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

## Mercury Control Cost Development Methodology

**Final**

March 2013

Project 12847-002

Systems Research and Applications Corporation

Prepared by

Sargent & Lundy LLC

55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

**LEGAL NOTICE**

*This analysis ("Deliverable") was prepared by Sargent & Lundy, L.L.C. ("S&L"), expressly for the sole use of Systems Research and Applications Corporation ("Client") in accordance with the agreement between S&L and Client. This Deliverable was prepared using the degree of skill and care ordinarily exercised by engineers practicing under similar circumstances. Client acknowledges: (1) S&L prepared this Deliverable subject to the particular scope limitations, budgetary and time constraints, and business objectives of the Client; (2) information and data provided by others may not have been independently verified by S&L; and (3) the information and data contained in this Deliverable are time sensitive and changes in the data, applicable codes, standards, and acceptable engineering practices may invalidate the findings of this Deliverable. Any use or reliance upon this Deliverable by third parties shall be at their sole risk.*

*This work was funded by the U.S. Environmental Protection Agency and reviewed by William A. Stevens, Senior Advisor – Power Technologies.*

# Mercury Control Cost Development Methodology

## Technology Description

On February 16, 2012, the U.S. Environmental Protection Agency (EPA) published in the Federal Register a final rule regulating hazardous air pollutant (HAP) emissions from coal- and oil-fired electric utility steam generating units. The rule, referred to as the Mercury and Air Toxics Standards ("MATS Rule" or "Utility MACT Rule"), requires coal- and oil-fired electric utility steam generating units to meet emission standards for several pollutants including mercury.

The MATS Rule requires units that burn either subbituminous or bituminous coal to comply with a mercury emission limit of 1.2 lb/TBtu. The limit would typically require a removal of greater than 90% from the fuel mercury content. Units that burn lignite coal must comply with a mercury emission limit of 4.0 lb/TBtu. Commercial experience has shown that activated carbon injection (ACI) can meet a 90% reduction in total Hg in some cases. There are also non-carbon based sorbents that are being developed for Hg capture. One type of non-carbon sorbent, amended silicates, has been demonstrated and is included in the cost model as an alternative to ACI for baghouse applications only.

It should be noted that with the addition of an ACI system, and capture of the carbon in the same particulate collector as the fly ash, beneficial use of the fly ash may be limited. The carbon may prevent sale of the fly ash to the cement markets. Even the "concrete friendly" activated carbons are not well accepted in the cement industry without prior testing by the fly ash purchaser. It is claimed by the sorbent developer that amended silicates are completely compatible with fly ash beneficial use in the cement industry.

## 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 ($Hg^0$),
- Ionic or Oxidized ($Hg^{++}$), or
- Particulate.

The conversion of elemental mercury to the other forms depends upon several factors; cooling rate of the gas, presence of halogens or $SO_3$ in the flue gas, amount and composition of fly ash, presence of unburned carbon, and the installed air pollution control equipment. Particulate mercury typically is bound to fly ash or unburned carbon.

Considering the interaction of the various parameters, ionic mercury can vary between 10% and 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.

## Air Pollution Control Equipment Co-Benefits

SCR catalysts promote the oxidation of elemental mercury. However, the extent of oxidation through the SCR catalyst beds can be limited by other factors, such as low flue gas halogen concentrations. SCR systems may have the ability to convert some elemental mercury to ionic mercury depending on the halide content in the coal. The catalyst used in SCR systems is designed to facilitate the conversion of $NO_x$ to $N_2$ and $H_2O$. The active ingredient used in SCR catalysts is vanadium pentoxide, which oxidizes sulfur dioxide ($SO_2$) to sulfur trioxide ($SO_3$) as well as elemental mercury to ionic mercury. Mercury oxidation is inhibited by ammonia injection. Typically, most of the mercury oxidation occurs in the last layer of catalyst where the concentration of ammonia is the lowest.

Another mechanism of mercury oxidation occurs across fabric filter elements in a baghouse. Unburned carbon in the fly ash accumulates in the filter cake on the filter elements. The unburned carbon oxidizes $Hg^0$ to $Hg^{++}$ in the presence of chlorides in the flue gas. The degree of oxidation depends on the quantity of unburned carbon present in the filter cake. The ionic mercury converted in a baghouse could be captured by an FGD system downstream of the baghouse.

Through intimate contact of the flue gas with the filter cake on the fabric filters, mercury can be adsorbed on the carbon particles present in the fly ash. The mercury is bound to the particulates in the filter cake and the particulate mercury is removed at the same efficiency as the solids. For this reason, fabric filters can result in extremely high mercury capture depending on the unburned carbon concentration or can improve the capture with any mercury sorbent.

## Mercury Capture

The speciation of the mercury plays a significant role in its capture. Elemental mercury is insoluble in water. Therefore, $Hg^0$ is not collected in downstream FGD systems. Nor do particulate collectors remove elemental mercury. Elemental mercury can be removed with injected sorbents or it must be converted to another form to be captured in downstream FGD systems.

## Mercury Control Cost Development Methodology

Some flue gas constituents, especially $SO_3$, reduce the mercury removal effectiveness of both activated carbon and non-carbon sorbents. With flue gas $SO_3$ concentrations greater than 5 - 7 ppmv, the sorbent feed rate may be increased significantly to meet a high Hg removal and 90% or greater mercury removal may not be feasible in some cases. Based on commercial testing, capacity of activated carbon can be cut by as much as one half with an $SO_3$ increase from just 5 ppmv to 10 ppmv. Some utilities are planning to inject alkali (typically Trona) before the mercury sorbent injection system to reduce the $SO_3$ concentration. For the purposes of the evaluation, no alkali injection cost was included. It is likely that the amount of alkali injected for $SO_3$ control would be small, and its associated cost compared to activated carbon cost could likewise be relatively small. Furthermore, any benefits from alkali injection would reduce the mercury sorbent feed rate, thus reducing the costs otherwise estimated in this study. However, to perform detailed analysis on high sulfur bituminous coal, the capital and O&M cost for $SO_3$ control system must be considered.

