# IPM Model - Updates to Cost and Performance for APC Technologies

Mercury Control Incremental Operating Cost Methodology

Final

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Prepared by

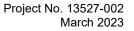
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#### **IPM Model Overview**

Cost algorithms in the IPM model are based primarily on a statistical evaluation of cost data available from various industry publications, and do not take into consideration site-specific cost issues. The primary purpose of the IPM cost modules is to provide generic order-of-magnitude costs for various air quality control technologies that can be applied to the electric power generating industry on a system-wide basis, not on an individual unit basis. By necessity, the cost algorithms were designed to require minimal site-specific information. The IPM cost equations can provide order-of-magnitude capital costs for various air quality control systems based only on a limited number of inputs such as unit size, gross heat rate, inlet NOx level, fuel sulfur level, % removal efficiency, fuel type, and a subjective retrofit factor. The outputs from these equations represent the "average" costs associated with the "average" project scope for the subset of data utilized in preparing the equations. The IPM cost equations do not account for site-specific factors that can significantly impact costs, such as flue gas volume, temperature and do not address regional labor productivity, local workforce characteristics, local unemployment and labor availability, project complexity, local climate, and working conditions. Finally, the indirect capital costs included in the IPM cost equations do not account for all project-related indirect costs a facility would incur to install a retrofit control such as project contingency.

EPA requested that S&L develop new cost algorithms for mercury controls, specifically focusing on the incremental capture that may be achieved with an existing control system, which is summarized in this report. The cost algorithms in this report build on the previously developed Mercury Control IPM cost algorithms developed by S&L including updated industry information for injection rates and reagent costs to reflect changes since the previous IPM model. As the focus of these cost algorithms are incremental improvements, these cost algorithms calculate the incremental operating costs only. For the purposes of this evaluation, it is assumed that no capital improvements will be made to the existing system, therefore no capital costs are estimated.

### **Mercury Speciation**

Mercury is contained in varying concentrations in different coal supplies. During combustion, mercury is released in the form of elemental mercury. As the combustion gases cool, a portion of the mercury transforms to ionic mercury. Ultimately, there are three possible forms of mercury:

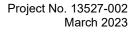
- Elemental (Hg<sup>0</sup>),
- Ionic or Oxidized (Hg<sup>++</sup>), or
- Particulate-bound.

The proportion of the various mercury forms is called its speciation. The conversion of elemental mercury to the other forms depends upon several factors: cooling rate of the gas, presence of halogens or sulfur trioxide ( $SO_3$ ) in the flue gas, amount and composition of fly ash, presence of unburned carbon, and the installed air pollution control equipment. Particulate-bound mercury typically is bound to fly ash or unburned carbon.

Considering the interaction of the various parameters, ionic mercury can vary between 10%-90% of the total mercury in the flue gas. Particulate mercury generally ranges from about 5-15% of the total mercury. The remainder is elemental mercury that typically makes up 10-90% of the total mercury.

### **Activated Carbon Injection Technology**

Activated carbon injection (ACI) involves the adsorption of mercury on activated carbon by injection of powdered activated carbon (PAC) in the flue gas. Commercial experience has shown that ACI can





achieve up to a 95% reduction in total Hg in some cases. The speciation of the mercury plays a significant role in the ease of its capture. ACI can remove both oxidized and elemental mercury; however, the choice of carbon sorbent is highly dependent on the speciation. In addition, some flue gas constituents, especially SO<sub>3</sub>, reduce the effectiveness of ACI.

#### **Mercury Capture**

Particulate-bound mercury is removed very efficiently from the flue gas by the particulate control device (i.e. baghouse or electrostatic precipitator) and therefore it is desirable to convert as much mercury as possible to particulate-bound mercury. Activated carbon and/or the addition of halogens increase the conversion of elemental and ionic mercury to particulate-bound mercury.

#### **Establishment of Incremental Operating Cost Basis**

Bituminous coals will have relatively high halogen concentrations in the flue gas while sub-bituminous, i.e., Powder River Basin (PRB), and lignite coals have relatively low halogen concentrations. Halogens contribute to the conversion of elemental to ionic mercury for more efficient capture rates. For fuels with low halogen concentrations, halogenated sorbents can be used to help increase the conversion of elemental mercury and thus increase the rate of mercury capture. The type of PAC selected is dependent on the fuel type and the required outlet mercury emission rate.

