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ASSESSMENT OF THE LEVEL OF POSSIBLE CONTROL OF MERCURY EMISSIONS-TO-AIR FROM CANADIAN ELECTRIC POWER GENERATION FACILITIES

DELIVERABLE 3 – 2ND DRAFT TASK 1 REPORT

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Executive Summary

The central objective of this project is to quantify the cost of mercury control for the Canadian coal fired power industry. The focus of Task 1 was to identify mercury control technologies most appropriate for application by the Canadian coal fired power industry to achieve nominal mercury removal targets of 70%, 80%, and 95%. The analysis was conducted around three nominal plant configurations, which were representative of Canadian units burning bituminous, subbituminous, and lignite coals. A two stage assessment approach was used. First, a long list of technology options was assessed using a multi-criteria decision model that considered commercial, performance, and cost criteria. This assessment resulted in a short list of a number of technologies that were at relatively advanced state of commercial development. The economic analysis then compared the short-listed technologies based on their respective costs to achieve the target levels of mercury removal.

Canadian utilities have made mercury-specific investments in air pollution control equipment to meet the Canada-wide Standards for 2010 for mercury from coal-fired electricity generating stations. This state of technology is a reference case for analysis and discussion within this Report and becomes the Status Quo in further analysis. .

The options for mercury reduction can be conveniently grouped into three approaches. The first changes the mercury content in the fired fuel by cleaning, typically coal washing, or blending coals to obtain lower mercury content, or to provide an oxidants composition that will produce a high share of oxidized mercury from its combustion under typical conditions. The first can also be thought of as a form of pollution prevention, respecting coal combustion, because it avoids the entry of mercury to the system.

The second group of technologies are based on activated carbon sorbents. If oxidized mercury is present, it can be captured on Powdered Activated Carbon (PAC). If PAC is used, it can be made more effective by use of Sorbent Enhancement Additives, until all of the oxidized mercury is captured. If the mercury is captured on carbon, the collection of the mercury-containing carbon can be made more effective by changing the particulate collection system from an Electrostatic Precipitator to a Fabric Filter (FF). Fine particulate matter (PM), with its associated mercury that would have passed the ESP will be captured in a FF, increasing the effectiveness of mercury reduction.

If the mercury is not present as oxidized mercury, oxidants can be added to make it amenable to capture. The oxidants can be added to the PAC, like brominated activated carbon, so that some elemental mercury is oxidized in situ and adsorbed on the PAC. Oxidants, like hydrogen bromide, can be added with the coal at the front end of the process, producing an oxidizing environment in the boiler, so that oxidized mercury is dominant when the flue gases reach the sorbents at the back end.

It was noted above that a FF will provide a better collection of PM fines, with adsorbed mercury, then ESPs. Hence the availability, or switch to, an FF provides better mercury capture, where the mercury is adsorbed on particles or PAC. The effective capture of mercury in the fly ash may change the potential or price for ash sales, because of the presence of mercury and/or carbon. To retain the greatest sales potential, and to avoid the cost of full replacement of an ESP, a "polishing" FF (pFF) may be added to the ESP, to capture mercury at a location following the main collection of ash. This limits the mass of ash that might not be eligible for sale, or might need special management. The addition of a pFF also enhances the overall mercury collection, when added after an ESP, because it will remove fines that by-pass the ESP, but contain high mercury content.

If a pFF is not an optimum choice, the PAC can be added to the final field of an ESP, after the main collection of ash has occurred, again limiting the mass of ash in which mercury and carbon would be present.

The third technology group represents "opportunity" for mercury capture as a "co-benefit" of the presence of air pollution collection devices installed for other operational or environmental performance requirements. The use of Selective Catalytic Reduction for control of nitrogen oxides (NO_x) also has been shown to oxidize mercury in the flue gas. The activity of oxidized mercury is also reflected as enhanced water solubility, so the presence of a wet scrubber for sulphur oxides and acid gas control, provides a capture point for oxidized mercury.

If not all of the oxidized mercury is collected in the water of the scrubber, PAC can be added to provide to ability to capture the remainder, and the presence of a FF maximizes the mercury and sorbent collection. The presence of SCR and wet FGD occurs in response to simultaneous sulphur and nitrogen oxides requirements. Hence, the "opportunity" for mercury co-beneficiation, which can, as described, be further enhanced.

