APPENDIX I

Direct PM2.5 Emission Control Option Analysis for Boilers and Steam Generators

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Direct $PM_{2.5}$ Emission Control Option Analysis for Boilers and Steam Generators

I. Types of Permitted Natural Gas-Fired Equipment and their Exhaust Characteristics

The San Joaquin Valley has numerous permitted boilers and steam generators serving diverse types of operations. A detailed characterization of particulate matter (PM) emissions from natural gas (NG)-fired boilers and steam generators is provided in AP-42 Section 1.4. Assumptions adopted from this guidance include:

- PM results from incomplete combustion of gaseous fuel.
- All PM is less than 1 micron in size, therefore, all PM may be considered $PM_{2.5}$.
- 25% of total PM is filterable at the exhaust temperature. 75% of PM is condensable and forms solid PM upon cooling of the exhaust gas as it enters into the atmosphere.

The District has compiled a survey of PM_{10} source tests performed on permitted NG-fired boilers and steam generators. Based on this survey, it has been concluded that the PM emission factor listed in Section 1.4 of AP-42 greatly overestimates the PM emissions from NG-fired boilers and steam generators permitted in the San Joaquin Valley. Therefore, the District's practice is to use an emission factor of 0.003 lb-PM_{10}/MMBtu, which is based on the surveyed source test data with a conservative margin of compliance. As discussed above, since all of the PM is less than 1 micron in size, this emission factor is equivalent to 0.003 lb-$PM_{2.5}$/MMBtu.

Exhaust characteristics of representative NG-fired boilers and steam generators are presented in the Table 1 below.

Table 1: Representative Exhaust Characteristics

Equipment	Flow (cfm)[a]	Exhaust Temp (°F)	$PM_{2.5}$ Concentration (gr/ft^3)
NG 20 MMBtu Boiler with ultra-low NOx burner	5,765	400	0.002
NG 50 MMBtu Boiler with ultra-low NOx burner and economizer	10,221	150	0.002
NG 62.5 MMBtu Steam Generator with ultra-low NOx burner	14,872	250	0.002

Exhaust flow rate may be calculated based on fuel heat input, F-Factor, and temperature. Similarly, the quantity of PM emissions is proportional to fuel heat input. Therefore, the concentration of PM in the exhaust stream is determined by exhaust temperature and emission

[a] Calculated per 40 CFR part 60, Appendix A, Method 19. Heating value = 1,050 MMBtu/MMscf, F-Factor 10,610 Wscf/MMBtu.

factor. When converted to standard temperature the exhaust PM concentration becomes independent of heat input rating. As such, NG-fired equipment is expected to have an exhaust concentration of 0.002 gr/scf.

II. Potential Control Technologies for Direct Control of $PM_{2.5}$ Emissions

Baghouse (Pulse Jet[1]/Reverse Air[2], Ceramic Dust collector[3])

Baghouses force exhaust through filters which capture PM by impingement. Filter media may be cloth/paper bags, pleated cloth in cartridge form, or even packed ceramic media within cages. Per EPA fact sheets for this technology, Cloth/paper filters can only control filterable PM. Per manufacturer data, ceramic media can only provide limited control (≤20%) of condensable PM.

Wet[4]/Dry[5] ESP

Electro-Static Precipitators (ESP) use ionized gas and/or electromagnetic field to impart static charge to particles in the exhaust stream which are then attracted to collection plates held at high voltage. To clean the collection plates, dry ESP use mechanical or acoustical methods while wet ESP uses wash liquid. Per EPA fact sheets for this technology, a dry ESP can only control filterable PM and can have difficulty collecting particles with an aerodynamic diameter of 0.1 to 1 micron. Since all of the PM from NG-fuel combustion is assumed to be less than 1 micron in size, the $PM_{2.5}$ control efficiency of a dry ESP is assumed to be 90%.

Venturi Scrubber[6]

Venturi scrubbers introduce an atomized liquid into the exhaust stream upon which PM agglomerates. The liquid mist is subsequently removed by cyclonic separator and/or mist eliminator. Venturi Scrubbers require high differential pressure (20 to 24 inches water column) which may require additional fans.

