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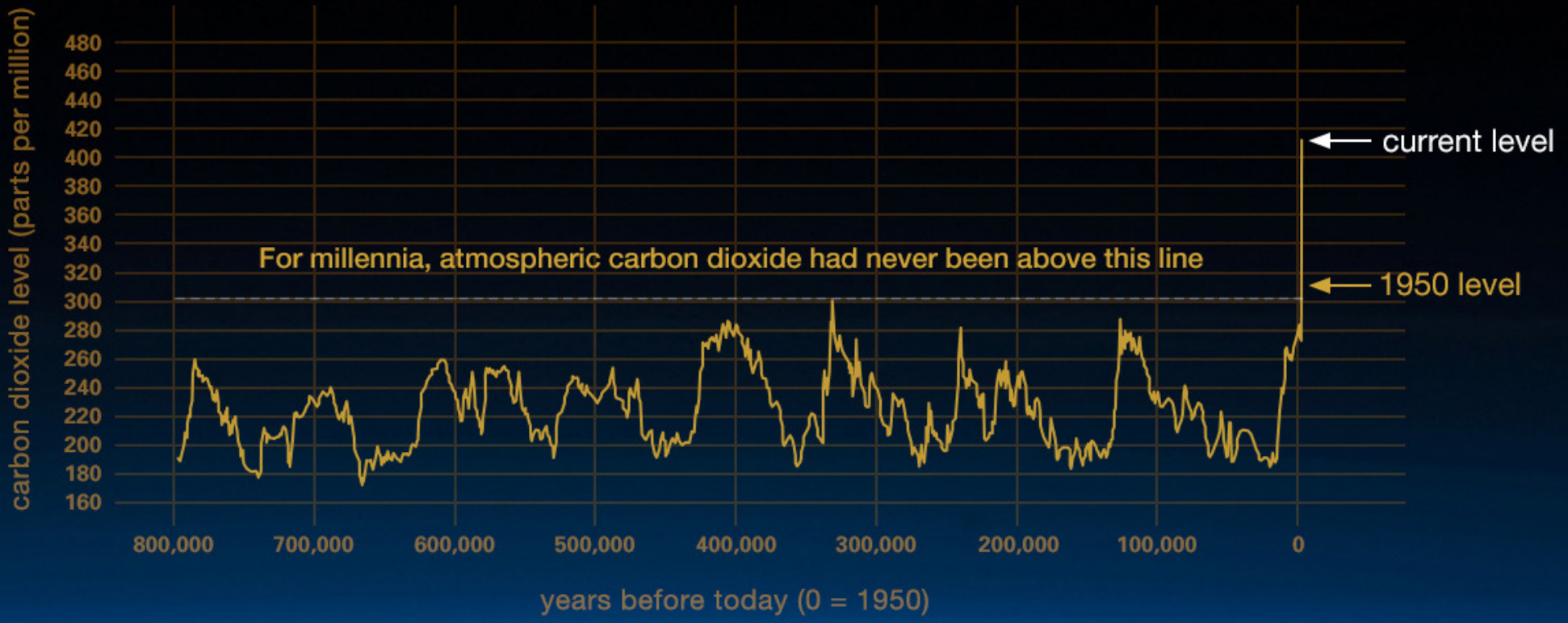
2020 World Energy and Fuels Outlook

By Peter Baldwin



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World 2020 Energy and Fuels Outlook

By Peter Baldwin, President base-e

Every year at about this time, the ASME Electric Power Committee (EPC) Fuels Committee prepares its Fuels Report for presentation at the International Gas Turbine Institute (IGTI) annual meeting, scheduled for June 22-26 in London this year, but which was cancelled.

Also at about this time, British Petroleum (BP) publishes its annual World Energy Outlook, valuable not only because if its content, but because of its year-to-year consistency. This year, BP put off formal presentation of its Outlook to the September time frame, but did publish its 2019 World Energy Statistical Review in June.

Gas Turbine World offered to present this shortened version of the EPC Fuels Report as a way to connect the gas turbine community. The full report is being made available at: www.GasTurbineWorld.com

A world of uncertainties

We are living in a world that has both colliding and parallel impacts of Covid19 and Climate Change, and no one really knows what's going to happen.

What should be apparent is that we were, and are still, unprepared for either, and given today's differences of opinion, we are nowhere near a "World's Shared Purpose".

What should also be apparent moving forward is a renewed understanding of the value of time, or the lack of it.The stats for 2019 serve as a good point of reference, likely the last full year of "business as (was) usual."This is my attempt to reframe the discussion around today's current events and critical issues.

What I worry about

- **I worry about** the apparent Russian strategy to dominate the Eurasian fuels market with its supply abundance and proximity to Europe, Asia and their corresponding trade/pipeline routes.
- And, I worry about **conflict** in the South China Sea over real or perceived hydrocarbon resources. Any conflict, trade barriers or otherwise, would seriously impact trade balances.
- Most of all, I worry about **time**…or the lack of it, to get serious about climate change. We have 20 years to get it right, but the most important participants lack objective reasoning and remain motivated by self-interest.

We're running out of time!

1.0 World Energy Consumption By Fuel – 2019

Primary energy: Consumption by fuel*

Exajoules	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renew-ables	2019 Total	Percent of 2019	Annual Change
Canada	4.50	4.33	0.56	0.90	3.41	0.52	14.21	2.4%	-0.9%
Mexico	3.29	3.26	0.51	0.10	0.21	0.35	7.72	1.3%	-1.4%
US	36.99	30.48	11.34	7.60	2.42	5.83	94.65	16.2%	-1.0%
Total North America	44.78	38.07	12.41	8.59	6.03	6.70	116.58	20.0%	-1.0%
Brazil	4.73	1.29	0.66	0.14	3.56	2.02	12.40	2.1%	2.2%
Total S. & Cent. America	11.86	5.95	1.48	0.22	6.37	2.73	28.61	4.9%	0.3%
France	3.15	1.56	0.27	3.56	0.52	0.61	9.68	1.7%	-1.9%
Germany	4.68	3.19	2.30	0.67	0.18	2.12	13.14	2.3%	-2.2%
Italy	2.49	2.55	0.30	-	0.40	0.64	6.37	1.1%	-2.4%
Spain	2.72	1.30	0.21	0.52	0.22	0.75	5.72	1.0%	-1.7%
Turkey	2.03	1.56	1.70	-	0.79	0.41	6.49	1.1%	3.2%
United Kingdom	3.11	2.84	0.26	0.50	0.05	1.08	7.84	1.3%	-1.6%
Other Europe	2.63	1.08	1.43	0.34	0.62	0.56	6.67	1.1%	0.1%
Total Europe	30.40	19.95	11.35	8.28	5.66	8.18	83.82	14.4%	-1.1%
Russian Federation	6.57	16.00	3.63	1.86	1.73	0.02	29.81	5.1%	-0.8%
Total CIS	8.37	20.65	5.53	1.88	2.21	0.03	38.68	6.6%	-0.3%
Iran	3.92	8.05	0.05	0.06	0.26	^	12.34	2.1%	4.3%
Saudi Arabia	6.92	4.09	^	-	-	0.02	11.04	1.9%	1.2%
Total Middle East	17.80	20.10	0.40	0.06	0.30	0.12	38.78	6.6%	3.1%
Total Africa	8.28	5.40	4.47	0.13	1.18	0.41	19.87	3.4%	2.5%
Australia	2.14	1.93	1.78	-	0.13	0.42	6.41	1.1%	6.9%
China	27.91	11.06	81.67	3.11	11.32	6.63	141.70	24.3%	4.4%
India	10.24	2.15	18.62	0.40	1.44	1.21	34.06	5.8%	2.3%
Indonesia	3.38	1.58	3.41	-	0.15	0.39	8.91	1.5%	8.3%
Japan	7.53	3.89	4.91	0.59	0.66	1.10	18.67	3.2%	-0.9%
South Korea	5.30	2.01	3.44	1.30	0.02	0.29	12.37	2.1%	-1.4%
Thailand	2.72	1.83	0.71	-	0.06	0.29	5.61	1.0%	0.3%
Total Asia Pacific	71.54	31.32	122.22	5.77	15.90	10.81	257.56	44.1%	3.3%
Total World	193.03	141.45	157.86	24.92	37.66	28.98	583.90		
Percent of 2019	33.1%	24.2%	27.0%	4.3%	6.4%	5.0%	100.0%		
Annual Change	0.8%	2.0%	-0.6%	3.2%	0.9%	12.2%	1.3%		

