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COALCAST
FUELCAST

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Capital Investments in Emission Control Retrofits in the U.S. Coal-fired Generating Fleet through the Years – 2016 Update

To comply with U.S. environmental regulations, the power industry has made (and continues to make) significant capital investments in air emission control technologies to remove sulfur dioxide (SO_2), particulate matter, nitrogen oxides (NO_x), mercury, and other emissions at coal-fired power plants. Environmental regulations such as the Title IV Acid Rain program, the OTR NO_x Budget Trading program, the Clean Air Interstate Rule (CAIR), the Cross-State Air Pollution Rule (CSAPR), and the Mercury and Air Toxics Standards (MATS) have already spurred more than $110 billion (nominal) of capital investments in new and retrofitted air emission controls at U.S. coal-fired generating units through 2015 with announced plans to reach $122 billion by the end of 2017. These large air pollution control capital investments are in addition to the other power industry environmental investments made in water treatment and waste disposal or at their non-coal generating units. The capital costs exclude the significant operating costs for these air controls which add significantly to coal power generation costs.

Table 1 shows the annual capital expenditures on new or retrofitted emission control equipment installed at coal-fired power plants by year. This study includes capital investments made for selective catalytic and non-catalytic reductions (SCR/SNCR) to reduce NO_x emissions, wet scrubber, dry scrubber and dry sorbent injection (DSI) equipment to reduce SO_2 emissions, fabric filter and electrostatic precipitators (hot-side/cold-side) to reduce emissions of particulate matter, as well as activated carbon injection (ACI) to reduce emissions of mercury and other hazardous air pollutants.

Table 1: Annual Capital Investments in Emission Controls at Coal Units ($ Million):

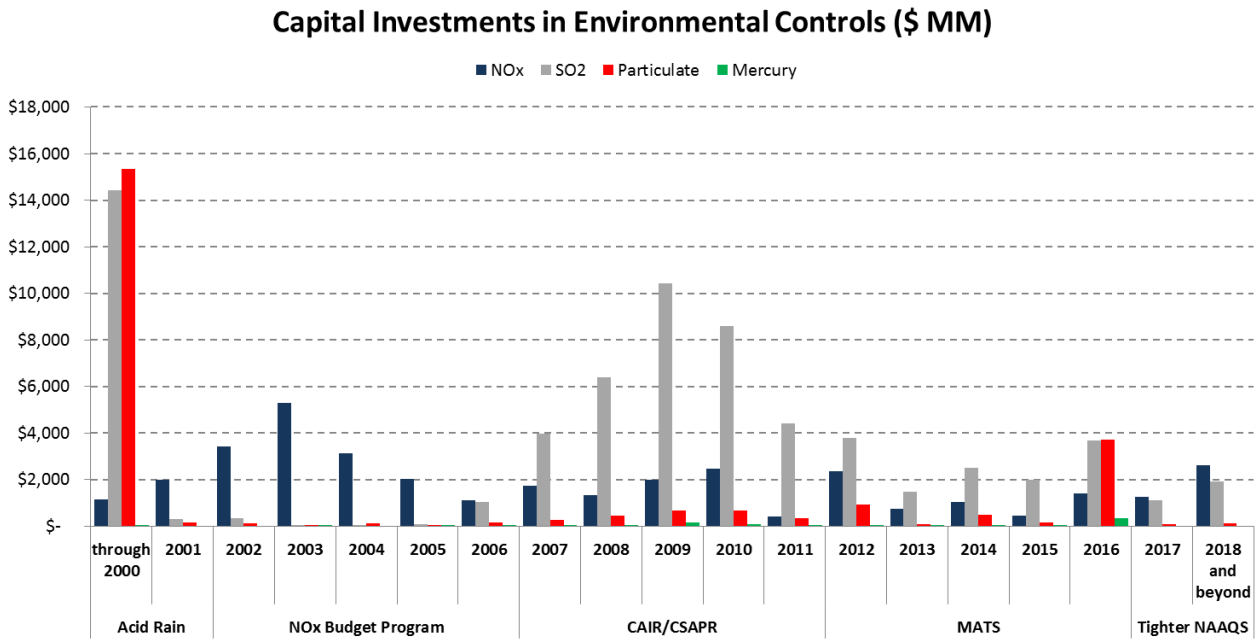
Year	NO_x	SO_2	Particulate	Mercury	Ann. Total	Cum. Total
through 2000	$ 1,149	$ 14,430	$ 15,338	$ 3	n/a	**$ 30,920**
2001	$ 1,986	$ 297	$ 148	$ -	$ 2,431	**$ 33,351**
2002	$ 3,424	$ 351	$ 114	$ -	$ 3,889	**$ 37,240**
2003	$ 5,288	$ 51	$ 58	$ 3	$ 5,400	**$ 42,640**
2004	$ 3,119	$ 13	$ 111	$ -	$ 3,242	**$ 45,882**
2005	$ 2,039	$ 71	$ 54	$ 2	$ 2,166	**$ 48,048**
2006	$ 1,128	$ 1,049	$ 161	$ 10	$ 2,348	**$ 50,396**
2007	$ 1,754	$ 3,971	$ 253	$ 10	$ 5,988	**$ 56,384**
2008	$ 1,318	$ 6,394	$ 468	$ 33	$ 8,214	**$ 64,598**
2009	$ 1,982	$ 10,427	$ 679	$ 169	$ 13,256	**$ 77,854**
2010	$ 2,467	$ 8,598	$ 659	$ 91	$ 11,815	**$ 89,669**
2011	$ 406	$ 4,428	$ 329	$ 22	$ 5,185	**$ 94,854**
2012	$ 2,344	$ 3,799	$ 915	$ 7	$ 7,066	**$ 101,920**
2013	$ 737	$ 1,475	$ 80	$ 12	$ 2,304	**$ 104,224**
2014	$ 1,036	$ 2,493	$ 498	$ 24	$ 4,050	**$ 108,274**
2015	$ 450	$ 2,001	$ 149	$ 66	$ 2,666	**$ 110,939**
2016	$ 1,408	$ 3,675	$ 3,724	$ 339	$ 9,146	**$ 120,086**
2017	$ 1,259	$ 1,112	$ 80	$ -	$ 2,452	**$ 122,537**
2018-2020	$ 2,633	$ 1,920	$ 126	$ -	$ 4,679	**$ 127,216**