Table 2: Typical Applications of Control Technologies

Control Technology	Recommended Inlet Loading (gr-$PM_{2.5}$/ft^3)	Inlet Temp (°F)	$PM_{2.5}$ Control Efficiency
Baghouse Cloth/Paper Filter	0.5 – 10	<500	99% of filterable, 0% of condensable
Baghouse Ceramic Filter	0.5 – 10	<800	99% of filterable, 20% of condensable
Wet ESP	0.5 – 5	<200	98% of total
Dry ESP	0.5 – 5	<500	90% of filterable, 0% of condensable
Venturi/wet Scrubber	0.1 – 50	<750	99% of total

As shown in the table above, the recommended inlet $PM_{2.5}$ loading concentrations where these control technologies are applied are orders of magnitude above the typical exhaust $PM_{2.5}$ concentrations produced by NG-fired boilers and steam generators. As the control device must be sized to accommodate the airflow, these devices must be substantially oversized for the quantity of PM they will control. All of these control technologies are able to provide good control efficiency of filterable PM. However, since the majority of total $PM_{2.5}$ from NG boilers and steam generators is condensable $PM_{2.5}$, baghouses with cloth/paper/ceramic filter media and dry ESPs are not well suited to control $PM_{2.5}$ emissions from NG-fired boilers and steam generators because these emission control technologies have minimal to no ability to control condensable $PM_{2.5}$ emissions.

Nonetheless, cost analyses for all of these control technologies listed in Table 2 above is presented in the following section.

III. Cost Analysis

Since the cost to deploy these technologies on a 50 MMBtu/hr boiler is similar to that of a 62.5 MMBtu/hr steam generator, a cost analysis is performed for each control technology for units at two heat input sizes: 20 MMBtu/hr and 62.5 MMBtu/hr. Purchased equipment costs were provided by equipment vendors. Detailed cost analyses units are included in Appendix A and summarized in Table 3, below.

Table 3: PM2.5 Reduction Cost Effectiveness for NG-Fired Boilers and Steam Generators

Control Technology	Cost Effectiveness ($/ton)	
	20 MMBtu/hr	62.5 MMBtu/hr
Baghouse - Fabric Filter	$1,850,704	$811,478
Baghouse - Ceramic Filter	$1,145,674	$506,243
Wet ESP	$1,777,505	$724,566
Dry ESP	$6,783,207	$2,363,826
Venturi/wet Scrubber	$1,042,138	$494,482

The cost effectiveness values in Table 3 above are based on assumed full time (8,760 hr/yr) operation at full capacity, which results in the largest possible $PM_{2.5}$ emission reductions. In reality, boilers and steam generators typically do not operate 8,760 hr/yr. Reduction in operational hours would reduce $PM_{2.5}$ emissions proportionally. Since the design capacity of these control devices must be suited to maximum flow, reductions in operational time would not reduce purchase and operational costs of the control device to the same extent. Therefore, the cost effectiveness values presented herein represent a lower limit, and the true cost of reductions are expected to be higher.

IV. Conclusion

As discussed in Section III, the typical exhaust $PM_{2.5}$ concentration from NG-fired boilers and steam generators is significantly below the recommended range of inlet loading concentrations for all of the $PM_{2.5}$ emission control technologies assessed. Further, with the exception of wet ESP and Venturi Scrubbers, these control technologies offer poor control of condensable $PM_{2.5}$ and therefore poor control of total $PM_{2.5}$ emissions from NG-fired boilers and steam generators.

Furthermore, this analysis shows that the cost of direct $PM_{2.5}$ control on NG-fired boilers and steam generators with these technologies ranges between $494,482 and $6,783,207 per ton of $PM_{2.5}$ emissions reduced.

Therefore, use of these emission control technologies to control direct $PM_{2.5}$ emissions from NG-fired boilers and steam generators is not cost effective.

