Estimated Costs Related to the Implementation of the Mercury Reduction Rules

Minnesota Pollution Control Agency
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This document is prepared to describe the methodology used to estimate costs and emission reductions at affected air emission facilities in Minnesota in complying with the requirements of the proposed mercury reduction rule.

I. Summary

Affected facilities

The proposed rules are requiring reduction plans from facilities to meet the reduction target of the Minnesota Statewide Mercury Total Maximum Daily Load (TMDL) study. Actions will be necessary at certain facilities to reduce mercury emissions, some of those actions requiring capital investment and related ongoing annual costs to operate air pollution controls.

The proposed rule establishes reduction requirements and timetables to achieve reductions. Taconite furnaces, a direct iron production facility, an electric arc furnace steelmaking facility, industrial boilers and potentially a lime kiln appear to be subject to the requirement to implement mercury control projects.

Total annual cost of proposed rule

Costs of this rulemaking are expressed in terms of capital investment to purchase and install activated carbon injection (ACI), and additional particulate matter control if warranted, and annual costs related to due to operation of mercury controls, recordkeeping and reporting.

The Minnesota Pollution Control Agency (MPCA) sought to estimate reasonable upper-bound estimates assuming sources install ACI. Other control strategies are possible, and are likely of lower cost to a specific facility. Other available or developing control strategies are discussed in this document for each sector. Table 1 below summarizes the estimate for this rulemaking.

Table 1. Summary of Estimate Annualized Cost and Mercury Emission Reduction

Sector	Number of Affected Units/Facilities	Total Capital Costs	Total Annual Cost	Pounds of Mercury Reduced
Ferrous Mining and processing	14 furnaces	$109,000,000	$22,800,000	782
Iron and Steel Melters	1 unit	$3,000,000	$523,000	26
Industrial Boilers	10 boilers	$27,900,000	$4,700,000	79
Mercury Reduction Plan Preparation	17 facilities	$460-$800,000		
Mercury Emissions Reporting	35 facilities		$10,000	
TOTAL		$140,360,000	$32,500,000	887

Mercury controls within the ferrous mining and processing sector represent the majority of the capital and operating costs of this rulemaking. Controlling mercury emissions by 75 percent and greater has been demonstrated at taconite facilities to be feasible with halogenated ACI, however balance of plant impacts are still under evaluation. A critical aspect for this industrial sector is to maintain compliance with federal standards for particulate matter when using ACI. Injecting carbon represents an additional particulate matter (PM) load. Pilot testing indicates that carbon may not be captured in existing control equipment. In order to account for this potential, cost estimates include additional PM capture.

The proposed rule requires a facility owner to prepare a plan for reducing mercury emissions, and is structured to allow facility owners to make choices that should lower the economic impact—emissions averaging if there is more than one unit, using a combination of technologies. The rule also provides for very long compliance timeframes, allowing for technology developments to improve control efficiencies and minimize costs.

Activated carbon injection is a well-developed technology for coal-fired boilers. The cost estimate for ACI at industrial boilers is also expected to be reasonable upper bound estimates. Within this sector, additional stack testing to confirm emissions will likely be undertaken to determine if the boiler is near the five pound threshold.

Facilities required to prepare reduction plans under this rule—but for two municipal-owned utilities—are owned and operated by very large corporations competing in global markets. The ferrous mining/processing industry and sugar beet processing industries in Minnesota are each billion dollar a year sectors in Minnesota economy, and are growing. The MPCA believes that flexibility within the rule will minimize its costs, and for those facilities that are affected, the cost of compliance is not significant.

Compliance with federal rules does not affect costs from state rulemaking

This rulemaking proposes to adopt by reference a number of federal rules regulating emissions of mercury. Within this rulemaking, the MPCA seeks to give the federal rules the force of state law, a necessary provision when seeking delegation of the standard from the US Environmental Protection Agency (EPA).

Federal rules controlling mercury affect industrial, commercial and institutional boilers, process heaters at major sources of hazardous air pollutant (HAPs), sewage sludge incinerators, and commercial and industrial solid waste incinerators. The federal standards have been evaluated to determine whether in the act of incorporating the federal rules into state rules, additional action by an affected facility is required, and if so, what the addition costs are related to the state rulemaking action. The mercury reduction rule relies first on federal rules to accomplish mercury emission reductions. MPCA has determined that no additional compliance costs are expected as a result of standards being incorporated by reference into state rules.

Mercury reduction plans

Facilities will be required to prepare mercury reduction plans for MPCA to review. The estimate for the preparation of these plans is a one-time cost for each facility ranging from $20,000 to $35,000. Total statewide expected expenditures for the plans thus range between $460,000 to $800,000. This estimate is based on assuming that a cost to develop a plan is about 1 percent of the initial estimated construction cost of the project at hand.

Compliance with mercury inventory reporting requirements

The proposed rule requires that mercury emission sources report their emissions annually. The MPCA estimates that reporting facilities individually will spend $300/yr to report mercury

emissions, and total statewide expected expenditures will be $10,000 to calculate and report mercury emissions to the MPCA.

II. Ferrous Mining and Processing

A. Taconite Furnaces

Owners and operators of existing taconite furnaces have been evaluating mercury controls, beginning in 2002/2003 with work being done by the Minnesota Department of Natural Resources (DNR)[1]. Recently, pilot testing of a number of technologies was completed in 2012, funded in part by a grant to the DNR from the EPA under the Great Lakes Restoration Initiative.[2]

A number of mercury control methods were piloted. The tests were initial tests aimed at determining which technologies present the best promise for further development. Of the technologies piloted, brominated activated carbon injection upstream of wet scrubbers was found to have the potential to control mercury at levels needed for the industry to achieve its 75 percent reduction goal. Other tested technologies may also be developed as future investigation is conducted, and may become available as feasible technologies. The tested technologies that reduced mercury:

- Calcium Bromide injection into process streams
- Addition of brominated carbon sorbents to greenball feed
- Mercury capture by fixed carbon beds downstream of wet scrubbers

For purposes of estimating the cost of compliance for the mercury reduction rule, based on the results of the pilot testing, carbon injection will be used.

The TMDL Implementation Plan and the proposed rule require a mercury reduction plan from emission units that emit greater than three pounds of mercury per year. The furnaces at Northshore Mines in Silver Bay, Minnesota are not expected to be subject to the requirement to prepare a reduction plan, and are not included in the cost estimates.

Additionally, US Steel and the MPCA have executed a schedule of compliance (SOC) that affects the Keetac and MinnTac facilities. The SOC establishes a schedule for reductions of mercury at Minntac while constructing and initiating operation of a second furnace at the Keetac plant. The schedule secures mercury reductions earlier than what is prescribed in the TMDL Implementation Plan. The SOC also establishes a schedule for replacing wet scrubbers on two furnaces at Minntac with dry scrubbing. While this SOC establishes a schedule that is earlier than that contemplated in the TMDL Implementation Plan and resulting rule, estimates for mercury controls at Minntac and Keetac are included in this exercise.