The PAC feed rate is a function of the fuel type, PAC type, required Hg emission rate, and particulate collection device. The PAC rate was based on the use of either Standard PAC or Premium PAC. Further, for PRB and Lignite fuels, a halogenated version of these PACs was assumed to be required to meet specified Hg emission rates due to the low halogen content of the fuel. To summarize:

Fuel Type	РАС Туре				
	Hg Emission Rate <1.2 lb/TBtu	Hg Emission Rate ≥1.2 lb/TBtu			
PRB	Halogenated Premium PAC	Halogenated Standard PAC			
Bituminous	Premium PAC	Standard PAC			
	Hg Emission Rate <4.0 lb/TBtu	Hg Emission Rate ≥4.0 lb/TBtu			
Lignite	Halogenated Premium PAC	Halogenated Standard PAC			

Injection curves were generated based on industry values for Standard and Premium PAC dependent on the fuel type and controlled outlet emission rate requirement, which can be applied directly to the halogenated versions (i.e. halogenation does not vary the injection rate). The cut-off for selection of Premium PAC is based on current MATS rule Hg emission limits, assuming the industry Standard PAC can achieve current limits in most cases. PRB and bituminous fuels will have similar injection curves while Lignite will require additional PAC due to higher levels of fuel mercury.

The injection curves were used to develop equations below to estimate the incremental changes to the injection rates and outlet mercury emissions based on the current system operation. These calculations are also based on the following design considerations:

- Flue gas rate established downstream of the air preheater consistent with previous ACI model,
- Existing system is assumed to have sufficient residence time needed to meet model specified emission rates,



- The existing ACI injection system and particulate control device are assumed to have sufficient capacity to handle a 20% increase in the injection rate relative to current operating rates,
- No co-benefit or other unit operations considered, and
- Minimum Hg emission rates by fuel:
  - PRB & Bituminous Fuel: 0.25 lb/TBtu
  - o Lignite: 1.1 lb/TBtu

#### **Injection Rate / Emission Rate Calculations**

Current Injection Rate:

$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

Where,

x is the **current** injection rate (lb/MMacf),

y is the current emission rate (lb/TBtu), and

a and b are coefficients dependent on the fuel, particulate collection device, and PAC type (see table below).

Option 1 – Achievable Emission Rate based on New Injection Rate (Recommended Maximum 20% Increase):

$$y = a * e^{b * x}$$

Option 2 – New Injection Rate based on New Emission Rate (Per Minimum Limits Above):

$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

Where,

x is the **new** injection rate (lb/MMacf),

y is the new emission rate (lb/TBtu), and

a and b are coefficients dependent on the fuel, particulate collection device, and PAC type (see table below).

Fuel Type	PRB or Bi	tuminous	Lignite					
Particulate Control Type	Baghouse	ESP	Baghouse	ESP				
Coefficient 'a'								
Premium PAC	4.3552	4.3552	21.567	21.567				
Standard PAC	3.7609 3.7609		25.886	25.886				
Coefficient 'b'								
Premium PAC	-0.988	-0.593	-1.647	-1.086				
Standard PAC	-0.636	-0.381	-0.987	-0.69				

Note that in order to account for the existing system efficiencies, the new injection rate should be considered as the existing injection rate plus the difference in injection rates to go from the current



emission rate to the new achievable emission rate. Additionally, the new injection must be limited to no more than 20% increase above the existing injection rate.

#### Methodology Inputs

Several input variables are required in order to estimate the incremental ACI operating costs:

- Unit size,
- Unit heat rate,
- Uncontrolled Hg emission rate,
- Current controlled Hg emission rate,
- Additional system capacity remaining,
- Model estimated or user entered new controlled emission rate,
- Type of coal,
- Existing PM control,
- Current PAC type,
- Future PAC type,
- · Model estimated or user entered current PAC injection rate, and
- Unit costs for current sorbent, future sorbent and waste disposal.

Flue gas flowrate is calculated by the model and used to determine the hourly injection rate along with the design PAC loading (lb/MMacf) and is based on typical flue gas conditions downstream of air preheater. The cost methodology is based on a unit located within 500 feet of sea level. The actual elevation of the site should be considered separately and factored into the flue gas rate as the rate is directly impacted by the site elevation. The flue gas rate should be increased based on the ratio of the atmospheric pressure between sea level and the unit location. As an example, a unit located 1 mile above sea level would have an approximate atmospheric pressure of 12.2 psia. Therefore, the flue gas rate should be increased by:

14.7 psia/12.2 psia = 1.2 multiplier to the flue gas rate

#### Outputs

Note that the purpose of this estimate is to determine incremental costs of achieving stricter mercury emission limits on units with existing ACI systems. As such, the model restricts operating modifications to updates that would not require capital improvements.

#### Fixed O&M (FOM)

All modifications to existing ACI systems are based on operating changes only and include no capital improvements. Change in existing FOM rates related to increasing the injection rate of an existing system or upgrading the PAC are expected to be negligible and therefore excluded from the model.

