

Electric Power Committee Fuels Report

PowerGen Conference
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New Orleans, LA

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“Practical Strategies for Emerging Energy Technologies”

Primary Energy Consumption by Fuel 2018 - Mtoe

Million tonnes oil equivalent	2017							2018							Percent of 2018	Annual Change
	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renewables	Total	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renewables	Total		
Canada	108.8	94.3	18.6	22.7	89.7	9.5	343.7	110.0	99.5	14.4	22.6	87.6	10.3	344.4	2.5%	0.2%
Mexico	85.8	74.3	15.2	2.5	7.2	4.3	189.3	82.8	77.0	11.9	3.1	7.3	4.8	186.9	1.3%	-1.3%
US	902.0	635.8	331.3	191.7	67.2	94.5	2222.5	919.7	702.6	317.0	192.2	65.3	103.8	2300.6	16.6%	3.5%
Total North America	1096.6	804.4	365.1	216.9	164.1	108.4	2755.5	1112.5	879.1	343.3	217.9	160.3	118.8	2832.0	20.4%	2.8%
Brazil	136.1	32.4	16.6	3.6	83.9	21.4	293.9	135.9	30.9	15.9	3.5	87.7	23.6	297.6	2.1%	1.3%
Total S. & Cent. America	317.2	148.4	34.8	4.9	163.0	31.5	699.8	315.3	144.8	36.0	5.1	165.5	35.4	702.0	5.1%	0.3%
France	79.1	38.5	9.3	90.1	11.1	9.4	237.5	78.9	36.7	8.4	93.5	14.5	10.6	242.6	1.7%	2.2%
Germany	119.0	77.2	71.5	17.3	4.6	44.4	333.9	113.2	75.9	66.4	17.2	3.8	47.3	323.9	2.3%	-3.0%
Italy	62.0	61.5	9.6	-	7.8	15.3	156.3	60.8	59.5	8.9	-	10.4	14.9	154.5	1.1%	-1.1%
Poland	31.7	16.5	49.8	-	0.6	4.9	103.4	32.8	17.0	50.5	-	0.4	4.4	105.2	0.8%	1.7%
Spain	65.0	27.3	13.4	13.1	4.2	15.7	138.8	66.6	27.1	11.1	12.6	8.0	16.0	141.4	1.0%	1.8%
Turkey	49.2	44.3	39.5	-	13.2	6.6	152.7	48.6	40.7	42.3	-	13.5	8.5	153.5	1.1%	0.5%
United Kingdom	78.0	67.8	9.1	15.9	1.3	21.1	193.2	77.0	67.8	7.6	14.7	1.2	23.9	192.3	1.4%	-0.5%
Total Europe	746.2	481.9	315.5	211.8	132.3	162.3	2050.0	742.0	472.0	307.1	212.1	145.3	172.2	2050.7	14.8%	0.0%
Russian Federation	151.5	370.7	83.9	46.0	41.9	0.3	694.3	152.3	390.8	88.0	46.3	43.0	0.3	720.7	5.2%	3.8%
Total CIS	191.1	472.3	126.4	46.6	54.3	0.5	891.2	193.5	499.4	134.9	46.7	55.4	0.6	930.5	6.7%	4.4%
Iran	84.5	180.5	1.4	1.6	3.9	0.1	272.0	86.2	193.9	1.5	1.6	2.4	0.1	285.7	2.1%	5.0%
Saudi Arabia	168.8	93.9	0.1	-	-	^	262.8	162.6	96.4	0.1	-	-	^	259.2	1.9%	-1.4%
United Arab Emirates	43.8	64.0	1.0	-	-	0.1	109.0	45.1	65.8	1.1	-	-	0.2	112.2	0.8%	3.0%
Total Middle East	412.5	453.2	8.2	1.6	4.7	1.3	881.4	412.1	475.6	7.9	1.6	3.4	1.7	902.3	6.5%	2.4%
South Africa	27.5	3.8	84.3	3.6	0.2	2.4	121.8	26.3	3.7	86.0	2.5	0.2	2.8	121.5	0.9%	-0.2%
Total Africa	192.1	121.0	97.6	3.6	28.2	6.1	448.6	191.3	129.0	101.4	2.5	30.1	7.2	461.5	3.3%	2.9%
Australia	51.1	35.5	45.1	-	3.1	5.8	140.5	53.3	35.6	44.3	-	3.9	7.2	144.3	1.0%	2.7%
China	610.7	206.7	1890.4	56.1	263.6	111.4	3139.0	641.2	243.3	1906.7	66.6	272.1	143.5	3273.5	23.6%	4.3%
India	227.1	46.2	415.9	8.5	30.7	21.7	750.1	239.1	49.9	452.2	8.8	31.6	27.5	809.2	5.8%	7.9%
Indonesia	79.3	33.1	57.2	-	4.2	3.0	176.9	83.4	33.5	61.6	-	3.7	3.3	185.5	1.3%	4.9%
Japan	187.8	100.6	119.9	6.6	17.9	22.4	455.2	182.4	99.5	117.5	11.1	18.3	25.4	454.1	3.3%	-0.2%
South Korea	130.0	42.8	86.2	33.6	0.6	4.0	297.1	128.9	48.1	88.2	30.2	0.7	5.0	301.0	2.2%	1.3%
Taiwan	50.1	20.0	39.4	5.1	1.2	1.2	117.0	50.0	20.3	39.3	6.3	1.0	1.5	118.4	0.9%	1.2%
Thailand	64.4	43.1	18.3	-	1.1	3.4	130.2	65.8	42.9	18.5	-	1.7	4.0	133.0	1.0%	2.1%
Total Asia Pacific	1651.3	660.6	2770.8	111.7	373.2	180.2	5748.0	1695.4	709.6	2841.3	125.3	388.9	225.4	5985.8	43.2%	4.1%
Total World	4607.0	3141.9	3718.4	597.1	919.9	490.2	13474.6	4662.1	3309.4	3772.1	611.3	948.8	561.3	13864.9	100.0%	2.9%
% of Total	34.2%	23.3%	27.6%	4.4%	6.8%	3.6%	100.0%	33.6%	23.9%	27.2%	4.4%	6.8%	4.0%	100.0%		
Annual Change								1.2%	5.3%	1.4%	2.4%	3.1%	14.5%	2.9%		

U.S. = 91.2 Quads

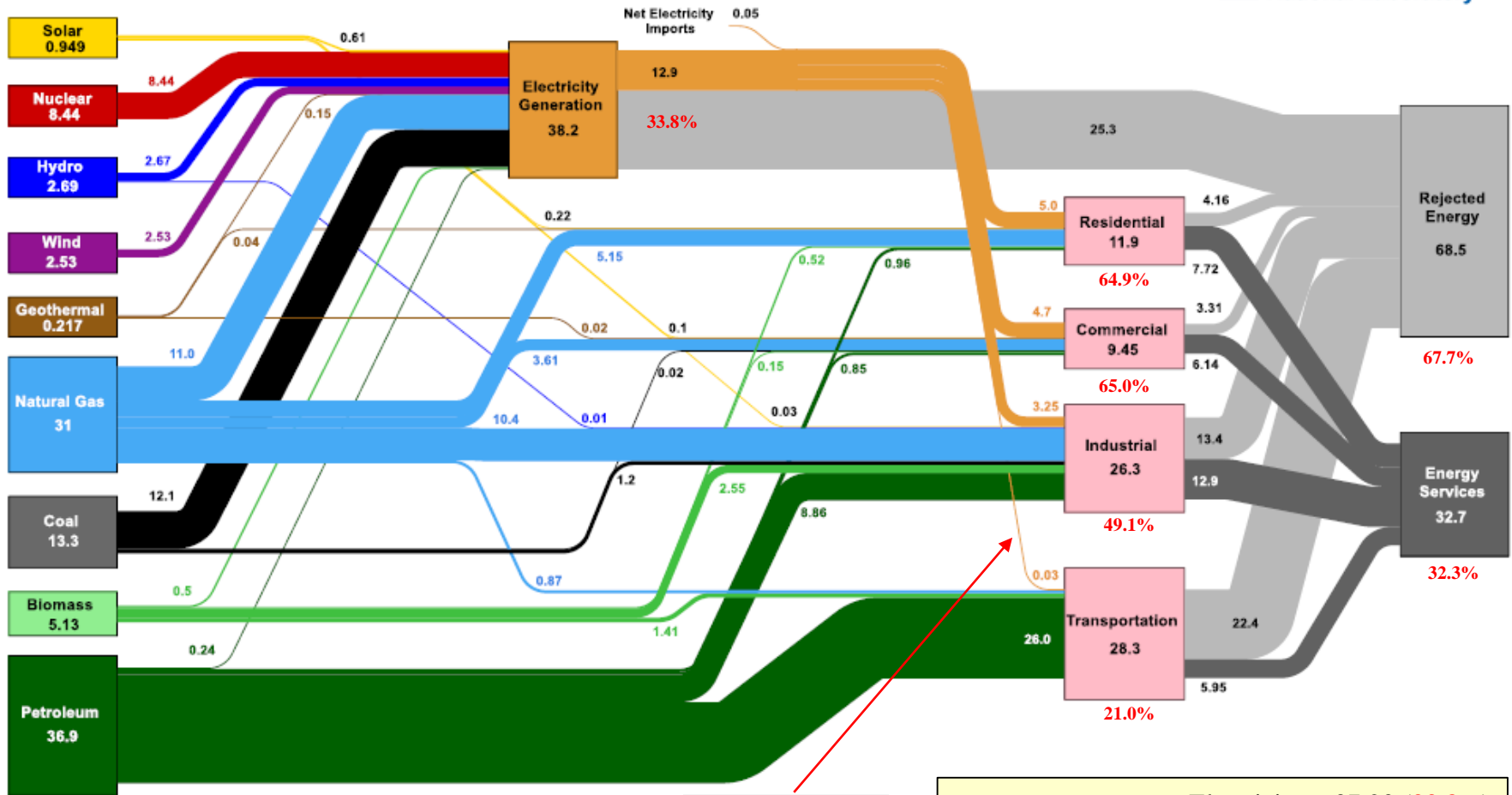


13,864.9 Mtoe = 549.8 Quads

U.S. 2018 Energy Flow – 101.2 Quads

BP Stats 2018 = 91.2
Renewables (no Hydro) = 8.8

Estimated U.S. Energy Consumption in 2018: 101.2 Quads



Electric Vehicles

Electricity = 37.20 (33.8%)
Residential = 10.70 (65.0%)
Commercial/Industrial = 34.19 (49.1%)
Transportation = 28.10 (21.0%)



“Practical Strategies for Emerging Energy Technologies”

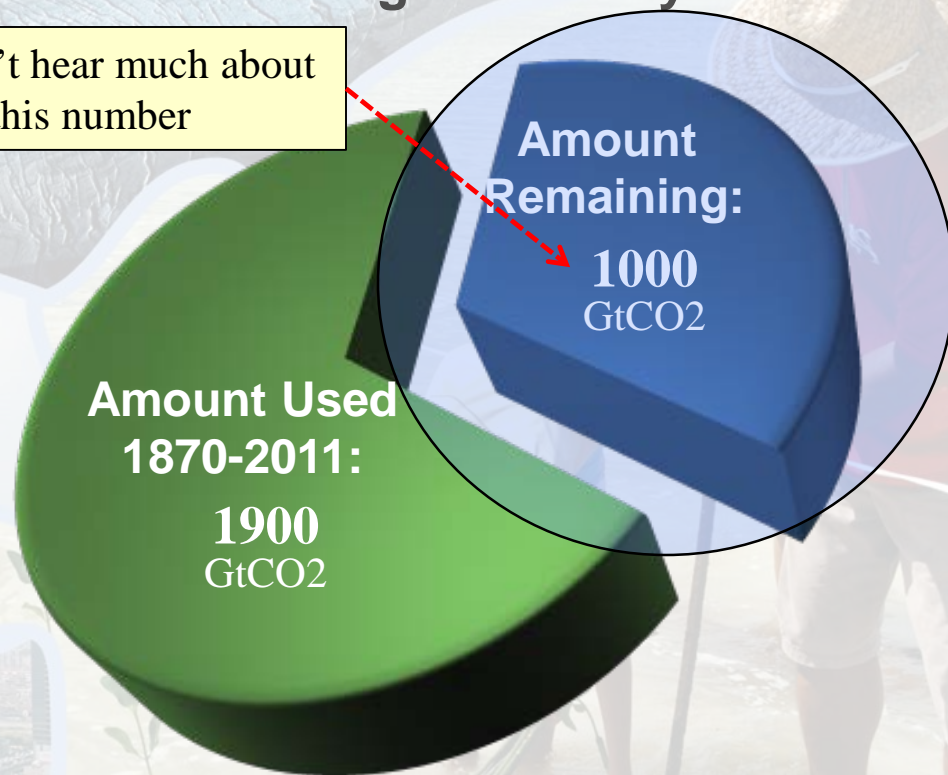
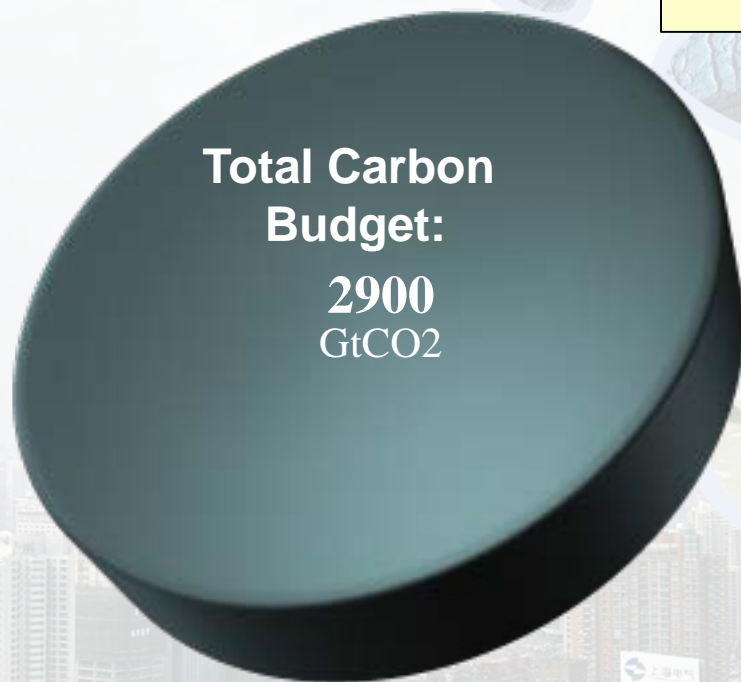
Issues

- **Climate Change**
- **Renewables**
 - System Integration
- **Natural Gas**
 - Supply/Demand
 - LNG
- **Geopolitical**
 - China
 - Russia
 - Iran
- **H2 Economy**
 - Impact on Gas Turbine Industry

