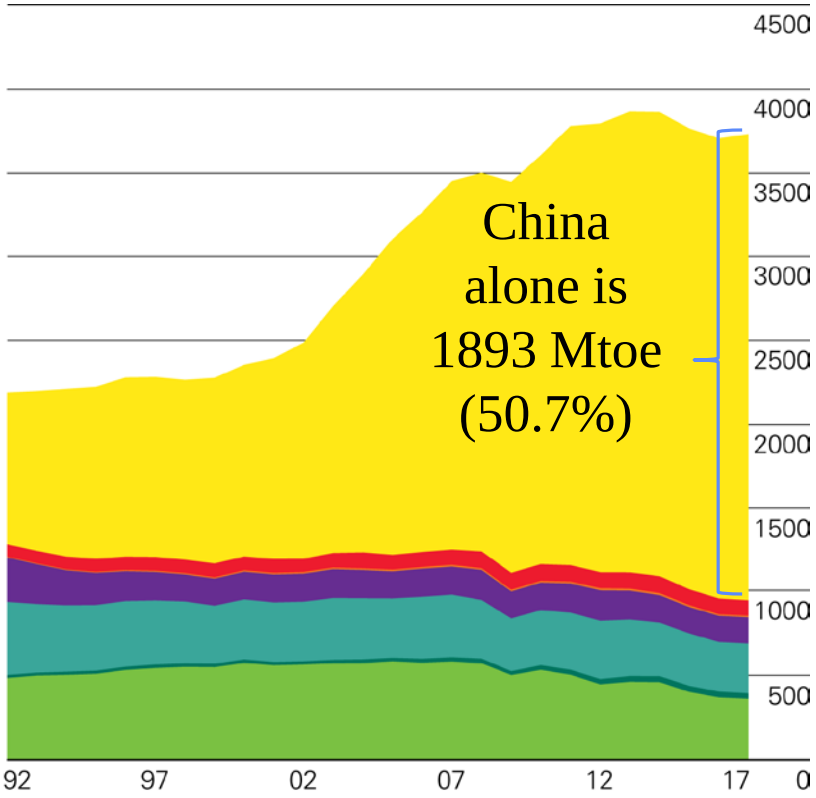
Coal - Regional Consumption - Mtoe

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

Production by region

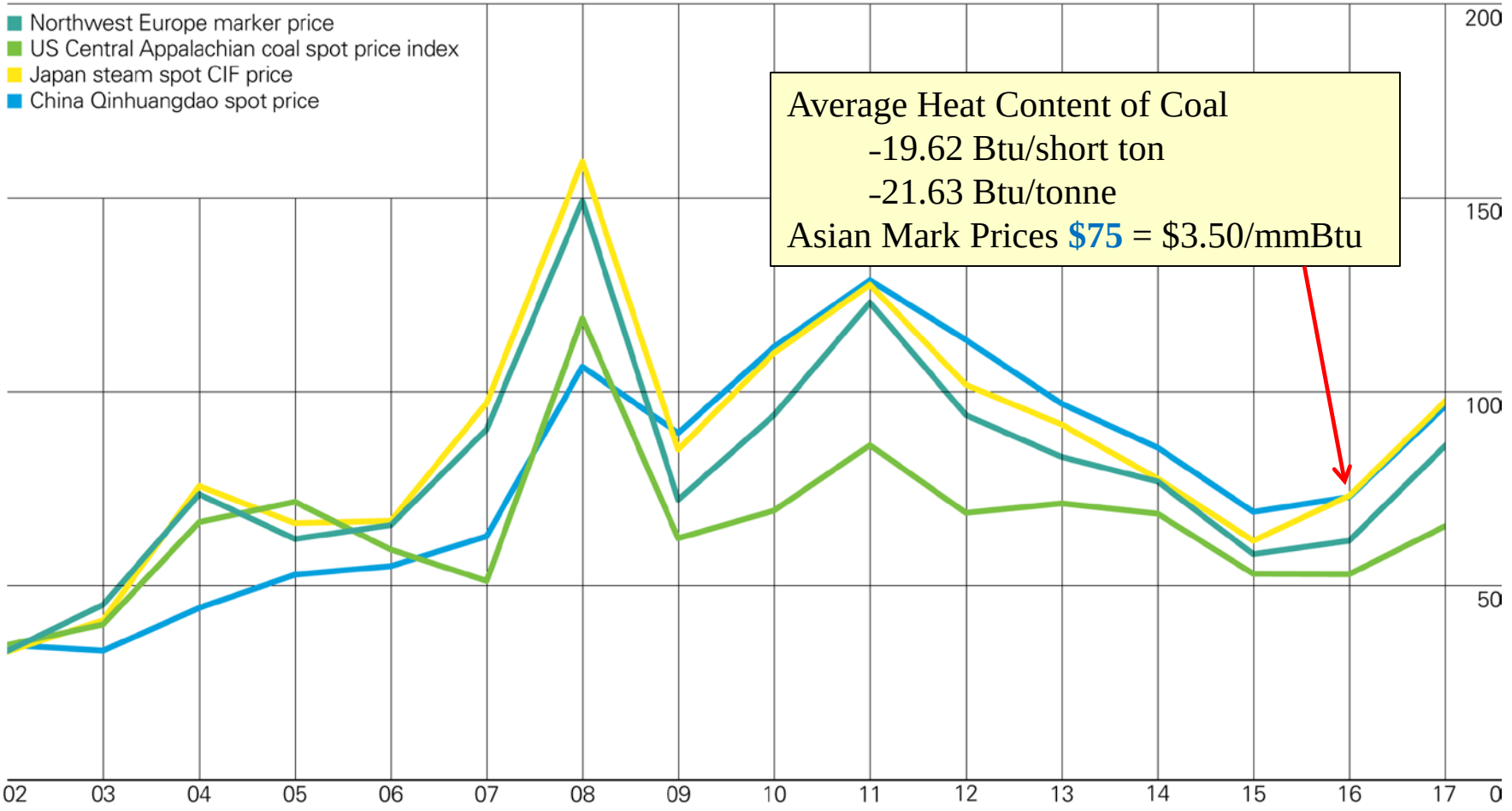


Consumption by region



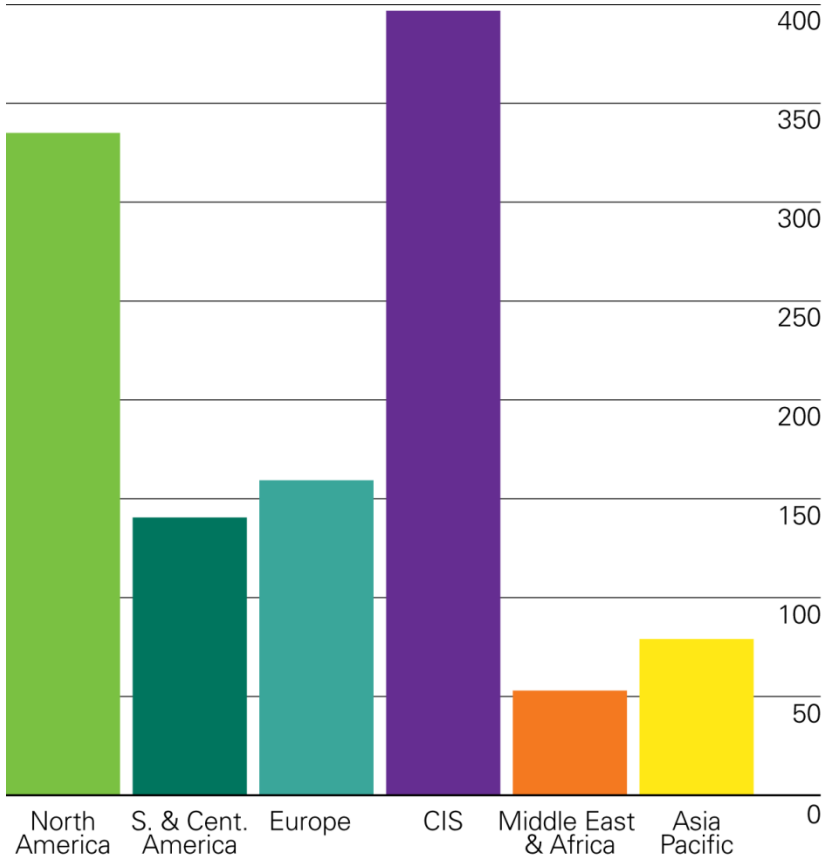
Source: BP Statistical Review of World Energy 2018

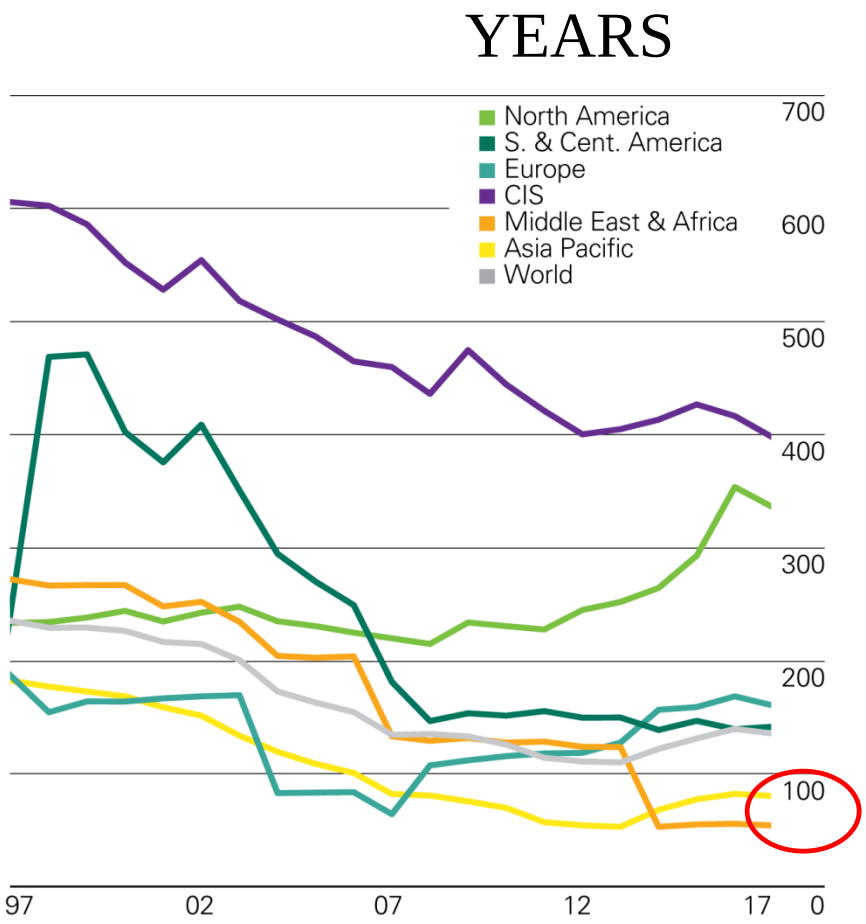
Coal Prices



Average Heat Content of Coal
-19.62 Btu/short ton
-21.63 Btu/tonne
Asian Mark Prices $75 = $3.50/mmBtu

Coal Reserves to Production Ratio - 2017





Source: BP Statistical Review of World Energy 2018

Coal Reserves to Production Ratio - 2017

Coal:
Total proved reserves at end 2017

Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of Total	R/P ratio
US	220800	30116	**250916**	24.2%	357
Canada	4346	2236	**6582**	0.6%	111
Total North America	226306	32403	**258709**	25.0%	335
Brazil	1547	5049	**6596**	0.6%	*
Colombia	4881	-	**4881**	0.5%	55
Total S. & Cent. America	8943	5073	**14016**	1.4%	141
Germany	8	36100	**36108**	3.5%	206
Poland	19808	6003	**25811**	2.5%	203
Serbia	402	7112	**7514**	0.7%	188
Turkey	378	10975	**11353**	1.1%	115
Total Europe	24220	76185	**100405**	9.7%	**159**
Kazakhstan	25605	-	**25605**	2.5%	230
Russian Federation	69634	90730	**160364**	15.5%	391
Ukraine	32039	2336	**34375**	3.3%	*
Total CIS	130162	93066	**223228**	21.6%	397
South Africa	9893	-	**9893**	1.0%	39
Total Middle East & Africa	14354	66	**14420**	1.4%	53
Australia	68310	76508	**144818**	14.0%	301
China	130851	7968	**138819**	13.4%	39
India	92786	4942	**97728**	9.4%	136
Indonesia	15068	7530	**22598**	2.2%	49
New Zealand	825	6750	**7575**	0.7%	*
Total Asia Pacific	314325	109909	**424234**	41.0%	79
Total World	**718310**	**316702**	**1035012**	**100.0%**	**134**

There's a lot of it except in China!

base e

"Practical Strategies for Emerging Energy Technologies"

