

## 5. Emission Control Technologies

EPA Platform v6 includes an update of emission control technology assumptions. EPA contracted with engineering firm Sargent & Lundy to update and add to the retrofit emission control cost models originally developed for EPA and used in EPA Base Case v.4.10 and updated in EPA Base Case v.5.13. EPA Platform v6 includes updated assumptions regarding control options for sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), mercury (Hg), carbon dioxide (CO<sub>2</sub>), and acid gases (HCl). These emission control options are listed in Table 5-1. They are available in EPA Platform v6 for meeting existing and potential federal, regional, and state emission limits. Besides the emission control options shown in Table 5-1 and described in this chapter, EPA Platform v6 offers other compliance options for meeting emission limits. These include fuel switching, adjustments in the dispatching of electric generating units, and the option to retire a unit.

**Table 5-1 Summary of Emission Control Technology Retrofit Options in EPA Platform v6**

| SO <sub>2</sub> Control Technology Options | NO <sub>x</sub> Control Technology Options      | Mercury Control Technology Options  | CO <sub>2</sub> Control Technology Options | HCl Control Technology Options             |
|--|---|---|--|--|
| Limestone Forced Oxidation (LSFO) Scrubber | Selective Catalytic Reduction (SCR) System      | Activated Carbon Injection (ACI) System                                   | CO <sub>2</sub> Capture and Sequestration  | Limestone Forced Oxidation (LSFO) Scrubber |
| Lime Spray Dryer (LSD) Scrubber            | Selective Non-Catalytic Reduction (SNCR) System | SO <sub>2</sub> and NO <sub>x</sub> Control Technology Removal Cobenefits | Coal-to-gas                                | Lime Spray Dryer (LSD) Scrubber            |
| Dry Sorbent Injection (DSI)                |   |   | Heat Rate Improvement                      | Dry Sorbent Injection (DSI)                |

Detailed reports and example calculation worksheets for Sargent & Lundy retrofit emission control models used by EPA are available in Attachment 5-1 through Attachment 5-7.

### 5.1 Sulfur Dioxide Control Technologies - Scrubbers

Two commercially available Flue Gas Desulfurization (FGD) scrubber technology options for removing the SO<sub>2</sub> produced by coal-fired power plants are offered in EPA Platform v6: Limestone Forced Oxidation (LSFO) — a wet FGD technology and Lime Spray Dryer (LSD) — a semi-dry FGD technology which employs a spray dryer absorber (SDA). In wet FGD systems the polluted gas stream is brought into contact with a liquid alkaline sorbent (typically limestone) by forcing it through a pool of the liquid slurry or by spraying it with the liquid. In dry FGD systems the polluted gas stream is brought into contact with the alkaline sorbent in a semi-dry state through use of a spray dryer. The removal efficiency for SDA drops steadily for coals whose SO<sub>2</sub> content exceeds 3 lbs SO<sub>2</sub>/MMBtu, the technology is therefore provided to only plants which have the option to burn coals with sulfur content no greater than 3 lbs SO<sub>2</sub>/MMBtu. In EPA Platform v6 when a unit retrofits with an LSD SO<sub>2</sub> scrubber, it loses the option of burning certain high sulfur content coals (see Table 5-2).

The LSFO and LSD SO<sub>2</sub> emission control technologies are available to existing unscrubbed units. They are also available to existing scrubbed units with reported removal efficiencies of less than 50%. Such units are considered to have an injection technology and are classified as unscrubbed for modeling purposes in the NEEDS v6 database. The scrubber retrofit costs for these units are the same as those for regular unscrubbed units retrofitting with a scrubber.

Default SO<sub>2</sub> removal rates for wet and dry FGD were based on data reported in EIA 860 (2015). These default removal rates were the average of all SO<sub>2</sub> removal rates for a dry or wet FGD as reported in EIA 860 (2015) for the FGD installation year.

To reduce the incidence of implausibly high, outlier removal rates, the following adjustment is made. Units for which reported EIA Form 860 (2015) SO<sub>2</sub> removal rates are higher than the average of the upper

quartile of SO<sub>2</sub> removal rates across all scrubbed units are assigned the upper quartile average. The adjustment is not made, however, if a unit's reported removal rate was recently confirmed by utility comments. Furthermore, one upper quartile removal rate is calculated across all installation years and replaces any reported removal rate that exceeds it no matter the installation year.

Existing units not reporting FGD removal rates in EIA Form 860 (2015) will be assigned the default SO<sub>2</sub> removal rate for a dry or wet FGD for that installation year.

As shown in Table 5-2, for FGD retrofits installed by the model, the assumed SO<sub>2</sub> removal rates will be 98% for wet FGD and 95% for dry FGD.

The procedures used to derive the cost of each scrubber type are discussed in detail in the following sections.

**Table 5-2 Summary of Retrofit SO<sub>2</sub> Emission Control Performance Assumptions in EPA Platform v6**

| Performance Assumptions      | Limestone Forced Oxidation (LSFO)                                  | Lime Spray Dryer (LSD)  |
|------------------------------|--|---|
| Percent Removal*             | 98%<br>with a floor of 0.06 lbs/MMBtu                              | 95%<br>with a floor of 0.08 lbs/MMBtu                             |
| Capacity Penalty             | Calculated based on characteristics of the unit:<br>See Table 5-3  | Calculated based on characteristics of the unit:<br>See Table 5-3 |
| Heat Rate Penalty            |  |   |
| Cost (2016\$)                |  |   |
| Applicability                | Units ≥ 25 MW  | Units ≥ 25 MW   |
| Sulfur Content Applicability |  | Coals ≤ 3 lbs SO <sub>2</sub> /MMBtu                              |
| Applicable Coal Types        | BA, BB, BD, BE, BG, BH, SA, SB, SD, SE, LD, LE, LG, LH, PK, and WC | BA, BB, BD, BE, SA, SB, SD, SE, LD, and LE                        |

\* If the SO<sub>2</sub> permit rate of the unit is lower than the floor rate then the SO<sub>2</sub> permit rate is considered as the floor rate.

Potential (new) coal-fired units built by IPM are also assumed to be constructed with a wet scrubber achieving a removal efficiency of 98%. In EPA Platform v6 the costs of potential new coal units include the cost of scrubbers.

### 5.1.1 Methodology for Obtaining SO<sub>2</sub> Controls Costs

Sargent & Lundy's updated performance/cost models for wet and dry SO<sub>2</sub> scrubbers are implemented in EPA Platform v6 to develop the capital, fixed O&M (FOM), and variable O&M (VOM) components of cost. For details of Sargent & Lundy Wet FGD and SDA FGD cost models, see Attachment 5-1 and Attachment 5-2.

**Capacity and Heat Rate Penalty:** In IPM the amount of electrical power required to operate a retrofit emission control device is represented through a reduction in the amount of electricity that is available for sale to the grid. For example, if 1.6% of the unit's electrical generation is needed to operate the scrubber, the generating unit's capacity is reduced by 1.6%. This is the "capacity penalty." At the same time, to capture the total fuel used in generation both for sale to the grid and for internal load (i.e., for operating the control device), the unit's heat rate is scaled up such that a comparable reduction (1.6% in the previous example) in the new higher heat rate yields the original heat rate<sup>39</sup>. The factor used to scale up

<sup>39</sup> Mathematically, the relationship of the heat rate and capacity penalties (both expressed as positive percentage values) can be represented as follows:

$$\text{Heat Rate Penalty} = \left( \frac{1}{\left(1 - \frac{\text{Capacity Penalty}}{100}\right)} - 1 \right) \times 100$$

the original heat rate is called “heat rate penalty.” It is a modeling procedure only and does not represent an increase in the unit’s actual heat rate (i.e., a decrease in the unit’s generation efficiency)<sup>40</sup>. In EPA Platform v6 specific LSFO and LSD heat rate and capacity penalties are calculated for each installation based on equations from the Sargent & Lundy models that take into account the rank of coal burned, its uncontrolled SO<sub>2</sub> rate, and the heat rate of the model plant.

Table 5-3 presents the capital, VOM, and FOM costs as well as the capacity and heat rate penalty for two SO<sub>2</sub> emission control technologies (LSFO and LSD) included in EPA Platform v6 for an illustrative set of generating units with a representative range of capacities and heat rates.

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<sup>40</sup> The NEEDS heat rate is an unmodified, “original” heat rate to which this retrofit-based heat rate penalty procedure is applied. This procedure is limited to units at which IPM adds a retrofit in the model.

**Table 5-3 Illustrative Scrubber Costs (2016\$) for Representative Sizes and Heat Rates under the Assumptions in EPA Platform v6**

| Scrubber Type   | Heat Rate (Btu/kWh) | Capacity Penalty (%) | Heat Rate Penalty (%) | Variable O&M (mills/kWh) | Capacity (MW)        |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|---|---------------------|----------------------|-----------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|   |                     |                      |                       |                          | 100                  |                      | 300                  |                      | 500                  |                      | 700                  |                      | 1000                 |                      |
|   |                     |                      |                       |                          | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) |
| <b>LSFO</b>   |                     |                      |                       |                          |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| Minimum Cutoff: ≥ 25 MW                                     | 9,000               | -1.60                | 1.63                  | 2.24                     | 879                  | 24.3                 | 638                  | 11.6                 | 550                  | 8.6                  | 499                  | 8.0                  | 450                  | 6.6                  |
| Maximum Cutoff: None  | 10,000              | -1.78                | 1.82                  | 2.47                     | 919                  | 24.7                 | 667                  | 11.9                 | 575                  | 8.9                  | 522                  | 8.2                  | 470                  | 6.8                  |
| Assuming 3 lb/MMBtu SO <sub>2</sub> Content Bituminous Coal | 11,000              | -1.96                | 2.00                  | 2.70                     | 956                  | 25.1                 | 694                  | 12.2                 | 599                  | 9.1                  | 543                  | 8.4                  | 490                  | 7.0                  |
| <b>LSD</b>  |                     |                      |                       |                          |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| Minimum Cutoff: ≥ 25 MW                                     | 9,000               | -1.18                | 1.20                  | 2.60                     | 745                  | 17.8                 | 546                  | 8.9                  | 472                  | 6.8                  | 424                  | 5.8                  | 424                  | 5.3                  |
| Maximum Cutoff: None  | 10,000              | -1.32                | 1.33                  | 2.89                     | 779                  | 18.2                 | 571                  | 9.2                  | 494                  | 7.0                  | 443                  | 5.9                  | 443                  | 5.5                  |
| Assuming 2 lb/MMBtu SO <sub>2</sub> Content Bituminous Coal | 11,000              | -1.45                | 1.47                  | 3.17                     | 812                  | 18.5                 | 594                  | 9.4                  | 514                  | 7.3                  | 461                  | 6.1                  | 461                  | 5.7                  |

Note 1: The above cost estimates assume a boiler burning 3 lb/MMBtu SO<sub>2</sub> Content Bituminous Coal for LSFO and 2 lb/MMBtu SO<sub>2</sub> Content Bituminous Coal for LSD.