Carbon injection operation and cost estimate assumptions for taconite furnaces

Of the methods piloted to date, direct injection of carbon into furnace off-gases is believed to be the most feasible and least costly method of reducing mercury. Tests by Miller et al. (2012) using brominated carbon at a three pounds per million actual cubic feet (lb/MMacf) (of air

[1] Mercury Controls for Taconite Stack Emissions. Minn. Dept. of Nat. Resources. http://www.dnr.state.mn.us/lands_minerals/dnr_hg_research.html

[2] M. Berndt. "Minnesota Taconite Mercury Control Advisory Committee: Summary of Phase One Research Results (2010-2012), A final report submitted to the United States Environmental Protection Agency, Grant No. GL00E00655-0" Minnesota Dept of Nat Resources. St Paul, MN http://files.dnr.state.mn.us/lands_minerals/reclamation/berndt_2012_final.pdf

flow in the stack) injection rate at Hibbing Taconite exceeded the 75 percent reduction goal[3]. The study authors reported that test limitations on injection port locations (and carbon distribution within the duct) meant that the amount of sorbent needed to control mercury emissions was larger than expected. Using this brominated carbon injection rate thus represents a reasonable estimate of carbon for this reduction technology to achieve the 75 percent reduction necessary to achieve the mercury TMDL for this sector.

The estimate of capital and annual costs of carbon injection systems in this analysis uses EPA's algorithm used to estimate costs of carbon injection at industrial boilers. See Appendix A. The estimate from the algorithm was compared to the estimate prepared for the industry in the report on a slipstream test of a fabric filter (see footnote 4). That ACI installation cost estimate is considerably less that the cost generated by the EPA algorithm, therefore the MPCA is confident the algorithm is producing an upper bound, reasonable estimate. Long-term ACI testing has not been conducted at multiple sites, and site specific factors are unknown meaning that an upper bound estimate is necessary to account for as-yet unknown site limitations. As more information is developed, the MPCA expects installation costs to fall.

During the pilot testing at one taconite furnace, increased particulate mercury emission was associated with high carbon injection rates. Because ACI represents an increased PM loading on the wet scrubbers, additional PM controls may be needed. The MPCA assessed existing PM controls in use, and applied additional "polishing" fabric filter at furnaces that in MPCA's judgment could require improved particulate capture when using ACI. No additional PM control was applied where fabric filters are scheduled for installation by 2025. The MPCA believes that fabric filters are necessary at six taconite furnaces. Longer periods of mercury technology trials will determine appropriate carbon injection rates, which determine necessary improvements in particulate capture.

A fabric filter with carbon injection was tested on a slipstream from a grate kiln and capital and operating costs estimated4. The capital and operating cost for the fabric filter was used in the MPCA's estimates to represent the cost of the additional PM controls if high carbon injection rates caused PM emission increases. Operation of a fabric filter would require that a portion of untreated (hot) flue gases would be routed to the fabric filter to reheat flue gases or heat exchanger would be installed to provide reheat of flue gases.

This arrangement of using carbon injection after the existing wet scrubber with very efficient PM capture appears to be able to achieve very high mercury capture. Carbon injection rates were lower; results show that by using 2.2 lb/MMacf of standard activated carbon or 1.1 lb/MMacf of brominated carbon, removal efficiencies greater than 75 percent were achieved. When using a carbon injection rate of 0.6 lb/MMacf while burning coal, mercury removal was greater than 88 percent. Cost estimates assume that when a fabric filter is in place, the carbon injection rate is 1.1 lb/MMacf. While the fabric filter represents an increased capital cost, the annual carbon use drops by half.

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[3] Miller, J. M. Zerangue, et. Al. Mercury control for taconite plants using gas-phase brominated sorbents. Minnesota Dept. of Nat. Resources. St. Paul, MN. 2012.
http://files.dnr.state.mn.us/lands_minerals/reclamation/miller_zerangue_2012.pdf

[4] http://files.dnr.state.mn.us/lands_minerals/reclamation/laudal_2012.pdf

B. Direct Reduced Iron Furnace

Minnesota has one facility direct reduced iron furnace, Mesabi Nugget, which is a rotary hearth iron nugget production plant. The iron nuggets are created by mixing coals, fluxes, binders and iron ore concentrate, then forming into "green balls". The balls are dried and fed to the rotary hearth furnace to be converted to metallic iron and slag. The iron and slag are cooled and separated, and the iron sent to blast furnaces elsewhere.

The TMDL Implementation Plan places this ferrous processing plant in the same industrial sector as taconite, even though it is not processing taconite iron ore. Mesabi Nugget was not operating when the plan was developed, and so the reduction required is based on the facility's "potential to emit" mercury as determined in the air emissions construction permit. The potential to emit for mercury is 75 pounds, meaning that Mesabi Nugget is expected to emit no greater than 18.75 pounds (a 75 percent reduction from the 75 pounds baseline) by 2025, the compliance deadline for the ferrous mining sector.

Carbon injection operation and cost estimate assumptions for direct reduced iron (DRI). This facility is the first full scale facility operated to produce DRI pellets in this manner. Options for controlling mercury will rely on piloting technologies at the facility. At this time, two methods appear feasible for removing mercury: substituting raw materials, or installing a polishing fabric filter after the existing controls to inject carbon**.**

Substituting raw materials. Mesabi Nugget uses iron concentrate, flux, clay and coal to produce iron nuggets. Substitution for iron concentrate is unlikely, since most of the mercury comes from the other materials being used in the furnace. The remaining materials are purchased from various offsite sources. The facility may have access to other, lower-mercury content materials to achieve some of the necessary reduction in mercury emissions.

Polishing fabric filter and activated carbon injection. Short-term pilot testing of a high-temperature, brominated activated carbon was conducted at Mesabi Nugget, showing at best 28 percent removal from inlet mercury levels. Because at this time ACI injection ahead of the furnace's wet scrubber used for acid gases and particulate matter capture does not achieve the reduction requirements of the TMDL Implementation Plan, it is expected that a polishing baghouse with brominated ACI would be necessary.

The cost of installing a fabric filter with carbon injection was estimated at one of the pilot mercury control tests on a flue gas slipstream from a grate kiln[5]. This arrangement of using carbon injection after the existing wet scrubber with very efficient PM capture achieved very high mercury capture. Flue gases passing from the wet scrubber would need to be reheated prior to entering the fabric filter. It is assumed that existing waste heat from the furnaces would be used for flue gas reheat.

The MPCA is using the capital and operating costs from the study to represent the cost of treating this facility's flue gases for mercury to address the current unknown cost related to reheating flue gases. The capital and operating cost estimated in the pilot study was for a furnace with a flue gas volume of 600,000 standard cubic feet per minute (scfm), about twice the volume as Mesabi Nugget's flue gases. Using the estimated capital and annual cost at a taconite furnace is a reasonable upper estimate in the absence of site specific information. More site specific engineering will result in more specific cost estimates.