Source: BP Statistical Review of World Energy 2018

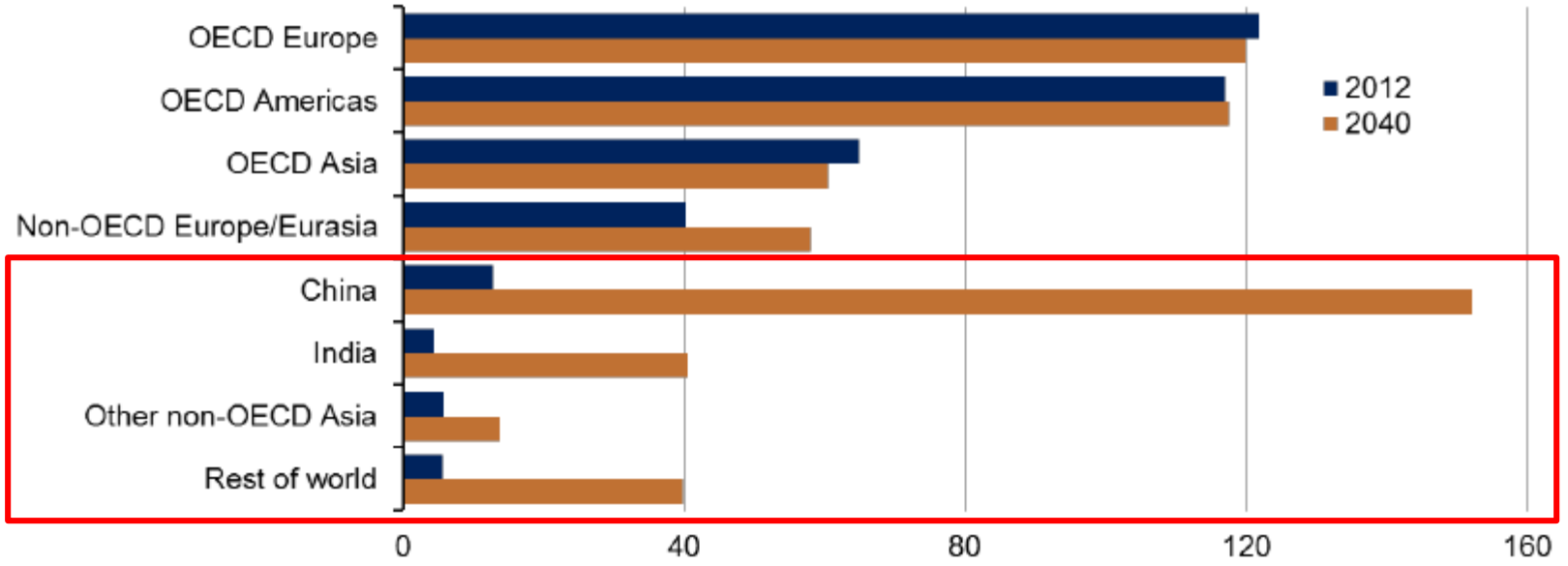
Nuclear

Nuclear Power Growth

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

world installed nuclear capacity by region

gigawatts

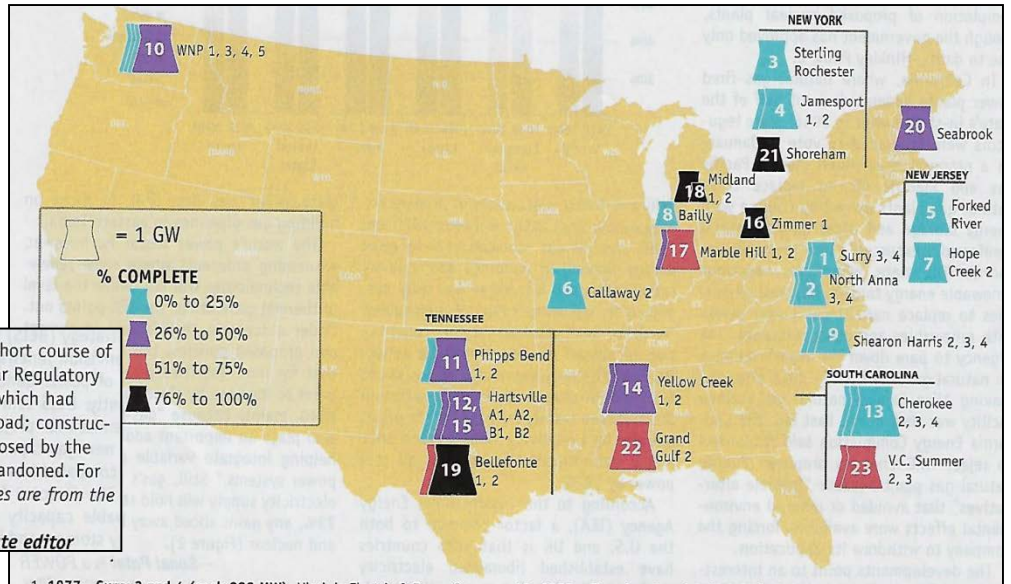


Source: EIA, International Energy Outlook 2016

Abandoned Nuclear Plants

Owners' decisions last year to abandon two under-construction reactor units isn't unprecedented. Over the short course of nuclear power's history in the U.S., more than 100 reactors (of about 230 projects scrutinized by the Nuclear Regulatory Commission [NRC] and its predecessor the Atomic Energy Commission) have been canceled—nearly half of which had already begun construction. Many had been faced with increasing uncertainties concerning low forecasted load; construction financing constraints and reversals; state certification hurdles; and challenges to nuclear profitability posed by the growing share of coal plants at the time. The graphic below offers a sampling of projects that have been abandoned. For more detail, see a supplement associated with this infographic at www.powermag.com. *Note: All dollar figures are from the corresponding year. Source: NRC*

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



1. **1977—Surry 3 and 4 (each 882 MW):** Virginia Electric & Power Co. (VEPCO) had invested $53 million in the project and had contracts for another $93 million when the units were abandoned.
2. **1980—North Anna 4 (907 MW):** VEPCO had spent $485 million to build Unit 3 (abandoned two years later) and 4.
3. **1980—Sterling Rochester (1.2 GW):** Sterling Rochester Gas & Electric Corp. recovered $129 million associated with the project.
4. **1980—Jamesport 1 and 2 (1.2 GW):** Long Island Lighting recovered abandonment costs of about $120 million.
5. **1980—Forked River 1 (1.1 GW):** Abandonment cost Jersey Central Power & Light $414 million.
6. **1981—Callaway 2 (1.2 GW):** Abandonment cost Union Electric Co. $70 million.
7. **1981—Hope Creek 2 (1.1 GW):** 19% complete, abandonment cost Public Service Electric & Gas $419 million.
8. **1981—Bailly 1 (645 MW):** Abandonment cost Northern Indiana Public Service $191 million.
9. **1981—Shearon Harris 3 and 4 (900 MW each):** Abandonment cost Carolina Power & Light $187 million. Unit 2 was scrapped in 1983.
10. **1982—Washington Nuclear 4 and 5 (1.2 GW each):** Unit 4 was 26% complete and Unit 5 17% complete when Energy Northwest's predecessor Washington Public Power Supply System (WPPSS) halted construction. Abandonment of the two units alone forced the company to default on $2.2 billion in municipal bonds. Units 1 and 3 were scrapped in 1995.
11. **1982—Phipps Bend 1 and 2 (1.2 GW each):** The decision cost Tennessee Valley Authority (TVA) $1.2 billion.
12. **1982—Hartsville B1 and B2 (1.2 GW each):** The decision cost TVA $718 million.
13. **1982—Cherokee 2 and 3 (1.3 GW):** Duke Power, which also scrapped Unit 1 in 1983, paid $63 million for its decision.
14. **1984—Yellow Creek 1 and 2 (1.3 GW each):** TVA estimated Yellow Creek would have cost $10 billion to build.
15. **1984—Hartsville A1 and A2 (1.2 GW each):** TVA said the project would have cost $6.5 billion to complete.
16. **1984—Zimmer 1 (810 MW):** Cincinnati Gas & Electric Co. chose to convert Zimmer to a coal plant when the project was 97% complete and had so far cost $1.6 billion.
17. **1985—Marble Hill 1 and 2 (each 1.1 GW):** Public Service of Indiana, stricken with a cash emergency, had already spent $2.5 billion.
18. **1986—Midland 1 (492 MW) and 2 (818 MW):** Consumers Power Co. had spent $4 billion when it abandoned the project.
19. **1988—Bellefonte 1 and 2 (1.2 GW each):** TVA had invested $6 billion in the project.
20. **1988—Seabrook 2 (1.2 GW):** Public Service Co. of New Hampshire had spent $800 million on the project.
21. **1989—Shoreham (820 MW):** While fully complete, Shoreham Long Island Lighting Co. never produced commercial power from the project owing to state opposition. Costs for the project escalated from an original estimate of $75 million to $6 billion, including decommissioning costs.
22. **1990—Grand Gulf 2 (1.3 GW):** Middle South Utilities—Entergy's predecessor—cited a massive debt load and political imbroglio for cancellation.
23. **2017—V.C. Summer 3 and 4 (each 1.1 GW):** SCANA Corp. and Santee Cooper had spent $9 billion on a project they estimated could cost up to $24 billion to complete.

400

Palo Verde nuke can remain open with 50% Arizona RPS, NRDC report finds

Dive Brief:

- A new analysis performed by ICF for the Natural Resources Defense Council (NRDC) concludes Arizona's Palo Verde nuclear plant will not be forced to close, should the state enact a 50% renewable portfolio standard, which may appear on the ballot in November.
- The research contradicts claims made by Arizona Public Service (APS), which operates and owns part of the plant, that the proposed ballot initiative could cost the state more than two thousand jobs.
- ICF's analysis concluded that as the largest nuke in the country, Palo Verde has economies of scale that make it capable of continuing to operate profitably in an environment of low-cost gas and renewable power.

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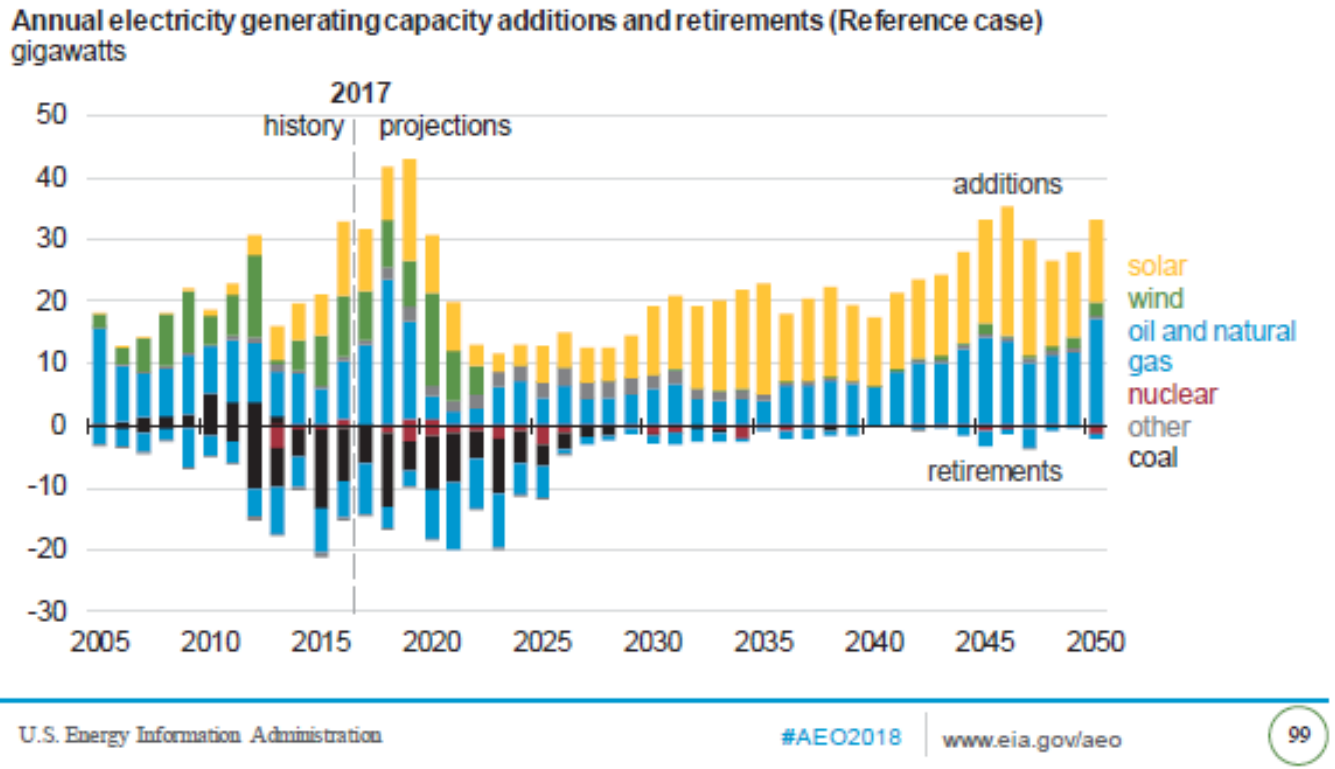
Renewables
(Renewables Integration & Grid Modernization)

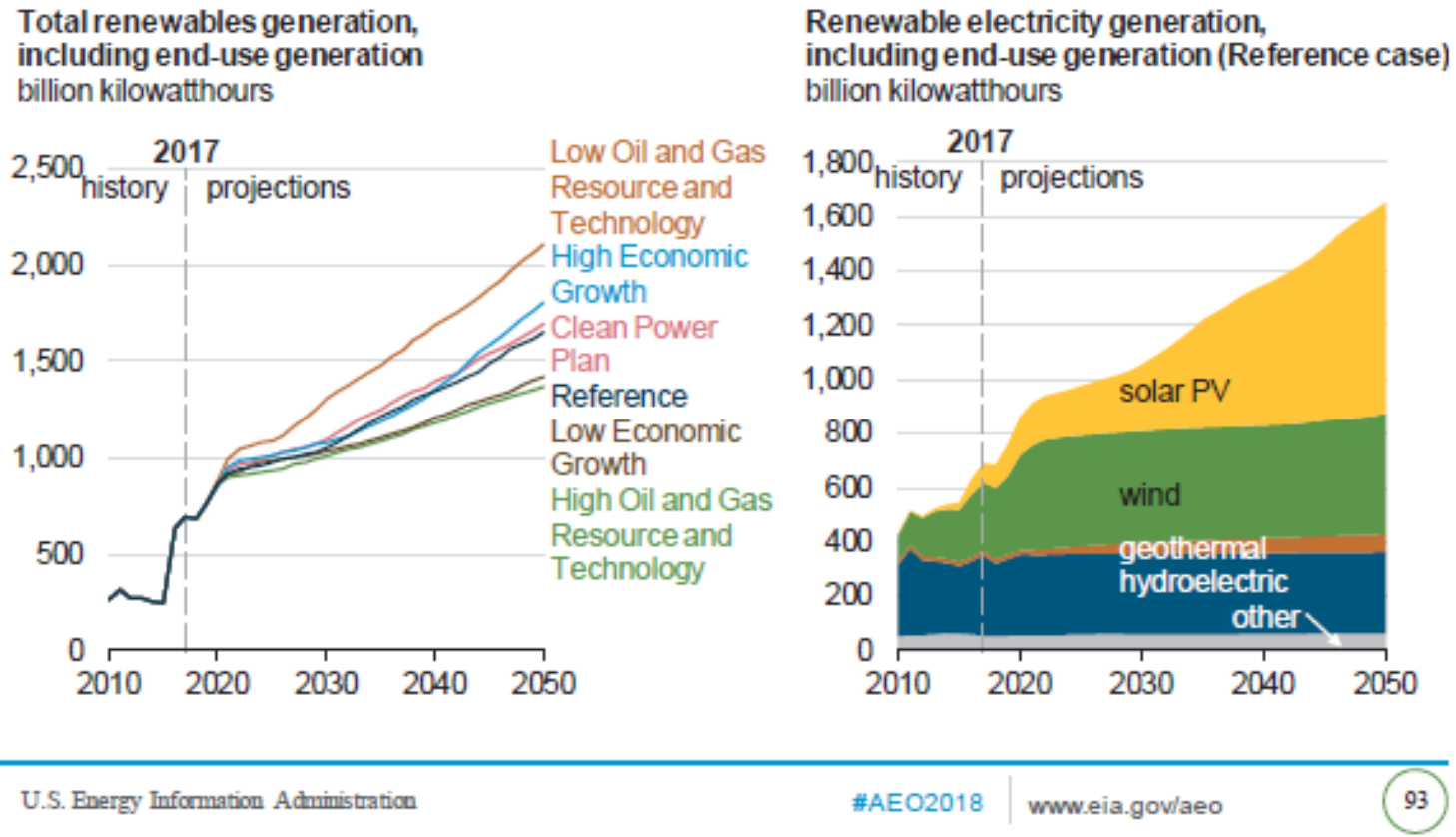
U.S. PowerGen Capacity Additions & Retirements

Renewables and natural gas comprise most of the capacity additions through the projection period in the Reference case—