Note 2: The Variable O&M costs in this table do not include the cost of additional auxiliary power (VOMP) component in the Sargent & Lundy tool as for modeling purposes, IPM reflects the auxiliary power consumption through capacity penalty.

## 5.2 Nitrogen Oxides Control Technology

There are two main categories of NO<sub>x</sub> reduction technologies: combustion and post-combustion controls. Combustion controls reduce NO<sub>x</sub> emissions during the combustion process by regulating flame characteristics such as temperature and fuel-air mixing. Post-combustion controls operate downstream of the combustion process and remove NO<sub>x</sub> emissions from the flue gas. All the technologies included in EPA Platform v6 are commercially available and currently in use in numerous power plants.

### 5.2.1 Combustion Controls

EPA Platform v6 does not model combustion control upgrades as a retrofit option. The decision was based on two considerations, the relatively low cost of combustion controls compared with that of post combustion NO<sub>x</sub> controls and the possible impact on model size. EPA identified units in NEEDS that have not employed state-of-the-art combustion controls. EPA then estimated the NO<sub>x</sub> rates for such units based on an analysis of historical rates of units with state-of-the-art NO<sub>x</sub> combustion controls. Emission rates provided by State-of-the-Art combustion controls are presented in Attachment 3-1.

### 5.2.2 Post-combustion NO<sub>x</sub> Controls

EPA Platform v6 provides two post-combustion retrofit NO<sub>x</sub> control technologies for existing coal units: Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR). In EPA Platform v6, oil/gas steam units are provided with only SCR retrofits. NO<sub>x</sub> reduction in a SCR system takes place by injecting ammonia (NH<sub>3</sub>) vapor into the flue gas stream where the NO<sub>x</sub> is reduced to nitrogen (N<sub>2</sub>) and water (H<sub>2</sub>O) abetted by passing over a catalyst bed typically containing titanium, vanadium oxides, molybdenum, and/or tungsten. As its name implies, SNCR operates without a catalyst. In SNCR a nitrogenous reducing agent (reagent), typically urea or ammonia, is injected into, and mixed with, hot flue gas where it reacts with the NO<sub>x</sub> in the gas stream reducing it to nitrogen gas and water vapor. Due to the presence of a catalyst, SCR can achieve greater NO<sub>x</sub> reductions than SNCR. However, SCR costs are higher than SNCR costs.

Table 5-4 summarizes the performance and applicability assumptions for each post-combustion NO<sub>x</sub> control technology and provides a cross-reference to information on cost assumptions.

**Table 5-4 Summary of Retrofit NO<sub>x</sub> Emission Control Performance Assumptions in EPA Platform v6**

| Control Performance Assumptions | Selective Catalytic Reduction (SCR)                                   |               | Selective Non-Catalytic Reduction (SNCR)  |
|---------------------------------|---|---------------|---|
|                                 | Coal  | Oil/Gas       | Coal  |
| Unit Type                       | Coal  | Oil/Gas       | Coal  |
| Percent Removal                 | 90%   | 80%           | Pulverized Coal: 25% (25-200 MW), 20% (200-400 MW), 15% (>400 MW)<br>Fluidized Bed: 50% |
| Rate Floor                      | Bituminous: 0.07 lb/MMBtu<br>Subbituminous and Lignite: 0.05 lb/MMBtu | --            | Pulverized Coal: 0.1 lb/MMBtu<br>Fluidized Bed: 0.08 lb/MMBtu                           |
| Size Applicability              | Units ≥ 25 MW   | Units ≥ 25 MW | Units ≥ 25 MW   |
| Costs (2016\$)                  | See Table 5-5   | See Table 5-6 | See Table 5-5   |

### **5.2.3 Methodology for Obtaining SCR Costs for Coal**

The updated performance and cost models for SCR and SNCR technologies developed for EPA by Sargent & Lundy are implemented in EPA Platform v6 to develop the capital, fixed O&M (FOM), and variable O&M (VOM) components of cost. For details of Sargent & Lundy SCR and SNCR cost models, see Attachment 5-3 and Attachment 5-4.

Table 5-5 presents the SCR and SNCR capital, VOM, and FOM costs and capacity and heat rate penalties for an illustrative set of coal generating units with a representative range of capacities and heat rates.

**Table 5-5 Illustrative Post-combustion NO<sub>x</sub> Control Costs (2016\$) for Coal Plants for Representative Sizes and Heat Rates under the Assumptions in EPA Platform v6**

| Control Type   | Heat Rate (Btu/kWh) | Capacity Penalty (%) | Heat Rate Penalty (%) | Variable O&M (mills/kWh) | Capacity (MW)        |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|--|---------------------|----------------------|-----------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|  |                     |                      |                       |                          | 100                  |                      | 300                  |                      | 500                  |                      | 700                  |                      | 1000                 |                      |
|  |                     |                      |                       |                          | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) |
| <b>SCR</b><br>Minimum Cutoff: ≥ 25 MW  | 9,000               | -0.54                | 0.54                  | 1.35                     | 373                  | 1.95                 | 304                  | 0.85                 | 282                  | 0.72                 | 269                  | 0.66                 | 257                  | 0.60                 |
|  | 10,000              | -0.56                | 0.56                  | 1.45                     | 405                  | 2.06                 | 333                  | 0.91                 | 309                  | 0.78                 | 295                  | 0.71                 | 282                  | 0.66                 |
|  | 11,000              | -0.58                | 0.59                  | 1.56                     | 437                  | 2.17                 | 361                  | 0.97                 | 335                  | 0.83                 | 321                  | 0.76                 | 307                  | 0.71                 |
| <b>SNCR - Tangential, 25% Removal Efficiency</b><br>Minimum Cutoff: ≥ 25 MW<br>Maximum Cutoff: 200 MW  | 9,000               |                      |                       | 1.17                     | 55                   | 0.49                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
|  | 10,000              | -0.05                | 0.78                  | 1.29                     | 56                   | 0.51                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
|  | 11,000              |                      |                       | 1.42                     | 58                   | 0.52                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
| <b>SNCR - Tangential, 20% Removal Efficiency</b><br>Minimum Cutoff: ≥ 200 MW<br>Maximum Cutoff: 400 MW | 9,000               |                      |                       | 0.93                     | N/A                  | N/A                  | 29                   | 0.26                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
|  | 10,000              | -0.05                | 0.63                  | 1.04                     | N/A                  | N/A                  | 30                   | 0.26                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
|  | 11,000              |                      |                       | 1.14                     | N/A                  | N/A                  | 31                   | 0.27                 | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  | N/A                  |
| <b>SNCR - Tangential, 15% Removal Efficiency</b><br>Minimum Cutoff: ≥ 400 MW<br>Maximum Cutoff: None   | 9,000               | -0.05                | 0.49                  | 0.70                     | N/A                  | N/A                  | N/A                  | N/A                  | 21                   | 0.19                 | 18                   | 0.16                 | 15                   | 0.13                 |
|  | 10,000              |                      |                       | 0.78                     | N/A                  | N/A                  | N/A                  | N/A                  | 22                   | 0.19                 | 18                   | 0.16                 | 15                   | 0.13                 |
|  | 11,000              |                      |                       | 0.85                     | N/A                  | N/A                  | N/A                  | N/A                  | 22                   | 0.20                 | 19                   | 0.16                 | 15                   | 0.13                 |
| <b>SNCR - Fluidized Bed</b><br>Minimum Cutoff: ≥ 25 MW<br>Maximum Cutoff: None                         | 9,000               | -0.05                | 1.51                  | 2.33                     | 44                   | 0.38                 | 24                   | 0.21                 | 18                   | 0.16                 | 15                   | 0.13                 | 12                   | 0.11                 |
|  | 10,000              |                      |                       | 2.59                     | 45                   | 0.39                 | 24                   | 0.21                 | 18                   | 0.16                 | 15                   | 0.13                 | 12                   | 0.11                 |
|  | 11,000              |                      |                       | 2.85                     | 46                   | 0.40                 | 25                   | 0.22                 | 19                   | 0.16                 | 15                   | 0.13                 | 13                   | 0.11                 |

Note 1: \*Assumes Bituminous Coal, NO<sub>x</sub> rate: 0.5 lb/MMBtu, and SO<sub>2</sub> rate: 2.0 lb/MMBtu

Note 2: The Variable O&M costs in this table do not include the cost of additional auxiliary power (VOMP) component in the S&L tool as for modeling purposes, IPM reflects the auxiliary power consumption through capacity penalty.

Note 3: Heat rate penalty includes the effect of capacity penalty.

## 5.2.4 Methodology for Obtaining SCR Costs for Oil/Gas Steam Units

The cost calculations for SCR described in section 5.2.3 apply to coal units. For SCR on oil/gas steam units, the cost calculation procedure shown in Table 5-6 is used. The scaling factor for capital and fixed O&M costs, described in footnote <sup>a</sup>, applies to all size units from 25 MW and up.

**Table 5-6 Post-Combustion NO<sub>x</sub> Controls for Oil/Gas Steam Units in EPA Platform v6**

| Post-Combustion Control Technology | Capital (\$/kW) | Fixed O&M (\$/kW-yr) | Variable O&M (\$/MWh) | Percent Removal |
|------------------------------------|-----------------|----------------------|-----------------------|-----------------|
| SCR <sup>a</sup>                   | 86.38           | 1.25                 | 0.14                  | 80%             |

Notes:

The “Coefficients” in the table above are multiplied by the terms below to determine costs.

