A Coal Phase-Out Pathway for 1.5°C

MODELING A COAL POWER PHASE-OUT PATHWAY FOR 2018–2050 AT THE INDIVIDUAL PLANT LEVEL IN SUPPORT OF THE IPCC 1.5°C FINDINGS ON COAL

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CoalSwarm is a global network of researchers developing collaborative informational resources on fossil fuels and alternatives. Current projects include the Global Coal Plant Tracker, the Global Fossil Projects Tracker (coal, oil, and gas infrastructure), the CoalWire newsletter, and the CoalSwarm and FrackSwarm wiki portals.

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Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

ABOUT THE GLOBAL COAL PLANT TRACKER

The Global Coal Plant Tracker is an online database that identifies, maps, describes, and categorizes every known coal-fired generating unit and every new unit proposed since January 1, 2010 (30 MW and larger). Developed by CoalSwarm, the tracker uses footnoted wiki pages to document each plant and is updated biannually. For further details, see Tracker Methodology at EndCoal.org.

AUTHOR

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PRODUCTION

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FURTHER RESOURCES

For additional data on proposed and existing coal plants, see Summary Statistics at EndCoal.org. For links to reports based on GPCT data, see Reports at EndCoal.org. To obtain primary data from the GCPT, contact Ted Nace (ted@tednace.com).

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SUMMARY

In its special report, *Global Warming of 1.5°C,* the Intergovernmental Panel on Climate Change (IPCC) has assessed mitigation pathways limiting warming to 1.5 degrees Celsius above pre-industrial levels. The IPCC has analyzed various pathways, all of which require a near-total reduction in coal use for electricity generation by 2050, with reductions of approximately two-thirds by 2030.*

This briefing examines how such drastic cuts, two-thirds reduction in coal power generation in 2030 and a near-total reduction by 2050, can be achieved.

A rapid transition away from coal is technically and economically possible, but it will require aggressive retirement of coal plants coupled with equally aggressive deployment of efficiency measures and low-carbon power sources. The briefing explores the specifics of how such reductions could be implemented over the coming three decades, given the geographical distribution and age structure of the global coal plant fleet and the new coal plant pipeline.

The 1.5°C Pathway described in this briefing is based on CoalSwarm's Global Coal Plant Tracker (GCPT), which provides unit-specific details on all coal-fired generating units of 30 MW or more. The 1.5°C Pathway models two "oldest-first" phase-out schedules, one for OECD countries and the other for non-OECD countries. For the OECD countries, which tend to have older coal plants, the schedule retires plants by reverse age order until the entire fleet is phased out in 2030. For the non-OECD countries, where coal fleets are newer, the schedule retires plants by reverse age order at a pace rapid enough to meet the IPCC benchmarks for 2030 and 2050.

*The IPCC's summary findings of necessary reductions in primary energy from coal for 2030, relative to 2010, are 59%–78% (interquartile range) for scenarios with no or low overshoot. For modeling purposes, this briefing uses the pathway defined in Chapter 2, Table 2.7, in which generation from coal declines to 10.41 EJ in 2030 and 1.29 EJ in 2050, i.e. approximately a two-thirds reduction from current levels in 2030 and a near-total reduction by 2050. For additional background on the IPCC recommendations, see "IPCC Findings on Coal" at http://bit.ly/2IHWrKM.

THE CHALLENGE: A TWO-THIRDS REDUCTION IN COAL POWER GENERATION BY 2030, THEN A FULL PHASEOUT BY 2050

In order to examine how the steep reductions in coal power mandated by the IPCC report can be accomplished, this briefing explores three critical measures:

- **Plugging the pipeline.** Other than coal plants currently under active construction, no more coal plants are built.
- **Retiring the current coal fleet, oldest first.** Under the 1.5°C Pathway, OECD fleets are fully retired by 2030, and non-OECD fleets by 2050.
- **Making room for renewables.** As solar, wind, and other clean sources gain a larger share in the generation mix, coal plants shift toward a supporting role. Along with reductions in capacity, the global average coal plant load factor (i.e. energy output compared to maximum possible) declines at a rate of 3.5% per year as renewable sources of power and more flexible forms of back-up power take on an increasing share of the generation mix. This rate of decline in utilization is slightly lower than the rate of decline observed in the U.S. over the past decade (3.6% per year).