The window for action is rapidly closing

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

We don't hear much about this number



AR5 WGI SPM

base

IPCC AR5 Synthesis Report

“Practical Strategies for Emerging Energy Technologies”

ipcc

climate change



EIA WW Annual Energy Outlook 2017

Reference Case includes CPP

Carbon dioxide emissions (Mmt): Reference Case											Growth	
	2010	2015	2016	2017	2020	2025	2030	2035	2040	2045	2050	(2015-2050)
OECD Americas	6622.5	6341.5	6237.4	6271.3	6341.1	6175.4	5966.9	5970.4	6074.2	6217.4	6384.6	0.00%
United States	5570.5	5247.6	5145.5	5171.3	5260.2	5057.0	4839.4	4815.6	4866.8	4956.8	5072.6	-0.10%
Canada	555.0	590.3	592.6	603.8	586.8	600.6	595.7	607.6	626.3	649.2	671.8	0.40%
Mexico/Chile	497.0	503.7	499.2	496.3	494.2	517.8	531.8	547.2	581.0	611.3	640.1	0.70%
OECD Europe	4159.8	3858.0	3930.0	3962.6	3922.6	3814.0	3798.1	3902.6	3988.2	4096.9	4260.6	0.30%
OECD Asia	2093.9	2233.6	2240.6	2228.4	2185.8	2209.0	2243.1	2284.3	2332.5	2389.0	2466.2	0.30%
Japan	1108.0	1154.1	1139.6	1132.8	1072.6	1058.4	1038.2	1014.2	987.1	961.3	944.5	-0.60%
South Korea	563.0	663.0	687.8	683.4	702.3	720.9	751.3	791.0	835.2	881.2	930.2	1.00%
Australia/New Zealand	422.9	416.5	413.3	412.3	410.9	429.7	453.7	479.1	510.1	546.5	591.5	1.00%
Total OECD	12876.2	12433.1	12408.0	12462.4	12449.5	12198.4	12008.1	12157.4	12394.9	12703.2	13111.4	0.20%
Non-OECD Europe and Eurasia	2646.7	2691.8	2661.9	2665.1	2630.4	2582.8	2570.0	2616.9	2624.6	2599.8	2574.1	-0.10%
Russia	1620.0	1675.8	1636.5	1632.9	1609.8	1583.3	1587.1	1615.8	1615.0	1582.3	1540.9	-0.20%
Other	1026.7	1016.0	1025.3	1032.3	1020.6	999.4	983.0	1001.1	1009.6	1017.5	1033.3	0.00%
Non-OECD Asia	11320.1	14293.8	14546.9	14819.4	15167.5	16050.0	16589.1	17384.2	18285.7	19226.4	20056.6	1.00%
China	7746.0	9923.6	10009.5	10157.3	10205.1	10464.0	10421.8	10298.1	10161.1	10017.6	9792.9	0.00%
India	1612.0	2001.8	2108.3	2160.7	2305.3	2552.1	2883.6	3388.8	3959.2	4544.9	5043.1	2.70%
Other	1962.1	2368.4	2429.1	2501.3	2657.1	3033.8	3283.6	3697.3	4165.4	4663.9	5220.6	2.30%
Middle East	1730.4	1959.1	1966.1	2020.3	2085.0	2192.3	2315.6	2495.1	2691.8	2923.3	3117.4	1.30%
Africa	1067.3	1251.4	1274.6	1319.7	1370.4	1444.2	1505.5	1591.5	1739.8	1905.7	2100.1	1.50%
Non-OECD Americas	1193.7	1272.4	1237.9	1232.3	1269.6	1354.9	1409.5	1472.8	1580.8	1693.7	1811.7	1.00%
Brazil	457.0	482.3	459.8	452.1	470.0	513.7	540.2	561.1	595.8	633.2	668.4	0.90%
Other	736.7	790.2	778.1	780.2	799.7	841.2	869.3	911.7	985.0	1060.5	1143.3	1.10%
Total Non-OECD	17958.2	21468.6	21687.3	22056.8	22522.9	23624.1	24389.7	25560.6	26922.7	28349.0	29660.0	0.90%
Total World	30834.4	33901.8	34095.3	34519.2	34972.4	35822.5	36397.8	37717.9	39317.6	41052.2	42771.4	0.70%

Source: U.S. Energy Information Administration

<https://www.eia.gov/outlooks/aeo/data/browser/#/?id=10-IEO2017®ion=0-0&cases=Reference-2010&end=2050&f=A&linechart=Reference-d082317.2-10-IEO2017&sourcekey=0>

Wed Sep 20 2017 12:46:07 GMT-0400 (Eastern Daylight Time)

2018 = 37.1Gt

34519.2 MMT = 34.5 Gt

base_e

“Practical Strategies for Emerging Energy Technologies”

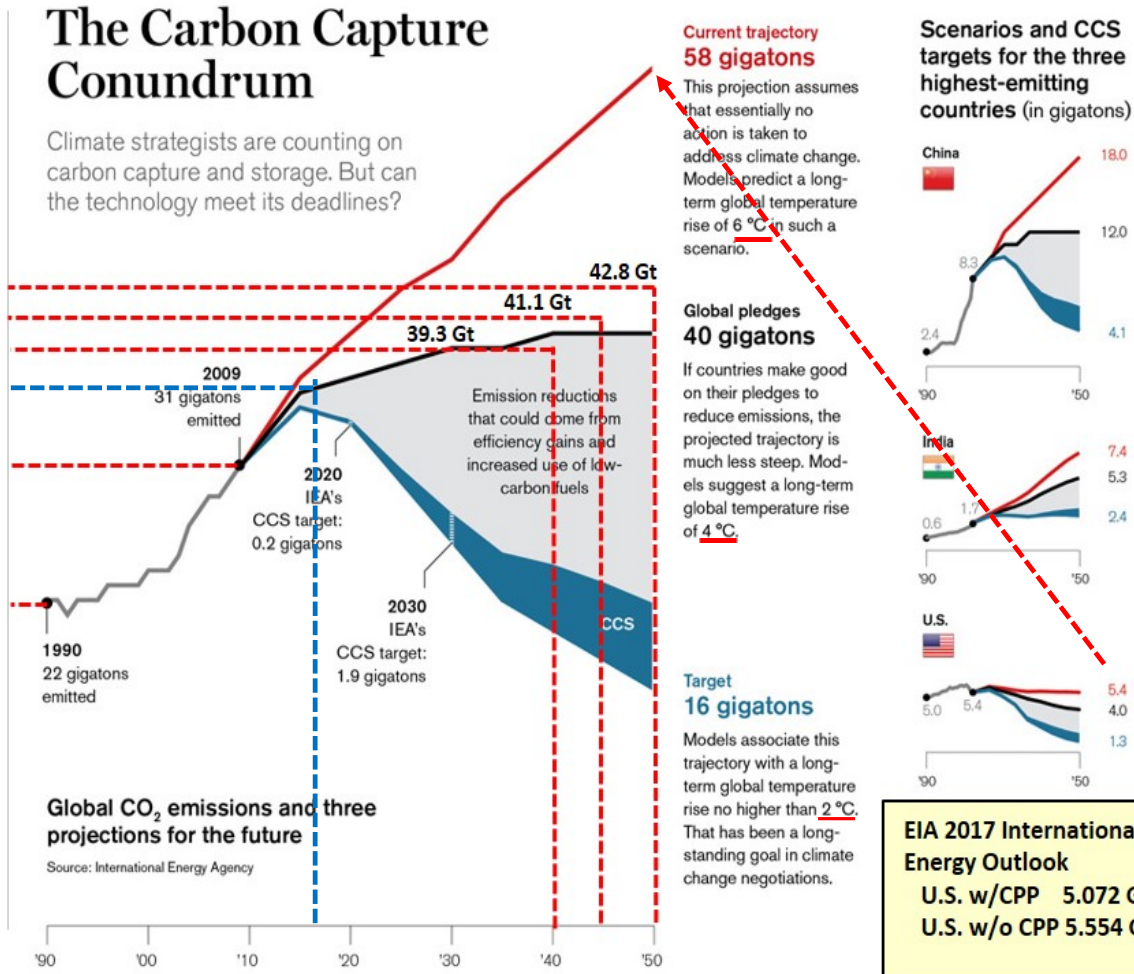
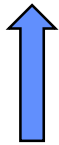
EIA Annual Energy Outlook 2018

The world is on the 4°C trajectory!!!

The Carbon Capture Conundrum

Climate strategists are counting on carbon capture and storage. But can the technology meet its deadlines?

Values from EIA WW Annual Energy Outlook 2017 (previous slide)
37.1 Gt in 2018
4°C trajectory



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



U.S. EIA Annual Energy Outlook 2018

10 Cases
Sorted High-Low, 2050

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%

~6°C Trajectory

CPP Impact Ref Case	0	24	43	87	121	205	319	266	Clean Power Plan Effect is tiny
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Energy-Related Carbon Dioxide Emissions Intensity by Sector and Source (MMmtCO ₂ /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%



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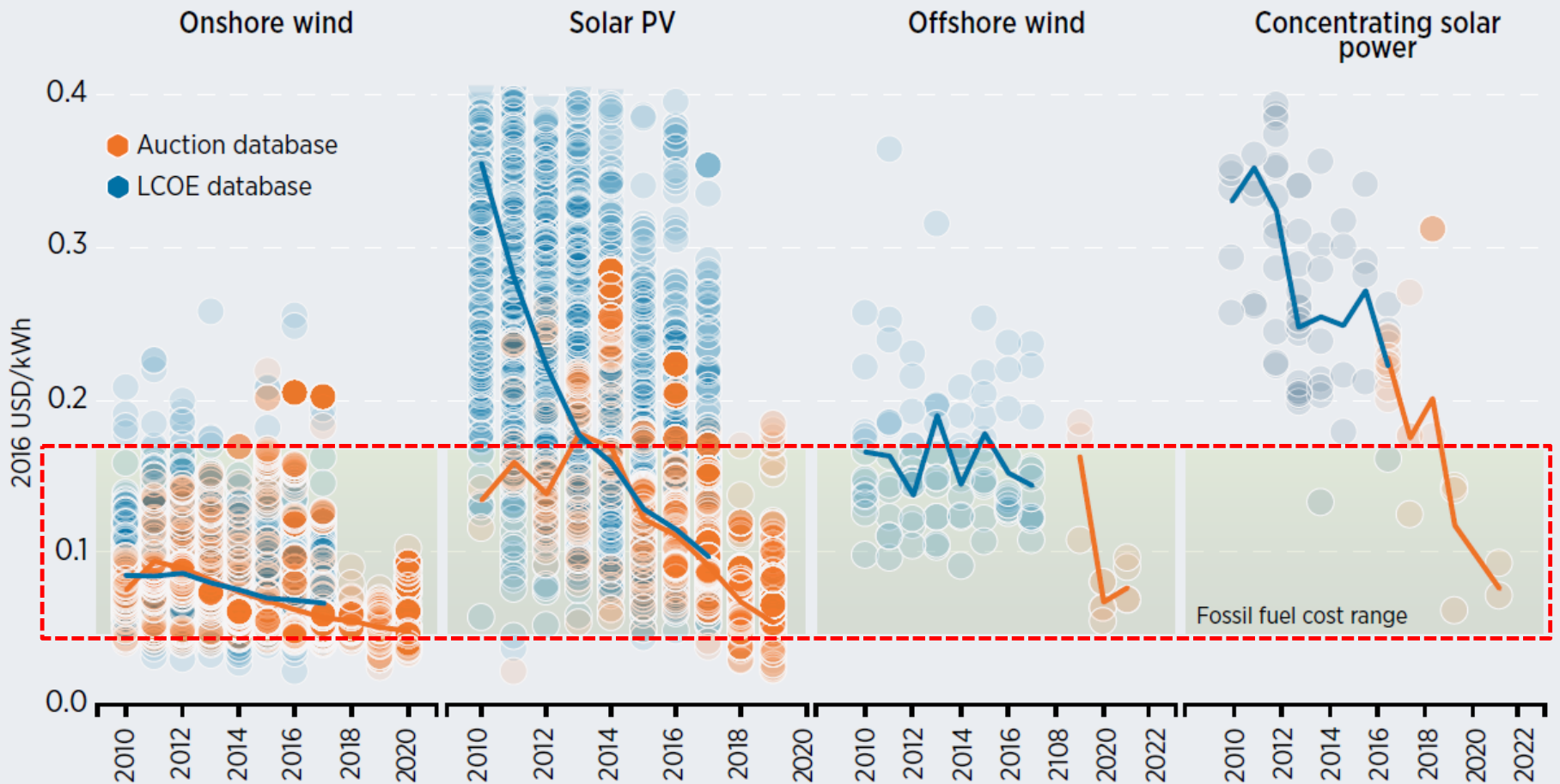
U.S. Energy-Related CO₂ Emissions by Sector & Source

Sector and Source	2015	2020	2025	2030	2035	2040	2015-2040
Residential							
Petroleum	64	59	53	49	45	41	-1.7%
Natural Gas	253	258	256	255	253	251	0.0%
Electricity 1/	711	664	586	538	531	529	-1.2%
Total Residential	1,028	981	895	841	829	821	-0.9%
Commercial							
Petroleum	47	50	49	49	48	47	0.0%
Natural Gas	176	183	184	188	194	202	0.5%
Coal	6	5	5	5	5	5	-0.4%
Electricity 1/	690	654	599	566	569	572	-0.7%
Total Commercial	918	893	836	807	817	826	-0.4%
Industrial 2/							
Petroleum	378	410	431	434	443	458	0.8%
Natural Gas 3/	478	524	560	579	609	636	1.2%
Coal	130	120	128	131	130	131	0.0%
Electricity 1/	486	504	481	443	436	434	-0.5%
Total Industrial	1,472	1,558	1,600	1,587	1,618	1,660	0.5%

Sector and Source	2015	2020	2025	2030	2035	2040	2015-2040
Transportation							
Petroleum 4/	1,800	1,802	1,720	1,652	1,629	1,628	-0.4%
Natural Gas 5/	51	49	55	62	74	93	2.4%
Electricity 1/	5	6	10	12	15	16	5.1%
Total Transportation	1,855	1,857	1,784	1,726	1,717	1,737	-0.3%
Electric Power 6/							
Petroleum	20	11	10	8	7	6	-4.4%
Natural Gas	524	451	509	602	608	653	0.9%
Coal	1,340	1,360	1,150	943	930	885	-1.6%
Other 7/	6	6	6	6	6	6	0.0%
Total Electric Power	1,891	1,829	1,675	1,559	1,551	1,551	-0.8%
Total by Fuel							
Petroleum 4/	2,309	2,332	2,262	2,191	2,171	2,181	-0.2%
Natural Gas	1,482	1,466	1,563	1,685	1,737	1,835	0.9%
Coal	1,476	1,485	1,283	1,079	1,065	1,021	-1.5%
Other 7/	6	6	6	6	6	6	0.0%
Total	5,273	5,289	5,115	4,961	4,980	5,044	-0.2%
Carbon Dioxide Emissions							
(tons carbon dioxide per person)	16.4	15.8	14.7	13.8	13.4	13.3	-0.8%

