APPENDIX C

Cost Effectiveness Analysis for Proposed Amendments to Rule 4354 (Glass Melting Furnaces)

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COST EFFECTIVENESS ANALYSIS FOR PROPOSED RULE 4354 (GLASS MELTING FURNACES)

I. SUMMARY

The California Health and Safety Code 40920.6(a) requires the San Joaquin Valley Air Pollution Control District (District) to conduct both an absolute cost effectiveness analysis and an incremental cost effectiveness analysis of available emission control options prior to adopting each Best Available Retrofit Control Technology (BARCT) rule. The purpose of conducting a cost effectiveness analysis is to evaluate the economic reasonableness of the pollution control measure or rule. The analysis also serves as a guideline in developing the control requirements of a rule.

Absolute cost effectiveness of a control option is the added annual compliance cost to meet the proposed rule requirements, in dollars per year ($/year), of a control technology or technique, divided by the emission reduction achieved in tons reduced per year. The costs includes capital equipment costs, engineering design costs, labor and maintenance costs.

Incremental cost effectiveness (ICE) is intended to measure the change in costs (in $/year) and emissions reductions (in tons reduced/year) between two progressively more effective control options or technologies. ICE compares the differences in costs and the differences in emissions reductions of candidate control options. ICE does not reveal the emission reduction potential of the control options. Unlike the absolute cost effectiveness analysis that identifies the control option with the greatest emission reduction, ICE does not present any correlation between emissions reductions and cost effectiveness. Therefore, the relative values produced in the ICE analysis and the absolute cost effectiveness values are not comparable and cannot be evaluated in the same way as absolute cost effectiveness numbers.

Table 1 shows the summary of the cost effectiveness analysis for glass melting furnaces to comply with the proposed rule. The ‘cost effectiveness range’ shown in the table below represents the values for the technologies that are expected to be installed at glass melting furnaces in the San Joaquin Valley.

Table C-1: Summary of Cost Effectiveness

Compliance Scenarios (Current Permitted Limits to Proposed New Limits)	Cost Effectiveness Range* ($/ton)
Container Glass – NOx limit	$6,293/ton -$22,660/ton
Container Glass – SOx limit	$10,543/ton - $12,245/ton
Container Glass – PM10 limit	N/A*
Flat Glass – NOx limit	$3,945/ton - $9,501/ton
Flat Glass – PM10 limit	N/A*

*Values taken from tables C-4 through C-7.
**Facilities are already operating in compliance with the proposed PM_{10} emission limits. Some modifications to facility controls or operations may be required to ensure an adequate margin of compliance with the updated emissions limits, however costs are not expected to be significant. Therefore, a cost effectiveness analysis is not required.

Table 2 shows the total direct and indirect capital cost associated with the various technologies. Facilities are likely to install technologies highlighted in italicized text in the table below to comply with the proposed emission limits.

Table C-2: Estimated Capital Cost for Control Technology by Glass Category

Glass Category	NOx Reduction Technology	Total Direct and Indirect Capital Costs
Container Glass	Install Ceramic Catalytic Filters (CCF) with Housing	$14,983,125
	Install New SCR System	*$6,223,644*
	Install CCF without Housing	*$5,075,545*
	Enhancements of Existing SCR System (for three furnaces)	*$6,369,158*
	Oxy-Fuel Conversion	$24,177,454
Flat Glass	*Enhancements to existing SCR system (for one furnace)*	*$2,123,053*
	Oxy-fuel conversion	$28,307,370
	Install SCR	*$5,246,382*
	Install CCF	$13,235,844
Glass Category	**SOx Reduction Technology**	**Total Direct and Indirect Capital Costs**
Container Glass	*Enhancements to dry sorbent injection system (DSI) using hydrated lime*	*$141,537*
	Enhancements to DSI using Trona	*$424,611*

II. BACKGROUND

Proposed Rule 4354 would implement more stringent NOx, SOx, and PM10 limits for container glass melting furnaces and more stringent NOx and PM10 limits for flat glass melting furnaces. These facilities will require a significant investment to install new control equipment or make significant modifications to their existing equipment in order to meet the proposed emission limits. After careful evaluation, District staff found requiring the lowest limits immediately is not cost effective, and instead staff recommends incorporating the requirements in two phases, with the most costly equipment upgrades to begin in Phase II. The longer compliance schedule allows operators to better combine the control system modifications with their normal furnace rebuild schedule, rather than have the significant additional expense of off-schedule furnace shutdowns and cold restarts. These facilities are expected to be capable of achieving the Phase I proposed NOx and PM10 limits with existing equipment, with marginal costs associated with control tuning, testing and monitoring, as well as permit modifications. These facilities will be required to upgrade their NOx control technology as early as 2024, and no later than 2030, and in addition will be required to make permit modifications for the Phase I SOx emission limits by 2024.