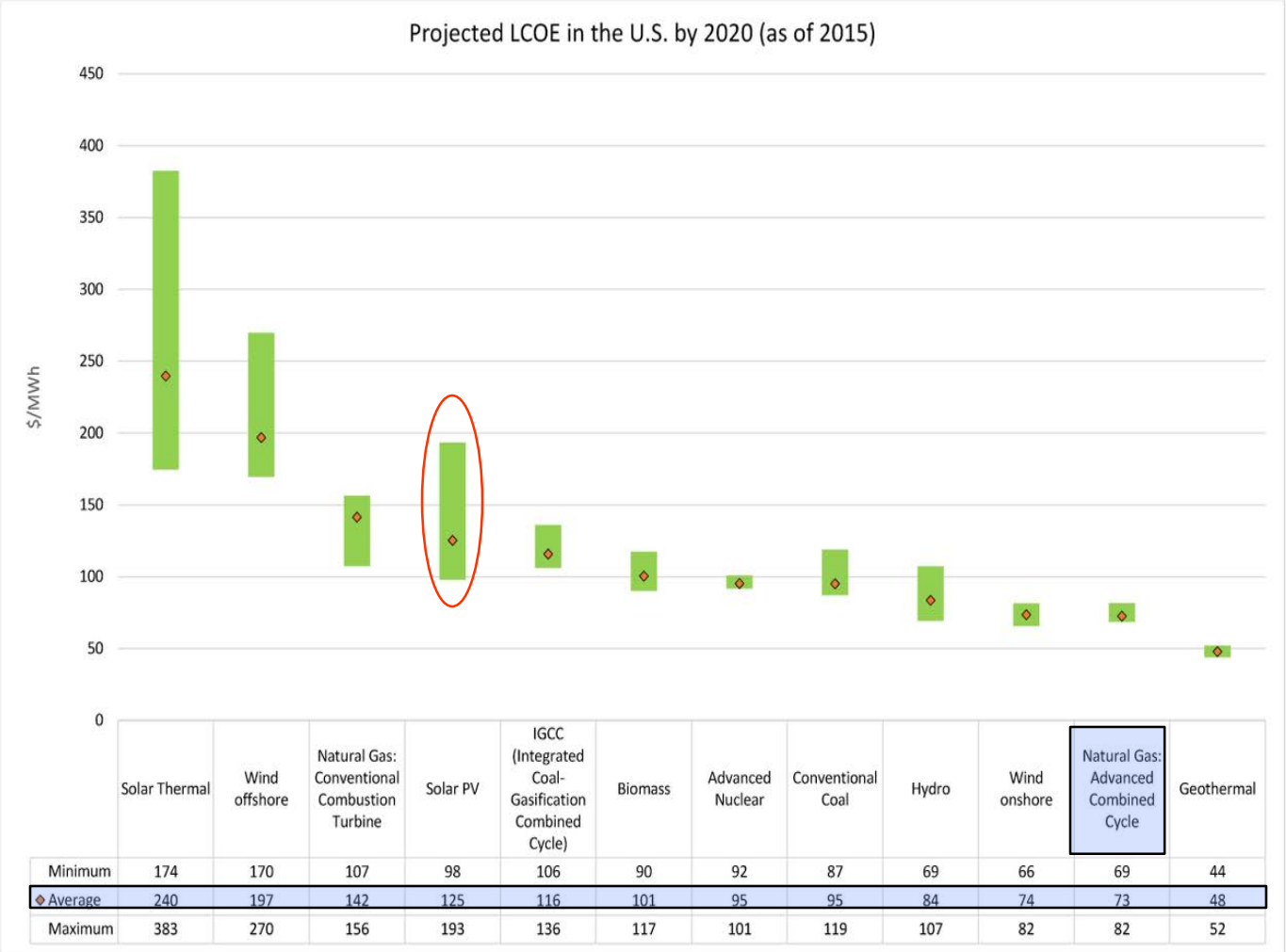


EIA AEO2018 Renewables Growth

Generation from renewable sources grows across all cases, led by growth in wind and solar photovoltaic generation—

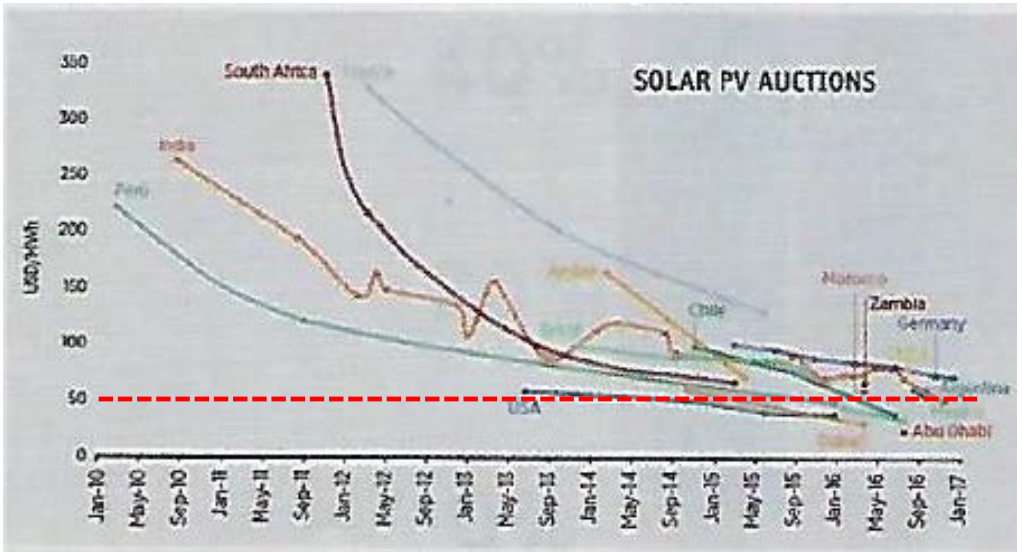


Lazard 2017 “Projected LCOE by 2020”:

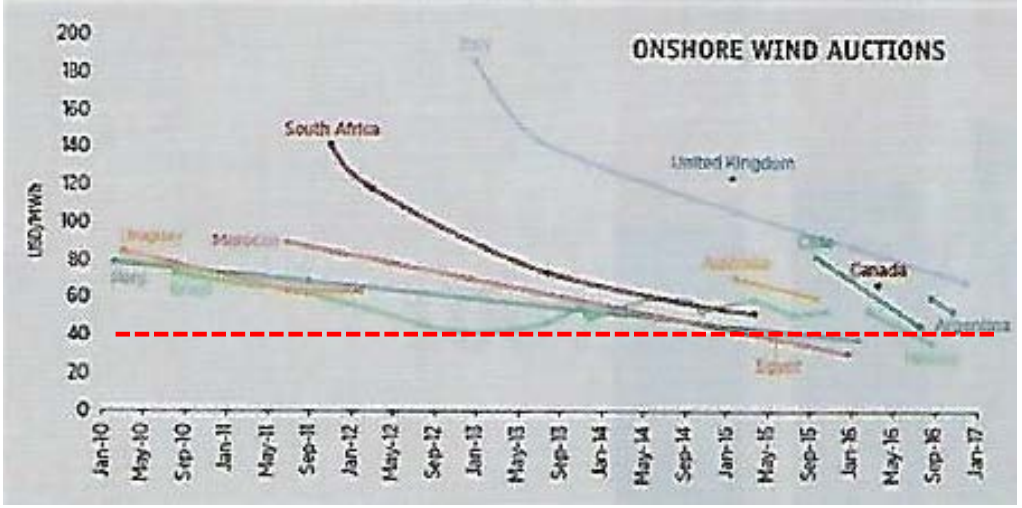


	Solar Thermal	Wind offshore	Natural Gas: Conventional Combustion Turbine	Solar PV	IGCC (Integrated Coal-Gasification Combined Cycle)	Biomass	Advanced Nuclear	Conventional Coal	Hydro	Wind onshore	Natural Gas: Advanced Combined Cycle	Geothermal
Minimum	174	170	107	98	106	90	92	87	69	66	69	44
Average	240	197	142	125	116	101	95	95	84	74	73	48
Maximum	383	270	156	193	136	117	101	119	107	82	82	52

Renewables Auction Prices are dropping



$50/MWh

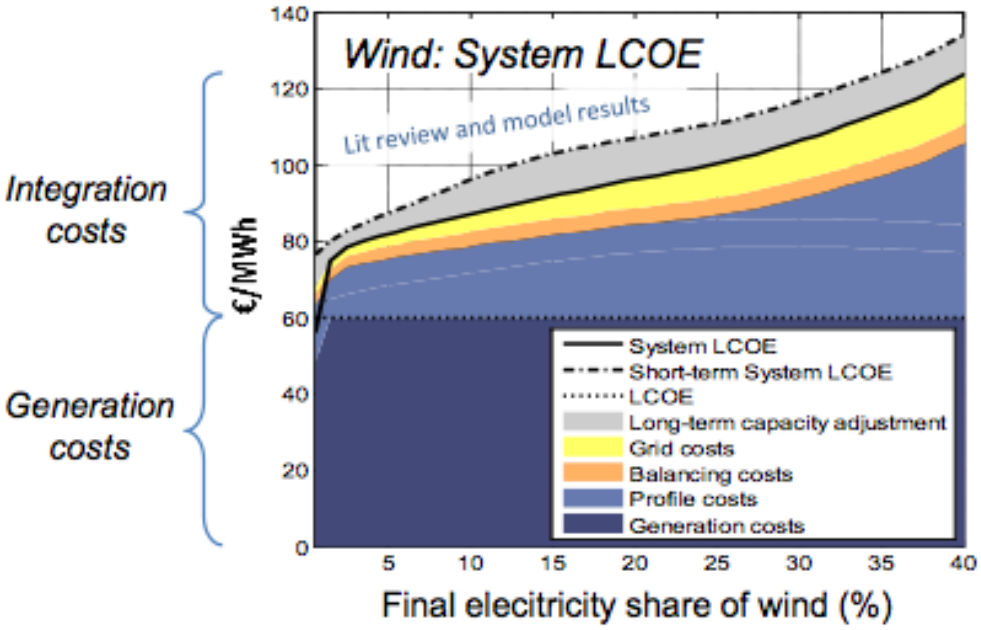


$40/MWh

Integration costs not included

Wind Integration Costs

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



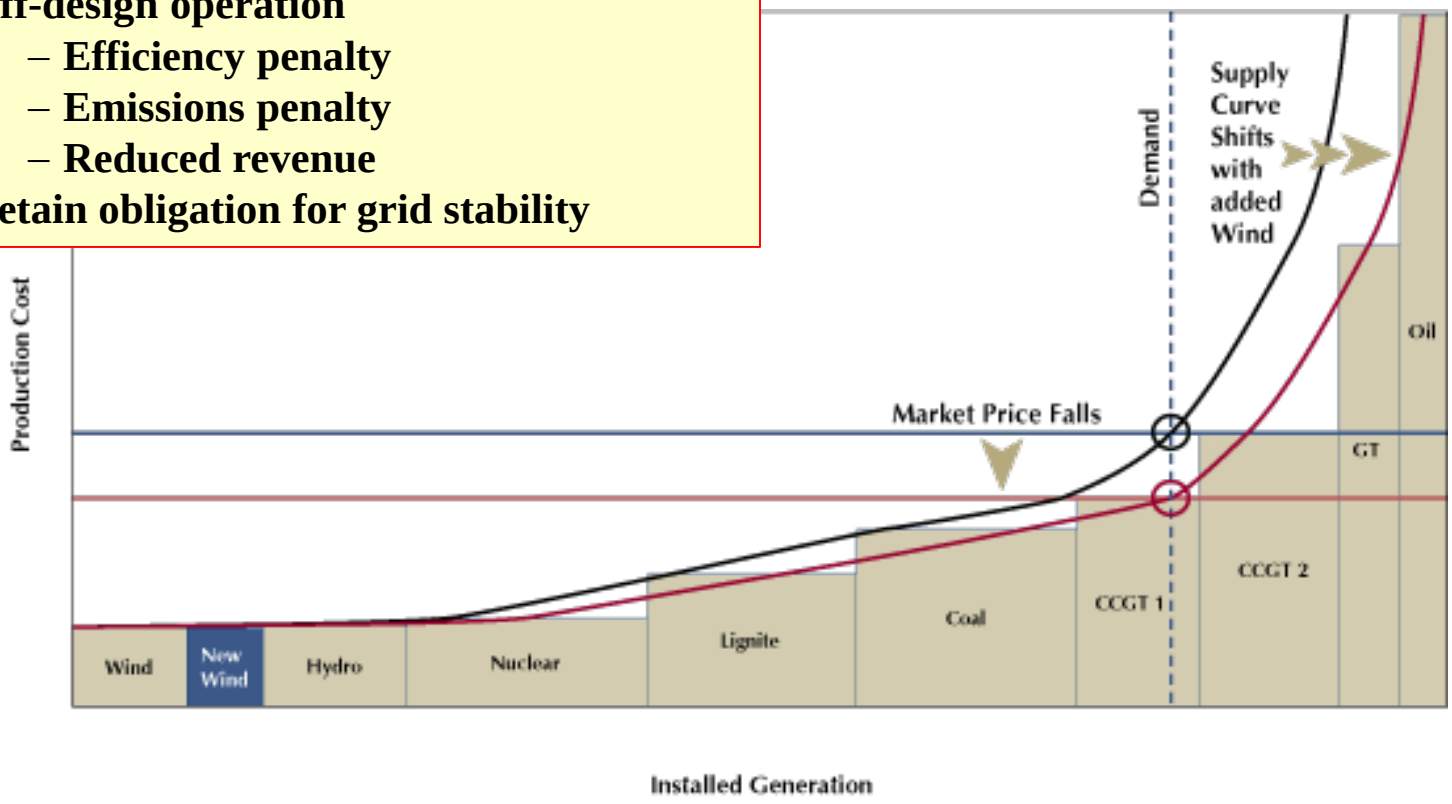
At higher penetration, integration costs for wind exceed generation costs.

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

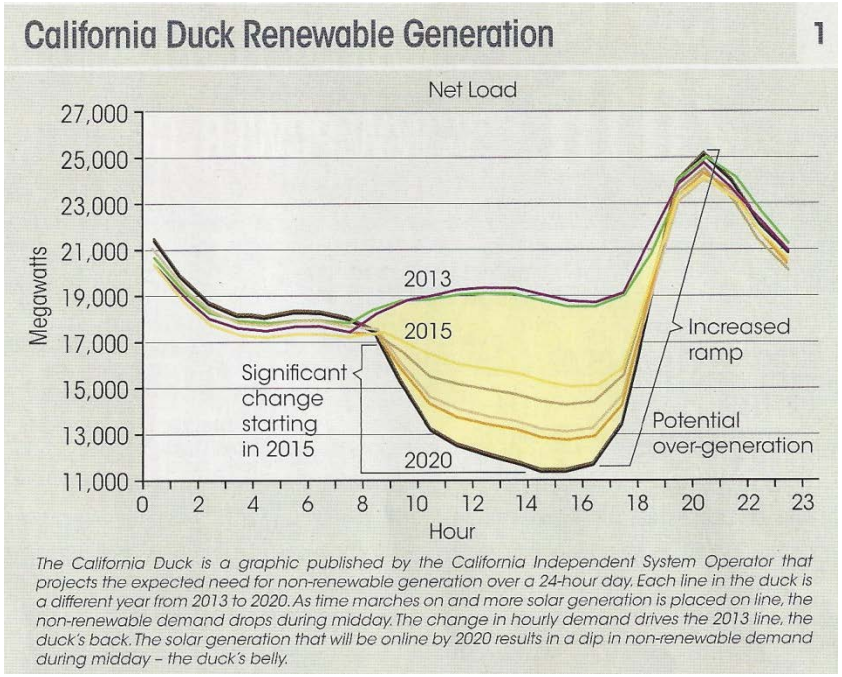
As presented by John Thompson Clean Air Task Force CCS – Pittsburgh 2014

Shift in Supply Cost Curve with Renewables

Fossil Assets Pushed Back In Merit Order
- **Reduced load factor 85% to 65%**
- **Rapid ramp rates and start/stop operation**
- **Off-design operation**
  - **Efficiency penalty**
  - **Emissions penalty**
  - **Reduced revenue**
- **Retain obligation for grid stability**