Appendix A
Cost Analyses of Control Technologies Applied to NG-Fired Boilers/Steam Generators

20 MMBtu/hr NG-Fired Boiler Controlled by a Fabric Filter Baghouse

Boiler Size	**20**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Western Pneumatics (7,300 acfm)	$100,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$5,000.00
C	Sales Tax	8.25% PEC	$8,250.00
D	Direct Installation Costs	25% PEC	$25,000.00
E	Total Direct Capital Costs	A+B+C+D	$138,250.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$5,000.00
G	Engineering	10% PEC	$10,000.00
H	Process Contingency	5% PEC	$5,000.00
I	Total Indirect Capital Costs	F+G+H	$20,000.00
J	Project Contingency	20% PEC	$20,000.00
K	Total Capital Costs	E+I+J	$178,250.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$21,924.75
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$10,196.00
R	Total Direct Annual Costs	M+N+O+P+Q	$54,680.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$2,000.00
U	Insurance	0.01 x PEC	$1,000.00
V	Property Tax	0.01 x PEC	$1,000.00
W	Capital Recovery	0.13 x PEC	$13,000.00
X	Total Indirect Annual Costs	S+T+U+V+W	$43,690.63
Total Annualized Cost		L+R+X	**$120,295.76**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	526
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	131
AB	PM10 Captured by Baghouse (lb/year)	99% control of filterable	130
	PM10 Captured (tons/year)	AB/2000	**0.065**
	Cost Effectiveness ($/ton)	**$1,850,704.00**	

62.5 MMBtu/hr NG-Fired Boiler Controlled by a Fabric Filter Baghouse

Boiler Size	**62.5**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Western Pneumatics (17,400 acfm)	$180,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$9,000.00
C	Sales Tax	8.25% PEC	$14,850.00
D	Direct Installation Costs	25% PEC	$45,000.00
E	Total Direct Capital Costs	A+B+C+D	$248,850.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$9,000.00
G	Engineering	10% PEC	$18,000.00
H	Process Contingency	5% PEC	$9,000.00
I	Total Indirect Capital Costs	F+G+H	$36,000.00
J	Project Contingency	20% PEC	$36,000.00
K	Total Capital Costs	E+I+J	$320,850.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$39,464.55
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$24,302.00
R	Total Direct Annual Costs	M+N+O+P+Q	$68,786.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$3,600.00
U	Insurance	0.01 x PEC	$1,800.00
V	Property Tax	0.01 x PEC	$1,800.00
W	Capital Recovery	0.13 x PEC	$23,400.00
X	Total Indirect Annual Costs	S+T+U+V+W	$57,290.63
Total Annualized Cost		L+R+X	**$165,541.56**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	1,643
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	411
AB	PM10 Captured by Baghouse (lb/year)	99% control of filterable	407
	PM10 Captured (tons/year)	AB/2000	**0.204**
	Cost Effectiveness ($/ton)	**$811,478.24**	

20 MMBtu/hr NG-Fired Boiler Controlled by a Ceramic Filter Baghouse

Boiler Size	**20**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Western Pneumatics (7,300 acfm)	$100,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$5,000.00
C	Sales Tax	8.25% PEC	$8,250.00
D	Direct Installation Costs	25% PEC	$25,000.00
E	Total Direct Capital Costs	A+B+C+D	$138,250.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$5,000.00
G	Engineering	10% PEC	$10,000.00
H	Process Contingency	5% PEC	$5,000.00
I	Total Indirect Capital Costs	F+G+H	$20,000.00
J	Project Contingency	20% PEC	$20,000.00
K	Total Capital Costs	E+I+J	$178,250.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$21,924.75
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$10,196.00
R	Total Direct Annual Costs	M+N+O+P+Q	$54,680.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$2,000.00
U	Insurance	0.01 x PEC	$1,000.00
V	Property Tax	0.01 x PEC	$1,000.00
W	Capital Recovery	0.13 x PEC	$13,000.00
X	Total Indirect Annual Costs	S+T+U+V+W	$43,690.63
Total Annualized Cost		L+R+X	**$120,295.76**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	526
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	131
AA	Condensable PM10 (lb/year)	Y-Z	395
AB	PM10 Captured by Baghouse (lb/year)	0.99*Z+0.2*AA	209
	PM10 Captured (tons/year)	AB/2000	**0.105**
	Cost Effectiveness ($/ton)	**$1,145,673.90**	