#### Variable O&M (VOM)

Variable O&M is a function of:

- Current & incremental PAC use and unit costs;
- Incremental waste production and unit disposal costs; and

The following factors and assumptions underlie calculations of the VOM:



- All of the VOM costs were tabulated on a per megawatt-hour (MWh) basis.
- Increased Injection Rate:
  - Existing ACI systems are assumed to be built with some design margin that can be utilized to increase PAC injection rates without capital improvement. The remaining design margin is assumed to be 20% and therefore, the increased injection rate is assumed to be 20% higher than the current injection rate of the existing system as long as it meets the following conditions:
    - The new controlled mercury rate does not drop below 1.1 lb/TBtu for Lignite or 0.25 lb/TBtu for PRB or Bituminous fuels.

• The overall control rate does not exceed 95% from the uncontrolled rate. In either of these cases, the model will reduce the increased injection rate in order to satisfy both conditions.

- User can enter a site-specific remaining design margin value, however, it is recommended not to use more than 20% without obtaining site-specific information on remaining ACI system capacity.
- PAC Usage:
  - The total PAC usage is calculated from the total flue gas flow rate and the expected design injection rate to achieve the new Hg emission rate.
  - The incremental sorbent usage is calculated from the flue gas flow rate and the difference between the new expected injection rate and the current injection rate.
- Since the model was developed for units with an existing ACI system, it is assumed that no additional flyash will be captured as a result of increased PAC injection. Therefore, the PAC waste generation rate is equal to the PAC feed rate for the total and incremental rates.
- There is not expected to be an appreciable change in the power consumption of the existing system, therefore, no increase in power VOM is included in the model.

Due to the variability in PAC costs depending on the selected sorbent type, sorbent unit costs (\$/ton) can be entered by the user, otherwise the user can choose to use estimated sorbent costs which are based on current industry values as of 2021.

Input options are provided for the user to adjust the variable O&M costs per unit. Average default values are included in the base estimate. The variable O&M costs per unit options are:

- Current and Future PAC costs in \$/ton
- Waste disposal costs in \$/ton

The variables that contribute to the overall VOM are:

VOMR =	Variable O&M costs for incremental PAC
VOMW =	Variable O&M costs for incremental waste disposal
VOMP =	Variable O&M costs for additional auxiliary power (set to zero)

The total VOM is the sum of VOMR, VOMW and VOMP.

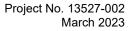




Table 1 contains an example of the complete O&M cost estimate worksheet when firing Lignite coal with an ESP using an existing Hg emission rate of 4.0 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type. Table 1 contains an example of the complete O&M cost estimate worksheet when firing Lignite coal with a baghouse using an existing Hg emission rate of 4.0 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type. Table 3 contains an example of the complete O&M cost estimate worksheet when firing PRB coal with a baghouse using an existing Hg emission rate of 1.2 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type. Table 4 contains an example of the complete O&M cost estimate worksheet when firing PRB coal with a baghouse using an existing Hg emission rate of 1.2 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type. Table 4 contains an example of the complete O&M cost estimate worksheet when firing PRB coal with an ESP using an existing Hg emission rate of 1.2 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type. Table 4 contains an example of the complete O&M cost estimate worksheet when firing PRB coal with an ESP using an existing Hg emission rate of 1.2 lb/TBtu (existing MATS limit) and upgrading PAC from standard to premium type.



# Table 1. Example Complete O&M Estimate for Increased ACI Rate on Lignite-fired Boiler w/ ESP

Fill in the yellow cells with the known data inputs. The resulting costs are tabulated below. Variable names are defined as outlined in the table.