If the nitrogen oxides removal occurs using low- NO_x burners, there will often be increased carbon in the fly ash. This can, under the right conditions, provide a useful surface for mercury capture, but it would not compete with PAC in terms of surface area/mass. Hence, SEA can be used in this technology chain to improve the potential capture of the carbon in ash. When PAC is used, a FF always provides better mercury capture efficiency than an ESP.

The actions to reduce the mercury entering the boiler, to enhance the likelihood of producing oxidized mercury, to provide the means to capture and remove oxidized mercury, or to take advantage of those present for other purposes, provide a number of options in their permutations and combinations. Some of the combinations have been developed to the point of trademarked technology, e.g. EPRI's TOXECON is simply the addition of PAC to a standard system, with the addition of a pFF to enhance mercury removal. TOXECON II™ is the process of adding PAC to the final field of an ESP, as discussed. The choices among the technology options become an optimization of the benefits and costs of changing the amount of oxidized mercury present and the most effective removal from that state.

Several observations on the status with respect to mercury control in coal fired power plants have bearing on the conclusions and recommendations made in this report. First, the majority of mercury control technology evaluation and testing conducted in North America over the last 10 years has been under the auspices of the United States Department of Energy National Energy Technology Laboratory (U.S. DOE/NETL). While there has been some participation by Canadian units within the U.S. DOE/NETL mercury program, most of the units used in the analysis were U.S. based, largely fired by U.S. coal grades, and utilizing plant emissions control regimes influenced by federal and state regulatory regimes. While there are many similarities between U.S. and Canadian based plants there are also differences, coal grade being an important example, which call for caution in basing an economic assessment of the cost of mercury control in Canada based substantially on U.S. data.

A related consideration is the variation in performance of the same technology, when applied at different plants. Differences in coal grade, air pollution control device configuration, and plant operating conditions will influence the cost and effectiveness of mercury control equipment. Cost and performance figures presented earlier in Section 5 are estimated based on simple averages of plants burning similar coal grades and employing similar air pollution control equipment as the characteristics of the hypothetical facilities described in the Reference Scenarios. In particular, test data suggests there may be considerable variation in sorbent injection rates required to achieve a stated level of mercury control between units that share similar characteristics. As sorbent consumption is the largest variable cost item in units employing sorbent injection systems, prudence suggests that conclusions made based on average consumption figures should be qualified with an error band that accounts for the variability in injection rates.

A third observation is with respect to the overall state of development of mercury control technology. The industry overall is still in a developmental state, characterized by having numerous technology options still in a developmental or early commercialization state and only a few that have been implemented on a commercial scale for which long term performance and cost data is available. Thus when recommending between technology options one must not only consider apparent technical and economic performance but also the "weight of evidence" that supports those figures. Conclusions based on long term testing at multiple units may likely more be representative than those based on long term testing at a single unit only, while long term testing is likely more indicative of permanent performance than parametric testing.

Similarly, there was considerable variation in availability and quality of economic data between different technology options. At one end of the scale, cost estimates for sorbent injection systems, and to a degree, sorbent injection plus polishing fabric filter are supported by numerous unit specific technical and economic evaluations, as well as surveys of technology adopters conducted by the United States Government Accountability Office (U.S. GAO). Thus, cost and performance estimates derived for these technologies, while subject to numerous unit specific factors, at least is based on a reasonably strong data set.

In contrast, data and literature on several technologies is limited, thus warranting caution when developing generalized conclusions on cost and performance. Mer-cure™ for example, offers potential for high rates (95% +) of mercury removal effectiveness at a lower cost than other technology options in plants burning subbituminous and lignite coals. Based strictly on the test results available, one might conclude that Mer-cure™ would be the technology of choice for subbituminous and lignite-fired plants. However, the data set behind the Mer-cure™ results, appears limited. Tests conducted at four plants, summarized in XXX, were based on the use of a modular test platform rather than permanently installed equipment, and it is uncertain that the very promising test results could be reproduced under long term plant operating conditions. As well, there is limited hard data on equipment and sorbent costs supporting the economic case for Mer-cure.™ Thus, while the Mer-cure™ system may be worth considering as a means of lowering the cost of mercury control, its recommended that the baseline cost assessment be based around technologies for which there is a richer data set, such as carbon sorbent injection.