In contrast to elemental mercury, ionic mercury is highly water soluble. In dry FGD systems, the ionic mercury is captured in the injected lime slurry. Dry FGD systems evaporate the liquid phase, allowing the ionic mercury to be removed with the solid by-product in the baghouse. In wet FGD systems, ionic mercury is soluble in the liquid. The captured mercury leaves the system with the purge water or the mercury can bind with the solid phases in the FGD slurry and leave with the solid by-product. Recent commercial data indicates that some of the ionic mercury captured by the wet FGD can be reduced to the elemental form and be re-emitted to the stack under certain circumstances. Extensive testing is on-going to determine the mechanism for re-emission and to develop additives to mitigate the problem. For the purposes of the cost estimation, a wet FGD additive that eliminates re-emission is modeled as an additional variable operating cost.

Particulate mercury is removed very efficiently from the flue gas by the particulate control device. Therefore, it is desirable to convert as much mercury as possible to particulate mercury. High $SO_3$ levels have been shown to inhibit the binding of ionic mercury to fly ash or mercury sorbents. Low halogen levels in the coal will also inhibit formation of particulate mercury by first inhibiting formation of ionic mercury. Activated carbon, non-carbon based sorbents, and/or the addition of halogens increase the conversion of elemental and ionic mercury to particulate mercury.

### Establishment of Cost Basis

Commercial experience indicates that wet or dry FGD systems can capture greater than 90% of the ionic mercury. SCR catalysts can convert much of the elemental mercury to ionic mercury in the presence of halogens. When an SCR exists and there are relatively high halogen concentrations in the flue gas, it is possible that greater than 90% of the

## Mercury Control Cost Development Methodology

mercury could be ionic mercury. Therefore, the capture by an FGD following an SCR would be in the range of 80 to 90% of the total mercury if there is no re-emission.

Bituminous coals will have relatively high halogen concentrations in the flue gas. So flue gas mercury from bituminous coals that is treated by an SCR could be approximately 90% ionic mercury. Sorbent injection is not required when an FGD system exists downstream of an SCR for bituminous fuels and the required total mercury removal is less than 80%. To ensure full wet FGD co-benefit capture, costs are included to provide slurry additives that inhibit re-emission of the mercury. Both capital and variable O&M costs were included for the slurry additive injection system. If a total mercury removal of greater than 80% is required, it is probable that a sorbent injection system (either with activated carbon or a non-carbon sorbent) would be installed and no slurry additives would be required. However, alkali injection may be required for $SO_3$ control to meet the removal requirements with ACI or the non-carbon sorbents. No costs were included for alkali injection.

PRB and lignite coals have relatively low halogen concentrations. For those fuels, coal additives can promote ionic mercury speciation. With an SCR followed by an FGD and coal additives included, a maximum of 80% total mercury removal could be achieved without a sorbent injection system. Coal additives, for PRB and lignite fuels, are included in the cost estimate when an SCR and an FGD system exist and the total mercury removal is less than 80%. The coal additive costs include capital, variable O&M and a one time royalty fee associated with the injection process. The variable operating cost is based on a 100 $ppm_w$ addition of bromine to the coal. In the future, there might be additional costs associated with water treatment systems based on emission limits of bromine in the waste water. This evaluation does not address the potential future water treatment requirements.

If a removal of greater than 80% of the total mercury is required for PRB or lignite coals, a mercury sorbent injection system would need to be installed. The sorbent injection system could include coal additives to promote ionic mercury speciation or halogenated carbon or non-carbon sorbents could be used. The user of the cost model is required to pick the type of sorbent to be injected. If “standard” activated carbon, which does not contain added halogens, is chosen, then a coal additive system is included in the cost model. The non-carbon sorbent does not require halogens to remove mercury form the flue gas.

When a sorbent injection system is required, the design feed rate will dictate the size of the equipment and the resulting capital costs. The feed rate is a function of required removal, particulate collection device, and in some cases state regulations.

# Mercury Control Cost Development Methodology

A consistent basis was established to calculate the carbon feed rate. The activated carbon rate was based on the use of brominated carbon. Current industry experience indicates that 5 pounds of carbon injected for every 1,000,000 acfm of flue gas will ensure adequate mercury capture and is a common design target for systems with an ESP. When a baghouse is used to capture the carbon, a reduced feed rate of 2 pounds of carbon injected for every 1,000,000 acfm is generally acceptable. No co-benefit removal was considered in the carbon feed rate. No additional alkali injection was included to remove $SO_3$ or other inhibitors.

Development of the non-carbon sorbents is continuing. Current industry test data has shown that the non-carbon sorbent is effective for mercury capture with a baghouse particulate collector. An injection rate of approximately 3.5 lb/MMacf was required for greater than 90%. Test data on ESP applications is still pending. Therefore, the non-carbon sorbent is not currently recommended for units with ESPs as the only particulate capture device.

In summary:

- 2 lb per 1,000,000 acfm carbon feed rate with a baghouse
- 3.5 lb per 1,000,000 acfm non-carbon sorbent feed rate with a baghouse
- 5 lb per 1,000,000 acfm carbon feed rate with an ESP
- Non-carbon sorbent is not applicable to an ESP only application
- Flue gas rate established after the air preheater
- No co-benefit or other unit operations considered
- No alkali injection considered

To account for all of the variables, the capital cost was established based on the actual anticipated sorbent feed rate, not the plant power rating. Cost data for several ACI systems was reviewed and a relationship was developed for the capital costs of the system on a feed rate basis. The developer of the amended silicates claims the sorbent will use the same equipment as an ACI system. Therefore, no changes to the capital costs were included based on the use of a non-carbon sorbent.

Another capital cost impact from a sorbent injection system is often the addition of a baghouse to capture the sorbent. A baghouse can be required for several reasons:

- The existing ESP cannot remove the additional particulate load associated with the sorbent injection.
- A new baghouse should be installed whenever flue gas conditioning ($SO_3$ injection) is required for the existing ESP. Use of flue gas conditioning indicates that the existing ESP is marginally acceptable for the current solids

load and the additional sorbent load would result in excessive particulate emissions.

- PRB coals tend to be low in chloride; therefore, most of the flue gas mercury is elemental mercury. Installation of a baghouse can result in varying degrees of oxidation of the elemental mercury through contact with the unburned carbon in the fly ash. The oxidized mercury may be captured in downstream FGD systems. Mercury oxidation does not proceed at the same rate through an ESP.