62.5 MMBtu/hr NG-Fired Boiler Controlled by a Ceramic Filter Baghouse

Boiler Size	**62.5**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Western Pneumatics (17,400 acfm)	$180,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$9,000.00
C	Sales Tax	8.25% PEC	$14,850.00
D	Direct Installation Costs	25% PEC	$45,000.00
E	Total Direct Capital Costs	A+B+C+D	$248,850.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$9,000.00
G	Engineering	10% PEC	$18,000.00
H	Process Contingency	5% PEC	$9,000.00
I	Total Indirect Capital Costs	F+G+H	$36,000.00
J	Project Contingency	20% PEC	$36,000.00
K	Total Capital Costs	E+I+J	$320,850.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$39,464.55
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$24,302.00
R	Total Direct Annual Costs	M+N+O+P+Q	$68,786.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$3,600.00
U	Insurance	0.01 x PEC	$1,800.00
V	Property Tax	0.01 x PEC	$1,800.00
W	Capital Recovery	0.13 x PEC	$23,400.00
X	Total Indirect Annual Costs	S+T+U+V+W	$57,290.63
Total Annualized Cost		L+R+X	**$165,541.56**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	1,643
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	411
AA	Condensable PM10 (lb/year)	Y-Z	1,232
AB	PM10 Captured by Baghouse (lb/year)	0.99*Z+0.2*AA	653
	PM10 Captured (tons/year)	AB/2000	**0.327**
	Cost Effectiveness ($/ton)	**$506,243.30**	

20 MMBtu/hr NG-Fired Boiler Controlled by a Wet ESP

Boiler Size	**20**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			

	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Envitech (7,000 acfm quencher & ESP)	$900,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$45,000.00
C	Sales Tax	8.25% PEC	$74,250.00
D	Direct Installation Costs	25% PEC	$225,000.00
E	Total Direct Capital Costs	A+B+C+D	$1,244,250.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$45,000.00
G	Engineering	10% PEC	$90,000.00
H	Process Contingency	5% PEC	$45,000.00
I	Total Indirect Capital Costs	F+G+H	$180,000.00
J	Project Contingency	20% PEC	$180,000.00
K	Total Capital Costs	E+I+J	$1,604,250.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$197,322.75
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	Envitech 25kW; 0.1694/kw-hr	$37,098.60
R	Total Direct Annual Costs	M+N+O+P+Q	$81,582.98
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$18,000.00
U	Insurance	0.01 x PEC	$9,000.00
V	Property Tax	0.01 x PEC	$9,000.00
W	Capital Recovery	0.13 x PEC	$117,000.00
X	Total Indirect Annual Costs	S+T+U+V+W	$179,690.63
Total Annualized Cost		L+R+X	**$458,596.36**

	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	526
AB	PM10 Captured by ESP (lb/year)	98% control efficiency, Z*0.98	515
	PM10 Captured (tons/year)	AB/2000	**0.258**

	Cost Effectiveness ($/ton)	**$1,777,505.27**

62.5 MMBtu/hr NG-Fired Boiler Controlled by a Wet ESP

Boiler Size	**62.5**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Envitech (17,000 acfm quencher & ESP)	$1,125,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$56,250.00
C	Sales Tax	8.25% PEC	$92,812.50
D	Direct Installation Costs	25% PEC	$281,250.00
E	Total Direct Capital Costs	A+B+C+D	$1,555,312.50
	Indirect Capital Costs		
F	Facilities	5% PEC	$56,250.00
G	Engineering	10% PEC	$112,500.00
H	Process Contingency	5% PEC	$56,250.00
I	Total Indirect Capital Costs	F+G+H	$225,000.00
J	Project Contingency	20% PEC	$225,000.00
K	Total Capital Costs	E+I+J	$2,005,312.50
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$246,653.44
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	Envitech 50kW; 0.1694/kw-hr	$74,197.20
R	Total Direct Annual Costs	M+N+O+P+Q	$118,681.58
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$22,500.00
U	Insurance	0.01 x PEC	$11,250.00
V	Property Tax	0.01 x PEC	$11,250.00
W	Capital Recovery	0.13 x PEC	$146,250.00
X	Total Indirect Annual Costs	S+T+U+V+W	$217,940.63
Total Annualized Cost		L+R+X	**$583,275.65**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	1,643
AB	PM10 Captured by ESP (lb/year)	98% control efficiency, Z*0.98	1,610
	PM10 Captured (tons/year)	AB/2000	**0.805**
	Cost Effectiveness ($/ton)	**$724,566.02**	