Scenario 1 215 MW, 70% capacity factor, bituminous coal

Scenario 1 represents a hypothetical Nova Scotian unit, burning eastern bituminous coals, and equipped with a cold side electrostatic precipitator for particulate matter control. Nova Scotian units import a proportion of the coal fired at their facilities and thus could potentially employ coal blending as a means of reducing mercury emissions. However, coal blending alone would be insufficient to achieve 70% mercury removal due to the limited ability of cs-ESP in removing oxidized mercury. As well, unit operators need to consider potential trade-offs between a variety of emission and performance related objectives (including SO_2, emissions) thus possibly reducing the effectiveness of coal blending as a stand-alone tool for mercury emissions control.

Eastern bitumuminous coals sold on the open market are typically washed by the mine operator, in order to reduce both the mineral fraction and sulphur content. Given the limited potential to remove mercury through blending suggests that the minimum 70% target cannot be achieved without resorting to mercury specific technologies. An exception to this conclusion is found in the case of the Maxim Power's H.R. Milner Plant in Grand Cache, Alberta, which burns washed bituminous grade coal. The Milner plant is equipped with a fabric filter baghouse, enabling it to achieve total mercury removal of over 85% without employing mercury specific control technology.

A number of technology options have been shown to remove at least 80% of total mercury from bituminous coals, including PAC, brominated PAC, Mer-Cure™, PAC and TOXECON™. As the 70% to 80% mercury removal target can likely be achieved without the need for a polishing filter fabric the technology choices at these levels of mercury removals would focus on the most cost optimal combination of oxidation and sorbent removal technology.

Activated carbon injection using a brominating PAC is estimated as the most cost effective technology for achieving 70% to 80% total mercury in a bituminous burning unit. Oxidizing agents have not been widely tested in bituminous plants. Mer-Cure™ has been tested at only one bituminous-fired unit – while it achieved high reported levels of mercury removal, sorbent consumption rates were also high, likely rending the process uneconomical in comparison to a conventional injection system using brominated PAC.

Mer-Cure™ and TOXECON™ (activated carbon injection plus polishing fabric filter) were the only technologies identified as having removed over 95% total mercury in bituminous burning facilities. Of the two technologies, Mer-Cure^{TM} would likely require much lower capital expenditure. However, based on limited industry testing, a relatively high level of sorbent injection is required using to Mer-Cure^{TM} to achieve 95% mercury removal. Therefore, the TOXECON^{TM} configuration is the recommended benchmark technology for the 95% mercury removal target.

Units that sell their fly ash would incur additional disposal cost and forgone revenue if they switched to BACI for mercury control. However, for Scenario 1, the estimated amount of revenue foregone and added disposal cost would not justify adding a polishing fabric filter, assuming target mercury capture of 80%. Toxecon II^{TM} may be a cost effective means of maintaining fly ash sales at the 70% mercury capture level, though the effectiveness of Toxecon II^{TM} in bituminous burning units has not been evaluated.

Scenario 2 400 MW, 70% capacity factor, subbituminous coal

Mercury control technologies have been most widely tested on units that burn subbituminous grades of coal. However, such tests have been conducted on plants burning powder river basin coals, which have several qualitative differences to coals typically burned by the typical "Albertan" subbituminous burning unit employing cs-ESP as PM control, which served as the basis for the hypothetical Scenario 2 unit.

Coal blending and washing were not identified as effective strategies for reducing mercury emissions from subbituminous coals. While partial blending subbituminous coal with small quantities of higher halogen western bituminous coals has been shown to result in native mercury capture of over 70% in a unit equipped with a fabric filter (source), this level of mercury removal is generally not achievable in units that use cs-ESP for PM control. Coal washing would not likely be an economic method for removing mercury in Albertan subbituminous coals as such coals feature low pyritic mineral levels, and therefore would not benefit from conventional gravimetric separation technologies.