A polishing baghouse with an air-to-cloth (A/C) ratio of 6.0 or lower should be considered when the baghouse is installed after an existing particulate capture device that will remain in service to capture the majority of the fly ash. The sorbent system could be installed downstream of the existing particulate capture device and upstream of the new baghouse. The design has two benefits. First, a smaller capital investment is required for a polishing baghouse when compared to a full sized baghouse. Second, any beneficial use of the fly ash can be maintained.

A full sized baghouse, with an A/C ratio of 4.0 or lower, should be specified when the baghouse will be the primary particulate collection device for the fly ash and mercury sorbent. The lower A/C ratio will provide better bag life with the high inlet particulate loading expected for the single particulate capture device in the process.

Capital costs were developed for the baghouse addition. The option to include a 4.0 A/C or a 6.0 A/C baghouse or not to include a baghouse is left to the user of the cost algorithm. Cost data from the S&L current database of projects, for several different baghouse installations, was reviewed and a relationship was developed for the capital costs of the system on a flue gas rate basis. The capital costs include:

- Duct work modifications and reinforcement,
- Foundations,
- Structural steel,
- ID fan modifications or new booster fans, and
- Electrical modifications.

## Methodology
### Inputs

Several input variables are required in order to predict the total future retrofit costs:

- Type of coal,
- Unit size,
- Unit heat rate,

- Baghouse addition option and required size, and
- Type of sorbent.

A retrofit factor that equates to difficulty in construction of the system must be defined.

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

### *Total Project Costs (TPC)*

First the installed costs are calculated for a sorbent injection system as required (BMC). Then an installed cost for the baghouse (as applicable) is calculated (BMB). However, if a sorbent system is not needed because of the existing equipment co-benefit capture, some form of additive addition may be required. If a wet FGD is used to remove 90% of the ionic mercury, slurry additives may be required. A base module price for the slurry additives would be included in the capital estimate (BMF). If PRB or lignite is fired, and the total mercury removal is less than 80%, then additional halogens can be added to the coal. The installed capital cost for the coal additive system is included as applicable (BMA).

The base modules are:

| | |
|---|---|
| BMC = | Base sorbent injection system |
| BMB = | Base baghouse |
| BMF = | Base wet FGD re-emission additive system |
| BMA = | Base coal halogen additive system |
| BM = | BMC + BMB + BMF + BMA |

## Mercury Control Cost Development Methodology

The base module installed costs include:

- All equipment;
- Installation;
- Buildings;
- Foundations;
- Electrical; and
- Average retrofit difficulty.

The total base module installed cost (BM) is then increased by:

- Engineering and construction management costs are included at 5% of the BM cost for a sorbent only system or 10% of the BM cost when a new baghouse;
- Labor adjustment for 6 x 10 hour shift premium, per diem, etc., are included at 5% of the BM cost for a sorbent only system or 10% of the BM cost when a new baghouse; and
- Contractor profit and fees are included at 5% of the BM cost for a sorbent only system or 10% of the BM cost when a new baghouse.

A capital, engineering, and construction cost subtotal (CECC) is established as the sum of the BM and the additional engineering and construction fees.

Additional costs and financing expenditures for the project are computed based on the CECC. Financing and additional project costs include:

- Owner's home office costs (owner's engineering, management, and procurement) at 5% of the CECC; and
- Allowance for Funds Used During Construction (AFUDC) at 0% of the CECC and owner's costs as mercury sorbent injection projects are expected to be completed in less than a year.
- With the addition of a baghouse, 6% of the CECC is added to account for AFUDC based on a complete project duration of 2 years.
- If coal additives are required, based on the type of fuel, existing equipment, total mercury removal, and sorbent type; then a one time royalty fee must be added to the total project cost (C2). The royalty fee is added to the bottom line project cost with no burden allowances.

The total project cost is based on a multiple lump sum contract approach. Should a turnkey engineering procurement construction (EPC) contract be executed, the total project cost would be 10 to 15% higher than what is currently estimated.

## Mercury Control Cost Development Methodology

Escalation is not included in the estimate. The total project cost (TPC) is the sum of the CECC and the additional costs and financing expenditures.

***Fixed O&M (FOM)***
The fixed operating and maintenance (O&M) cost is a function of the additional operations staff (FOMO), maintenance labor and materials (FOMM), and administrative labor (FOMA) associated with the sorbent installation. The FOM is the sum of the FOMO, FOMM, and FOMA.

The following factors and assumptions underlie calculations of the FOM:

- All of the FOM costs were tabulated on a per kilowatt-year (kW yr) basis.

- In general, 0 additional operators are required for a sorbent or additive system or a baghouse. Therefore, the operations staff fixed cost (FOMO) is zero.

- The fixed maintenance materials and labor is a direct function of the process capital cost at 1.0% of the BM for a sorbent system only and 0.5% of the BM when a baghouse is added.

- The administrative labor is a function of the FOMO and FOMM at 3% of (FOMO + 0.4FOMM).

***Variable O&M (VOM)***
Variable O&M is a function of:

- Sorbent use and unit costs;
- Waste production and unit disposal costs;
- Additional power required and unit power cost; and
- Bag and cage replacement as applicable.

The following factors and assumptions underlie calculations of the VOM:

- All of the VOM costs were tabulated on a per megawatt-hour (MWh) basis.

- The sorbent usage is calculated from the unit size and heat rate.

- The sorbent waste generation rate is equal to the sorbent feed rate.

## Mercury Control Cost Development Methodology

- When the activated carbon is captured in the same particulate collector as the fly ash, any fly ash produced may have to be landfilled. As a worst case cost estimate, the entire fly ash amount is included in the waste rate. Typical ash contents for each fuel are used to calculate a total fly ash production rate.

- The fly ash production is only added to the sorbent waste when a new baghouse is not included. With the addition of a new baghouse, the existing particulate collector should remain in operation to capture the fly ash and maintain any beneficial uses.

- The non-carbon based amended silicates should continue to allow for the beneficial reuse of the fly ash. Therefore, if a non-carbon sorbent is used only the additional sorbent waste rate is included in the cost estimate.

- Bag and cage replacement every 3 and 9 years respectively for unit operations with 6.0 A/C.

- Bag and cage replacement every 5 and 10 years respectively for unit operations with 4.0 A/C.