[5] http://files.dnr.state.mn.us/lands_minerals/reclamation/laudal_2012.pdf

C. Estimated Cost of Compliance

The estimated capital and annual costs are presented in Table 2. Industry wide, the total capital investment is estimated at approximately $41.7 million dollars to install carbon injection systems and fabric filters at seven furnaces, with an annualized cost of $11.1 million per year. If improved PM capture was necessary (which is what Table 2 assumes), represented by the installation of a fabric filter, the total capital cost increases to $109 million industry-wide, with an annualized cost of $23 million. The estimated mercury reduction is 782 pounds per year. Thus, across all the facilities the average annual estimated cost per pound of mercury captured is approximately $14,000 to $29,000.

Table 2. Calculation of Retrofit Cost of ACI for Ferrous Processing in MN*

Capital Cost	$109 million
Total Annual Costs	$29.7 million
Total amount of mercury reduced, pounds per year	782
$/lb Mercury	$37,966

**See Appendix A for a detailed breakdown of these costs.*

While the estimate assumes that owners and operators will install air pollution controls on each furnace, the proposed rule is allowing facility owners to achieve reductions facility-wide for the facilities with more than one furnace. Reductions could then be achieved by installing and operating ACI to achieve reductions closer to 80 or 90 percent (removals demonstrated in pilot testing with various ACI configurations) at a single facility and leaving other units uncontrolled.

Additionally, the mercury reduction deadline for all the ferrous processing furnaces is in 2025, significantly far enough away to expect additional research to develop more efficient, cheaper, mercury control systems. Thus, due to the following three issues: 1) each individual facility can choose its own most cost effective technology to achieve necessary reductions; 2) the potential economies of scale for facilities with multiple furnaces; and 3) the likelihood of technological developments that will reduce costs to achieve the necessary reductions by 2025, actual costs may be considerably less that the estimates in this report and these estimates can be viewed as upper bound cost estimates.

To put these estimated costs into perspective, according to a 2009 University of Minnesota Duluth (UMD) study[6] on the economic impacts of mining on the state of Minnesota, iron ore mining contributed over $1.5 billion value added[7] to Minnesota's gross state product in 2007 and nearly $3.2 billion in total direct output in the state. More recent 2011 data suggest that the current gross state product of the mining industry in Minnesota is even larger[8]. This helps to show that additional annual expenses for Minnesota ferrous producers of $29.7 million to reduce mercury emissions are not greatly significant.

[6] https://lsbe.d.umn.edu/departments/bber/projects/2009MNMiningImpact.pdf

[7] "Value added" denotes the industry's contribution to the local community in wages, rents, interest and profits. This includes direct value added from the initial spending of the industry as well as indirect inter industry spending resulting from the direct impact and induced household expenditure resulting from direct and indirect impacts of the industry.

[8] http://www.house.leg.state.mn.us/hrd/databook/gspind.aspx

Whether there are indirect or spillover costs in addition to the direct costs of implementing mercury control measures for Minnesota's taconite industry is unclear. Any costs that befall an industry may have repercussions that serve to diminish sales and potentially employment of the industry. When environmental regulation pollution control measures lead to higher operating costs the result is generally a higher market price of the product(s) being produced, which can lower the demand for the product(s) and in turn lead to lower employment in the industry being regulated. However, a counteracting affect is that pollution abatement activities (in this case the installation, operation and maintenance of mercury control equipment) require additional labor to produce the same level of output. A third potential impact on employment is the fact that post-regulation production technologies may be more or less labor intensive. Several empirical studies of a variety of regulated industries suggest that the net employment change is zero or economically small. The MPCA does not expect there to be significant employment impacts to the ferrous mining and processing industry in Minnesota as a result of this rule. According to the UMD study, as of 2007, the iron ore industry in Minnesota employs 10,193 workers. This level of employment is not expected to change as a result of this rule.

Additionally, inter-industry linkages mean that any additional costs to one industry may have detrimental impacts on other industries that either provide inputs to the affected industry or use the outputs of the affected industry due to potential changes in operation costs and market prices pointed out above. In this case, the iron ore mining industry provides the source of primary iron for the iron and steel industry in the United States. However, given the small size of costs needed to reduce mercury relative to the size of the taconite industry in Minnesota, it is unlikely that there will be significant indirect or spillover effects throughout the economy caused by the adoption of mercury control measures as required by these rules.

III. Iron and Steel Melter

Minnesota has one iron and steel melter affected by this rule: Gerdau Ameristeel in St Paul. This facility accepts scrap metal, including shredded vehicles, for melting in its electric arc furnace (EAF).

The EAF operation is a batch process, taking about an hour to complete each batch. Air emissions are controlled by a positive pressure fabric filter; air is pulled out of the building containing the EAF and passes through the fabric filter.

Mercury is likely emitted within a very short time frame; as the scrap is heated, un-containerized mercury will be emitted immediately, while mercury within a container or capsule within the scrap will be released at the point that its container melts. Once the mercury is vaporized, the scrap has been depleted and mercury is unlikely to continue to be emitted from the melting process, although it might be released from duct walls etc. when at temperature.

The estimate to treat mercury emissions is a "brute force" assessment: the MPCA is assuming that activated carbon will be injected continuously, rather than trying to inject mercury during some shorter time frame that mercury is likely actively released. The MPCA is assuming total operating hours of 5300 hours per year, the number of hours Gerdau operated in the past three years, and assuming carbon is being injected whenever the EAF process in operation, not just during the melting phase. To improve cost efficiencies, the owner could investigate synchronizing carbon injection with the batch process, rather than during all hours of operation.

Currently, fabric filter dust is sent off for refining. It is assumed that once carbon injection is used, the dust would no longer be suitable for refining and instead is landfilled.

Table 3. Calculation of Retrofit Cost of ACI for Gerdau Ameristeel, St. Paul, MN*

Capital Cost	$ 3,039,061
Total Fixed Annual Costs	$ 217,327
Annual Variable Costs (Carbon)	$ 252,810
Flue dust landfilling	$ 53,217
Total annual cost	$ 523,354
Total amount of mercury reduced, pounds	26
$/lb mercury	$ 20,129

**See Appendix B for an additional break-down of the costs.*

As Table 3 shows the average cost per pound of mercury reduced is within the same range as compared to the ferrous industry ($20,129 compared to about $14,000-$29,000 per pound of mercury removed).

This corporation is a large long steel producer with facilities throughout the United States and Canada with annual sales in excess of $5 billion. The company operates an EAF in New Jersey which operates in compliance with the same mercury emissions limit proposed in this rule (35 mg/ton of steel produced), although the melting/pouring system is a continuous system and not a batch system.

IV. Industrial Boilers

The EPA promulgated National Emission Standards for Hazardous Air Pollutants (NESHAPs) applicable to industrial, commercial and institutional (ICI) boilers located at both major and area sources in January and February 2013 respectively. (78 FR 7138) (78 FR 7488).

The NESHAPs establish mercury limits:

Federal NESHAP mercury limits

MAJOR source boilers using solid fuel/coal	5.7 x 10-6 lb/MMBtu heat input
AREA source boilers using solid fuel/coal	2.2 x 10-5 lb /MMBtu heat input

The TMDL Implementation Plan anticipated mercury reductions under federal rules to reduce mercury emission considerably[9]. The 2013 NESHAP limit for mercury emissions will not reduce mercury emissions sufficiently to achieve the necessary TMDL reductions. Therefore, the MPCA is requiring mercury reduction plans from existing ICI boiler owners.