CO₂ emissions flat thru 2040
New metric introduced tonnes(?) per person

Renewables Levelized Cost 2010 & 2014



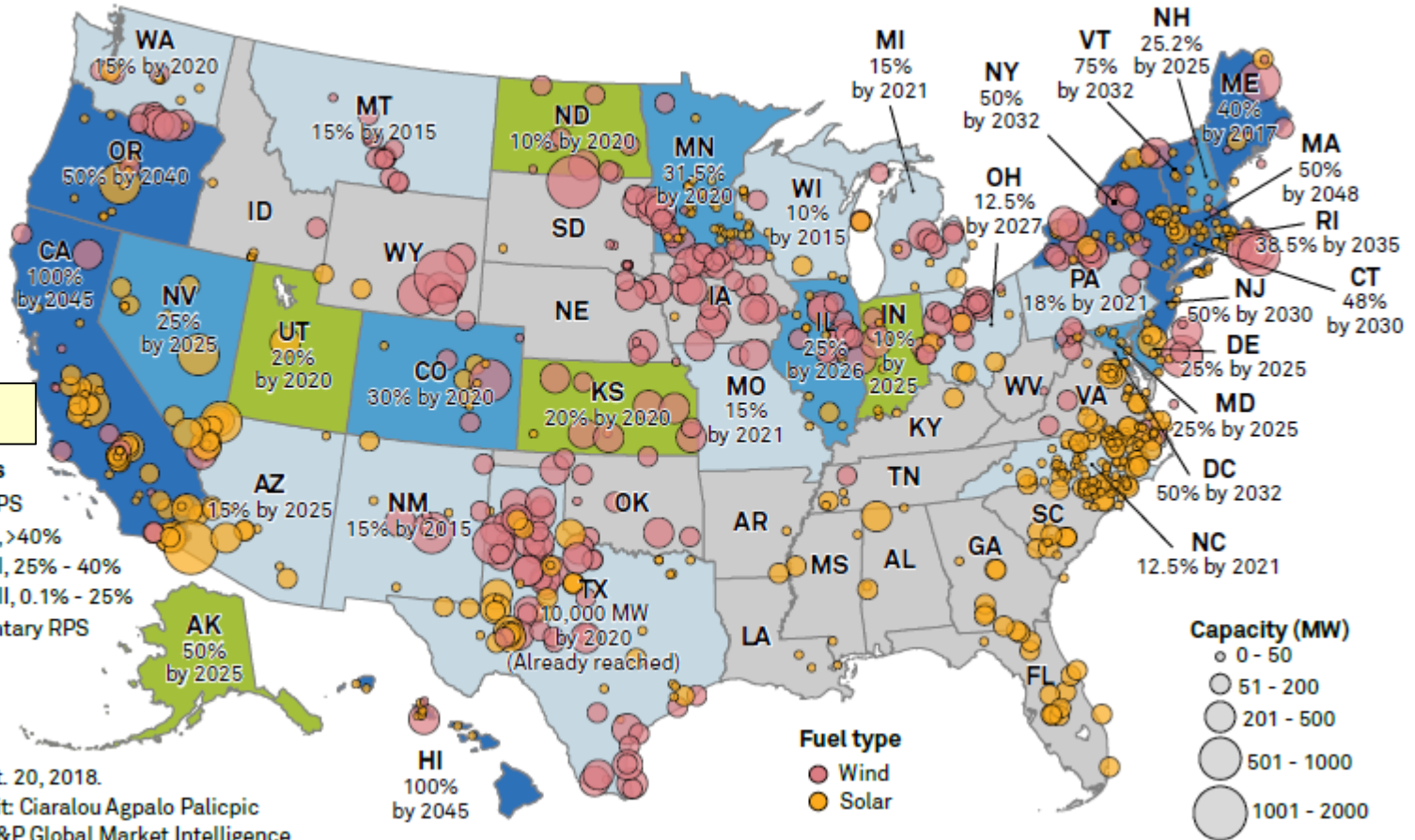
Source: IRENA Renewable Cost Database and Auctions Database.



“Practical Strategies for Emerging Energy Technologies”

Planned Wind & Solar Project 2018-2025

US Wind and Solar Planned Projects 2018-2025



Note: RPS Tiers

As of Sept. 20, 2018.
 Map credit: Ciaralou Aggalo Palicpic
 Source: S&P Global Market Intelligence

Phase Out of PTC in 2024



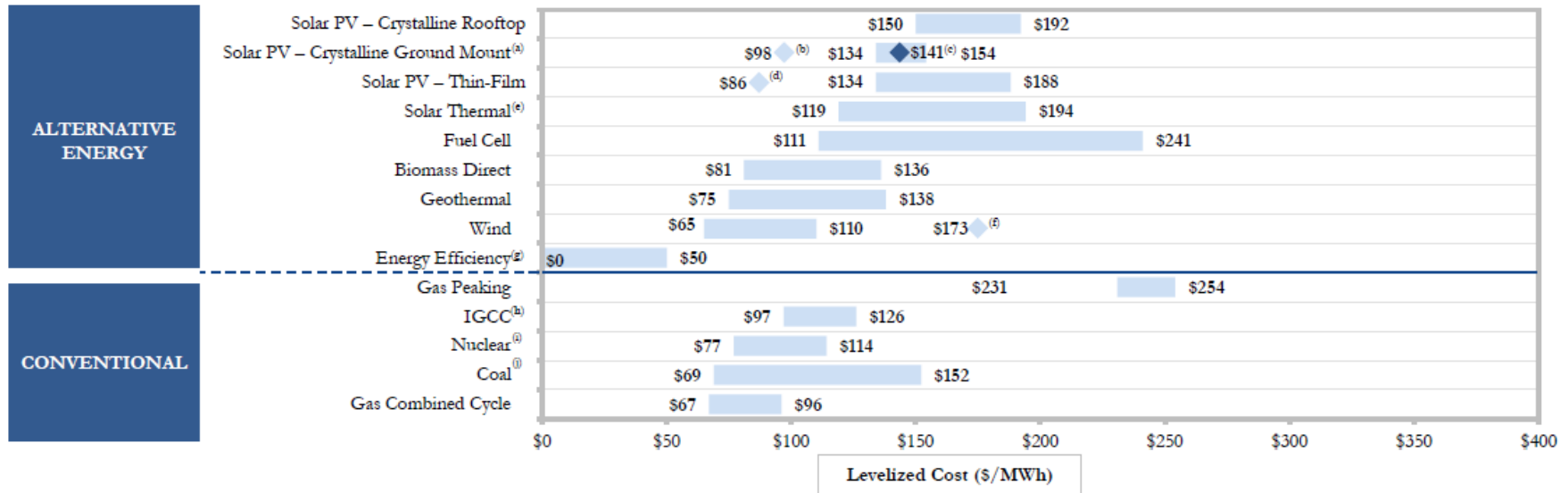
“Practical Strategies for Emerging Energy Technologies”

Offshore Wind (OSW) & Storage

- Currently, OSW's midpoint unsubsidized levelized cost of energy (LCOE) is **\$92/MWh** and its capital cost is \$3,025/kW, according to [the 2018 Lazard report](#). By comparison, natural gas ranges \$41/MWh to \$74/MWh.
- Advances in Europe and China have brought prices to as low as **\$61.56/MWh** and **\$51.48/MWh** in 2018, according to [the Global Wind Energy Council \(GWEC\) April 2019 market report](#).
- With scale, [U.S. prices can match those in Europe](#), National Renewable Energy Laboratory (NREL) Research Scientist, Walt Musial told Utility Dive last year.
- That is why states like [New York](#), [New Jersey](#) and [Massachusetts](#) have set targets for both storage and offshore wind, and Maryland requires [a portion of its renewable portfolio standard](#) come from offshore wind and has a 30% investment tax credit for storage.
- Connecticut has a [2 GW offshore wind](#) mandate and [Maine](#) and [Delaware](#) currently have policy in place encouraging offshore wind buildout as well.
- Consolidated Edison (ConEd) has a competitive solicitation out for 300 MW of storage by December 2022.
- Currently, only one 30 MW U.S. project is operational, but eight projects representing 1,958 MW are in development, [a June 2019 industry white paper reported](#).
- The unsubsidized levelized cost of a utility-scale solar plus storage project with 4-hour lithium ion batteries is \$108/MWh to \$140/MWh, and its capital cost is \$1,559/kW to \$2,162/kW, [Lazard reported in November 2018](#).
- More important are Lazard's forecasted drops in storage costs, Huber said. By 2022, the cost of lithium ion storage is expected to drop 28% and longer-duration flow battery chemistries are forecasted to fall 38% to 45%.



Lazar's LCOE



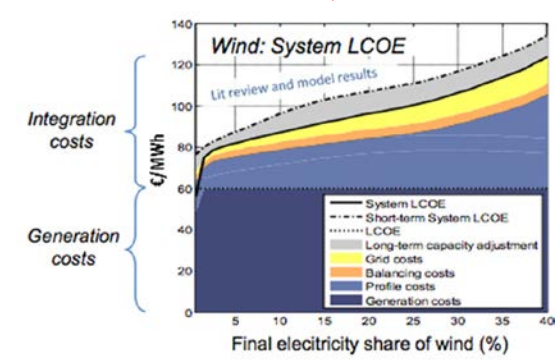
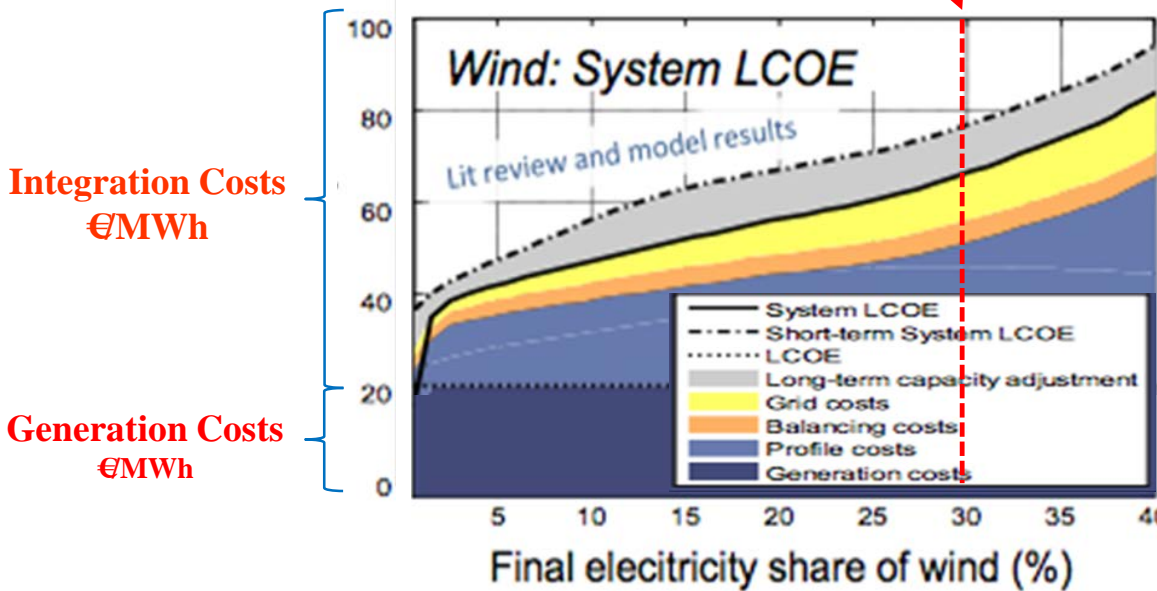
Levelized Cost of Energy Comparison

Certain Alternative Energy generation technologies are becoming increasingly cost-competitive with conventional generation technologies under some scenarios, before factoring in environmental and other externalities (e.g., RECs, potential carbon emission costs, transmission and back-up generation/system reliability costs) as well as construction and fuel costs dynamics affecting conventional generation technologies

Wind System Integration Cost – “Eye-Balled”

- Original slide (lower right) needed to be adjusted for lower wind generation costs
- I “eye-balled” this chart to adjust
- At a **30% Renewable Portfolio Standard** value
 - Generation is €20/MWh
 - Integration is €55/MWh
 - Total is €75/MWh (~\$85/MWh)
- **The original study should be updated**

Who Pays for Renewables Integration????

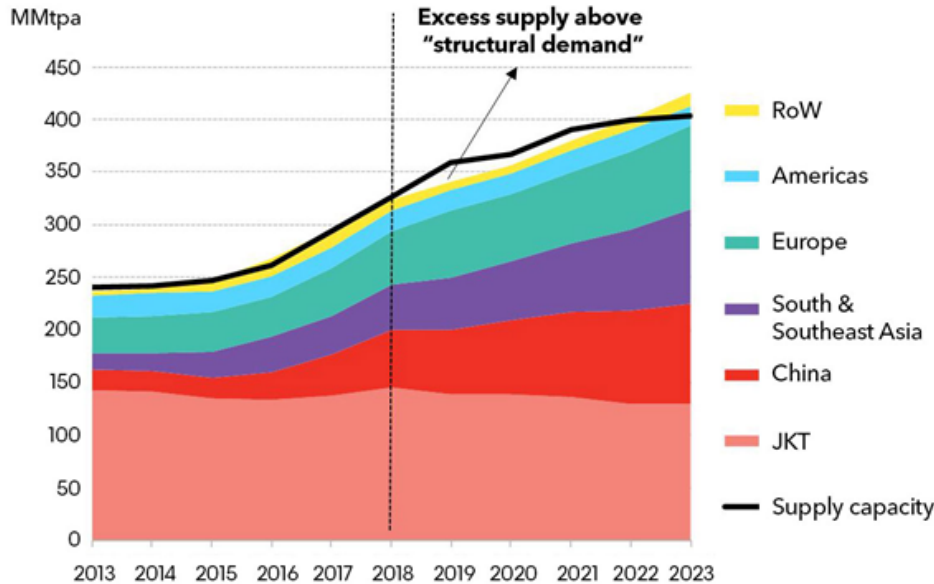


BNEF LNG Supply/Demand Analysis

- Recent years have seen rapid growth in the global market for LNG, with volumes of exports and imports up 10% in 2018 alone.
- Growth rates of **LNG exports and imports are seen moving out of sync in 2019-2023**, with exports increasing faster than imports in 2019 and **then imports outstripping exports in 2022-2023**.
- BNEF's *Global LNG Outlook 2019-2023* sees LNG supply jumping by 33 million metric tons per year in 2019, reaching a record 358MMtpa, with the U.S. Gulf Coast, Australia and Russia commissioning or expanding export facilities. Meanwhile, 'structural' LNG demand, or weather-neutral demand at current LNG prices, is expected to rise by 17MMtpa this year, thanks to additional purchases for power generation and heating in Europe and Asia.
- A further seven multibillion-dollar LNG export projects, including three in Louisiana in the U.S. and two in Mozambique, are close to a final investment decision and are likely to put extra supply into world markets post-2023.
- John Twomey, head of European gas analysis at BNEF, said: "Europe will become increasingly import-dependent for its gas over the next few years. The LNG market is forecast to tighten by 2023, and European prices will need to be high enough to compete with those of fast-growing markets in Asia and to attract LNG imports."
- On the supply side, 2018 saw the start of production at three LNG 'trains', or liquefaction and export facilities, in Australia, at two more in Russia and three in the U.S. The world's largest LNG producer, Qatar, increased production only marginally.
- One important symbolic change for LNG is the gradual shift away from using crude oil as the price benchmark for contracts, to using a gas index

LNG Supply/Demand

Global LNG demand and supply capacity balance



Source: BloombergNEF. Note: *Structural demand* refers to weather neutral demand at current LNG prices. Supply capacity is available capacity each year after taking into consideration of quarterly-prorated nameplate capacity based on expected project commissioning timelines and maintenance and retirement assumptions on existing project capacity. JKT stands for Japan, South Korea and Taiwan. RoW stands for rest of the world. Europe includes EU28, Turkey and all other European importing countries.