For flat glass furnaces, the SOx emissions limit in proposed Rule 4354 will be retained at the same level that is currently required by the rule. Use of a semi-dry scrubbing technology that could potentially lower the SOx emissions cannot be deployed at one of the facility utilizing natural gas and an SCR system without making cost prohibitive changes to their NOx control system. Such NOx control system changes may include conversion to oxy-fuel firing, which is estimated to cost upwards of 28 million dollars to retrofit this plant. Per facility personnel, the exhaust gas temperature must be maintained in the range of 630 ºF to 650 ºF at the SCR catalyst to effectively reduce NOx emissions. Since this facility is currently using SCR to control NOx, using semi-dry scrubbing technology will lower the exhaust gas temperatures below the required range needed for the SCR system to operate effectively.

A. Estimated Compliance Cost

District staff used cost information provided by control equipment manufacturers, vendors, and from stakeholders to conduct a cost effectiveness analysis of the proposed NOx, SOx, and PM10 limits in Proposed Rule 4354. Specifically the data used in the analysis came from the following sources:

1. Guardian Industries LLC
2. Gallo Glass Company
3. Tri-Mer Corporation
4. GEA Systems North America LLC
5. Precision Partners LLC

Cost information submitted to the District was used to establish the costs located in Tables C-4 through C-7.

III. GLASS FURNACE STATUS RELATIVE TO PROPOSED EMISSION LIMITS

There are six facilities that manufacture glass within the District, five that will be impacted by this proposed rule amendment. These five facilities produce glass from a total of 11 furnaces – nine are container glass and two are flat glass. A summary of these five facilities, their control equipment and their current permitted emission limits are shown in the table below:

Table C-3: Summary of Existing Glass Plants in San Joaquin Valley

Facility	Pollutant	Current Reduction Technology	Current Permitted Throughput (ton/year)	Current Permitted Emission Limits (lb/ton)
Container Glass Facility 1	NOx	Oxy-Fuel Firing	736,531	1.3
	PM10	Ceramic Filters		0.45
	SOx	DSI (hydrated lime)		0.95
Container Glass Facility 2	NOx	Oxy-Fuel Firing	351,890	1.3
	PM10	ESP		0.45
	SOx	SDA (soda ash)		0.8
Container Glass Facility 3	NOx	SCR	357,335	1.5
	PM10	ESP		0.5
	SOx	DSI (trona)		0.9
Flat Glass Facility 1	NOx	Oxy-Fuel Firing	237,250	2.9
	PM10	ESP		0.7
	SOx	SDA (soda ash)		1.2
Flat Glass Facility 2	NOx	SCR	255,500	3.2
	PM10	ESP		0.7
	SOx	DSI (trona)		1.2

IV. Cost Effectiveness Analysis Procedure

To illustrate the cost effectiveness of complying with the proposed limits, District staff's analysis provides varying cost effectiveness values depending on the size of the unit, and the annual capacity factor that the unit is operated. The actual compliance costs and cost effectiveness values would depend on several factors such as the type of unit, site-specific operating conditions, and the appropriate emission limits the unit has to meet.

A. Absolute Cost Effectiveness (ACE) Calculation Method

Absolute cost effectiveness examines the cost of reaching the proposed emission limits using the current emissions as a baseline. Cost effectiveness is calculated as the added annual cost (in $/year) of a control technology or technique, divided by the emission reduction achieved (in tons reduced/year). The annual costs include annualized capital equipment costs and engineering design costs plus the annual labor and maintenance costs.

The absolute cost effectiveness of a control technology is calculated as follows:

1. Determine an equivalent annual equipment cost using a capital recovery factor based on an assumed interest rate of 4 percent and equipment life of 10 years.
2. Determine the annual electricity, fuel, and operation and maintenance costs of a control technology.
3. Calculate the total annual cost by adding the costs calculated in Step 1 and Step 2.
4. Calculate the emission reduction in tons/year. Appendix B provides a detailed explanation of the calculations performed to determine the emission reductions for the potential rule limits.
5. Calculate the absolute cost effectiveness by dividing the total annual cost in Step 3 by the emissions reduction in Step 4.

B. Incremental Cost Effectiveness (ICE) Calculation Method

Incremental cost effectiveness (ICE) indicates the additional cost for further controlling a unit from the proposed limit to the lowest possible level. Costs are evaluated similar to absolute costs but are only calculated for the controls and reductions beyond what is required to comply with the rule. ICE does not reveal the emission reduction potential of the control options, but examines the more stringent options which were not considered to be cost effective. Due to the increased costs and marginal emission reductions, the ICE calculations typically result in a much higher cost effectiveness than the absolute cost effectiveness values, and are not directly comparable.