A number of technology options have been shown to remove at least 80% of total mercury from subbituminous coals, including PAC, brominated PAC, PAC plus coal additives, Mer-Cure^{TM}, TOXECON^{TM} and TOXECON^{TM} II. As the 70% to 80% mercury removal target can likely be achieved without the need for a polishing filter fabric the technology choices at these levels of mercury removals would focus on the most cost optimal combination of oxidation and sorbent removal technology.

Activated carbon injection using Mer-Cure^{TM} was found to be the most cost effective technology for achieving 70% to 80% total mercury in a subbituminous burning units, followed by PAC plus coal additive, then brominated PAC (BPAC). As discussed above, Mer-Cure^{TM} has been demonstrated to remove high levels of mercury at low sorbent consumption rates for subbituminous coal grades, but there has been only limited testing, no identified commercial installations, and limited economic data for which to conduct a cost analysis. By contrast the mercury removal effectiveness as well as cost estimates for ACI based on BPAC are supported by a relatively rich data set. As well, ACI using BPAC is the technology of choice by many U.S. and Canadian subbituminous burning units that have, or are in the process of installing mercury control technology. Therefore, it is recommended that ACI based on BPAC be the benchmark technology for evaluating the cost of achieving 70% to 80% mercury control for Canadian subbituminous burning units. Brominated PAC, Mer-Cure™ and TOXECON™ (activated carbon injection plus polishing fabric filter) have all been reported to achieve over 95% total mercury in subbituminous burning facilities during parametric testing.

If the unit is selling fly ash, then the use of sorbent injection systems could result in foregone ash sales and additional ash disposal cost. Assuming that the unit foregoes ash sales based on 50% of the quantity of fly ash generated each year, ash sales price of $21/MT and ash disposal cost of $20/MT then the unit would incur and additional $4.1 million in costs and forgone revenue each year. In this case, the lowest cost technology is TOXECON II™, which allows for recovery of 70% to 80% of fly ash, and has been proven effective at collecting up to 80% of mercury in units burning subbituminous coals. While a polishing fabric filter plus ACI combination (i.e. TOXECON™) results in a higher proportion of saleable fly ash, the capital cost of TOXECON™ render it not economically competitive at the 70% mercury recovery level. TOXECON II™ has been shown effective at up to 80% total mercury removal, though it has been subject to only limited commercial testing. At the 95% level of mercury removal, TOXECON™ is the recommended benchmark technology for units that sell a proportion of their fly ash.

Scenario 3 170 MW, 70% capacity factor, lignite coal

The situation regarding natural endowment from provincial coal fields is dominant in lignite facilities, which means that the substitution and blending options are not likely to meet decision making criteria for these facilities. As with subbituminous grades, coal washing is generally not considered an economically viable method of mercury removal for lignite coals.

The technology choices available for lignite fired facilities is comparable to those burning subbituminous coals, though the breadth of commercial testing has been more limited. At the 70% to 80% level of mercury removal, Mer-Cure™ has been demonstrated to be the lowest cost technology option, followed by ACI plus oxidation additives, and then brominated PAC. As with bituminous and subbituminous grades, there is limited data available on Mer-Cure™, so while the technology appears promising it is not recommended as the benchmark technology for the industry cost analysis. BPAC and PAC plus oxidation additives have been subject to more extensive testing in lignite facilities. As test results indicate PAC plus oxidation additives are the most cost effective of these two technologies, it is recommended as the benchmark technology for the industry cost analysis.

If the unit is selling fly ash, then the use of sorbent injection systems could result in foregone ash sales and additional ash disposal cost. Assuming that the unit foregoes ash sales based on 50% of the quantity of fly ash generated each year, ash sales price of $21/MT and ash disposal cost of $20/MT then the unit would incur and additional $2.3 million in costs and forgone revenue each year. This level of additional operating cost would justify an investment in a polishing fabric filter at the 70% mercury removal level.