BNEF

McKinsey

Over the past 12 months, the gas market expanded by 5.3%, while the LNG segment grew at 8.6% in 2018

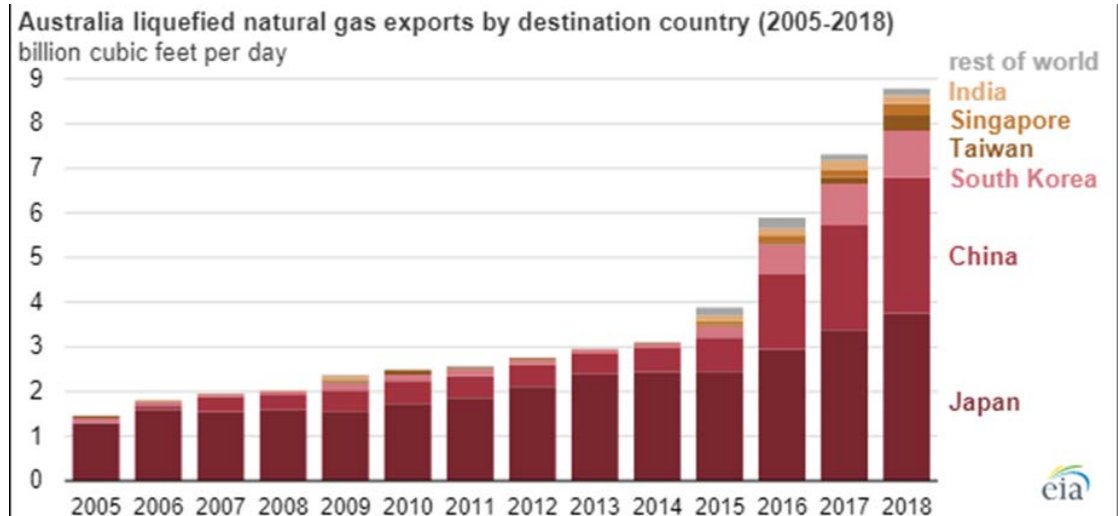
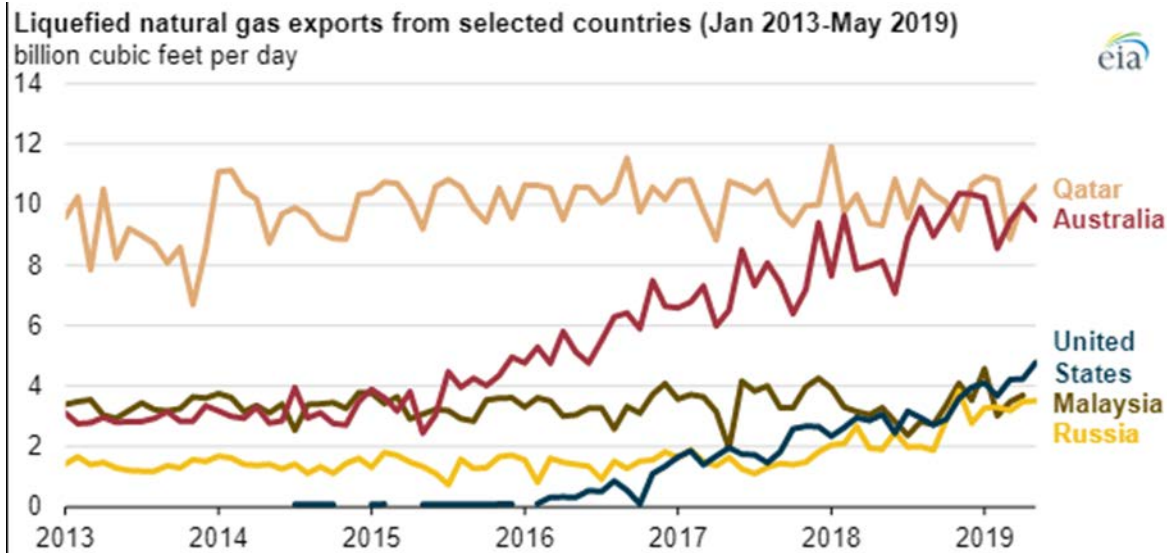
Until 2035, gas will be the fastest-growing fossil fuel, with growth of 0.9% per year

While LNG demand will grow at 3.6% per year in 2018–35, supply-capacity additions will create a 'long' market until 2025—and possibly until 2027

Meeting additional LNG demand after 2027–28 will require more than \$400 billion of investment across the LNG value chain

Long-term LNG contract-pricing mechanisms, including price indexation and slope, are evolving rapidly

Australia to become World's Largest LNG exporter

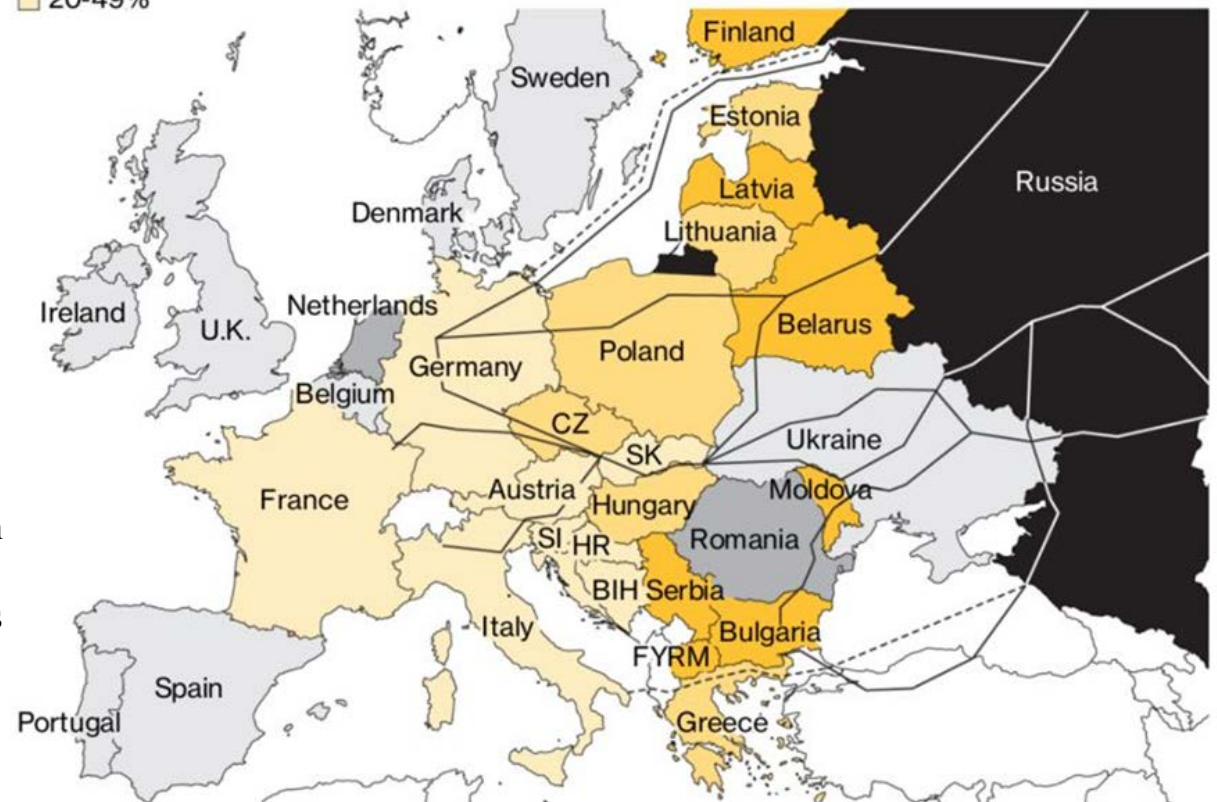
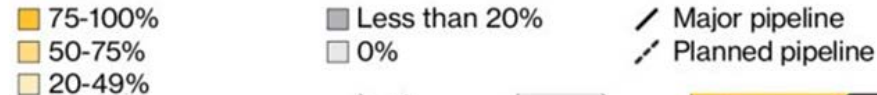


1/3 of Europe's Gas Comes From Russia

- H2 is already blended in a small proportion into Europe's gas pipeline network.
- What Gazprom is envisioning is gradually boosting the share of hydrogen in those pipelines and then **turning its natural gas into hydrogen through green processes that don't exacerbate global warming.**
 - Several technologies to produce hydrogen including water electrolysis are being developed
 - Gazprom is investigating one process known as thermal methane pyrolysis.
- A ratio of over 25 percent of hydrogen used in the pipeline networks can lead to lower crack resistance in steel pipes and increases over 30 percent may require adaptation of turbines and compressors, according to Thinkstep.

Who's Dependent on Russian Gas?

About a third of Europe's gas comes from Russia



2017 data. Source: Agency for the Cooperation of Energy Regulators BloombergQuickTake