The NESHAP also has emission limits for particulate matter as a surrogate for metals, hydrogen chloride (HCl), and carbon monoxide. Minnesota facilities will have to comply with all of the emission limits, in addition to the mercury limit of the NESHAP.

US Environmental Protection Agency estimates that most industrial boilers at major HAP sources in Minnesota will require retrofit controls to remove HCl. Because wet scrubbers are less expensive, EPA estimated that HCl control devices would be wet scrubbers, but for two boilers. Those boilers were identified as needing fabric filters in order to control mercury emissions.

[9] The December 2011 draft industrial boiler rule proposed a mercury emissions rate of 3.1E-6 lb/mmbtu, 45 percent lower than the final value of 5.7E-6 adopted in February 2013.

Recognizing that EPA's compliance impact evaluation lacked considerable site-specific information, the MPCA reviewed its performance test database to approximate likely compliance responses at industrial boilers burning coal. In particular, particulate matter compliance tests were evaluated to determine whether facilities would need to upgrade particulate matter capture devices to meet the NESHAP limit of 0.040 lb/mmbtu[10]. The MPCA identified a number of industrial/institutional boilers that appear to require PM capture upgrades. A number emit PM at rates greater than the boiler standard, while several boilers are very close to the limit, suggesting that those facility owners may consider improving the PM removal performance of existing electrostatic precipitators to provide larger compliance margins. Few boilers have tested for HCl emissions; however, the one emissions test at Southern Minnesota Beet Sugar Cooperative shows very low HCl emissions, suggesting that in fact few industrial boilers will be installing scrubbers to comply with HCl emission limits.

To learn something about planned compliance efforts in Minnesota, MPCA staff contacted six of the facilities with ICI boilers that used the higher levels of coal. While the facilities were just starting to formulate strategies for coming into compliance with the ICI boiler standard, we learned:

- Two facilities had tested mercury emission rates above the NESHAP and therefore were in the process of evaluating changes necessary to achieve compliance with the NESHAP.
- One facility determined that no changes were necessary to meet the mercury limit in the NESHAP but other issues required plant updates.
- One facility converted to natural gas in 2012.

The other facilities did not share whether changes were expected to achieve compliance with the mercury limit in the NESHAP.

Mercury control options

Reducing mercury emissions can be accomplished through a number of methods. All of these methods are being evaluated at existing Minnesota facilities to address mercury and/or particulate matter controls:

- **Improve mercury emission rate estimates.** Some facilities appear to require mercury emission reductions because there is no site-specific information. Testing at existing industrial boilers show that actual emissions can be lower than EPA emission factors due to site-specific characteristics, e.g. burning low-mercury coal, or existing air pollution control devices remove enough mercury to be below a threshold. By performing a stack test, site-specific information can be used to determine actual emission rates rather than using EPA emission factors. Site-specific information may reduce the estimated release of mercury.
- **Improve PM capture overall.** Improving PM capture will improve mercury capture by collecting mercury being emitted as a particle, as well as allowing for the inherent ability of fly ash to act as a sorbent. Installation of a "polishing" fabric filter following the electrostatic precipitator (ESP) to capture mercury also controls mercury by providing contact surface and residence time to facilitate the mercury removal process. Improved mercury capture with better PM controls may be demonstrated at ADM Mankato, where the boiler has a fabric filter. Stack testing has demonstrated low mercury emissions. If an industrial boiler needs to improve PM capture to comply with the federal industrial boiler NESHAP, installing a fabric filter may be sufficient to address both PM and mercury.

[10] The NESHAP measures PM emissions according U.S. EPA Method 5, called filterable PM.

- **Switch to natural gas.** Because the purchase price of natural gas has dropped significantly, this becomes a more viable option for controlling emissions of a number of regulated pollutants. The ability to switch to natural gas depends on a number of factors, including the availability of natural gas supply. Data collected by the Energy Information Agency indicates that industry has consumed more natural gas than in the previous five years for firing boilers and in combined heat and power operations, like municipal utilities, suggesting that fuel switching may already be underway.[11]
- **Purchase lower-mercury coal.** Depending on current sources, owners or operators may be able to switch coal suppliers.
- **Use a halogen additive on coal.** Improving the halogen content of coal improves mercury capture in existing air pollution control devices. In cost analyses prepared for utilities in Minnesota, this option has been more expensive that retrofitting air pollution controls, but may be more feasible at industrial boilers where the reduction requirements are not as aggressive as required at Minnesota utilities.
- **Use biomass in place of coal.** This alternative is similar in approach to burning natural gas, by switching to a fuel with less mercury. The feasibility of this alternative will depend on fuel availability, current fuel use (is the unit already burning biomass?) and the total reductions necessary at a single boiler.
- **Install activated carbon injection.** ACI has been shown to be very effective in controlling mercury, depending on carbon injection rates.

Estimating mercury control costs at ICI boilers

In order to estimate compliance costs and emission reductions under the NESHAP for ICI boilers, EPA identified boilers and estimated compliance costs. The MPCA has reviewed this work, and has chosen to use EPA cost algorithms for ACI to estimate compliance costs for Minnesota boilers. Most boilers have existing PM controls that are compatible with ACI. For purposes of determining capital and annual costs, the MPCA is assuming that each Minnesota boiler operator would select activated carbon injection to achieve mercury reductions. As identified above, there are a number of other options for addressing mercury emissions, and the MPCA understands that each of the alternatives is under consideration at different boiler locations in Minnesota. Each alternative has a capital and annual operating cost; it is likely that ACI injection would represent the highest cost because of higher ongoing annual costs in purchasing carbon.

The cost estimate for ACI is based on utility experience in installing and operating activated carbon injection. As directed by the TMDL Implementation Plan strategy for this mercury-emitting industrial sector, the MPCA identified each coal-fired boiler emitting more than two pounds of mercury in 2011, then estimated the total capital and annual cost of an ACI system for each boiler.

Carbon injection rates are affected by the type of particulate matter capture device. When ESPs are used for PM capture, a carbon injection rate of five lbs/MMacf of stack gas (flue gas) is used in the cost algorithm; the assumed carbon injection rate for facilities with fabric filters is two lbs/MMacf. Carbon is assumed to cost $1500/ton, and ash is landfilled. Injecting carbon increases the particulate matter load on existing particulate matter capture devices, and so the impact on PM compliance must also be evaluated.

Estimated cost of compliance

The results are shown in Table 4. With a compliance threshold of five lbs/yr (such that industrial boilers in the table emitting between two to five lbs/yr of mercury would not be subject to

[11] U.S. Energy Information Agency. "Industrial Sector Natural Gas Use Rising". http://www.eia.gov/todayinenergy/detail.cfm?id=11771 June 20, 2013.

emission reduction requirements), the MPCA estimates that the proposed rule will result in the potential expenditure of approximately $26.8 million in capital costs. Total statewide annualized costs are estimated at $4.9 million per year. Annual costs include a capital recovery factor, carbon purchase, maintenance, and testing. Testing costs are discussed later in this document. At the five lbs/yr threshold, MPCA estimates that there will be a reduction of 79 lbs/yr of mercury emissions. This indicates a per pound cost of mercury reduction of approximately $60,000 for industrial boilers, the least cost-efficient mercury reduction of the different types of facilities to which this rule applies.

