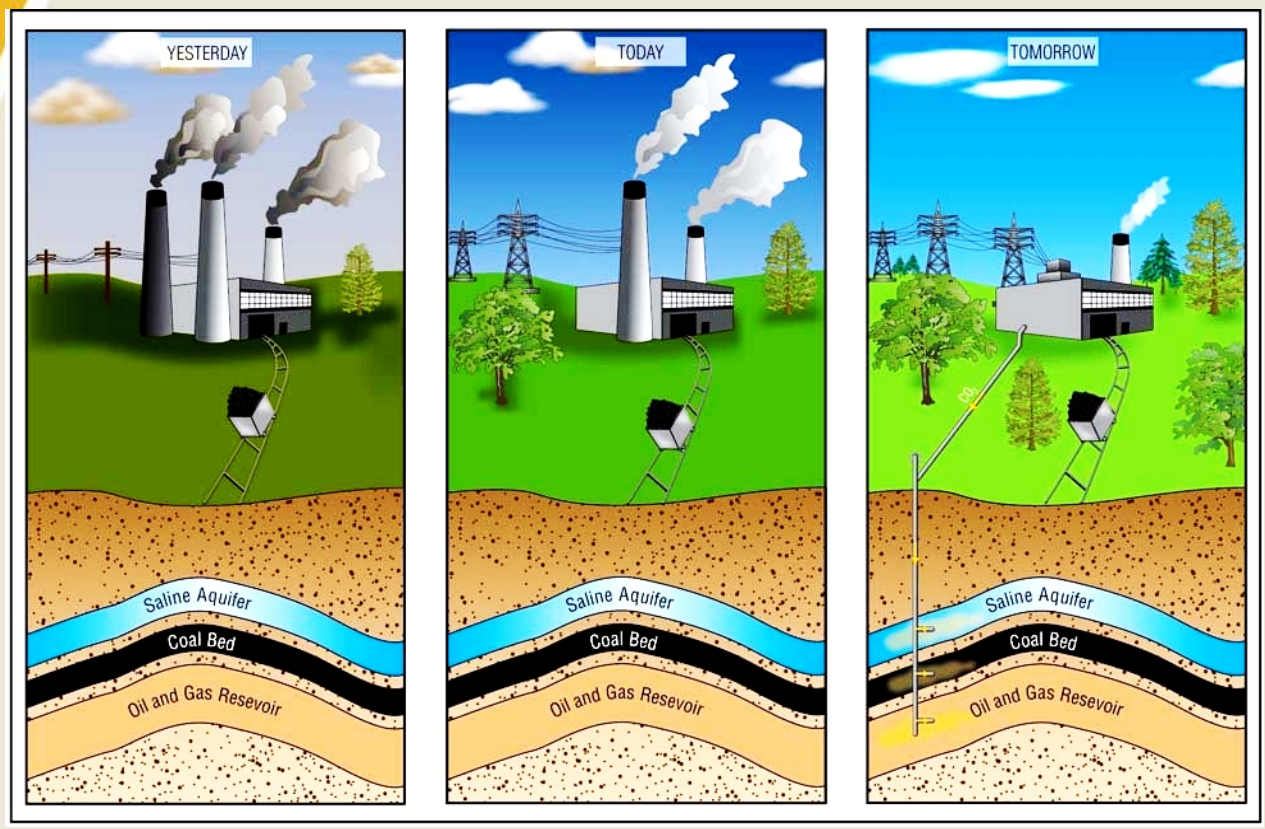
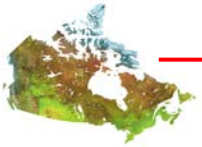
Clean Coal: A Compendium of Canada's Participation



Natural Resources Canada
Ressources naturelles Canada
Canada



Disclaimer

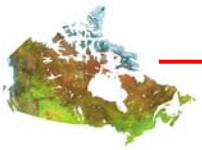
This publication is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada, nor its ministers, officers, employees and agents make any warranty in respect to this publication or assume any liability arising out of this publication.

Permission to Reproduce

The information in this publication may be reproduced, in part or in whole and by any means, without charge or further permission from Natural Resources Canada, provided that: due diligence is exercised in ensuring the accuracy of the information reproduced; that Natural Resources Canada is identified as the source institution; and that the reproduction is not represented as an official version of the information reproduced, nor as having been made in affiliation with, or with the endorsement of, Natural Resources Canada.

Aussi disponible en français sous le titre :
Le charbon propre : Recueil de la participation canadienne

Catalogue No.: M159-4/2007E-MRC
ISBN : 978-0-662-45998-9



CLEAN COAL:
A COMPENDIUM OF CANADA'S PARTICIPATION

Prepared for:

Natural Resources Canada, Industry Canada, Environment Canada
May, 2007

Prepared by:

Frank R. Campbell
14 Dalecroft Cresent
Ottawa, Ontario, Canada K2G 5V9

John F. Legg
418 Thessaly Circle
Ottawa, Ontario, Canada K1H 5W5

Scientific Authority:

Graham Campbell, Dubravka Bulut, Leah Dell, Andrew Henderson
Office of Energy Research and Development
Natural Resources Canada
580 Booth Street, 14th Floor
Ottawa, Ontario, Canada K1A 0E4

EXECUTIVE SUMMARY

Coal remains a key component of Canada's diverse energy supply picture, accounting for as much as 20% of electricity generation. Six of Canada's provinces rely to some degree on coal to supply electrical power, with three (Nova Scotia, Saskatchewan and Alberta) almost fully reliant. It is estimated that Canada has sufficient coal resources for more than 1000 years at current rates of utilization, with particularly extensive deposits in Western Canada. Moreover, a substantial portion of these resources can be recovered at costs that are a fraction of the current prices for oil and natural gas. Given that over the next 25 years Canada will need to replace 18,000 MW of existing coal-fired generation as well as expand its overall generation capacity by roughly 40,000 MW, there is the potential for a strong role for coal in future energy supply. Other solid fuels, such as petroleum coke, bitumen and others are also used in significant quantities to generate electricity and steam in Canada.

Despite its attributes and the continued need for it, if coal is to play a significant role in Canada's future energy supply, serious environmental impacts of coal usage will have to be dramatically reduced. Emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO and NO_2) have traditionally been the main concern. Proven technologies, such as flue gas desulphurisation, selective catalytic reactors, low NO_x burners and fluidized bed combustion, are available – albeit at a cost – to reduce these emissions. Recently, pending legislation on air toxics, especially mercury, on fine particulates, and on GHG emissions has emerged as a more formidable challenge. Canada's GHG emissions from electricity generation in 2004 were 130 Mt. The overwhelming proportion, about 75%, was from the use of coal.

The importance of retaining coal as a viable option for future electricity production has given rise to a great deal of work in Canada and across the world to identify, develop and implement clean coal technology (CCT). The needed technologies must be capable of approaching near-zero air emissions yet be implemented without excessive cost and low financial and operating risk. Compared to existing coal power plants, new CCT plants will soon be targeting near-zero emissions as a performance standard, and Canadian researchers, electric utilities and industry are at the forefront of making this happen.

The importance of coal in energy and environmental policy, the substantial public and private sector investment in clean coal science and technology (S&T), and the potential for Canadian industrial capacity to supply clean coal technologies to international markets has led Natural Resources Canada, Industry Canada, and Environment Canada to initiate a survey of Canadian clean coal activities. This Compendium is the result of that survey. It is expected that the Compendium will help the Canadian community engaged in CCT to identify gaps, set priorities, and promote cooperation. The Compendium can also serve to inform regulators and other decision makers of the extensive amount of work underway and the progress that has been made.

The Compendium is a broad compilation of current work and active participants, including not only scientific and engineering aspects, but also activities that address

economics, implementation, public education and outreach, and regulation. The Compendium applies the term clean coal in its broadest sense, including the full range of coals, pet coke, other residuals of oil sands processing, biomass co-firing, and so on. It covers not only efforts towards near-zero emission coal incorporating CO_2 capture but also activities targeted to a subset of current emissions (e.g. mercury) either individually or incorporated into a multi-pollutant approach.

This report seeks to compile all Canadian activity in CCT. The report has four main components. The first provides brief descriptions of the principal Canadian organizations engaged in CCT and the international organizations involved in CCT in which Canada or Canadian organizations play an active role. Ninety-five (95) organizations are so featured. The second component features summaries of specific projects underway (as of early 2007) or recently completed (2004 or later); 86 projects are described. Part 3 describes four documents that help define Canada's strategy of developing capacity in CCT. The final component provides an overview of current coal-fired practice in Canada, including the units that make up the current coal-fired utility fleet, the combustion technology and emission reduction strategies employed, the regulatory regimes under which they operate, and the emission performance achieved.

Each entry in the compendium provides a brief description of the organization or activity, highlights the role it plays in CCT, identifies and provides links to contacts for additional information and, for projects, sets out the duration, cost and participants.

Of the 95 organizations described (see Figure 1):

- 20 provide coordination and planning of CCT activities, of which 8 operate within Canada and 12 are international;
- 15 perform the vast majority of the R&D in CCT in Canada, of which 11 are universities (including 4 universities with substantial engagement (having a significant group with substantial concentration in clean coal or related aspects) and 7 with lesser involvement (a few projects by individual professors)) and the balance are federal (2) and provincial (2) research organizations;
- 31 are companies who are developing and marketing CCT technologies or providing design and engineering services in support of CCT;
- 9 are Canadian electrical utilities that use coal for at least part of their fuel supply, some of which are active in the development and implementation of clean coal technologies;
- 7 are federal and provincial government agencies involved in regulation or aspects other than research performance;
- 5 are environmental non-government organizations; and
- 8 are government programs supporting CCT projects.

Of the 86 projects, 68 are at the R&D stage, 16 are focused on commercial implementation and demonstration and 2 address outreach (see Figure 2). Of the 68 R&D projects, the dominant focus is CO_2 capture (54 projects – for a breakout see Figure 3) with a number of other subjects with much smaller frequencies - emission reduction without CO2 capture (7), generic modeling/ characterization (3), biomass co-firing (2)

and coal beneficiation (2). Two of the generic modeling/characterization projects are also largely, but not exclusively, targeted to CO_2 capture technologies.