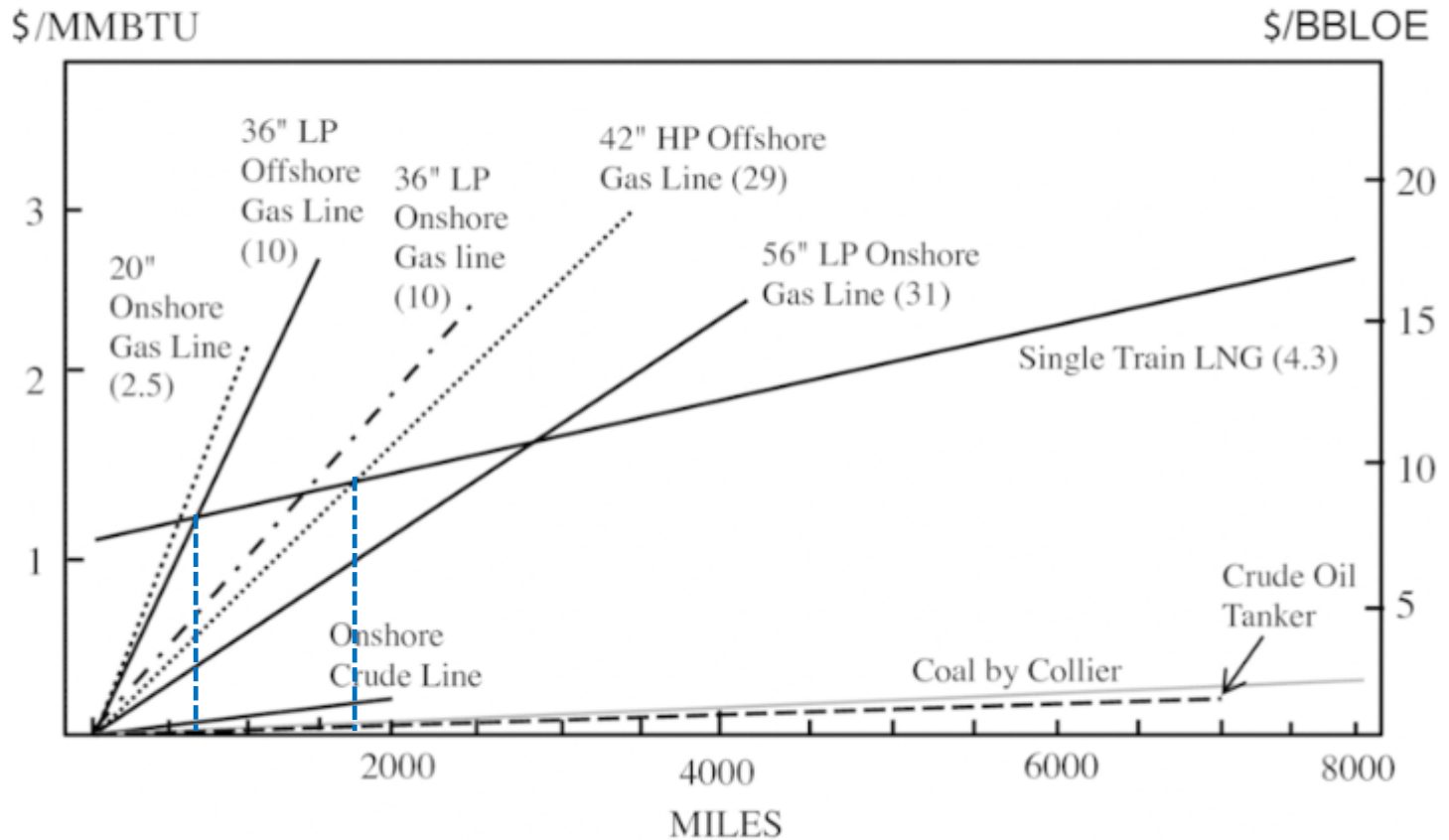
Russian LNG Projects

Russian LNG Projects



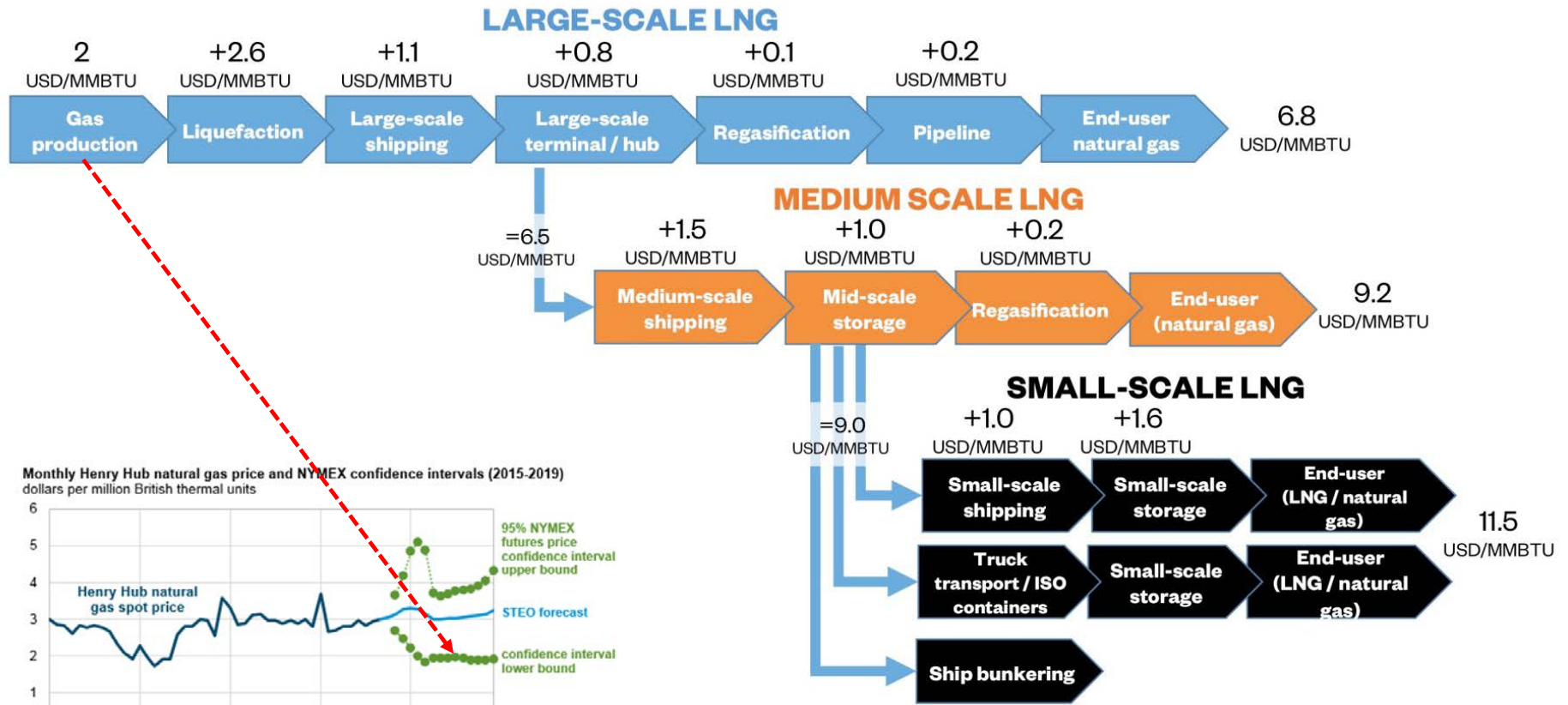
Jensen 2004 Break-even Points

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

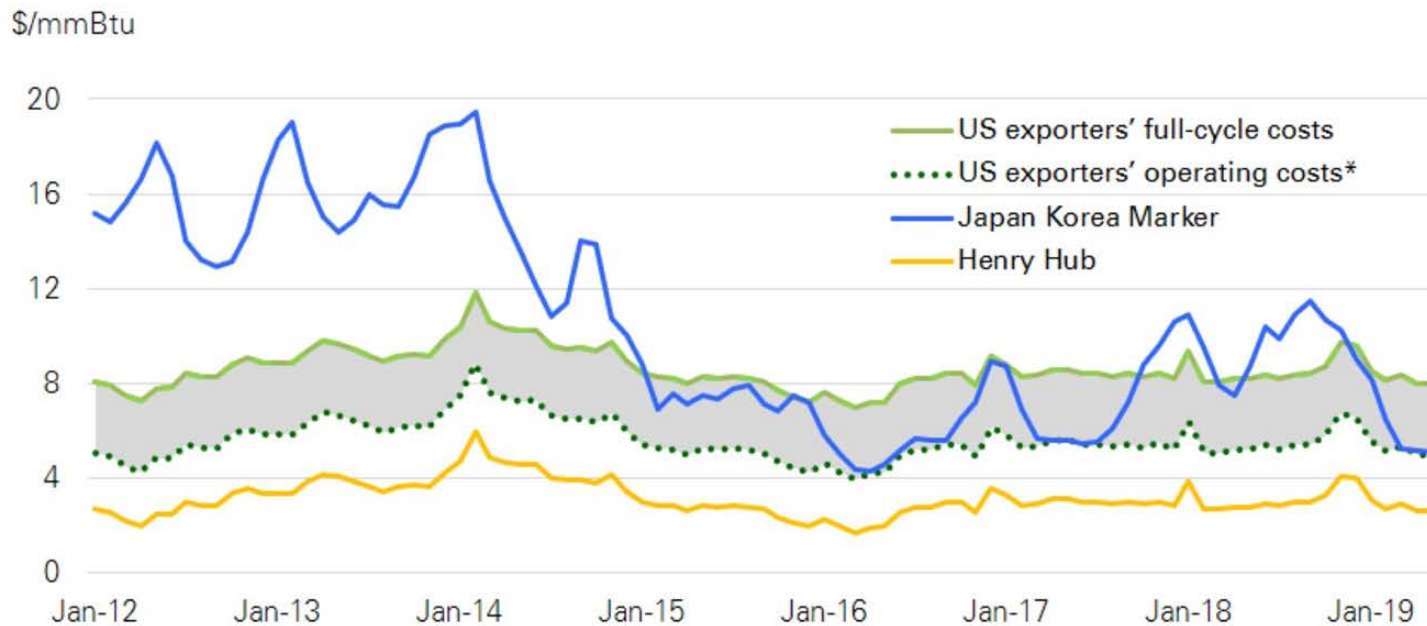


“Practical Strategies for Emerging Energy Technologies”

U.S. LNG Exporters' Costs & Asian Spot Prices



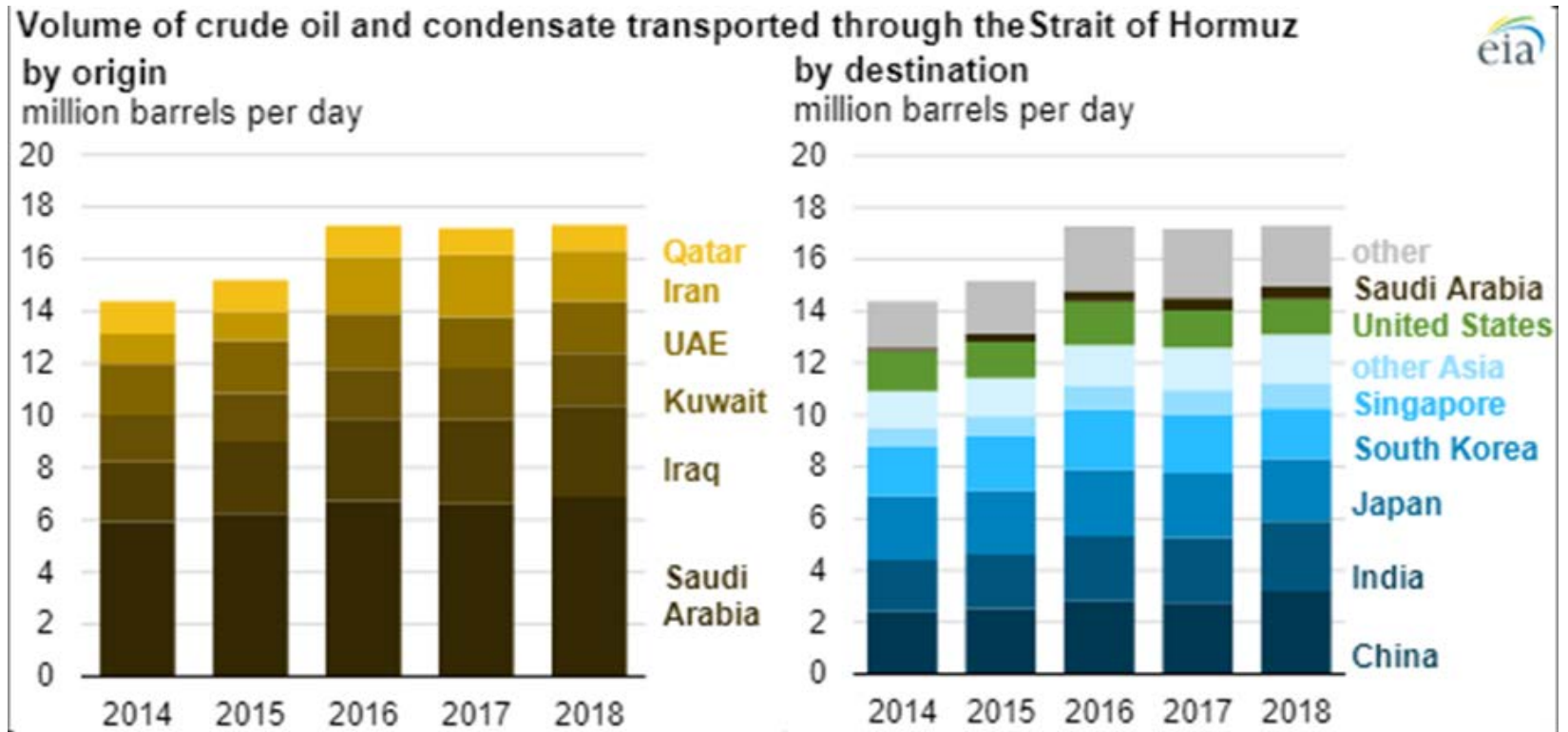
U.S. continues to produce & sell at is operating cost, in Asia!!!



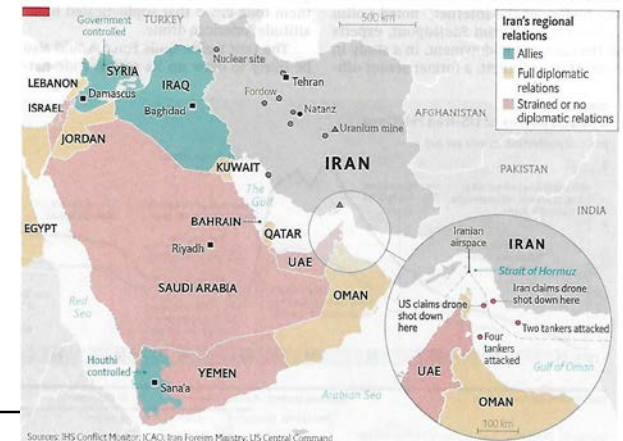
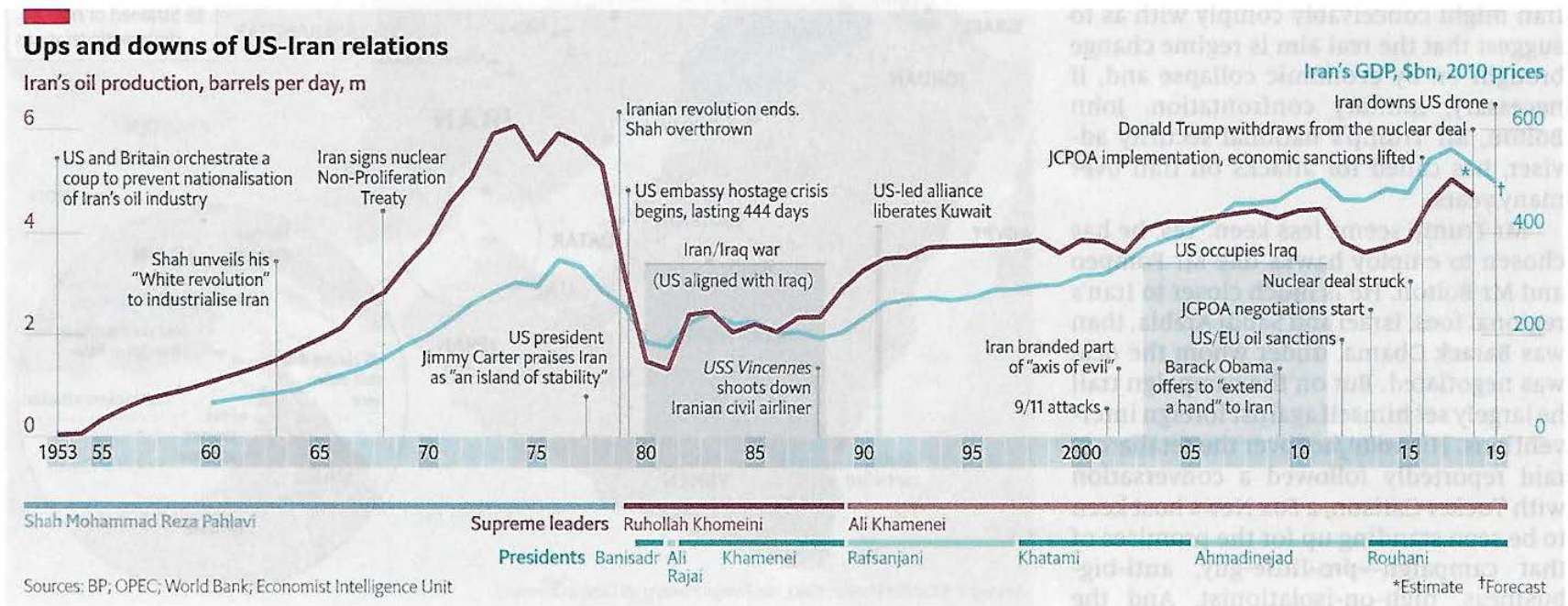
* Operating costs = 1.15* Henry Hub + \$2/mmBtu (transport) ; Full costs also include liquefaction fee (\$3/mmBtu)

BP Statistical Review of World Energy

Strait of Hormuz



Ups & Downs of US-Iran Sanctions



base^e

“Practical Strategies for Emerging Energy Technologies”

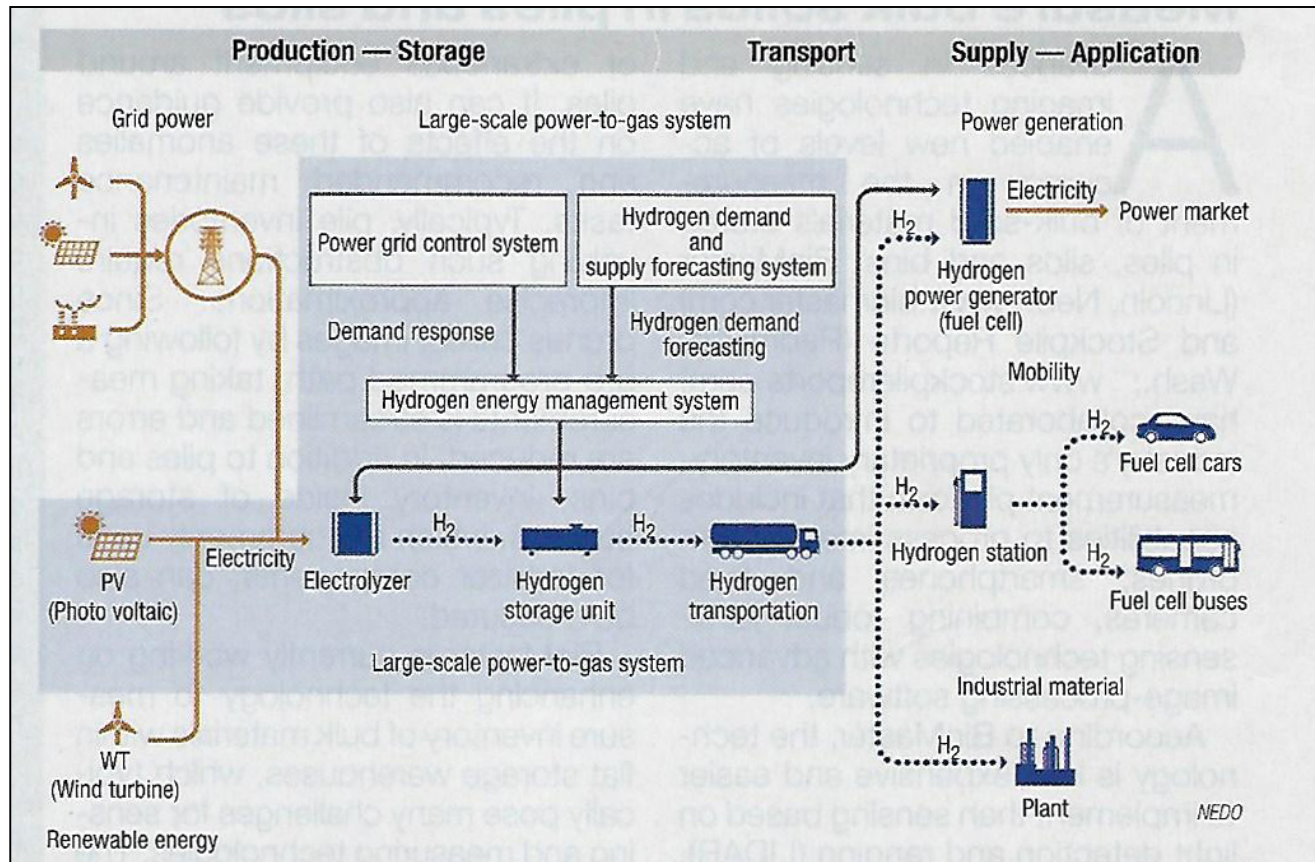
Tariffs

- Latest US tariff threat would hurt US oil, gas output: API
- US depends on China for key drilling fluid component
- API says US energy security at stake in trade dispute
- US Q1 crude flows to China shrink to 6,991 b/d
- Washington — The latest US tariffs threatened against Chinese imports would hamper US energy exports, hurt domestic energy security, and push China to import more oil and gas from countries like Iran and Russia, the American Petroleum Institute argued Tuesday during US Trade Representative hearings.
- US President Donald Trump has threatened to impose 25% tariffs on \$300 billion worth of Chinese goods that have not been targeted so far, leaving room for an escalation of the trade dispute on both sides.
- "China's expected retaliation against US crude oil, refined products, and LNG would disadvantage US exports and could cascade into US domestic production," Aaron Padilla, API's senior adviser for international policy, told the USTR in written comments.
- "US market share in China for LNG and other petroleum products may be difficult to restore with China turning to alternative suppliers," he added.
- For LNG flows, the US/China dispute initially affected spot US LNG cargoes, but has recently started to have a more severe impact on long-term investments in US liquefaction and export projects.