Dealing with an even “Bigger” Duck



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

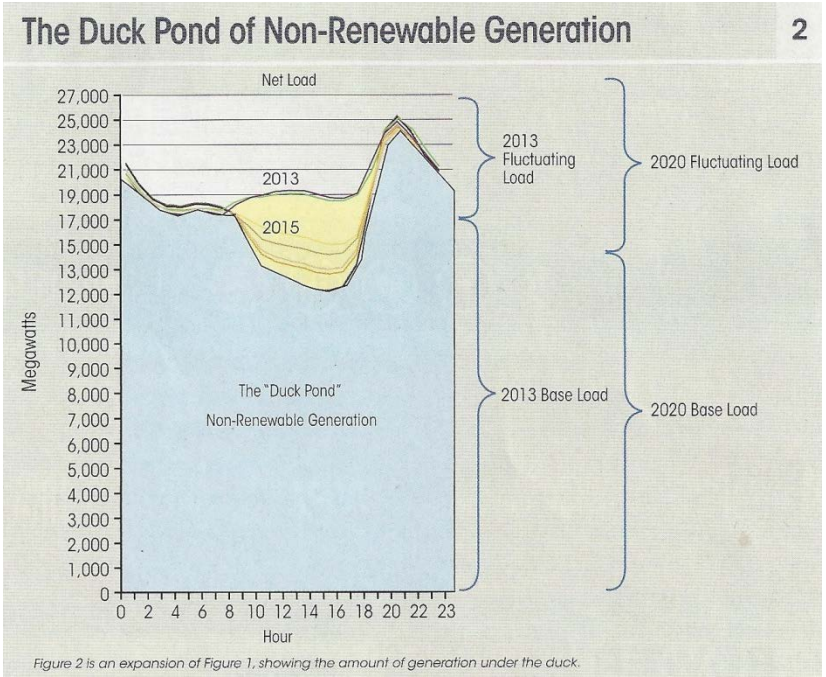
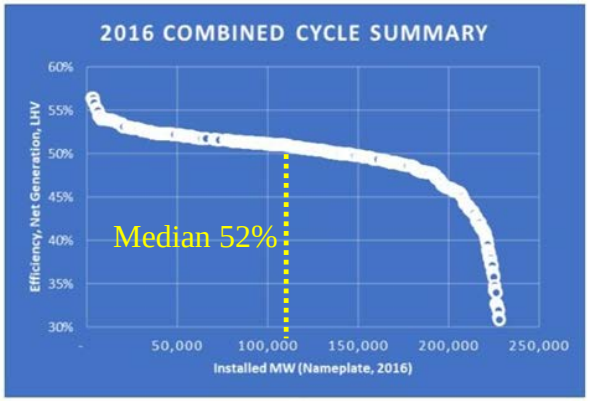


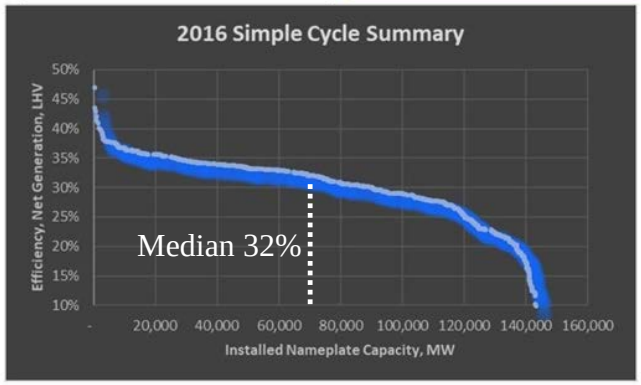
Figure 2 is an expansion of Figure 1, showing the amount of generation under the duck.

Source: Bonnie Marini – Siemens Energy
Through Power Engineering

2016 EIA Operating Data

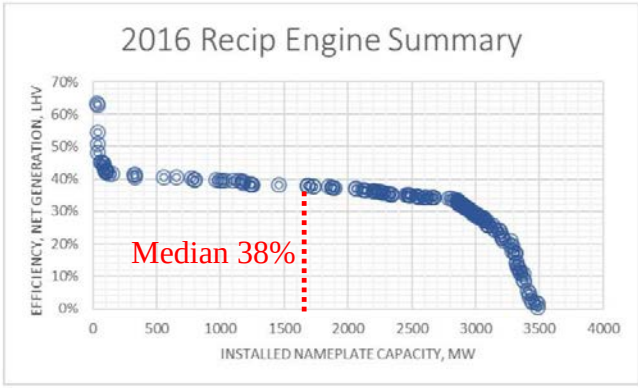
Here's a different way of looking at the performance of the power fleet, with the emphasis on those elements that could be classified as "internal combustion engines", which happens to include gas turbines. On the right it is evident (using 2016 annual EIA 923 data) that a fairly large segment of the fleet operates at modest efficiency levels. Note that these are at the "plant" level, not the turbine.





Eliminating the thermal cycle, and looking at the gas turbine components, the gas turbine fleet (peaking units) looks like this. Similar form. That sharp spike on the left is the due to the presence of high efficiency aero-engines dispatched into the fleet. But much of the fleet operates at very low (annual) efficiencies.

And then there is the reciprocating engine fleet. Essentially diesel cycle machines repurposed to operate on natural gas. Similar form. But the horizontal stretch in the middle "averages" about 40%. Probably 99% of the gas turbine fleet is below that average, and probably the same is true for the combined cycle a fleet.



Data from EIA 923 and 860 for the year 2016. https://www.eia.gov/electricity/data/eia923/

Via Bruce Rising on Linked In

NOPR: FERC vs. DOE

- The DOE's recent Notice of Proposed Rulemaking (NOPR), advertised as "Grid Stabilization", was immediately demonized by the Renewables Community as a subsidy for Coal and Nuclear Power Generation.
- The Federal Energy Regulatory Commission (FERC) quickly voted down the initiative.
- **The NOPR, under whatever name, was a legitimate attempt to create a market and associated compensation for the backup services essential to the continued growth of renewables.**
- The growth of renewables has been both impressive and important, and we continue to hear that renewables are now competitive with conventional generation.
  - This is **only true if the system integration costs for those renewables are not charged to their account**
  - For the most part, these system **Integration costs have fallen to the utility in residence**, but without identified compensation.
  - To say that the grid has been taken for granted is an understatement.
  - The Clean Power Plan (CPP), or whatever remains of it, includes assumptions of ~30% renewables embedded in the identified state goals. At 30% penetration, the integration cost is equal to the generation costs, but are for the most part, uncompensated.
  - The DOE NOPR was an attempt to provide that compensation.
- **With the elimination of the NOPR, it should be no surprise that this issue has surfaced again in the form of "Emergency Aid for Some Coal Plants", apparently available as an "emergency authorization" from DOE.**

This is more like "the tragedy of the commons" where the grid is the proverbial "common", and conventional generation backing it up is the "depleted resource", i.e., the decommissioning of conventional generation as uncompetitive.

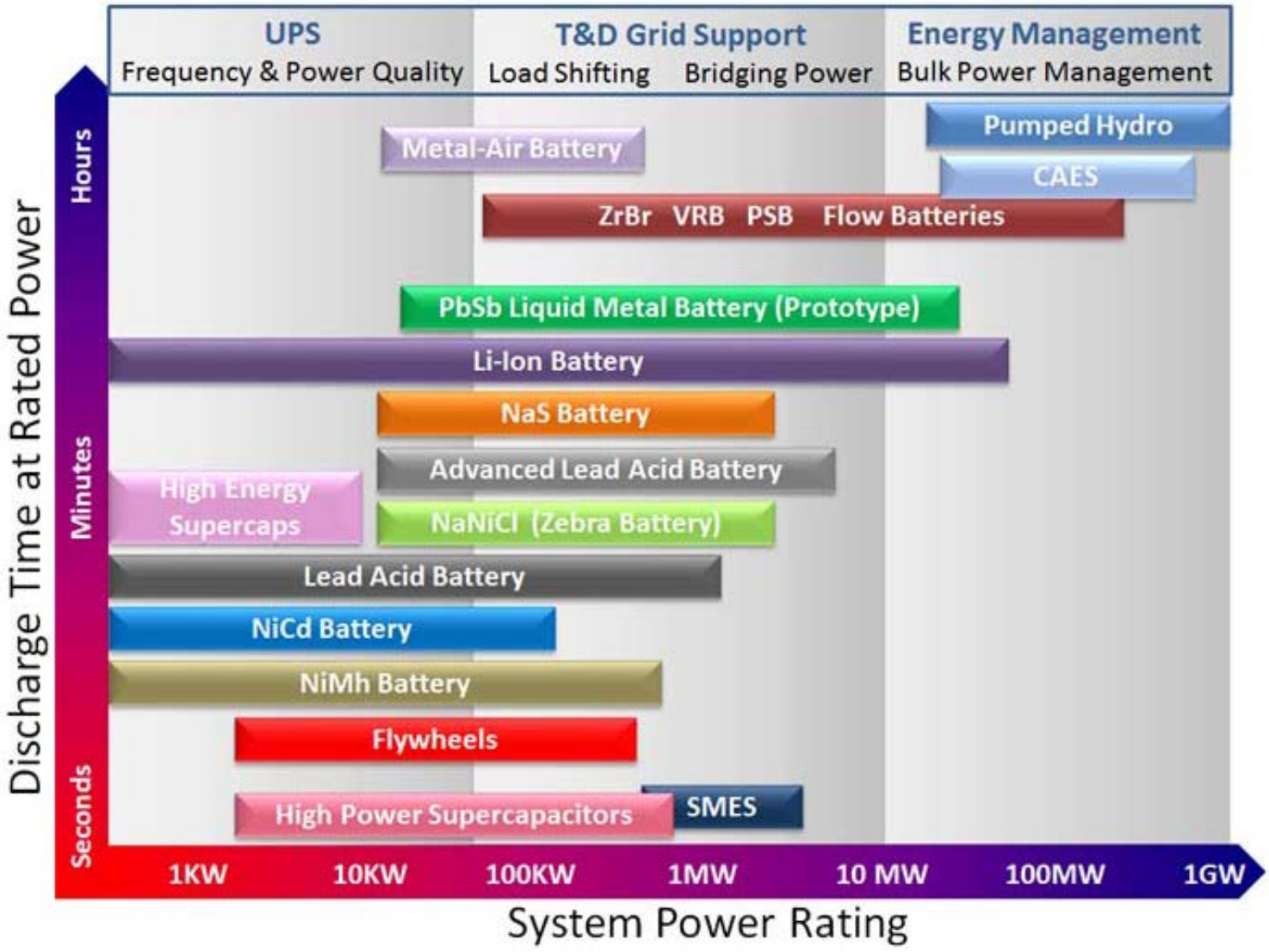
California-PV Solar Required on New Homes 2020

- The cost-effective 2019 Building Energy Efficiency Standards, which take effect on Jan. 1, 2020, focus on four key areas
  - Smart residential photovoltaic systems
  - Updated thermal envelope standards (preventing heat transfer from the interior to exterior and vice versa),
  - Residential and nonresidential ventilation requirements
  - Nonresidential lighting requirements

- The ventilation measures improve indoor air quality, protecting homeowners from air pollution originating from outdoor and indoor sources
- The standards also establish requirements for newly constructed healthcare facilities.

Storage

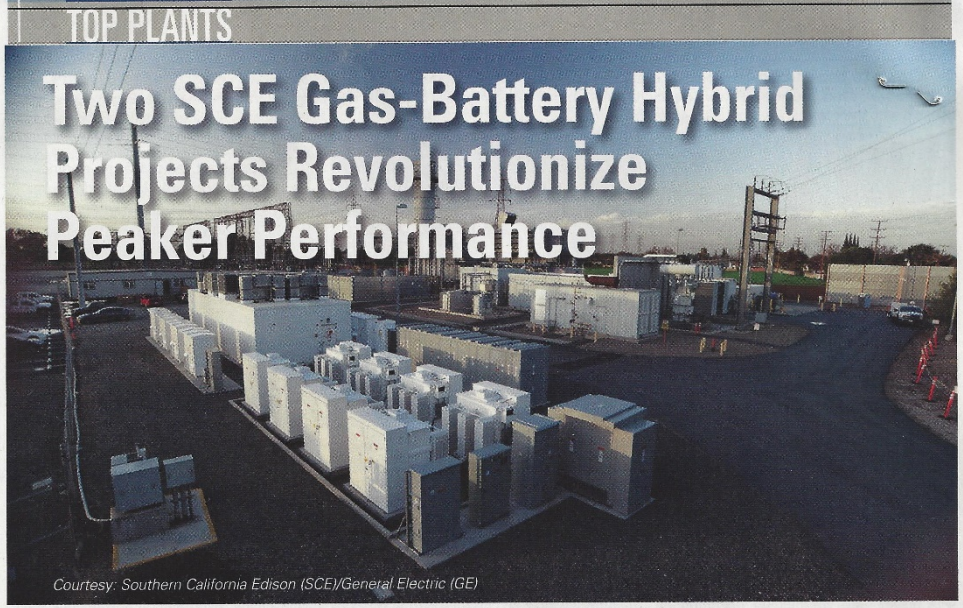
Energy Storage Technologies



Gas-Battery Spinning Reserve

TOP PLANTS

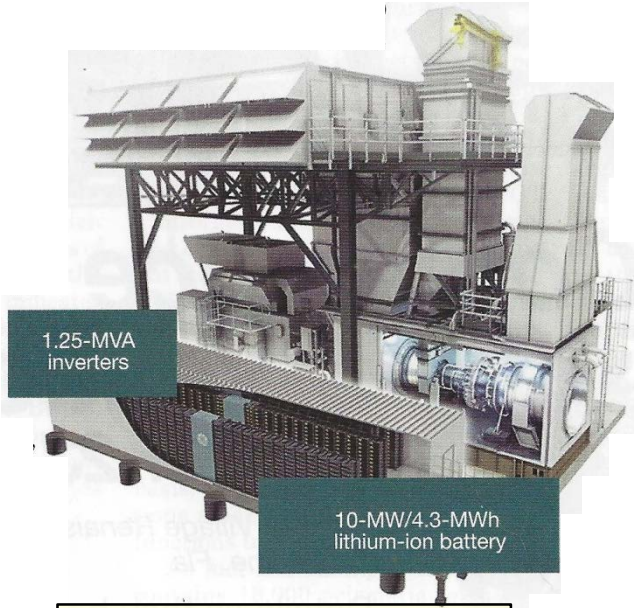
Two SCE Gas-Battery Hybrid Projects Revolutionize Peaker Performance



Courtesy: Southern California Edison (SCE)/General Electric (GE)

For deploying a novel, groundbreaking gas-battery hybrid technology along with environmentally significant upgrades within a tight installment window, and despite logistical hurdles, Southern California Edison's Center Peaker and Grapeland Peaker plants are especially deserving of *POWER*'s Top Plant recognition.

