Appendix 5-9b

The sorbet costs included in the Particulate Control Cost Development Methodology (April 2017) were for the newly added SO3 mitigation system assumed for contributions to condensable PM (and thereby PM2.5). The model can be used for a baghouse only; essentially the capital cost calculation for BMC (the sorbent system) would be zero, and all variable O&M cost parameters include annotation for if only considering a baghouse vs. the baghouse with SO3 mitigation. To help expedite this, please see the examples below showing the baghouse only approach.

Example of a Complete Cost Estimate for a 4.0 A/C PJFF Installation

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
SO2 Rate	E	(lb/MMBtu)	2	<--- User Input
Existing FGD System	F		Wet FGD	<--- User Input (Removal by Wet FGD may not meet future PM2.5 limits)
Existing SCR	G	☑	TRUE	<--- User Input
Existing PM Control	H		ESP	<--- User Input
Baghouse Air-to-Cloth Ratio	J		4.0 Air-to-Cloth	<--- User Input for retrofit of new baghouse for PM control.
Heat Input	K	(Btu/hr)	4.75E+09	= A*C*1000
Flue Gas Rate	L	(acfm)	1,719,500	Downstream of an air preheater For Bituminous Coal = A*C*0.362 For PRB Coal = A*C*0.400 For Lignite Coal = A*C*0.435
SO2 Feed Rate	M	(lb/hr)	9,500	= E*K/1,000,000
SO2 to SO3 Oxidation	N		0.02	If SCR and PRB then 3% If no SCR and PRB then 0.5% If SCR and Not PRB then 2% If no SCR and Not PRB then 1%
SO3 Mitigation Sorbent Type	P		No SO3 Mitigation	<--- User Input
Sorbent Injection Location	Q		No SO3 Mitigation	<--- User Input
Fly Ash Waste Rate	W	(ton/hr)	20.7	(A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV) For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11,000 For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8,400 For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7,200
Total Waste Rate	X	(ton/hr)	20.7	Baghouse only = W Baghouse + SO3 Mitigation = W + V/2000 Polishing Baghouse + SO3 Mitigation = V/2000
Aux Power Include in VOM? ☑	Y	(%)	0.60	Baghouse only = 0.6 Baghouse + SO3 Mitigation = 0.6 + U*0.009/A
				<--- User Input (Trona = $170, Hydrated Lime = $150)
Waste Disposal Cost	AA	($/ton)	50	<--- User Input (Disposal cost with fly ash = $50. Without fly ash, the sorbent waste alone will be more dificult to dispose = $100)
Aux Power Cost	AB	($/kWh)	0.06	<--- User Input
Bag Cost	AC	($/bag)	100	<--- User Input
Cage Cost	AD	($/cage)	30	<--- User Input
Operating Labor Rate	AE	($/hr)	60	<--- User Input (Labor cost including all benefits)

Costs are all based on 2016 dollars

	Example	Comments
Capital Cost Calculation		
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty		
BMB ($) = if(J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600)*B*L^0.81	$ 67,426,000	Base module for an additional baghouse including: ID or booster fans, piping, ductwork, etc…
BMC ($) = 9,000,000*B*((U/2000)^0.284)	$ -	Base module for unmilled sorbent includes all equipment from unloading to injection, including dehumification system, as applicable
BM ($) = BMB + BMC	$ 67,426,000	Total Base module cost including retrofit factor
BM ($/KW) =	135	Base module cost per kW
Total Project Cost		
A1 = 10% of BM	$ 6,743,000	Engineering and Construction Management costs
A2 = 10% of BM	$ 6,743,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 10% of BM	$ 6,743,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3	**$ 87,655,000**	Capital, engineering and construction cost subtotal
CECC ($/kW) =	**175**	Capital, engineering and construction cost subtotal per kW
B1 = 5% of CECC	$ 4,383,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
B2 = 6% of (CECC + B1)	$ 5,522,000	AFUDC for baghouse: 6% for a 2 year engineering and construction cycle
TPC ($) = CECC + B1 + B2	**$ 97,560,000**	Total project cost
TPC ($/kW) =	**195**	Total project cost per kW
Fixed O&M Cost		
FOMO ($/kW yr) = if(baghouse only = 0 additional operators, baghouse and SO3 mitigation = 0.5 additional operators)*2080*AE/(A*1000)	$ -	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = BM*0.005/(B*A*1000)	$ 0.67	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 ($/kW yr) = FOMO + FOMM + FOMA	**$ 0.68**	Total Fixed O&M costs
Variable O&M Cost		
VOMB ($/MWh) = L/(J*A*341640)*if(J = 6.0 Air-to-Cloth then ((AC)/3+(AD)/9) else J = 4.0 Air-to-Cloth then ((AC)/5+(AD)/10))	$ 0.06	Variable O&M costs for bags and cages.
VOMP ($/MWh) =Y*(AB)*10	$ 0.36	Variable O&M costs for additional auxiliary power required.
VOMR ($/MWh) = U*Z/(2000*A)	$ -	Variable O&M costs for sorbent, as applicable
VOMW ($/MWh) = X*(AA)/A	$ 2.07	Variable O&M costs for waste disposal that includes fly ash and sorbent waste, as applicable
VOM ($/MWh) = VOMP + VOMB + VOMR + VOMW	**$ 2.49**	