June 2019



METI “Basic Hydrogen Strategy”



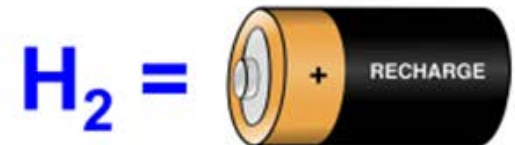
Fukushima Hydrogen Energy Research Field (FH2R)
 900 ton/year H₂
 Operational 2020

The Gas Turbine Advantage

Filling The Renewable Gap



- The Gas Turbine Advantage
- Flexible fast load coverage
- Cleanest of the fossil fuels
- Ability to run on wide range of fuels, including green fuels such as **hydrogen**
- Large installed base in Europe, and many mothballed facilities are awakening!
- Excess renewable energy can be harvested, stored and released in gas turbines
- Ability to follow the transition to renewable World at a pace which is flexible and dependent on local & regional market drivers



Gas Turbines Can Meet the Flexibility Need ... and Start Going Greener

base_e

“Practical Strategies for Emerging Energy Technologies”

Appendix

Crude Oil Consumption 2018 – 98.8 MMb/d

Thousand barrels daily	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum		Share
												2018	2007-17	2018
Canada	2323	2209	2358	2436	2376	2398	2442	2401	2448	2448	2447	♦	0.4%	2.5%
Mexico	2080	2021	2040	2065	2083	2034	1960	1939	1950	1883	1812	-3.8%	-1.0%	1.8%
US	19490	18771	19180	18882	18490	18961	19106	19531	19687	19958	20456	2.5%	-0.4%	20.5%
Total North America	23894	23001	23578	23383	22949	23393	23507	23871	24086	24289	24714	1.8%	-0.3%	24.8%
Brazil	2481	2498	2714	2832	2884	3100	3210	3140	2960	3052	3081	0.9%	2.8%	3.1%
Total S. & Cent. America	6041	6016	6335	6579	6715	6964	7034	7001	6792	6798	6795	♦	1.7%	6.8%
France	1889	1822	1763	1725	1673	1661	1613	1612	1597	1608	1607	-0.1%	-1.7%	1.6%
Germany	2502	2409	2441	2365	2352	2404	2344	2336	2374	2443	2321	-5.0%	0.3%	2.3%
Italy	1661	1563	1532	1475	1384	1274	1204	1257	1266	1279	1253	-2.0%	-3.0%	1.3%
Spain	1559	1474	1447	1383	1300	1203	1199	1243	1288	1301	1335	2.7%	-2.1%	1.3%
United Kingdom	1738	1669	1652	1600	1546	1532	1536	1578	1623	1637	1618	-1.2%	-0.7%	1.6%
Total Europe	16558	15876	15752	15321	14826	14631	14389	14713	15032	15351	15276	-0.5%	-0.8%	15.3%
Russian Federation	2861	2775	2878	3074	3119	3134	3298	3146	3217	3207	3228	0.7%	1.4%	3.2%
Total CIS	3602	3486	3567	3838	3935	3914	4099	3955	4034	4033	4099	1.6%	1.3%	4.1%
Iran	1925	1919	1788	1851	1882	2064	1959	1804	1749	1843	1879	2.0%	♦	1.9%
Saudi Arabia	2622	2914	3206	3295	3460	3451	3764	3886	3875	3838	3724	-3.0%	4.8%	3.7%
Total Middle East	7386	7727	7974	8301	8631	8910	9053	9099	9172	9138	9136	♦	2.7%	9.2%
Total Africa	3198	3322	3481	3398	3574	3705	3770	3857	3878	3962	3959	-0.1%	2.7%	4.0%
Australia	944	950	954	1001	1025	1034	1047	1005	1038	1055	1094	3.7%	1.2%	1.1%
China	7914	8295	9446	9808	10242	10750	11239	11986	12304	12840	13525	5.3%	5.1%	13.5%
India	3137	3300	3381	3550	3747	3789	3914	4245	4654	4870	5156	5.9%	5.0%	5.2%
Indonesia	1288	1321	1415	1590	1646	1677	1708	1571	1628	1696	1785	5.2%	2.5%	1.8%
Japan	4847	4390	4442	4442	4702	4516	4303	4151	4019	3975	3854	-3.1%	-2.3%	3.9%
Singapore	973	1049	1157	1208	1202	1225	1268	1338	1385	1419	1449	2.1%	4.4%	1.5%
South Korea	2312	2345	2378	2401	2466	2464	2463	2587	2781	2811	2793	-0.6%	1.6%	2.8%
Taiwan	1010	1022	1043	950	950	981	1013	1021	1046	1069	1075	0.5%	-0.4%	1.1%
Thailand	1016	1075	1121	1184	1250	1299	1309	1360	1396	1444	1478	2.3%	3.4%	1.5%
Total Asia Pacific	25940	26351	28043	28942	30094	30759	31343	32551	33743	34835	35863	3.0%	2.9%	35.9%
Total World	86619	85780	88730	89763	90724	92276	93194	95048	96737	98406	99843	1.5%	1.2%	100.0%

+1,437
MMb/d

Crude Oil Production 2018 – 94.7 MMbbl/d

Oil: Production*

Thousand barrels daily	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018	2007-17	Share
												2018	2007-17	2018
												2018	2007-17	2018
Canada	3207	3202	3332	3515	3740	4000	4271	4388	4451	4798	5208	8.5%	3.8%	5.5%
Mexico	3165	2978	2959	2940	2911	2875	2784	2587	2456	2224	2068	-7.0%	-4.4%	2.2%
US	6783	7259	7552	7870	8910	10073	11773	12773	12340	13135	15311	16.6%	6.7%	16.2%
Total North America	13156	13440	13843	14326	15561	16948	18828	19748	19247	20157	22587	12.1%	4.0%	23.8%
Brazil	1887	2019	2125	2173	2132	2096	2341	2525	2591	2721	2683	-1.4%	4.1%	2.8%
Colombia	588	671	786	915	944	1010	990	1006	886	854	866	1.4%	4.9%	0.9%
Venezuela	3228	3038	2842	2755	2704	2680	2692	2631	2347	2096	1514	-27.8%	-4.3%	1.6%
Total S. & Cent. America	7426	7387	7407	7450	7362	7397	7663	7759	7355	7160	6537	-8.7%	-0.2%	6.9%
Norway	2458	2342	2132	2033	1911	1832	1881	1940	1991	1963	1844	-6.0%	-2.6%	1.9%
United Kingdom	1549	1469	1356	1112	946	864	852	963	1013	999	1085	8.6%	-4.9%	1.1%
Total Europe	4876	4621	4274	3903	3592	3419	3443	3587	3616	3565	3523	-1.2%	-3.6%	3.7%
Azerbaijan	916	1027	1037	932	882	888	861	851	838	792	795	0.4%	-1.0%	0.8%
Kazakhstan	1485	1609	1676	1684	1664	1737	1710	1695	1655	1838	1927	4.8%	2.7%	2.0%
Russian Federation	9965	10152	10379	10533	10656	10807	10860	11007	11269	11255	11438	1.6%	1.1%	12.1%
Total CIS	12712	13125	13415	13485	13539	13784	13784	13909	14099	14215	14483	1.9%	1.1%	15.3%
Iran	4415	4285	4421	4452	3810	3609	3714	3853	4586	5024	4715	-6.1%	1.4%	5.0%
Iraq	2428	2446	2469	2773	3079	3103	3239	3986	4423	4533	4614	1.8%	7.8%	4.9%
Kuwait	2781	2495	2556	2909	3164	3125	3097	3061	3141	3001	3049	1.6%	1.2%	3.2%
Oman	757	813	865	885	918	942	943	981	1004	971	978	0.8%	3.2%	1.0%
Qatar	1432	1415	1630	1824	1928	1991	1975	1933	1938	1874	1879	0.3%	4.0%	2.0%
Saudi Arabia	10665	9709	9865	11079	11622	11393	11519	11998	12406	11892	12287	3.3%	1.5%	13.0%
United Arab Emirates	3113	2795	2937	3303	3440	3577	3603	3898	4038	3910	3942	0.8%	2.4%	4.2%
Total Middle East	26506	24859	25626	28001	28493	28205	28490	30012	31818	31497	31762	0.8%	2.2%	33.5%
Algeria	1951	1775	1689	1642	1537	1485	1589	1558	1577	1540	1510	-2.0%	-2.5%	1.6%
Angola	1876	1754	1812	1670	1734	1738	1701	1796	1745	1676	1534	-8.5%	0.1%	1.6%
Egypt	715	730	725	714	715	710	714	726	691	660	670	1.4%	-0.6%	0.7%
Libya	1875	1739	1799	516	1539	1048	518	437	412	929	1010	8.7%	-6.9%	1.1%
Nigeria	2172	2211	2533	2461	2412	2279	2276	2201	1900	1991	2051	3.0%	-1.0%	2.2%
Total Africa	10299	9923	10227	8520	9270	8607	8216	8133	7643	8133	8193	0.7%	-2.3%	8.6%
China	3814	3805	4077	4074	4155	4216	4246	4309	3999	3846	3798	-1.3%	0.3%	4.0%
India	818	838	901	937	926	926	905	893	874	884	869	-1.7%	1.2%	0.9%
Indonesia	1006	994	1003	952	917	883	847	838	876	838	808	-3.5%	-1.5%	0.9%
Malaysia	727	688	733	659	663	627	649	696	704	683	682	-0.1%	-0.6%	0.7%
Total Asia Pacific	8095	8055	8463	8324	8411	8287	8313	8399	8044	7774	7633	-1.8%	-0.2%	8.1%
Total World	83069	81410	83255	84009	86228	86647	88736	91547	91822	92502	94718	2.4%	1.2%	100.0%
OPEC	37290	34999	35894	36724	38292	37293	37228	38601	39736	39673	39338	-0.8%	0.9%	41.5%
Non-OPEC	45779	46412	47361	47285	47936	49354	51508	52946	52086	52828	55380	4.8%	1.3%	58.5%

+2,176 MMb/d

Natural Gas Demand 2018 (+5.3%) – 3848.9 BCM

Billion cubic metres	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum		Share 2018
												2018	2007-17	
Canada	89.3	86.6	88.3	97.5	97.2	104.3	109.6	109.8	105.9	109.7	115.7	5.5%	1.9%	3.0%
Mexico	60.0	65.2	66.0	70.8	73.7	77.8	78.8	80.8	83.0	86.4	89.5	3.6%	4.2%	2.3%
US	628.9	617.6	648.2	658.2	688.1	707.0	722.3	743.6	749.1	739.4	817.1	10.5%	1.7%	21.2%
Total North America	778.2	769.4	802.5	826.6	859.0	889.1	910.7	934.1	938.0	935.5	1022.3	9.3%	1.9%	26.6%
Argentina	43.2	41.8	42.1	43.8	45.7	46.0	46.2	46.7	48.2	48.3	48.7	0.8%	1.2%	1.3%
Total S. & Cent. America	138.1	132.9	143.7	148.7	157.7	163.5	168.5	174.7	171.6	172.6	168.4	-2.5%	2.3%	4.4%
France	46.4	44.7	49.6	43.0	44.4	45.1	37.9	40.8	44.5	44.8	42.7	-4.6%	♦	1.1%
Germany	89.5	84.4	88.1	80.9	81.1	85.0	73.9	77.0	84.9	89.7	88.3	-1.6%	0.1%	2.3%
Italy	80.9	74.3	79.1	74.2	71.4	66.7	59.0	64.3	67.5	71.6	69.2	-3.3%	-1.3%	1.8%
Turkey	35.3	33.7	35.8	41.8	43.3	44.0	46.6	46.0	44.5	51.6	47.3	-8.3%	4.3%	1.2%
United Kingdom	97.8	91.2	98.5	81.9	76.9	76.3	70.1	72.0	81.2	78.8	78.9	0.1%	-1.9%	2.0%
Total Europe	625.6	577.1	622.6	580.1	565.4	554.4	500.0	508.8	537.6	560.4	549.0	-2.1%	-1.0%	14.3%
Russian Federation	422.7	397.8	423.9	435.6	428.6	424.9	422.2	408.7	420.6	431.1	454.5	5.4%	0.1%	11.8%
Uzbekistan	44.1	44.1	44.0	47.4	46.2	46.2	48.5	46.3	43.3	43.1	42.6	-1.2%	-0.8%	1.1%
Total CIS	521.3	499.9	531.3	549.5	545.2	537.3	539.9	530.0	537.7	549.3	580.8	5.7%	0.3%	15.1%
Iran	125.8	134.8	144.4	153.2	152.5	153.8	173.4	184.0	196.3	209.9	225.6	7.4%	5.9%	5.9%
Qatar	20.7	21.3	25.4	28.7	33.6	35.6	38.6	42.5	40.4	43.1	41.9	-2.8%	8.4%	1.1%
Saudi Arabia	76.4	74.5	83.3	87.6	94.4	95.0	97.3	99.2	105.3	109.3	112.1	2.6%	4.4%	2.9%
United Arab Emirates	58.0	57.6	59.3	61.6	63.9	64.7	63.4	71.5	72.7	74.4	76.6	2.9%	4.5%	2.0%
Total Middle East	337.1	347.3	380.1	398.1	410.8	423.3	447.5	478.3	500.9	527.0	553.1	4.9%	5.6%	14.4%
Algeria	24.4	26.2	25.3	26.8	29.9	32.1	36.1	37.9	38.6	38.9	42.7	9.9%	5.2%	1.1%
Egypt	39.3	40.9	43.4	47.8	50.6	49.5	46.2	46.0	49.4	55.9	59.6	6.5%	4.2%	1.5%
Total Africa	94.8	95.6	98.9	107.2	115.1	116.6	119.9	128.1	135.0	140.8	150.0	6.6%	4.5%	3.9%
Australia	28.5	29.1	33.8	35.3	35.4	37.2	40.1	42.1	41.7	41.2	41.4	0.4%	3.6%	1.1%
China	81.9	90.2	108.9	135.2	150.9	171.9	188.4	194.7	209.4	240.4	283.0	17.7%	13.0%	7.4%
India	40.0	49.1	59.0	60.3	55.7	49.0	48.5	47.8	50.8	53.7	58.1	8.1%	3.3%	1.5%
Indonesia	39.7	42.1	44.0	42.7	42.9	41.4	41.5	41.0	39.1	38.5	39.0	1.1%	1.1%	1.0%
Japan	99.1	92.5	99.9	112.0	123.2	123.5	124.8	118.7	116.4	117.0	115.7	-1.1%	2.1%	3.0%
Malaysia	43.5	40.0	38.0	38.3	42.0	44.6	44.7	43.9	42.4	41.8	41.3	-1.2%	0.3%	1.1%
Pakistan	34.6	34.7	35.3	35.3	36.6	35.6	35.0	36.5	38.7	40.7	43.6	7.0%	1.9%	1.1%
South Korea	37.3	35.5	45.0	48.4	52.5	55.0	50.0	45.6	47.6	49.8	55.9	12.4%	3.2%	1.5%
Thailand	36.9	38.1	43.2	44.3	48.6	48.9	49.9	51.0	50.6	50.1	49.9	-0.3%	3.6%	1.3%
Total Asia Pacific	503.7	515.6	577.6	623.1	664.3	685.5	706.2	712.5	729.3	768.3	825.3	7.4%	5.0%	21.4%
Total World	2998.8	2937.8	3156.7	3233.3	3317.5	3369.8	3392.6	3466.5	3550.2	3654.0	3848.9	5.3%	2.2%	100.0%