- The additional power required includes air blowers for the injection system and power for the baghouse compressors as applicable.

- The additional power is reported as a percent of the total unit gross production. In addition, a cost associated with the additional power requirements can be included in the total variable costs.

- An allowance for wet FGD additives, to reduce re-emission of the mercury, is included for wet FGD systems with SCRs only.

- An additional allowance is included for PRB or lignite coals. The allowance is based on halogen coal additives to enhance ionic mercury formation with units that have both an FGD and an SCR or for units that choose to inject standard carbon.

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:

## Mercury Control Cost Development Methodology

- Sorbent cost in \$/ton;
- Waste disposal costs in \$/ton;
- Auxiliary power cost in \$/kWh;
- Bag and cage costs in \$/item; and
- Operating labor rate (including all benefits) in \$/hr.

The variables that contribute to the overall VOM are:

| | |
|---|---|
| VOMR = | Variable O&M costs for sorbent |
| VOMW = | Variable O&M costs for waste disposal |
| VOMP = | Variable O&M costs for additional auxiliary power |
| VOMB = | Variable O&M costs for bags and cage replacement |
| VOMF = | Variable O&M costs for a wet FGD additive, only applies when there is an SCR, wet FGD system, and less than 80% total mercury capture. In that case, no mercury sorbent injection system is required. |
| VOMA = | Variable O&M costs for a coal additive, only applies to units burning PRB or lignite coal and when there is an SCR, FGD system, and less than 80% total mercury capture or to units burning PRB or lignite coal that choose to inject standard carbon. |

The total VOM is the sum of VOMR, VOMW, VOMP, VOMB, and VOMF and/or VOMA as applicable. The additional auxiliary power requirement is also reported as a percentage of the total gross power of the unit.

Table 1 contains an example of the complete capital and O&M cost estimate worksheet when using an existing ESP for the activated carbon and fly ash capture. Table 2 contains an example of the complete capital and O&M cost estimate worksheet when using an existing baghouse for the activated carbon and fly ash capture. Table 3 shows a complete cost methodology with injection of activated carbon and the addition of a baghouse while burning PRB coal. Table 4 contains details of an existing SCR and wet FGD system burning PRB coal and requiring less than 80% total mercury removal. Table 5 shows an example of a non-carbon sorbent addition for mercury removal.

## Mercury Control Cost Development Methodology

**Table 1. Example Complete Cost Estimate for an ACI System with an Existing ESP**

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <— User Input |
| Retrofit Factor | B | | 1 | <— User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <— User Input |
| Type of Coal | D | | Bituminous | <— User Input |
| Existing FGD System | E | | Wet FGD | <— User Input |
| Exisitng SCR | F | | ☑ TRUE | <— User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☐ FALSE | <— User Input |
| Existing PM Control | H | | ESP | <— User Input |
| Baghouse Addition | J | | Not Added | <— User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <— User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 516 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 516 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 21.0 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <— User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <— User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <— User Input |
| Bag Cost | V | ($/bag) | 100 | <— User Input |
| Cage Cost | W | ($/cage) | 30 | <— User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <— User Input (Labor cost including all benefits) |

### Costs are all based on 2012 dollars

| Capital Cost Calculation | | Example | | Comments |
|---|---|---|---|---|
| Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty | | | | |
| BMC ($) = | 1,600,000*B*(M^0.15) | $ | 4,083,000 | Base sorbent injection module includes all equipment from unloading to injection |
| BMB ($) = | if (J = Not Added then 0, J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600) *B*L^0.81 | $ | - | Base module for an additional PJFF including:<br>Duct work modifications and reinforcement, foundations, structual steel, ID or booster fans, piping, electrical, etc… |
| BMF ($) = | if there is a wet FGD, SCR, and capture is less than 80% then $500,000 else 0 | $ | - | Base module for wet FGD additive addition (as applicable) |
| BMA ($) = | if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then $1,000,000 else 0 | $ | - | Base module for coal additive addition (as applicable) |
| BM ($) =<br>BM ($/KW) = | BMC + BMB + BMF + BMA | $ | 4,083,000<br>8 | Total Base module cost including retrofit factor<br>Base module cost per kW |
| **Total Project Cost** | | | | |
| A1 = if baghouse addition then 10% else 5% of BM | | $ | 204,000 | Engineering and Construction Management costs |
| A2 = if baghouse addition then 10% else 5% of BM | | $ | 204,000 | Labor adjustment for 6 x 10 hour shift premium, per diem, etc… |
| A3 = if baghouse addition then 10% else 5% of BM | | $ | 204,000 | Contractor profit and fees |
| **CECC ($) = BM+A1+A2+A3**<br>**CECC ($/kW) =** | | **$** | **4,695,000**<br>**9** | Capital, engineering and construction cost subtotal<br>Capital, engineering and construction cost subtotal per kW |
| B1 = 5% of CECC | | $ | 235,000 | Owners costs including all "home office" costs (owners engineering, management, and procurement activities) |
| B2 = if baghouse addition then 6% else 0% of CECC + B1 | | $ | - | AFUDC<br>For ACI system only: 0% for less than 1 year engineering and construction cycle<br>For additional baghouse: 6% for a 2 year engineering and construction cycle |
| C2 = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent in standard PAC then 2500*A else 0 | | $ | - | One time coal additive royalty fee (as applicable) |
| **TPC ($) = CECC + B1 + B2 + C2**<br>**TPC ($/kW) =** | | **$** | **4,930,000**<br>**10** | Total project cost<br>Total project cost per kW |

## Mercury Control Cost Development Methodology

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <-- User Input |
| Retrofit Factor | B | | 1 | <-- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <-- User Input |
| Type of Coal | D | | Bituminous | <-- User Input |
| Existing FGD System | E | | Wet FGD | <-- User Input |
| Exisitng SCR | F | | ☑ TRUE | <-- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☐ FALSE | <-- User Input |
| Existing PM Control | H | | ESP | <-- User Input |
| Baghouse Addition | J | | Not Added | <-- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <-- User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 516 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 516 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 21.0 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | R | (%) | 0.02 | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <-- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <-- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <-- User Input |
| Bag Cost | V | ($/bag) | 100 | <-- User Input |
| Cage Cost | W | ($/cage) | 30 | <-- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <-- User Input (Labor cost including all benefits) |