“MW” in the terms below is the unit’s capacity in megawatts.

Cost data are adjusted to 2016\$ by EPA.

<sup>a</sup> SCR Cost Equations:

SCR Capital Cost and Fixed O&M:  $(200/\text{MW})^{0.35}$

The scaling factors shown above apply up to 500 MW. The cost obtained for a 500 MW unit applies for units larger than 500 MW.

Example for 275 MW unit:

SCR Capital Cost (\$/kW) =  $86.38 * (200/275)^{0.35} \approx 77.27$  \$/kW

SCR FOM Cost (\$/kW-yr) =  $1.25 * (200/275)^{0.35} \approx 1.12$  \$/kW-yr

SCR VOM Cost (\$/MWh) = 0.14 \$/MWh

## 5.2.5 Methodology for Obtaining SNCR Costs for Coal

In the Sargent & Lundy’s cost update for SNCR, the NO<sub>x</sub> removal efficiency varies by unit size and burner type as summarized in Table 5-4. Additionally, the capital, fixed, and variable operating and maintenance costs of SNCR on circulating fluidized bed (CFB) units are distinguished from the corresponding costs for other boiler types (e.g., cyclone and wall fired). As with SCR, an air heater modification cost applies for plants that burn bituminous coal whose SO<sub>2</sub> content is 3 lbs/MMBtu or greater.

## 5.2.6 SO<sub>2</sub> Controls for Units with Capacities from 25 MW to 100 MW (25 MW ≤ capacity < 100 MW)

In EPA Platform v6, coal units with capacities between 25 MW and 100 MW are offered the same SO<sub>2</sub> control options as larger units. However, for purposes of modeling, the costs of controls for these units are assumed to be equivalent to that of a 50 MW for Dry FGD and 100 MW for Wet FGD. These assumptions are based on several considerations. First, to achieve economies of scale, several units in this size range are likely to be ducted to share a single common control, so the minimum capacity cost equivalency assumption, though generic, would be technically plausible. Second, single units in this size range that are not grouped to achieve economies of scale are likely to switch to a lower sulfur coal, repower or convert to natural gas firing, use dry sorbent injection, and/or reduce operating hours.

Illustrative scrubber costs for 25-100 MW coal units with a range of heat rates can be found by referring to the LSFO 100 MW and LSD 100MW “Capital Costs (\$/kW)” and “Fixed O&M” columns in Table 5-3. The Variable O&M cost component, which applies to units regardless of size, can be found in the fifth column in this table.

## 5.3 Biomass Co-firing

Biomass co-firing is provided as an option for those coal-fired units in EPA Platform v6 that per EIA Form 923 had co-fired biomass during the 2012-2016 period. Table 5-7 lists the units provided with the co-firing option and the limit on share of the biomass co-firing. The remaining coal power plants are not

provided this choice as logistics and boiler engineering considerations place limits on the extent of biomass that can be fired. The logistical considerations arise primarily because biomass is only economic to transport a limited distance from where it is grown due to its relatively low energy density. In addition, the extent of storage that can be devoted at a power plant to such a fuel is another limiting factor. Boiler efficiency and other engineering considerations, largely driven by the relatively higher moisture content and lower heat content of biomass compared to fossil fuel, also plays a role in limiting the potential adoption of co-firing.

**Table 5-7 Coal Units with Biomass Co-firing Option in EPA Platform v6**

| <b>Plant Name</b>                   | <b>Unit ID</b> | <b>Biomass Co-Firing Share Limit (%)<sup>41</sup></b> |
|-------------------------------------|----------------|---|
| Virginia City Hybrid Energy Center  | 1              | 8   |
| Virginia City Hybrid Energy Center  | 2              | 8   |
| University of Iowa Main Power Plant | BLR11          | 10  |
| University of Iowa Main Power Plant | BLR10          | 10  |
| Northampton Generating Company LP   | BLR1           | 10  |
| TES Filer City Station              | 2              | 10  |
| TES Filer City Station              | 1              | 10  |
| Manitowoc                           | 9              | 10  |
| Schiller                            | 6              | 10  |
| Schiller                            | 4              | 10  |
| T B Simon Power Plant               | BLR4           | 10  |

## 5.4 Mercury Control Technologies

For any power plant, mercury emissions depend on the mercury content of the fuel used, the combustion and physical characteristics of the unit, and the emission control technologies deployed. In the absence of activated carbon injection (ACI), mercury emission reductions below the mercury content of the fuel are strictly due to characteristics of the combustion process and incidental removal resulting from other pollution control technologies, e.g., the SO<sub>2</sub>, NO<sub>x</sub>, and particulate matter controls. The following discussion is divided into three parts. Sections 5.4.1 and 5.4.2 explain the two factors that determine mercury emissions that result from unit configurations lacking ACI under EPA Platform v6. Section 5.4.1 discusses how mercury content of fuel is modeled in EPA Platform v6. Section 5.4.2 looks at the procedure used in EPA Platform v6 to capture the mercury reductions resulting from different unit and (non-mercury) control configurations. Section 5.4.3 explains the mercury emission control options that are available under EPA Platform v6. Each section indicates the data sources and methodology used.

### 5.4.1 Mercury Content of Fuels

#### Coal

Assumptions pertaining to the mercury content of coal (and the majority of emission modification factors discussed below in Section 5.4.2) are derived from EPA's "Information Collection Request for Electric Utility Steam Generating Unit Mercury Emissions Information Collection Effort" (ICR).<sup>42</sup> A two-year effort

<sup>41</sup> In EPA Platform v6, the limit on biomass co-firing is expressed as the percentage of the facility (ORIS code) level power output that is produced from biomass. Based on analysis by EPA's power sector engineering staff, a maximum of 10% of the facility level power output (not to exceed 50 MW) can be fired by biomass in modeling projections.

<sup>42</sup> Data from the ICR can be found at <http://www.epa.gov/ttn/atw/combust/utilttox/mercury.html>. In 2009, EPA collected some additional information regarding mercury through the Collection Effort for New and Existing Coal- and Oil-Fired Electricity Utility Steam Generating Units (EPA ICR No.2362.01 (OMB Control Number 2060-0631)), however the information collected was not similarly comprehensive and was thus not used to update mercury assumptions in this EPA Platform.

initiated in 1998 and completed in 2000, the ICR had three main components: (1) identifying all coal-fired units owned and operated by publicly-owned utility companies, Federal power agencies, rural electric cooperatives, and investor-owned utility generating companies, (2) obtaining “accurate information on the amount of mercury contained in the as-fired coal used by each electric utility steam generating unit with a capacity greater than 25 megawatts electric [MWe]), as well as accurate information on the total amount of coal burned by each such unit,” and (3) obtaining data by coal sampling and stack testing at selected units to characterize mercury reductions from representative unit configurations.

The ICR resulted in more than 40,000 data points indicating the coal type, sulfur content, mercury content and other characteristics of coal burned at coal-fired utility units greater than 25 MW. To make this data usable, these data points were first grouped by IPM coal types and IPM coal supply regions. IPM coal types divide bituminous, subbituminous, and lignite coal into different grades based on sulfur content.

#### Oil, natural gas, and waste fuels

Assumptions pertaining to the mercury content for oil, gas, and waste fuels are based on data derived from previous EPA analysis of mercury emissions from power plants.<sup>43</sup> Table 5-8 provides a summary of the assumptions on the mercury content for oil, gas, and waste fuels.

**Table 5-8 Assumptions on Mercury Concentration in Non-Coal Fuel in EPA Platform v6**

| Fuel Type             | Mercury Concentration (lbs/TBtu) |
|-----------------------|----------------------------------|
| Oil                   | 0.48                             |
| Natural Gas           | 0.00 <sup>a</sup>                |
| Petroleum Coke        | 2.66                             |
| Biomass               | 0.57                             |
| Municipal Solid Waste | 71.85                            |
| Geothermal Resource   | 2.97 - 3.7                       |

Note:

<sup>a</sup> The values appearing in this table are rounded to two decimal places. The zero value shown for natural gas is based on an EPA study that found a mercury content of 0.000138 lbs/TBtu. Values for geothermal resources represent a range.

#### **5.4.2 Mercury Emission Modification Factors**

Emission Modification Factors (EMFs) represent the mercury reductions attributable to the specific burner type and configuration of SO<sub>2</sub>, NO<sub>x</sub>, and particulate matter control devices at an electric generating unit. An EMF is the ratio of outlet mercury concentration to inlet mercury concentration, and depends on the unit's burner type, particulate control device, post-combustion NO<sub>x</sub> control and SO<sub>2</sub> scrubber control. In other words, the mercury reduction achieved (relative to the inlet) during combustion and flue-gas treatment process is (1-EMF), such that the lower the EMF, the greater the mercury reduction. If the EMF is 0.25, then only 25% of the inlet mercury concentration is emitted as outlet mercury concentration, and therefore the unit has achieved a 75% reduction in mercury that would otherwise be emitted without the properties influencing the EMF. The EMF varies by the type of coal (bituminous, subbituminous, and lignite) used during the combustion process.

Deriving EMFs involves obtaining mercury inlet data by coal sampling and mercury emission data by stack testing at a representative set of coal units. As noted above, EPA's EMFs were initially based on 1999 mercury ICR emission test data. More recent testing conducted by the EPA, DOE, and industry

<sup>43</sup> Analysis of Emission Reduction Options for the Electric Power Industry,” Office of Air and Radiation, U.S. EPA, March 1999.

participants<sup>44</sup> has provided a better understanding of mercury emissions from electric generating units and mercury capture in pollution control devices. Overall the 1999 ICR data revealed higher levels of mercury capture for bituminous coal-fired plants than for subbituminous and lignite coal-fired plants, and significant capture of ionic Hg in wet-FGD scrubbers. Additional mercury testing indicates that for bituminous coals, SCR systems have the ability to convert elemental Hg into ionic Hg and thus allow easier capture in a downstream wet-FGD scrubber. This understanding of mercury capture with SCRs is incorporated in EPA Platform v6 mercury EMFs for unit configurations with SCR and wet scrubbers.