Source: EIA 767/860 form, EVA estimates, industry data

Figure 1 below shows the multi-billion annual capital investments presented in Table 1 and connects them to EPA environmental programs that have stimulated these investments. Prior to 2000, the majority of investments in emission control technologies can be linked to the beginning of the Title IV Acid Rain program in 1995 and existing unit emission limitations. Starting with the Ozone Transport Region program started in 1999 in combination with the NO_x acid rain provisions, coal plant operators began to invest in advanced post-combustion NO_x emission controls such as SCRs and SNCRs. 2009 marked the beginning of EPA's CAIR program, which triggered an additional wave of SO_2 and particulate matter emission control installations. Recent investments in emission control technologies are primarily linked to the regional haze BART program, the reinstatement of CSAPR in 2014 (with compliance start on Jan 1, 2015) and the compliance start of MATS on April 16, 2015 (200 1-year extensions for individual coal-fired have been granted). Although the U.S. Supreme Court remanded EPA's MATS rule on June 29, 2015, for more than 62 GW of coal-fired generating capacity that has already been retired or converted to natural gas this

decision came too late. Other still operating coal plants have already invested more than $27 billion in MATS related emission controls since the final rule was published in 2011.[1]

Figure 1: Annual Capital Investments in Emission Controls at Coal Units by Program



Source: EIA 767/860 form, EVA estimates, industry data

Despite all these investments in state-of-the-art air emission controls, more than 77 GW of coal-fired capacity has already retired this decade or will be retired before the end of 2020. The 77 GW of coal capacity slated to be retired have spent more than $11 billion in emission controls technologies.

While most investments in new emission control equipment to comply with current EPA air regulations has either been already done or has been announced to be installed within the next couple of years, some newly finalized, as well as proposed and expected EPA regulations will most likely spur a new wave of investments and/or coal retirements. While the final rules for reducing GHG emissions from new and existing U.S. power plants will most likely result in additional retirements of coal-fired capacity and eliminate pulverized coal without carbon capture and storage as an option for new power plant builds, it could spur additional investments in process upgrades to improve the unit heat rates that would not be included as air pollution investments. However, other regulations such as EPA's recently-proposed update of the CSAPR rule, plus further tightening of National Ambient Air Quality Standards (NAAQS) for ozone and SO_2 will likely result in additional investments in emission controls at several coal-fired generating

[1] $27 billion have been invested in SO_2, particulate matter, and Mercury emission controls between 2011 and 2017.

stations without advanced post combustion control systems. Some additional post-combustion NO_x controls are expected for coal-fired units in the Western U.S. with the continued implementation of stricter plans to control regional haze. For example, EPA's final regional haze plan for the state of Texas, in which the agency imposes new SO_2 emission limits on 14 coal units, is expected to cost operators more than $2 billion in new or upgraded emission control technologies.