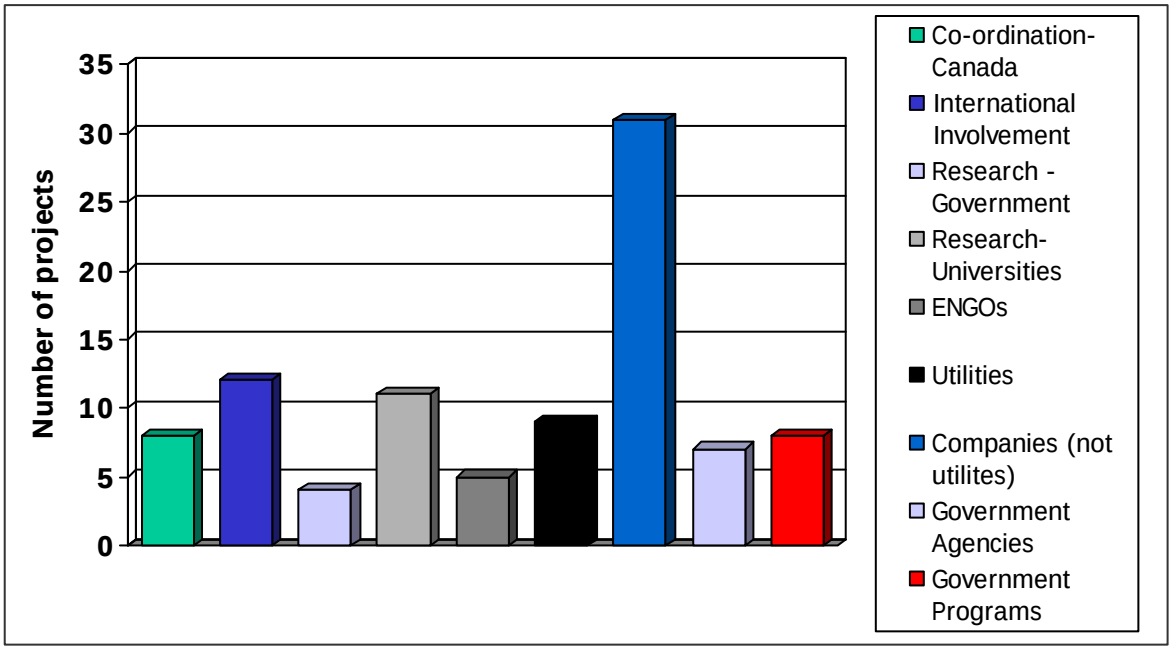


Figure 1: Distribution of the 95 organizations involved in Clean Coal Technologies

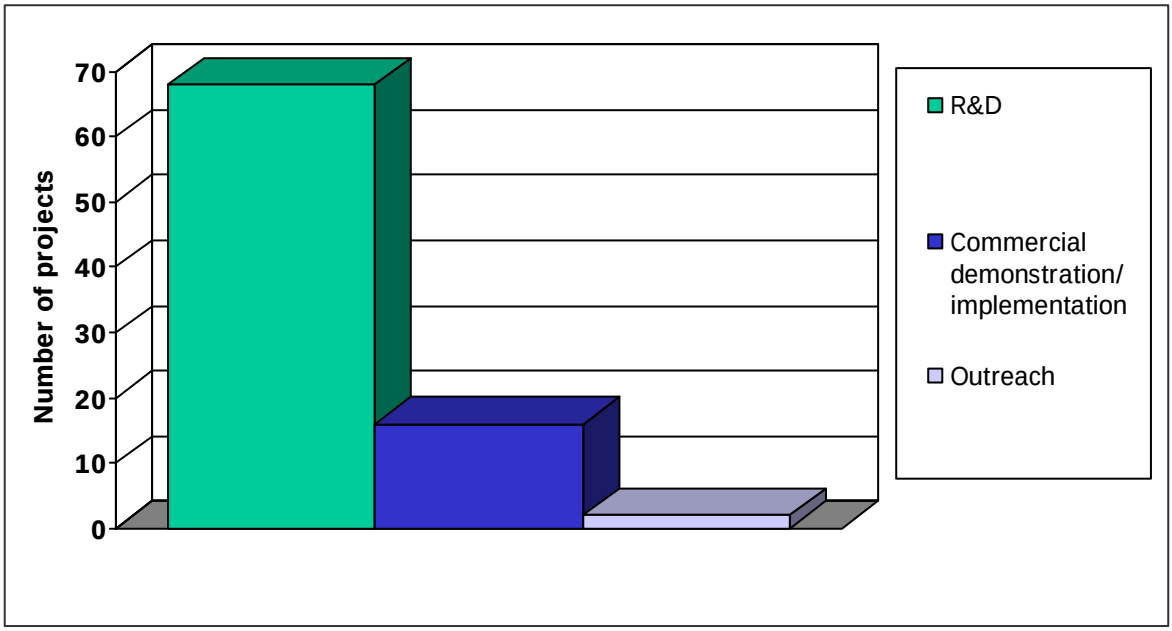


Figure 2: Distribution of the 86 Clean Coal Technology related projects by position in technology development and implementation cycle

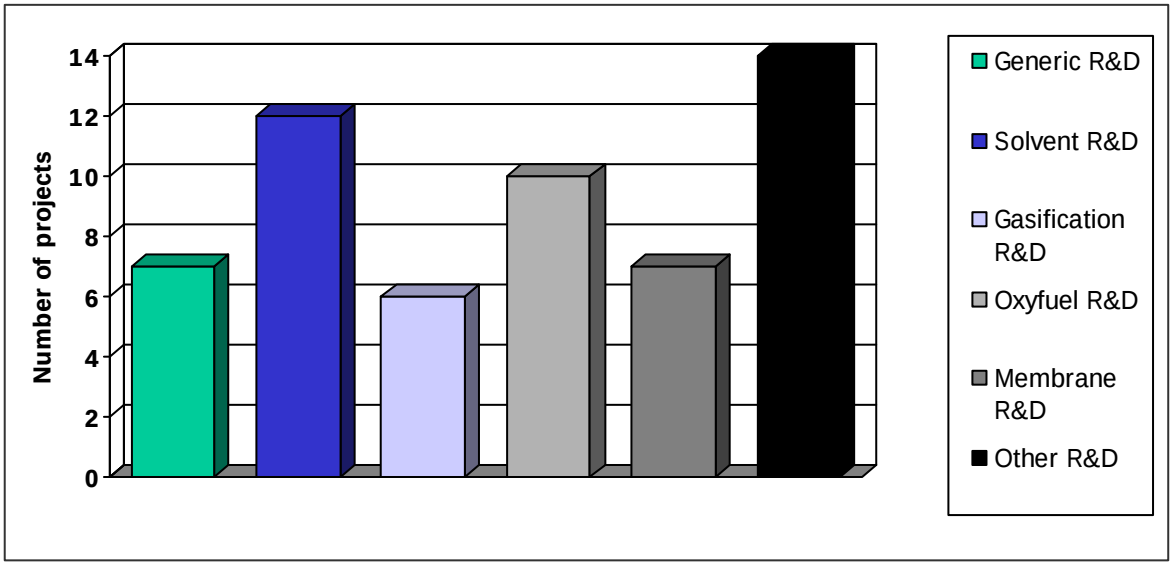


Figure 3: Distribution of technologies in the 54 R&D projects with CO_2 capture as a major element

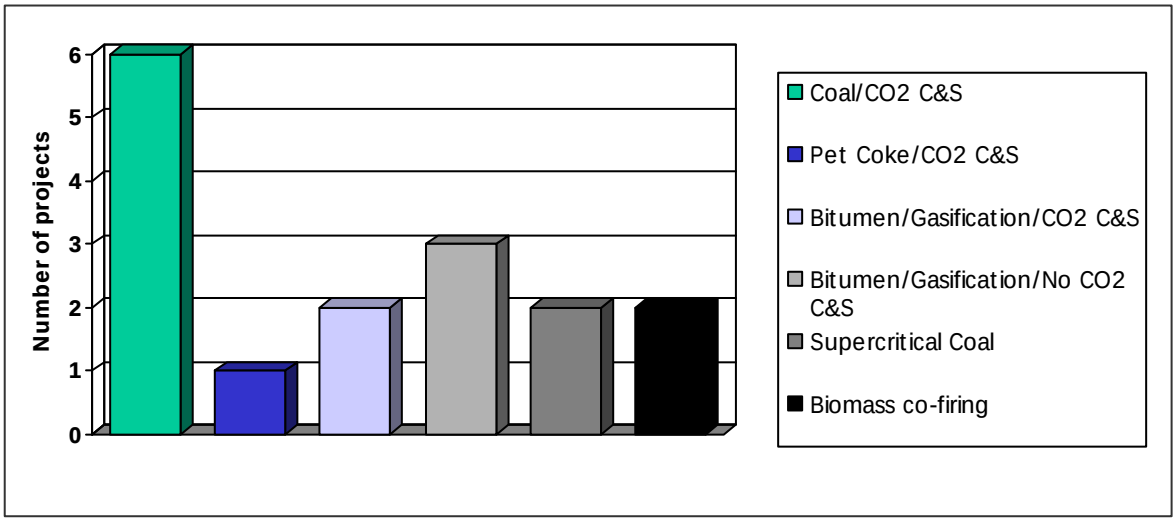


Figure 4: Types of new commercial plant proposed, designed or recently built

The 16 commercial demonstration/implementation projects are varied: (see Figure 4)

- Six are focused on new coal-fired plant with CO_2 capture and storage, 3 of which involve the design of specific coal-fired plants, 1 is centred on general commercial implementation of near-zero emission CCT and 2 others propose the construction of large-scale demos for their proprietary CO_2 capture technologies;
- One has begun the process of designing a pet coke-fired IGCC plant producing a mixture of chemical and energy products;
- Five have begun the process of designing and constructing gasification plants to produce energy and hydrogen for oil sands processing from oil sands by-products, of which 2 include CO_2 capture and storage in the design assessment;

- 2 feature construction of higher efficiency (supercritical) coal-fired plants; and
- 2 propose new biomass/coal co-fired plants.

Many of the projects involve multiple performers and multiple funding partners. However, if they are categorized by lead performer, 40 of the projects are conducted or led by universities, 24 by government research agencies (including provincial research organizations), 21 by industry (a category which includes any utility or for-profit company) and 1 by ENGOs (see Figure 5). The individual performers with the greatest number of CCT projects are the University of Regina and its associated International Test Centre for CO_2 Capture (12 projects) and Natural Resources Canada's CANMET Energy Technology Centre-Ottawa (18 projects).