Sonal Patel



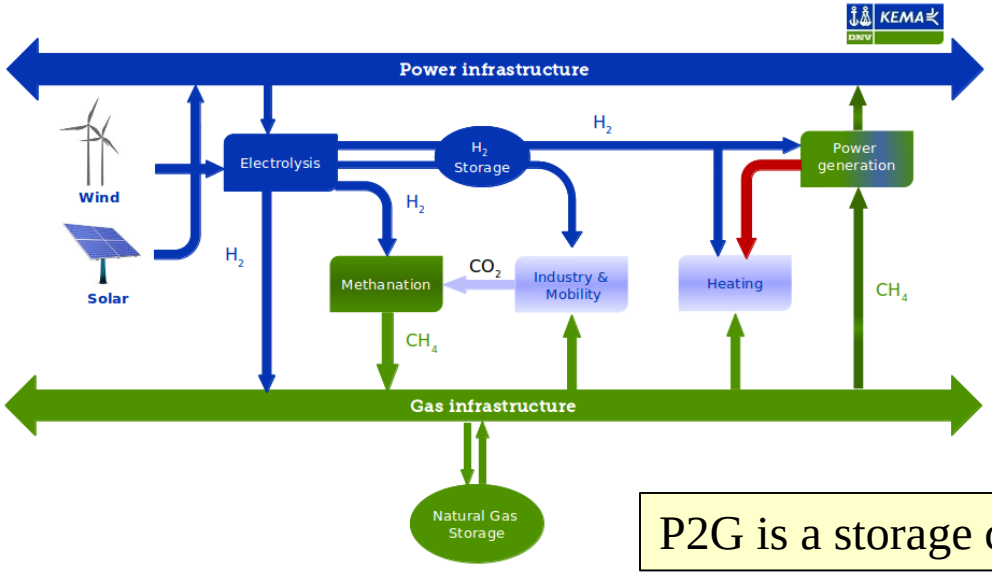
1. Hybrid EGT's most valuable function is, perhaps, its ability to respond instantaneously to grid needs

Solar-Battery Hybrid

- Arizona Public Service/First Solar announced a 50-MW battery storage project to be coupled with a 65-MW solar field.
  - This project adds to the more than one million solar panels and three grid-scale batteries to APS's system. Over the next 15 years, APS plans to adopt more than 500 MW of additional battery storage.
  - Florida Power & Light Company today unveiled a new solar-plus-storage
  - The new system features a 4,000-KW/16,000-KWh storage capacity comprised of multiple batteries integrated into the operations of the FPL Citrus Solar Energy Center.
- Under the rate agreement supported by the state's consumer advocate and approved unanimously by the Florida Public Service Commission in 2016, FPL plans to develop 50 megawatts of battery storage over the next few years.
  - FPL is in the midst of a major solar expansion with more than 520 MW added in the last two years and nearly 300 MW more scheduled to enter service by March 1. From 2016 to 2023, FPL expects to install a total of more than 10 million solar panels.

Power-to-Gas (P2G)

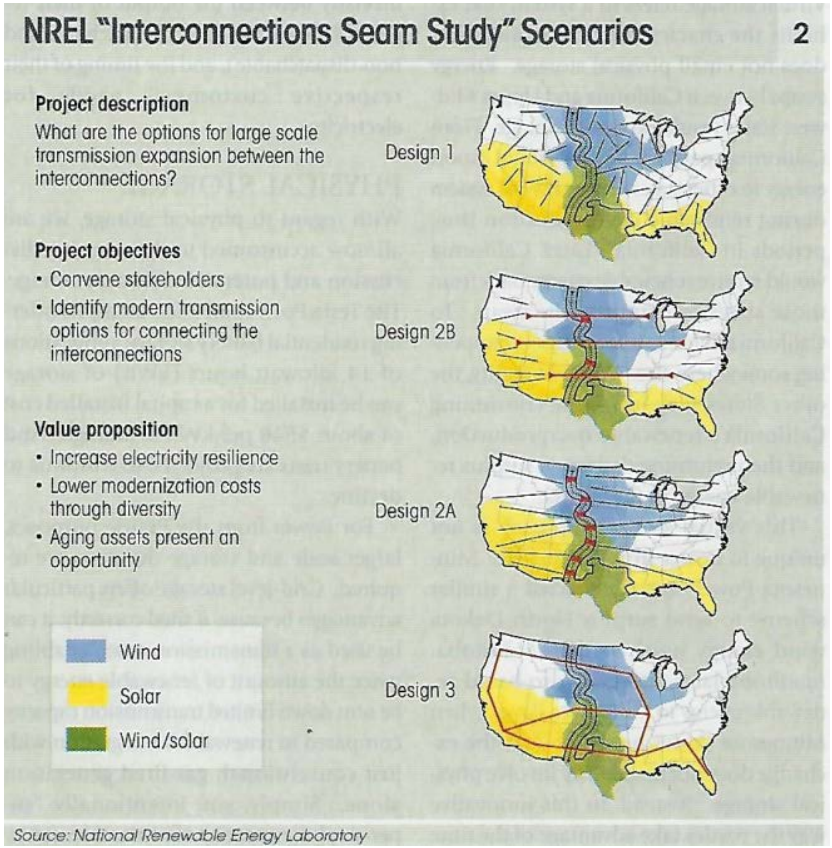
- **Power-to-gas** (often abbreviated **P2G**) is a technology that converts electrical power to a gas fuel
- When using surplus power from wind generation, the concept is sometimes called **windgas**
- There are currently three methods in use; all use electricity to split water into hydrogen and oxygen by means of electrolysis
  1. Hydrogen is injected into the natural gas grid or is used in transport or industry.
  2. Combine the hydrogen with CO2 and convert the two gases to methane using a methanization reaction such as the Sabatier reaction or biological methanation resulting in an extra energy conversion loss of 8%.
  3. Use the output gas of a wood gas generator or a biogas plant, after the biogas upgrader is mixed with the produced hydrogen from the electrolyzer, to upgrade the quality of the biogas