Table 5-9 below provides a summary of EMFs used in EPA Platform v6. Table 5-10 provides definitions of acronyms for existing controls that appear in Table 5-9. Table 5-11 provides a key to the burner type designations appearing in Table 5-9.

**Table 5-9 Mercury Emission Modification Factors Used in EPA Platform v6**

| Burner Type | Particulate Control      | Post-combustion Control - NO <sub>x</sub> | Post-combustion Control - SO <sub>2</sub> | Bituminous EMF | Subbituminous EMF* | Lignite EMF |
|-------------|--------------------------|---|---|----------------|--------------------|-------------|
| FBC         | Cold Side ESP            | No SCR                                    | None                                      | 0.65           | 0.1                | 0.62        |
| FBC         | Cold Side ESP            | No SCR                                    | Dry FGD                                   | 0.64           | 0.1                | 1           |
| FBC         | Cold Side ESP + FF       | No SCR                                    | None                                      | 0.05           | 0.1                | 0.43        |
| FBC         | Cold Side ESP + FF       | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| FBC         | Fabric Filter            | No SCR                                    | None                                      | 0.05           | 0.1                | 0.43        |
| FBC         | Fabric Filter            | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 0.43        |
| FBC         | Hot Side ESP + FGC       | No SCR                                    | None                                      | 1              | 0.1                | 1           |
| FBC         | Hot Side ESP + FGC       | No SCR                                    | Dry FGD                                   | 0.6            | 0.1                | 1           |
| FBC         | No Control               | No SCR                                    | None                                      | 1              | 0.1                | 1           |
| Non FBC     | Cold Side ESP            | SCR                                       | None                                      | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP            | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP            | SCR                                       | Dry FGD                                   | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP            | No SCR                                    | None                                      | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP            | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP            | No SCR                                    | Dry FGD                                   | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FF       | SCR                                       | None                                      | 0.2            | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FF       | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FF       | SCR                                       | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FF       | No SCR                                    | None                                      | 0.2            | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FF       | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FF       | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC      | SCR                                       | None                                      | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC      | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FGC      | SCR                                       | Dry FGD                                   | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC      | No SCR                                    | None                                      | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC      | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FGC      | No SCR                                    | Dry FGD                                   | 0.64           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC + FF | SCR                                       | None                                      | 0.2            | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC + FF | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FGC + FF | SCR                                       | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC + FF | No SCR                                    | None                                      | 0.2            | 0.1                | 1           |
| Non FBC     | Cold Side ESP + FGC + FF | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 0.56        |
| Non FBC     | Cold Side ESP + FGC + FF | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Fabric Filter            | SCR                                       | None                                      | 0.11           | 0.1                | 1           |
| Non FBC     | Fabric Filter            | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Fabric Filter            | SCR                                       | Dry FGD                                   | 0.05           | 0.1                | 1           |

<sup>44</sup> For a detailed summary of emissions test data see Control of Emissions from Coal-Fired Electric Utility Boilers: An Update, EPA/Office of Research and Development, February 2005. This report can be found at [www.epa.gov/ttnatw01/utility/hgwhitepaperfinal.pdf](http://www.epa.gov/ttnatw01/utility/hgwhitepaperfinal.pdf).

| Burner Type | Particulate Control     | Post-combustion Control - NO <sub>x</sub> | Post-combustion Control - SO <sub>2</sub> | Bituminous EMF | Subbituminous EMF* | Lignite EMF |
|-------------|-------------------------|---|---|----------------|--------------------|-------------|
| Non FBC     | Fabric Filter           | No SCR                                    | None                                      | 0.11           | 0.1                | 1           |
| Non FBC     | Fabric Filter           | No SCR                                    | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Fabric Filter           | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | SCR                                       | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | SCR                                       | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | No SCR                                    | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP            | No SCR                                    | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FF       | SCR                                       | None                                      | 0.11           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FF       | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 0.56        |
| Non FBC     | Hot Side ESP + FF       | SCR                                       | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FF       | No SCR                                    | None                                      | 0.11           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FF       | No SCR                                    | Wet FGD                                   | 0.03           | 0.1                | 0.56        |
| Non FBC     | Hot Side ESP + FF       | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | SCR                                       | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | SCR                                       | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | No SCR                                    | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC      | No SCR                                    | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC + FF | SCR                                       | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC + FF | No SCR                                    | None                                      | 0.11           | 0.1                | 1           |
| Non FBC     | Hot Side ESP + FGC + FF | No SCR                                    | Dry FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | No Control              | SCR                                       | None                                      | 1              | 0.1                | 1           |
| Non FBC     | No Control              | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 1           |
| Non FBC     | No Control              | SCR                                       | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | No Control              | No SCR                                    | None                                      | 1              | 0.1                | 1           |
| Non FBC     | No Control              | No SCR                                    | Wet FGD                                   | 0.58           | 0.1                | 1           |
| Non FBC     | No Control              | No SCR                                    | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | PM Scrubber             | SCR                                       | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | PM Scrubber             | SCR                                       | Wet FGD                                   | 0.1            | 0.1                | 1           |
| Non FBC     | PM Scrubber             | SCR                                       | Dry FGD                                   | 0.6            | 0.1                | 1           |
| Non FBC     | PM Scrubber             | No SCR                                    | None                                      | 0.9            | 0.1                | 1           |
| Non FBC     | PM Scrubber             | No SCR                                    | Wet FGD                                   | 0.05           | 0.1                | 1           |
| Non FBC     | PM Scrubber             | No SCR                                    | Dry FGD                                   | 0.6            | 0.1                | 1           |

Note: 2017 annual emissions data suggests that, with subbituminous coal, many configurations are now achieving at least 90% removal of mercury. This table was updated from previous versions to reflect this recent observation. For 2017 emissions data, see: <https://ampd.epa.gov>.

**Table 5-10 Definition of Acronyms for Existing Controls**

| Acronym | Description                            |
|---------|--|
| ESP     | Electrostatic Precipitator - Cold Side |
| HESP    | Electrostatic Precipitator - Hot Side  |
| ESP/O   | Electrostatic Precipitator - Other     |
| FF      | Fabric Filter                          |
| FGD     | Flue Gas Desulfurization - Wet         |
| DS      | Flue Gas Desulfurization - Dry         |
| SCR     | Selective Catalytic Reduction          |
| PMSCRUB | Particulate Matter Scrubber            |

**Table 5-11 Key to Burner Type Designations in Table 5-9**

“**PC**” refers to conventional pulverized coal boilers. Typical configurations include wall-fired and tangentially fired boilers (also called T-fired boilers). In wall-fired boilers the burner’s coal and air nozzles are mounted on a single wall or opposing walls. In tangentially fired boilers the burner’s coal and air nozzles are mounted in each corner of the boiler.

“**Cyclone**” refers to cyclone boilers where air and crushed coal are injected tangentially into the boiler through a “cyclone burner” and “cyclone barrel” which create a swirling motion allowing smaller coal particles to be burned in suspension and larger coal particles to be captured on the cyclone barrel wall where they are burned in molten slag.

“**Stoker**” refers to stoker boilers where lump coal is fed continuously onto a moving grate or chain, which moves the coal into the combustion zone in which air is drawn through the grate and ignition takes place. The carbon gradually burns off, leaving ash which drops off at the end into a receptacle, from which it is removed for disposal.

“**FBC**” refers to “fluidized bed combustion” where solid fuels are suspended on upward-blowing jets of air, resulting in a turbulent mixing of gas and solids and a tumbling action which provides especially effective chemical reactions and heat transfer during the combustion process.

“**Other**” refers to miscellaneous burner types including cell burners and arch-, roof-, and vertically-fired burner configurations.

### **5.4.3 Mercury Control Capabilities**

EPA Platform v6 offers two options for mercury pollution control: (1) combinations of SO<sub>2</sub>, NO<sub>x</sub>, and particulate controls which deliver mercury reductions as a co-benefit; and (2) Activated Carbon Injection (ACI), a retrofit option specifically designed for mercury control. These two options are discussed below.

#### Mercury Control through SO<sub>2</sub> and NO<sub>x</sub> Retrofits

Units that install SO<sub>2</sub>, NO<sub>x</sub>, and particulate controls reduce mercury emissions as a byproduct of these retrofits. Section 5.4.2 described how EMFs are used to capture mercury emissions depending on the rank of coal burned, the generating unit’s combustion characteristics, and the specific configuration of SO<sub>2</sub>, NO<sub>x</sub>, and particulate controls (i.e., hot and cold-side electrostatic precipitators (ESPs), fabric filters (also called “baghouses”), and particulate matter (PM) scrubbers).

#### Activated Carbon Injection (ACI)

The technology used for mercury control in EPA Platform v6 is Activated Carbon Injection (ACI) downstream of the combustion process in coal fired units. Sargent & Lundy’s updated cost and performance assumptions for ACI are used (and are described further below).

Three alternative ACI options are represented as capable of providing 90% mercury removal for all possible configurations of boiler, emission controls, and coal types used in the U.S. electric power sector. The three ACI options differ, based on whether they are used in conjunction with an electrostatic precipitator (ESP) or a fabric filter (also called a “baghouse”). The three ACI options are:

- ACI with Existing ESP
- ACI with Existing Baghouse
- ACI with an Additional Baghouse (also referred to as Toxecon)

In the third option listed above the additional baghouse is installed downstream of the pre-existing particulate matter device and the activated carbon is injected after the existing controls. This configuration allows the fly ash to be removed before it is contaminated by the mercury.

For modeling purposes, EPA assumes that all three configurations use brominated ACI, where a small amount of bromine is chemically bonded to the powdered carbon, which is injected into the flue gas stream. EPA recognizes that amended silicates and possibly other non-carbon, non-brominated

substances are in development and may become available as alternatives to brominated carbon as a mercury sorbent.

The applicable ACI option depends on the coal type burned, its SO<sub>2</sub> content, the boiler and particulate control type, and in some instances consideration of whether an SO<sub>2</sub> scrubber (FGD) system and SCR NO<sub>x</sub> post-combustion control are present. Table 5-12 shows the ACI assignment scheme used to achieve 90% mercury removal. EPA Platform v6 does not explicitly model ACI retrofit options.