Source: BP Statistical Review of World Energy 2020

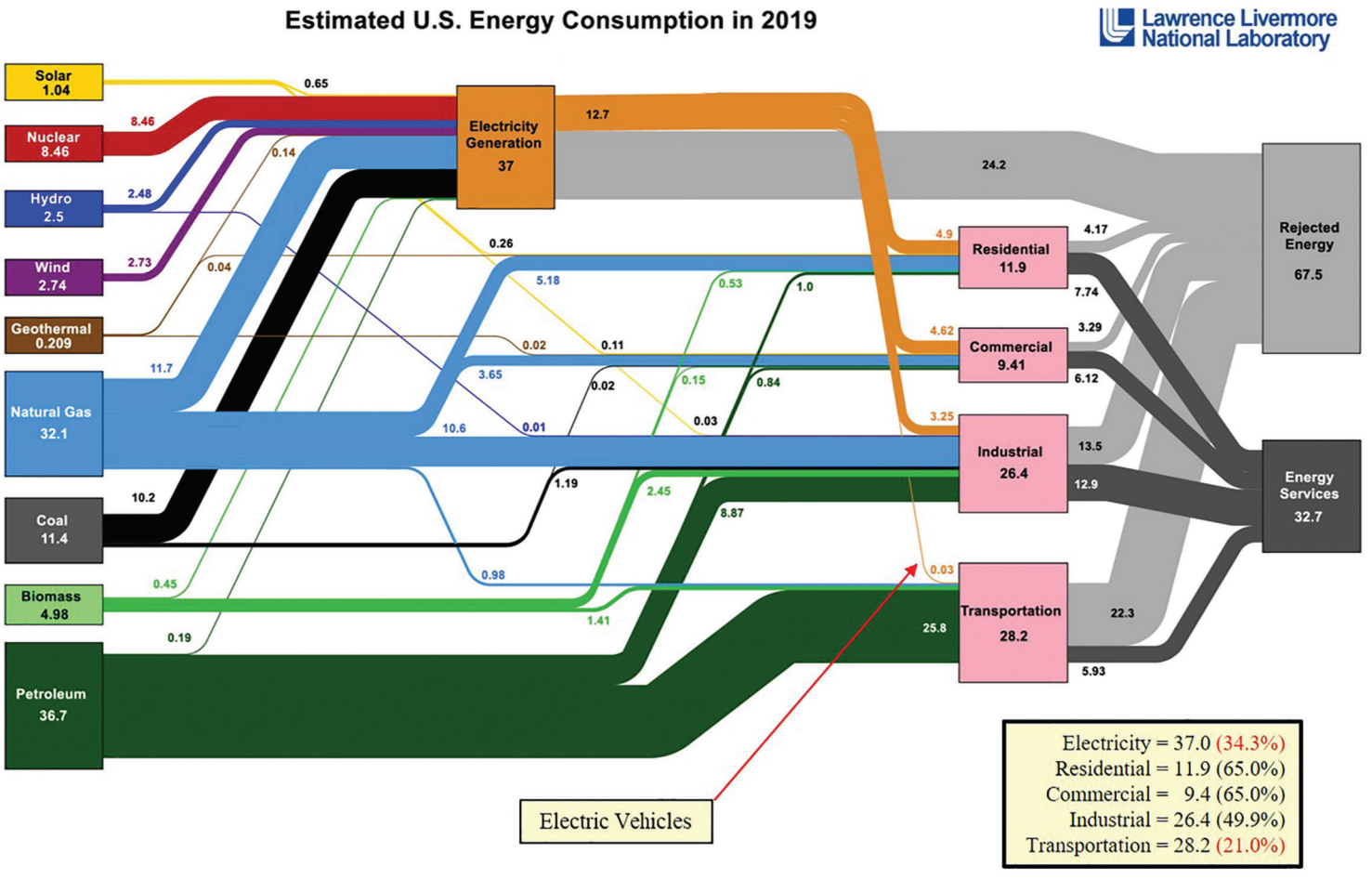
World Primary Energy Consumption

Table provides details of 2019 energy consumption by fuel and by country.

Some noteworthy takeaways:

- Natural Gas (24.2%) and Coal (27.0%) made up 51.2% of the world's primary energy consumption.
- Total of Hydroelectric (6.5%) and Renewables (5.0%) represented 11.5%.
- Oil represented 33.1% of the total (~70% of which was used for transportation).
- Natural gas experienced a year-over-year increase of 2% and renewables 12.2%.
- Total U.S. consumption was 94.65 Exajoules or 89.71 Quads, or more than 16% of world's total.

2.0 2019 U.S. Energy Flow - 100.2 Quads



Lawrence Livermore 2019 Sankey diagram of U.S. Energy Flow by source and sector indicates an estimated 100.2 Quads total consumption.

Of note:

- The U.S. wastes 67.5% of the energy we consume
- The transportation efficiency is only 21.0%
- Overall US electricity generation efficiency is 34.3%
- Electric vehicles represent 0.03% of the total

3.0 World Electricity Generation By Fuel - 2019

Electricity generation by fuel*

Teraw att-hours	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renew - ables	Other#	2019 Total	% of 2019	Annual Change
Canada	4.1	69.3	54.6	100.5	382.0	49.3	0.7	660.4	2.4%	1.2%
Mexico	37.7	205.6	26.3	11.3	23.8	37.8	21.6	364.0	1.3%	4.2%
US	20.0	1700.9	1053.5	852.0	271.2	489.8	14.0	4401.3	16.3%	-1.3%
Total North America	61.8	1975.8	1134.4	963.7	676.9	576.9	36.2	5425.7	20.1%	-0.6%
Brazil	7.9	58.9	25.7	16.2	399.3	117.7	-	625.6	2.3%	4.0%
Other S. & Cent. America	75.6	103.8	47.8	-	278.3	58.3	-0.1	563.8	2.1%	-3.3%
Total S. & Cent. America	86.3	245.0	74.3	24.6	714.7	184.1	0.4	1329.3	4.9%	-0.1%
Germany	5.1	91.0	171.2	75.1	20.2	224.1	25.7	612.4	2.3%	-4.8%
Italy	10.2	126.5	29.7	-	45.1	67.6	4.7	283.8	1.1%	-2.0%
Spain	13.4	86.0	13.1	58.4	25.2	77.5	2.1	275.8	1.0%	0.5%
Turkey	0.2	58.1	114.6	-	89.2	45.3	1.1	308.5	1.1%	1.2%
United Kingdom	1.0	132.5	6.9	56.2	6.0	113.4	7.8	323.7	1.2%	-2.8%
Other Europe	19.0	179.1	175.6	651.9	438.0	258.3	27.9	1749.7	6.5%	-1.6%
Total Europe	51.8	768.1	698.6	928.5	632.5	836.6	77.2	3993.3	14.8%	-1.8%
Russian Federation	6.9	519.5	182.2	209.0	194.4	1.8	4.3	1118.1	4.1%	0.8%
Total CIS	8.6	693.0	264.2	211.2	248.4	3.3	2.3	1431.0	5.3%	1.0%
Iran	82.6	199.5	0.6	6.4	29.0	0.6	-	318.7	1.2%	1.4%
Saudi Arabia	149.6	206.0	-	-	-	1.8	-	357.4	1.3%	-0.5%
Other Middle East	163.9	253.5	21.9	-	4.3	6.8	-	450.5	1.7%	8.7%
Total Middle East	396.1	792.9	22.6	6.4	33.3	13.3	-	1264.7	4.7%	3.3%
Other Africa	51.9	186.1	36.2	-	118.6	26.0	-1.8	417.0	1.5%	6.9%
Total Africa	81.3	340.5	253.6	14.2	132.7	45.1	2.8	870.1	3.2%	2.9%
Australia	5.8	54.4	149.5	-	14.3	41.1	0.1	265.1	1.0%	0.8%
China	6.0	236.5	4853.7	348.7	1269.7	732.3	56.5	7503.4	27.8%	4.7%
India	8.2	71.0	1137.4	45.2	161.8	134.9	0.2	1558.7	5.8%	0.5%
Indonesia	17.3	51.6	177.0	-	17.0	16.0	0.3	279.1	1.0%	4.5%
Japan	44.7	362.4	326.2	65.6	73.9	121.2	42.3	1036.3	3.8%	-1.9%
South Korea	7.4	150.8	238.7	146.0	2.8	29.2	9.7	584.7	2.2%	-1.5%
Taiwan	5.8	91.1	126.4	32.3	5.5	8.0	5.0	274.2	1.0%	-0.5%
Other Asia Pacific	39.1	231.4	148.0	9.5	139.7	35.7	0.5	604.0	2.2%	3.7%
Total Asia Pacific	139.5	1482.6	7376.4	647.3	1783.7	1146.2	114.8	12690.5	47.0%	3.1%
Total World	825.3	6297.9	9824.1	2796.0	4222.2	2805.5	233.6	27004.7	100.0%	1.3%
	3.1%	23.3%	36.4%	10.4%	15.6%	10.4%	0.9%	100.0%		

Source: BP Statistical Review of World Energy 2020

Electricity Generation

Table shows detailed statistics for 2019 world electric power generation by fuel and country.

Of note:

- The world made some progress toward renewables by increasing its power generation contribution by more than a full point, from 9.3% to 10.4%.
- Hydroelectric and nuclear remained virtually constant (15.6% and 10.4%, respectively).
- There were measurable changes throughout the U.S., Asia and parts of Africa.
- Fossil fuels (primarily gas and coal) contribution of world electricity production dropped from 64.0% in 2018 to 62.8% in 2019.
- Worldwide, coal accounted for 36.4% of total electric power generation. U.S. coal-fired power now under 25% of total, while China is at 65% and India at 73%. Europe is at 17.5%.

4.0 World Oil Report

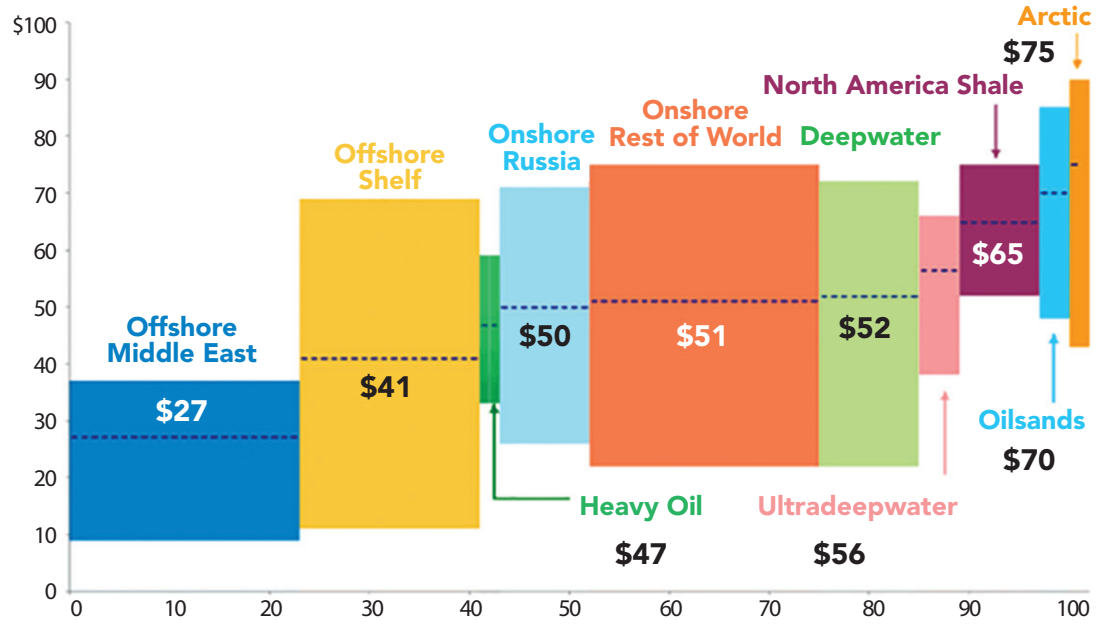
Wavering Demand Clouds Outlook

Saudi Arabia and Russia had become a *duopoly*, known as **OPEC+**, and attempted to jointly manage the market. As others, including the U.S., sought a piece of the action, Saudi Arabia and Russia began to tangle over their share of the weakening market, even before Covid19.