It should be noted that this coal reduction pathway cannot be interpreted as a "climate safe" scenario. Only a scenario that provided a much higher probability of success could be judged "safe." Rather, it models reductions that provide a one-in-two to two-in-three chance of keeping warming below 1.5°C, with no or low overshoot.

STEP 1: PLUG THE COAL POWER PIPELINE

As the saying goes, "If you're in a hole, stop digging."

Reducing power generation by two-thirds in the next 12 years cannot be achieved if the global coal power pipeline continues to grow. Under the 1.5°C Pathway developed here, coal power projects currently under construction are assumed to be completed and added to the global fleet. However, as shown in Table 1, projects that have not yet begun construction are cancelled. These include 365 GW of projects in pre-construction development (announced, pre-permit, and permitted) and 573 GW of projects in the "shelved," i.e. on hold, category. The shelved category includes 57 GW of shelved construction in China which are currently judged likely to resume construction if not cancelled. (See CoalSwarm's recent report Tsunami Warning: Can China's Central Authorities Stop a Massive Surge in New Coal Plants Caused by Provincial Overpermitting?)

Table 1. Proposed Coal Plants by Region (MW)

July 2018 - Includes units 30 MW and larger

Region	Announced	Pre-permit	Permitted	Shelved	Construction	Operating
East Asia	25,160	45,916	25,468	367,000	141,127	1,068,186
South Asia	31,304	34,585	25,425	107,795	46,013	223,275
SE Asia	34,075	22,596	17,892	40,360	28,517	71,924
non-EU Europe	18,000	18,827	8,255	26,614	1,130	28,899
Africa and Middle East	25,130	5,780	8,000	20,648	11,045	52,517
Eurasia	1,080	4,660	0	2,210	1,102	85,201
EU28	3,550	5,330	1,000	0	5,810	155,592
Latin America	900	450	1,666	3,735	2,175	16,352
Canada/US	0	0	0	1,895	0	275,302
Australia/NZ	0	0	0	2,666	0	25,372
Total	**139,199**	**138,144**	**87,706**	**572,923**	**236,919**	**2,002,620**

Global coal power pipeline. Under the 1.5°C Pathway, plants in construction (blue) are assumed to be completed, but plants in pre-construction or shelved (lavender) are cancelled. (Source: Global Coal Plant Tracker, July 2018)

STEP 2: RETIRE PLANTS, FROM OLDEST TO YOUNGEST

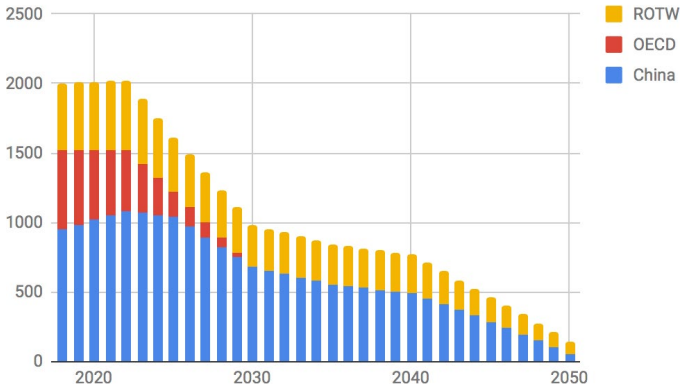
Achieving the reductions in coal-fired power generation required by the IPCC 1.5°C findings means a reduction of approximately two-thirds between 2018 and 2030, followed by a near-total reduction by 2050. Applying two oldest-first retirement schedules, one for the OECD countries, the other for non-OECD countries, we found that the phase-out schedule shown in Table 2, combined with the decline in average global load factor shown in Figure 6 below, would reduce global coal production enough the meet the IPCC benchmarks for 2020, 2030, and 2050.