Table 2 shows the actual and announced capital investments in emissions controls by state and type through 2020. This table includes historical investments as well as already announced investments through 2020. The five states with the highest capital investments are listed below:

1. Indiana -- $11.8 billion
2. Ohio -- $9.6 billion
3. Kentucky – $8.4 billion
4. West Virginia -- $8.2 billion
5. Pennsylvania -- $8.1 billion

Not surprisingly, given the larger number of coal-fired power plants in the Midwest and East, larger investments in emissions controls are shown in these areas. These states also had to comply with all EPA regulations listed above that have triggered capital investments in emission controls.

Table2: Total Estimated Capital Cost for Emission Controls by State through 2020 ($ Million):

State	NO_x	SO_2	Particulate	Mercury	Total	Rank	State	NO_x	SO_2	Particulate	Mercury	Total	Rank
AK	$ 93	$ 1	$ 23	$ -	$ 118	42	MT	$ 6	$ 645	$ 16	$ 15	$ 681	35
AL	$ 885	$ 1,734	$ 804	$ 3	$ 3,426	15	NC	$ 3,115	$ 2,801	$ 507	$ 5	$ 6,429	6
AR	$ 120	$ 567	$ 374	$ 19	$ 1,081	26	ND	$ 47	$ 859	$ 113	$ 17	$ 1,037	27
AZ	$ 664	$ 1,415	$ 737	$ 13	$ 2,828	18	NE	$ 36	$ 242	$ 347	$ 30	$ 656	36
CA	$ 3	$ 26	$ 20	$ -	$ 49	45	NH	$ 36	$ 435	$ 16	$ 1	$ 487	38
CO	$ 952	$ 936	$ 645	$ 15	$ 2,549	19	NJ	$ 234	$ 1,195	$ 85	$ 13	$ 1,527	24
CT	$ -	$ 26	$ 87	$ 3	$ 116	43	NM	$ 682	$ 524	$ 342	$ 16	$ 1,563	23
DE	$ 114	$ 130	$ 193	$ 7	$ 444	39	NV	$ 12	$ 143	$ 164	$ 2	$ 321	40
FL	$ 2,026	$ 2,433	$ 520	$ 10	$ 4,990	10	NY	$ 107	$ 369	$ 272	$ 8	$ 757	33
GA	$ 1,502	$ 2,801	$ 1,200	$ 55	$ 5,557	8	OH	$ 2,695	$ 4,958	$ 1,926	$ 4	$ 9,583	2
HI	$ 0	$ 4	$ 14	$ -	$ 18	46	OK	$ -	$ 713	$ 288	$ 28	$ 1,029	28
IA	$ 375	$ 933	$ 395	$ 16	$ 1,719	22	OR	$ -	$ 32	$ 27	$ -	$ 58	44
IL	$ 1,156	$ 3,216	$ 583	$ 89	$ 5,044	9	PA	$ 1,521	$ 5,772	$ 794	$ 23	$ 8,111	5
IN	$ 3,698	$ 5,590	$ 2,492	$ 51	$ 11,832	1	SC	$ 524	$ 1,133	$ 357	$ -	$ 2,014	21
KS	$ 625	$ 906	$ 466	$ 29	$ 2,026	20	SD	$ 243	$ 291	$ 20	$ -	$ 554	37
KY	$ 2,071	$ 4,469	$ 1,847	$ 39	$ 8,426	3	TN	$ 2,103	$ 2,033	$ 97	$ -	$ 4,234	12
LA	$ 43	$ 493	$ 207	$ -	$ 744	34	TX	$ 1,444	$ 2,998	$ 1,264	$ 90	$ 5,796	7
MA	$ 201	$ 324	$ 331	$ 10	$ 867	32	UT	$ -	$ 730	$ 167	$ 1	$ 898	31
MD	$ 1,149	$ 2,278	$ 1,110	$ 18	$ 4,555	11	VA	$ 820	$ 1,667	$ 394	$ 3	$ 2,883	17
ME	$ -	$ -	$ 4	$ -	$ 4	47	WA	$ 20	$ 153	$ -	$ -	$ 173	41
MI	$ 33	$ 643	$ 607	$ 54	$ 1,337	25	WI	$ 1,119	$ 1,757	$ 631	$ 21	$ 3,528	14
MN	$ 109	$ 548	$ 302	$ 13	$ 973	29	WV	$ 2,539	$ 4,454	$ 1,252	$ 9	$ 8,254	4
MO	$ 1,133	$ 946	$ 1,466	$ 18	$ 3,562	13	WY	$ 1,510	$ 1,474	$ 402	$ 35	$ 3,421	16
MS	$ 160	$ 755	$ 35	$ 8	$ 958	30	**U.S. Total**	**$ 35,928**	**$ 66,554**	**$ 23,943**	**$ 791**	**$ 127,216**	