Example of a Complete Cost Estimate for a 6.0 A/C PJFF Installation

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
SO2 Rate	E	(lb/MMBtu)	2	<--- User Input
Existing FGD System	F		Wet FGD	<--- User Input (Removal by Wet FGD may not meet future PM2.5 limits)
Existing SCR	G	☑	TRUE	<--- User Input
Existing PM Control	H		ESP	<--- User Input
Baghouse Air-to-Cloth Ratio	J		6.0 Air-to-Cloth	<--- User Input for retrofit of an additional baghouse after the existing PM control.
Heat Input	K	(Btu/hr)	4.75E+09	= A*C*1000
Flue Gas Rate	L	(acfm)	1,719,500	Downstream of an air preheater For Bituminous Coal = A*C*0.362 For PRB Coal = A*C*0.400 For Lignite Coal = A*C*0.435
SO2 Feed Rate	M	(lb/hr)	9,500	= E*K/1,000,000
SO2 to SO3 Oxidation	N		0.02	If SCR and PRB then 3% If no SCR and PRB then 0.5% If SCR and Not PRB then 2% If no SCR and Not PRB then 1%
SO3 Mitigation Sorbent Type	P		No SO3 Mitigation	<--- User Input
Sorbent Injection Location	Q		No SO3 Mitigation	<--- User Input
Fly Ash Waste Rate	W	(ton/hr)	20.7	(A*C)* Ash in Coal*(1-Boiler Ash Removal)/(2*HHV) For Bituminous Coal: Ash in Coal = 0.12; Boiler Ash Removal = 0.2; HHV = 11,000 For PRB Coal: Ash in Coal = 0.06; Boiler Ash Removal = 0.2; HHV = 8,400 For Lignite Coal: Ash in Coal = 0.08; Boiler Ash Removal = 0.2; HHV = 7,200
Total Waste Rate	X	(ton/hr)	20.7	Baghouse only = W Baghouse + SO3 Mitigation = W + V/2000 Polishing Baghouse + SO3 Mitigation = V/2000
Aux Power Include in VOM? ☑	Y	(%)	0.60	Baghouse only = 0.6 Baghouse + SO3 Mitigation = 0.6 + U*0.009/A
				<--- User Input (Trona = $170, Hydrated Lime = $150)
Waste Disposal Cost	AA	($/ton)	50	<--- User Input (Disposal cost with fly ash = $50. Without fly ash, the sorbent waste alone will be more dificult to dispose = $100)
Aux Power Cost	AB	($/kWh)	0.06	<--- User Input
Bag Cost	AC	($/bag)	100	<--- User Input
Cage Cost	AD	($/cage)	30	<--- User Input
Operating Labor Rate	AE	($/hr)	60	<--- User Input (Labor cost including all benefits)

Costs are all based on 2016 dollars

		Example	Comments
Capital Cost Calculation			
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty			
BMB ($) =	if(J = 6.0 Air-to-Cloth then 530, J = 4.0 Air-to-Cloth then 600)*B*L^0.81	$ 59,560,000	Base module for an additional baghouse including: ID or booster fans, piping, ductwork, etc…
BMC ($) =	9,000,000*B*((U/2000)^0.284)	$ -	Base module for unmilled sorbent includes all equipment from unloading to injection, including dehumification system, as applicable
BM ($) =	BMB + BMC	$ 59,560,000	Total Base module cost including retrofit factor
BM ($/KW) =		119	Base module cost per kW
Total Project Cost			
A1 = 10% of BM		$ 5,956,000	Engineering and Construction Management costs
A2 = 10% of BM		$ 5,956,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 10% of BM		$ 5,956,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3		**$ 77,428,000**	Capital, engineering and construction cost subtotal
CECC ($/kW) =		**155**	Capital, engineering and construction cost subtotal per kW
B1 = 5% of CECC		$ 3,871,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
B2 = 6% of (CECC + B1)		$ 4,878,000	AFUDC for baghouse: 6% for a 2 year engineering and construction cycle
TPC ($) = CECC + B1 + B2		**$ 86,177,000**	Total project cost
TPC ($/kW) =		**172**	Total project cost per kW
Fixed O&M Cost			
FOMO ($/kW yr) =	if(baghouse only = 0 additional operators, baghouse and SO3 mitigation = 0.5 additional operators)*2080*AE/(A*1000)	$ -	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = BM*0.005/(B*A*1000)		$ 0.60	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 ($/kW yr) = FOMO + FOMM + FOMA		**$ 0.60**	Total Fixed O&M costs
Variable O&M Cost			
VOMB ($/MWh) = L/(J*A*341640)*if(J = 6.0 Air-to-Cloth then ((AC)/3+(AD)/9) else J = 4.0 Air-to-Cloth then ((AC)/5+(AD)/10))		$ 0.06	Variable O&M costs for bags and cages.
VOMP ($/MWh) =Y*(AB)*10		$ 0.36	Variable O&M costs for additional auxiliary power required.
VOMR ($/MWh) = U*Z/(2000*A)		$ -	Variable O&M costs for sorbent, as applicable
VOMW ($/MWh) = X*(AA)/A		$ 2.07	Variable O&M costs for waste disposal that includes fly ash and sorbent waste, as applicable
VOM ($/MWh) = VOMP + VOMB + VOMR + VOMW		**$ 2.50**	