As shown in Figures 1 and 2, retiring coal plants from oldest to youngest will tend to concentrate the initial retirements in the OECD, from 2018 to 2030, followed by a phase-out in China and the rest of the world from 2030 to 2050. The heaviest retirements would need to occur in the OECD countries from 2019 to 2030, when 46.9 GW of coal power capacity would need to be retired each year, and in China from 2041 to 2050, when 39.5 GW of coal power capacity would need to be retired each year.

Table 2. Phase-out Schedule for 1.5°C Pathway

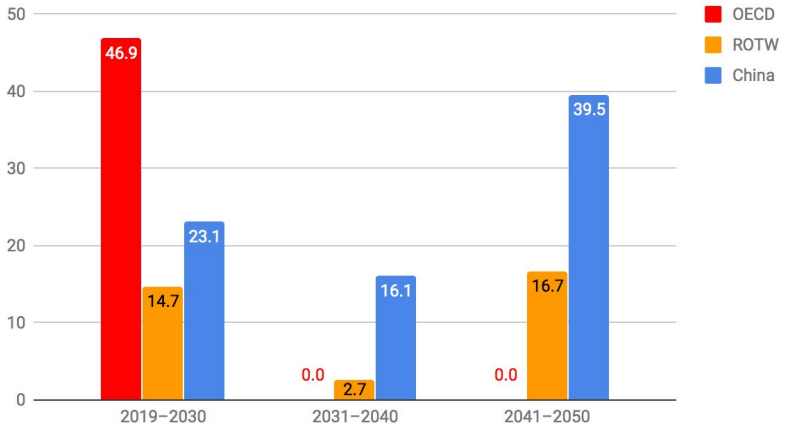
	Start Year of Oldest Remaining Plants	
Year	OECD	non-OECD
2018		
2022	**1974**	**1977**
2025	**1993**	**1993**
2030	**all**	**2008**
2035		**2010**
2040		**2011**
2045		**2015**
2050		**2026**

Figure 1. Coal Power Capacity in the 1.5°C Pathway (GW)



Coal power capacity in the 1.5°C Pathway, OECD, China, and rest of the world.

Figure 2. 1.5°C Pathway: Average Annual Capacity Reductions (GW)



Average annual capacity reduction in 1.5°C Pathway (GW), OECD, China, and rest of the world.

This approach to retirement has two benefits. First, it places the burden on the countries that have benefited the longest from coal power. Second, since older plants tend to be dirtier and less efficient than newer plants, it starts by eliminating those plants first, creating immediate climate and health benefits.

Under the 1.5°C Pathway, average capacity reductions from 2018 to 2030 will be 84.7 GW per year, approximately two and a half times the current three-year moving average of global retirements (32.4 GW per year), shown in Figure 3.

The contraction of the global coal power fleet, from 1,999 GW in 2018 to 1,005 GW in 2030, amounts to an average annual reduction in coal power capacity of 5.75%. This is faster than the rate of contraction of the U.S. coal fleet from 2006 to 2016 (1.59% per year) but slower than the average rate of contraction of the UK coal fleet over the same period (7.21% per year).

Figure 4 shows the country breakdown of the global coal fleet under the 1.5°C Pathway from 2018 to 2050. Currently, China has the world's largest coal fleet, with half of global capacity. Half of the Chinese fleet has been built since 2000. Similarly, India's coal fleet is relatively new, with most capacity built in the past decade. For that reason, Chinese and Indian coal plants will comprise two-third of global coal capacity after 2025 and an even larger share between 2030 and 2050.