Unit Size (Gross)         A         MV         900         cUser legut           Gross Heat Rate         B         But X/M         9500         cUser legut         Construct Control (Section 2)           Concent Control (Set Naminal)         D         But X/M         9500         cUser legut         Environments on control as when injecting the design rate.           Calculated based on specified remaining consolid (Section 2)         CUser legut         Section 2)         CUser legut         C	Variable	Designation	Units	Yalue	Calculation	
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Uncontrolled Hg Fate         C         IJ/TBu         6         CUser Input. Enter Hg emission rate with no control.           Rate         D         IJ/TBu         4.00         C			Btu/kWh			
Current Controlled Hg         D         In TBu         4.80						
Capacity Formaling         E         2000         (i.e. current injection rate plus Xo).           New Controlled Flate         Image: Controled Flate         Image: Controled Flate	Current Controlled Hg	D	lb/TBtu	4.00		
Basis         Control         Presiduation         Constraints         Constraintact <thconstraints< th=""> <thco< td=""><td></td><td>E</td><td></td><td>20%</td><td>&lt; User Input. S&amp;L recommends not exceeding 20%. Note this will be applied as additional capacity (i.e. current injection rate plus X%).</td></thco<></thconstraints<>		E		20%	< User Input. S&L recommends not exceeding 20%. Note this will be applied as additional capacity (i.e. current injection rate plus X%).	
Controlled Rate         Ib/TBtu         LU         Lighte, or 0.25 ib/TBtu for PRB or bit/minous fuel           New Controlled Hig Rate         F         ib/TBtu         110           Type of Coal         G         Lighte, or 0.25 ib/TBtu for PRB or bit/minous fuel         -           Esting PM Control         H         Esting PM Control         H         Esting PM Control         H           Current Sorbent         J         Standard PAC         Cortocit rates 3 = 41 b/TBtu. PRB and Bituminous require standard           New Selected Sorbent         K         Frainer P         Uprite requires standard PAC for control rates 3 = 41 b/TBtu. PRB and Bituminous 1 bit for effect rate 1 bit for effe				Madel Ertima 🔻	< User Input. Select basis for controlled emission rate.	
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Rate         P         Britiski         Los           Type of Coal         G         Linke         User Input           Existing PM Control         H         EP         User Input           Current Sorbent         J         Seaster/PAO	Controlled Rate		lb/TBtu	1.10	Calculated based on specified remaining capacity (Line E) with minimum values set at 1.1 lb/TBtu for Lignite, or 0.25 lb/TBtu for PRB or bituminous fuel.	
Type To Costa       Constant Input         Existing PM Control       H       Is#		F	lb/TBtu	1.10		
Current Sorbent       J       Structure Register	Type of Coal	G		Lignito 💌	< User Input	
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Flue Gas Rate     Q     aofm     2,066,250     Downstream of an air preheater       Flue Gas Rate     Q     aofm     2,066,250     Downstream of an air preheater       For Bituminous Coal = A'B'0.400     For Light Coal = A'B'0.400       For Light Coal = A'B'0.400     For Light Coal = A'B'0.400       Estimated Current     R2     Ib/hr       Total Sorbent Vaste     S     Ib/hr       Total Sorbent Vaste     S     Ib/hr       Total Sorbent Vaste     S     Ib/hr       Feed Rate     T     Ib/hr       Incremental Sorbent     T     Ib/hr       Feed Rate     U     Ib/hr       Current Sorbent Cost -     V     \$/ton       Belvered     V     \$/ton       Bolent Cost -     W     \$/ton       Delivered     W     \$/ton						
Flue Gas Rate     Q     acfm     2,066,250     For Bituminous Coal = A'B'0.362 For Light Coal = A'B'0.400 For Light Coal = A'B'0.400       Total Sorbent Feed     R1     Ib/hr     340     = Q'60'M/1000000       Estimated Current     R2     Ib/hr     336     = Q'60'M/1000000       Total Sorbent Vaste     S     Ib/hr     340     = R1       Incremental Sorbent     T     Ib/hr     4     = Q'60'(M1-L)/1000000       Feed Rate     U     Ib/hr     4     = T       Current Sorbent Cost - Delivered     V     \$/ton     880     < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801       Sorbent Cost - Delivered     W     \$/ton     1080     < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801	Heat Input	P	Btułhr	4.75E+09	= A'B'1000	
Estimated Current         R2         Ib/hr         336         = Q*60*L/10000000           Total Sorbent Waste         S         Ib/hr         340         = R1           Incremental Sorbent         T         Ib/hr         4         = Q*60*(M1-L)/1000000           Feed Rate         Ib/hr         4         = Q*60*(M1-L)/1000000           Incremental Sorbent         U         Ib/hr         4         = T           Current Sorbent Cost - Delivered         V         \$/ton         880         < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801           Sorbent Cost - Delivered         W         \$/ton         1080         < User input cost (Standard PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801	Flue Gas Rate	Q	acfm	2,066,250	For Bituminous Coal = A'B'0.362 For PRB Coal = A'B'0.400	
Total Sorbent Waste         S         Ib/hr         340         = R1           Incremental Sorbent Feed Rate         T         Ib/hr         4         = Q*60*(M1-L)/1000000           Feed Rate         T         Ib/hr         4         = Q*60*(M1-L)/1000000           Incremental Sorbent         U         Ib/hr         4         = T           Current Sorbent Cost - Delivered         V         \$kton         \$800         < User input cost (Standard PAC = \$830, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801           Sorbent Cost - Delivered         W         \$kton         1080         < User input cost (Standard PAC = \$280, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801						
Incremental Sorbent Feed Rate         T         Ib/hr         4         = Q*60*(M1-L)/1000000           Incremental Sorbent Waste Rate         U         Ib/hr         4         = T           Current Sorbent Cost - Delivered         V         \$/ton         880         < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280]           Sorbent Cost - Delivered         V         \$/ton         1080         < User input cost (Standard PAC = \$1280)						
Feed Rate         I         Ibmin         4         = Q 50 (WFL_/P0000000           Incremental Sorbent         U         Ib/In         4         = T           Current Sorbent Cost - Duriner Sorbent Cost - Delivered         V         \$/ton         880         < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$12801           Sorbent Cost - Delivered         W         \$/ton         1080         <		s	lbŕhr	340	= R1	
Waste Rate         U         Immi         *         = 1           Current Sorbent Cost - Delivered         V         \$kton         880         User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)           Sorbent Cost - Delivered         V         \$kton         1080	Feed Rate	т	lb/hr	4	= Q*60*(M1-L)/1000000	
Delivered         V         \$rron         880         Halogenated Premium PAC = \$1280)           Sorbent Cost - Delivered         V         \$rron         1080         < User input cost (Standard PAC = \$1280)	Waste Rate	U	lb/hr	4		
Sorbent Cost - V \$/ton 1080 < User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)		۷	\$/ton	880	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)	
	Sorbent Cost -	V	\$/ton	1080	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and	
In any composition of the international second se	Waste Disposal Cost	Х	\$/ton	30	< User Input	