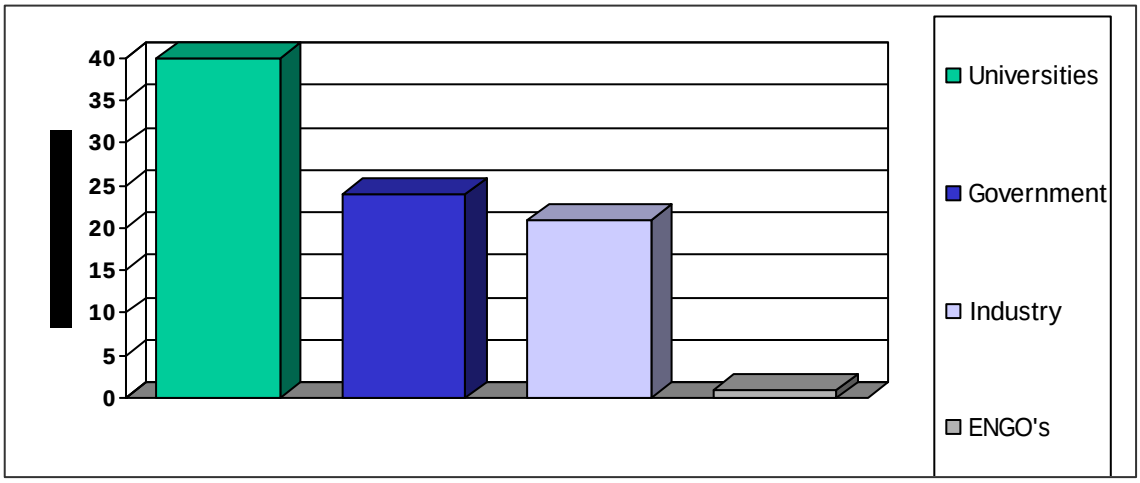


Figure 5: Distribution of 86 projects by nature of lead organization

Activity in Canada related to clean coal is growing rapidly, especially in the area of CO_2 capture. Of particular note is the number of commercial plants being designed and nearing construction that will achieve near-zero emissions. Also, the number of Canadian companies involved in technology development and implementation is very encouraging, both from the standpoint of implementation in Canada and for the potential to help implement these technologies in other countries.

While the contents of this compendium will quickly become out-dated, it is hoped that it will have a useful life, not least to demonstrate the resources the Canadian energy community is prepared to invest in this promising way of reducing our environmental emissions while retaining an attractive energy option.

TABLE OF CONTENTS

BACKGROUND

In its reference scenario, the International Energy Agency (IEA) projects that the use of coal worldwide will remain roughly constant in relative terms, providing some 25% of global energy demand (40% of electric power) until 2030. While its share is lower, coal plays an important role in Canada's diversified energy portfolio, currently accounting for 18% of Canada's electricity production. The picture varies by province, with Alberta, Saskatchewan and Nova Scotia being almost fully reliant on coal to generate electric power and Quebec, Newfoundland, Prince Edward Island, British Columbia and the three Territories having no coal-fired power. Moreover, two provinces are moving in opposite directions, with British Columbia poised to accept its first coal-fired (or more likely coal/biomass co-fired) plants while Ontario has a policy to phase out its extensive coal-fired capacity. Notwithstanding these regional differences, there is every reason to believe that coal will remain a key component of Canada's diverse energy mix.

Based on today's production rate, Canada has more than 220 years of proven coal reserves and about one thousand years when considering measured reserves. Over and above this, increasing oil sands production will produce additional millions of tonnes of petroleum coke and other by-product fuels (e.g. asphaltenes) each year. Canada also has extensive biomass resources for co-firing with coal. Furthermore, the cost of Western Canadian surface-mined thermal coals (sub-bituminous and lignite) and pet cokes are a fraction of that of oil and gas. Even the coals and pet cokes imported by Ontario and Nova Scotia (from the US and South America) are much less expensive than oil and gas. It is the prospect of long-term abundant supply and relatively low fuel cost that makes coal (and related fuels) attractive to utilities for electric power generation.

Canada's ability to rely on these abundant and inexpensive energy sources is threatened by their poor environmental performance. The most serious challenges are associated with airborne emissions, including oxides of sulphur and nitrogen (acid rain and smog precursors), particulates (smog), carbon dioxide (greenhouse gas) and heavy metals, especially mercury (bioaccumulative toxins). Currently, Canada's electricity generation contributes the following percentages of total Canadian emissions: 20% of SO_2, 11% of NO_x, 13% of particulates, 26% of toxics and 17% of GHGs. All fuels emit some of these pollutants, but coal, some of the opportunity fuels (e.g. petroleum coke) and some biomass emit especially high levels.

Given the importance of coal-based energy to the global economy and the need to reduce emissions, nations throughout the world are cooperating in accelerating the development of clean coal technologies (CCTs). While Canada is active in a number of cooperative mechanisms with other countries, this must be complemented by a "made-in-Canada" approach. Canada must rely for the most part on lower quality solid fuels than most other countries. These fuels present significant problems to existing plant operations as utilities struggle for improved combustion performance, higher efficiencies and lower emissions. They become even more problematic when next generation technologies are concerned where issues such as low carbon burn-outs and high ash contents render some of the front running technologies unacceptable at their current state of development.

By 2030, Canada needs to replace some 18,000 MWe of aging coal-fired power plants. Also in this same time frame, the electricity sector projects an additional 45,000 MWe of new generating capacity to meet increased demand. It is critical that technologies that offer radical improvements in efficiency, environmental performance and economic viability are available as soon as possible to meet these needs. These new plants must be ready to meet this increasing demand for energy without unacceptable impacts on the environment, while avoiding the need for costly replacement or retrofit technologies in future years. The technologies under development in Canada and elsewhere can enable Canada to enjoy the benefits of a plentiful, inexpensive resource while achieving near-zero air emissions. To do so, such technologies must be economically attractive and capable of being adopted with minimal capital and operating risk.

INTRODUCTION

The Canadian government has a continuing interest in examining means of controlling greenhouse gas and air pollutant emissions. As part of this interest, Canada has been exploring and developing clean coal technologies because of their potential to reduce emissions (NO_x, SO_x, fine particulates, Hg and CO_2) while utilizing Canada's abundant and inexpensive coal resources for electric power generation. In furthering this interest, it is vital to understand Canada's technical and resource capacity in this area of technology. It is also important to identify emerging commercial activities and the attendant economic opportunities and environmental pressures. Finally, shaping Canada's efforts related to clean coal requires knowledge of the work underway, possible gaps and coordination opportunities.

These considerations led the Office of Energy Research and Development of Natural Resources Canada and the Resource Processing Industries Branch of Industry Canada, with the cooperation of Environment Canada, to identify a requirement for a report that contains summary descriptions of all Canadian clean coal activities. This report is the resulting compilation.

This report is a collection and description of Canadian activities underway or recently completed (since 2004) and of the associated Canadian players in the field of clean coal. This compendium has been developed and written in a manner analogous to an earlier report, *Carbon Dioxide Capture and Storage: A Compendium of Canada's Participation*[1], completed in early 2006. In fact, as might be expected, there is significant overlap in the subject matter and in particular in the area of CO_2 capture. As a result, many project and organization descriptions appear in both documents, albeit updated as appropriate for this document.

This report applies the term **"clean coal"** in its broadest sense. **Coal** in this report refers to the widest possible range of solid fuels including coal (bituminous, sub-bituminous, lignite) petroleum coke, bitumen, refinery bottoms, asphaltenes, as well as solid waste

[1] Available at www.nrcan.gc.ca/es/etb/cetc/combustion/co2network/pdfs/ccs_canadian_compendium_e.pdf

and biomass co-firing. This usage applies whether these fuels are used individually or in blends, whether dry-fed, slurried or emulsified. The term **clean** in this report refers to all efforts to reduce air-borne emissions associated with the conversion of coal to electricity, including coal beneficiation, combustion and gasification. Specifically, the report incorporates activities associated with reducing emissions of oxides of nitrogen and sulphur, carbon dioxide (capture only), mercury and other heavy metals, and fine particulate, which could be included in an integrated multi-pollutant reduction approach. In effect, this compendium will include all activities associated with "cleaner" coal (cleaner than current practice), "clean" coal (defined as at least as clean as natural gas fired electricity) and "near-zero emissions" or truly clean coal.

The term clean coal could be extended to include such aspects as land use, reclamation and water use associated with the mining of coal plus the management of the wastes arising from coal conversion such as fly ash, gypsum, and carbon dioxide; however, these aspects are not included within the scope of this report.

The scope of the compendium includes not only relevant activities but also the characterization of the companies, organizations, agencies and structures that are engaged in these activities. Activities range from RD&D; commercialization; engineering and economic analyses; regulatory, policy and program initiatives; technologies and processes offered by Canadian companies; and public outreach activities. Organizations include those involved in the activities noted above and run from individual companies, research performers, key government agencies, organizing structures, coordination mechanisms and funding programs. Canada's involvement in relevant international activities is also included.

The compendium is expected to have a number of uses including:

- Alerting not only the federal government sponsors but all Canadian players to the full range of who is doing what as a basis for promoting collaboration and reducing duplication.
- Defining Canada's emerging commercial capacity to develop, implement and market clean coal technologies.
- Alerting funding agencies and programs to the scope of work being conducted and potential gaps in key areas so that priorities for additional work can be defined.
- Alerting regulators and other key decision makers to the effort underway towards the potential for truly clean coal in Canada.

Canada's challenge includes the need to investigate a labyrinth of CCT technology developments for retrofit and new installations, assess the merits of CCT for electricity generation against other options, identify CCT technology needs for Canada and a strategy for their development and implementation.

STRUCTURE OF DOCUMENT

This document is organized into four principal parts:

1. Part A catalogs and describes the major agencies, companies and mechanisms involved in Canadian CCT;
2. Part B catalogs and describes currently active or recently completed (roughly since 2004) science & technology (S&T) and related projects and a number of new commercial scale plants incorporating some aspects of clean coal technology and which have either recently been completed or for which engineering design has begun;
3. Part C describes a number of overview documents that have particular impact on Canadian activities;
4. Part D describes the existing utility fleet in Canada (province by province), the national, federal and provincial regulatory regimes under which these plants operate and recent environmental performance of these plants.