Figure 3. Global Coal Power Retirements 2000–2017, Yearly and Three-Year Moving Average (GW)

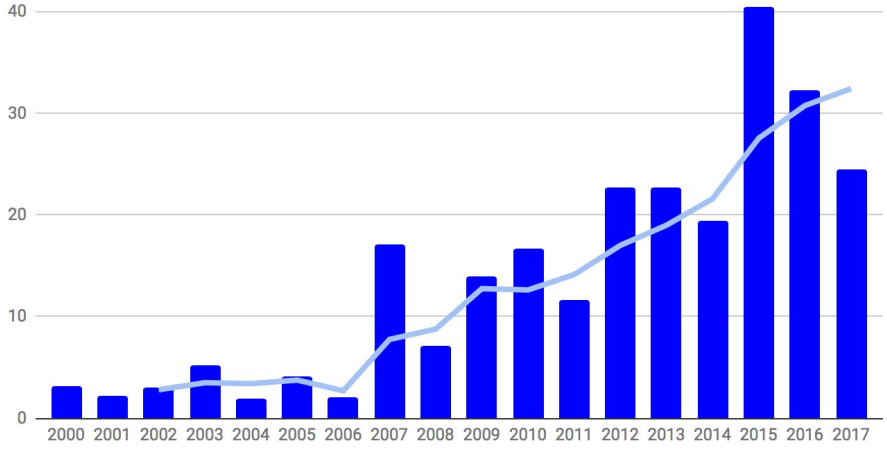
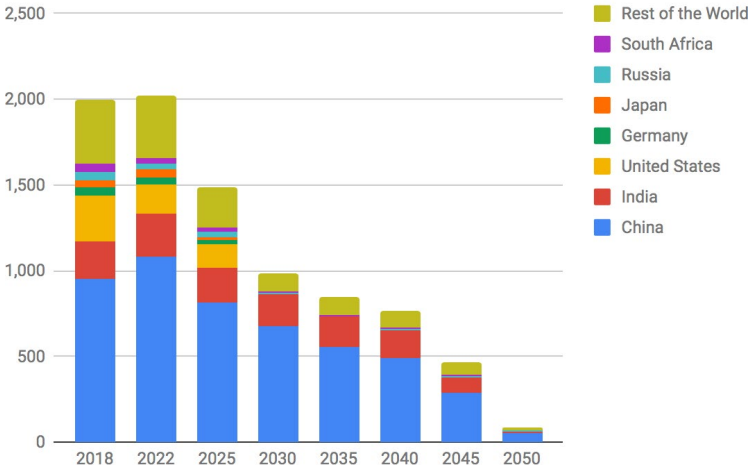


Figure 4. Capacity by Country (GW)



Coal power capacity of leading power fleets and rest of the world, 2018–2050.

STEP 3: SHIFT REMAINING COAL PLANTS TO SUPPORT RENEWABLES, THEREBY LOWERING LOAD FACTORS

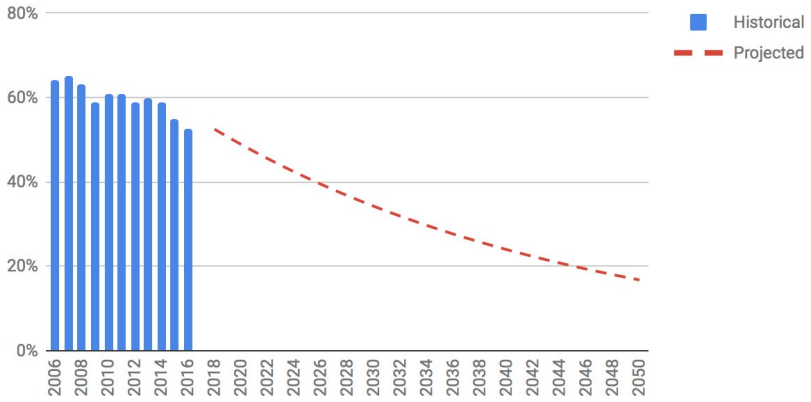
As zero-marginal-cost renewable power sources have increased their penetration and taken on a greater share in the overall power generation mix, the role of fossil plants has begun to shift. Coal plants have been pushed back from their usual baseload position to mid-load/balancing roles; the result has been a steady decrease in global coal plant load factors, from 64% in 2006 to 52% in 2016.

Contrary to conventional wisdom, which views coal-fired power plants exclusively as providers of baseload power, many utilities have considerable experience with deploying coal plants in load-following roles that in some cases require cycling up to four times per day. Extensive studies have been performed detailing modifications to boilers, turbines, and other plant equipment, as well as operational changes, that can allow cycling to take place without producing excess wear and tear. Such modifications make it possible for coal plants to shift into new roles in support of renewable power sources (U.S. DOE 2013, IEA 2014, EPRI 2011).