Estimated Existing Variable O&M Cost								
VOMR (\$/MWh)= (R2*V)/(2000*A)	\$	0.30	Estimated current variable O&M costs for sorbent.					
VOM₩ (\$/M₩h) = R2/2000"X/A	\$	0.01	Estimated current variable $0\&M$ costs for waste disposal.					
VOMP (\$/MWh) = 0			Not estimated					
¥0M (\$/M¥h) = ¥0MR + ¥0M¥ + ¥0MP	\$	0.31						
Incremental Variable O&M Cost	Incremental Variable O&M Cost							
VOMR (\$/MWh) = [(T*W+(R2)*(W-V)]/(2000*A)	\$	0.07	Incremental variable 0&M costs for sorbent, including incremental price difference for upgrading PAC, if applicable.					
VOMV (\$/MWh) = U/2000*X/A	\$		Variable O&M costs for waste disposal that includes the incremental sorbent waste					
VOMP (\$/MVh) = 0	\$		Additional power consumption is assumed to be a negligible amount compared to the current sustem requirements.					
YOM (\$/M¥h) = YOMR + YOM¥ + YOMP	\$	0.07						



# Table 2. Example Complete O&M Estimate for Increased ACI Rate on Lignite-fired Boiler w/ Baghouse

Fill in the yellow cells with the known data inputs. The resulting costs are tabulated below. Variable names are defined as outlined in the table.