Table 4. Calculation of Retrofit Cost of ACI for ICI Boilers in MN*

Capital cost	$ 27,966,374
Total annual cost	$ 4,643,000
Total amount of mercury reduced, pounds	79
$/lb mercury	$ 58,777

**See Appendix C for an additional break-down of the costs.*

Activated carbon injection installations are similar in equipment and space requirements. Activated carbon injection systems include footings/slab for carbon storage, a carbon storage silo, pneumatic pumping, metering, piping, and lances within flue gas ducts. The cost algorithm for this technology is based on utility experience. Most utility boilers using this technology are far larger than industrial boilers of interest here; as ACI is developed, costs will potentially fall. The MPCA is confident that these estimates are upper-bound estimates.

The capital and annual cost has been calculated for each boiler. Some facilities have more than one boiler, and it is possible that ACI systems could be designed to share equipment. It is expected that facilities will investigate alternatives to select the least-cost option for reducing mercury. Each facility will make a decision based on site-specific factors. As was the case for the ferrous mining and processing industry, due to firms being able to select least-cost options to achieve the required emissions reductions as well as potential economies of scale for facilities with multiple boilers, the compliance costs estimated in this report are likely to be upper bound estimates.

More importantly, the proposed rule anticipates that an affected facility will evaluate mercury control options at the same time as it is evaluating overall pollution control requirements to comply with the federal NESHAP. This timing will allow for the facility to address mercury emissions in concert with the other pollutants that require control, and will help control, and potentially reduce, the cost of ACI. Otter Tail Power describes this cost savings potential in its quarterly report to the Minnesota Public Utilities Commission on the progress of the Big Stone Power Plant air pollution control retrofit project:

> *"The EPA has issued the Mercury and Air Toxic Standards ("MATS") rule, also known as the utility Maximum Achievable Control Technology ("MACT") rules, which require control of hazardous air pollutants….The rule as issued requires the Big Stone Plant to reduce mercury emissions, which can be controlled by adding ACI to the project. The estimated cost to add ACI as a standalone project is $5M [million]. Because of the synergies of installing the system at the same time as the AQCS [air quality control system] the owners have decided to include the ACI system as part of the scope of the AQCS project. Because of the synergies captured by doing construction at the same time as the AQCS Project, we have only*

increased the projected cost of the AQCS project by $2.1M to account for the ACI system."[12]

The cost estimates for ACI assume a stand-alone project, and are likely to be high. As demonstrated above, simply by including the ACI system within a total facility project will result in lower costs due to fixed costs (engineering, financing, contractor costs, owner's costs) be distributed over a larger project, as well as the factors described by Otter Tail Power. Additionally, especially for units emitting near the five pound threshold, other control alternatives are likely to be lower cost. For some sources, current emission estimates are based on EPA emission factors and not on site-specific information; expending effort to conduct stack testing may demonstrate the unit to be emitting below the threshold and thus not be affected by this rule. Alternatively, if the service is available, it may be more economic to purchase some natural gas to displace coal and its corresponding mercury emissions rather than investing in air pollution controls.

Indirect or spillover costs or other economic impacts are even harder to predict that was the case for ferrous processing furnaces since these industrial boilers come from a variety of industrial sectors, including agriculture/food production, ferrous mining, and electrical utility, and represent both private sector corporations and public sector utility providers. The sugar beet industry is the most affected industry, comprising just over 60 percent of all the estimated costs incurred by industrial boilers. Minnesota and North Dakota sugar beet producers represent the largest sugar beet producing region in the United States accounting for about half of the nation's production[13]. Total direct economic impacts from the sugar beet industry (sugar beet production, processing and marketing) just in Minnesota were estimated at $670 million in 2003, with an additional $1.2 billion in secondary impacts in Minnesota[14]. It is a large and growing industry in the state. As was the case for ferrous processing furnaces, there is the potential for both positive and negative impacts on employment in the industry resulting from the adoption of this rule. Installation, operation and maintenance of mercury control equipment could produce additional jobs in the sugar beet industry and the other industries that operate industrial boilers and are subject to this mercury reduction rule. Yet, if higher operating costs lead to higher market prices and decreased consumer demand, a decrease in employment could result. Due to the relatively small abatement costs associated with this rule relative to the size of the industries that need to adopt them, the MPCA does not expect significant employment impacts on the industries that operate industrial boilers.

Mercury emissions threshold for affected boilers

The total statewide estimated capital investment of $27.9 million, with a total annualized cost of $4.6 million, will reduce 79 pounds of mercury annually at boilers whose current mercury emissions are estimated to be at or greater than five pounds per year. The proposed rules establish a five lb/yr threshold for ICI boiler owner/operators to prepare a reduction plan.

The MPCA has evaluated the cost of controlling mercury from industrial boilers emitting above two pounds per year, as recommended in the TMDL Implementation Plan[15]. For this larger set of affected boilers the total statewide estimated capital investment at ICI boilers increases to approximately $40.7 million, with a total annualized cost of $6.2 million, reducing an additional nine pounds of mercury. With the expanded list of boilers subject to reduction requirements at

[12] Rolfes, M. Otter Tail Power Company. In the Matter of Otter Tail Power Company's Petition for an Advance Determination of Prudence (ADP) for the Big Stone Air Quality Control System Project Docket No. E017/M-10-1082 Compliance Filing. July 12, 2013.
[13] http://www.crystalsugar.com/coopprofile/532.pdf
[14] Ibid.
[15] See Appendix C.

the two lbs/year threshold, these additional nine pounds of mercury reduced cost an average of $195,000 per pound. The MPCA believes it is uneconomic to require controls at units emitting less than five lbs of mercury per year.

V. Incorporation of Federal Mercury and Air Toxics Standard for Electric Generating Units

Proposed Minnesota rules for controlling mercury emissions from electric generating units establish the requirements for monitoring mercury emissions and incorporating federal rules.

The rule is needed to implement mercury emissions monitoring and reporting required by current Minnesota statute. The rulemaking does not on its own create additional requirements that require capital investment.

The federal rule being incorporated by reference in this rulemaking, the Mercury and Air Toxics Standard, has specific mercury reduction requirements that are more stringent than Minnesota's mercury TMDL implementation Plan for some of Minnesota's coal-fired EGUs. Therefore, the mercury TMDL is not imposing additional requirements; the federal rule is driving compliance requirements at these small EGUs.

As a result, no separate cost estimate is prepared for EGUs, as the rule does not on its own create requirements for which additional costs are expected.

VI. Solid Waste Incineration

Minnesota rule for controlling mercury is incorporating by reference federal standards for solid waste incineration: existing and new commercial and industrial solid waste incinerators, existing and new sewage sludge incinerators, new large municipal waste combustors, new small municipal waste combustors, new hospital/medical/infectious waste incinerators, and new other solid waste incinerators. The standards include mercury emission limits in addition to limits for other hazardous air pollutants.