- Crude oil consumption, in millions of barrels per day, totaled **98.3 mb/d** in 2019. Less than 1% increase over 2018.
- For 2020, it's all about demand or the lack of it, and when we might expect a recovery.
- In its recent Short Term Energy Outlook, the U.S. Energy Information Agency (EIA) forecasts U.S. crude oil production will average 11.6 million b/d in 2020 and 10.8 million b/d in 2021. The EIA said 2020 world oil consumption is expected to plummet by 8.30 million bpd to **92.53 mb/d**.
- The International Energy Agency (IEA) first-half report also forecasts that the world's demand for crude will drop by about 8 million bpd this year, with global consumption for 2020 to be down around **92.1 bpd**.
- In April, OPEC and its allies agreed to reduce crude output by 9.7 mb/d in May and June, and by 5.8 mb/d in 2021 through April 2022. As of this writing (July, 2020), they have now agreed to a one-month extension of their collective **9.7 mb/d** reduction, with Saudi Arabia and Russia aligned on the issue.
- Bloomberg reported in mid-May that oil demand in China has almost returned to its level before the coronavirus pandemic spurred the government to impose lockdowns and shut down industries.
- Consumption has rebounded to about **13 mb/d**, Bloomberg said, citing Chinese energy officials who were not authorized to speak publicly on the matter. That isn't far off the 13.4 mb/d consumed in May, and the 13.7 mb/d in December.
- Outlook for 2020/2021 is clouded by uncertainties. A second wave of coronavirus infections could compromise the global economy's faster-than-expected recovery, dragging global oil demand with it.

4.0 World Oil Report (cont'd)

Breakeven Price of Crude Oil – by Source



Source: Seadrill, Morgan Stanley Equity Research, International Energy Agency

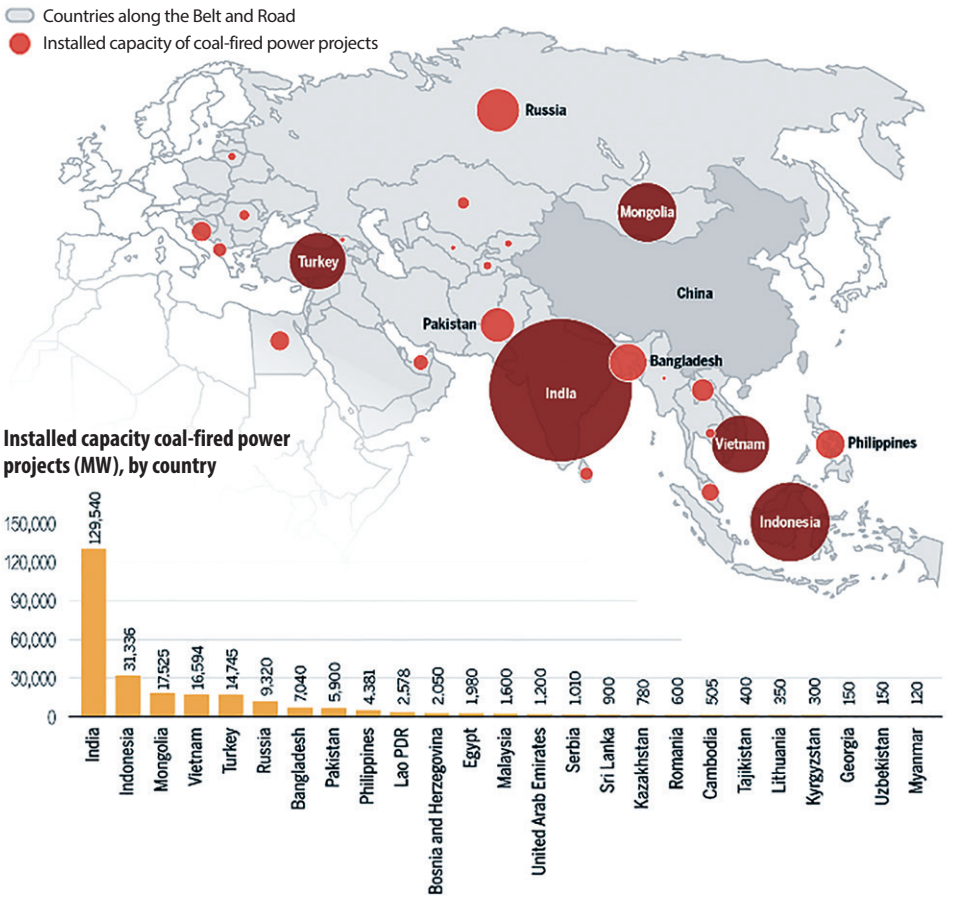
Oil prices

Brent crude oil prices rose in May, reflecting a tightening in the global oil market balance. Initial data show that increased global oil demand and a high adherence to production cuts by OPEC and partner countries (OPEC+) drove the price increase.

- In its June 2020 Short-Term Energy Outlook, EIA forecasts that Brent crude oil prices will average $37 per barrel in the second half of 2020.
- Rystad Energy is projecting demand recovery to the 100 mb/d level by year-end 2020.
- Rystad also produces a Production Breakeven Price estimate for each of the market share contenders. (Chart)
- There are several geopolitical uncertainties, including Iran, Venezuela, Libya and Nigeria. Together they account for 3 mb/d supply.
- Export volumes from Iran, alone, have declined from 2.3 mb/d to less than 0.5mb/d as a result of the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA), aka, The Iran Nuclear Deal, and the sanctions that followed. Pending China/Iran "Partnership" deal could change that.

5.0 World Coal Report

Belt and Road Coal-Fired Projects with Chinese Involvement, by Installed Capacity



* This map includes projects that are not yet in operation, representing the total 240 coal-fired power plant projects with which China is involved, which span various stages.

Source: Global Environmental Institute

Coal – is not dead!

Far from it. In fact, world coal consumption declined by only 0.6% in 2019, and represented **33.1%** of world energy consumption.

- U.S. + Europe coal consumption **declined** by ~15%.
- But together, China and India represented **63.5%** of 2019 world coal consumption, as Asia overall accounted for some 77.1%, and continues to grow; by 2.2% year-over-year, and by 2.4% annually over the prior 10 years.
- *India coal consumption has experienced a 10-year compound annual growth rate of 5.5%.*
- To meet its climate goal per the Paris agreement, China must reduce its coal power capacity by 40% over the next decade, according to Global Energy Monitor. This would appear to be highly unrealistic.
- In addition to roughly 1,000 gigawatts of existing coal capacity, China still has **121 gigawatts** of coal plants under construction, which is more than is being built in the rest of the world combined.

China is also involved in projects worldwide as part of its *Belt and Road* strategy.

6.0 World Natural Gas and LNG Report

LNG imports 2019 – 485 BCM

Pipeline Trade	499.4 BCM -1.7%
LNG	485.1 BCM +12.7%
Europe LNG	119.8 BCM +68.1%
WW Natural Gas Demand	3929.2 BCM