Yariable	Designation	Units	¥alue	Calculation	
Unit Size (Gross)	A	MV	500	< User Input	
Gross Heat Rate	B	BtułkWh	9500	< User Input	
Uncontrolled Hg Rate	c	Ib/TBtu	6	< User Input. Enter Hg emission rate with no controls.	
Current Controlled Hg		IDITID(G			
Rate	D	lb/TBtu	4.00	< User Input. Enter the current control rate when injecting the design rate.	
Additional System Capacity Remaining	E		20%	< User Input. S&L recommends not exceeding 20%. Note this will be applied as additional capacity (i.e. current injection rate plus X%).	
New Controlled Hg Rate Basis			Madel Ertima 🔻	< User Input. Select basis for controlled emission rate.	
			1.20		
Estimated Best Hg Controlled Rate		lb/TBtu	1.10	Calculated based on specified remaining capacity (Line E) with minimum values set at 1.1 lb/TBtu for Lignite, or 0.25 lb/TBtu for PRB or bituminous fuel.	
New Controlled Hg Rate	F	lb/TBtu	1.10		
Type of Coal	G		Lignito 💌	< User Input	
Existing PM Control	н		Baghouro 💌	< User Input	
Current Sorbent	J		Standard PAC 🔻	< User Input	
			Promium Pr 🔻	Lignite requires standard PAC for control rates >=4 Ib/TBtu. PRB and Bituminous require standard PAC for control rates >=12 Ib/Tbtu. Lignite requires Halogenated Premium PAC to achieve 11-4 Ib/TBtu. PRB and Biminous fuels require Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/TBtu. PRB and Biminous fuels requires Premium PAC for 0.25-12 Ib/Tbtu. Additionally, PRB and Ib/Tbtu. PRB and Ib/Tbtu. Ib/Tbtu. PRB and Ib/Tbtu. Additionally, PRB and Ib/Tbtu. PRB and Ib/Tbtu. PRB and Ib/Tbtu. PRB and Ib/Tbtu. Additionally, PRB and Ib/Tbtu. Additionally, PRB and Ib/Tbtu. Additionally, PRB and Ib/Tbtu. Additionally, PRB and Ib/Tbtu. PRB	
New Selected Sorbent	к		1	Lignite fuels require halogenated PAC in any case in order to convert Hg from elemental to ionic for more efficient capture. Although both standard and premium PAC can in some cases achieve the same emission rate with different injection rates, it is assumed the most efficient selection is relative to current MATS limit (4.0 lbr/Btu for Lignite and 1.2 lbr/Tbtu for PFB and Bituminous).	
Existing Injection Rate	L		Madel Estimated 💌	If current injection rate (Ib/Mmacf) is known, select User Entered. If not, enter Model Estimated.	
Estimated Injection Rate		Ib/MMacf	1.9	Injection rate calculated based on the current outlet emission rate, fuel type and PM removal type.	
New Injection Rate	MI	Ib/MMacf	1.8	New injection rate calculated based on the new outlet emission rate, fuel type and PM removal type. Limited to remaining system capacity increase, applied to current injection rate, based on no modifications to existing equipment.	
New Estimated Emission Rate	M2	lb/TBtu	1.1		
Additional Control	N	%	72.5	= (D-E)/D*100	
Heat Input	Р	Btu/hr	4.75E+09	= A'B'1000	
Flue Gas Rate	Q	acfm	2,066,250	Downstream of an air preheater For Bituminous Coal = A'B'0.362 For PRB Coal = A'B'0.400 For Lighte Coal = A'B'0.435	
Total Sorbent Feed	R1	lb/hr	224	= Q*60*M1/1000000	
Estimated Current	R2	lb/hr	235	= Q*60*L/1000000	
Total Sorbent Waste	S	lb/hr	224	= R1	
Incremental Sorbent Feed Rate	т	lb/hr	-11	= Q*60*(M1-L)/1000000	
Incremental Sorbent Waste Rate	U	lb/hr	-11	= T	
Current Sorbent Cost - Delivered	٧	\$/ton	880	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)	
Sorbent Cost - Delivered	V	\$/ton	1080	User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)	
Waste Disposal Cost	X	\$/ton	30	< User Input	

Estimated Existing Variable O&M Cost		
VOMR (\$/MWh) = (R2"V)/(2000"A)	\$ 0.21	Estimated current variable $0\%M$ costs for sorbent.
VOMW (\$/MWh) = R2/2000"X/A	\$ 0.01	Estimated current variable $0 \& M$ costs for waste disposal.
VOMP (\$/MWh) = 0		Not estimated
¥0M (\$/M¥h) = ¥0MR + ¥0M¥ + ¥0MP	\$ 0.21	
Incremental Yariable O&M Cost		
VOMR (\$/MWh) = [(T*V+(R2)*(V-V)]/(2000*A)	\$ 0.04	Incremental variable O&M costs for sorbent, including incremental price difference for upgrading PAC, if applicable.
VOMW (\$łMWh) = Uł2000"X/A	\$	Variable O&M costs for waste disposal that includes the incremental sorbent waste
VOMP (\$/MWh) = 0	\$ -	Additional power consumption is assumed to be a negligible amount compared to the current sustem requirements.
YOM (\$/M¥h) = YOMR + YOM¥ + YOMP	\$ 0.04	



# Table 3. Example O&M Estimate for Increased ACI Rate on PRB-fired Boiler w/ Baghouse Fill in the yellow cells with the known data inputs. The resulting costs are tabulated below. Variable names are defined as outlined in the table.