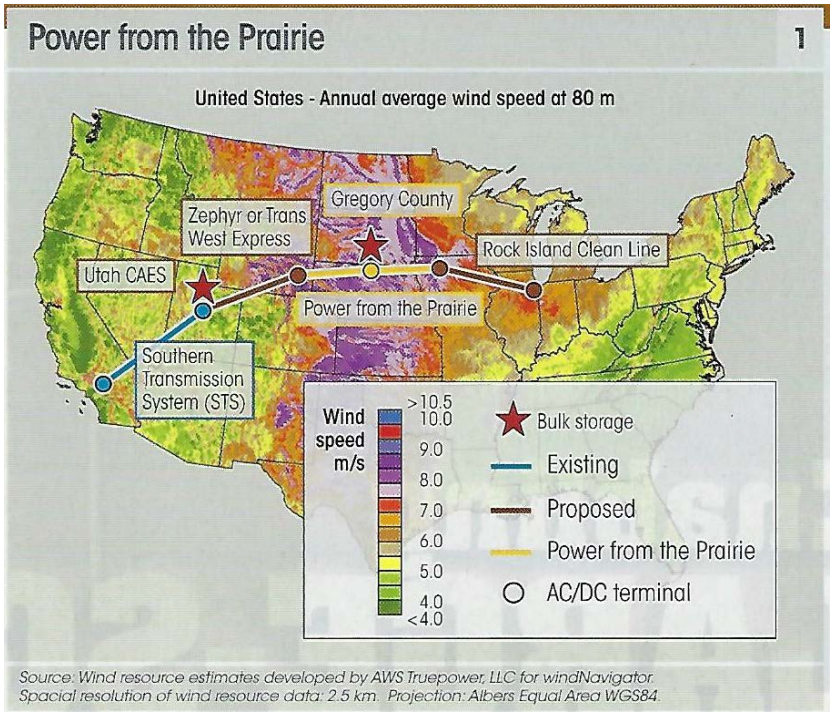


P2G is a storage concept

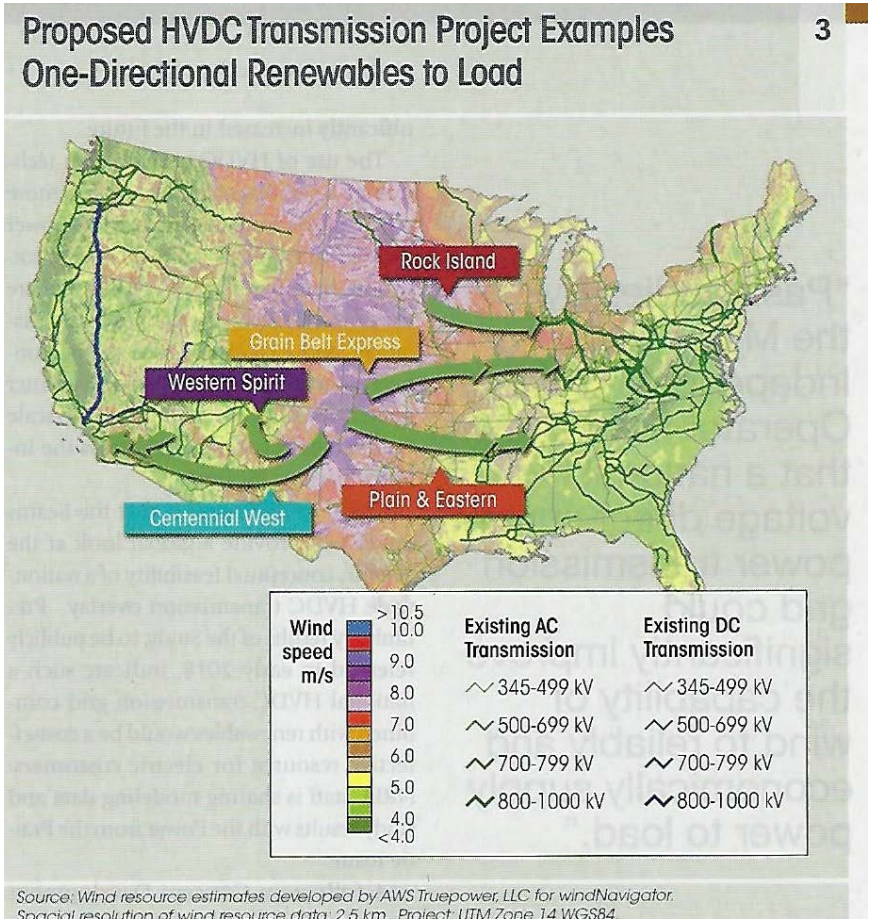
Transmission

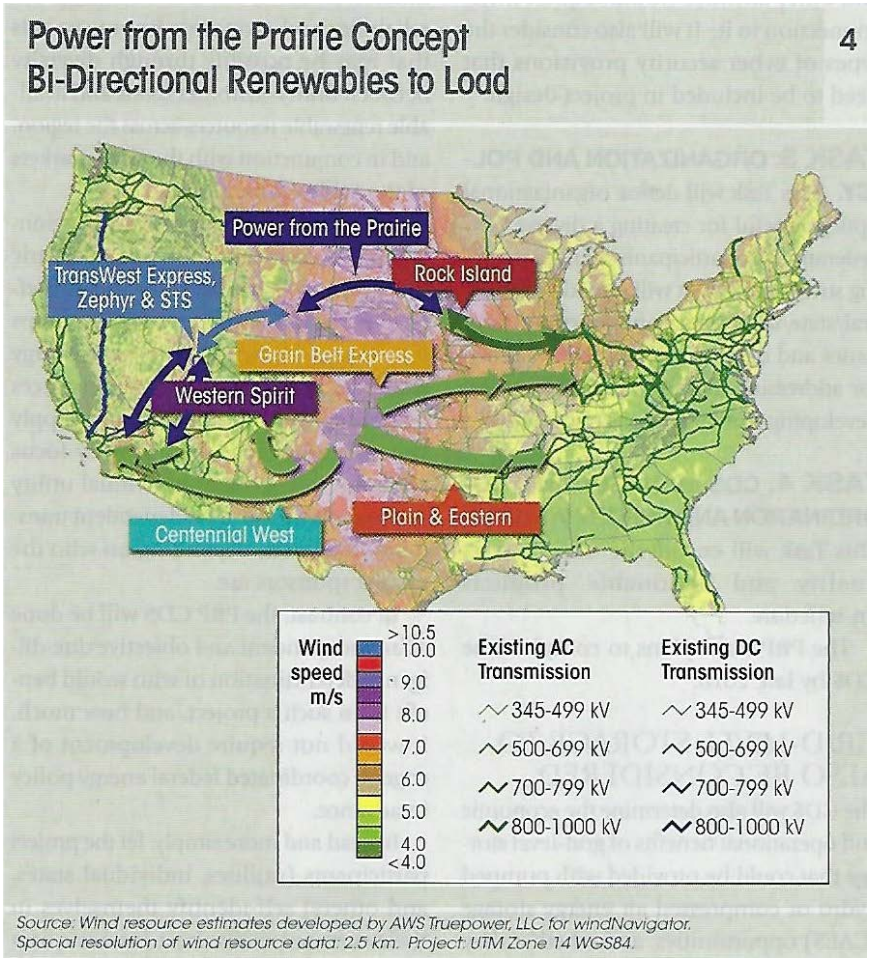
High-Voltage DC Grid





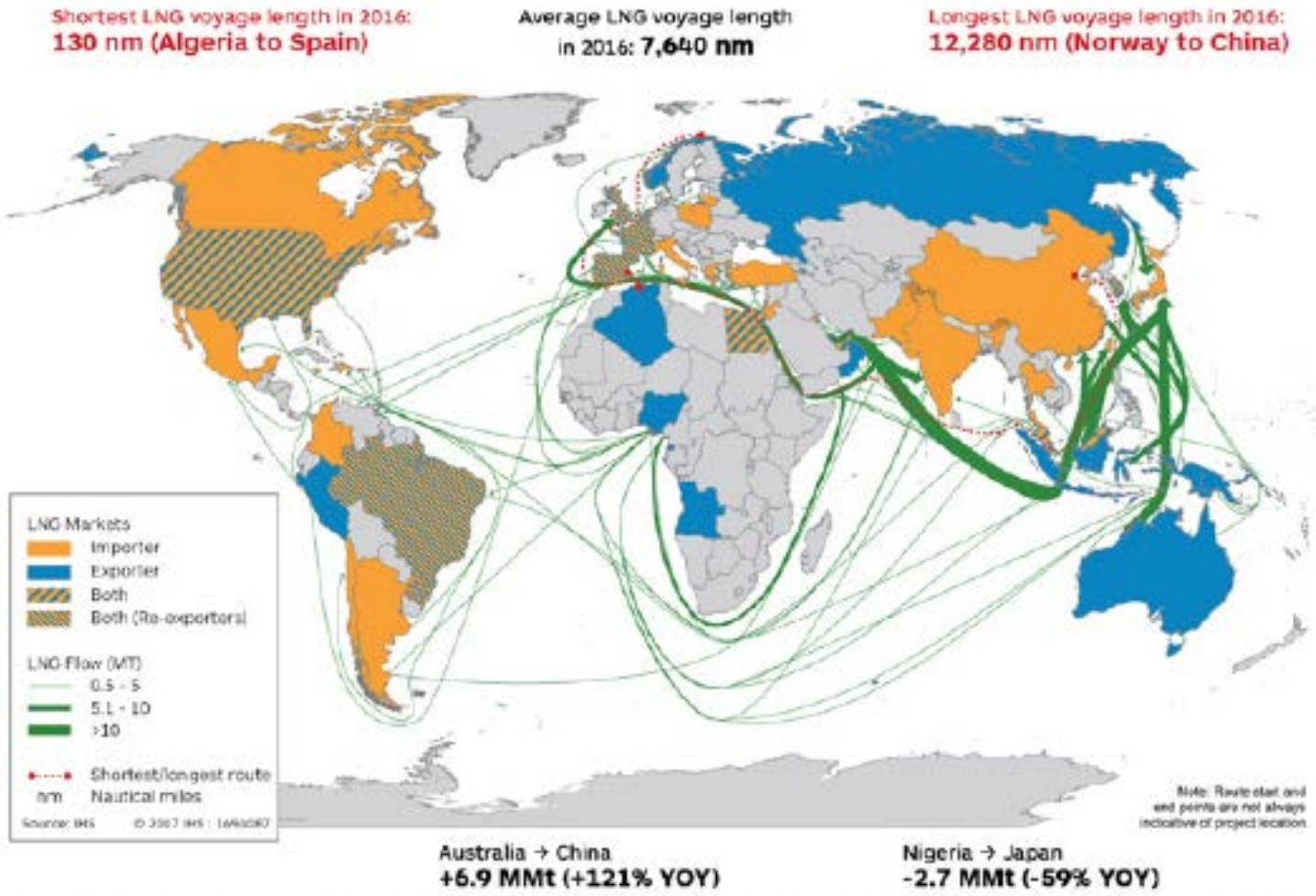
High-Voltage Bi-Directional DC Grid



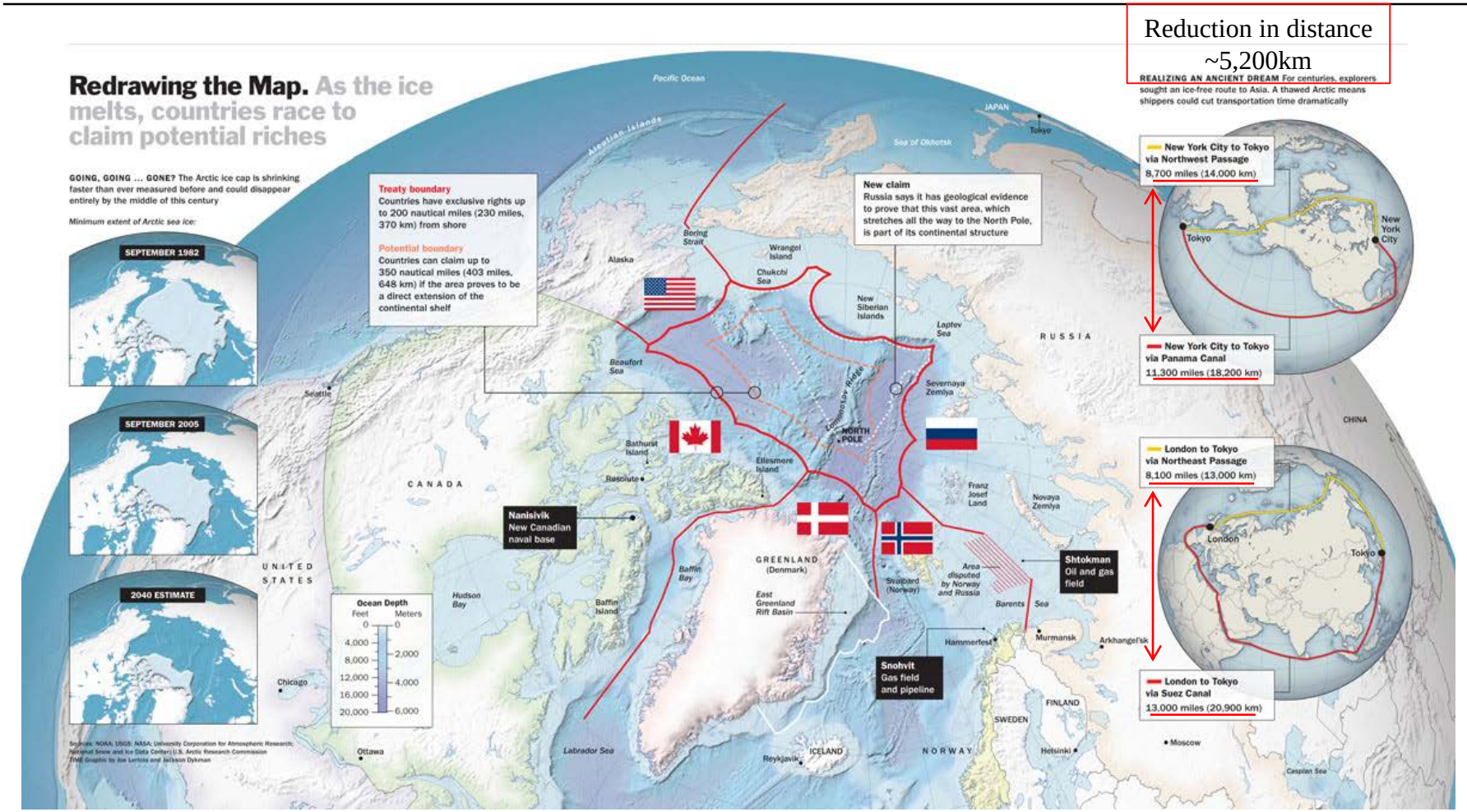


Trade

Major LNG Shipping Routes 2016



The Arctic


Reduction in distance
~5,200km
Redrawing the Map. As the ice melts, countries race to claim potential riches
GOING, GOING ... GONE? The Arctic ice cap is shrinking faster than ever measured before and could disappear entirely by the middle of this century
Minimum extent of Arctic sea ice:
SEPTEMBER 1982
SEPTEMBER 2005
2040 ESTIMATE
Treaty boundary
Countries have exclusive rights up to 200 nautical miles (230 miles, 370 km) from shore
Potential boundary
Countries can claim up to 350 nautical miles (403 miles, 648 km) if the area proves to be a direct extension of the continental shelf
New claim
Russia says it has geological evidence to prove that this vast area, which stretches all the way to the North Pole, is part of its continental structure
Nanisivik
New Canadian naval base
Shtokman
Oil and gas field
Snohvit
Gas field and pipeline
Ocean Depth
Feet
Meters
REALIZING AN ANCIENT DREAM For centuries, explorers sought an ice-free route to Asia. A thawed Arctic means shippers could cut transportation time dramatically
New York City to Tokyo via Northwest Passage
8,700 miles (14,000 km)
New York City to Tokyo via Panama Canal
11,300 miles (18,200 km)
London to Tokyo via Northeast Passage
8,100 miles (13,000 km)
London to Tokyo via Suez Canal
13,000 miles (20,900 km)
Pacific Ocean
Aleutian Islands
JAPAN
Tokyo
Sea of Okhotsk
Bering Strait
Alaska
Wrangel Island
Chukchi Sea
New Siberian Islands
Laptev Sea
RUSSIA
Beaufort Sea
Seattle
Lomonosov Ridge
NORTH POLE
Severnaya Zemlya
CHINA
Bathurst Island
Resolute
Ellesmere Island
CANADA
Franz Josef Land
Novaya Zemlya
UNITED STATES
GREENLAND (Denmark)
Baffin Bay
Hudson Bay
Baffin Island
East Greenland Rift Basin
Svalbard (Norway)
Area disputed by Norway and Russia
Barents Sea
Hammerfest
Murmansk
Arkhangel'sk
Chicago
Ottawa
Labrador Sea
Reykjavik
ICELAND
NORWAY
SWEDEN
FINLAND
Helsinki
Moscow
Caspian Sea
London

World Oil Choke Points

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

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

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

Figure 2. Map of the Strait of Hormuz

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

Figure 3. Map of the Strait of Malacca

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

A New Choke Point

Bering Strait 51 miles

Natural Gas Trade – 1134.1 BCM

Pipeline trade grew 3.7%
LNG trade grew 10.3%
Consumption grew 5.9%

Gas Trade in 2016 and 2017

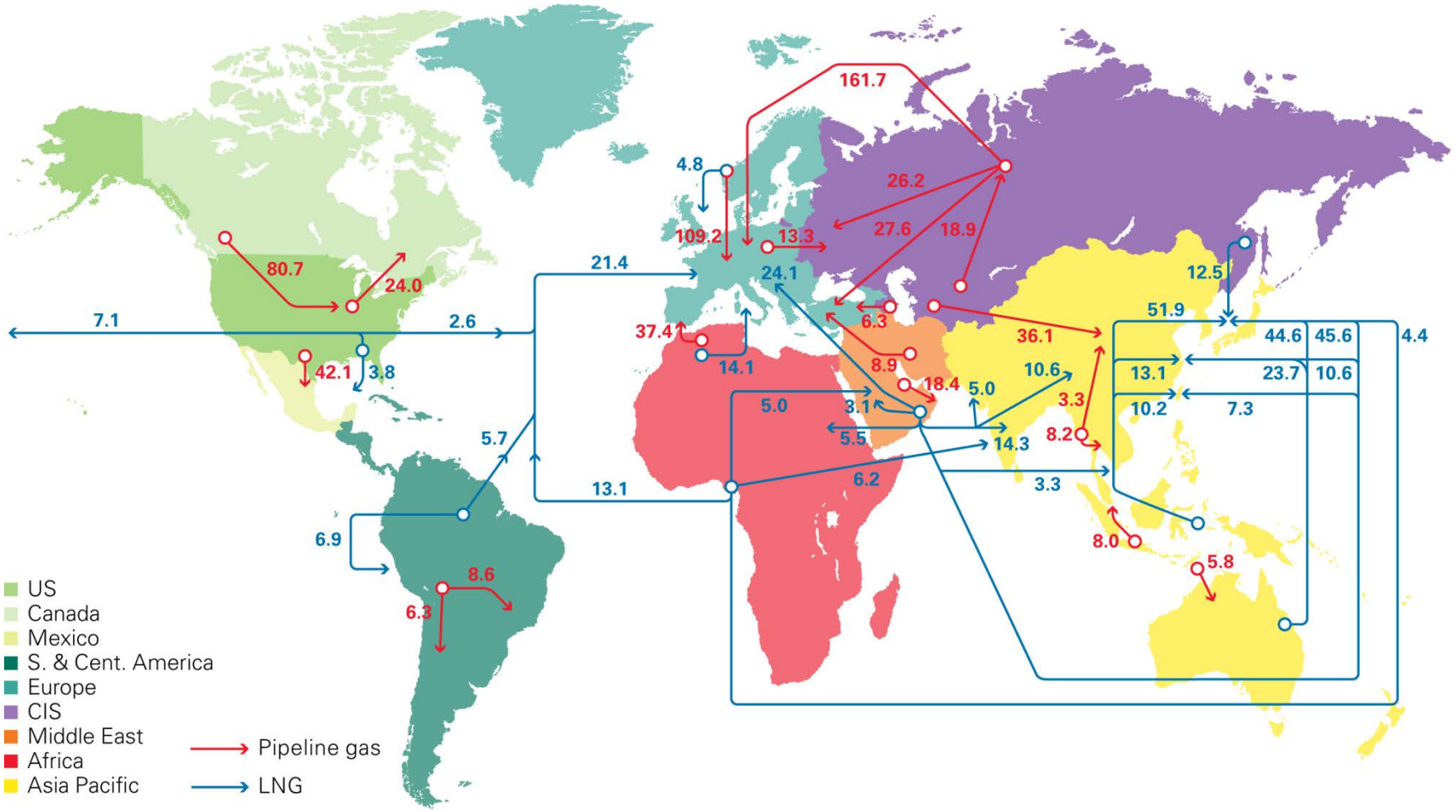
Billion cubic metres	2016				2017				2017 vs. 2016			
	Pipeline imports	LNG imports	Pipeline exports	LNG exports	Pipeline imports	LNG imports	Pipeline exports	LNG exports	Pipeline imports	LNG imports	Pipeline exports	LNG exports
US	79.5	2.4	58.6	4.3	80.7	2.2	66.1	17.4	1.2	(0.3)	7.4	13.1
Canada	21.1	0.3	79.5	†	24.0	0.4	80.7	†	2.9	0.1	1.2	0.0
Mexico	37.5	5.9	†	-	42.1	6.6	†	-	4.5	0.7	0.0	0.0
Trinidad and Tobago	-	-	-	14.3	-	-	-	13.4	0.0	0.0	0.0	(0.9)
Other S. & Cent. America	16.2	15.6	16.2	6.4	15.4	13.8	15.4	5.8	(0.8)	(1.8)	(0.8)	(0.6)
France	32.2	9.1	-	1.5	33.5	10.8	-	1.0	1.4	1.7	0.0	(0.5)
Germany	95.6	-	9.1	-	94.8	-	7.1	-	(0.8)	0.0	(2.0)	0.0
Italy	60.5	5.9	-	-	53.8	8.4	-	-	(6.7)	2.5	0.0	0.0
Netherlands	36.8	1.3	46.8	0.9	40.9	1.6	43.3	0.8	4.1	0.3	(3.6)	(0.0)
Norway	†	-	109.4	6.0	†	-	109.2	5.8	0.0	0.0	(0.2)	(0.3)
Spain	15.5	13.8	0.6	0.2	14.4	16.6	0.1	0.1	(1.1)	2.8	(0.5)	(0.0)
Turkey	36.9	7.8	0.6	-	42.8	10.9	0.6	-	5.9	3.1	(0.0)	0.0
United Kingdom	35.2	11.0	9.7	0.6	39.4	7.2	10.8	0.3	4.2	(3.9)	1.2	(0.3)
Other Europe	94.8	7.9	13.9	1.3	103.7	10.2	21.6	0.2	8.9	2.3	7.8	(1.1)
Russian Federation	18.1	-	200.1	14.6	18.9	-	215.4	15.5	0.8	0.0	15.4	0.9
Ukraine	10.5	-	-	-	13.3	-	-	-	2.8	0.0	0.0	0.0
Other CIS	29.3	-	68.5	-	30.1	-	67.5	-	0.8	0.0	(0.9)	0.0
Qatar	-	-	18.5	107.2	-	-	18.4	103.4	0.0	0.0	(0.1)	(3.8)
Other Middle East	25.8	13.7	8.0	18.8	22.2	13.0	12.5	19.1	(3.6)	(0.6)	4.5	0.3
Algeria	-	-	38.1	15.8	-	-	36.4	16.6	0.0	0.0	(1.7)	0.8
Other Africa	8.3	10.7	8.6	30.0	7.6	8.2	8.7	38.9	(0.7)	(2.5)	0.1	9.0
Australia	6.4	0.1	-	59.2	5.8	-	-	75.9	(0.6)	(0.1)	0.0	16.7
China	36.0	35.9	-	-	39.4	52.6	-	-	3.4	16.7	0.0	0.0
India	-	23.6	-	0.1	-	25.7	-	-	0.0	2.1	0.0	(0.1)
Japan	-	113.6	-	-	-	113.9	-	-	0.0	0.4	0.0	0.0
Indonesia	-	-	8.2	22.2	-	-	8.0	21.7	0.0	0.0	(0.2)	(0.5)
South Korea	-	45.7	-	0.1	-	51.3	-	0.1	0.0	5.6	0.0	(0.0)
Other Asia Pacific	18.1	32.5	20.0	53.4	17.7	40.0	18.8	57.2	(0.4)	7.4	(1.2)	3.8
Total World	**714.4**	**356.7**	**714.4**	**356.7**	**740.7**	**393.4**	**740.7**	**393.4**	26.3	36.7	26.3	36.7

Source: Includes data from FGE MENAgas service, IHS.