As penetration of renewables rises, average coal plant load factors can be expected to continue declining. From 2018 to 2050, the 1.5°C Pathway assumes the average load factor of the global coal power fleet declines at a rate of 3.5% per year, from 52.5% in 2018 to 16.8% in 2050, as shown in Figure 5. This rate of decline is slightly lower than the rate of decline seen over the past decade in the U.S., where the coal fleets average load factor dropped from 73.6% in 2007 to 53.1% in 2016, a 3.6% average annual reduction. It should be noted that average load factors well below 50% are already observed for certain countries and in certain seasons. U.S. coal plant load factors of of 36% and 37.8% were recorded in March and April of 2016, respectively (US EIA 2016), while Russia's average coal plant load factor was 31.8% in 2016 (IEA 2017).

Other factors assumed to reduce load factors are various country policies restricting the use of coal power capacity except as reserve capacity, or policies increasing the cost of coal power, for example reducing local air pollution and setting a cost for carbon dioxide.

Figure 5. Global Coal Plant Load Factor: Historical and Projected



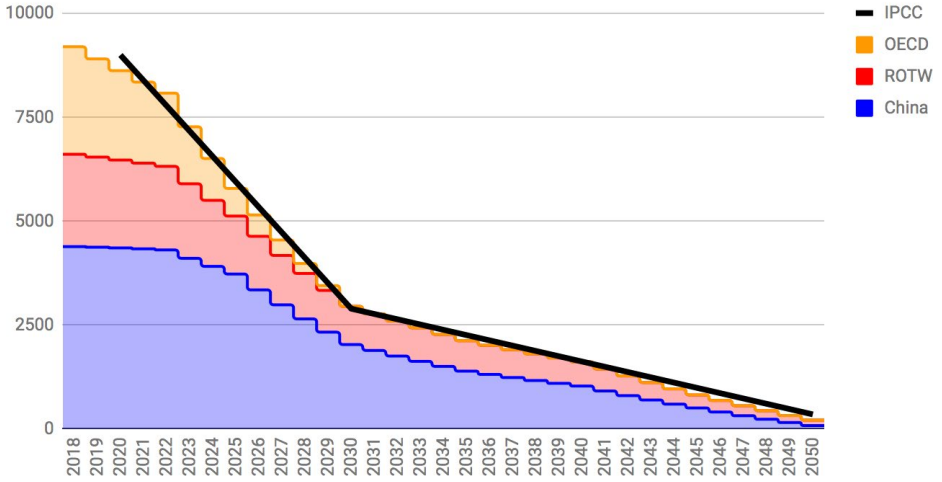
Under the 1.5°C Pathway, average global load factor declines at a 3.5% annual rate from 52.5% in 2018 to 16.8% in 2050. Source of 2006–2016 data: IEA 2017.

CONCLUSION

A 1.5°C-Compatible Reduction Schedule for Coal Can Be Achieved Through a Combination of Plugging the Pipeline, Oldest-First Retirements, and Lowered Load Factors

The result of all three measures—plugging the coal power pipeline, retiring fleets in oldest-first order, and lowering load factors—is shown in Figure 6.

Figure 6. Power Generation from Coal: Comparison of 1.5°C Pathway and IPCC 1.5°C Finding (TWh)