Natural Gas Production 2018 (+5.2%) – 3867.9BCM

Billion cubic metres	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum		Share 2018
												2018	2007-17	
Canada	166.5	155.1	149.6	151.1	150.3	151.9	159.0	160.8	171.8	177.6	184.7	4.0%	0.2%	4.8%
Mexico	47.2	52.6	51.2	52.1	50.9	52.5	51.3	47.9	43.7	38.3	37.4	-2.4%	-2.0%	1.0%
US	546.1	557.6	575.2	617.4	649.1	655.7	704.7	740.3	727.4	745.8	831.8	11.5%	3.6%	21.5%
Total North America	759.8	765.2	775.9	820.5	850.3	860.1	915.0	949.0	942.8	961.6	1053.9	9.6%	2.6%	27.2%
Argentina	42.8	40.3	39.0	37.7	36.7	34.6	34.5	35.5	37.3	37.1	39.4	6.1%	-1.6%	1.0%
Trinidad & Tobago	37.4	38.6	40.3	38.7	38.5	38.7	38.1	36.0	31.3	31.9	34.0	6.6%	-1.7%	0.9%
Venezuela	33.4	31.8	30.5	30.2	31.9	30.6	31.8	36.1	37.2	38.6	33.2	-13.9%	0.4%	0.9%
Total S. & Cent. America	157.9	152.3	160.4	164.1	170.6	173.8	176.0	178.0	176.7	180.3	176.7	-2.0%	1.4%	4.6%
Norway	99.4	103.6	106.4	100.5	113.9	107.9	108.0	116.2	115.9	123.2	120.6	-2.1%	3.2%	3.1%
United Kingdom	72.8	61.2	57.9	46.1	39.2	37.0	37.4	40.7	41.7	41.9	40.6	-3.1%	-5.7%	1.0%
Total Europe	321.0	304.1	310.7	285.5	288.1	280.6	267.5	261.7	260.5	263.2	250.7	-4.8%	-1.5%	6.5%
Russian Federation	611.5	536.2	598.4	616.8	601.9	614.5	591.2	584.4	589.3	635.6	669.5	5.3%	0.6%	17.3%
Turkmenistan	61.6	33.3	40.1	56.3	59.0	59.0	63.5	65.9	63.2	58.7	61.5	4.8%	-0.5%	1.6%
Uzbekistan	61.0	58.4	57.1	56.6	56.5	55.9	56.3	53.6	53.1	53.4	56.6	6.1%	-1.0%	1.5%
Total CIS	768.6	663.2	732.7	766.2	754.3	768.5	751.4	745.0	747.2	789.1	831.1	5.3%	0.5%	21.5%
Iran	123.6	135.7	143.9	151.0	156.9	157.5	175.5	183.5	199.3	220.2	239.5	8.8%	6.4%	6.2%
Qatar	79.7	92.4	123.1	150.4	162.5	168.2	169.6	175.0	173.8	172.4	175.5	1.8%	10.2%	4.5%
Saudi Arabia	76.4	74.5	83.3	87.6	94.4	95.0	97.3	99.2	105.3	109.3	112.1	2.6%	4.4%	2.9%
United Arab Emirates	49.0	47.6	50.0	51.0	52.9	53.2	52.9	58.7	60.3	62.0	64.7	4.4%	2.4%	1.7%
Total Middle East	392.3	413.8	474.7	520.0	545.5	562.9	582.7	600.3	624.1	650.4	687.3	5.7%	6.0%	17.8%
Algeria	82.6	76.6	77.4	79.6	78.4	79.3	80.2	81.4	91.4	93.0	92.3	-0.7%	1.3%	2.4%
Egypt	56.8	60.3	59.0	59.1	58.6	54.0	47.0	42.6	40.3	48.8	58.6	20.0%	-0.9%	1.5%
Nigeria	32.8	23.2	30.9	36.4	39.2	33.1	40.0	48.0	46.2	48.1	49.2	2.4%	3.6%	1.3%
Total Africa	203.8	192.1	202.3	201.7	206.8	198.3	198.6	203.6	208.8	225.7	236.6	4.8%	1.4%	6.1%
Australia	41.7	46.7	54.0	55.7	59.5	61.8	66.6	76.0	96.4	112.8	130.1	15.3%	10.2%	3.4%
China	80.9	85.9	96.5	106.2	111.5	121.8	131.2	135.7	137.9	149.2	161.5	8.3%	7.9%	4.2%
Indonesia	74.8	78.0	87.0	82.7	78.3	77.6	76.4	76.2	75.1	72.9	73.2	0.4%	♦	1.9%
Malaysia	69.2	66.9	65.8	67.0	69.3	72.9	72.0	73.9	72.4	74.5	72.5	-2.6%	1.0%	1.9%
Thailand	29.8	32.0	37.5	38.3	42.9	43.3	43.6	41.2	40.4	38.7	37.7	-2.6%	3.7%	1.0%
Total Asia Pacific	426.3	447.9	494.3	499.1	508.4	518.9	539.8	564.1	581.6	607.5	631.7	4.0%	4.1%	16.3%
Total World	3029.8	2938.6	3151.0	3257.0	3323.8	3363.1	3431.1	3501.7	3541.7	3677.7	3867.9	5.2%	2.3%	100.0%

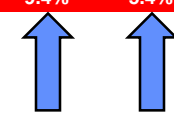


LNG Imports 2018 – 431BCM

Pipeline trade grew	3.7%
LNG trade grew	9.4%
Consumption grew	5.9%

Billion cubic metres	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum		Share
												2018	2007-17	
Mexico	3.8	3.7	6.1	3.8	4.9	7.8	9.3	6.8	5.6	6.6	6.9	4.2%	11.3%	1.6%
Total North America	13.5	17.3	20.2	16.8	11.4	11.4	11.5	10.0	8.3	9.2	9.6	5.0%	-9.1%	2.2%
Total S. & Cent. America	1.8	3.5	9.2	9.9	14.6	18.1	19.6	18.9	15.2	13.5	14.5	7.6%	27.9%	3.4%
France	12.8	13.3	14.7	14.4	9.8	8.3	6.9	6.4	9.1	10.9	13.1	20.8%	-1.9%	3.1%
Italy	1.6	3.0	9.3	9.1	7.1	5.8	4.5	5.9	5.9	8.2	8.0	-1.8%	12.4%	1.9%
Spain	29.8	27.5	28.2	23.9	21.4	15.7	16.2	13.7	13.8	16.6	15.0	-9.2%	-4.1%	3.5%
Turkey	5.6	6.0	7.8	5.9	7.6	5.9	7.1	7.5	7.6	10.9	11.5	6.1%	6.8%	2.7%
United Kingdom	0.8	10.1	18.8	24.7	13.9	9.2	11.2	13.7	10.8	7.2	7.3	1.5%	18.3%	1.7%
Other EU	3.7	3.7	3.9	4.9	4.4	3.7	3.3	5.2	6.9	10.2	12.8	25.3%	10.8%	3.0%
Total Europe	57.4	70.5	89.1	89.2	68.2	51.8	52.1	56.0	56.5	65.3	71.5	9.6%	1.8%	16.6%
Kuwait	-	0.9	2.8	3.0	2.8	2.3	3.6	4.3	4.7	4.8	4.3	-10.0%	n/a	1.0%
Total Middle East & Africa	-	0.9	3.0	4.4	4.2	4.3	5.3	13.7	24.5	21.4	12.5	-41.3%	n/a	2.9%
China	4.6	8.0	13.0	16.9	20.1	25.1	27.3	27.0	36.8	52.9	73.5	38.8%	29.3%	17.0%
India	11.3	13.0	11.5	17.4	18.4	18.0	19.1	20.0	24.3	26.1	30.6	17.0%	9.6%	7.1%
Japan	95.4	88.9	96.4	108.6	119.8	120.4	121.8	115.9	113.6	113.9	113.0	-0.9%	2.2%	26.2%
Pakistan	-	-	-	-	-	-	-	1.5	4.0	6.1	9.4	54.2%	n/a	2.2%
Singapore	-	-	-	-	-	1.3	2.6	3.0	3.2	4.1	4.5	8.6%	n/a	1.0%
South Korea	38.3	35.3	45.0	47.7	49.7	55.3	51.8	45.8	46.3	51.4	60.2	17.1%	3.6%	14.0%
Taiwan	12.6	12.4	15.0	16.3	17.1	17.2	18.6	19.6	20.4	22.7	22.8	0.5%	7.1%	5.3%
Thailand	-	-	-	1.1	1.4	2.0	1.9	3.6	3.9	5.2	6.2	19.1%	n/a	1.4%
Total Asia Pacific	162.2	157.5	180.9	207.9	226.6	241.2	245.2	238.5	253.9	284.6	322.8	13.4%	6.3%	74.9%
Total World	234.9	249.7	302.4	328.3	324.9	326.8	333.6	337.1	358.3	393.9	431.0	9.4%	5.4%	100.0%

LNG Trade represents approximately 11% of the consumption
 Japan, China & Korea represent almost 55% of all LNG Imports



Nuclear Generation 1965-2018 – TWh

Terawatt-hours	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum 2018	2007-17	Share 2018
Canada	0.1	1.0	11.8	35.7	60.5	72.5	97.2	72.3	91.4	90.0	92.9	94.2	102.7	106.5	101.1	100.4	100.4	100.0	-0.4%	0.8%	3.7%
US	3.8	23.0	181.6	264.3	403.9	607.2	708.8	793.6	823.1	849.4	831.8	809.8	830.5	839.1	839.1	848.1	847.3	849.6	0.3%	♦	31.4%
Total North America	4.0	24.0	193.4	300.1	464.4	682.6	814.5	874.1	925.3	945.3	934.8	912.8	945.1	955.3	951.8	959.1	958.6	963.2	0.5%	0.1%	35.7%
Total S. & Cent. America	-	^	2.3	2.3	9.1	9.5	9.6	12.2	16.7	21.7	22.1	22.4	21.7	20.9	21.8	24.1	21.8	22.5	3.1%	1.1%	0.8%
Belgium	-	0.1	6.8	12.5	34.6	42.7	41.4	48.2	47.6	47.9	48.2	40.3	42.6	33.7	26.1	43.5	42.2	28.5	-32.6%	-1.3%	1.1%
Czech Republic	-	-	-	-	2.4	12.6	12.2	13.6	24.7	28.0	28.3	30.3	30.7	30.3	26.8	24.1	28.3	29.9	5.6%	0.8%	1.1%
France	1.1	5.7	18.2	61.3	224.1	314.1	377.2	415.2	451.5	428.5	442.4	425.4	423.7	436.5	437.4	403.2	398.4	413.2	3.7%	-1.0%	15.3%
Germany	0.1	6.5	24.1	55.6	138.7	152.5	154.1	169.6	163.0	140.6	108.0	99.5	97.3	97.1	91.8	84.6	76.3	76.1	-0.3%	-5.9%	2.8%
Spain	-	0.9	7.5	5.2	28.0	54.3	55.5	62.2	57.5	61.6	57.7	61.5	56.7	57.3	57.3	58.6	58.1	55.6	-4.2%	0.5%	2.1%
Sweden	^	0.1	12.0	26.5	58.6	68.2	69.9	57.3	72.7	57.7	60.5	64.0	66.5	64.9	56.3	63.1	65.7	68.6	4.4%	-0.2%	2.5%
Switzerland	-	2.5	7.4	13.6	22.4	23.5	24.7	26.3	23.2	26.5	26.9	25.6	26.2	27.8	23.3	21.3	20.5	25.7	25.2%	-3.0%	1.0%
Ukraine	-	-	-	-	53.3	76.2	70.5	77.3	88.8	89.2	90.2	90.1	83.2	88.4	87.6	81.0	85.6	84.4	-1.4%	-0.8%	3.1%
United Kingdom	15.1	26.0	30.3	37.0	61.1	65.8	89.0	85.1	81.6	62.1	69.0	70.4	70.6	63.7	70.3	71.7	70.3	65.1	-7.5%	1.1%	2.4%
Total Europe	19.9	45.4	115.6	238.2	695.6	894.4	977.0	1048.8	1110.2	1032.0	1024.2	998.4	986.5	992.7	968.3	942.2	936.1	937.5	0.1%	-1.2%	34.7%
Russian Federation	n/a	n/a	n/a	n/a	99.3	118.3	99.5	130.7	149.4	170.4	172.9	177.5	172.5	180.8	195.5	196.6	203.1	204.5	0.7%	2.4%	7.6%
Total CIS	1.9	4.4	28.6	73.9	104.6	118.3	99.9	132.7	152.2	172.9	175.5	179.8	174.9	183.2	198.3	199.0	205.8	206.6	0.4%	2.4%	7.6%
Iran	-	-	-	-	-	-	-	-	-	-	0.1	1.5	4.3	4.1	3.5	6.6	7.1	7.0	-1.0%	♦	0.3%
Total Middle East	-	-	-	-	-	-	-	-	-	-	0.1	1.5	4.3	4.1	3.5	6.6	7.1	7.0	-1.0%	♦	0.3%
Total Africa	-	-	-	-	5.3	8.4	11.3	13.0	11.3	13.5	12.9	13.0	14.1	13.8	12.2	15.9	15.8	11.1	-29.6%	3.4%	0.4%
China	-	-	-	-	-	-	12.8	16.7	53.1	73.9	86.4	97.4	111.6	132.5	170.8	213.3	248.1	294.4	18.6%	14.9%	10.9%
India	-	1.3	2.1	2.4	4.5	6.4	7.6	15.8	17.8	23.1	32.2	33.1	33.3	34.7	38.3	37.9	37.4	39.1	4.4%	7.7%	1.4%
Japan	^	3.3	21.7	82.6	159.6	194.6	286.9	319.1	293.0	292.4	162.9	18.0	14.6	-	4.5	17.7	29.1	49.1	68.9%	-20.2%	1.8%
South Korea	-	-	-	3.5	16.7	52.9	67.0	109.0	146.8	148.6	154.7	150.3	138.8	156.4	164.8	162.0	148.4	133.5	-10.1%	0.4%	4.9%
Taiwan	-	-	-	8.2	28.7	32.9	35.3	38.5	40.0	41.6	42.1	40.4	41.6	42.4	36.5	31.7	22.4	27.7	23.3%	-5.7%	1.0%
Total Asia Pacific	^	4.6	24.5	96.8	209.9	287.1	410.2	500.0	553.3	581.9	482.2	344.6	345.2	370.7	419.7	468.3	493.8	553.6	12.1%	-1.0%	20.5%
Total World	25.8	78.4	364.4	711.4	1489.0	2000.5	2322.4	2580.9	2769.1	2767.5	2651.8	2472.4	2491.7	2540.8	2575.6	2615.2	2639.0	2701.4	2.4%	-0.4%	100.0%