Parts A and B are further subdivided by the types of players and the project subject areas. Each subdivision is assigned a sequential number, and each entry within a subdivision is assigned a second sequential number. Thus, players are identified as "Org *a.b*", where *a* is the number of the subdivision, and *b* is the number of the organization within the subdivision. Similarly, projects are identified as "Proj *a.b*". Documents are identified simply as "Doc *a*". The overall structure is best appreciated by examining the Contents page.

Part A (Organizations) includes 10 sections, each containing a group of organizations that play similar roles in clean coal, ranging from coordination, through R&D performers, utilities/companies, ENGOs and government agencies/programs.

Part B (S&T projects) contains 12 different sections, covering different strategies for emission reduction, new and proposed commercial plant and a section on outreach activities related to clean coal technology. The first section includes projects with general application to many emission reduction strategies. Three subsequent sections deal with projects investigating and developing a number of strategies that could reduce emissions (compared with current levels), but which would not by themselves lead to near-zero emission clean coal. The next five sections deal with various subsets of CO_2 capture strategies, all of which could lead to near-zero emission operation of coal plants. The next and perhaps most important section describes a number of commercial-scale projects. These are at various stages, some recently completed, some soon to begin operation and some at early design stages. These plants incorporate a range of the technologies referred to in the Compendium, including efficiency gains, advanced pollution control, biomass co-firing and alternative approaches to CO_2 capture. Some are coal-fired (both sub-bituminous and lignite coals), some use biomass and quite a number propose the use of by-products of oil sands production.

We have tried to make it relatively easy to navigate the roughly 190 separate entries in the document. The Table of Contents page (ToC) is key. All titles in the ToC are "linked" to the corresponding player, project, document or provincial summary. When you are viewing the ToC, a "Ctrl + left click" on a title will bring you directly to the location of the relevant entry in the body of the document. Each organization entry contains references to the projects in which that organization is involved, if any. Similarly, each project contains references to the relevant players. However, these references are not themselves "linked". To link to a particular project or player, you will have to return to the ToC.

Caveats

The authors have made a determined effort to ensure that:

- the compilation is exhaustive. Although an exhaustive listing was the objective, so much activity is underway that we have almost assuredly not included all activities and players. The field is a dynamic one, and new projects are taking shape all the time. We trust that gaps in the coverage are not many and certainly not so numerous as to distort the overall picture of Canadian activity in CCT.
- entries are accurate and reasonably complete. In all cases, we tried to solicit feedback about the quality of the summaries from the organizations and individuals cited. We were not always successful, in spite of repeated efforts. In some other cases, key information could not be acquired. Finally, we also exercised some editorial discretion on specific text, and so the wording may be slightly different from that proposed by project proponents; however, we have tried to stay true to the basic descriptive material provided.

A word about verb tenses: In the project descriptions, the reader will note the use of a variety of verb tenses. The future tense is used often, even for projects already completed, because in many cases the authors of this report relied on descriptive information contained in proposals. Proponents left most of these descriptions unchanged during their reviews, and so there was no confirmation that all proposed work had been completed successfully. Consequently, the tenses were left as they appeared in the proposal. In other cases, proponents revised project descriptions to reflect actual outcomes, in which case the past tense was used. The authors regret any confusion this may cause.

ACKNOWLEDGMENTS

The authors (Frank R. Campbell and John F. Legg) owe a great measure of thanks to the many people who contributed to the development of this compilation. First of all, we must thank the project sponsors - NRCan, Industry Canada and Environment Canada. We would like to thank especially Dubravka Bulut and Leah Dell of the Office of Energy Research and Development of Natural Resources Canada, Catherine Kerr of the Resource Processing Industries Branch of Industry Canada and Lorie Cummings of Environment Canada who identified the need for this document and provided extensive guidance regarding its scope and structure. We would also like to thank them for their help and support throughout the project.

But we have to save our special thanks for all the individual contributors who responded to our many requests for information, comments, corrections, and approvals. This report is a testimony to their foresight, innovation, persistence, and curiosity, but most of all to their success in bringing CCT from an apparent oxymoron to near commercial application in a very short time. In many cases, you will be able to identify these individuals from the contact names that we include. Nevertheless, the reader should be aware that the work reflected herein is usually the product of teams. Each member of those teams has earned a mention for his or her contribution; however, we chose not to attempt an exhaustive listing of all contributors, and so only principal contacts are shown. We can only hope that they will not begrudge their contribution to the preparation of the document when they receive their copies.

ACRONYMS AND INITIALISMS

The meaning of each major acronym and initialism used in this document appears here.

AERI	Alberta Energy Research Institute
APEC	Asia–Pacific Economic Cooperation
ARC	Alberta Research Council
CASA	Clean Air Strategic Alliance (Alberta)
CCCSTN	Canadian CO_2 Capture and Storage Technology Network
CCME	Canadian Council of Ministers of the Environment
CCPC	Canadian Clean Power Coalition
CCS	CO_2 (or Carbon) Capture and Storage
CCT	Clean Coal Technology
CC T&I (or CCTII)	Climate Change Technology and Innovation Initiative (NRCan)
CDM	Clean Development Mechanism
CEA	Canadian Electricity Association
CEATI	CEA Technologies Inc.
CEPA	Canadian Environmental Protection Act
CETC-O	CANMET Energy Technology Centre –Natural Resources Canada
CO_2	Carbon Dioxide
CSLF	Carbon Sequestration Leadership Forum

CWS	Canada Wide Standard
EPRI	Electric Power Research Institute (US)
ESP	Electrostatic Precipitator
ENGO	Environmental non-governmental organization
GHG	Greenhouse gas
Hg	Mercury
IEA	International Energy Agency
IEA GHG	International Energy Agency Greenhouse Gas R&D Programme
IGCC	Integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
m^3	Cubic meter
MDEA	Methyldiethanolamine
MEA	Monoethanolamine
Mt	Megatonne
MW	Megawatt (10^6 watts)
MWe	Megawatts of electrical power
NGO	Non-governmental organization
NO_x	Oxides of nitrogen
NRC	National Research Council
NRC-ICPET	NRC-Institute for Chemical Process and Environmental Technology
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council
OERD	Office of Energy Research and Development (NRCan)
OPG	Ontario Power Generation
PC	Pulverized Coal
PERD	Program of Energy Research & Development (NRCan)
R&D	Research and Development
RD&D	Research, Development and Demonstration

S&T	Science and Technology
SCPC	Super Critical Pulverized Coal (combustion process)
SDTC	Sustainable Technology Development Canada
SOFC	Solid oxide fuel cell
SO_2	Sulphur dioxide
UNFCCC	UN Framework Convention on Climate Change
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency

PART A: ORGANIZATIONS

1. COORDINATION/PLANNING - CANADA

Org 1.1 Canadian Clean Power Coalition

What is it? The Coalition, formed in 2000, is a national association of Canadian coal and coal-fired electricity producers representing most of Canada's coal-fired electricity generation.

Role Played in Canadian Clean Coal Activities The Coalition leads projects in Canada aimed at demonstrating that coal-fired electricity generation can effectively address all environmental issues, including greenhouse gases.

Description The Coalition, with a small headquarters in Regina, was formed in 2000 and is advancing through phases to its ultimate goal of commercial-scale demonstrations [Proj 11.1].

Phase I (2001-2004) assessed candidate technologies, principally gasification, amine solvent stripping and oxy-fuel combustion.

Phase II (2004-2007) investigated improvements to gasification technologies for low rank coals (lignite and sub-bituminous).

The Coalition is helping in the facilitation of Phase III, the Front End Engineering Design (FEED) studies for two identified projects as well as ongoing support of R&D. Additional, as yet unidentified projects, are under discussion. The two identified projects are large (billion-dollar-scale) commercial demonstrations, each with a different technology:

> a plant using integrated gasification combined-cycle (IGCC) technologies, fuelled by sub-bituminous coal, under the lead of EPCOR, and co-sited at the pre-existing Genesee coal-fired stations in Alberta [Proj 11.2];
>
> a plant, based on super-critical pulverized coal (SCPC) with oxy-fuel technologies, under the lead of SaskPower and sited at the Shand power station near Estevan, Saskatchewan [Proj 11.3].

Current members of CCPC are Basin Electric Power Cooperative (USA), EPCOR [Org 5.7], Electric Power Research Institute [Org 2.5], Sherritt International [Org 8.27], SaskPower [Org 5.5], TransAlta [Org 5.9] and Nova Scotia Power [Org 5.1].

Contact

Bob Stobbs,
Canadian Clean Power Coalition
306-566-3326
bstobbs@saskpower.com
The CCPC web site is at www.canadiancleanpowercoalition.com

Org 1.2 Canadian CO_2 Capture and Storage Technology Network

What is it? The Canadian CO_2 Capture and Storage Technology Network (CCCSTN) is an extensive, voluntary network of people and organizations working on CCS development in Canada. The scope of the network includes economic and environmental issues relating to CCS.

Role Played in Canadian Clean Coal Activities CCCSTN participants use the network to exchange information and to facilitate coordination of their research, development, and demonstration project initiatives.

CCCSTN represents Canadian projects at international and national events hosted by such organizations as the Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2 CRC), the Carbon Sequestration Leadership Forum (CSLF), the International Energy Agency (IEA), and the Intergovernmental Panel on Climate Change (IPCC).

Description Participation in the network is open to the entire Canadian CCS community, including industry, academia, and government. International collaboration is active and encouraged. CCCSTN is funded by the federal government (NRCan). There is no membership fee.

Resources for conferences and other activities are provided in-kind from network members. Many of the participants have worked on major documents that, although not formally a product of the network, reflect the views of the Canadian CCS community. [Documents 1.1, 1.2, 1.3]

National coordination and a secretariat are currently provided by the federal government's CANMET Energy Technology Centre–Ottawa [Org 3.1].

The CCCSTN now produces a periodic newsletter; requests for this newsletter should be made to the National Secretariat, below.

Contacts

Bill Reynen
CETC–Ottawa
613-996-5759
cccstn.info@nrcan.gc.ca

Donna Baskin
CETC–Ottawa
613-947-2651
cccstn.info@nrcan.gc.ca

The CCCSTN web site is at www.co2network.gc.ca.