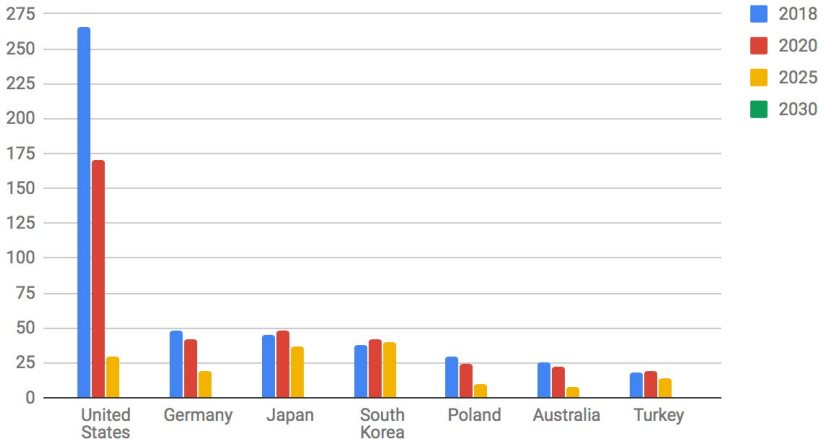


Reduction in power output for OECD, China, and rest of the world, 2018–2050, compared with IPCC finding of 10.41 EJ (2,892 TWh) electricity output in 2030 and 1.29 EJ (350 TWh) in 2050, median values for a 1.5°C pathway, from Table 2.7 of the supportive material.

COUNTRY DETAILS - OECD

The OECD coal fleets include large numbers of older coal plants. As of January 2018, the U.S. and the EU had a combined total of 203 GW of plants older than 40. Under the 1.5°C Pathway, OECD plants older than 50 are retired by 2022 (built before 1972), OECD plants older than 35 are retired by 2025 (built before 1990), and all remaining OECD plants are retired by 2030. The largest retirements must happen in the United States.

Figure 7. Total Capacity of Selected OECD Coal Plant Fleets in the 1.5°C Pathway, 2018–2030 (GW)



COUNTRY DETAILS - NON-OECD

While some countries outside the OECD have large, aging coal fleets, notably Russia, most non-OECD coal plants were built since 2000. For this reason, deep cuts in the non-OECD coal fleet would require some plants as young as 22 years to be retired. To meet the two-thirds cut in coal power generation, plants built before 2008 must be retired by 2030. The plan includes the following retirement thresholds:

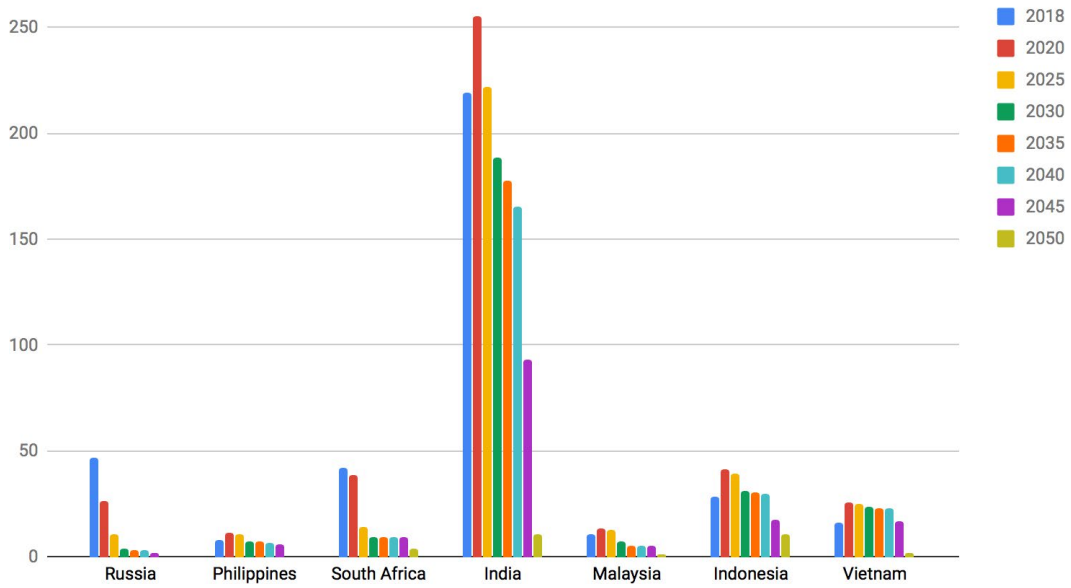
- Plants older than 45 years by 2022 (built before 1977),
- Plants older than 32 by 2025 (built before 1993),
- Plants older than 22 by 2030 (built before 2008),
- Plants older than 25 by 2035 (built before 2010),
- Plants older than 29 by 2040 (built before 2011),
- Plants older than 30 by 2045 (built before 2015),
- Plants older than 24 by 2050 (built before 2026).