The incremental cost effectiveness of a control technology is calculated as follows:

1. Identify the complying control options appropriate for the existing equipment.
2. Estimate the annual average cost of each control option by using Steps 1 to 3 of the ACE calculation method.
3. Calculate the potential emission reduction for each control option. The potential emission reductions (PE) are the difference between the current emissions and the potential emissions using the new control technology.

V. Absolute Cost Effectiveness

District staff reviewed the Permit Services Permits Database to determine the existing control technology and current permitted limits for glass melting furnaces operating in the Valley to determine which facilities would require to be retrofitted to comply with the proposed emission limits.

Compliance costs include both one-time costs and on-going annual operation and maintenance costs. Examples of one-time costs are the purchase of equipment and installation costs. On-going costs include maintenance costs, reagent purchases, and the additional fuel burned because of the control technology (fuel penalty). In order to determine a single figure for costs, District staff use a capital recovery factor to allocate the one-time costs over the life of the equipment. For all cost analyses in this report, District staff used a 4 percent rate of return and a 10-year equipment life to convert the capital costs to equivalent annual cost.

A. NOx Compliance Costs

For compliance with the proposed NOx limits, District staff assumed that operators with furnaces that did not meet the proposed NOx limits based on their recent emission monitoring and source test data would either install a selective catalytic reduction (SCR) system, install a ceramic catalytic filter (CCF) system or enhance their existing SCR system to achieve better NOx emission reductions. Although some operators may consider converting from oxygen assisted firing to full oxy-fuel firing, District staff estimated that the capital cost plus annual operating costs of the conversion to oxy-fuel firing are higher than converting to an SCR/CCF system, therefore operators would choose the option with the lowest cost, in this case choosing SCR/CCF systems over oxy-fuel firing.

Due to the high costs of complying with the lower Phase II NOx emissions limits and the costs associated with performing a furnace rebuild, District staff are proposing a phased compliance schedule, with longer timeframes allowed for facilities to comply with the final NOx limits. The interior of a glass furnace is made up of refractory bricks that hold the pool of molten glass and raw materials that helps to retain heat within furnace combustion chamber, thus improving the overall thermal efficiency of the furnace. The refractory bricks have an expected life of approximately 10 to 15 years. Rebuilding a glass furnace and replacing the refractory brick costs $15 million dollars or more depending on furnace size, design, and scope of work. In addition, during a furnace rebuild, the facility cannot produce any glass for up to three months, so there is additional dollars in lost revenue.

The proposed rule requires facilities to meet a Phase I NOx limit in 2024, and then a more stringent limit upon the completion of the next furnace rebuild, or by 2030, whichever comes sooner. Complying with the Phase II emissions limits will require major modifications to facility furnaces and control technologies. By allowing these modifications to occur at the time the furnace is already planned to be shut down and out of operation, the compliance cost is greatly reduced, ensuring that the proposed requirements are cost-effective and economically feasible. If the District was to require that operations meet the Phase II limits on a more expedited timeframe, additional costs would be incurred, including an additional estimated $15 million dollar cost per facility to shutdown and rebuild their furnaces outside of their regularly schedule rebricking cycle.

Unless otherwise stated, all costs shown in Table C-4 and Table C-5 are various technologies that could be potentially used to comply the proposed Tier II NOx limits in this rule.

1. Oxy-Fuel Fired Glass Furnaces

Three of the existing glass plants (two container glass and one flat glass) are currently equipped with oxy-fuel firing combustion technology to reduce NOx emissions. In order for these facilities to comply with the proposed NOx emission limits, it is expected that they would either install SCR or install a CCF system.

Table C-4: NOx Compliance Costs for Oxy-Fuel Fired Glass Furnace Retrofits

<table>
<tr><th>Facility</th><th>Technology Evaluated</th><th>Capital Cost</th><th>O&M Cost ($/yr)</th><th>Annualized Cost ($/yr)</th><th>Emission Reductions (tons/yr)</th><th>Cost-Effectiveness ($/ton NOx)</th></tr>
<tr><td rowspan="2">Container Glass Facility 1</td><td>Install SCR</td><td>$5,497,996</td><td>$1,009,094</td><td>$1,686,997</td><td rowspan="2">202.6</td><td>$8,327</td></tr>
<tr><td>Install CCF without Housing[1]</td><td>$5,075,545</td><td>$648,974</td><td>$1,274,789</td><td>$6,293</td></tr>
<tr><td rowspan="2">Container Glass Facility 2</td><td>Install CCF with Housing</td><td>$17,532,031</td><td>$2,417,925</td><td>$5,270,387</td><td rowspan="2">96.8</td><td>$54,446</td></tr>
<tr><td>Install SCR</td><td>$6,949,291</td><td>$1,062,170</td><td>$2,192,819</td><td>$22,660</td></tr>
<tr><td rowspan="2">Flat Glass Facility 1</td><td>Install CCF with Housing</td><td>$13,235,844</td><td>$1,954,575</td><td>$3,586,555</td><td rowspan="2">166.1</td><td>$21,592</td></tr>
<tr><td>Install SCR</td><td>$5,246,382</td><td>$931,045</td><td>$1,577,924</td><td>$9,500</td></tr>
</table>

2. Natural Gas Fired Glass Furnaces Served by SCR

Two of the existing glass plants (one container glass and one flat glass) are currently equipped with regular natural gas firing combustion technology with SCR systems installed on each glass furnace exhaust stack to reduce NOx emissions. In order for these facilities to comply with the proposed NOx emission limits, it is expected that they would either enhance their existing SCR system or convert their glass furnaces over to oxy-fuel firing.