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ACRONYMS

ACI	Activated Carbon Injection
AEA	Air Entrainment Agent
BACI	Brominated Activated Carbon Injection
BPAC	Brominated Powdered Activated Carbon
cs-ESP	cold side Electrostatic Precipitator
CAMR	Clean Air Mercury Rule (U.S. regulation)
CCME	Canadian Council of Ministers of Environment
CEA	Canadian Electricity Association
CWS	Canadian Wide Standards
ECRF	Emission Control Research Facility (SaskPower)
EERC	Energy and Environmental Research Centre
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulphurization
hs-ESP	hot side Electrostatic Precipitator
HAP	Hazardous Air Pollutant (U.S. regulatory definition)
NETL	National Energy Technology Laboratory
OFA	Over fired air
OPG	Ontario Power Generation
SDA	Spray Dry Absorption or Spray Dry Absorber
PAC	Powdered Activated Carbon

PM	Particulate matter
PRB	Powder River Basin (subbituminous coal)
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency

1.0 Introduction

1.1 Background

Research into mercury emissions from coal-fired power plants has been undertaken in Canada since the 1990's. In 2002 the Canadian Electricity Association (CEA) implemented the CEA Mercury Program. The objective of this program is to improve the information base around mercury generation from coal-fired power plants. Participating firms consist of eight of the largest Canadian utilities that operate coal-fired power stations. Under the program, participating firms share information on mercury research and development, sampling, and analysis. The intent of the program are to provide information to assist with development of mercury emission standards and to assess options for mercury emission control by the power generating sector (CEA website).

The Canadian Council of Ministers of Environment (CCME) has been investigating the means of reducing mercury emissions from coal-fired power plants since the 1990's. In 1998 the CCME contracted SENES Consultants Limited to assess the costs of mercury controls for the Canadian power generation sector. The final report entitled *Evaluation of Technologies for Reducing Mercury Emissions: Power Generation & Base Metal Smelting* (SENES 1999) included mercury control costs estimates based on Environment Canada's RDIS II database.

SENES was contracted by the CCME in 2002 to update its earlier work. The report entitled *Evaluation of Technologies for Reducing Mercury Emissions from the Electric Power Generation Sector* (SENES 2002) was based on a more comprehensive review of literature, data from the Coal-fired power generation sector, and personal communications with industry experts. SENES (2002) drew on data collected by the U.S. Environmental Protection Agency to estimate mercury removal efficiencies by control technology for bituminous, subbituminous, and lignite coal types. SENES (2002) then estimates the cost of installing and operating mercury control equipment at each of the operating units in the Canadian coal-fired power industry, through the use of mathematical Cost Estimating Functions (CEFs) developed by the U.S. EPA. By applying the CEFs to the stock of operating units in Canada SENES (2002) estimates the efficiency and costs of a variety of mercury control technologies (and technology combinations) for each plant and operating unit.

In 2003 the CCME contracted the Energy and Environmental Research Centre (EERC) to review mercury control technologies for the Canadian coal-fired power sector. The report entitled *Technical Review of Mercury Technology Options for Canadian Utilities* (EERC 2005) drew on data provided by the U.S. Department of Energy (DOE) National Energy Technology Center, the U.S. E.P.A., and the Canadian Electricity Association. EERC (2005) is an "applicability - focused" technical evaluation of mercury control technologies, which assess the relative merits of the technology options based on a number of criteria including applicability, technology effectiveness, technology cost, commercial maturity, multi-pollutant capability, balance of plant issues, and environmental and technical implementation issues (EERC 2005). The report then assesses promising technology options for power plants in Alberta, Manitoba, New Brunswick, Nova Scotia, and Saskatchewan in consideration of unit sizes, coal types consumed, and type of particulate matter control.

There are over 50 mercury control technologies under development, but few have been commercially applied in operating power plants. While retrofitting a plant to burn non-mercury containing hydrocarbons (such as natural gas) is also a form of mercury control, most mercury control technologies seek to either reduce the mercury content of coal being combusted in a plant (such as through coal washing), improve the capture of oxidized mercury (i.e. through activated carbon injection) or chemical capture of elemental and ionic mercury species found in flue gases (such as sorbent enhancement additives, treated sorbents, and oxidation technologies). Depending on the fuel type burned at the plant, a large proportion of particle-bound mercury may be captured by equipment used to capture ash (i.e. electrostatic precipitator or baghouse). As well, NO_x and SO_2 control equipment can have the desirable co-benefits of capturing mercury.