No Growth Between 2005-2018



- China 2007-17 CAGR 14.9%; 2018 +18.6%
- Iran shown for reference only
- U.S. more or less constant for 30 years



“Practical Strategies for Emerging Energy Technologies”

Source: BP Statistical Review of World Energy 2019

Coal Consumption 2018– 3772 Mtoe

- Coal consumption increased by 14% in 2018
- India grew by 5.7%
- China grew by 0.9%
- Asia represents 75.3% of 2018
- China represents 50.5% of consumption in 2018

Million tonnes oil equivalent	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth rate per annum		Share 2018
												2018	2007-17	
US	535.9	471.4	498.8	470.6	416.0	431.8	430.9	372.2	340.6	331.3	317.0	-4.3%	-4.9%	8.4%
Total North America	575.5	505.2	536.3	507.5	449.9	465.4	463.2	404.8	371.7	365.1	343.3	-6.0%	-4.6%	9.1%
Total S. & Cent. America	27.7	23.3	28.3	30.2	31.7	34.6	36.4	35.8	35.5	34.8	36.0	3.7%	2.9%	1.0%
Germany	80.1	71.7	77.1	78.3	80.5	82.8	79.6	78.7	76.5	71.5	66.4	-7.2%	-1.9%	1.8%
Poland	55.2	51.8	55.1	55.0	51.2	53.4	49.4	48.7	49.5	49.8	50.5	1.5%	-1.2%	1.3%
Turkey	29.6	30.9	31.4	33.9	36.5	31.6	36.1	34.7	38.5	39.5	42.3	7.2%	3.0%	1.1%
Total Europe	391.2	350.4	366.3	381.8	390.2	377.6	354.5	339.2	326.8	315.5	307.1	-2.7%	-2.6%	8.1%
Kazakhstan	33.8	30.9	33.4	36.3	37.9	37.5	37.0	34.2	33.9	36.4	40.8	12.2%	1.6%	1.1%
Russian Federation	100.7	92.2	90.5	94.0	98.4	90.5	87.6	92.1	89.3	83.9	88.0	4.9%	-1.1%	2.3%
Total CIS	137.2	125.6	126.4	133.2	139.6	131.4	128.3	130.0	128.3	126.4	134.9	6.7%	-0.1%	3.6%
Total Middle East	9.7	9.6	10.1	10.3	11.9	11.2	11.2	10.5	9.7	8.2	7.9	-2.7%	-1.9%	0.2%
South Africa	93.3	93.8	92.8	90.5	88.3	88.4	89.5	85.2	86.9	84.3	86.0	2.0%	0.1%	2.3%
Total Africa	101.4	101.0	100.1	98.4	96.0	97.2	101.9	97.7	99.1	97.6	101.4	3.9%	0.6%	2.7%
Australia	58.2	56.3	52.2	50.9	47.8	45.4	45.0	46.5	46.5	45.1	44.3	-1.8%	-2.1%	1.2%
China	1609.3	1685.8	1748.9	1903.9	1927.8	1969.1	1954.5	1914.0	1889.1	1890.4	1906.7	0.9%	1.8%	50.5%
India	259.3	280.8	290.4	304.6	330.0	352.8	387.5	395.3	400.4	415.9	452.2	8.7%	5.7%	12.0%
Indonesia	31.5	33.2	39.5	46.9	53.0	57.0	45.1	51.2	53.4	57.2	61.6	7.7%	4.7%	1.6%
Japan	120.3	101.6	115.7	109.6	115.8	121.2	119.1	119.3	118.8	119.9	117.5	-2.1%	0.2%	3.1%
South Korea	66.1	68.6	77.1	83.7	80.6	81.5	84.4	85.4	81.5	86.2	88.2	2.4%	3.7%	2.3%
Taiwan	37.0	35.2	37.6	38.9	38.0	38.6	39.0	37.8	38.6	39.4	39.3	-0.3%	0.2%	1.0%
Total Asia Pacific	2260.8	2335.5	2442.6	2621.1	2677.8	2749.7	2768.6	2751.0	2738.9	2770.8	2841.3	2.5%	2.3%	75.3%
Total World	3503.4	3450.6	3610.1	3782.5	3797.2	3867.0	3864.2	3769.0	3710.0	3718.4	3772.1	1.4%	0.7%	100.0%



AEO2019 Cost & Performance New Generating Tech

Technology	First available year ¹	Size (MW)	Lead time (years)	Base overnight cost (2018 \$/kW)	Project contingency factor ²	Technological optimism factor ³	Total overnight cost ^{4,10} (2018 \$/kW)	Variable O&M ⁵ (2018 \$/MWh)	Fixed O&M (2018\$/kW/yr)	Heat rate ⁶ (Btu/kWh)	Final heat rate (Btu/kWh)	
Coal with 30% carbon sequestration (CCS)	2022	650	4	4,713	1.07	1.03	5,169	7.31	72.12	9,750	9,221	
Coal with 90% CCS	2022	650	4	5,212	1.07	1.03	5,716	9.89	83.75	11,650	9,257	36.9%
Conv gas/oil combined cycle (CC)	2021	702	3	952	1.05	1.00	999	3.61	11.33	6,600	6,350	53.7%
Adv gas/oil CC	2021	1,100	3	736	1.08	1.00	794	2.06	10.30	6,300	6,200	
Adv CC with CCS	2021	340	3	1,963	1.08	1.04	2,205	7.34	34.43	7,525	7,493	45.5%
Internal combustion engine	2020	85	2	1,306	1.05	1.00	1,371	6.03	7.11	8,500	8,160	
Conv combustion turbine ⁷	2020	100	2	1,072	1.05	1.00	1,126	3.61	18.03	9,840	9,600	35.5%
Adv combustion turbine	2020	237	2	658	1.05	1.00	691	11.02	7.01	9,800	8,550	39.9%
Fuel cells	2021	10	3	6,250	1.05	1.10	7,197	46.56	0.00	9,500	6,960	
Adv nuclear	2022	2,234	6	5,224	1.10	1.05	6,034	2.37	103.31	10,461	10,461	32.6%
Distributed generation – base	2021	2	3	1,501	1.05	1.00	1,576	8.40	18.90	8,958	8,900	
Distributed generation – peak	2020	1	2	1,804	1.05	1.00	1,894	8.40	18.90	9,948	9,880	
Battery storage	2019	30	1	1,857	1.05	1.00	1,950	7.26	36.32	NA	NA	
Biomass	2022	50	4	3,642	1.07	1.00	3,900	5.70	114.39	13,500	13,500	
Geothermal ^{8,9}	2022	50	4	2,654	1.05	1.00	2,787	0.00	122.28	NA	NA	
MSW - landfill gas	2021	50	3	8,313	1.07	1.00	8,895	9.47	425.38	18,000	18,000	
Conventional hydropower ⁹	2022	500	4	2,680	1.10	1.00	2,948	1.36	40.85	NA	NA	
Wind ¹⁰	2021	100	3	1,518	1.07	1.00	1,624	0.00	48.42	NA	NA	
Wind offshore ⁸	2022	400	4	4,758	1.10	1.25	6,542	0.00	80.14	NA	NA	
Solar thermal ⁸	2021	100	3	4,011	1.07	1.00	4,291	0.00	72.84	NA	NA	
Solar PV - tracking ^{8, 10, 11}	2020	150	2	1,876	1.05	1.00	1,969	0.00	22.46	NA	NA	
Solar PV – fixed tilt ^{8,10,11}	2020	150	2	1,698	1.05	1.00	1,783	0.00	22.46	NA	NA	



“Practical Strategies for Emerging Energy Technologies”

AEO2019 Cost & Performance New Generating Tech

¹ Represents the first year that a new unit could become operational.

² AACE International (the Association for the Advancement of Cost Engineering) has defined contingency as, “An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs.”

³ The technological optimism factor is applied to the first four units of a new, unproven design; it reflects the demonstrated tendency to underestimate actual costs for a first-of-a-kind unit.

⁴ Overnight capital cost includes contingency factors and excludes regional multipliers (except as noted for wind and solar PV) and learning effects. Interest charges are also excluded. The capital costs represent current costs for plants that would come online in 2019.

⁵ O&M = Operations and maintenance.

⁶ The nuclear average heat rate is the weighted average tested heat rate for nuclear units as reported on the Form EIA-860, *Annual Electric Generator Report*. No heat rate is reported for battery storage because it is not a primary conversion technology; conversion losses are accounted for when the electricity is first generated; electricity-to-storage losses are accounted for through the additional demand for electricity required to meet load. For hydropower, wind, solar, and geothermal technologies, no heat rate is reported because the power is generated without fuel combustion and no set Btu conversion factors exist. The model calculates the [average heat rate for fossil generation](#) in each year for purposes of reporting primary energy consumption displaced for these resources.

⁷ Conventional combustion turbine units can be built by the model before 2020, if necessary, to meet a region's reserve margin.

⁸ Capital costs are shown before investment tax credits are applied.

⁹ Because geothermal and hydropower cost and performance characteristics are specific for each site, the table entries show the cost of the least expensive plant that could be built in the Northwest Power Pool region, where most of the proposed sites are located.

¹⁰ Wind and both solar PV technologies' total overnight cost shown in the table shows the average input value across all 22 electricity market regions, as weighted by the respective capacity of that type installed during 2017 in each region to account for the substantial regional variation in wind and solar costs (as shown in Table 3). The input value used for wind in AEO2019 was \$1,920 per kilowatt (kW), solar PV with tracking was \$2,160/kW, and solar PV fixed tilt was \$2,024, representing the cost of building a plant excluding regional factors. Region-specific factors contributing to the substantial regional variation in cost include differences in typical project size across regions, accessibility of resources, and variation in labor and other construction costs through the country.

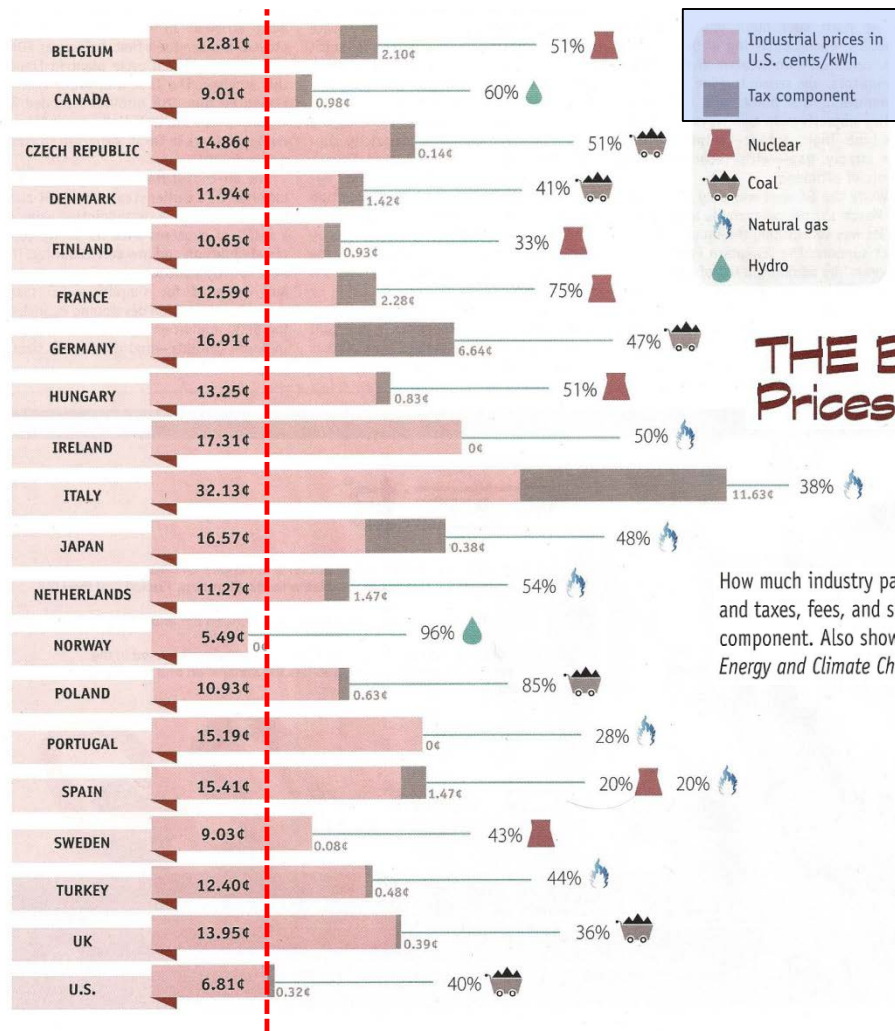
¹¹ Costs and capacities are expressed in terms of net AC power available to the grid for the installed capacity.

Source: Input costs other than Advanced Combined Cycle are consistent with those used in AEO2018, and they are primarily based on a [report](#) provided by external consultants. The base costs shown above reflect calculated learning cost reductions based on recent builds that occurred since the cost report was provided. The cost differential between the two PV technologies was based on Lawrence Berkeley National Lab's *Utility-Scale Solar Report*. Hydropower site costs for non-powered dams were updated for AEO2018 using data from Oak Ridge National Lab. Costs for advanced CC were updated for AEO2019 based on a PJM Interconnection *Cost of New Entry* report and EIA analysis of reported costs.



“Practical Strategies for Emerging Energy Technologies”

The Big Picture: World Industrial Power Prices



THE BIG PICTURE: World Industrial Power Prices

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

Only Norway has a lower Industrial Electricity price (without taxes) than the U.S.

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

McKinsey – Five Key LNG Themes Uncovered

- Global LNG-price indicators have partially converged with the differentials among Asia, Europe, and the United States, falling to the smallest they have been in longer than a decade.
- Asia is leading a third wave of market liberalization after those in the United States and Europe, likely bringing fundamental changes to Asian markets.
- Long-term contract-pricing mechanisms are evolving in indexation and slope as gas and oil markets diverge, placing pressure on buyers to reshape their contract portfolios, with up to \$15 billion per year at stake.
- Substantial new investment is necessary to deliver the infrastructure required to meet demand growth.
- Traditional, bilateral business models for LNG are being challenged today, and new business models with an increased focus on commercial and trading capabilities are emerging.