### Costs are all based on 2012 dollars

| | | | |
|---|---|---|---|
| **Fixed O&M Cost** | | | |
| FOMO ($/kW yr) = (0 additional operators)*2080*X/(A*1000) | $ | - | Fixed O&M additional operating labor costs |
| FOMM ($/kW yr) = BM/(B*A*1000)*(0.01 for a sorbent system only or 0.005 when a baghouse is added) | $ | 0.08 | Fixed O&M additional maintenance material and labor costs |
| FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM) | $ | 0.00 | Fixed O&M additional administrative labor costs |
| **FOM ($/kW yr) = FOMO + FOMM + FOMA** | **$** | **0.08** | Total Fixed O&M costs |
| **Variable O&M Cost** | | | |
| VOMR ($/MWh) = M*S/(2000*A) | $ | 0.88 | Variable O&M costs for sorbent |
| VOMW ($/MWh) = Q*T/A | $ | 1.26 | Variable O&M costs for waste disposal that includes the sorbent and the fly ash waste as applicable |
| VOMP ($/MWh) =U*R*10 | $ | 0.01 | Variable O&M costs for additional auxiliary power required. |
| VOMB ($/MWh) = if a baghouse is added then G/(E*A*341640)*<br>if(E = 6.0 Air-to-Cloth then (K/3+L/9) else<br>E = 4.0 Air-to-Cloth then (K/5+L/10)) | $ | - | Variable O&M costs for bags and cages. |
| VOMF ($/MWh) = if there is a wet FGD, SCR, and capture is less than 80% then 230/A else 0 | $ | - | Variable O&M costs for wet FGD additive addition |
| VOMA ($/MWh) = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then 0.0298*C/1000 else 0 | $ | - | Variable O&M costs for coal additive addition |
| **VOM ($/MWh) = VOMR + VOMW + VOMB + VOMF + VOMC** | **$** | **2.15** | |

## Mercury Control Cost Development Methodology

### Table 2. Example Complete Cost Estimate for an ACI System with an Existing Baghouse

| | | | | |
|---|---|---|---|---|
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <--- User Input |
| Type of Coal | D | | Bituminous | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | FALSE | <--- User Input |
| Existing PM Control | H | | Baghouse | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 206 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 206 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 20.8 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

## Costs are all based on 2012 dollars

| **Capital Cost Calculation** | | **Example** | | **Comments** |
|---|---|---|---|---|
| Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty | | | | |
| BMC ($) = | 1,600,000*B*(M^0.15) | $ | 3,559,000 | Base sorbent injection module includes all equipment from unloading to injection |
| BMB ($) = | if (J = Not Added then 0, J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600) *B*L^0.81 | $ | - | Base module for an additional PJFF including:<br>Duct work modifications and reinforcement, foundations, structual steel, ID or booster fans, piping, electrical, etc… |
| BMF ($) = | if there is a wet FGD, SCR, and capture is less than 80% then $500,000 else 0 | $ | - | Base module for wet FGD additive addition (as applicable) |
| BMA ($) = | if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then $1,000,000 else 0 | $ | - | Base module for coal additive addition (as applicable) |
| BM ($) = | BMC + BMB + BMF + BMA | $ | 3,559,000 | Total Base module cost including retrofit factor |
| BM ($/KW) = | | | 7 | Base module cost per kW |
| **Total Project Cost** | | | | |
| A1 = if baghouse addition then 10% else 5% of BM | | $ | 178,000 | Engineering and Construction Management costs |
| A2 = if baghouse addition then 10% else 5% of BM | | $ | 178,000 | Labor adjustment for 6 x 10 hour shift premium, per diem, etc… |
| A3 = if baghouse addition then 10% else 5% of BM | | $ | 178,000 | Contractor profit and fees |
| **CECC ($) = BM+A1+A2+A3** | | **$** | **4,093,000** | Capital, engineering and construction cost subtotal |
| **CECC ($/kW) =** | | | **8** | Capital, engineering and construction cost subtotal per kW |
| B1 = 5% of CECC | | $ | 205,000 | Owners costs including all "home office" costs (owners engineering, management, and procurement activities) |
| B2 = if baghouse addition then 6% else 0% of CECC + B1 | | $ | - | AFUDC<br>For ACI system only: 0% for less than 1 year engineering and construction cycle<br>For additional baghouse: 6% for a 2 year engineering and construction cycle |
| C2 = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent in standard PAC then 2500*A else 0 | | $ | - | One time coal additive royalty fee (as applicable) |
| **TPC ($) = CECC + B1 + B2 + C2** | | **$** | **4,298,000** | Total project cost |
| **TPC ($/kW) =** | | | **9** | Total project cost per kW |

# Mercury Control Cost Development Methodology

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <--- User Input |
| Type of Coal | D | | Bituminous | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | ☑ TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☐ FALSE | <--- User Input |
| Existing PM Control | H | | Baghouse | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 206 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 206 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 20.8 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

**Fixed O&M Cost**

| | | | |
|---|---|---|---|
| FOMO ($/kW yr) = (0 additional operators)*2080*X/(A*1000) | $ | - | Fixed O&M additional operating labor costs |
| FOMM ($/kW yr) = BM/(B*A*1000)*(0.01 for a sorbent system only or 0.005 when a baghouse is added) | $ | 0.07 | Fixed O&M additional maintenance material and labor costs |
| FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM) | $ | 0.00 | Fixed O&M additional administrative labor costs |
| **FOM ($/kW yr) = FOMO + FOMM + FOMA** | **$** | **0.07** | Total Fixed O&M costs |

**Variable O&M Cost**

| | | | |
|---|---|---|---|
| VOMR ($/MWh) = M*S/(2000*A) | $ | 0.35 | Variable O&M costs for sorbent |
| VOMW ($/MWh) = Q*T/A | $ | 1.25 | Variable O&M costs for waste disposal that includes the sorbent and the fly ash waste as applicable |
| VOMP ($/MWh) =U*R*10 | $ | 0.01 | Variable O&M costs for additional auxiliary power required. |
| VOMB ($/MWh) = if a baghouse is added then G/(E*A*341640)*<br>if(E = 6.0 Air-to-Cloth then (K/3+L/9) else<br>E = 4.0 Air-to-Cloth then (K/5+L/10)) | $ | - | Variable O&M costs for bags and cages. |
| VOMF ($/MWh) = if there is a wet FGD, SCR, and capture is less than 80% then 230/A else 0 | $ | - | Variable O&M costs for wet FGD additive addition |
| VOMA ($/MWh) = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then 0.0298*C/1000 else 0 | $ | - | Variable O&M costs for coal additive addition |
| **VOM ($/MWh) = VOMR + VOMW + VOMB + VOMF + VOMC** | **$** | **1.61** | |