Natural gas: LNG imports

												Grow th rate per annum		Share
Billion cubic metres	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**2019**	2019	2008-18	2019
Mexico	3.7	6.1	3.8	4.9	7.8	9.3	6.8	5.6	6.6	6.9	**6.6**	-4.4%	6.2%	1.4%
US	12.6	12.1	9.9	4.9	2.7	1.7	2.5	2.4	2.2	2.1	**1.5**	-30.9%	-14.2%	0.3%
Total North America	17.3	20.2	16.8	11.4	11.4	11.5	10.0	8.3	9.2	9.6	**8.6**	-10.8%	-3.4%	1.8%
Other S. & Cent. America	1.4	1.4	1.9	2.4	2.8	2.8	2.8	3.0	2.8	3.7	**4.8**	29.5%	10.7%	1.0%
Total S. & Cent. America	3.5	9.2	9.9	14.6	18.1	19.6	18.9	15.2	13.5	14.5	**13.1**	-9.5%	23.4%	2.7%
Belgium	6.8	6.5	6.3	4.1	3.1	2.9	3.6	2.4	1.3	3.3	**7.2**	117.9%	0.9%	1.5%
France	13.3	14.7	14.4	9.8	8.3	6.9	6.4	9.1	10.9	12.7	**22.9**	79.8%	-0.1%	4.7%
Italy	3.0	9.3	9.1	7.1	5.8	4.5	5.9	5.9	8.2	8.2	**13.5**	64.2%	17.5%	2.8%
Spain	27.5	28.2	23.9	21.4	15.7	16.2	13.7	13.8	16.6	15.0	**21.9**	46.0%	-6.6%	4.5%
Turkey	6.0	7.8	5.9	7.6	5.9	7.1	7.5	7.6	10.9	11.4	**12.9**	12.4%	7.5%	2.7%
United Kingdom	10.1	18.8	24.7	13.9	9.2	11.2	13.7	10.7	6.6	7.2	**18.0**	151.9%	24.3%	3.7%
Other EU	3.7	3.9	4.9	4.4	3.7	3.3	5.2	6.9	10.2	13.4	**23.4**	74.7%	13.6%	4.8%
Total Europe	70.5	89.1	89.2	68.2	51.8	52.1	56.0	56.4	64.7	71.3	**119.8**	68.1%	2.2%	24.7%
Kuw ait	0.9	2.8	3.0	2.8	2.3	3.6	4.3	4.7	4.8	4.3	**5.1**	19.0%	n/a	1.1%
Total Middle East & Africa	0.9	3.0	4.4	4.2	4.3	5.3	13.7	24.5	21.4	12.5	**9.5**	-24.1%	n/a	2.0%
China	8.0	13.0	16.9	20.1	25.1	27.3	27.0	36.8	52.9	73.5	**84.8**	15.4%	31.8%	17.5%
India	13.0	11.5	17.4	18.4	18.0	19.1	20.0	24.3	26.1	30.6	**32.9**	7.4%	10.5%	6.8%
Japan	88.9	96.4	108.6	119.8	120.4	121.8	115.9	113.6	113.9	113.0	**105.5**	-6.6%	1.7%	21.7%
Pakistan	-	-	-	-	-	-	1.5	4.0	6.1	9.4	**11.8**	25.6%	n/a	2.4%
Singapore	-	-	-	-	1.3	2.6	3.0	3.2	4.1	4.5	**5.0**	10.1%	n/a	1.0%
South Korea	35.3	45.0	47.7	49.7	55.3	51.8	45.8	46.3	51.4	60.2	**55.6**	-7.6%	4.6%	11.5%
Taiw an	12.4	15.0	16.3	17.1	17.2	18.6	19.6	20.4	22.7	22.9	**22.8**	-0.5%	6.2%	4.7%
Thailand	-	-	1.1	1.4	2.0	1.9	3.6	3.9	5.2	6.0	**6.7**	11.5%	n/a	1.4%
Other Asia Pacific	-	-	-	0.1	-	-	-	-	-	0.8	**5.7**	576.6%	n/a	1.2%
Total Asia Pacific	157.5	180.9	207.9	226.6	241.2	245.2	238.5	253.9	284.6	322.7	**334.1**	3.5%	7.1%	68.9%
Total World	249.7	302.4	328.3	324.9	326.8	333.6	337.1	358.3	393.3	430.6	**485.1**	12.7%	6.2%	100.0%

Source: BP Statistical Review of World Energy 2020

Natural Gas – The cleaner 'greener' bridge fuel?

Natural Gas, in particular LNG, entered the year as *"unstoppable"*, and for a while, it was….until, it wasn't.

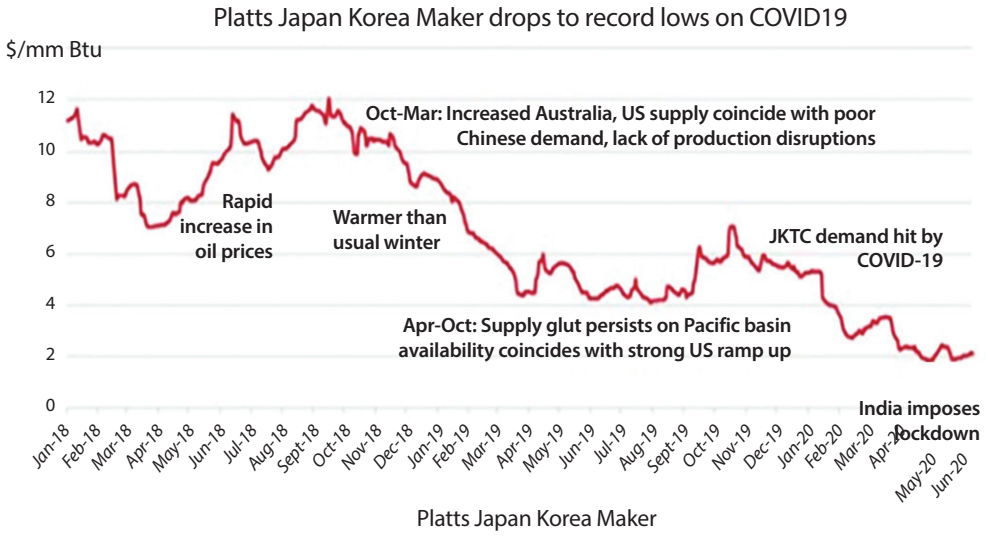
- 2019 world natural gas demand was 3,929 BCM, or ~2.9 billion tonnes LNG equivalent.
- U.S. growth rate for natural gas was at 3.3%, with a 2.7% 10-year compound rate.
- China **grew by 8.6%** and **13.2%**, respectively. That said, U.S. demand is still almost three times China's.

- LNG accounted for **over 12%** of gas consumption at 485 BCM, or the equivalent of 360 million tonnes of LNG.
- In 2019, **50% of all LNG** imports were by Japan, China and Korea, heightening interest and growth in a Northeast Asia Trading Hub that can affect spot pricing and contract terms.

In all, Asia accounts for 70% of world LNG imports and Europe 25%.

6.0 World Natural Gas and LNG Report (cont'd)

Spot LNG prices were already trending lower in 2019 on rapidly growing supplies relative to demand



LNG prices trending lower

- European LNG imports **grew by 68%** in 2019. This spike appears to be driven by supply diversification and opportunistic buying as LNG spot pricing fell (see chart).
- Natural gas consumption grew by 2.0% worldwide, while LNG grew by 12.7% and pipeline trade fell by 1.7%. LNG imports in 2019 grew to virtually equal that of pipeline imports.
- Enormous quantities of gas are being discovered and demand is being driven by its use as a "cleaner" fuel than coal, and/or a "bridge" to renewables.
- As seen with oil in 2017, supply exceeds demand putting pressure on the price and storage capacity.

- Prior to Covid-19, LNG to Asia and an emerging interest in Europe drove planned investments in more liquefaction and shipping capacity to accommodate an expected 2x growth from 431 BCM (317 Mt) to over 850 BCM (630 Mt) in 2050.
- In May, Reuters reported that U.S. LNG exports are down by **more than a third** since governments around the world started imposing lockdowns to stop the spread of the coronavirus.
- Buyers in Asia and Europe have already **canceled over 20 U.S. LNG cargoes** for June and July, and more cancellations are anticipated.
- The number of vessels carrying U.S. LNG peaked at 74 in January, according to federal data. But Refinitiv data said the number of vessels carrying U.S. LNG fell to 62 in April and was on track to drop to an eight-month low of 50 in May.
- Since much of the U.S. LNG goes to Asia, the prospects for an early recovery are promising.

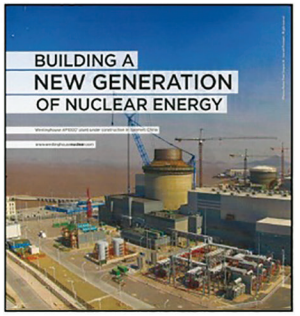
Adding to the confusion over market balance are the Iran sanctions and potential for China imposing more punitive tariffs on LNG imports from the U.S. Now, add pending China-Iran "Military and Trade Partnership".

7.0 Nuclear Report

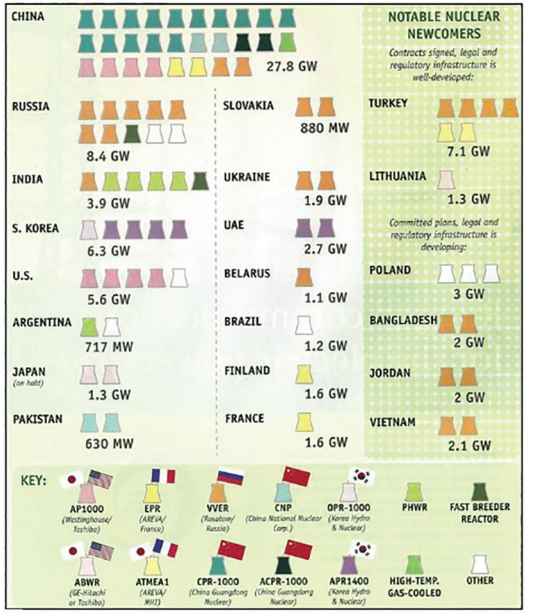
"The Big Picture: Next-Gen Nuclear"

Compliments of Power magazine April 2014

- 72 mostly advanced nuclear reactors under construction
- A total of 68GW (12% of installed base); China represents 40% of the total
- France will cap nuclear capacity at the current 63.2GW, forcing closures w/ capacity additions



Westinghouse AP1000® plant under construction in Sanmen, China



Installed Generating Capacity (2012) = 5,550 GW

Nuclear – Green but aging; enter China and India

- World nuclear generation has been more or less constant for thirty years.
- Totaled about 4% of world energy consumption in 2019, and 10.4% of electricity generation.
- Emergence of China and India is offsetting decline in Germany and Japan.
- Virtually no nuclear generation growth in the U.S. for ~25 years.
- The average age of the 96 U.S. reactors licensed-to-operate is **39 years** (according to EIA).
- There is **only one active nuclear project in the U.S.**, Plant Vogel Units 3 and 4, in Georgia. Two 1100 MW Westinghouse AP1000 (Advanced Passive) units, to be first new nuclear plant in three decades.

- Meanwhile, China has experienced an almost **16% compounded** annual growth in nuclear since 2009, and a single year growth of **18%** in 2019.
- China is dominating Asia and is the world's epicenter of nuclear technology today (see chart).
- Russia making **significant inroads** into Eastern Europe, the Mid-east and Africa.
- Nuclear retirements are of increasing concern, seemingly at odds to the quest for carbon-free generation. France wants to cap nuclear to 50% of its power generation (from ~75% currently).
- Developing interest in **Small Modular Reactor** (SMR) technologies. Major driver is to achieve a serial "product-level" fabrication while still meeting NRC codes and standards. Would replace costly traditional one-of-a-kind, on site construction. SMR also offers opportunities for alternative power-loop working fluids, including supercritical CO2.