Unit Size (Gross) Gross Heat Rate	Designation A B	MV	500	< User Input	
Gross Heat Rate					
		Btu/kWh	9500	< User Input	
Uncontrolled Hg Rate	c	Ib/TBtu	6	< User Input. Enter Hg emission rate with no controls.	
Current Controlled Hg		10111D/G		Consistent and the second seco	
Rate	D	lb/TBtu	1.20	< User Input. Enter the current control rate when injecting the design rate.	
Additional System Capacity Remaining	E		20%	< User Input. S&L recommends not exceeding 20%. Note this will be applied as additional capacit (i.e. current injection rate plus X%).	
New Controlled Hg Rate Basis			Madal Ertima 🔻	< User Input. Select basis for controlled emission rate.	
			1.20		
Estimated Best Hg Controlled Rate		lb/TBtu	0.52	Calculated based on specified remaining capacity (Line E) with minimum values set at 1.1 lb/TBtu for Lignite, or 0.25 lb/TBtu for PRB or bituminous fuel.	
New Controlled Hg Rate	F	Ib/TBtu	0.52		
Type of Coal	G		PRB 💌	< User Input	
Existing PM Control	н		Baghows 💌	< User Input	
Current Sorbent	J		Standard PAC 🔻	< User Input	
New Selected Sorbent	к		Promium Pr 🔻	Lignite requires standard PAC for control rates >=4 Ib/TBtu. PRB and Bituminous require standar PAC for control rates >=1.2 Ib/Tbtu. Lignite requires Halogenated Premium PAC to achieve 1.1 Ib/TBtu. PRB and Biminous fuels require Premium PAC for 0.25-12 Ib/Tbtu. Additionally. PRB an Lignite fuels require halogenated PAC in any case in order to convert Hq from elemental to ionic f	
New Selected Solbent	ĸ			Lignet rules require halogenated PAC in any case in order to convert the prometemental to ioni more efficient capture. Although both standard and premium PAC can in some cases achieve t same emission rate with different injection rates, it is assumed the most efficient selection is relative to current MATS limit (4.0 Ib/TBtu for Lignite and 1.2 Ib/TBtu for PRB and Bituminous).	
Existing Injection Rate	L		Madel Ertimated 🔻	If current injection rate (Ib/Mmacf) is known, select User Entered. If not, enter Model Estimated.	
Estimated Injection Rate		Ib/MMacf	1.8	Injection rate calculated based on the current outlet emission rate, fuel type and PM removal type.	
New Injection Rate	MI	Ib/MMacf	2.2	New injection rate calculated based on the new outlet emission rate, fuel type and PM removal typ Limited to remaining system capacity increase, applied to current injection rate, based on no modifications to existing equipment.	
New Estimated Emission Rate	M2	lb/TBtu	0.5		
Addtitional Control	N	%	56.8	= (D-E)/D*100	
Heat Input	P	Btu/hr	4.75E+09	= A"B"1000	
Flue Gas Rate	Q	acfm	1,900,000	Downstream of an air preheater For Bituminous Coal = A'B'0.362 For PRB Coal = A'B'0.400 For Lignite Coal = A'B'0.435	
Total Sorbent Feed	R1	lbłhr	246	= Q*60*M1/1000000	
Estimated Current	R2	lb/hr	205	= Q*60*L/1000000	
Total Sorbent Waste	S	lb/hr	246	= R1	
Incremental Sorbent Feed Rate	т	lb/hr	41	= Q*60*(M1-L)/1000000	
Incremental Sorbent Waste Rate	U	lb/hr	41	= T	
Current Sorbent Cost - Delivered	٧	\$/ton	880	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 an Halogenated Premium PAC = \$1280)	
o 1 10 1			1000	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 an	
Sorbent Cost - Delivered	V X	\$/ton	1080	Halogenated Premium PAC = \$1280)	

#### d Existing Variable O&M C E۶

Es	timated Existing Variable O&M Cost		
	VOMB (\$/MWh) = (B2*V)/(2000*A)	\$ 0.18	Estimated current variable O&M costs for sorbent.
	VOMW (\$/MWh) = R2/2000"X/A	\$ 0.01	Estimated current variable $O\&M$ costs for waste disposal.
	VOMP (\$/M\/h) = 0		Not estimated
	YOM (\$/MYh) = YOMR + YOMY + YOMP	\$ 0.19	
Inc	remental ¥ariable O&M Cost		
	VOMR (\$/MWh) = [(T*W+(R2)*(W-V)]/(2000*A)	\$ 0.09	Incremental variable O&M costs for sorbent, including incremental price difference for upgrading PAC, if applicable.
	VOMW (\$/MWh) = U/2000"X/A	\$ 0.00	Variable O&M costs for waste disposal that includes the incremental sorbent waste
	VOMP (\$/M\\h) = 0	\$ -	Additional power consumption is assumed to be a negligible amount compared to the current sustem requirements.
	YOM (\$/MYh) = YOMR + YOMY + YOMP	\$ 0.09	



# Table 4. Example Complete O&M Estimate for Increased ACI Rate on a PRB-fired Boiler w/ ESP

Fill in the yellow cells with the known data inputs. The resulting costs are tabulated below. Variable names are defined as outlined in the table.