## Mercury Control Cost Development Methodology

**Table 3. Example Complete Cost Estimate for an ACI System with an Additional Baghouse**

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9800 | <--- User Input |
| Type of Coal | D | | PRB | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | FALSE | <--- User Input |
| Existing PM Control | H | | ESP | <--- User Input |
| Baghouse Addition | J | | 6.0 Air-to-Cloth | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.90E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,960,000 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 235 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 235 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 14.0 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.1 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.62** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

## Costs are all based on 2012 dollars

| Capital Cost Calculation | | Example | Comments |
|---|---|---|---|
| Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty | | | |
| BMC ($) = | 1,600,000*B*(M^0.15) | $ 3,629,000 | Base sorbent injection module includes all equipment from unloading to injection |
| BMB ($) = | if (J = Not Added then 0, J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600) *B*L^0.81 | $ 66,222,000 | Base module for an additional PJFF including: Duct work modifications and reinforcement, foundations, structual steel, ID or booster fans, piping, electrical, etc… |
| BMF ($) = | if there is a wet FGD, SCR, and capture is less than 80% then $500,000 else 0 | $ - | Base module for wet FGD additive addition (as applicable) |
| BMA ($) = | if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then $1,000,000 else 0 | $ 1,000,000 | Base module for coal additive addition (as applicable) |
| BM ($) = | BMC + BMB + BMF + BMA | $ 70,851,000 | Total Base module cost including retrofit factor |
| BM ($/KW) = | | 142 | Base module cost per kW |
| **Total Project Cost** | | | |
| A1 = if baghouse addition then 10% else 5% of BM | | $ 7,085,000 | Engineering and Construction Management costs |
| A2 = if baghouse addition then 10% else 5% of BM | | $ 7,085,000 | Labor adjustment for 6 x 10 hour shift premium, per diem, etc… |
| A3 = if baghouse addition then 10% else 5% of BM | | $ 7,085,000 | Contractor profit and fees |
| **CECC ($) = BM+A1+A2+A3** | | **$ 92,106,000** | Capital, engineering and construction cost subtotal |
| **CECC ($/kW) =** | | **184** | Capital, engineering and construction cost subtotal per kW |
| B1 = 5% of CECC | | $ 4,605,000 | Owners costs including all "home office" costs (owners engineering, management, and procurement activities) |
| B2 = if baghouse addition then 6% else 0% of CECC + B1 | | $ 5,803,000 | AFUDC<br>For ACI system only: 0% for less than 1 year engineering and construction cycle<br>For additional baghouse: 6% for a 2 year engineering and construction cycle |
| C2 = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent in standard PAC then 2500*A else 0 | | $ 1,250,000 | One time coal additive royalty fee (as applicable) |
| **TPC ($) = CECC + B1 + B2 + C2** | | **$ 103,764,000** | Total project cost |
| **TPC ($/kW) =** | | **208** | Total project cost per kW |

## Mercury Control Cost Development Methodology

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9800 | <--- User Input |
| Type of Coal | D | | PRB | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | FALSE | <--- User Input |
| Existing PM Control | H | | ESP | <--- User Input |
| Baghouse Addition | J | | 6.0 Air-to-Cloth | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.90E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,960,000 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 235 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 235 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 14.0 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.1 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.62** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

**Fixed O&M Cost**

| | | | |
|---|---|---|---|
| FOMO ($/kW yr) = (0 additional operators)*2080*X/(A*1000) | $ | - | Fixed O&M additional operating labor costs |
| FOMM ($/kW yr) = BM/(B*A*1000)*(0.01 for a sorbent system only or 0.005 when a baghouse is added) | $ | 0.71 | Fixed O&M additional maintenance material and labor costs |
| FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM) | $ | 0.01 | Fixed O&M additional administrative labor costs |
| **FOM ($/kW yr) = FOMO + FOMM + FOMA** | **$** | **0.72** | Total Fixed O&M costs |

**Variable O&M Cost**

| | | | |
|---|---|---|---|
| VOMR ($/MWh) = M*S/(2000*A) | $ | 0.40 | Variable O&M costs for sorbent |
| VOMW ($/MWh) = Q*T/A | $ | 0.01 | Variable O&M costs for waste disposal that includes the sorbent and the fly ash waste as applicable |
| VOMP ($/MWh) =U*R*10 | $ | 0.37 | Variable O&M costs for additional auxiliary power required. |
| VOMB ($/MWh) = if a baghouse is added then G/(E*A*341640)* if(E = 6.0 Air-to-Cloth then (K/3+L/9) else E = 4.0 Air-to-Cloth then (K/5+L/10)) | $ | 0.07 | Variable O&M costs for bags and cages. |
| VOMF ($/MWh) = if there is a wet FGD, SCR, and capture is less than 80% then 230/A else 0 | $ | - | Variable O&M costs for wet FGD additive addition |
| VOMA ($/MWh) = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then 0.0298*C/1000 else 0 | $ | 0.29 | Variable O&M costs for coal additive addition |
| **VOM ($/MWh) = VOMR + VOMW + VOMB + VOMF + VOMC** | **$** | **1.14** | |

## Mercury Control Cost Development Methodology

### Table 4. Example Complete Cost Estimate for both Additives Systems without Sorbent

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9800 | <--- User Input |
| Type of Coal | D | | PRB | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | ☑ TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☑ TRUE | <--- User Input (Sorbent injection is not required for caputre less than 80%.) |
| Existing PM Control | H | | ESP | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.90E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,960,000 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 0 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 0 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 14.0 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.0 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