The survival of nuclear energy as a viable source of carbon-free power is questionable.

7.0 Nuclear Report (cont'd)

Is there a future for Nuclear as a meaningful source of carbon-free power?

There are ongoing concerns about the viability of nuclear power as posted on Wikipedia:

- Germany has permanently shut down eight of its 17 reactors and pledged to close the rest by the end of 2022.
- Italians voted overwhelmingly to keep their country non-nuclear after permanently closing all of its functioning nuclear plants.
- Switzerland and Spain have banned the construction of new reactors.
- Japan's prime minister has called for a dramatic reduction in Japan's reliance on nuclear power.
- Plan is to re-start only some of the 54 Japanese nuclear power plants (NPPs) and to continue NPP sites under construction.
- Taiwan's president did the same.
- Countries including Australia, Austria, Denmark, Greece, Ireland, Italy, Latvia, Liechtenstein, Luxembourg, Malaysia, Malta, New Zealand, Norway, Philippines, and Portugal have no nuclear power stations and remain opposed to nuclear power.
- Belgium, Germany, Spain and Switzerland plan nuclear phase-outs by 2030.

Globally, more nuclear power reactors have closed than opened in recent years but overall capacity has increased.

- Lithuania and Kazakhstan have shut down their only nuclear plants, but plan to build new ones to replace them.
- Armenia shut down its only nuclear plant but subsequently restarted it.
- Austria never used its first nuclear plant that was completely built.
- Due to financial, political and technical reasons Cuba, Libya, North Korea and Poland never completed their first nuclear plants, although North Korea and Poland plan to.
- Azerbaijan, Georgia, Ghana, Ireland, Kuwait, Oman, Peru, Venezuela have planned, but not constructed their first nuclear plants.

Seems short sighted and strategic error to:

- Shut down 10 % of the worldwide power production, when it is the largest source of base-load carbon free power.
- Cede technical leadership to China and Russia, who then use the technology to gain access to valuable raw materials and energy resources elsewhere.

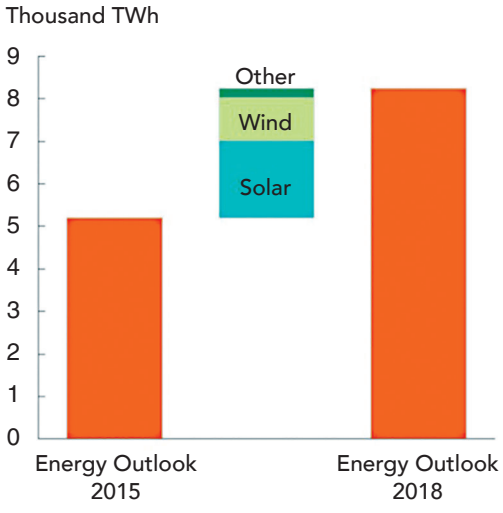
At the moment, there appears to be **no interest in U.S.** to seek operating permit extensions.

Why bother when you can't compete in a market with unabated natural gas fired units?

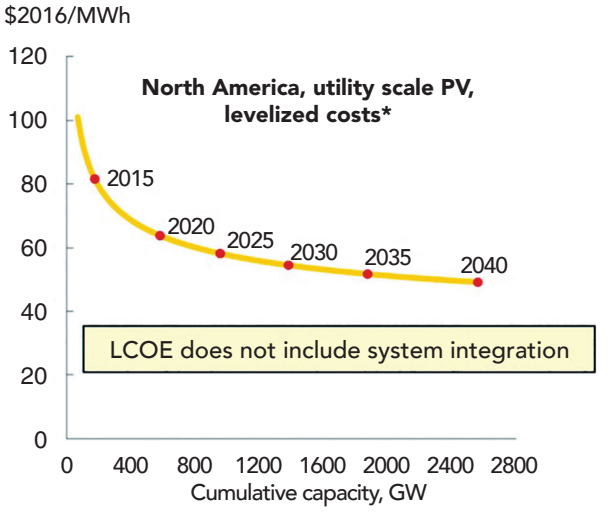
8.0 Renewables & Renewables Integration

Renewables Outlook

Change to the projected level of renewable power in 2035



Solar PV learning curve



*Note: Cost per MWh of building and operating a plant over its lifetime. Excludes subsidies, tariffs and the cost of grid integration.

Source: BP 2018 Energy Outlook

Renewable energy in all its forms is of great interest as we move forward.

- Both BP and Lazard offer projections on power generation (TWh) and levelized costs of electricity (LCOE) for various sources of renewable energy.
- Comparing TWh forecasts for 2035 made in 2015 and 2018 (chart) shows upwards revision by almost 60%.
- Breakdown of increment above 2015 forecast shows added solar outstripping added wind.
- BP forecast projects price of utility scale photovoltaic (PV) solar gradually settling out at $50/MWh or $.05/kWh in "homeowner language" (chart).

The footnote is important! The projected LCOE for PV does not include system integration.

8.0 Renewables & Renewables Integration (cont'd)

Wind a growing factor worldwide

According to a 2018 DOE Wind Technologies Market Report, wind power ranked third in capacity additions, behind solar and natural gas.

The average 2018 capacity factor, on a fleet-wide basis reached 35%. For more recently built (2014-2017) projects, the capacity factor **approached 42%**, indicating the extent to which backup sources and/or storage are required.

- The U.S., Germany and China account for **60%** of the installed wind capacity.
- China represents ~1/3 of the world, with annual growth rate of **almost 13%** and compound 10-year growth rate of 19.1%.
- India has great potential, currently at **just 4.4%** of the world total.
- Denmark, a wind turbine technology hub, is **only 1%** of world's installed capacity.
- Wind and Offshore O&G interests are converging:
  The U.S. Atlantic Outer Continental Shelf is on the verge of a major breakout with its proximity to major load centers, combined with favorable wind conditions and ocean depths, and Asia is expected to continue its aggressive growth throughout the region.

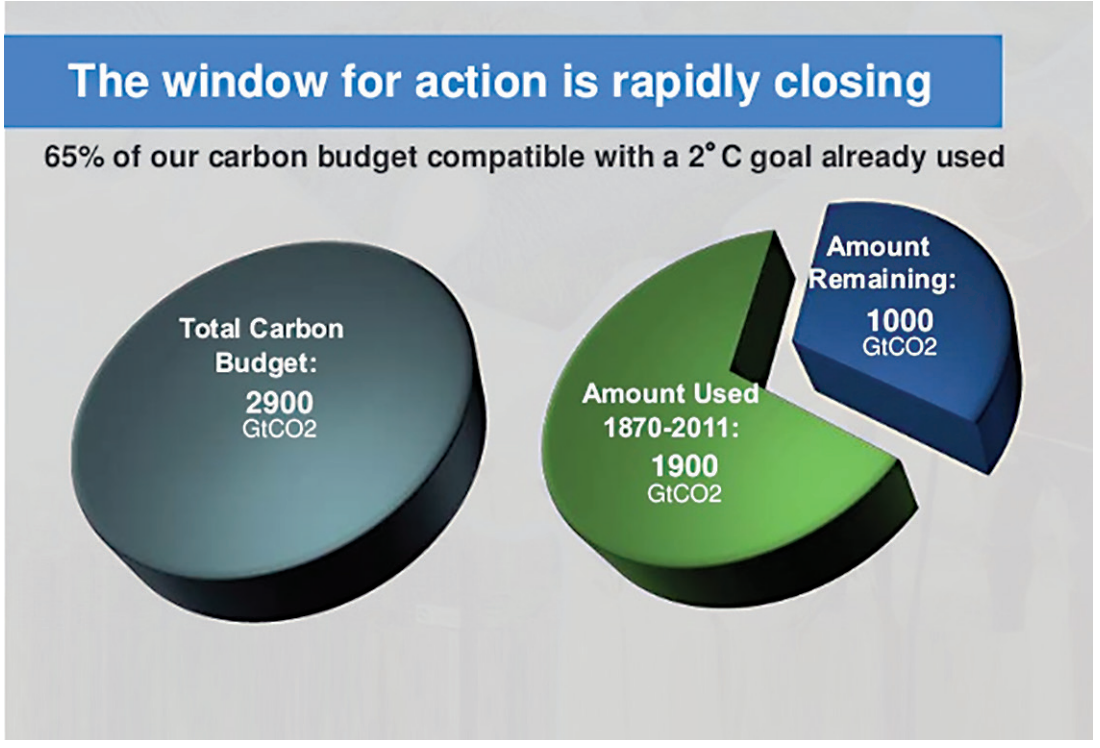
Hydroelectric - green but slow growing

Hydroelectric generation takes a long time to design, permit and build. Large projects must be able to survive government instabilities typical of the locations involved.

- Hydroelectric represents **6.8%** of world energy consumption and 15.6% of electric power generation.
- The prior 10-year growth rate was 2.5%, but 2019 saw **only 1.2%** growth over 2018.
- China accounts for **almost 30%** of the total world hydroelectric power generation, with Brazil at 9.5%, Canada at 9.0%. The U.S. accounted for 6.4% and Russia 4.6%.

9.0 World Carbon Emissions Challenge

Transition to Carbon-Free Energy - Observations and Conclusions



The conversation on world's energy future revolves around transitions toward:

- **Renewable energy**
- **Electrification of our societies**
- **Energy demand management**

All of which must happen while:

- Maintaining system reliability in the face of a world population growth from 7 billion to 10 billion people
- Widening access to electricity and the internet for one billion new rural users
- Reducing worldwide CO2 emissions trajectory to reach 16 Gt by 2050 to limit temperature rise to goal of 2°C

*That's **less than half** of today's world CO2 emissions rate.*

So, where are we?