[1] This facility has already installed the CCF system housing, and so costs for housing required to convert their control system from utilizing ceramic filters to catalytic ceramic filters are not included. Therefore, the cost analysis was performed for installing a CCF system without the housing for this facility.

Table C-5: NOx Compliance Costs for Glass Furnaces Equipped with SCR

Facility	Technology Evaluated	Capital Cost	O&M Cost ($/yr)	Annualized Cost ($/yr)	Emission Reductions (tons/yr)	Cost-Effectiveness ($/ton NOx)
Container Glass Facility 3	Oxy-Fuel Furnace Conversion	$24,177,454	$2,981,080	$6,128,825	134.0	$45,738
	Enhancement of Existing SCR[2]	$6,369,158	$785,317	$1,819,921		$13,582
Flat Glass Facility 2	Oxy-Fuel Furnace Conversion	$28,307,370	$3,676,829	$7,167,128	217.2	$32,998
	Enhancement of Existing SCR	$2,123,053	$595,088	$856,860		$3,945

C. PM10 Compliance Costs

Facilities subject to Rule 4354 have already installed the highest level of controls feasible, and are expected to be able to comply with the lower PM10 emission limits without major modifications to their existing PM control equipment, which includes either Electrostatic Precipitators (ESP) or ceramic dust collectors. In some cases, fine tuning of the current emission controls may be required to ensure compliance with the lower PM10 emissions limits. Costs incurred in such tuning are expected to be minimal. The capital costs associated with the PM10 emission limits attributed to permit modification fees are summarized in the table below by plant type.

D. SOx Compliance Costs

Use of semi-dry adsorber (SDA) or dry sorbent injection (DSI) systems are prevalent among glass manufacturing facilities in the valley. SDA systems uses soda ash and water solution, whereas, DSI systems use dry trona or hydrated lime. The District believes that the existing systems could be enhanced by upgrading feed conveying systems, installing more injection ports, upgrading blower fans, in order to optimize the use of current sorbent material. Costs incurred in enhancing the existing control equipment are summarized in Table C-7.

[2] This facility operates three glass furnaces with three separate SCR systems. Therefore, the cost analysis was performed by summing the costs associated with modifying all three of their furnaces and/or emission control systems.

Table C-7: SOx Compliance Costs

Facility type	Current Sorbent	Capital Cost ($)	O&M ($/yr)	Annualized Cost ($/yr)	Emission Reductions (tons/year)	Cost Effectiveness ($/ton SOx)
Container Glass Facility 1	Hydrated lime	$141,537	$658,997	$17,451	55.2	$12,245
Container Glass Facility 2[3]	Soda ash	--	--	--	--	--
Container Glass Facility 3	Trona	$424,611	$136,017	$52,354	18.0	$10,543

VI. ALTERNATIVE CONTROL TECHNOLOGIES EVALUATED

The District has identified and evaluated all practically feasible NOx, PM, and SOx control technologies that have been successfully deployed at the glass manufacturing operations. Based on the review of other District, State and Federal regulations, proposed Rule 4354 will have the most stringent NOx, PM10 and SOx emission limits in the nation. In addition, facilities will be employing the state of the art control technologies for this source category. The costs associated with these control technologies is already enumerated in the tables in section V above. The District believes that there are no other alternative control technologies that need further evaluation at this time.

VII. INCREMENTAL COST EFFECTIVENESS ANALYSIS

Health and Safety Code section 40920.6 requires an incremental cost-effectiveness analysis for Best Available Retrofit Control Technology (BARCT) rules or emission reduction strategies when there is more than one control option which would achieve the emission reduction objective of the proposed amendments. The incremental cost effectiveness is the difference in cost between successively more effective controls divided by the additional emission reductions achieved. District staff believes that the provisions of Proposed Rule 4354 meet Best Available Retrofit Control Technology, and therefore there is no more stringent option than the proposed provisions. For this reason, an incremental cost effectiveness analysis would serve no useful purpose because there is no more stringent option available to glass manufacturers.

[3] This facility is already meeting the proposed SOx emissions limit with existing control technology, and so no additional costs are expected to be incurred.

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