20 MMBtu/hr NG-Fired Boiler Controlled by a Dry ESP

Boiler Size	**20**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Envitech (7,000 acfm ESP)	$750,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$37,500.00
C	Sales Tax	8.25% PEC	$61,875.00
D	Direct Installation Costs	25% PEC	$187,500.00
E	Total Direct Capital Costs	A+B+C+D	$1,036,875.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$37,500.00
G	Engineering	10% PEC	$75,000.00
H	Process Contingency	5% PEC	$37,500.00
I	Total Indirect Capital Costs	F+G+H	$150,000.00
J	Project Contingency	20% PEC	$150,000.00
K	Total Capital Costs	E+I+J	$1,336,875.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$164,435.63
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	Envitech 25kW; 0.1694/kw-hr	$37,098.60
R	Total Direct Annual Costs	M+N+O+P+Q	$81,582.98
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$15,000.00
U	Insurance	0.01 x PEC	$7,500.00
V	Property Tax	0.01 x PEC	$7,500.00
W	Capital Recovery	0.13 x PEC	$97,500.00
X	Total Indirect Annual Costs	S+T+U+V+W	$154,190.63
Total Annualized Cost		L+R+X	**$400,209.24**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	526
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	131
AB	PM10 Captured by ESP (lb/year)	90% control of filterable	118
	PM10 Captured (tons/year)	AB/2000	**0.059**
	Cost Effectiveness ($/ton)	**$6,783,207.46**	

62.5 MMBtu/hr NG-Fired Boiler Controlled by a Dry ESP

Boiler Size	**62.5**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	Envitech (17,000 acfm ESP)	$750,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$37,500.00
C	Sales Tax	8.25% PEC	$61,875.00
D	Direct Installation Costs	25% PEC	$187,500.00
E	Total Direct Capital Costs	A+B+C+D	$1,036,875.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$37,500.00
G	Engineering	10% PEC	$75,000.00
H	Process Contingency	5% PEC	$37,500.00
I	Total Indirect Capital Costs	F+G+H	$150,000.00
J	Project Contingency	20% PEC	$150,000.00
K	Total Capital Costs	E+I+J	$1,336,875.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$164,435.63
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	Envitech 50kW; 0.1694/kw-hr	$74,197.20
R	Total Direct Annual Costs	M+N+O+P+Q	$118,681.58
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$15,000.00
U	Insurance	0.01 x PEC	$7,500.00
V	Property Tax	0.01 x PEC	$7,500.00
W	Capital Recovery	0.13 x PEC	$97,500.00
X	Total Indirect Annual Costs	S+T+U+V+W	$154,190.63
Total Annualized Cost		L+R+X	**$437,307.84**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	4,161
Z	Filterable PM10 (lb/year)	8760 hr/year x MMBtu/hr x 0.00075	411
AB	PM10 Captured by ESP (lb/year)	90% control of filterable	370
	PM10 Captured (tons/year)	AB/2000	**0.185**
	Cost Effectiveness ($/ton)	**$2,363,826.16**	

20 MMBtu/hr NG-Fired Boiler Controlled by a Venturi Scrubber

Boiler Size	**20**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			
	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	EnviroCare Micromist (7,000 acfm)	$400,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$20,000.00
C	Sales Tax	8.25% PEC	$33,000.00
D	Direct Installation Costs	25% PEC	$100,000.00
E	Total Direct Capital Costs	A+B+C+D	$553,000.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$20,000.00
G	Engineering	10% PEC	$40,000.00
H	Process Contingency	5% PEC	$20,000.00
I	Total Indirect Capital Costs	F+G+H	$80,000.00
J	Project Contingency	20% PEC	$80,000.00
K	Total Capital Costs	E+I+J	$713,000.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$87,699.00
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$45,124.00
R	Total Direct Annual Costs	M+N+O+P+Q	$89,608.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$8,000.00
U	Insurance	0.01 x PEC	$4,000.00
V	Property Tax	0.01 x PEC	$4,000.00
W	Capital Recovery	0.13 x PEC	$52,000.00
X	Total Indirect Annual Costs	S+T+U+V+W	$94,690.63
Total Annualized Cost		L+R+X	**$271,998.01**
	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	526
AB	PM10 Captured by Baghouse (lb/year)	99% efficiency	521
	PM10 Captured (tons/year)	AB/2000	**0.261**
	Cost Effectiveness ($/ton)	**$1,042,137.97**	