The federal standards apply to solid waste incinerators irrespective of their being incorporated into state rules. As the rulemaking is being conducted in order for the MPCA to maintain the administration of the state's regulatory program under the Clean Air Act, there is no additional cost to solid waste incinerators through this rulemaking action.

Incinerators in Minnesota are regulated in Minnesota by existing Minnesota waste combustor rules, Minnesota Rules parts 7011.1201 to 7011.1285. Minnesota statute additionally regulates the regulatory response of solid waste incinerators in Minnesota by requiring a solid waste incinerator to cease operating if there is a violation of an air emissions permit emissions limit. (Minn. Stat. § 116.95) The proposed rule incorporates the reporting requirements needed in the event an emissions violation does occur. Minnesota statute requires demonstrating compliance to resume operations, which in some cases requires conducting a performance test, an expense to the owner to resume operations.

Because expenditures for additional performance tests are only necessary if there is a violation, not because of a requirement of the rule, no separate cost estimate is prepared for these affected mercury emission facilities.

VII. Mercury Reduction Plans

Producing a plan for reducing mercury requires resources. The MPCA recognizes that producing a plan requires a facility to commit staff time to developing a plan. Additionally, a facility may find

that it needs to rely on experts in engineering, construction, emissions testing, and environmental permitting. These costs are difficult to estimate because the cost is specific to the existing facility and rely on factors that are not quantifiable by the MPCA.

As a result the MPCA is assuming that an initial engineering report prepared for a facility will likely cost one percent of the total capital investment of the project, excluding any site testing (e.g. air emission tests or soil borings, etc.).

It is expected that no more than 17 facilities will be required to prepare a mercury reduction plan to address mercury emissions from 23 units; because the capital cost of an activated carbon injection system is typically around $3 million per installation, and that each facility has one system to install, the cost of preparing a plan ranges from $20,000 to $35,000 for each system needed. Total one-time statewide expenditures for preparing a plan are estimated at $460,000 to $805,000. Because some facilities have up to five emission sources that are subject to reduction plans, the largest facility is expected to spend $100,000 to prepare a reduction plan.

Engineering related to the selected project has been included in the total capital investment estimates as provided in the EPA cost estimate algorithms.

VIII. Permit Processing

Based on MPCA data, known sources of mercury emissions impacted by this rule are currently permitted and are not required to obtain a permit.

New mercury emission sources may have to obtain a permit depending on their emissions of other regulated pollutants. However, that is not viewed as an additional cost as they would have normally been required to obtain a permit even in the absence of this rule.

IX. Mercury Emissions Reporting

Annual emissions inventory reporting

If a stationary source emits more than three pounds of mercury per year, it is considered a mercury emissions source and under the proposed rule, some type of action is required. At a minimum, the source will be required to report mercury emissions to the MPCA's annual emissions inventory. Most air emission sources likely to be affected by the proposed rules already report to the annual air pollutant inventory. Therefore, including mercury as a reportable is not expected to represent significant initial or ongoing cost.

The MPCA has a statewide estimate of mercury emissions, based on the MPCA's current triennial work to inventory toxic emissions. The 2005 inventory identifies 146 facilities that are identified as emitting mercury. Table 5 below shows the breakdown of the number of sources emitting mercury.

Table 5. Number of Sources Emitting Mercury

Inventoried Point Sources		"Actual" annual emissions of category Calendar Year 2005	Percent of all emissions
Number of sources greater than 0.000 lb/yr	146	3,011	100
Number of sources greater than 1.0 lb/yr	98	2,997	99.5
Number of sources greater than 2.0 lb/yr	36	2,985	99.1
Number of sources greater than 3.0 lb/yr	30	2,981	99.0
Number of sources greater than 5.0 lb/yr	25	2,951	98.0
Number of sources greater than 10.0 lb/yr	14	2,869	95.3
Number of sources greater than 25.0 lb/yr	9	2,790	92.7

The TMDL Implementation Plan selected a mercury emissions threshold of three pounds as the reporting threshold, in keeping with current statutory requirements at utilities (those EGUs emitting less than three pounds annually are not required to report mercury emissions annually to the MPCA).

Fewer than 35 facilities are expected to be reporting mercury emissions in an annual emissions inventory report to the agency. Facilities with air emission permits are already reporting annual emissions to the MPCA, and are using an online electronic data submittal process. The database is currently populated with mercury emission factors when available. After rulemaking, the facility will be responsible for ensure the accuracy of the emission factors and related activity factors, or include site-specific values if the database does not have such information.

The cost of preparing an annual mercury emissions report is therefore small. If it is assumed that for each facility, an additional two hours each year are added to the task of reporting mercury emissions to the MPCA, at the MPCA's staff labor rate of $150 per hour (direct and indirect), the 35 reporting facilities would be expend $10,500 annually statewide to report mercury emissions.

Mercury performance tests

Performance tests for mercury are expected to be needed by facilities to improve site-specific estimates, or to demonstrate ongoing compliance with mercury emission limits. The cost of testing is included in MPCA estimates of annual compliance costs.

EPA estimated the cost of performance testing in the industrial boiler NESHAP. The EPA's contractor estimated that mercury emission tests range from $10,000 to $15,000, assuming test ports are already installed. The MPCA compliance testing staff confirm that EPA's cost estimate is an upper bound reasonable estimate; therefore, it is used in this cost estimate to represent ongoing compliance testing costs for mercury.

X. Impacts to small business or cities

Minn. Stat. § 14.127 Subd. 1 requires the MPCA to assess the potential economic impact to small businesses or cities of this proposed rule. The statutory provision is as follows:

An agency must determine if the cost of complying with a proposed rule in the first year after the rule takes effect will exceed $25,000 for: (1) any one business that has less than 50 full-time employees; or (2) any one statutory or home rule charter city that has less than ten full-time employees.

For purposes of this section, "business" means a business entity organized for profit or as a nonprofit, and includes an individual, partnership, corporation, joint venture, association, or cooperative.

Of the source types expected to undertake compliance initiatives to comply with the proposed mercury rule (ICI boilers, ferrous processing facilities, iron and steel melters), none of the facilities can be classified as a small business.

However, it is expected that some small businesses may operate emission units that emit enough mercury that the business needs to report mercury emissions, and some effort is needed to quantify mercury emissions in the annual inventory. The definition of “mercury emission source” is intended to offer regulatory relief to sources with very low actual emissions, which are typically small businesses. The cost of preparing annual reports to the MPCA should be very small.

Therefore, the MPCA does not expect impacts to small businesses as a result of this rule.

Several cities in Minnesota operate coal fired boilers, providing electricity and/or steam for district heating and cooling. The coal-fired boilers are affected and compliance costs have been determined for these facilities as outlined within the discussion.