## Costs are all based on 2012 dollars

| **Capital Cost Calculation** | | **Example** | | **Comments** |
|---|---|---|---|---|
| Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty | | | | |
| BMC ($) = | 1,600,000*B*(M^0.15) | $ | - | Base sorbent injection module includes all equipment from unloading to injection |
| BMB ($) = | if (J = Not Added then 0, J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600) *B*L^0.81 | $ | - | Base module for an additional PJFF including:<br>Duct work modifications and reinforcement, foundations, structual steel, ID or booster fans, piping, electrical, etc… |
| BMF ($) = | if there is a wet FGD, SCR, and capture is less than 80% then $500,000 else 0 | $ | 500,000 | Base module for wet FGD additive addition (as applicable) |
| BMA ($) = | if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then $1,000,000 else 0 | $ | 1,000,000 | Base module for coal additive addition (as applicable) |
| BM ($) = | BMC + BMB + BMF + BMA | $ | 1,500,000 | Total Base module cost including retrofit factor |
| BM ($/KW) = | | | 3 | Base module cost per kW |
| **Total Project Cost** | | | | |
| A1 = if baghouse addition then 10% else 5% of BM | | $ | 75,000 | Engineering and Construction Management costs |
| A2 = if baghouse addition then 10% else 5% of BM | | $ | 75,000 | Labor adjustment for 6 x 10 hour shift premium, per diem, etc… |
| A3 = if baghouse addition then 10% else 5% of BM | | $ | 75,000 | Contractor profit and fees |
| **CECC ($) = BM+A1+A2+A3** | | **$** | **1,725,000** | Capital, engineering and construction cost subtotal |
| **CECC ($/kW) =** | | | **3** | Capital, engineering and construction cost subtotal per kW |
| B1 = 5% of CECC | | $ | 86,000 | Owners costs including all "home office" costs (owners engineering, management, and procurement activities) |
| B2 = if baghouse addition then 6% else 0% of CECC + B1 | | $ | - | AFUDC<br>For ACI system only: 0% for less than 1 year engineering and construction cycle<br>For additional baghouse: 6% for a 2 year engineering and construction cycle |
| C1 = 15% of CECC + B1 | | $ | - | EPC fees of 15% |
| C2 = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent in standard PAC then 2500*A else 0 | | $ | 1,250,000 | One time coal additive royalty fee (as applicable) |
| **TPC ($) = CECC + B1 + B2 + C2** | | **$** | **3,061,000** | Total project cost |
| **TPC ($/kW) =** | | | **6** | Total project cost per kW |

## Mercury Control Cost Development Methodology

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9800 | <--- User Input |
| Type of Coal | D | | PRB | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | ☑ TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☑ TRUE | <--- User Input (Sorbent injection is not required for caputre less than 80%.) |
| Existing PM Control | H | | ESP | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Standard PAC | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.90E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,960,000 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 0 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 0 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 14.0 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.0 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 1700 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

**Fixed O&M Cost**

| | | | |
|---|---|---|---|
| FOMO ($/kW yr) = (0 additional operators)*2080*X/(A*1000) | $ | - | Fixed O&M additional operating labor costs |
| FOMM ($/kW yr) = BM/(B*A*1000)*(0.01 for a sorbent system only or 0.005 when a baghouse is added) | $ | 0.03 | Fixed O&M additional maintenance material and labor costs |
| FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM) | $ | 0.00 | Fixed O&M additional administrative labor costs |
| **FOM ($/kW yr) = FOMO + FOMM + FOMA** | **$** | **0.03** | Total Fixed O&M costs |

**Variable O&M Cost**

| | | | |
|---|---|---|---|
| VOMR ($/MWh) = M*S/(2000*A) | $ | - | Variable O&M costs for sorbent |
| VOMW ($/MWh) = Q*T/A | $ | - | Variable O&M costs for waste disposal that includes the sorbent and the fly ash waste as applicable |
| VOMP ($/MWh) =U*R*10 | $ | 0.01 | Variable O&M costs for additional auxiliary power required. |
| VOMB ($/MWh) = if a baghouse is added then G/(E*A*341640)*<br>if(E = 6.0 Air-to-Cloth then (K/3+L/9) else<br>E = 4.0 Air-to-Cloth then (K/5+L/10)) | $ | - | Variable O&M costs for bags and cages. |
| VOMF ($/MWh) = if there is a wet FGD, SCR, and capture is less than 80% then 230/A else 0 | $ | 0.46 | Variable O&M costs for wet FGD additive addition |
| VOMA ($/MWh) = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then 0.0298*C/1000 else 0 | $ | 0.29 | Variable O&M costs for coal additive addition |
| **VOM ($/MWh) = VOMR + VOMW + VOMB + VOMF + VOMC** | **$** | **0.76** | |

## Mercury Control Cost Development Methodology

**Table 5. Example Complete Cost Estimate for a Non-Carbon Sorbent System with an Existing Baghouse**

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <--- User Input |
| Type of Coal | D | | Bituminous | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | FALSE | <--- User Input |
| Existing PM Control | H | | Baghouse | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Non-Carbon Sorb | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 361 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 361 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.2 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 2500 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

## Costs are all based on 2012 dollars

| **Capital Cost Calculation** | | **Example** | **Comments** |
|---|---|---|---|
| Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty | | | |
| BMC ($) = | 1,600,000*B*(M^0.15) | $ 3,870,000 | Base sorbent injection module includes all equipment from unloading to injection |
| BMB ($) = | if (J = Not Added then 0, J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600) *B*L^0.81 | $ - | Base module for an additional PJFF including:<br>Duct work modifications and reinforcement, foundations, structual steel, ID or booster fans, piping, electrical, etc… |
| BMF ($) = | if there is a wet FGD, SCR, and capture is less than 80% then $500,000 else 0 | $ - | Base module for wet FGD additive addition (as applicable) |
| BMA ($) = | if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then $1,000,000 else 0 | $ - | Base module for coal additive addition (as applicable) |
| BM ($) = | BMC + BMB + BMF + BMA | $ 3,870,000 | Total Base module cost including retrofit factor |
| BM ($/KW) = | | 8 | Base module cost per kW |
| **Total Project Cost** | | | |
| A1 = if baghouse addition then 10% else 5% of BM | | $ 194,000 | Engineering and Construction Management costs |
| A2 = if baghouse addition then 10% else 5% of BM | | $ 194,000 | Labor adjustment for 6 x 10 hour shift premium, per diem, etc… |
| A3 = if baghouse addition then 10% else 5% of BM | | $ 194,000 | Contractor profit and fees |
| **CECC ($) = BM+A1+A2+A3** | | **$ 4,452,000** | Capital, engineering and construction cost subtotal |
| **CECC ($/kW) =** | | **9** | Capital, engineering and construction cost subtotal per kW |
| B1 = 5% of CECC | | $ 223,000 | Owners costs including all "home office" costs (owners engineering, management, and procurement activities) |
| B2 = if baghouse addition then 6% else 0% of CECC + B1 | | $ - | AFUDC<br>For ACI system only: 0% for less than 1 year engineering and construction cycle<br>For additional baghouse: 6% for a 2 year engineering and construction cycle |
| C1 = 15% of CECC + B1 | | $ - | EPC fees of 15% |
| C2 = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent in standard PAC then 2500*A else 0 | | $ - | One time coal additive royalty fee (as applicable) |
| **TPC ($) = CECC + B1 + B2 + C2** | | **$ 4,675,000** | Total project cost |
| **TPC ($/kW) =** | | **9** | Total project cost per kW |