As shown in Figure 3 above, this means an average rate of retirement of 23.1 GW per year in China from 2019 to 2030, 16.1 GW per year from 2031 to 2040, and 39.5 GW per year from 2041 to 2050.

In the rest of the world, retirements are 14.7 GW per year from 2019 to 2030, 2.7 GW per year from 2030 to 2039, and 16.7 GW per year from 2041 to 2050.

While these levels of retirement are technically feasible, the sustained nature of the phase-out will require determined policies across key countries. Countries would also benefit from international cooperation on the technical, financial, and social aspects of this transition.

Figure 8. Total Capacity of Selected non-OECD Coal Plant Fleets in the 1.5°C Pathway 2018–2050 (GW)



CAN RENEWABLES AND CONSERVATION FILL THE GAP?

Under the IPCC's 1.5°C finding for coal power, generation drops from 32.37 EJ in 2020 to 10.41 EJ in 2030, a drop of 21.96 EJ or 6,100 TWh per year. The question of how to adapt to such a large reduction has been extensively studied. As one research group summarized the state of such research, "Electricity decarbonization scenarios, primarily consisting of solar and wind, have been presented over a range of areas spanning individual US states to whole continents." (Jenkins and Thernstrom 2018)

While it is beyond the scope of this briefing to fully address the range of system integration and reliability issues that need to be addressed by such a transition, it should be noted that the scope and speed of the renewable buildout needed to fill the gap produced by the retirement of coal plants is well within reach given current growth curves and cost trends. Assuming average load factors of 45% and 25% respectively for utility-scale wind and solar PV, replacing that amount of power would require the construction of 1,000 GW each of wind and solar PV, or 83.3 GW each per year for the 12 years from 2019 to 2030.

That level of deployment would require a doubling of the current pace of wind power deployment, which was 54.6 GW in 2016 and 52.6 GW in 2017 (McCracken 2018), and a continuation of the current pace of solar PV deployment, which was 50 GW in 2016 (IRENA 2017) and 95–98 GW in 2017 (IEA 2018b).

Overall, the IEA states that solar PV is "well on track to meet its SDS target" of 2700 TWh in 2030 (up from 416 TWh in 2017). Onshore wind is not "on track," according to the IEA, after a 10% decline in capacity additions in 2017. Offshore wind "showed strong signs of progress with 23% generation growth" in 2017, but needs to accelerate faster to be on track with SDS targets (IEA 2018a). According to the IEA's Sustainable Development Scenario, solar PV produced 303 TWh in 2016 and wind produced 981 TWh. Solar PV is targeted to grow to 2,732 TWh and wind (combined onshore and offshore) to 4,193 TWh in 2030, reaching 6,925 TWh total and representing an increase of 5,641 TWh above the 2016 level (IEA 2017).

REFERENCES

EPRI (2011). "Mitigating the Effects of Flexible Operation on Coal-Fired Power Plants." http://bit.ly/2yfr7y3)

IEA (2014). "Increasing the Flexibility of Coal-Fired Plants." http://bit.ly/2ydyWo3

IEA (2017). "World Energy Outlook," Annex. http://bit.ly/2y1ybyu

IEA (2018a). Tracking Clean Energy Progress: Power. http://bit.ly/2OBGuex

IEA (2018b). Tracking Clean Energy Progress: Solar PV. http://bit.ly/2y4UNhm

IRENA (2017). "Renewable energy highlights," March 30, 2017. http://bit.ly/2xZb07S

Jenkins, Jesse D., and Samuel Thernstrom (2017). "Deep Carbonization of the Electrical Sector: Insights from Recent Literature." EIRP, March 2017. http://bit.ly/2yfN93J

McCracken, Ross (2018). "Global wind capacity additions stall in 2017, but remain above 50 GW." S&P Global, February 14, 2018. http://bit.ly/2y1ga3m