Org 1.3 Canadian Council of Ministers of the Environment

What is it? CCME is comprised of environment ministers from the federal, provincial and territorial governments. These 14 ministers normally meet at least once a year to discuss national environmental priorities and determine work to be carried out under the auspices of CCME. The presidency of CCME rotates annually among member governments. Various working groups and committees with membership from the federal, provincial and territorial governments report to CCME.

Role Played in Canadian Clean Coal Activities CCME, through its Air Management Committee is not currently working directly on clean coal projects. CCME has endorsed Canada-Wide Standards (CWS) for particulate matter and ozone, as well as Canada-Wide Standards for Mercury Emissions from Coal-fired Electric Power Generation Plants. A monitoring protocol in support of the CWS for Mercury Emissions from Coal-Fired Power Generation Plants is currently in development. These standards may influence the use of cleaner coal.

Description Since jurisdiction over the environment in Canada is shared, CCME works to promote effective intergovernmental cooperation and coordinated approaches to interjurisdictional issues such as air pollution and toxic chemicals. CCME members collectively establish nationally consistent environmental standards, strategies and objectives to achieve a high level of environmental quality across the country. Ministers retain their individual authority and jurisdiction as members of CCME, while working together helps them to deliver their own mandates.

The CCME, jointly with the Council of Energy Ministers, developed the Canada-Wide Acid Rain Strategy for Post-2000, which has set limits for SO_2 emissions. The CCME (except Quebec) ratified the Canada-Wide Accord on Environmental Harmonization and its Canada-Wide Environmental Standards Sub-Agreement. Under this Sub-agreement, the CCME set out to establish a series of Canada-Wide Standards (CWS), which member governments would implement (see description under National in Part D of this Compendium).

Contact

Canadian Council of Ministers of the
Environment
204-948-2090
info@ccme.ca
The Council's web site is at www.ccme.ca

Org 1.4 Canadian Electricity Association

What is it? The Canadian Electricity Association is the national forum and voice of the electricity business in Canada.

Role Played in Canadian Clean Coal Activities The Association supports member company activities to develop and deploy clean coal technology.

Description Founded in 1891, the Canadian Electricity Association (CEA) is the voice of the Canadian electricity industry, promoting electricity as the critical enabler of the economy and Canadians' expectations for an enhanced quality of life.

At the heart of CEA is a core of corporate utility member companies. In addition, major electrical manufacturers and corporate consulting companies and several hundred other company and individual members are grouped within CEA's broad structure.

Contact

Corporate Office
Canadian Electricity Association
Ottawa, Ontario
613-230-9163
info@canelect.ca
The CEA's web site is at www.canelect.ca

Org 1.5 CEA Technologies Inc.

What is it? CEA Technologies Inc. (CEATI) is an organization based in Montreal that stimulates the formation of groups with common interests drawn from organizations in the fields of electricity generation, transmission, distribution and utilization.

Role Played in Canadian Clean Coal Activities A Thermal Generation Interest Group and a Strategic Options Interest Group address emissions from existing and new plant including greenhouse gases.

Description In 1974 CEA initiated its R&D Program to serve the research needs of Canadian electric utilities. In 1996, the CEA opened its doors to collaborative technology development and international participation. This evolution was the impetus for CEA Technologies Inc. (CEATI).

Over the last 5 years, CEATI has grown steadily, to serve Participants through 13 focused Interest Groups each facilitated by a technical expert devoted to that field of study. CEATI is continually expanding its international reach, with participants including utilities from the United States, Britain, Japan, Germany, France, Sweden, South Africa, Israel, Australia, and New Zealand.

CEATI brings electrical utility industry professionals together, through focused interest groups and collaborative projects, to identify and address technical issues that are critical to their organizations. Participants can undertake projects that respond to their strategic goals at a fraction of the cost of doing so independently. The need for international breadth and inter-industry applicability in technology development is addressed through a practical, dynamic and cost-effective program.

Contact

CEATI Montreal Office
Montreal, Quebec
514-866-5377
info@ceatech.ca
The CEA's web site is at www.ceatech.ca

Org 1.6 Clean Air Strategic Alliance

What is it? The Clean Air Strategic Alliance (CASA) is a multi-stakeholder partnership, composed of representatives selected by industry, government and non-government organizations, which recommends strategies to assess and improve air quality in Alberta.

Role Played in Canadian Clean Coal Activities CASA's work has fed into Alberta Environment's new standard entitled *Alberta Air Emission Standards for Electricity Generation* and new provincial regulations for mercury emissions. (See additional information in Part D (Alberta: Regulatory Regime).

Description The Electricity Project Team, a CASA working group, not only produced recommendations for "traditional" coal combustion emissions and emissions trading, but has also developed a conceptual greenhouse gas management framework for Alberta's electricity sector.

Contact

Jillian Flett
Clean Air Strategic Alliance
Edmonton, Alberta
780-427-9793
jflett@casahome.org
The web site is at www.casahome.org

Org 1.7 Coal Association of Canada

What is it? The Coal Association of Canada, headquartered in Calgary, represents companies engaged in the exploration, development, transportation and use of coal. Members include major coal producers and coal using utilities, railroads and ports that ship coal, industry suppliers of goods and services, and municipalities that have an interest in furthering the objectives of the Association.

Role Played in Canadian Clean Coal Activities: The coal industry and the Association are actively seeking ways to address environmental concerns at power plants where improved coal-burning technologies have reduced emissions and advanced technologies are promising even greater reductions.

Description The Association provides a forum to discuss and coordinate the views of its members on matters of common interest. It provides a voice that enhances the viability of the industry by advocating the clean use of coal through technology development. The Association's "Coal Core" program of Communications, Outreach and Education is instructive in helping stakeholders learn about the use of coal in the 21st century.

Contact

Scott Clarke
Coal Association of Canada
Calgary, Alberta
403-262-1544
clarke@coal.ca
The Association's web site is at www.coal.ca

Org 1.8 ecoENERGY Carbon Capture and Storage Task Force

What is it? A mechanism for building support for a comprehensive blueprint for implementing a large-scale carbon capture and storage system in Canada.

Role Played in Canadian Clean Coal Activities: The Task Force will build on existing work such as the CO_2 Capture and Storage Technology Roadmap [Doc. 1.2]. It will cover the capture of CO_2 from oil sands operations, coal-fired electrical plants and other industrial emitters.

Description The Task Force was established in early 2007 by the Minister of Natural Resources Canada and the Alberta Minister of Energy. It will be chaired by Steve Snyder, CEO of TransAlta [Org 5.9] and includes senior executives from coal burning utilities, integrated petroleum companies, pipeline companies, academe and the Canadian and Alberta governments. The Task Force will examine the opportunities for large-scale application of carbon capture and storage in Canada. Based on that examination, the Task Force will provide a comprehensive set of options describing how government and industry can work together to take advantage of those opportunities.

Contact

Larry Hegan
Natural Resources Canada
613-943-6522
lhegan@nrcan.gc.ca
The Task Force does not have a website at the time of printing this report.

2. CANADIAN INTERNATIONAL INVOLVEMENT

Note

There are many diverse connections among Canadian and non-Canadian organizations in clean coal activities. Examples are: Canadian membership in multi-national organizations such as the International Energy Agency; multi-player projects such as the Carbon Sequestration Leadership Forum; the presence of foreign subsidiaries in Canada, and support by non-Canadian companies of Canadian research projects.

In this section, we describe those international organizations of most significance to Canada. In other sections, we identify some subsidiaries of non-Canadian companies that have a significant presence in Canada. Non-Canadian companies that participate in or help fund projects are identified in those projects.

Org 2.1 Asia Pacific Economic Cooperation, Expert Group on Clean Fossil Energy

What is it? The Expert Group on Clean Fossil Energy (EGCFE), with membership from interested APEC members, promotes the use of clean fossil energy technologies, especially among developing countries.

Role played in Canadian Clean Coal Activities Canada is represented on the Expert Group, giving APEC exposure to Canadian clean fossil fuel activities and giving Canadian companies an opportunity to participate in projects in APEC countries.

Description The Expert Group, one of five reporting to the Energy Working Group (EWG), carries out clean fossil fuel projects, most of which are related to coal.

To accomplish its mission, the Expert Group first identifies a potential project, referring it to senior APEC bodies for approval and funding. Following funding approval, the country that initiated the project normally becomes the Project Overseer, who then leads the request for proposals, award of contract, contract supervision, and delivery of the product.

To date, Canada has primarily been involved on the carbon capture and storage side and has managed a series of three projects in this area (see CCS Compendium).

Contact

Frank Mourits
Natural Resources Canada
613-947-3482
fmourits@nrcan.gc.ca
The EGCFE website is: www.apec-egcfe.org

Org 2.2 Canada-United States Air Quality Agreement

What is it? The Canada-United States Air Quality Agreement is a formal agreement with the purpose of addressing transboundary air pollution.

Role Played in Canadian Clean Coal Activities Obligations and negotiations under the Agreement are factors in setting standards for emission controls on Canadian coal-fired thermal stations.

Description This 1991 Agreement was originally signed to address transboundary air pollution leading to acid rain. Both countries agreed to reduce emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), the primary precursors to acid rain and to work together on acid rain related scientific and technical cooperation. In 2000, an Ozone Annex was added to address transboundary air pollution leading to high levels of ground-level ozone, a major component of smog. Under the Agreement, regular reviews are held and progress reports published.

There is no dedicated site for the Air Quality Committee but the Agreement along with the Ozone Annex and progress reports can be found on the EC website at:
http://www.ec.gc.ca/cleanair-airpur/default.asp?lang=En&n=83930AC3-1

The International Joint Commission and the U.S.EPA also both have sites addressing the Agreement. They can be found at:
http://www.ijc.org/rel/agree/air.html#s and
http://www.epa.gov/airmarkets/progsregs/usca/index.html

Contact

Rand Jackson
Environment Canada
Gatineau, Quebec
819-994-3655
rand.Jackson@ec.gc.ca
The main website for Environment Canada is www.ec.gc.ca

Org 2.3 Carbon Sequestration Leadership Forum

What is it? The Carbon Sequestration Leadership Forum is an international organization whose aim is to facilitate and promote technical exchanges and policy implementation for the capture and sequestration of CO_2 as a climate change mitigation technology. It is composed of 21 countries that are major energy producers and users. The group encourages improvement in carbon capture and storage technologies through coordinated policy development and R&D with international partners and private industry.
Role played in Canadian Clean Coal Activities Carbon capture is a major part of the Forum's mandate. Canada has been participating in the CSLF from its beginning, with the aim of sharing information and participating in projects outside Canada when possible.