Trade represents approximately 30% of the consumption
Japan, China & Korea represent almost 55% of all LNG Imports

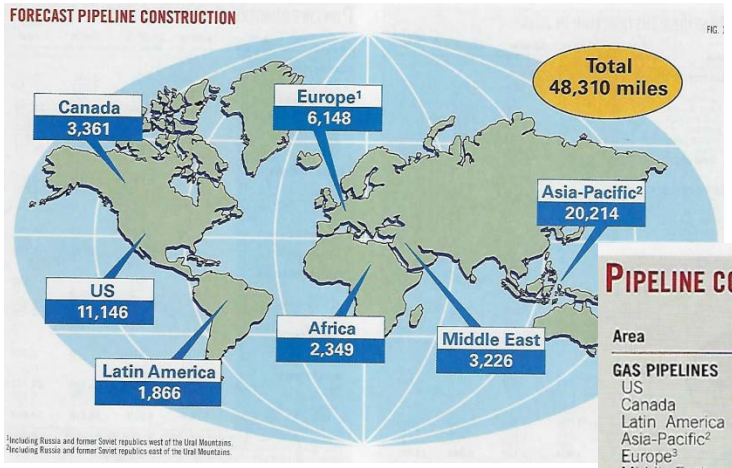
Source: BP Statistical Review of World Energy 2018

Major Natural Gas Trade Movements BCM - 2017



Source: BP Statistical Review of World Energy 2018

Lots of Gas Pipelines



Oil & Gas Journal Feb 5, 2018

PIPELINE CONSTRUCTION IN 2018[1]

Table 1

Area	4-10 in.	12-20 in.	22-30 in.	32+ in.	Total
			Miles		
GAS PIPELINES					
US	30	70	212	2,512	2,824
Canada	0	0	0	0	0
Latin America	0	0	0	879	879
Asia-Pacific[2]	0	848	652	3,658	5,158
Europe[3]	0	111	0	1,141	1,252
Middle East	0	0	16	1,321	1,337
Africa	0	0	465	21	486
Total gas	**30**	**1,029**	**1,345**	**9,532**	**11,936**
CRUDE PIPELINES					
US	34	151	220	0	405
Canada	0	0	0	0	0
Latin America	0	136	0	0	136
Asia-Pacific[2]	0	0	0	0	0
Europe[3]	0	0	0	0	0
Middle East	0	0	0	0	0
Africa	0	0	0	0	0
Total product	**34**	**287**	**220**	**0**	**541**
PRODUCT PIPELINES					
US	34	151	220	0	405
Canada	0	0	0	0	0
Latin America	0	136	0	0	136
Asia-Pacific[2]	0	0	0	0	0
Europe[3]	0	0	0	0	0
Middle East	0	0	0	0	0
Africa	0	0	0	0	0
Total product	**34**	**287**	**220**	**0**	**541**
WORLD TOTALS					
Gas	30	1,029	1,345	9,532	11,936
Crude	65	188	1,570	357	2,180
Product	34	287	220	0	541
Total	**129**	**1,504**	**3,135**	**9,889**	**14,657**

[1]Projects planned to be completed in 2018. [2]Regions east of the Ural Mountains and south of the Caucasus Mountains, excluding the Middle East. [3]Regions west of the Ural Mountains and north of the Caucasus Mountains.

PIPELINE CONSTRUCTION BEYOND 2018[1]

Table 2

Area	4-10 in.	12-20 in.	22-30 in.	30+ in.	Total
			Miles		
GAS PIPELINES					
US	0	0	91	3,541	3,632
Canada	0	85	0	1,989	2,074
Latin America	0	0	15	700	715
Asia-Pacific[2]	0	0	1,884	10,107	11,991
Europe[3]	0	93	832	3,796	4,721
Middle East	0	0	292	373	665
Africa	0	0	0	933	933
Total gas	0	178	3,114	21,439	24,731
CRUDE PIPELINES					
US	0	535	1,795	515	2,845
Canada	0	0	0	1,228	1,228
Latin America	0	0	0	0	0
Asia-Pacific[2]	0	0	0	0	0
Europe[3]	0	0	0	0	0
Middle East	0	0	109	1,043	1,152
Africa	0	0	930	0	930
Total crude	**0**	**535**	**2,834**	**2,786**	**6,155**
PRODUCT PIPELINES					
US	0	561	571	0	1,132
Canada	0	0	0	0	0
Latin America	0	136	0	0	136
Asia-Pacific[2]	0	1,499	0	0	1,499
Europe[3]	0	0	0	0	0
Middle East	0	0	0	0	0
Africa	0	0	0	0	0
Total product	**0**	**2,196**	**571**	**0**	**2,767**
WORLD TOTALS					
Gas	0	178	3,114	21,439	24,731
Crude	0	535	2,834	2,786	6,155
Product	0	2,196	571	0	2,767
Total	**0**	**2,909**	**6,519**	**24,225**	**33,653**

[1]Projects under way at the start of or set to begin in 2018 and be completed after 2018. Includes some probable major projects whose installation will begin in 2018 or later. [2]Regions east of the Ural Mountains and south of the Caucasus Mountains, excluding the Middle East. [3]Regions west of the Ural Mountains and north of the Caucasus Mountains.

Global LNG Growth

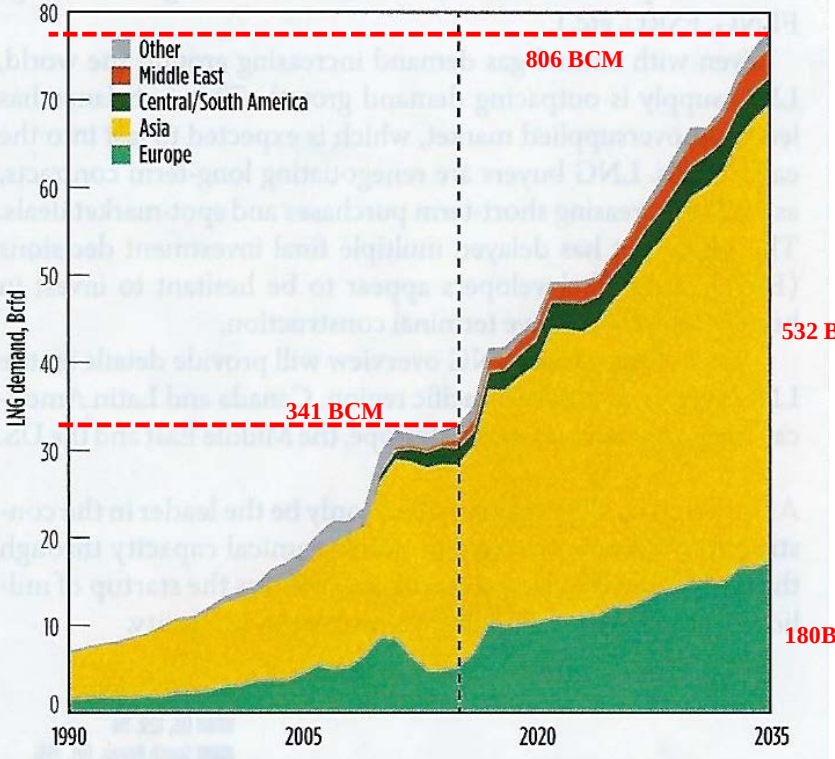


FIG. 3. Global growth in LNG demand to 2035. Source: BP.

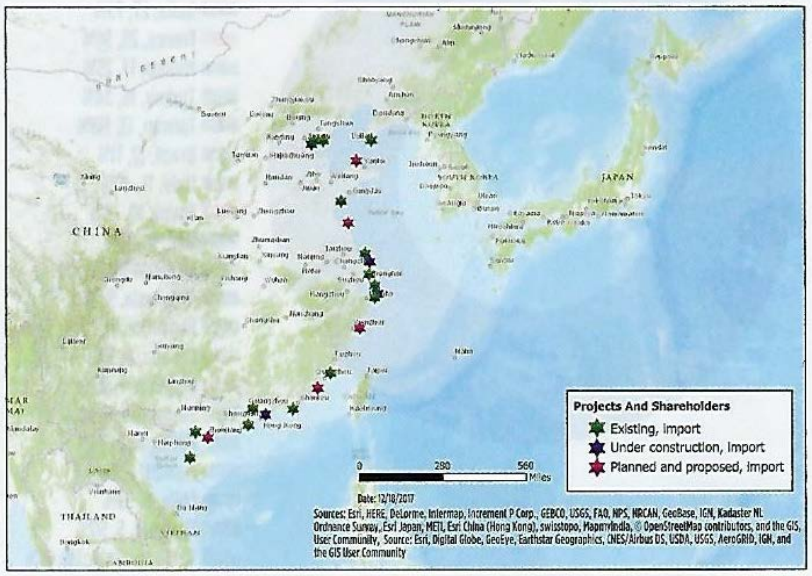


FIG. 4. LNG import terminals in China. Source: Energy Web Atlas.

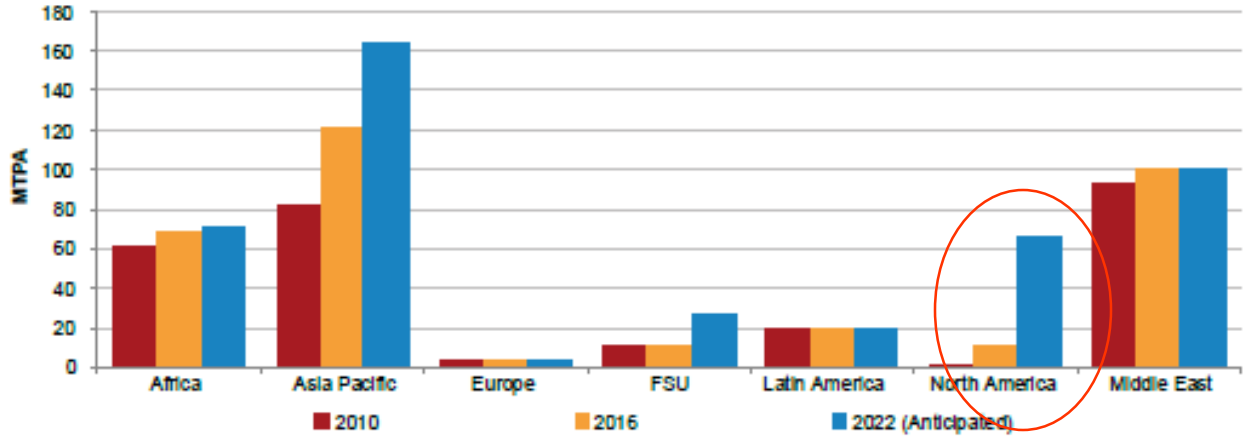
Liquefaction Capacity by Region

Table 4.2: Nominal Liquefaction Capacity by Region in 2010, 2016, and 2022

Region	2010	2016	2022 (Anticipated)	% Growth 2010-2016 (Actual)	% Growth 2017-2022 (Anticipated)
Africa	61.2	68.3	70.7	12%	4%
Asia Pacific	82.8	121.7	163.4	47%	34%
Europe	4.2	4.2	4.2	0%	0%
FSU	10.8	10.8	27.3	0%	153%
Latin America	19.8	19.8	19.8	0%	0%
North America	1.5	10.5	66.6	600%	534%
Middle East	93.0	100.8	100.8	8%	0%
Total Capacity	**273.2**	**336.1**	**452.7**	**23%**	**35%**

Note: Liquefaction capacity only refers to existing and under construction projects. Sources: IHS, Company Announcements

Figure 4.14: Liquefaction Capacity by Region in 2010, 2016, and 2022



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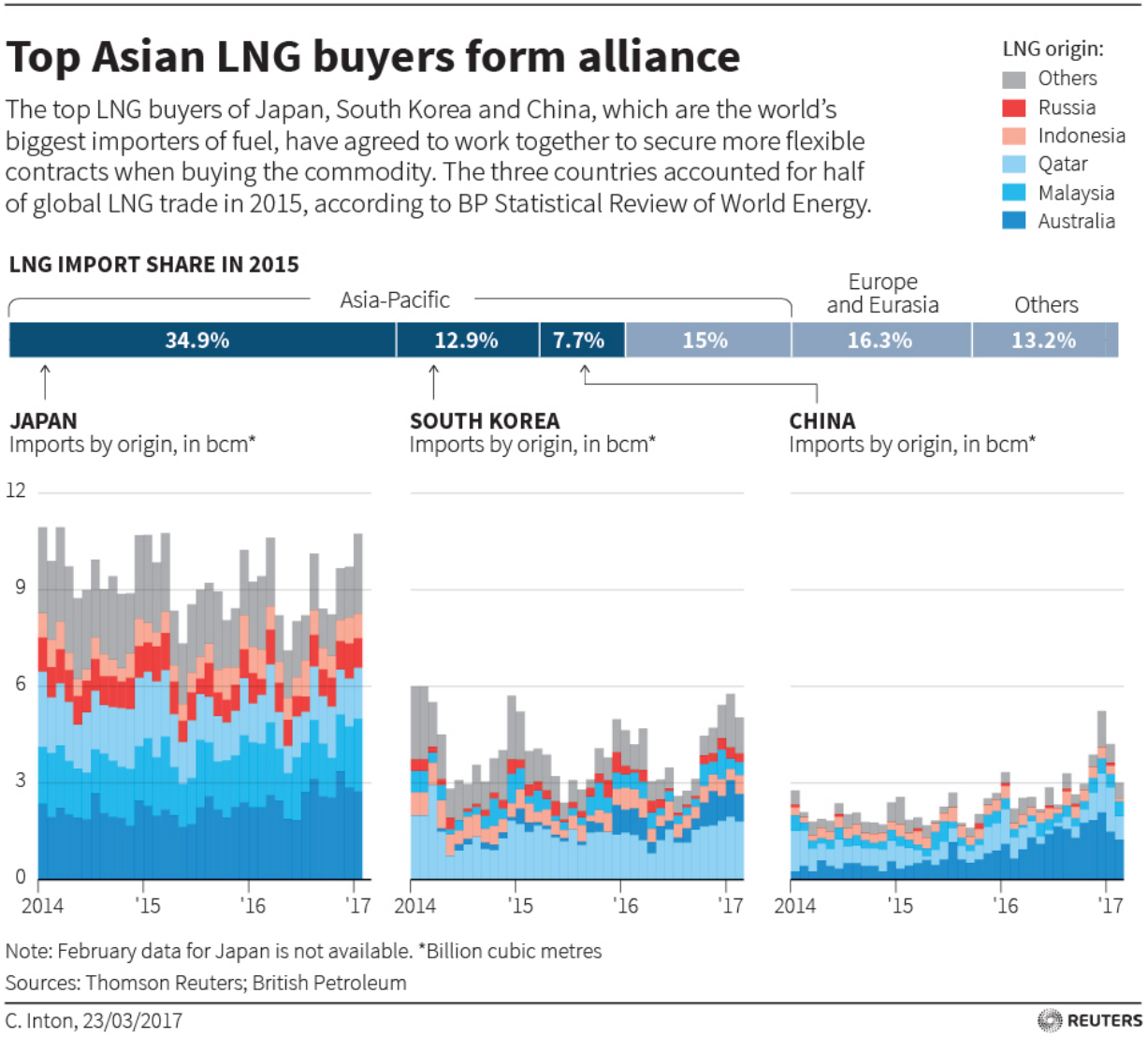
Changing LNG Contract Terms – More Flex together