Climate Change "Science" and Realities

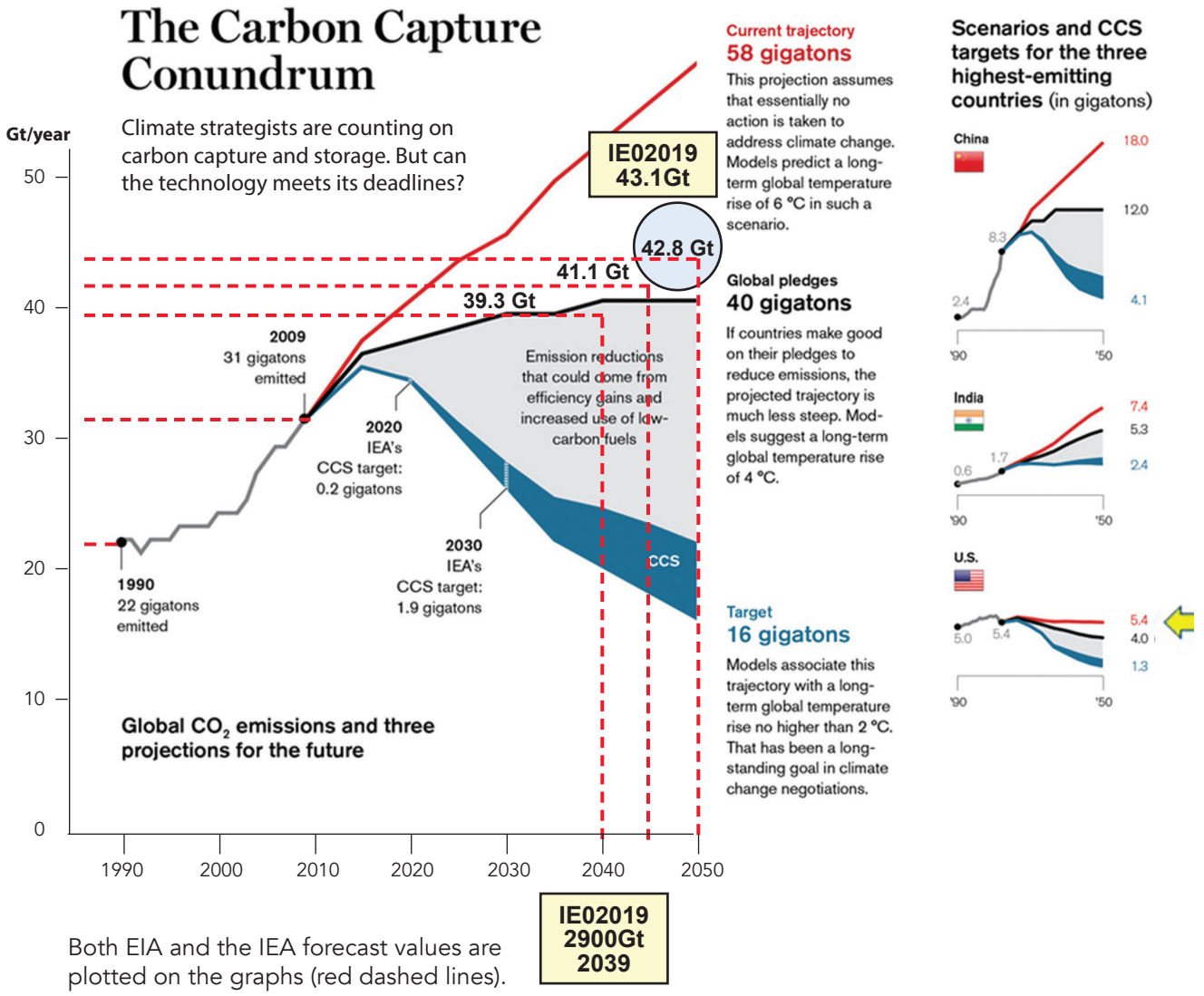
The "*science*" was best portrayed in the Fifth Assessment Report (AR-5) generated by the Intergovernmental Panel on Climate Change (IPCC) in 2014. (Ref. https://www.ipcc.ch/report/ar5/syr/)

Key finding is that the 2°C/450 ppm goal is the equivalent of 2900 Gt of CO2 in the atmosphere, and that 1900 Gt of that carbon budget had *already been used through 2011*.

This left only 1000 Gt remaining as available CO2 budget to limit atmospheric rise to 2°C.

BP estimates that worldwide CO2 emissions in 2019 were 34. 2 Gt, and that the cumulative emissions from 2012 through 2019 are estimated to be 265 Gt, leaving a remaining budget of ***only 735 Gt*** for 2°C limit.

9.0 World Carbon Emissions Challenge (cont'd)



Both EIA and the IEA forecast values are plotted on the graphs (red dashed lines).

IE02019 2900Gt 2039

Climate Change "Science" and Realities

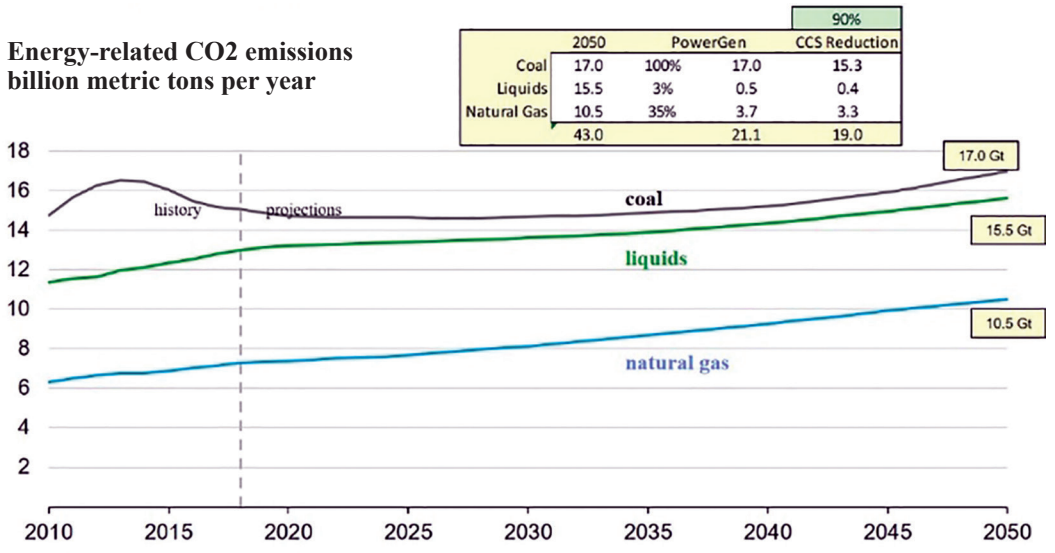
- The IEA 2019 International Energy Outlook (IEO) CO2 emissions estimate for 2018 was 35.3 Gt; forecasting 43.1 Gt for 2050.
- Graphic that best captures the essence of this issue is by Mike Orcott of MIT Tech. Review.
- It shows three scenarios for temperature rise outcomes by 2050: 6, 4 and 2°C (red, black, blue lines, respectively).
- It also shows three major CO2 emitters: China, India and U.S., and their contributions to those three scenarios.
- The Y-axis gives ***annual*** CO2 emissions in Gigatons (Gt). Difference between the 2°C and 6°C scenarios **in 2050** is 42Gt.

Based on the IEA 2050 projections we're are heading toward ~ 4.5°C temperature rise in 2050.

9.0 World Carbon Emissions Challenge (cont'd)

Climate Change "Science" and Realities

Using IEO2019 forecast for the 2050 Energy-Related CO2 Emissions by fuel source (chart) and allocating estimated percentage of each to power generation offers perspective of potential for reduction via Carbon Capture and Sequestration (CCS).



Source: IEA 2019

By applying 90% CCS to all fossil fuel power generating assets indicates potential to realize a 19 Gt reduction, or **44%**, potential savings vs. the 43.0 Gt IEO2050 projection of total.

- The key to meaningful reduction is *90% capture of the CO2 on **all** fossil fuel power plants.*
- Means deploying CCS on natural gas plants which, as of today, are still excused as "half" of coal, or "cleaner" or "bridge" fuel!
- Conversations about the "transition" to all-renewable are laudable, but accomplishments far too slow, don't get us even close, and generate even more ***stranded assets*** in the process of expanding fossil fuel generation – both gas and coal.

- *It's that "time" thing*! The awareness, the understanding, the planning and the preparation for an event we know is coming. *We have **20 years** to get this right and we're not on track!*
- The "bridge" or natural gas "fuel transition" has now been revealed as the myth it always was.

Bottom line: Effectively deployed, CCS can substantially reduce our CO2 footprint in a time frame consistent with our needs, and does not strand current and future assets. Generation assets can retain their value throughout their useful life. This is especially true as we continue to build fossil assets worldwide.

The real bridge is now, and always has been, CCS.

10.0 World Supply and Demand Outlook

Supply and demand was already unbalanced before the Covid-19 pandemic which made it more visible.

- Oil markets had somewhat stabilized by the end of 2018, after digesting the added North American shale oil supply, only to see Saudi Arabia and Russia begin their battle for market share.
- Demand was then reduced by 20-25 mmbbl/day and created temporary **negative** spot oil prices.

There were beginnings of large surpluses of natural gas and LNG and it appeared that 2020 was going to force an LNG market rationalization. On top of all this, three major trends were occurring:

- Renewables and their integration
- Tariffs, trade wars and sanctions
- Geopolitical ambitions and positioning – China, Russia and India

Renewable integration challenges

- Renewables integration is well understood, but certainly not resolved. In addition to the direct impact, there is considerable and ongoing collateral damage. Regulations and standards are a hindrance.
- Regulations favor added natural gas use. The U.S. EPA New Source Performance Standards (NSPS) of 2014, 2015, and now 2020, set the CO2 emissions to a level that natural gas plants can meet without capture.
- These very beneficial standards combined with the continuing low price of natural gas have driven the electricity market price levels down to a level that makes it difficult for the other technologies to compete.
- Nuclear power plants are not being re-permitted, CCS technologies are sitting on the shelf, and even Bonneville Power's hydroelectric assets have been challenged to sustain their role in the US northwest.
- The Renewable Portfolio Standard (RPS) exacerbates problems for electric utilities and system operators managing the grid.
- The RPS has two basic components: a mandated generation mix, which specifies a renewable source percentage; and a mandate that renewables dispatch first.
- The utility is given the responsibility to manage the intermittent nature of renewables, but without compensation. There are efforts to correct this anomaly, but outcomes to date are not convincing.