Description The CSLF was initiated by the U.S. Department of Energy in 2003. The group is open to developed countries regardless of whether they ratified the Kyoto protocol, and to developing countries. Notably, members include China, India, Brazil, and Saudi Arabia.

The activities of the CSLF are guided by a Policy Group, which sets the overall framework and policies, and by a Technical Group, which identifies technology gaps and reviews the progress of collaborative projects. "Projects" is broadly defined to include planning, R&D, demonstrations, public outreach, economics and markets, and regulatory issues. The CSLF has recognized 17 projects, of which four are Canadian.. Of these four, two involve capture technologies.

- Oxyfuel combustion for CO_2 capture, an existing project located at the CANMET Energy Technology Centre–Ottawa [Proj 8.5]
- CO_2 capture with chemical solvents, located at the International Test Centre, Regina [Proj 6.2]

The most recent meetings of the Policy and Technical groups were held in India in 2006 and in Paris in March 2007.

Contacts

For CSLF policy activities
Ian Hayhow
Natural Resources Canada
613-996-8644
mike.howarth@nrcan.gc.ca

Anne-Marie Thompson
Natural Resources Canada
613-947-0151
anne-marie.thompson@nrcan.gc.ca

For CSLF technology activities
Bill Reynen
CANMET Energy Technology Centre-Ottawa
613-996-5759
breynen@nrcan.gc.ca

Stefan Bachu
Alberta Energy and Utilities Board
780-427-1517
stefan.bachu@gov.ab.ca

The web site for the Forum is www.cslforum.org

Org 2.4 CO2 Capture Project

What is it? The CO_2 Capture Project (CCP) is a joint project (actually, a number of projects) backed by a small number of the world's leading energy companies.

Role played in Canadian Clean Coal Activities The Project gives one of the major Canadian energy companies, Suncor, a place at the table on international projects selected by a group of well-funded companies with considerable experience.

Description The Project is now in its second phase (2004-2007). Currently, the sole Canadian participant is Suncor Energy Inc. of Calgary [Org 8.29].

The primary objective of the CCP is to evaluate and develop new breakthrough technologies that reduce the costs of CO_2 separation, capture, and geologic storage from combustion sources such as turbines, heaters, and boilers.

Overall, the CO_2 Capture Project:

- Is a joint effort comprising eight of the world's leading energy companies.
- Aims to reduce the cost of CO_2 capture from combustion sources.
- Is developing methods for safely storing CO_2 underground.
- Is working together with governments, NGOs, and other stakeholders to deliver technology that is cost-effective and meets the needs of society.
- Sees CO_2 capture and geologic storage as bridging technologies that will help move society towards cleaner fuels in the future.

Three capture technologies are envisaged:

- Post-Combustion Scrubbing Considered the first step towards large-scale capture, CO_2 is removed from exhaust gas after combustion. This technology can be retrofitted to existing equipment.
- Pre-Combustion Decarbonization (Hydrogen) Natural Gas is converted to hydrogen and CO_2 in a reformer. The CO_2 is compressed for storage and the hydrogen is mixed with air for combustion, emitting only nitrogen and water.
- Oxyfuel Oxygen is separated from air and then burned with hydrocarbons to produce an exhaust with a high concentration of CO_2 for storage

Technologies developed by this project can be used in many different industries and applications around the world.

Contact

Cal Coulter
Suncor Energy Inc
Calgary, Alberta.
403-269-8616
ccoulter@suncor.com
The CO_2 Capture Project web site is at www.co2captureproject.org.

Org 2.5 Electric Power Research Institute

What is it? The Electric Power Research Institute, with major locations in Palo Alto, California, and Charlotte, North Carolina, is an independent, nonprofit centre for public interest energy and environmental research.

Role Played in Canadian Clean Coal Activities EPRI is a member/sponsor of an important Canadian project (CCPC – Org 1.1; Proj 11.1).

Description EPRI brings together members, participants, the Institute's scientists and engineers and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment.

EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program. A number of Canadian utilities are active in one or more of EPRI's programs including:

- EPRI Integrated Environmental Control Program
- EPRI Post-Combustion NO_x Reduction Program
- EPRI Gasification Users Association

Contact

Head Office
Palo Alto, California
650-855-2121
EPRI's web site is at www.epri.com

Org 2.6 FutureGen

What is it? FutureGen is a U.S. Department of Energy initiative, with foreign participation invited, to build a prototype zero emissions fossil fuel plant.

Role played in Canadian CCS Canada is considering participation in FutureGen.

Description The FutureGen web site states that FutureGen is "an initiative to build the world's first integrated sequestration and H_2 production research power plant. The $1-billion dollar project is intended to create the world's first zero emissions fossil fuel plant. When operational, the prototype will be the cleanest fossil fuel fired power plant in the world."

The plant will employ coal gasification technology and be nominally sized to produce 275 MW equivalent gross electricity output.

Opportunities for international participation in FutureGen are available at various levels and can take several forms, for example:

- government-to-government cooperation, including participation on the Government Steering Committee through cost-sharing.
- membership of foreign coal producers and coal-fuelled electric utilities in the consortium.
- competitive opportunities for equipment vendors and engineering services to bid on FutureGen procurements.
- academic, scientific, and researcher participation in FutureGen testing.

Contact

Office of Fossil Energy
U.S. Department of Energy
The FutureGen web site is at www.fossil.energy.gov/programs/powersystems/futuregen.

Org 2.7 Intergovernmental Panel on Climate Change

What is it? The Intergovernmental Panel on Climate Change (IPCC) is the world's largest network of scientists examining climate change.

Role played in Canadian Clean Coal Activities In 2006, the IPCC produced a major publication, *Special Report on Carbon Dioxide Capture and Storage*. Canadians participated in preparing that document.

Description The IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The role of the IPCC, as described on its web site, is "to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation." The IPCC does not itself carry out research, nor does it monitor climate-related data or other relevant parameters. It bases its assessment mainly on peer-reviewed and published scientific and technical literature. It does not recommend policy—it is policy relevant, not policy prescriptive.

The growing importance of CO_2 capture and storage (CO_2 C&S) led to extensive work by the IPCC, resulting in an exhaustive report on the subject. In the course of this work, Canada played host to a workshop in Regina and to a final Working Group III Approval Session (held in Montreal in 2005). The final product is *Special Report on Carbon Dioxide Capture and Storage,* an authoritative source on technology, environment, and other issues.

The report includes a chapter on CO2 capture, with sub-sections on post-combustion capture systems, oxy-fuel combustion capture systems, pre-combustion capture systems, as well as environmental and cost analyses. Much of this is relevant to clean coal technologies.

Nominally, individuals rather than governments contribute to the IPCC's work, although governments can help by coordinating the response. Canadians who helped to write the *CCS Special Report* include David Keith, University of Calgary ("Summary for Policy Makers"); Brad de Young, Memorial University ("Ocean Storage"); and Stefan Bachu, Alberta Energy and Utilities Board ("Properties of CO_2 and Carbon-Based Fuels").

Contact

Bill Reynen
CANMET Energy Technology Centre-
Ottawa
613-996-5759
breynen@nrcan.gc.ca
The IPCC web site is at www.ipcc.ch

Org 2.8 International Energy Agency – The Clean Coal Centre

What is it? The Clean Coal Centre is a long-established coordinating centre for advancing clean coal technologies. It now has an outreach mandate to work with developing countries.

Role played in Canadian Clean Coal Activities Provides access and contacts to advances around the world. Zero emissions technology (that is, eliminating CO_2 emissions) is studied, but the Centre's priority remains non-CO_2 emissions.

Description The Clean Coal Centre, located in London, UK, is a coordinating body for International Energy Agency (IEA) member countries. It has expanding connections to transition economies (ex-Soviet bloc countries) and to developing countries such as Poland and China. It is supported by member subscriptions.

The Centre produces about 15 special reports annually, and works on the reduction of all coal-combustion emissions. CO_2 reduction has been approached through improvements in process efficiency. In recent years the Centre has added zero emissions to its mandate.

By contrast, the other relevant IEA organization, the GHG R&D Programme [Org 2.11], has CO_2, especially CO_2 capture and storage, as its main focus. These IEA sister organizations have other differences.

Clean Coal Centre	GHG R&D Programme
Coal, all emissions	Carbon C&S, all fossil fuels
Short- and long-term issues	Long-term issues
All reports public	Detailed reports to members only
Work done in-house	Work mostly contracted out

Contact

IEA Clean Coal Centre
+44 (0) 20 8780 2111
mail@iea-coal.org.uk

Kourosh Zanganeh
CANMET Energy Technology Centre-Ottawa, Natural Resources Canada
613-996-3916
kzangane@nrcan.gc.ca

The Clean Coal Centre web site is at www.iea-coal.org.uk.

Org 2.9 International Energy Agency – Climate Technology Initiative

What is it? The Climate Technology Initiative (CTI) is an Implementing Agreement under the IEA, which, in contrast to other Implementing Agreements, reports directly to the Committee for Energy Research and Technology (CERT). Its mission is to bring developed and developing countries together to foster international co-operation in the accelerated development, transfer and diffusion of climate-friendly and environmentally sound technologies and practices.

Role played in Canadian Clean Coal Activities Canada is represented on the CTI, giving the CTI exposure to Canadian clean fossil fuel activities and giving Canadian companies an opportunity to participate in CTI projects.

Description Countries participating in the CTI initiate, formulate, manage and fund their own projects, where possible in collaboration with other members. There are few restrictions on the type and scope of these projects so long as they satisfy the CTI's overall objectives. In the recent past, Canada has sponsored a workshop on clean energy. Planning for a CCS training course for the storage of CO_2 from coal-fired power stations in India is underway.

Contact

Frank Mourits
Natural Resources Canada
613-947-3482
fmourits@nrcan.gc.ca
The CTI website is: www.climatetech.net

Org 2.10 International Energy Agency – Fossil Fuel Working Party

What is it? The Fossil Fuels Working Party (FFWP) is the International Energy Agency's permanent committee charged with advancing fossil fuel energy technologies.