Source: EIA 767/860 form, EVA estimates, industry data

Methodology

The primary resources utilized to estimate the capital investment in emission controls at coal-fired plants were the U.S. Energy Information Administration's (EIA) 2014 Form EIA-860 (767 for data prior to 2005), the Environmental Protection Agency's (EPA) Clean Air Markets Division's database, and EVA's emission control retrofit cost curves.

NO_x Emission Control Costs

This study only includes the capital investments associated with NO_x post-combustion controls (selective non-catalytic reduction, selective catalytic reduction). The estimated installed cost of SCRs and SNCRs were derived from industry-supplied cost data from 2014 EIA Form 860 (and 767), Schedule 6. While Form 860 provides a large amount of information on control expenditures, it is not complete. For NO_x control costs not provided, the following steps were taken.

1. Estimated NO_x control costs using historical cost data from EIA-860 from the same year/time period.
2. Estimated the cost of recently retrofitted and future NO_x controls using EVA's emission control cost curves for newer retrofit installations, which are dependent on type of control technology and size of the coal-fired unit.

SO_2 Emission Control Costs

The estimated installed cost of FGD was derived from industry-supplied cost data from EIA Form 860 (and 767), Schedule 6. While Form 860 provides a large amount of information on control expenditures, it is not complete. For SO_2 control costs not provided, the following steps were taken.

1. Estimated SO_2 control costs using historical cost data from EIA-860 from the same year/time period.
2. Estimated the cost of recently retrofitted and future SO_2 controls using EVA's emission control cost curves for newer retrofit installations, which are dependent on type of control technology and size of the coal-fired unit.

Fluidized bed combustors (FBC) have an integrated system that also reduces SO_2 emissions. However, most FBC owners did not assign any of the FBC value to SO_2 controls in the Form 860. As a result, the SO_2 estimates reflect all FGD capital investments but little to no capital costs for FBC SO_2 controls.

Particulate Matter Emission Control Costs

Particulate control installation costs were similarly determined from industry supplied cost data contained in EIA-860 Schedule 6 data. Particulate controls in coal units primarily include electrostatic precipitators, fabric filters, and particulate cyclones. Again, EIA-860 provides a large amount of information on installed particulate control costs but is not complete. So, in order to estimate the installed cost of particulate controls missing from EIA-860, historical cost data from the same year/time period and cost estimates using EVA's retrofit cost curves were utilized.

Mercury Emission Control Costs

Mercury controls include FGD (already included in SO_2 control costs) for bituminous coal units and activated carbon injection with particulate controls. Many utilities also made particulate control upgrades

to capture the greater activated carbon particulate loading as part of their mercury control compliance strategies. Both the FGD and particulate control costs are already accounted for in the SO_2 and particulate cost categories above and represent the vast majority of mercury control capital costs. Mercury emission control costs incurred by plants that installed additional ACI systems were included and captured in this cost category. In order to estimate the installed cost of mercury controls missing from EIA-860, historical cost data from the same year/time period and cost estimates using EVA's retrofit cost curves were utilized.

EIA Form 860 Data Limitation

Cost numbers on EIA Form 860 for projects that came online after the reporting year (2015 and beyond) might be underestimating the actual capital cost that will be incurred. EIA 860 data can also include cost estimates for emission controls for future years that might not be built due to changes in compliance strategy for that particular plant (retirement/ fuel-switching vs. retrofitting). Additionally, past reporting errors on the cost of already installed emission controls have been corrected in the newest EIA 860 form, changing historical cost estimates from past reports.