A more balanced regulation would be to require these renewable resources to manage the intermittency they create by including some form of storage in their offerings.

10.0 World Supply and Demand Outlook (cont'd)

Tariffs, Trade Wars & Sanctions

I will not offer political comment here, other than so far the tariff issue with China, and the Russia and Iran trade sanctions, have been disturbances on the market fringes.

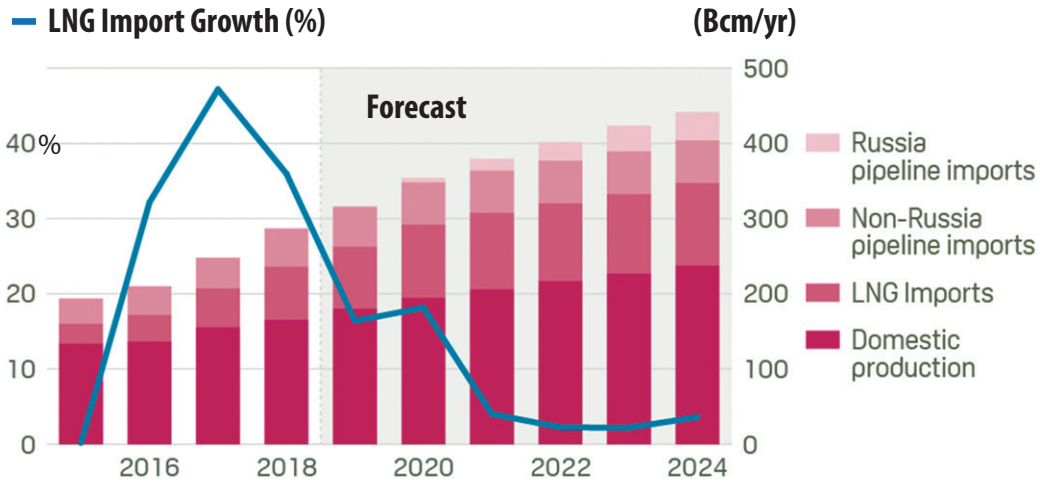
More importantly, these and other concerns seem to be causing countries to rethink alliances and partnerships. For example, recently announced *China-Iran "Military and Trade Partnership"* to partially offset growing Russian influence in the region.

- Sanctions have served to delay Russian Arctic development, at least on paper. The Rystad Breakeven Cost at $75 suggests that any unsubsidized near-term development would be unlikely anyway.
- The unresolved trade war with China has the potential to undermine the recent U.S. energy independence, largely the result of shale oil and gas developments. Any punitive tariffs on LNG from the U.S. would be a problem.
- To date, it appears that both parties see continuing value in the relationship, have invested heavily in infrastructure to support expanded trade and have not imposed any further tariffs.

China Gas Demand is driving world gas demand and investment, both pipeline and LNG. Platts expects to see lower LNG imports with increases both in domestic production and pipeline imports (mostly from Russia). The *Power of Siberia* Russia-China gas pipeline will weigh on China's LNG demand growth, adding another bearish factor to an already oversupplied Asian market:

- The northern section of the China-Russia gas pipeline was commissioned in December, 2019.
- Seen as one of the most anticipated energy projects in Asia, with significant implications for China's natural gas supply, LNG import demand in the region and Moscow's **energy strategy** in Asia.
- The project further enhances China's supply security, adding to merger of gas pipelines of the three national oil companies to boost connectivity and ease infrastructure constraints.

China's LNG Import Growth Slowing as Pipeline Gas Supplies and Domestic Production Increase

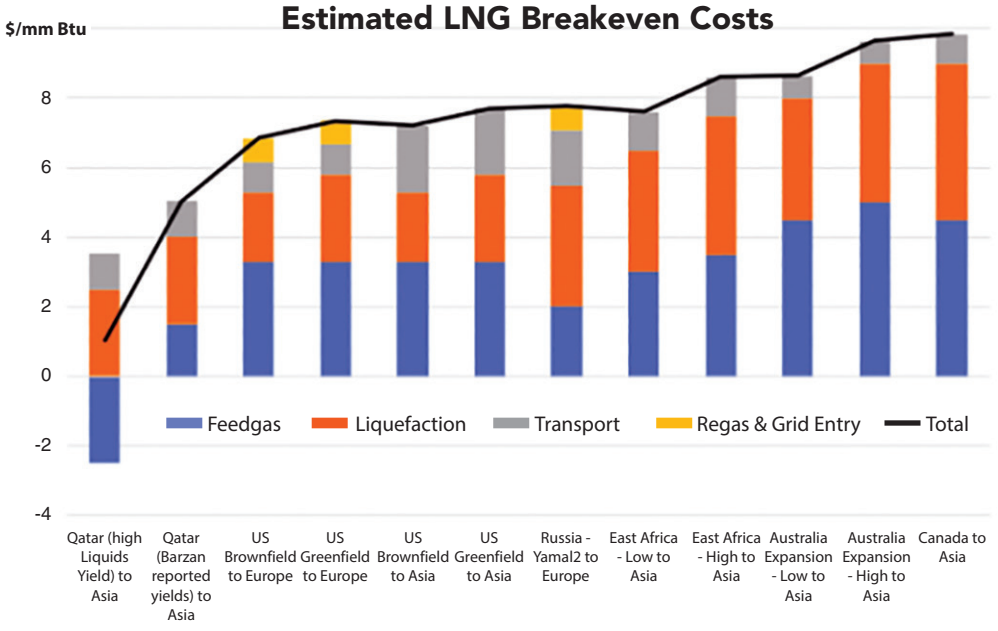


Source: S&P Global Platts Analytics, NDRC

10.0 World Supply and Demand Outlook (cont'd)

China Gas Demand

- From a source connected with one of China's major city gas suppliers regarding new **Russia-China** gas pipeline: "The growth of China's LNG imports should reduce the volume of LNG imports into northern China once Russian pipeline gas is made available."
- Despite impressive demand-growth projections, China's natural gas consumption is still only 1/3 that of the U.S., leaving plenty of room for more growth and **reduction in coal** use.
- Based on BP 2019 data, China already imports **43%** of its gas, 64% of which is LNG and 36% via pipelines from Turkmenistan, Uzbekistan and Myanmar.
- Novatek (Russian gas giant) data for an LNG breakeven price model provides insight into competitive sourcing tradeoffs (see chart).
- Pricing takes into account feed-gas origin and final destination, as well as costs of gas, liquefaction, transport, re-gasification and delivery. (Negative feed-gas cost in the case of Qatar "high liquids" yields near-zero breakeven price to Asian market.)
- Australia intends to **surpass Qatar** as the largest LNG supplier and is well positioned to remain a major supplier to both China and India if delivered cost can be competitive.
- United States LNG export capacity is growing in the expectation of continuing demand; hopeful but cautious about trade disputes and an oversupplied market.



Source: Author's estimates and calculations.

*Note: Due to the specific nature of the ice-breaking Yamal LNG carriers, the Yamal shipping costs were taken from the Novatek Strategy Presentation in December 2017, "Transforming into a Global Gas Company: From 2018 to 2030", http://www.novatek.ru/en/investors/strategy/, slide 56

10.0 World Supply and Demand Outlook (cont'd)

India Growing Energy Demand

India has not figured in much of the conversation to date, but we need to pay more attention.

	Level		Shares		Change (abs)		Change (%)		Annual Change	
	2017	2040	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
India Primary Fuel Consumption *										
Total*	754	1928	n/a	n/a	501	1174	199%	156%	5.1%	4.2%
Oil (Mb/d)	5	9	29%	23%	3	5	196%	101%	5.1%	2.1%
Gas (BCM)	54	185	6%	8%	36	131	200%	242%	5.1%	5.5%
Coal*	424	917	56%	48%	284	493	202%	116%	5.2%	3.4%
Nuclear*	8	43	1%	2%	7	35	391%	412%	7.5%	7.4%
Hydro*	31	56	4%	3%	14	25	79%	81%	2.7%	2.6%
Renewables including biofuel*	22	306	3%	16%	22	283	>1000%	>1000%	>10%	>10%

*Primary energy consumption in Mtoe except for oil and gas as noted.