**Table 5-12 Assignment Scheme for Mercury Emissions Control Using Activated Carbon Injection (ACI) in EPA Platform v6**

| Air pollution controls |   |            |            | Bituminous Coal |                   |                                    | Subbituminous Coal |                   |                                    | Lignite Coal  |                   |                                    |
|------------------------|---|------------|------------|-----------------|-------------------|------------------------------------|--------------------|-------------------|------------------------------------|---------------|-------------------|------------------------------------|
| Burner Type            | Particulate Control Type                  | SCR System | FGD System | ACI Required?   | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) | ACI Required?      | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) | ACI Required? | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) |
| FBC                    | Cold Side ESP + Fabric Filter without FGC | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| FBC                    | Cold Side ESP without FGC                 | --         | --         | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| FBC                    | Fabric Filter                             | --         | Dry FGD    | No              | No                | 0                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| FBC                    | Fabric Filter                             | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| FBC                    | Hot Side ESP with FGC                     | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | --         | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | --         | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | SCR        | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | SCR        | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter with FGC    | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | --         | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | --         | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | SCR        | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | SCR        | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP + Fabric Filter without FGC | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | --         | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | --         | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | SCR        | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | SCR        | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP with FGC                    | SCR        | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Cold Side ESP without FGC                 | --         | --         | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| Non-FBC                | Cold Side ESP without FGC                 | --         | Wet FGD    | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| Non-FBC                | Cold Side ESP without FGC                 | SCR        | --         | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| Non-FBC                | Cold Side ESP without FGC                 | SCR        | Dry FGD    | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| Non-FBC                | Cold Side ESP without FGC                 | SCR        | Wet FGD    | Yes             | No                | 5                                  | Yes                | No                | 5                                  | Yes           | No                | 5                                  |
| Non-FBC                | Fabric Filter                             | --         | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Fabric Filter                             | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Fabric Filter                             | --         | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Fabric Filter                             | SCR        | Dry FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Fabric Filter                             | SCR        | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Fabric Filter                             | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | --         | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | --         | Dry FGD    | No              | No                | 0                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | SCR        | Dry FGD    | No              | No                | 0                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter with FGC     | SCR        | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | --         | Dry FGD    | No              | No                | 0                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | --         | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | --         | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | SCR        | Dry FGD    | No              | No                | 0                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | SCR        | --         | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP + Fabric Filter without FGC  | SCR        | Wet FGD    | Yes             | No                | 2                                  | Yes                | No                | 2                                  | Yes           | No                | 2                                  |
| Non-FBC                | Hot Side ESP with FGC                     | --         | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP with FGC                     | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP with FGC                     | --         | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |

| Air pollution controls |                          |            |            | Bituminous Coal |                   |                                    | Subbituminous Coal |                   |                                    | Lignite Coal  |                   |                                    |
|------------------------|--------------------------|------------|------------|-----------------|-------------------|------------------------------------|--------------------|-------------------|------------------------------------|---------------|-------------------|------------------------------------|
| Burner Type            | Particulate Control Type | SCR System | FGD System | ACI Required?   | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) | ACI Required?      | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) | ACI Required? | Toxecon Required? | Sorbent Inj Rate (lb/million acfm) |
| Non-FBC                | Hot Side ESP with FGC    | SCR        | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP with FGC    | SCR        | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP with FGC    | SCR        | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | --         | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | --         | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | SCR        | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | SCR        | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | Hot Side ESP without FGC | SCR        | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | --         | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | --         | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | SCR        | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | SCR        | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | No Control               | SCR        | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | --         | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | --         | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | --         | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | SCR        | Dry FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | SCR        | --         | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |
| Non-FBC                | PM Scrubber              | SCR        | Wet FGD    | Yes             | Yes               | 2                                  | Yes                | Yes               | 2                                  | Yes           | Yes               | 2                                  |

Note: In the table above "Toxecon" refers to the option described as "ACI System with an Additional Baghouse" and "ACI + Full Baghouse with a Sorbent Injection (Inj) Rate of 2 lbs/million acfm" elsewhere in this chapter.

#### 5.4.4 Methodology for Obtaining ACI Control Costs

The updated ACI model developed by Sargent & Lundy assumes that the carbon feed rate dictates the size of the equipment and resulting costs. The feed rate in turn is a function of the required removal (in this case 90%) and the type of particulate control device. The model assumes a carbon feed rate of 5 pounds of carbon injected for every 1,000,000 actual cubic feet per minute (acfm) of flue gas would provide the stipulated 90% mercury removal rate for units shown in Table 5-13 as qualifying for ACI systems with existing ESP. For generating units with fabric filters a lower injection rate of 2 pound per million acfm is required. Alternative sets of costs were developed for each of the three ACI options: ACI systems for units with existing ESPs, ACI for units with existing fabric filters (baghouses), and the combined cost of ACI plus an additional baghouse for units that either have no existing particulate control or that require ACI plus a baghouse in addition to their existing particulate control. There are various reasons that a combined ACI plus additional baghouse would be required. These include situations where the existing ESP cannot handle the additional particulate load associate with the ACI or where SO<sub>3</sub> injection is currently in use to condition the flue gas for the ESP. Another cause for combined ACI and baghouse is use of PRB coal whose combustion produces mostly elemental mercury, not ionic mercury, due to this coal's low chlorine content.

For the combined ACI and fabric filter option a full size baghouse with an air-to-cloth (A/C) ratio of 4.0 is assumed, as opposed to a polishing baghouse with a 6.0 A/C ratio<sup>45</sup>.

Table 5-13 presents the capital, VOM, and FOM costs as well as the capacity and heat rate penalties for the three ACI options represented in EPA Platform v6. For each ACI option, values are shown for an illustrative set of generating units with a representative range of capacities and heat rates. For details of Sargent & Lundy ACI cost model, see Attachment 5-6.

### 5.5 Hydrogen Chloride (HCl) Control Technologies

The following sub-sections describe how HCl emissions from coal are represented, the emission control technologies available for HCl removal, and the cost and performance characteristics of these technologies in EPA Platform v6.

#### 5.5.1 Chlorine Content of Fuels

HCl emissions from the power sector result from the chlorine content of the coal that is combusted by electric generating units. Data on chlorine content of coals had been collected as part of EPA's 1999 "Information Collection Request for Electric Utility Steam Generating Unit Mercury Emissions Information Collection Effort" (ICR 1999) described above in section 5.4.1. This data is incorporated into the model in order to provide the capability for EPA Platform v6 to project HCl emissions. The procedures used for this are presented below.

Western subbituminous coal (such as that mined in the Powder River Basin) and lignite coal contain natural alkalinity in the form of non-glassy calcium oxide (CaO) and other alkaline and alkaline earth oxides. This fly ash (classified as 'Class C' fly ash) has a natural pH of 9 and higher and the natural alkalinity can effectively neutralize much of the HCl in the flue gas stream prior to the primary control device.

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<sup>45</sup> The "air-to-cloth" (A/C) ratio is the volumetric flow, (typically expressed in Actual Cubic Feet per Minute, ACFM) of flue gas entering the baghouse divided by the areas (typically in square feet) of fabric filter cloth in the baghouse. The lower the A/C ratio, e.g., A/C = 4.0 compared to A/C = 6.0, the greater area of the cloth required and the higher the cost for a given volumetric flow

**Table 5-13 Illustrative Activated Carbon Injection (ACI) Costs (2016\$) for Representative Sizes and Heat Rates under the Assumptions in EPA Platform v6**

| Control Type  | Heat Rate (Btu/kWh) | Capacity Penalty (%) | Heat Rate Penalty (%) | Variable O&M cost (mills/kWh) | Capacity (MW)        |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|---|---------------------|----------------------|-----------------------|-------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|   |                     |                      |                       |                               | 100                  |                      | 300                  |                      | 500                  |                      | 700                  |                      | 1000                 |                      |
|   |                     |                      |                       |                               | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) |
| ACI System with an Existing ESP ACI with a Sorbent Injection Rate of 5 lbs/million acfm assuming Bituminous Coal                        | 9,000               | -0.02                | 0.02                  | 2.22                          | 40.08                | 0.32                 | 15.76                | 0.13                 | 10.21                | 0.08                 | 7.67                 | 0.06                 | 5.66                 | 0.05                 |
|   | 10,000              | -0.02                | 0.02                  | 2.47                          | 40.73                | 0.33                 | 16.01                | 0.13                 | 10.37                | 0.08                 | 7.79                 | 0.06                 | 5.75                 | 0.05                 |
|   | 11,000              | -0.02                | 0.02                  | 2.71                          | 41.32                | 0.33                 | 16.24                | 0.13                 | 10.52                | 0.08                 | 7.90                 | 0.06                 | 5.84                 | 0.05                 |
| ACI System with an Existing Baghouse ACI with a Sorbent Injection Rate of 2 lbs/million acfm Assuming Bituminous Coal                   | 9,000               | -0.02                | 0.02                  | 1.59                          | 34.94                | 0.28                 | 13.74                | 0.11                 | 8.90                 | 0.07                 | 6.68                 | 0.05                 | 4.94                 | 0.04                 |
|   | 10,000              | -0.02                | 0.02                  | 1.77                          | 35.50                | 0.29                 | 13.95                | 0.11                 | 9.04                 | 0.07                 | 6.79                 | 0.05                 | 5.01                 | 0.04                 |
|   | 11,000              | -0.02                | 0.02                  | 1.95                          | 36.02                | 0.29                 | 14.16                | 0.11                 | 9.17                 | 0.07                 | 6.89                 | 0.06                 | 5.09                 | 0.04                 |
| ACI System with an Additional Baghouse ACI + Full Baghouse with a Sorbent Injection Rate of 2 lbs/million acfm Assuming Bituminous Coal | 9,000               | -0.62                | 0.62                  | 0.47                          | 293.68               | 1.03                 | 221.56               | 0.77                 | 196.97               | 0.69                 | 182.87               | 0.64                 | 169.38               | 0.59                 |
|   | 10,000              | -0.62                | 0.62                  | 0.52                          | 316.91               | 1.11                 | 240.14               | 0.84                 | 213.77               | 0.75                 | 198.60               | 0.69                 | 184.06               | 0.64                 |
|   | 11,000              | -0.62                | 0.62                  | 0.58                          | 339.68               | 1.19                 | 258.37               | 0.90                 | 230.25               | 0.81                 | 214.02               | 0.75                 | 198.45               | 0.69                 |

Note 1: The above cost estimates assume bituminous coal consumption.