Variable	Designation	Units	Yalue	Calculation	
Unit Size (Gross)	A	MV	500	< User Input	
Gross Heat Rate	B	Btu/kWh	9500	< User Input	
Uncontrolled Hg Rate	c	Ib/TBtu	6	< User Input. Enter Hg emission rate with no controls.	
Current Controlled Hg		IDITIE (G		· •	
Rate	D	lb/TBtu	1.20	< User Input. Enter the current control rate when injecting the design rate.	
Additional System Capacity Remaining	E		20%	User Input. S&L recommends not exceeding 20%. Note this will be applied as additional capacity (i.e. current injection rate plus X%).	
New Controlled Hg Rate Basis			Model Ertima 🔻	< User Input. Select basis for controlled emission rate.	
			1.20		
Estimated Best Hg Controlled Rate		lb/TBtu	0.52	Calculated based on specified remaining capacity (Line E) with minimum values set at 1.1 lb/TBtu for Lignite, or 0.25 lb/TBtu for PRB or bituminous fuel.	
New Controlled Hg Rate	F	lb/TBtu	0.52		
Type of Coal	G		PRB 💌	< User Input	
Existing PM Control	н		ESP 💌	< User Input	
Current Sorbent	J		Standard PAC 💌		
			Promium Pi 🔻	Lignite requires standard PAC for control rates >=4 Ib/TBtu. PRB and Bituminous require standard PAC for control rates >=1.2 Ib/Tbtu. Lignite requires Halogenated Premium PAC to achieve 1.1.4 (b/TBtu. PRB and Biminous fuels require Premium PAC for 0.25-1.2 Ib/Tbtu. Additionally, PRB and	
New Selected Sorbent	к		1	Lignite fuels require halogenated PAC in any case in order to convert Hg from elemental to ionic for more efficient capture. Although both standard and premium PAC can in some cases achieve the same emission rate with different injection rates, it is assumed the most efficient selection is relative to ourrent MATS limit (4.0 lbrtBtu for Lignite and 1.2 lb/TBtu for PRB and Bituminous).	
Existing Injection Rate	L		Madal Ertimatod 🔻 Z	If current injection rate (Ib/Mmacf) is known, select User Entered. If not, enter Model Estimated.	
Estimated Injection Rate		Ib/MMacf	3.0	Injection rate calculated based on the current outlet emission rate, fuel type and PM removal type.	
New Injection Rate	MI	Ib/MMacf	3.6	New injection rate calculated based on the new outlet emission rate, fuel type and PM removal type. Limited to remaining system capacity increase, applied to current injection rate, based on no modifications to existing equipment.	
New Estimated Emission Rate	M2	lb/TBtu	0.5		
Addtitional Control	N	%	57.0	= (D-E)/D*100	
Heat Input	P	Btułhr	4.75E+09	= A'B'1000	
Flue Gas Rate	Q	acfm	1,900,000	Downstream of an air preheater For Bituminous Coal = A1B10.362 For PBB Coal = A1B10.400 For Lignite Coal = A1B10.435	
Total Sorbent Feed	R1	lb/hr	410	= Q*60*M1/1000000	
Estimated Current	R2	lbŕhr	342	= Q*60*L/1000000	
Total Sorbent Waste	S	lbłhr	410	= R1	
Incremental Sorbent Feed Rate	т	lb/hr	68	= Q*60*(M1-L)/1000000	
Incremental Sorbent Waste Rate	U	lb/hr	68	= T	
Current Sorbent Cost - Delivered	٧	\$/ton	880	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)	
Sorbent Cost - Delivered	W	\$/ton	1080	< User input cost (Standard PAC = \$880, Halogenated PAC = \$1040, Premium PAC = \$1080 and Halogenated Premium PAC = \$1280)	
Waste Disposal Cost	X	\$/ton	30	< User Input	

	YOM (\$/MYh) = YOMR + YOMY + YOMP	\$	0.14					
	VOMP (\$/MWh) = 0	\$		Additional power consumption is assumed to be a negligible amount compared to the current sustem requirements.				
	VOMW (\$/MWh) = U/2000"X/A	\$	0.00	Variable O&M costs for waste disposal that includes the incremental sorbent waste				
	VOMR (\$/MWh) = [(T*V+(R2)*(V-V)]/(2000*A)	\$	0.14	Incremental variable O&M costs for sorbent, including incremental price difference for upgrading PAC, if applicable.				
Inci	Incremental Variable O&M Cost							
	YOM (\$/MYh) = YOMR + YOMY + YOMP	\$	0.31					
	VOMP (\$//MWh) = 0			Not estimated				
	VOMW (\$/MWh) = R2/2000"X/A	\$	0.01	Estimated current variable O&M costs for waste disposal.				
	VOMR (\$/MWh) = (R2*V)/(2000*A)	\$	0.30	Estimated current variable O&M costs for sorbent.				
Est	imated Existing Variable O&M Cost							