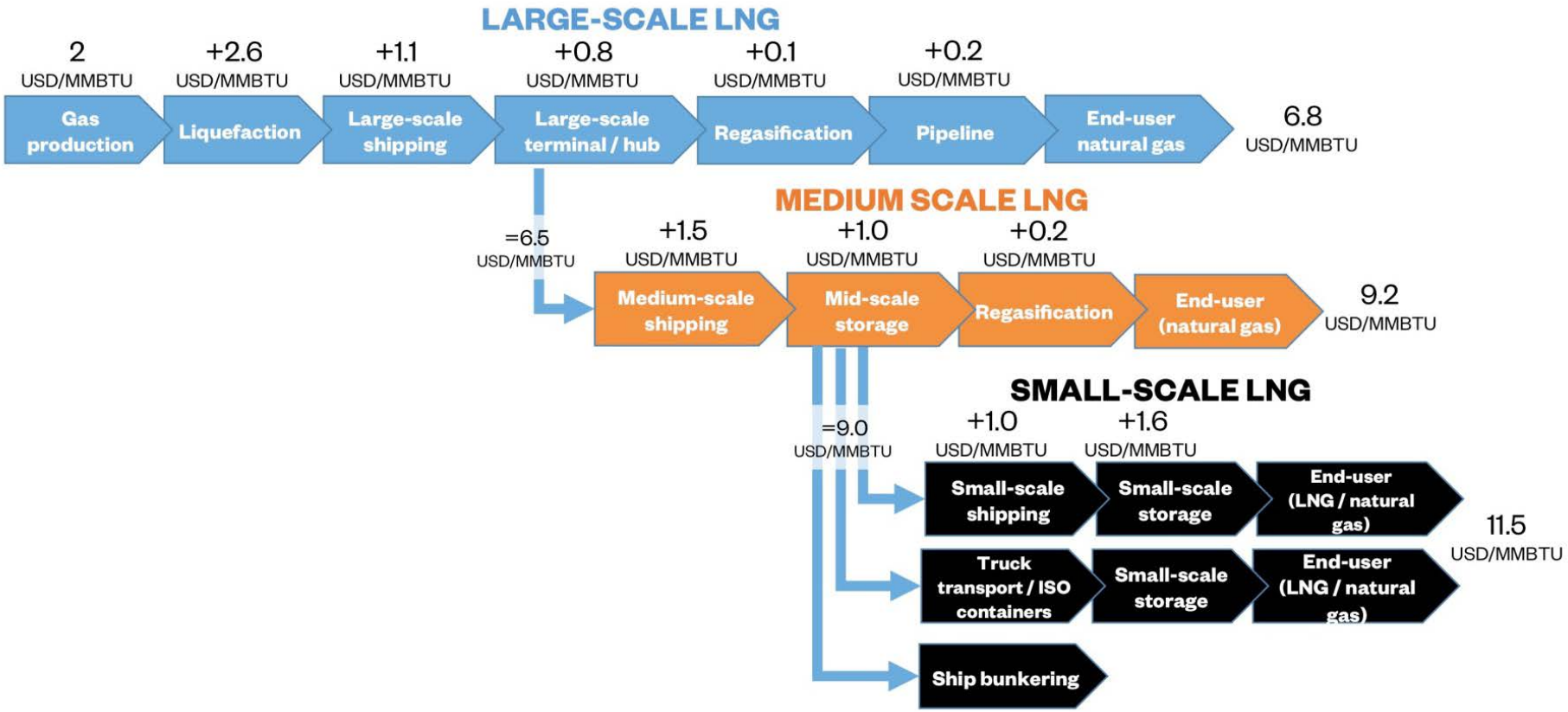
LNG vs. U.S./China “Trade War”

- **(Reuters) - China's interest in reducing its trade surplus with the United States through increased energy imports could advance plans for U.S. liquefied natural gas (LNG) plants and ethanol sales**
- "China represents an enormous economic opportunity for U.S. LNG and ethanol exports as both products will likely see dramatic demand growth in the coming years, during which time the United States is also expected to dominate global export markets," Katie Bays, energy analyst at Height Securities in Washington, DC, said in a note on Tuesday.
- Bays estimated that substantial **LNG sales commitments could bring in $20 billion to $30 billion an**nually and ethanol sales could reach $5 billion to $7 billion annually. She noted, however, that the LNG and ethanol markets were not big enough by themselves to meet President Donald Trump's **goal of reducing the Chinese trade deficit by $200 billion per year**.
- There are more than two dozen proposed U.S. LNG plants waiting for customer commitments to reach a final investment decision, many of them looking to China for deals.
- **China overtook South Korea in 2017 as the world's second biggest buyer of LNG behind Japan. The country, which imported 5.6 billion cubic feet per day last year, is looking to buy more low cost sources of energy, like gas, to reduce its use of coal and cut pollution.**
- "If you look at some forecasts for 2035, there are really only two places that have significant increases in LNG imports. Europe goes up about 100 mtpa and China goes up about 200 mtpa," Vesey said.
- Texas LNG, which is proposing a 4-mtpa export facility in Brownsville, Texas, and has five early-stage agreements with Chinese customers, hopes to make a final decision next year, about six months behind its original goal.
- "Sentiment in the LNG markets is heating up again," said Langtry Meyer, co-founder of the company. He added, however, that Texas LNG was not considering developing an import terminal in China, which would likely be needed to expand U.S. exports.
- **Cheniere, which signed a long-term LNG supply deal with a Chinese firm earlier this year, this month said it would soon make a final investment decision on a third liquefaction line at its Corpus Christi, Texas, facility.**

Power of Siberia

Oil & Gas Journal Feb 5, 2018

LNG Value Chain – The power of scale



Wärtsilä Technical Journal October 20, 2016

Summary

Countries/Regions

Liquefaction Capacity by Region

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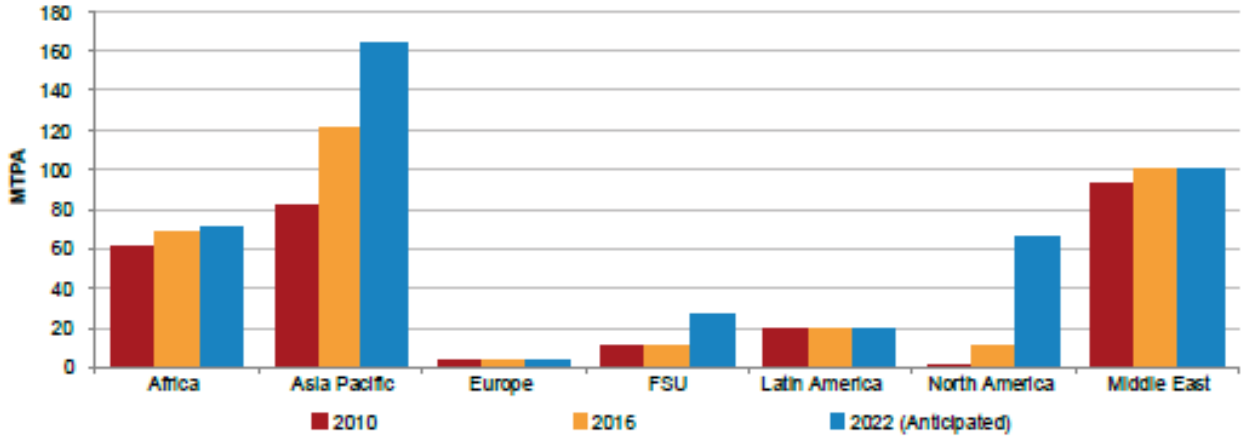
Figure 4.14: Liquefaction Capacity by Region in 2010, 2016, and 2022



Note: Liquefaction capacity only refers to existing and under-construction projects. Sources: IHS, Company Announcements

LNG Trade Between Basins

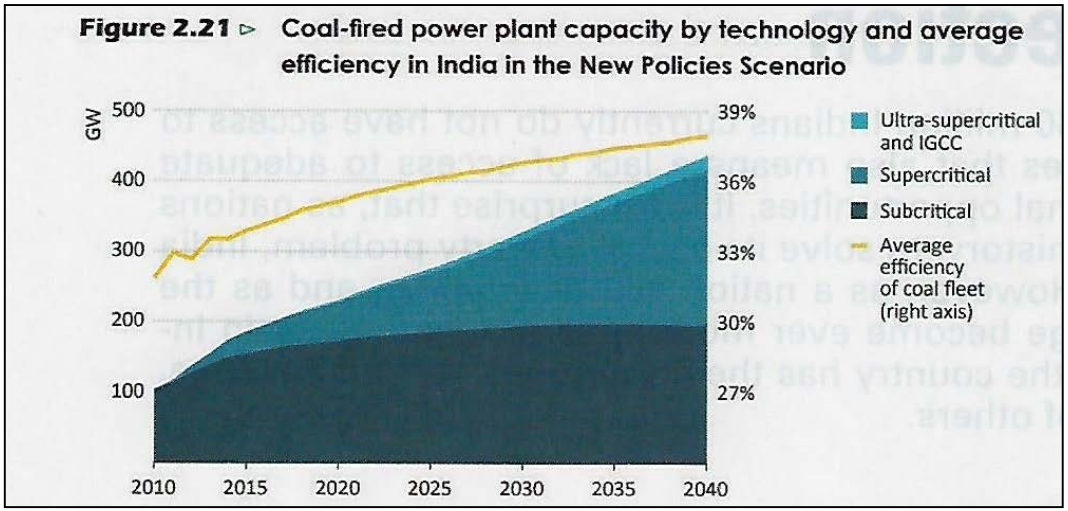
Table 3.1: LNG Trade between Basins, 2016, MT

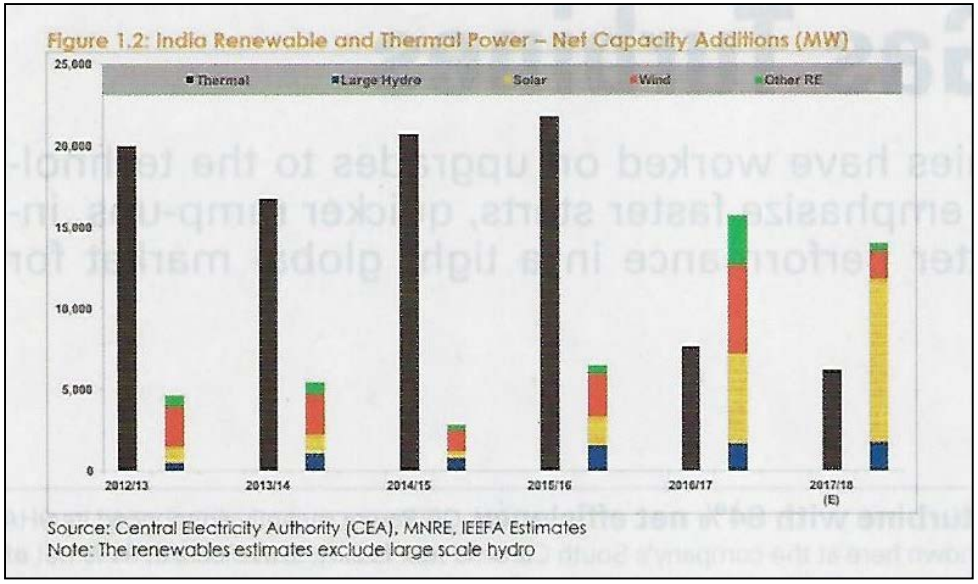
Exporting Region / Importing Region	Africa	Asia-Pacific	Europe	Former Soviet Union	Latin America	Middle East	North America	Re-exports Received	Re-exports Loaded	Total
Africa	1.2	0.3	0.2		0.4	4.4		0.8		7.3
Asia	5.5	21.5	0.2	0.3	1.1	18.9	0.5	0.7		48.6
Asia-Pacific	4.4	78.5	0.1	10.6	0.3	45.7		1.2	0.6	138.2
Europe	18.2		2.8		2.5	17.4	0.3	0.4	3.4	38.1
Latin America	1.7	0.1	0.7		5.2	1.0	1.2	0.7	0.4	10.1
Middle East	3.2	0.7	0.1		0.8	3.8	0.4	0.7		9.5
North America	0.7	0.5	0.1		4.3		0.5	0.1	0.1	6.1
Total	**34.8**	**99.5**	**4.3**	**10.8**	**14.6**	**91.0**	**2.9**	**4.5**	**-4.5**	**258.0**

Sources: IHS Markit, EIA, IGU

India

- Wind Power Installed Capacity
  - 25 GW 2015
  - 60 GW 2022
- Solar Power Installed Capacity
  - 4 MW 2005
  - 4,060 MW 2015
  - 100,000 MW 2022
- Cleaner, more efficient Biomass
  - 18% of total energy use
  - 70% of the population depends on it
- Small & Mini Hydro for electrification of remote villages
- Improve the efficiency of the Coal fleet
- 9,600 MW Jaitapur Nuclear Project
  - (6) PWR with EDF-France





Power Magazine May 2018

Stray Data
(Appendix)

AEO2014 Cost & Performance New Generating Tech

Technology	Online Year[1]	Size (MW)	Lead time (years)	Base Overnight Cost in 2013 (2012 $/kW)	Project Contingency Factor[2]	Technological Optimism Factor[3]	Total Overnight Cost in 2013[~] (2012 $/kW)	Variable O&M[~] (2012 $/MWh)	Fixed O&M (2012$/kW-yr.)	Heatrate[6] in 2013 (Btu/kWh)	nth-of-a-kind Heatrate (Btu/kWh)
Scrubbed Coal New	2017	1300	4	2,734	1.07	1.00	2,925	4.47	31.18	8,800	8,740
Integrated Coal-Gasification Comb Cycle (IGCC)	2017	1200	4	3,525	1.07	1.00	3,771	7.22	51.39	8,700	7,450
IGCC with carbon sequestration	2017	520	4	5,958	1.07	1.03	6,567	8.45	72.84	10,700	8,307
Conv Gas/Oil Comb Cycle	2016	620	3	871	1.05	1.00	915	3.60	13.17	7,050	6,800
Adv Gas/Oil Comb Cycle (CC)	2016	400	3	945	1.08	1.00	1,021	3.27	15.37	6,430	6,333
Adv CC with carbon sequestration	2017	340	3	1,856	1.08	1.04	2,084	6.78	31.79	7,525	7,493
Conv Comb Turbine[8]	2015	85	2	924	1.05	1.00	971	15.45	7.34	10,817	10,450
Adv Comb Turbine	2015	210	2	641	1.05	1.00	673	10.37	7.04	9,750	8,550
Fuel Cells	2016	10	3	6,099	1.05	1.10	7,044	42.99	0.00	9,500	6,960
Adv Nuclear	2019	2234	6	4,763	1.10	1.05	5,501	2.14	93.28	10,464	10,464
Distributed Generation - Base	2016	2	3	1,414	1.05	1.00	1,485	7.76	17.45	9,027	8,900
Distributed Generation - Peak	2015	1	2	1,698	1.05	1.00	1,783	7.76	17.45	10,029	9,880
Biomass	2017	50	4	3,590	1.07	1.02	3,919	5.26	105.64	13,500	13,500
Geothermal[7,9]	2016	50	4	2,375	1.05	1.00	2,494	0.00	112.92	9,716	9,716
Municipal Solid Waste	2014	50	3	7,751	1.07	1.00	8,294	8.75	392.81	18,000	18,000
Conventional Hydropower[3]	2017	500	4	2,213	1.10	1.00	2,435	2.65	14.83	9,716	9,716
Wind	2014	100	3	2,061	1.07	1.00	2,205	0.00	39.55	9,716	9,716
Wind Offshore	2017	400	4	4,503	1.10	1.25	6,192	0.00	74.00	9,716	9,716
Solar Thermal[7]	2016	100	3	4,715	1.07	1.00	5,045	0.00	67.26	9,716	9,716
Photovoltaic[7,10]	2015	150	2	3,394	1.05	1.00	3,564	0.00	24.69	9,716	9,716

AEO 2014 Early Release

BP Conversion Factors

Approximate conversion factors

Crude oil*

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

*Based on worldwide average gravity.

Products

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

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

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

Units

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

Calorific equivalents

One tonne of oil equivalent equals approximately:

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

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

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