Note 2: The Variable O&M costs in this table do not include the cost of additional auxiliary power (VOMP) component in the S&L tool as for modeling purposes, IPM reflects the auxiliary power consumption through capacity penalty.

Eastern bituminous coals, by contrast, tend to produce fly ash with lower natural alkalinity. Though bituminous fly ash (classified as 'Class F' fly ash) may contain calcium, it tends to be present in a glassy matrix and unavailable for acid-base neutralization reactions.

In order to assess the extent of expected natural neutralization, resulting in large part from the alkalinity of the fly ash, the 2010 ICR<sup>46</sup> data was examined. According to that data, units burning some of the subbituminous coals without operating acid gas control technology emitted substantially lower HCl emissions than would otherwise be expected if the emissions were based solely on the chlorine content of those coals. Comparing the assumed Cl content of the subbituminous coals modeled in EPA Platform v6 with the estimated values based on responses to the 2010 ICR supports the EPA Platform v6 assumption that combustion of subbituminous and lignite coals results in a 95% reduction in HCl emissions relative to the assumed chlorine content of the coal.

### 5.5.2 HCl Removal Rate Assumptions for Existing and Potential Units

SO<sub>2</sub> emission controls on existing and new (potential) units provide the HCl reductions indicated in Table 5-14. New supercritical pulverized coal units (column 3) that the model builds include FGD (wet or dry) which is assumed to provide a 99% removal rate for HCl. For existing conventional pulverized coal units with pre-existing FGD (column 5), the HCl removal rate is assumed to be 5% higher than the reported SO<sub>2</sub> removal rate up to a maximum of 99% removal. In addition, for fluidized bed combustion units (column 4) with no FGD and no fabric filter, the HCl removal rate is assumed to be the same as the SO<sub>2</sub> removal rate up to a maximum of 95%. FBCs with fabric filters are assumed to have an HCl removal rate of 95%.

**Table 5-14 HCl Removal Rate Assumptions for Potential (New) and Existing Units in EPA Platform v6**

|     |              | Potential (New)                                      | Existing Units with FGD  |   |
|-----|--------------|--|--|---|
| Gas | Controls ==> | Ultra-Supercritical Pulverized Coal with 30%/90% CCS | Fluidized Bed Combustion (FBC)   | Conventional Pulverized Coal (CPC) with Wet or Dry FGD            |
| HCl | Removal Rate | 99%  | <p><b>Without fabric filter:</b><br/>Same as reported SO<sub>2</sub> removal rate up to a maximum of 95%<br/>---</p> <p><b>With fabric filter: 95%</b></p> | Reported SO <sub>2</sub> removal rate + 5% up to a maximum of 99% |

### 5.5.3 HCl Retrofit Emission Control Options

The retrofit options for HCl emission control are discussed in detail in the following sub-sections and summarized in Table 5-15.

#### Wet and Dry FGD

In addition to providing SO<sub>2</sub> reductions, wet scrubbers (Limestone Forced Oxidation, LSFO) and dry scrubbers (Lime Spray Dryer, LSD) reduce HCl as well. For both LSFO and LSD the HCl removal rate is assumed to be 99% with a floor of 0.001 lbs/MMBtu. This is summarized in columns 2-5 of Table 5-15.

<sup>46</sup> Collection Effort for New and Existing Coal- and Oil-Fired Electricity Utility Steam Generating Units (EPA ICR No.2362.01 (OMB Control Number 2060-0631))

**Table 5-15 Summary of Retrofit HCl (and SO<sub>2</sub>) Emission Control Performance Assumptions in EPA Platform v6**

| Performance Assumptions      | Limestone Forced Oxidation (LSFO)                                  |  | Lime Spray Dryer (LSD)  |   | Dry Sorbent Injection (DSI)  |   |
|------------------------------|--|--|---|---|--|---|
|                              | SO <sub>2</sub>  | HCl  | SO <sub>2</sub>   | HCl   | SO <sub>2</sub>  | HCl                                       |
| Percent Removal              | 98%<br>with a floor of<br>0.06<br>lbs/MMBtu                        | 99%<br>with a floor of<br>0.001<br>lbs/MMBtu | 95%<br>with a floor<br>of<br>0.08<br>lbs/MMBtu                    | 99%<br>with a floor<br>of<br>0.001<br>lbs/MMBtu | 50%  | 98%<br>with a floor of<br>0.002 lbs/MMBtu |
| Capacity Penalty             | Calculated based on characteristics of the unit:<br>See Table 5-3  |  | Calculated based on characteristics of the unit:<br>See Table 5-3 |   | Calculated based on characteristics of the unit: See Excerpt from Table 5-17 |   |
| Heat Rate Penalty            |  |  |   |   |  |   |
| Cost (2011\$)                |  |  |   |   |  |   |
| Applicability                | Units ≥ 25 MW  |  | Units ≥ 25 MW   |   | Units ≥ 25 MW  |   |
| Sulfur Content Applicability |  |  | Coals ≤ 3.0 lbs of SO <sub>2</sub> /MMBtu                         |   | Coals ≤ 2.0 lbs of SO <sub>2</sub> /MMBtu                                    |   |
| Applicable Coal Types        | BA, BB, BD, BE, BG, BH, SA, SB, SD, SE, LD, LE, LG, LH, PK, and WC |  | BA, BB, BD, BE, SA, SB, SD, SE, LD, and LE                        |   | BA, BB, BD, SA, SB, SD, and LD   |   |

Dry Sorbent Injection

EPA Platform v6 includes dry sorbent injection (DSI) as a retrofit option for achieving (in combination with a particulate control device) both SO<sub>2</sub> and HCl removal. In DSI for HCl reduction, a dry sorbent is injected into the flue gas duct where it reacts with the HCl and SO<sub>2</sub> in the flue gas to form compounds that are then captured in a downstream fabric filter or electrostatic precipitator (ESP) and disposed of as waste. A sorbent is a material that takes up another substance by either adsorption on its surface or absorption internally or in solution. A sorbent may also chemically react with another substance. The sorbent assumed in the cost and performance characterization discussed in this section is Trona (sodium sesquicarbonate), a sodium-rich material with major underground deposits found in Sweetwater County, Wyoming. Trona is typically delivered with an average particle size of 30 µm diameter, but can be reduced to about 15 µm through onsite in-line milling to increase its surface area and capture capability. While the Sargent & Lundy description of the DSI technology includes references to the hydrated lime option, only the Trona option is implemented in EPA Platform v6.

Removal rate assumptions: The removal rate assumptions for DSI are summarized in Table 5-15. The assumptions shown in the last two columns of Table 5-15 were derived from assessments by EPA engineering staff in consultation with Sargent & Lundy. As indicated in this table, the assumed SO<sub>2</sub> removal rate for DSI + fabric filter is 50%. The retrofit DSI option on an existing unit with existing ESP is always provided in combination with a fabric filter (Toxecon configuration).

Methodology for Obtaining DSI Control Costs: The cost and performance model for DSI was updated by Sargent & Lundy. The model is used to derive the cost of DSI retrofits with two alternative, associated particulate control devices, i.e., ESP and fabric filter “baghouse”. The cost model notes that the cost drivers of DSI are quite different from those of wet or dry FGD. Whereas plant size and coal sulfur rates are key underlying determinants of FGD cost, sorbent feed rate and fly ash waste handling are the main drivers of the capital cost of DSI with plant size and coal sulfur rates playing a secondary role.

Furthermore, the DSI sorbent feed rate and variable O&M costs are based on assumptions that a fabric filter and in-line Trona milling are used, and that the SO<sub>2</sub> removal rate is 50%. The corresponding HCl removal effect is estimated to be 98% for units with fabric filter.

The cost of fly ash waste handling, the other key contributor to DSI cost, is a function of the type of particulate capture device and the flue gas SO<sub>2</sub>.

Total waste production involves the production of both reacted and unreacted sorbent and fly ash. Sorbent waste is a function of the sorbent feed rate with an adjustment for excess sorbent feed. Use of sodium-based DSI may make the fly ash unsalable, which would mean that any fly ash produced must be landfilled along with the reacted and unreacted sorbent waste. Typical ash contents for each fuel are used to calculate a total fly ash production rate. The fly ash production is added to the sorbent waste to account for the total waste stream for the VOM analysis.

For purposes of modeling, the total VOM includes the first two component costs noted in the previous paragraph, i.e., the costs for sorbent usage and the costs associated with waste production and disposal.

Table 5-16 presents the capital, VOM, and FOM costs as well as the capacity and heat rate penalties of a DSI retrofit for an illustrative and representative set of generating units with the capacities and heat rates indicated. For details of Sargent & Lundy DSI cost model, see Attachment 5-5.

## 5.6 Fabric Filter (Baghouse) Cost Development

Fabric filters are not endogenously modeled as a separate retrofit option. In EPA Platform v6, an existing or new fabric filter particulate control device is a pre-condition for installing a DSI retrofit, and the cost of these retrofits at plants without an existing fabric filter include the cost of installing a new fabric filter. This cost was added to the DSI costs discussed in section 5.5. The costs associated with a new fabric filter retrofit are derived from the cost and performance updated by Sargent & Lundy. Similarly, dry scrubber retrofit costs also include the cost of a fabric filter.

The engineering cost analysis is based on a pulse-jet fabric filter which collects particulate matter on a fabric bag and uses air pulses to dislodge the particulate from the bag surface and collect it in hoppers for removal via an ash handling system to a silo. This is a mature technology that has been operating commercially for more than 25 years. “Baghouse” and “fabric filters” are used interchangeably to refer to such installations.