U.S. DOE (2013). "Flexible Coal: Evolution from Baseload to Peaking Plant." http://bit.ly/2ycEak2

U.S. EIA (2016). Table 6.7.A. "Capacity Factors for Utility Scale Generators Primarily Using Fossil Fuels, January 2013–July 2018." http://bit.ly/2yblCAB

APPENDIX A

Model Results (TWh)

Year	China	ROTW	OECD	IPCC	Total	% of IPCC	Load Factor
2018	4384	2,404	2,404		9192		53%
2019	4371	2,348	2,180		8899		51%
2020	4353	2,293	1,969	8,992	8616	96%	49%
2021	4331	2,239	1,771	8,382	8341	100%	47%
2022	4306	2,186	1,583	7,772	8075	104%	46%
2023	4103	1,957	1,205	7,162	7266	101%	44%
2024	3910	1,741	852	6,552	6503	99%	42%
2025	3725	1,538	522	5,942	5784	97%	41%
2026	3344	1,414	403	5,332	5161	97%	39%
2027	2985	1,297	292	4,722	4573	97%	38%
2028	2647	1,187	188	4,112	4021	98%	37%
2029	2328	1,082	90	3,502	3501	100%	35%
2030	2029	984	0	2,892	3013	104%	34%
2031	1887	943	0	2,765	2830	102%	33%
2032	1753	901	0	2,638	2654	101%	32%
2033	1625	860	0	2,510	2485	99%	31%
2034	1505	819	0	2,383	2323	97%	30%
2035	1390	777	0	2,256	2168	96%	29%
2036	1311	746	0	2,129	2057	97%	28%
2037	1236	714	0	2,002	1950	97%	27%
2038	1165	682	0	1,875	1847	99%	26%
2039	1097	651	0	1,748	1747	100%	25%
2040	1032	619	0	1,621	1651	102%	24%
2041	913	563	0	1,494	1476	99%	23%
2042	801	508	0	1,367	1309	96%	22%
2043	696	452	0	1,240	1148	93%	22%
2044	597	397	0	1,113	994	89%	21%
2045	504	341	0	985	845	86%	20%
2046	408	301	0	858	709	83%	19%
2047	318	261	0	731	579	79%	19%
2048	234	220	0	604	454	75%	18%
2049	155	180	0	477	335	70%	17%
2050	81	140	0	350	221	63%	17%

APPENDIX B

Model Results (MW)

Year	China	OECD	ROTW	MW
2018	953,320	522726	522,614	1,998,660
2019	984,886	491,294	529,014	2,005,193
2020	1,016,452	459,861	535,413	2,011,726
2021	1,048,018	428,429	541,813	2,018,259
2022	1,079,584	396,996	548,212	2,024,792
2023	1,066,166	313,190	508,508	1,887,864
2024	1,052,748	229,385	468,804	1,750,937
2025	1,039,330	145579	429,100	1,614,009
2026	966,802	116,463	408,901	1,492,166
2027	894,273	87,347	388,702	1,370,323
2028	821,745	58,232	368,504	1,248,480
2029	749,216	29,116	348,305	1,126,637
2030	676,688	0	328,106	1,004,794
2031	652,146	0	324,429	976,575
2032	627,604	0	320,752	948,356
2033	603,062	0	317,075	920,137
2034	578,520	0	313,398	891,918
2035	553,978	0	309,721	863,699
2036	541,457	0	306,712	848,168
2037	528,936	0	303,702	832,638
2038	516,414	0	300,693	817,107
2039	503,893	0	297,683	801,577
2040	491,372	0	294,674	786,046
2041	450,476	0	274,558	725,033
2042	409,579	0	254,441	664,020
2043	368,683	0	234,325	603,008
2044	327,786	0	214,208	541,995
2045	286,890	0	194,092	480,982
2046	240,552	0	174,313	403,825
2047	194,214	0	154,534	326,668
2048	147,876	0	134,755	249,511
2049	101,538	0	114,976	172,354
2050	55,200	0	95,197	95,197