APPENDIX A

Calculation of Retrofit Costs for Ferrous Mining/Processing

PARAMETER	KEEWATIN TACONITE (KEETAC)	HIBBING TACONITE (HIBTAC)			Arcelor	MinnTAC					UNITED TACONITE (U-TAC)		Essar	Mesabi Nugget	TOTAL
LOCATION	Keewatin	Hibbing				Mountain Iron					Eveleth				
LINE NO.	1	1	2	3	1	3	4	5	6	7	1	2	1		
INDURATION TYPE	Grate Kiln	Straight Grate	Straight Grate	Straight Grate	Straight Grate	Grate Kiln	Grate Kiln	Grate Kiln	Grate Kiln	Grate Kiln	Grate Kiln	Grate Kiln	Straight Grate	Rotating Hearth	
FUEL	natural gas, coal	NG	NG	NG	NG	NG, biomass	NG, biomass	NG, biomass	NG, biomass	NG, biomass	NG, coal	NG, coal	NG		
Mercury Conc.	7	5	5	5	6	5.2	5.2	5.2	5.2	5.2	7	7	4		
SCRUBBER TYPE		Once through	Once through	Once through	Recirculating	Recirculating		Once Through	Once Through	Once Through	Recirculating	Recirculating			
WASTE GAS TO SCRUBBER	570000	620	620	620	629	247	381	349	302	304	250	580			
WASTE GAS AFTER SCRUBBER	750	771	771	771	854	276	581	533	461	464	289	493	756	400	
SOLID RECYCLE TO THE PROCESS	No	Yes	Yes	Yes	Yes	No	Yes	Not given	no	Not given	Not given	Yes	NA		
RECYCLE LOCATION	N/A	Grinding Mills	Grinding Mills	Grinding Mills	Tailing Thickener	N/A	Green Ball Feed	Not given	Not given	Not given	Not given	Green Ball Feed			
modify recycle location:	no	no	no	no	yes	NO	yes	Yes	*no*	*no*	no	no			
lbs Hg /yr (at 8250 operating hours per year)	122	96	96	96	116	40	40	36	31	32	54	125	77	70	1030
Lb controlled (75% reduction)	30.5	23.9	23.9	23.9	29.1	9.9	9.9	9.1	7.9	7.9	10.8	25.0	19.3	17.5	249
Mercury reduction															**782**
capital cost ACI															
ACI injection rate	7	3	3	3	5	3	3	3	1.1	1.1	5	5	1.1	1.1	
ACI injection rate	315	139	139	139	256	50	105	96	30	31	87	148	50	26	
Pipe diameter					10		15	15			10	10		10	
ACI system TCI	$ 3,863,381	$ 3,416,410	$ 3,416,410	$ 3,416,410	$ 3,745,483	$ 2,928,520	$ 3,274,449	$ 3,232,368	$ 2,720,869	$ 2,723,518	$ 3,183,639	$ 3,449,182		$ 2,663,554	
scrubber sludge reroute					$190,000		$265,000	$265,000						$190,000	
Total Capital Investment	$ 3,863,381	$ 3,416,410	$ 3,416,410	$ 3,416,410	$ 3,935,483	$ 2,928,520	$ 3,539,449	$ 3,497,368	$ 2,720,869	$ 2,723,518	$ 3,183,639	$ 3,449,182	$ -	$ 2,853,554	**$ 42,944,190.52**
Annual operating costs															
tons carbon /yr	1,299	572	572	572	1,057	205	431	396	126	126	358	610	206	109	
carbon purchase $/ton	$ 1,949,063	$ 858,701	$ 858,701	$ 858,701	$ 1,585,238	$ 307,395	$ 647,089	$ 593,629	$ 188,261	$ 189,486	$ 536,456	$ 915,131	$ 308,732	$ 163,350	
Fixed OM	$ 19,549	$ 17,287	$ 17,287	$ 17,287	$ 18,952	$ 14,818	$ 16,569	$ 16,356	$ 13,768	$ 13,781	$ 16,109	$ 17,453	$ -	$ 13,478	
CRF (5%, n=20 years)	$ 309,998	$ 274,133	$ 274,133	$ 274,133	$ 315,783	$ 234,984	$ 284,005	$ 280,629	$ 218,323	$ 218,535	$ 255,455	$ 276,762	$ -	$ 228,969	
TOTAL ANNUAL COST	$ 2,278,609	$ 1,150,121	$ 1,150,121	$ 1,150,121	$ 1,919,973	$ 557,198	$ 947,663	$ 890,613	$ 420,351	$ 421,802	$ 808,021	$ 1,209,346	$ 308,732	$ 405,797	**$ 13,618,466.98**
Capital cost for Baghouse and ACI															
ACI injection rate					1.1	1.1	1.1	1.1			1.1	1.1		1.1	
ACI injection rate					56.4	18.2	38.3	35.2			19.1	32.5		26.4	
scrubber sludge reroute					$190,000		$265,000	$265,000						$ 190,000	
baghouse					$ 10,000,000	$10,000,000	$ 10,000,000	$10,000,000			$10,000,000	$ 10,000,000		10,000,000	
ACI System					$ 2,984,497	$ 2,519,352	$ 2,816,949	$ 2,780,748			$ 2,536,806	$ 2,748,397		$ 2,663,554	
Total Capital Investment					$ 13,174,497	$12,519,352	$ 13,081,949	$13,045,748			$12,536,806	$ 12,748,397		$ 12,853,554	
Annual Operating Cost--Baghouse					$ 2,011,920	$ 2,011,920	$ 2,011,920	$ 2,011,920			$ 2,011,920	$ 2,011,920		$ 2,011,920	
Annual Operating Cost--ACI															
tons carbon /yr					233	75	158	145			79	134		109	
carbon purchase $/ton					$ 348,752	$ 112,712	$ 237,266	$ 217,664			$ 118,020	$ 201,329		$ 163,350	
Fixed OM					$ 15,102	$ 12,748	$ 14,254	$ 14,071			$ 12,836	$ 13,907		$ 13,478	
CRF (5%, n=20 years)					$ 1,057,122	$ 1,004,553	$ 1,049,696	$ 1,046,791			$ 1,005,953	$ 1,022,931		$ 1,031,369	
TOTAL ANNUAL COST Baghouse + ACI					$ 3,432,895	$ 3,141,932	$ 3,313,135	$ 3,290,445			$ 3,148,730	$ 3,250,087		$ 3,220,117	
Total Capital Investment in Mercury Control	$ 3,863,381	$ 3,416,410	$ 3,416,410	$ 3,416,410	$ 13,174,497	$12,519,352	$ 13,081,949	$13,045,748	$ 2,720,869	$ 2,723,518	$12,536,806	$ 12,748,397		$ 12,853,554	**$ 109,517,298.63**
Total Annual Cost of Mercury Control	$ 2,278,609	$ 1,150,121	$ 1,150,121	$ 1,150,121	$ 3,432,895	$ 3,141,932	$ 3,313,135	$ 3,290,445	$ 420,351	$ 421,802	$ 3,148,730	$ 3,250,087	$ 308,732	$ 3,220,117	**$ 29,677,198.35**