1.2 Objectives

Environment Canada is committed to protecting both the environment and the health of Canadians from pollution, and is interested in exploring means of further reducing mercury emissions from coal-fired power plants. The objective of the current study are to better understand the technological options available to the power sector for reducing mercury emissions, and the potential costs involved in applying such technologies on the Canadian fleet of coal-fired electric power generation facilities.

1.3 Project Scope and Methodology

This project consists of two components, an assessment of mercury control technology options available to the Canadian fleet of coal-fired electric power generation industry, and an estimate of the cost of applying the most appropriate technologies to the fleet.

1.3.1 Phase 1 – Technology assessment

The technology assessment consisted of two parts. First, a broad review of mercury control options available or under development is presented. This review builds on earlier work (SENES 2002, EERC 2005) by providing more recent results of mercury control technology development in North America. Second, a performance assessment was conducted based on three hypothetical Reference Scenarios, identified by Environment Canada, to select technologies appropriate for use by Canadian coal-fired utilities.

1.3.1.1 Technology performance assessment and selection

The three Reference Scenarios are intended as generic facilities that cover a range of coal types and utility sizes. The scenarios are:

- **Scenario 1** – a 215 MW facility combusting bituminous coal and operating at 70% capacity while supplying baseload generation.
- **Scenario 2** – a 400 MW facility combusting subbituminous grade coal and operating at 70% capacity while supplying baseload generation.
- **Scenario 3** – a 180 MW facility combusting lignite grade coal and operating at 70% capacity while supplying baseload generation.

For each of these scenarios, technology options were identified that most cost effectively captured mercury based on three thresholds: >70%, >80%, and >95%.

To assist with the technology assessment, simplifying assumptions were used in regards to coal characteristics, plant boiler configuration and air pollution control devices (APCD), and fly ash disposal. These assumptions are based on characteristics of "typical" coal-fired utilities in Canada for each of the Reference Scenarios provided in the analysis, based on industry data. In Phase 2 of the project, plant specific characteristics and conditions were considered in estimating the cost of applying various levels of pollution control to the fleet of Canadian coal-fired power utilities.

Technologies were compared on the basis of several criteria related to commercial maturity, technology performance, and cost. A three step process was used to screen technologies. First, a number of technologies were screened from further consideration because either: (i) they could not capture the threshold levels of mercury, (ii) the technology is still in early testing phases and is not commercially available, and/or (iii) there was no identified data on costs associated with the technology. Short-listed technologies were then evaluated based on eight criteria related to commercial application, performance, and cost. An analytical hierarchical process (AHP) model was used to assist in the technology evaluation.

1.3.1.2 Technology cost assessment

The second component of the technology assessment was the evaluation of cost of mercury capture. The cost analysis was applied only to those technologies short listed for consideration from the technology performance assessment. The cost of mercury control for the reference scenario was based on estimated operating parameters by reference scenario, such as flue gas volume flow rate, and from capital and operating costs estimated from the literature

1.3.1.3 Technology recommendation

Based on a combination of technical feasibility, environmental performance, and ratio of total cost to capture efficiency, technologies or groups of technologies were recommended to control mercury emissions from Canada's fleet of electric power generation facilities.

1.3.2 Estimating cost to control mercury emission from the Canadian Fleet

1.3.2.1 Industry cost for achieving 70%, 80%, and 95% mercury capture efficiency

Based on information developed during Task 1 (Description of Canada coal-fired power industry) the size, fuel type, extent of existing mercury control equipment, and mercury speciation for each of the operating units within Canada's fleet of coal-fired power plants was identified. From the results of the technology assessment (Task 5) technologies (or groups of technologies) were proposed that have optimal characteristics of cost effectiveness, technical feasibility, and environmental performance at the 70%, 80%, and 95% mercury capture efficiency in consideration of the operating characteristics of each unit.