62.5 MMBtu/hr NG-Fired Boiler Controlled by a Venturi Scrubber

Boiler Size	**62.5**	**MMBtu/hr**	
Exhaust Temp < 400 Deg F			

	Item	**Method of Calculation**	**Cost**
	Direct Capital Costs		
A	Total Purchased Equip Cost	EnviroCare Micromist (20,000 acfm)	$520,000.00
B	Freight	5% Purchased Equip Cost (PEC)	$26,000.00
C	Sales Tax	8.25% PEC	$42,900.00
D	Direct Installation Costs	25% PEC	$130,000.00
E	Total Direct Capital Costs	A+B+C+D	$718,900.00
	Indirect Capital Costs		
F	Facilities	5% PEC	$26,000.00
G	Engineering	10% PEC	$52,000.00
H	Process Contingency	5% PEC	$26,000.00
I	Total Indirect Capital Costs	F+G+H	$104,000.00
J	Project Contingency	20% PEC	$104,000.00
K	Total Capital Costs	E+I+J	$926,900.00
L	**Annualized Capital Costs (10 Years @ 4%)**	0.123*K	$114,008.70
	Direct Annual Costs		
	Operating Costs		
M	Operator	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
N	Supervisor	15% of operator	$3,421.88
	Maintenance Costs		
O	Labor	0.5 hr/shift, $25/hr, 3 shifts/day	$13,687.50
P	Material	100% of Labor Cost	$13,687.50
	Utility Costs		
Q	Electricity Costs	0.1694/kw-hr EPA Cost Manual (452/B-02-001), Section 6, Chapter 1, Formula 1.14	$128,925.00
R	Total Direct Annual Costs	M+N+O+P+Q	$173,409.38
	Indirect Annual Costs		
S	Overhead	60% of O&M (M+N+O+P)	$26,690.63
T	Administrative	0.02 x PEC	$10,400.00
U	Insurance	0.01 x PEC	$5,200.00
V	Property Tax	0.01 x PEC	$5,200.00
W	Capital Recovery	0.13 x PEC	$67,600.00
X	Total Indirect Annual Costs	S+T+U+V+W	$115,090.63
Total Annualized Cost		L+R+X	**$402,508.71**

	Emission Reductions		
Y	Total PM10 Emissions (lb/year)	8760 hr/year x MMBtu/hrx 0.003	1,643
AB	PM10 Captured by Baghouse (lb/year)	99% efficiency	1,627
	PM10 Captured (tons/year)	AB/2000	**0.814**

	Cost Effectiveness ($/ton)	**$494,482.44**	

Appendix B
References

References

[1] EPA-452/F-03-025 https://www3.epa.gov/ttnchie1/mkb/documents/ff-pulse.pdf
[2] EPA-452/F-03-026 https://www.epa.gov/sites/default/files/2020-10/documents/ff-revar.pdf
[3] Correspondence from Clean Air Systems
[4] EPA-452/F-03-029 https://www3.epa.gov/ttn/chief/mkb/documents/fwespwpi.pdf#:~:text=An%20ESP%20is%20a%20particulate%20control%20device%20that,effluent%20is%20collected%2C%20andoften%20treated%20on-site%20%28EPA%2C%201998%29.
[5] EPA-452/F-03-027https://www3.epa.gov/ttn/catc/dir1/fdespwpi.pdf
[6] EPA-452/F-03-017https://www3.epa.gov/ttnchie1/mkb/documents/fventuri.pdf#:~:text=EPA-452%2FF-03-017%20Air%20Pollution%20Control%20Technology%20Fact%20Sheet%20Name,venturi%20jet%20scrubbers%2C%20gas-atomizing%20spray%20scrubbers%2C%20and%20ejector-venturiscrubbers