APPENDIX B

Calculation of Retrofit Cost of ACI for Gerdau Ameristeel, St Paul, MN

Parameters/Costs		**Equation**	
B. Total Capital Investment			
	1. Base cost, $ (BC)	= 1,350,000 x (CF^0.15)	$2,516,821
	2. Engineering and Construction Management costs, $ (ECM)	= 0.05 x BC	$ 125,841
	3. Labor adjustment for 6 x 10 hour shift premium, per diem, etc., $ (LA)	= 0.05 x BC	$ 125,841
	4. Contractor profit and fees, $ (CP)	= 0.05 x BC	$ 125,841
	5. Capital, Engineering and Construction Cost Subtotal (CEC)	= BC + ECM + LA + CP	$ 2,894,344
	6. Owners costs, $ (OC)	= 0.05 x CEC	$ 144,717
	7. Total capital, $ (TCI)	= CEC + OC	$ 3,039,061
C. Annual Cost - Fixed O&M			
	1. Maintenance material and labor, $/yr (MML)	= 0.005 x TCI	$ 15,195
	2. Administrative labor, $/yr (AL)	= 0.03 x 0.4 x MML	$ 182
	3. Total fixed O&M, $/yr (FOM)	= MML + AL + (CRF x TCI)	$ 217,327
D. Annual Cost - Variable O&M			
	1. Carbon sorbent, $/yr (CS)	= CF x Ca x H / (2000 lb/ton)	$ 252,810
	2. Waste disposal $/yr (WD) (flue dust landfilling)	= flue dust *45	$ 53, 217
	3. Total variable O&M, $/yr (VOM)	= CS + WD	
E. Total Annual Cost			
	1. $/yr	= FOM + VOM	$ 523,354
Sources:			

(1) Sargent & Lundy, IPM Model – Revisions to Cost and Performance for APC Technologies: Mercury Control Cost Development Methodology (Project 12301-009). March 2011. U.S. EPA Industrial Boiler Standards

(2) Activated carbon cost: The Innovation Group. Chemical Profiles: Carbon, Activated. 2002. Assumed 20% price increase based on online information from Norit, an activated carbon vendor.

APPENDIX C

Calculation of Retrofit Cost for Industrial Boilers in Minnesota

FacilityID	UnitID	PM Emission lb/mmbtu	2011 mmbtu	Mercury EF lb/mmbtu	2011 Hg emissions, pounds	Total Capital Investment	Total Annual Cost	mercury reduced (70% reduction from 2011)	$/lb	TCI	TAC GT 5 lb/yr	mercury reduced (70% reduction from 2011)	$/lb
AmericanCrystalMoorhead	Boiler 2	0.011	4,477,865	4.54E-06	20.33	$ 2,601,912	$ 352,314	14.23	$ 24,757	$ 2,601,912	$ 352,314	14.23	$ 24,757
AmericanCrystalMoorhead	Boiler 3	0.0046	4,444,159	3.80E-06	16.89	$ 2,675,513	$ 384,216	11.82	$ 32,502	$ 2,675,513	$ 384,216	11.82	$ 32,502
SouthernMNBeetSugarCoop	Boiler#1 EU-001	0.023	2,766,563	4.88E-06	13.50	$ 2,984,698	$ 581,926	9.45	$ 61,576	$ 2,984,698	$ 581,926	9.45	$ 61,576
NorthshoreMining	Unit 2 (EU 002)		4,686,492	2.31E-06	10.83	$ 2,876,110	$ 515,210	7.58	$ 67,987	$ 2,876,110	$ 515,210	7.58	$ 67,987
AmericanCrystalEastGrandForks	Boiler 1	0.028	1,407,566	7.22E-06	10.16	$ 2,929,580	$ 550,157	7.11	$ 77,336	$ 2,929,580	$ 550,157	7.11	$ 77,336
NorthshoreMining	Unit 1 (EU 001)		3,786,546	2.67E-06	10.11	$ 2,711,939	$ 426,813	7.08	$ 60,309	$ 2,711,939	$ 426,813	7.08	$ 60,309
Hibbing	Unit 3A	0.025	1,052,419	8.70E-06	9.16	$ 2,835,472	$ 463,062	6.41	$ 72,249	$ 2,835,472	$ 463,062	6.41	$ 72,249
CityofVAPublicUtil	Boiler 9	0.026	1,057,526	6.80E-06	7.19	$ 2,768,475	$ 422,514	5.03	$ 83,935	$ 2,768,475	$ 422,514	5.03	$ 83,935
AmericanCrystalEastGrandForks	Boiler 2	0.049	1,582,173	4.54E-06	7.18	$ 2,929,580	$ 550,157	5.03	$ 109,415	$ 2,929,580	$ 550,157	5.03	$ 109,415
ADMMankato	ASEA Boiler #5		1,130,704	7.00E-07	0.79	$ 2,653,097	$ 397,206	0.55	$ 716,921				
University of MN Twin Cities	SG201	0.037	641,818	5.24E-06	3.36	$ 2,413,425	$ 273,664	2.35	$ 116,356				
Willmar	Boiler 3	0.54	582,369	4.80E-06	2.80	$ 2,653,226	$ 360,241	1.96	$ 184,101				
AmericanCrystalCrookston	Boiler 3	0.0081	507,688	4.54E-06	2.30	$ 2,601,972	$ 322,733	1.61	$ 200,029				
AmericanCrystalCrookston	Boiler 2	0.024	492,762	4.54E-06	2.24	$ 2,530,394	$ 300,373	1.57	$ 191,809				
AmericanCrystalMoorhead	Boiler 1	0.022	473,773	4.54E-06	2.15	$ 2,601,912	$ 352,314	1.51	$ 233,995				
CityofVAPublicUtil	Boiler 7	0.025	399,959	3.50E-06	1.40								
DESPHansONyman	EU003	0.184	191,165	4.88E-06	0.93								
Hibbing	Unit 2A	0.034	264,486	3.40E-06	0.90								
Hibbing	Unit 1A	0.035	206,091	3.75E-06	0.77								
ADMCornDivision Marshall	Coal Boiler #1 EU049		143,293	4.88E-06	0.70			0.70				0.70	
ADMCornDivision Marshall	Coal Boiler #2 EU050		143,293	4.88E-06	0.70			0.70				0.70	
DESPHansONyman	EU002	0.189	138,431	4.88E-06	0.68								
AmericanCrystalCrookston	Boiler 1	0.016	492,762	4.21E-07	0.21								
University of MN Twin Cities	SE4		28900	5.24E-06	0.15	$ -	$ -						
					125	**$40,767,302**	**$6,252,900**	**84.69**	**$ 73,833**	**$ 25,313,277**	**$4,246,369**	**75**	**$ 56,512**

Notes:

Locations with site-specific mercury emission factors: University of MN SE Heating Plant (December 2007), Northshore Mines (July 2008), City of Virginia (January 2011), City of Hibbing (September 2004), American Crystal Sugar Moorhead (2005), ADM Mankato (2008)

ADM in Marshall air emissions permit issued in April 2012 authorizes the decommissioning of two coal fired boilers with the installation of two new natural gas fired boilers by 2014.

Estimated capital, annual costs from "Revised (November 2011) Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants-Major Source" EPA HQ-OAR-2002-0058-3384 www. Regulations.gov

Capital recovery: i=5%, n=20 years.