A spreadsheet model that estimated the costs associated with implementing the recommended mercury control equipment at each of the units was prepared. Costs were estimated on both a Net Present Value (NPV) basis and on a levelized basis for each unit and Reference Scenario. NPV calculations were based on a discount rate of 10%, along with sensitivity analysis based on parametric values identified in the Scope section of the RFP. Costs were also estimated on a $ per kW (NPV, levelized, and first year) for each of the Reference Scenarios. Where applicable, revenue lost from fly ash sales was considered. Separate estimates of the cost of mercury capture were also preformed, assuming the Canadian industry had installed NO_x and SO_2, control equipment.

1.3.2.2 Context

The objective of this report is to assess the cost of mercury control to the fleet of Canadian coal-fired power utilities based on three levels of mercury capture: >70%, >80%, and >95%. These targets exceed the current federal policy objective of 60% mercury capture, as defined in the *Canada wide standards for Mercury Emissions from Coal-fired Power Stations (CCME 2006).*

This analysis was conducted from a "mercury-centric" perspective. By this, technologies are selected assuming mercury emission control is the principal emissions policy objective. However, there are numerous federal and provincial objectives, regulations, and standards, concerning, for example, emissions of SO_2, NO_x, and greenhouse gases, as well as mercury emissions. In reality plants may select technologies that have potential for addressing multiple air quality objectives (including mercury) over those that are mercury specific.

The estimate of cost for mercury control to the Canadian coal-fired power industry was prepared on the basis of the state of the industry as of April 2010. As of that date, a number of plants had already installed mercury control equipment, including Nova Scotia Power's Lingan and Point Tupper and Trenton generating stations, and SaskPower's Poplar River generating station. Other utilities, have selected, and are in the process of installing mercury control equipment, including ATCO Power's Battle River and Sheerness generating stations, Capital Power's Genesee generating station and TransAlta's Sundance and Keephills generating stations. In the calculation of cost of mercury control to the fleet of coal-fired power units, historic or current investment in mercury control is included in the estimate, and likely extent of mercury capture by the selected technologies is considered. In other words, past or current investments in mercury control are not considered as "sunk" costs in the financial analysis.

Finally, it is recognized provincial regulatory or policy initiatives may render installation of mercury control equipment moot in the near term. For instance, in Manitoba, the *Climate Change and Emissions Reductions Act* (enacted June 2008) phases out the use of coal-fired generation by Manitoba Hydro, except in support of emergency operations. Application of this policy, which limits the utilization of the Brandon station to a maximum of 15% of operating capacity, would enable Manitoba Hydro to exceed its CCME target without having to invest in mercury control equipment.

Ontario currently has four coal burning plants, but Ontario Regulation 496/07 states these plants must cease burning coal by 2014. Ontario Power Generation is considering converting at least some of its coal burning stations to biomass.

For this analysis, it is assumed the Manitoba and Ontario plants will be available to produce power at full capacity, and mercury control options will be recommended accordingly. A sensitivity analysis was performed that incorporated reducing utilization at Brandon and the phase out of coal-fired plants in Ontario by 2014.

1.4 Report Structure

The report is divided into two parts. Part 1 is the performance assessment of current mercury control technologies and Part 2 is estimating the cost to control mercury emissions from the Canadian fleet of coal-fired power stations. Report elements are summarized below:

1.0 Introduction

This section provides the background to the current study, outlines the scope of work, report objectives and the report structure. The background section will describe the historical context of the current work, in light of Environment Canada's programs and initiatives with respect to Hg control in the coal-fired power industry, identify previous work in evaluating and estimating the cost of mercury control technology in Canada and provide the rationale for the current project.

PART I – PERFORMANCE ASSESSMENT OF CURRENT MERCURY CONTROL TECHNOLOGIES

2.0 Canada's Coal-fired Power Industry

This section provides an overview of the coal-fired power industry in Canada. It begins with a brief discussion of federal and provincial mercury control policy, regulations, and programs. Additional information on provincial programs will be included in sections on the coal-fired power industry in each province.