Role played in Canadian Clean Coal Activities Clean coal technologies are included in the mandate of the FFWP. Canada is a full and active member of the Working Party.

Description The Working Party, with representation from most of the IEA member countries, undertakes studies and organizes workshops that assist members with technology policy development. The IEA (and therefore the working party) uses legal Implementing Agreements to formalize collective work by members interested in particular areas.

Several initiatives are undertaking at least some clean coal work, the most significant being the IEA Clean Coal Centre. This very active organization, located in the United Kingdom, is described in a separate entry in this compendium [Org 2.8]

Contact

Kim Smith
(IEA FFWP)
OERD, Natural Resources Canada
613-995-5299
kinsmith@nrcan/gc.ca
The IE web site is at www.iea.org

Org 2.11 International Energy Agency – Greenhouse Gas R&D Programme

What is it? The IEA Greenhouse Gas R&D Programme (IEA GHG) is an international program, with offices and staff in the United Kingdom that promotes international research projects, issues reports, and organizes meetings and conferences, all with the aim of reducing GHG emissions.

Role played in Canadian Clean Coal Activities The Programme recently commissioned a study into near-zero emissions from power plants, in which CO_2 and other emissions are considered.

Description Canada is a full member of the Programme, which is a window into international progress and events, especially with respect to technology. The Programme operates under an IEA Implementing Agreement. Nearly 20 countries are members, including Canada, the United States, Japan, and the European Union. More than 10 corporations sponsor the Programme's work. Nearly all the Programme's activities involve CO_2 capture and storage, with the aim of evaluating technologies that reduce GHGs, disseminating results of the evaluations, and facilitating research, development, and demonstration.

Activities to date have covered all the main anthropogenic greenhouse gases—CO_2, CH_4, N_2O, and high global warming potential gases—although the primary focus is on CO_2 capture and storage.

With respect to clean coal, it is worth noting that an article has appeared in the Programmes's periodical (Greenhouse Issues) titled *Near-Zero Emissions Technology for CO2 Capture from Power Plants.*

Canadians are involved in several of the Programme's activities. Information on the Programme's work and Canadian participation is available through the CANMET Energy Technology Centre–Ottawa.

The Programme organizes the prominent biennial Greenhouse Gas Control Technologies conference series, most recently held in Vancouver in 2006. The next in the series, GHGT-9, will be held in Washington D.C. in November 2008.

The Programme is now covered by an Implementing Agreement, under the IEA Fossil Fuels Working Party [Org 2.10].

Contact

Bill Reynen (Federal government representative on the IEA GHG R&D Programme)
CANMET Energy Technology Centre–Ottawa
613-996-5759
breynen@nrcan.gc.ca
The web site for the Programme is www.ieagreen.org.uk

Org 2.12 United Nations Framework Convention on Climate Change

What is it? The UN Framework Convention on Climate Change (UNFCCC) is an agreement, signed by nearly 200 countries, that sets an overall framework for world efforts to tackle the challenge posed by climate change. Under the Convention, GHG emission reduction targets and rules are established.

Role played in Canadian Clean Coal Activities Canada will be subject to UNFCCC rules (or those to which it adopts) with respect to GHG emissions. Canada, like all countries, plays a role in setting those rules.

Description Under the UNFCCC, governments:

- share information on GHG emissions, policies, and practices;
- launch national strategies for addressing GHG emissions, including the provision of support to developing countries; and
- cooperate in preparing for adaptation to the impacts of climate change.

Technical advice to the UNFCCC is received from the Intergovernmental Panel on Climate Change.

A recent major meeting of the UNFCCC (December 2005, in Montreal) was followed by a press release outlining the next steps in general terms (UNFCCC press release [10 December 2005] *United Nations Climate Change Conference agrees on future critical steps to tackle climate change*). Notably, CO_2 capture and storage was the only technology mentioned in the press release. Reference was also made to the recent IPCC *Special Report on Carbon Dioxide Capture and Storage* [Doc 1.4].

The Clean Development Mechanism (CDM), which promotes GHG reductions in developing countries, has a mandate that includes CO_2 capture and storage.

Many Canadians are involved in the activities of the UNFCCC.

Contact

Margaret E. Martin (UNFCCC)
International Environment Policy Division
Natural Resources Canada
613-996-6474
margarete.martin@nrcan.gc.ca

Sushma Gera (CDM)
Foreign Affairs Canada
Climate Change Division
613-944-0051
sushma.gera@international.gc.ca

The UNFCCC web site is at www.unfccc.int.

3. RESEARCH – GOVERNMENTS

Org 3.1 Natural Resources Canada: CANMET Energy Technology Centre

What is it? CANMET Energy Technology Centre–Ottawa (CETC-O) is a major research arm of Natural Resources Canada. It conducts and funds research, technology development, and implementation in conventional and alternative energy supply and efficient utilization.

Role played in Canadian Clean Coal Activities CETC-O uses its facilities and expertise in combustion and gasification science and technology to identify and develop approaches to reduce emissions from coal-fired power generation. It also funds clean coal research, development and demonstration and provides coordination (national and international) for many Canadian activities in clean coal.

Description CETC-O, with a staff of about 250, conducts in-house R&D using its extensive research and pilot facilities in many aspects of energy technology (clean sources, renewables, and efficient end use) with a strong focus on environmental issues, notably climate change. It also manages a number of S&T funding programs for the federal government in these same areas (approximately $25 million annually) including one specifically targeted at clean coal. CETC-O has established wide-ranging partnerships with universities, other government agencies, and especially industry.

One of CETC-O's strengths is its extensive combustion program, which for clean coal includes comprehensive programs in fuel property characterization (Proj 1.1) and modeling (Proj 1.2); oxyfuel combustion (Proj 8.1, 8.5, 8.6, 8.7, 8.8, 8.9, 8.10), gasification (Proj 7.3, 7.4, 7.6), plasma cleaning (Proj 6.12), and chemical looping combustion (Proj 10.7, 10.8). CETC-O also has clean coal related projects in fuel cells (Proj 10.9, 10.11) and membranes (Proj 7.4).

CETC-O representatives are active in several Canadian CCT organizations, the most prominent being the Canadian CO_2 Capture and Storage Technology Network (Org 1.1). CETC-O also coordinated the development of the Technology Roadmaps (Doc 1.1, 1.2)

Contact

John Marrone
CANMET Energy Technology Centre-
Ottawa
613-996-8201
jmarrone@nrcan.gc.ca
The CETC-O web site is at www.nrcan.gc.ca/es/etb/cetc/cetc01/htmldocs/home_e.htm

Org 3.2 Saskatchewan Research Council

What is it? The Saskatchewan Research Council is the largest research organization in the province, with a particular focus on energy, complementing the province's energy resources.

Role played in Canadian Clean Coal The SRC's research program includes support of emission reduction technologies.

Description The SRC, with laboratories in Regina and Saskatoon, is a corporation of the provincial government, responsible to the Minister of Industry and Resources. It has a staff of 225 and annual revenues of about $25 million. Energy is one of SRC's six divisions.

Two projects found in this Compendium are:

- Novel biochar and coal char sorbents for the removal of mercury from coal combustion flue gas (Proj 4.4)
- A novel method for capturing CO_2 from flue gas involving the formation of CO_2 clathrates (Proj 10.14)

Contact

Ernie Pappas
Vice-President
SRC Energy Division
306-787-9400
pappas@src.sk.ca
The SRC web site is at www.src.sk.ca

Org 3.3 Alberta Research Council: Carbon and Energy Management Unit

What is it? The Carbon and Energy Management Unit (CEMU) of the Alberta Research Council (ARC) consists of about 20 scientists (and associated staff) working on programs of clean energy, geological storage, and unconventional natural gas.

Role played in Canadian Clean Coal Activities While the majority of the work of the CEMU related to clean coal is on CO_2 storage, they are also active in CO_2 capture science and technology, notably in gas separation and process economics.

Description ARC is a not-for-profit corporation wholly owned by the province of Alberta and governed by a seven-member board of directors drawn from the private, public, and higher education sectors. ARC employs over 500 scientists, engineers, business managers and support staff that operate in five facilities located throughout Alberta. The CEMU is one of thirteen specialized areas of research.

The ARC projects in this Compendium are:

- an integrated economic model for CO2 capture and storage [Proj 5.5]
- jointly with the University of Waterloo, ARC plans to develop hollow-fibre technology as a way of separating CO_2 from gas streams that is more effective than amine solvents [Proj 9.1].

Contact

Bill Gunter
Alberta Research Council
780-450-5467
gunter@arc.ab.ca
The ARC web site is at www.arc.ab.ca

Org 3.4 National Research Council of Canada: Institute for Chemical Processing and Environmental Technology

What is it? The National Research Council (NRC) is the government of Canada's premier science and technology research organization. Within NRC, the mandate of the Institute for Chemical Processing and Environmental Technology (ICPET) includes support for Canada's energy-intensive industries.

Role played in Canadian Clean Coal Activities ICPET conducts research on chemical systems, giving it the capacity to undertake some projects on CO_2 capture.

Description NRC-ICPET contributes to increasing the competitiveness of Canada's chemistry intensive industries through research into innovative processes and technologies that enable sustainable development. ICPET has chemical science and engineering capabilities directed toward research, development, and technology commercialization. ICPET has become engaged in several projects related to clean coal:

- High selectivity gas separation by mixed-matrix polymer-zeolite membranes (Proj 9.5)
- Direct $C0_2$ reductions from industrial emissions using membranes (Proj 9.6)
- Hydrate technology for gas separation and CO_2 capture (Proj 10.13)

ICPET is also involved in two projects lead by CETC-O in the area of fuel cells (Proj 10.9, 10.11).

Contact

Kevin Jonasson
NRC/ICPET
613-993-6570
kevin.jonasson@nrc-cnrc.gc.ca
The NRC/ICPET website is at http://icpet-itpce.nrc-cnrc.gc.ca/research.html

4. RESEARCH – UNIVERSITIES

Org 4.1 Overview (includes Dalhousie, Université du Québec à Montréal, Ottawa, Carleton, McMaster, Saskatchewan, Alberta)

What is it? Many Canadian universities are engaged in leading-edge S&T for Canada's resource industries and for protection of the environment.