# Mercury Control Cost Development Methodology

| Variable | Designation | Units | Value | Calculation |
|---|---|---|---|---|
| Unit Size (Gross) | A | (MW) | 500 | <--- User Input |
| Retrofit Factor | B | | 1 | <--- User Input (An "average" retrofit has a factor = 1.0) |
| Gross Heat Rate | C | (Btu/kWh) | 9500 | <--- User Input |
| Type of Coal | D | | Bituminous | <--- User Input |
| Existing FGD System | E | | Wet FGD | <--- User Input |
| Exisitng SCR | F | | ☑ TRUE | <--- User Input (Sorbent injection may not be required. Co-benefit of SCR and FGD system should achieve 80% removal.) |
| Removal Less Than 80%? | G | | ☐ FALSE | <--- User Input |
| Existing PM Control | H | | Baghouse | <--- User Input |
| Baghouse Addition | J | | Not Added | <--- User Input for retrofit of an additional baghouse after the existing PM control. |
| Type of Sorbent | Y | | Non-Carbon Sorb | <--- User Input |
| Heat Input | K | (Btu/hr) | 4.75E+09 | = A*C*1000 |
| Flue Gas Rate | L | (acfm) | 1,719,500 | Downstream of an air preheater<br>For Bituminous Coal = A*C*0.362<br>For PRB Coal = A*C*0.400<br>For Lignite Coal = A*C*0.435 |
| Sorbent Feed Rate | M | (lb/hr) | 361 | = If Existing FGD, SCR, and if mercury removal is less than 80% then 0<br>else L*60/1000000* 2 lb/MMacf for baghouse applications with carbon<br>* 3.5 lb/MMacf for baghouse applications with non-carbn sorbent<br>* 5 lb/MMacf for ESP applications with carbon<br>Not applicable for ESP applications with non-carbn sorbent<br>(Flow determined downstream of an air preheater) |
| Sorbent Waste Rate | N | (lb/hr) | 361 | = M |
| Fly Ash Waste Rate | P | (ton/hr) | 20.7 | (A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV)<br>For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11000<br>For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8400<br>For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7200 |
| Total Waste Rate | Q | (ton/hr) | 0.2 | Based on no beneficial uses for fly ash with activated carbon without an additional baghouse. The use of a the non-carbon sorbent should maintain the current fly ash disposal method. Therefore, only the sorbent waste rate is included for the non-carbon sorbent.<br>if (J = True or G = True or Non-carbon sorbent then 0 else P) + N/2000 |
| **Aux Power**<br>**Include in VOM?** ☑ | **R** | **(%)** | **0.02** | if J = True then 0.6 else 0 + (0.02) |
| Sorbent Cost - Delivered | S | ($/ton) | 2500 | <--- User Input (Standard PAC = $1700, Halogenated PAC = $2100, Non-Carbon Sorbent = $2500) |
| Waste Disposal Cost | T | ($/ton) | 30 | <--- User Input |
| Aux Power Cost | U | ($/kWh) | 0.06 | <--- User Input |
| Bag Cost | V | ($/bag) | 100 | <--- User Input |
| Cage Cost | W | ($/cage) | 30 | <--- User Input |
| Operating Labor Rate | X | ($/hr) | 60 | <--- User Input (Labor cost including all benefits) |

**Fixed O&M Cost**

| | | | |
|---|---|---|---|
| FOMO ($/kW yr) = (0 additional operators)*2080*X/(A*1000) | $ | - | Fixed O&M additional operating labor costs |
| FOMM ($/kW yr) = BM/(B*A*1000)*(0.01 for a sorbent system only or 0.005 when a baghouse is added) | $ | 0.08 | Fixed O&M additional maintenance material and labor costs |
| FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM) | $ | 0.00 | Fixed O&M additional administrative labor costs |
| **FOM ($/kW yr) = FOMO + FOMM + FOMA** | **$** | **0.08** | Total Fixed O&M costs |

**Variable O&M Cost**

| | | | |
|---|---|---|---|
| VOMR ($/MWh) = M*S/(2000*A) | $ | 0.90 | Variable O&M costs for sorbent |
| VOMW ($/MWh) = Q*T/A | $ | 0.01 | Variable O&M costs for waste disposal that includes the sorbent and the fly ash waste as applicable |
| VOMP ($/MWh) =U*R*10 | $ | 0.01 | Variable O&M costs for additional auxiliary power required. |
| VOMB ($/MWh) = if a baghouse is added then G/(E*A*341640)*<br>if(E = 6.0 Air-to-Cloth then (K/3+L/9) else<br>E = 4.0 Air-to-Cloth then (K/5+L/10)) | $ | - | Variable O&M costs for bags and cages. |
| VOMF ($/MWh) = if there is a wet FGD, SCR, and capture is less than 80% then 230/A else 0 | $ | - | Variable O&M costs for wet FGD additive addition |
| VOMA ($/MWh) = if there is an FGD, SCR, the coal is PRB or Lignite, and capture is less than 80% or the coal is PRB or Lignite and the sorbent is standard PAC then 0.0298*C/1000 else 0 | $ | - | Variable O&M costs for coal additive addition |
| **VOM ($/MWh) = VOMR + VOMW + VOMB + VOMF + VOMC** | **$** | **0.93** | |