**Capital Cost:** The major driver of fabric filter capital cost is the “air-to-cloth” (A/C) ratio. The A/C ratio is defined as the volumetric flow, (typically expressed in Actual Cubic Feet per Minute, ACFM) of flue gas entering the baghouse divided by the areas (typically in square feet) of fabric filter cloth in the baghouse. The lower the A/C ratio, e.g., A/C = 4.0 compared to A/C = 6.0, the greater the area of the cloth required and the higher the cost for a given volumetric flow. An air-to-cloth ratio of 4.0 is used in EPA Platform v6, and it is assumed that the existing ESP remains in place and active.

Table 5-17 presents the capital, VOM, and FOM costs for fabric filters as represented in EPA Platform v6 for an illustrative set of generating units with a representative range of capacities and heat rates. See Attachment 5-7 for details of the Sargent & Lundy fabric filter PM control cost model.

**Table 5-16 Illustrative Dry Sorbent Injection (DSI) Costs (2016\$) for Representative Sizes and Heat Rates under Assumptions in EPA Platform v6**

| Control Type                          | Heat Rate (Btu/kWh) | SO <sub>2</sub> Rate (lb/MMBtu) | Capacity Penalty (%) | Heat Rate Penalty (%) | Variable O&M (mills/kWh) | Capacity (MW)        |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|---------------------------------------|---------------------|---------------------------------|----------------------|-----------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                                       |                     |                                 |                      |                       |                          | 100                  |                      | 300                  |                      | 500                  |                      | 700                  |                      | 1000                 |                      |
|                                       |                     |                                 |                      |                       |                          | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) |
| DSI<br>Assuming<br>Bituminous<br>Coal | 9,000               | 2.0                             | -0.37                | 0.37                  | 5.86                     | 124.2                | 3.57                 | 56.6                 | 1.31                 | 39.2                 | 0.83                 | 30.8                 | 0.62                 | 23.9                 | 0.45                 |
|                                       | 10,000              | 2.0                             | -0.41                | 0.41                  | 6.51                     | 128.0                | 3.60                 | 58.3                 | 1.33                 | 40.4                 | 0.84                 | 31.8                 | 0.62                 | 24.6                 | 0.46                 |
|                                       | 11,000              | 2.0                             | -0.45                | 0.45                  | 7.16                     | 131.5                | 3.63                 | 59.9                 | 1.34                 | 41.5                 | 0.85                 | 32.6                 | 0.63                 | 25.3                 | 0.46                 |

Note 1: A SO<sub>2</sub> removal efficiency of 50% is assumed in the above calculations.

Note: The Variable O&M costs in this table do not include the cost of additional auxiliary power (VOMP) component in the S&L tool as for modeling purposes, IPM reflects the auxiliary power consumption through capacity penalty.

**Table 5-17 Illustrative Particulate Controls Costs (2016\$) for Representative Sizes and Heat Rates under the Assumptions in EPA Platform v6**

| Coal Type  | Heat Rate (Btu/kWh) | Capacity Penalty (%) | Heat Rate Penalty (%) | Variable O&M (mills/kWh) | Capacity (MW)        |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|------------|---------------------|----------------------|-----------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|            |                     |                      |                       |                          | 100                  |                      | 300                  |                      | 500                  |                      | 700                  |                      | 1000                 |                      |
|            |                     |                      |                       |                          | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) | Capital Cost (\$/kW) | Fixed O&M (\$/kW-yr) |
| Bituminous | 9,000               |                      |                       | 0.05                     | 254                  | 0.9                  | 206                  | 0.7                  | 187                  | 0.7                  | 175                  | 0.6                  | 164                  | 0.6                  |
|            | 10,000              | -0.60                | 0.60                  | 0.06                     | 276                  | 1.0                  | 224                  | 0.8                  | 203                  | 0.7                  | 191                  | 0.7                  | 178                  | 0.6                  |
|            | 11,000              |                      |                       | 0.07                     | 298                  | 1.0                  | 242                  | 0.8                  | 220                  | 0.8                  | 206                  | 0.7                  | 193                  | 0.7                  |

Note: The Variable O&M costs in this table do not include the cost of additional auxiliary power (VOMP) component in the S&L tool as for modeling purposes, IPM reflects the auxiliary power consumption through capacity penalty.

## 5.7 Coal-to-Gas Conversions<sup>47</sup>

In EPA Platform v6, existing coal plants are given the option to burn natural gas in addition to coal by investing in a coal-to-gas retrofit. There are two components of cost in this option: boiler modification costs and the cost of extending natural gas lateral pipeline spurs from the boiler to a natural gas main pipeline. These two components of cost and their associated performance implications are discussed in the following sections.

### 5.7.1 Boiler Modifications for Coal-To-Gas Conversions

Enabling natural gas firing in a coal boiler typically involves installation of new gas burners and modifications to the ducting, windbox (i.e., the chamber surrounding a burner through which pressurized air is supplied for fuel combustion), and possibly to the heating surfaces used to transfer energy from the exiting hot flue gas to steam (referred to as the “convection pass”). It may also involve modification of environmental equipment. Engineering studies are performed to assess operating characteristics like furnace heat absorption and exit gas temperature; material changes affecting piping and components like superheaters, reheaters, economizers, and recirculating fans; and operational changes to sootblowers, spray flows, air heaters, and emission controls.

The following table summarizes the cost and performance assumptions for coal-to-gas boiler modifications as incorporated in EPA Platform v6. The values in the table were developed by EPA’s engineering staff based on technical papers<sup>48</sup> and discussions with industry engineers familiar with such projects. They were designed to be broadly applicable across the existing coal fleet (with the exceptions noted in the table). Coal-to-gas retrofit options in EPA Platform v6 force a permanent change in fuel type from coal to natural gas. Coal therefore can no longer be fired.

**Table 5-18 Cost and Performance Assumptions for Coal-to-Gas Retrofits in EPA Platform v6**

| Factor                           | Description   | Notes   |
|----------------------------------|---|---|
| <b>Applicability:</b>            | Existing pulverized coal (PC) fired and cyclone boiler units of a size greater than 25 MW:    | Not applicable for fluidized bed combustion (FBC) and stoker boilers.   |
| <b>Capacity Penalty:</b>         | None  | The furnace of a boiler designed to burn coal is oversized for natural gas, and coal boilers include equipment, such as coal mills, that are not needed for gas. As a result, burning gas should have no impact on net power output.  |
| <b>Heat Rate Penalty:</b>        | + 5%  | When gas is combusted instead of coal, the stack temperature is lower and the moisture loss to stack is higher. This reduces efficiency, which is reflected in an increase in the heat rate.  |
| <b>Incremental Capital Cost:</b> | PC units: $2016\$/kW = 288*(75/MW)^{0.35}$<br>Cyclone units: $2016\$/kW = 403*(75/MW)^{0.35}$ | The cost function covers new gas burners and piping, windbox modifications, air heater upgrades, gas recirculating fans, and control system modifications.<br><u>Example for 50 MW PC unit:</u><br>$\$/kW = 288*(75/50)^{0.35} = 332$ |

<sup>47</sup> As discussed here coal-to-gas conversion refers to the modification of an existing boiler to allow it to fire natural gas. It does not refer to the addition of a gas turbine to an existing boiler cycle, the replacement of a coal boiler with a new natural gas combined cycle plant, or to the gasification of coal for use in a natural gas combustion turbine

<sup>48</sup> For an example see Babcock and Wilcox’s White Paper MS-14 “Natural Gas Conversions of Existing Coal-Fired Boilers” 2010 (<https://slidex.tips/download/natural-gas-conversions-of-existing-coal-fired-boilers>).

| Factor                               | Description   | Notes  |
|--------------------------------------|---|--|
| <b>Incremental Fixed O&amp;M:</b>    | -33% FOM cost of the existing coal unit   | Due to reduced needs for operators, maintenance materials, and maintenance staff when natural gas combusted, FOM costs decrease by 33%.                  |
| <b>Incremental Variable O&amp;M:</b> | -25% VOM cost of the existing coal unit   | Due to reduced waste disposal and miscellaneous other costs, VOM costs decrease by 25%.  |
| <b>Fuel Cost:</b>                    | Natural Gas   | To obtain natural gas the unit incurs the cost of extending lateral pipeline spurs from the boiler to the local transmission mainline. See section 5.7.2 |
| <b>NO<sub>x</sub> emission rate:</b> | 50% of existing coal unit NO <sub>x</sub> emission rate, with a floor of 0.05 lbs/MMBtu | The 0.05 lbs/MMBtu floor is the same as the NO <sub>x</sub> rate floor for new retrofit SCR on units burning subbituminous coal                          |
| <b>SO<sub>2</sub> emissions:</b>     | Zero  |  |

### 5.7.2 Natural Gas Pipeline Requirements for Coal-To-Gas Conversions

For every individual coal boiler in the U.S., EPA had ICF to determine the miles and associated cost of extending pipeline laterals from each boiler to the interstate natural gas pipeline system. This work was performed for EPA Base Case v5.13 and has not been updated for EPA Platform v6. For further detail, please see EPA Base Case v5.13 documentation.

Table 5-21 shows the pipeline costing results for each qualifying existing coal fired unit represented in EPA Platform v6.

### 5.8 Retrofit Assignments

In IPM, model plants that represent existing generating units have the option of maintaining their current system configuration, retrofitting with pollution controls, or retiring. The decision to retrofit or retire is endogenous to IPM and based on the least cost approach to meeting demand subject to modeled system and operational constraints. IPM is capable of modeling retrofits and retirements at each applicable model unit at three different points in time, referred to as three stages. At each stage a retrofit set may consist of a single retrofit (e.g. LSFO Scrubber) or pre-specified combinations of retrofits (e.g., ACI + LSFO Scrubber +SCR). In EPA Platform v6, first stage retrofit options are provided to existing coal-steam and oil/gas steam plants. These plants - as well as combined cycle plants, combustion turbines, biomass and nuclear plants - are also given retirement as an option in stage one. Third stage retrofit options are offered to coal-steam plants only. Table 5-19 presents the first stage retrofit options available by plant type; Table 5-20 presents the second and third stage retrofit options available to coal-steam plants. The cost of multiple retrofits on the same model plant, whether installed in one or multiple stages, are additive. In linear programming models such as IPM, projections of pollution control equipment capacity and retirements are limited to the pre-specified combinations listed in Table 5-19 and Table 5-20 below.