3.0 Mercury control technology

This section provides an overview of mercury control technologies. It begins with a discussion on technical considerations that influence the effectiveness of mercury control, including coal types and mercury speciation, plant operating characteristics, compatibility with existing air quality control equipment, and balance of plant issues with respect to installation and operation of mercury control equipment. The discussion on existing air quality control equipment considers the effectiveness of technologies for SO_2, NO_x, and PM in capturing mercury. The second sub-section provides an overview of the current state of mercury control technology development in the U.S. and Canada. The third sub-section provides an overview of mercury control technologies, including current state of commercial development, reported mercury capture effectiveness, considerations and constraints to use (coal type, other emission control equipment, operational constraints, and balance of plant issues).

4.0 Technical feasibility and performance assessment

This section provides a technical feasibility and performance assessment for technologies identified in Section 3.0. Technical feasibility and performance will be assessed using a multi-criteria evaluation model, which evaluates each technology or combination of technologies. The intent of the analysis is to develop a short list of 3 to 5 technologies for each of the Reference Scenarios to be included in the cost analysis, and for consideration for recommended technologies for use by the fleet of coal-fired power utilities in Canada.

5.0 Cost of reducing mercury

This section will present the analysis of cost of capturing mercury for the three Reference Scenarios by different technology options. Technologies short listed in Section 4.0 will be considered in this analysis. The technology cost assessment includes a work up of the total costs for each technology considered as well as technology cost levelized over an assumed 20 year operating life. Sensitivity analysis will include C$:US$ exchange rate and This exercise will be performed for technologies and groups of technologies required to achieve > 70%, > 80%, and greater than 95% capture efficiency. The final part of the cost analysis is estimating the lowest ratio of total cost to capture efficiency.

6.0 Part 1 conclusions and recommendations

The objective of this section is to identify technologies and groups of technologies recommended for adoption by the Canadian fleet of coal-fired power stations. The recommendations will be based on results from the technology feasibility and performance assessment and from the cost assessment. Discussion will include the rationale for the technology recommendations.

PART 2 – ESTIMATING THE COST TO CONTROL MERCURY EMISSION FROM THE CANADIAN FLEET OF COAL-FIRED POWER STATIONS

7.0 Industry cost analysis - approach and methodology

This section outlines the approach, methodology, and assumptions used to estimate the total cost of mercury control to the Canadian fleet of coal-fired power companies. This begins with a discussion of the relevant factors to be considered in proposing a technology or combination of technologies to any particular units. Factors include age and size of unit, coal type used, mercury speciation, current emission control equipment, existing Hg control equipment (as of March 31, 2010), planned Hg control equipment, estimated likely Hg capture of existing technologies, plant operating conditions, and balance of plant issues. Assumptions will include operating rate by unit and technology scalability. Based on the unit by unit considerations, and in consideration of the technology evaluation performed in Part 1 technology recommendations will be provided for each of the Canadian operating units.

8.0 Industry costs to implement mercury control

Presentation of analysis of industry costs to achieve three levels of mercury capture efficiency >70%, >80%, and >95%. Included in each sub-section is proposed technology or technology combinations for each unit and sensitivity analysis around financial parameters. If the plant already achieves required level of performance then this will be noted in the summary table. Scenarios considered include (a) three levels of capture efficiency: > 70%, > 80%, and > 95%, (b) same three level of capture efficiency as in (a) but assuming industry has already made the investment in NO_x or SO_2 resulting in a co-benefit control of mercury in the range of 70% to 85%. Factored into the analysis will be potential revenue lost if the technology choice prevents a firm from selling fly ash to the concrete industry (and thus also incurring additional disposal costs).

9.0 Industry cost to implement mercury control – assuming additional investment in NO_x and SO_2 control

Presentation of analysis of industry costs to achieve three levels of mercury capture efficiency >70%, >80%, and >95% assuming investment in NO_x and/or SO_2 achieving 70% to 85% Hg control has been made (by those units not already having such equipment). The section begins with a discussion of the considerations used in selecting SO_2 or NO_x technology for each of the operating units, such as fuel type and current boiler configuration. Based on this notional technology choice and estimated mercury co-benefit capture rate the cost of additional mercury control to achieve >70%, > 80%, and > 95% capture is provided. .

10.0 Conclusions and recommendations

The final section presents the overall conclusions and recommendations of the study. This includes a re-cap of key findings on the current state of the coal fire power industry in Canada, mercury control options, and costs for installing various technology combinations to achieve mercury reduction targets.