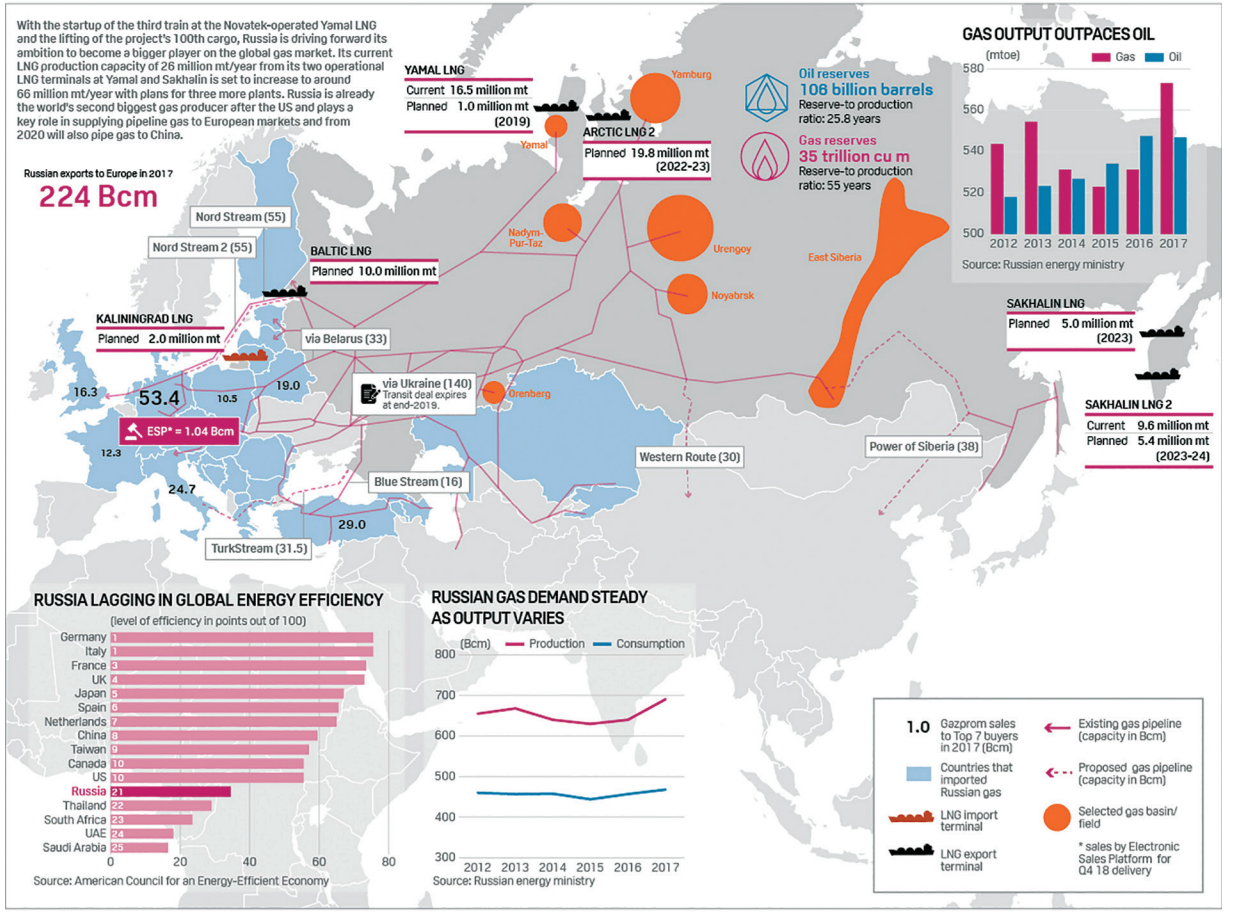
From the BP 2019 Outlook:

- India accounts for more than a **quarter** of the net global primary energy demand growth between 2017-2040.
- 42% of this new energy demand is met through coal, meaning *CO2 emissions **roughly double** by 2040.*
- Gas production grows, but fails to keep pace with demand, implying a significant **growth** in gas imports.

India's growing population, and associated energy consumption and CO2 emissions, is an important component of the world's efforts on climate change.

10.0 World Supply and Demand Outlook (cont'd)

Russia Gas, LNG Landscape



Source: S&P Global Platts, Gazprom

Russian Geopolitics scrambling the old and finding the new

Russian resources and China consumption are at the heart of many international supply/demand discussions. Which of course, are not unrelated 😊 .

As reported by Platts:

- Fully **1/3** of Europe's gas consumption comes from Russia.
- Europe rightly concerned about its heavy dependency on Russian gas has become more interested in LNG as an offset.
- There remains great controversy over Nordstream 2, a second pipeline from Russia, (directly to Germany and Northern European Pipeline System), over **increased reliance** on Russian gas.

Russia's "*Power of Siberia*" gas pipeline will have a major impact on sourcing decisions.

10.0 World Supply and Demand Outlook

Russia (cont'd)

Russia's "Power of Siberia" gas pipeline will have a major impact on sourcing decisions.

- Russia can now send gas east or west, or both, seasonally or otherwise.
- Developing assets to supply gas to China to offset any threat of European curtailment and support China's growing demand.

Russia has now become China's largest supplier of crude oil.

According to Reuters (January 2019), Russia became China's top crude oil supplier; its third year in a row ahead of Saudi Arabia. For the full year (2018), China's imports rose to1.43 mmb/d, **up 19.7%** from 2017.

- Meanwhile, **geopolitical uncertainties** force China to import less from countries such as Iran and Venezuela.

Russia continues to pursue LNG as well.

According to Reuters, the *Arctic LNG-2* project is latest in a raft of new projects aimed at **doubling** LNG capacity over next 15 years.

- Project is expected to launch in 2023, aiming to export **80%** of its LNG to Asia.

Russia also may play role in emerging Mediterranean natural gas resources.

Evolving alignment between Russia and **Turkey** could impact growing tensions between Turkey and its regional neighbors over development and ownership of natural gas resources.

- Turkey is the crossroads of cultures, migration, religion, trade deals and fuel supply, with conflicted loyalties that play the EU, the U.S. and Russia against one another.
- Turkey is now provoking **territorial conflict** with Cyprus over the emerging eastern Mediterranean gas resource. That could jeopardize the flow of goods and services to and from the region.
- A further Turkish-Russia alliance would secure this important economic corridor and pressure EU solidarity.

A final point: Russia controls a substantial portion of the world's Uranium supply, with **2/3** of global production. According to the World Nuclear Association, available resources are located in only five countries. *Russia, Kazakhstan and Canada (with Russian Investment) control **30%** of the resource.*

11.0 Conclusions

The Way Forward

There are plenty of opinions on the way forward but, in the end, *virtually all agree on need for CO2-free electricity.*

By now, it should be obvious to all that **natural gas is *not* a "bridge fuel"**.

- Natural gas is a fossil fuel. It produces ~ 800-1100 lbs-CO2/MWh, when used to produce electricity.
- Yes, it is "cleaner", but by no means is it "clean" let alone, "clean enough".

How do we "bridge" the gap from 60+% of electricity being produced by fossil fuels, **to ~5-10% by 2040**, just 20 years, when our current trajectory is set to breach the 2900Gt limit of atmospheric CO2 for 2°C rise?

- Protect trees and **plant more trees**.
- Use the nuclear power plants that we have, but with a 20-year extended life and 15% power uprates.
- Mandate all fossil-fueled power plants, including natural gas-fired simple and combined cycle units, deploy **90% CCS**, to "level the playing field" so nuclear and CCS can compete. **Whatever happened to "Capture *Ready*"?**
- Require renewables to **include storage** in their offerings to the grid; and remove any "first to dispatch" subsidies, embedded in the Renewable Portfolio Standards.
- Improve transmission capacity to **reach stranded renewables** and to spread the effects of intermittency over a wider area.
- Continue development of advanced nuclear options.
- Put a value on CO2 to fund above. Some like a **CO2 "tax"**; but I prefer a cost-based CO2 **"Disposal Fee"** that actually reflects the cost of dealing with the CO2 life cycle. Proceeds would go toward building and operating **CO2 pipelines** and remote **underground storage**, which has been estimated to cost **about $50/tonne**.The plant owner's "capture" cost would also be around $50/tonne.

No, I am not sold on hydrogen as **"the answer"** as appears to be the case in Europe, and among many in the gas turbine community, but most claims gloss over the true costs to produce, compress, transport and store the hydrogen; **costs** essential to its success.

- Question: Why is **CCS acceptable** when talking about hydrogen production process, but **not** for gas-fired generation?

Carbon Intensity (e.g., lbs. CO2/MWh) is a term used to suggest we can meet **any CO2 targets** by producing more at a lower rate, but Mother Nature is **not buying** the pitch!

The only positive outcome from this approach would be that the U.S., China and India might converge on a common metric to begin a *real conversation* about absolute reductions.

11.0 Conclusions

What Worries Me

I worry about the apparent Russian strategy **to dominate the Eurasian fuels market** with its supply abundance and proximity to Europe and Asia, and their control over trade/pipeline routes – east and west.

- The short-lived oil price war between Saudi Arabia and Russia appears to have been an attempt to undermine the U.S. shale resource and its newfound energy independence.
- Evolving alliance between Russia and Turkey has major implications concerning balance of influence in the Mediterranean as conflicts arise between perennial enemies over ownership of gas reserves and route of planned pipelines to EU.

And, I worry about **conflict in the South China Sea** over real or perceived hydrocarbon resources.

- Any conflict, trade barriers or otherwise, would **seriously impact trade balances**. The pending new *China-Iran Military and Trade Partnership* may actually lessen the tension in this very sensitive area.

Most of all, I worry about **time**…**or the lack of it**. If Covid-19 has taught us anything, it is the value of time. **Climate Change** is the **existential** threat. We have 20 years to get this right, but that means we **must** start now.

- Unfortunately, the most important participants still lack objective reasoning and remain motivated by self-interest. There are **practical decisions** we must make now.

WE'RE RUNNING OUT OF TIME !

About the author: International consultant Peter Baldwin has been involved for over 50 years in the engineering and global marketing aspects of the gas turbine and compressor industries. His independent Boston-based consulting company, ***base-e***, is focused on existing and new product positioning and commercialization strategies for distributed energy technologies, gas turbines, and air and gas compression.

Before this, Pete was President of ***Ramgen Power Systems***, a developer of advanced shock compression technology for utility scale CCS systems. During his 10-year tenure there he was the principal point of contact for all equipment selection, technical and commercial issues. Ramgen was acquired by Dresser-Rand in 2015 and since acquired by Siemens.

Before Ramgen, Pete worked for 33 years at ***Ingersoll-Rand*** where he held a variety of executive level positions, including international assignments in the UK and Italy. He was made V-P Sales & Service for the Air Compressor Group and then president of ***NREC*** which developed and marketed Ingersoll's microturbine-based product line.

Pete has a BSME degree from Purdue University. He can be contacted at pete_baldwin@base-e.net