**Table 5-19 First Stage Retrofit Assignment Scheme in EPA Platform v6**

| <b>Plant Type</b>                             | <b>Retrofit Option 1<sup>st</sup> Stage</b>        | <b>Criteria</b>   |
|---|--|---|
| <b>Coal Steam</b>                             |  |   |
|   | Coal Retirement                                    | All coal steam boilers  |
|   | Coal Steam SCR                                     | All coal steam boilers that are 25 MW or larger and do not possess an existing SCR control option   |
|   | Coal Steam SNCR – Non FBC Boilers                  | All non FBC coal steam boilers that are 25 MW or larger and do not possess an existing post combustion NO <sub>x</sub> control option   |
|   | Coal Steam SNCR – FBC Boilers                      | All coal FBC units that are 25 MW or larger and do not possess an existing post combustion NO <sub>x</sub> control option   |
|   | LSD Scrubber                                       | All unscrubbed coal steam boilers 25 MW or larger and burning less than 3 lbs/MMBtu SO <sub>2</sub> coal  |
|   | LSFO Scrubber                                      | All unscrubbed and non FBC coal steam boilers 25 MW or larger   |
|   | CO <sub>2</sub> Capture and Storage                | All scrubbed coal steam boilers 400 MW or larger  |
|   | ACI - Hg Control Option (with and without Toxecon) | All coal steam boilers larger than 25 MW that do not have an ACI and have an Hg EMF greater than 0.1. Actual ACI technology type will be based on the boilers fuel and technology configuration. See discussion in Chapter 5. |
|   | LSD Scrubber + SCR                                 | Combination options – Individual technology level restrictions apply  |
|   | LSD Scrubber + SNCR                                |   |
|   | LSFO Scrubber + SCR                                |   |
|   | LSFO Scrubber + SNCR                               |   |
|   | ACI + SCR  |   |
|   | ACI + SNCR   |   |
|   | ACI + LSD Scrubber                                 |   |
|   | ACI + LSFO Scrubber                                |   |
|   | ACI + LSD Scrubber + SCR                           |   |
|   | ACI + LSFO Scrubber + SCR                          |   |
|   | ACI + LSD Scrubber + SNCR                          |   |
|   | ACI + LSFO Scrubber + SNCR                         |   |
|   | DSI  |   |
|   | DSI + Fabric Filter                                | All unscrubbed and non FBC-coal steam boilers 25 MW or larger without Fabric Filter, with CESP or HESP, and burning less than 2 lbs/MMBtu SO <sub>2</sub> coal.   |
|   | DSI + SCR  | Combination options – Individual technology level restrictions apply  |
|   | DSI + SNCR   |   |
|   | ACI + DSI  |   |
|   | ACI + DSI + SCR                                    |   |
|   | ACI + DSI + SNCR                                   |   |
|   | Heat Rate Improvement                              |   |
|   | Coal-to-Gas  | All coal steam boilers that are 25 MW or larger   |
| <b>Integrated Gasification Combined Cycle</b> |  |   |
|   | IGCC Retirement                                    | All integrated gasification combined cycle units  |

| Plant Type                | Retrofit Option 1 <sup>st</sup> Stage | Criteria   |
|---------------------------|---------------------------------------|--|
| <b>Combined Cycle</b>     |                                       |  |
|                           | CC Retirement                         | All combined cycle units   |
| <b>Combustion Turbine</b> |                                       |  |
|                           | CT Retirement                         | All combustion turbine units   |
| <b>Nuclear</b>            |                                       |  |
|                           | Nuclear Retirement                    | All nuclear power units  |
| <b>Oil and Gas Steam</b>  |                                       |  |
|                           | Oil/Gas Retirement                    | All oil/gas steam boilers  |
|                           | Oil/Gas Steam SCR                     | All oil/gas steam boilers 25 MW or larger that do not possess an existing post combustion NO <sub>x</sub> control option |

**Table 5-20 Second and Third Stage Retrofit Assignment Scheme in EPA Platform v6**

| Plant Type                                       | Retrofit Option 1 <sup>st</sup> Stage   | Retrofit Option 2 <sup>nd</sup> Stage | Retrofit Option 3 <sup>rd</sup> Stage |
|--|---|---------------------------------------|---------------------------------------|
| <b>Coal Steam</b>                                |   |                                       |                                       |
|  | NO <sub>x</sub> Control Option <sup>1</sup>   | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|  |   | HCl Control Option                    | Heat Rate Improvement                 |
|  |   | CO <sub>2</sub> Control Option        | None                                  |
|  |   | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|  |   | Coal Retirement                       | None                                  |
|  | SO <sub>2</sub> Control Option <sup>2</sup>   | NO <sub>x</sub> Control Option        | Heat Rate Improvement                 |
|  |   | CO <sub>2</sub> Control Option        | None                                  |
|  |   | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|  |   | Coal Retirement                       | None                                  |
|  | Hg Control Option <sup>3</sup>  | NO <sub>x</sub> Control Option        | Heat Rate Improvement                 |
|  |   | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|  |   | HCl Control Option                    | Heat Rate Improvement                 |
|  |   | CO <sub>2</sub> Control Option        | None                                  |
|  |   | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|  | CO <sub>2</sub> Control Option <sup>4</sup>   | Coal Retirement                       | None                                  |
|  |   | None                                  | None                                  |
|  | NO <sub>x</sub> Control Option <sup>1</sup> + SO <sub>2</sub> Control Option <sup>2</sup> | CO <sub>2</sub> Control Option        | None                                  |
|  |   | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|  |   | Coal Retirement                       | None                                  |
|  | NO <sub>x</sub> Control Option <sup>1</sup> + Hg Control Option <sup>3</sup>              | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|  |   | HCl Control Option                    | Heat Rate Improvement                 |
|  |   | CO <sub>2</sub> Control Option        | None                                  |
|  |   | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|  |   | Coal Retirement                       | None                                  |
| SO <sub>2</sub> Control Option <sup>2</sup> + Hg | NO <sub>x</sub> Control Option  | Heat Rate Improvement                 |                                       |

| Plant Type                     | Retrofit Option 1 <sup>st</sup> Stage  | Retrofit Option 2 <sup>nd</sup> Stage | Retrofit Option 3 <sup>rd</sup> Stage |
|--------------------------------|--|---------------------------------------|---------------------------------------|
|                                | Control Option <sup>3</sup>  | CO <sub>2</sub> Control Option        | None                                  |
|                                |  | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|                                |  | Coal Retirement                       | None                                  |
|                                | NO <sub>x</sub> Control Option <sup>1</sup> + SO <sub>2</sub> Control Option <sup>2</sup> + Hg Control Option <sup>3</sup> | CO <sub>2</sub> Control Option        | None                                  |
|                                |  | Heat Rate Improvement                 | CO <sub>2</sub> Control Option        |
|                                |  | Coal Retirement                       | None                                  |
|                                | HCl Control Option <sup>5</sup>  | NO <sub>x</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | Heat Rate Improvement                 | None                                  |
|                                |  | Coal Retirement                       | None                                  |
|                                | NO <sub>x</sub> Control Option <sup>1</sup> + HCl Control Option <sup>5</sup>  | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | Heat Rate Improvement                 | None                                  |
|                                |  | Coal Retirement                       | None                                  |
|                                | Hg Control Option <sup>3</sup> + HCl Control Option <sup>5</sup>   | NO <sub>x</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | Heat Rate Improvement                 | None                                  |
|                                |  | Coal Retirement                       | None                                  |
|                                | NO <sub>x</sub> Control Option <sup>1</sup> + HCl Control Option <sup>5</sup> + Hg Control Option <sup>3</sup>             | SO <sub>2</sub> Control Option        | Heat Rate Improvement                 |
|                                |  | Heat Rate Improvement                 | None                                  |
|                                |  | Coal Retirement                       | None                                  |
|                                | Heat Rate Improvement  | NO <sub>x</sub> Control Option        | None                                  |
| SO <sub>2</sub> Control Option |  | None                                  |                                       |
| HCl Control Option             |  | None                                  |                                       |
| CO <sub>2</sub> Control Option |  | None                                  |                                       |
| Coal Retirement                |  | None                                  |                                       |
| Coal-to-Gas                    | NO <sub>x</sub> Control Option   | None                                  |                                       |
|                                | Oil/Gas Retirement   | None                                  |                                       |
| Coal Retirement                | None   | None                                  |                                       |
| <b>Oil and Gas Steam</b>       |  |                                       |                                       |
|                                | NO <sub>x</sub> Control Option <sup>1</sup>  | Oil/Gas Retirement                    | None                                  |
|                                | Oil/Gas Retirement   | None                                  | None                                  |

**Notes:**

<sup>1</sup>"NO<sub>x</sub> Control Option" implies that a model plant may be retrofitted with one of the following NO<sub>x</sub> control technologies: SCR, SNCR - non-FBC, or SNCR - FBC

<sup>2</sup>"SO<sub>2</sub> Control Option" implies that a model plant may be retrofitted with one of the following SO<sub>2</sub> control technologies: LSFO scrubber or LSD scrubber

<sup>3</sup>"Hg Control Option" implies that a model plant may be retrofitted with one of the following activated carbon injection technology options for reduction of mercury emissions: ACI or ACI + Toxecon

<sup>4</sup>"CO<sub>2</sub> Control Option" implies that a model plant may be retrofitted with carbon capture and storage technology

<sup>5</sup>"HCl Control Option" implies that a model plant may be retrofitted with a DSI (with milled Trona)

**List of tables and attachments that are directly uploaded to the web:**

Attachment 5-1 Wet FGD Cost Methodology

Attachment 5-2 SDA FGD Cost Methodology

Attachment 5-3 SCR Cost Methodology

Attachment 5-4 SNCR Cost Methodology

Attachment 5-5 DSI Cost Methodology

Attachment 5-6 Hg Cost Methodology

Attachment 5-7 PM Cost Methodology

Table 5-21 Cost of Building Pipelines to Coal Plants in EPA Platform v6