Role played in Canadian Clean Coal Activities The universities of Waterloo, Regina and British Columbia have a number of projects and are each given a separate page in this Compendium. A number of research projects are also underway in other universities, listed below.

Description

- University of Waterloo
  The new (2003) Green Energy Research Institute [Org 4.2] brings together CCS research at the university.
- University of Regina
  Two research centres are the CO_2 Capture Research Group [Org 4.3] and the International Test Centre for CO_2 Capture [Org 4.4].
- University of British Columbia
  Two groups, the Department of Chemical and Biological Engineering and the Department of Mining are described on one page [Org 4.5].

Many other Canadian universities have clean coal projects. These are listed below. This Compendium does not devote one-page descriptions to these universities.

- Dalhousie University
  Clean energy from coal and biomass (Proj 3.1) [Prabir Basu]
- Université du Québec à Montréal
  New solid sorbents for carbon dioxide capture (Proj 10.1) [Daniel Bélanger]
- University of Ottawa
  Gas permeation properties of commercial polyphenylene oxide and cardo-type polyimide hollow fibre membranes (Proj 9.3) [Takeshi Matsuura]
  CO_2 scrubbing : the dry route (Proj 10.2) [Abdelhamid Sayari]
  Novel adsorbents for acid gas removal (Proj 10.3) [Abdelhamid Sayari]
- Carleton University
  Closed gas turbine cycle project (joint with Waterloo University) (Proj 8.2) [Donald Gauthier]
  Advanced Brayton-cycle-based zero emission power plants burning fossil fuels Proj 8.3 [Donald Gauthier]
- McMaster University
  Development of integrated electrostatic air pollution control system for small-scale combustion passed power generators (Proj 4.1) [JenShih Chang]

Electrohydraulic discharge and energetic atmospheric plasma processes in multi-phase flow systems (Proj 4.2) [JenShih Chang]

- University of Saskatchewan
  Mathematical modeling of a Circulating Fluidized Bed (CFB) lignite combustor (Proj 1.3) [Todd Pugsley]
  Novel biochar and coal char sorbents for the removal of mercury from coal combustion flue gas (Proj 4.4) [Ajay Dalai]
- University of Alberta
  Fluid coke as a sorbent for mercury (Proj 4.6) [Sieg Wanka]
  Mercury emission control from coal-fired power plants [Zhenghe Xu]

Contact Please refer to the individual organization and project pages.

Org 4.2 University of Waterloo

What is it? The Green Energy Research Institute (GERI) is a new organization at the University of Waterloo that promotes collaboration among researchers from engineering and environmental studies to develop and promote clean energy alternatives and sustainable energy systems.

Role played in Canadian Clean Coal Activities Several projects are targeted at clean coal including the development of CO_2 capture and mitigation technologies and tools to inform regional planning for CO_2 emission reduction in the utility sector.

Description GERI is a multi-disciplinary cluster of UW researchers who conduct a broad range of sustainable energy technology and policy studies. Research topics include greenhouse gas mitigation; solar and wind power; bioenergy; fuel cells; hydrogen production, storage and retailing; distributed power generation; power conditioning; and energy conservation and demand management. For clean coal activities, the projects include:

- Optimisation of integrated CO_2 capture, transportation and storage in Canada (Proj 5.1) [Peter Douglas]
- Development of a generalised systems scheduling framework for the operation of generating stations with CO_2 constraints in Canada (Proj 5.2) [Peter Douglas]
- CO_2 capture and mitigation technologies for Canada's power generation system (Proj 5.3) [Peter Douglas]
- Improvements in efficiency and process modifications for CO_2 capture in western Canadian hydrogen plants (Proj 5.4) [Peter Douglas]
- Closed gas turbine cycle project (with Carleton University) (Proj 8.2) [Eric Croiset]
- Decarbonization of fossil fuels for CO2 mitigation (Proj 8.4) [Eric Croiset]
- Novel CO_2 separation processes for CO_2 mitigation (Proj 9.2) [Amit Chakma]
- Pressure swing permeation and integrated membrane/adsorption processes for enhanced separation of gases (Proj 9.4) [Xianshe Feng]
- Solid oxide fuel cell (SOFC) power generation systems (Proj 10.10) [Eric Croiset]

Contact

Michael Worswick
Green Energy Research Institute, University
of Waterloo
Waterloo, Ontario
519-888-4567, extension 37543
worswick@lagavulin.uwaterloo.ca
The GERI web site is at www.geri.uwaterloo.ca.

Org 4.3 University of Regina - CO_2 Capture Research Group

What is it? The CO_2 Capture Research Group is a team of about 20 scientists and graduate students working at laboratories and in small pilot plant units. It conducts research that complements that of the International Test Centre (Org 4.4)

Role played in Canadian Clean Coal Activities The Group, which has close ties to industry, pursues advanced CO_2 separation technologies, based predominantly on solvent capture.

Description Main areas of research are industrial gas processing and CO_2 removal from flue gases and other industrial gas streams. The Group's focus and location complement Saskatchewan's hydrocarbon industry. The Group emphasizes CO_2 capture through the development and optimization of amine solvents and related processes. Projects found in this Compendium are:

- High efficiency gas testing systems for CO_2 (greenhouse gas) capture and separation (Proj 6.1) [Paitoon Tontiwachwuthikul]
- University of Regina International Test Centre Consortium Program (Proj 6.2) [Paitoon Tontiwachwuthikul]
- Capture of CO_2 from combustion flue gases using amines (Proj 6.3) [R. Idem]
- Fundamental studies of mass transfer with chemical reaction for CO_2 separation processes (Proj 6.4) [Adisorn Aroonwilas]
- Separation of CO_2 from flue gases: alkanolamine degradation prevention studies (Proj 6.5) [Raphael Idem]
- CO_2 capture from coal-fired power plant flue gases using formulated amines: degradation prevention studies (Proj 6.6) [Raphael Idem]
- High pressure solubility studies in acid gas removal (Proj 6.7) [Amr Henni]
- Solubility, kinetics and calorimetric studies in acid gas removal (Proj 6.8) [Amr Henni]
- Molecular design and solvent development of cost effective processes for CO_2 capture from industrial gas streams (Proj 6.9) [Paitoon Tontiwachwuthikul]
- Fundamental studies of CO_2 (greenhouse gas) capture and separation using extra-high concentration formulated solvents (Proj 6.10) Paitoon Tontiwachwuthikul]
- Comprehensive corrosion studies and development of low toxic corrosion inhibitors for CO_2 separation process Proj 6.11) [Amornvadee Veawab]
- Membrane screening and development for CO2 absorption in a membrane contactor (Proj 9.7) [David deMontigny]
- Integration of mercury into pollutant removal units of coal-fired power plant (Proj 4.5) [Raphael Idem]

Contact

Paitoon Tontiwachwuthikul
University of Regina
306-585-4160
paitoon.tontiwachwuthikul@uregina.ca
The CO_2 Capture Research Group web site is at www.uregina.ca/engg/co2/co2res.htm.

Org 4.4 University of Regina – International Test Centre for CO_2 Capture

What is it? The International Test Centre (ITC) is a university-located CO_2 capture laboratory and a nearby pre-commercial demonstration facility.

Role played in Canadian Clean Coal Activities The Centre has analytic and research capability with capacity for technology demonstration of post-combustion CO_2 capture technologies, especially separation using amines.

Description ITC is developing post-combustion capture technologies that can reduce the cost and energy penalty of CO_2 production. The Centre relies on existing expertise at the University of Regina. Eight professors (researchers) are on staff, plus plant operators and others.

The Centre has two capital components:

- A $3 million pilot plant installation at the University site for GHG capture technology development and screening.
- A $5M pre-commercial technology demonstration plant at SaskPower's coal-fired Boundary Dam Power Station near Estevan, Saskatchewan.

The Centre also uses three university pilot plant units to test high efficiency gas-treating systems; varying sizes of absorption and regeneration towers are used with a variety of high-performance packing. Other research components are used for solvent absorption capacity, for solvent stability and corrosion, and for gas and liquid diffusivity determination.

The ITC's program is planned in close cooperation with the University of Regina's CO_2 Capture Research Group [Org 4.3]. Also involved are the Universities of Waterloo, British Columbia, and Calgary.

There are numerous funders. They are listed elsewhere in this Compendium [Proj 6.2].

Contact

Ralph Idem
University of Regina
Regina, Saskatchewan
304-585-4470
raphael.idem@uregina.ca

Malcolm Wilson
University of Regina
Regina, Saskatchewan
306-337-2287/2296
malcolm.wilson@uregina.ca

The ITC web site is at www.co2-research.ca.

Org 4.5 University of British Columbia – Clean Energy Research Centre

What is it? The Clean Energy Research Centre is a multi-disciplinary organization housed in the Faculty of Applied Science at the University of British Columbia.

Role Played in Canadian Clean Coal Activities The Centre provides state-of-the-art research facilities for the exploration of clean energy technology, including some projects related to clean coal.

Description At the Centre, faculty and other researchers are primarily from mechanical engineering, chemical and biological engineering, and metals and materials engineering departments. Currently, there are more than 20 professors and nearly 100 graduate students working in CERC.

CERC's projects that can be found in this Compendium:

- CO_2 separation technology in combustion systems (Proj 10.4) [Naoko Ellis]
- Experimental and numerical studies of fluidized bed and its application to chemical looping combustion (Proj 10.5) [Naoko Ellis]
- SO_2 and CO_2 capture using limestone-derived sorbents (Proj 10.6) [John Grace]
- Advanced greenhouse mitigation based on hydrates (Proj 10.12) [Peter Englezos]
- Coal reverse flotation: a new method of improving flotation column throughput and coal-water slurry technology. (Proj 2.1) [Janusz Laskowski]

Contact

Robert Evans
Clean Energy Research Centre, UBC
Vancouver, British Columbia
604-822-3483
Email evans@mech.ubc.ca
The Centre's web site is at www.cerc.ubc.ca

5. CANADIAN COAL-BURNING UTILITIES

Org 5.1 Nova Scotia Power Inc.

What is it? Nova Scotia Power Inc. (NSPI) is a private company providing virtually all the electric power to Nova Scotia. It is a wholly-owned subsidiary of Emera Inc., a publicly-traded holding company.

Role Played in Canadian Clean Coal Activities NSPI, a customer for clean coal technologies, identifies and sponsors research in the field. It operates the only utility-scale fluidized-bed combustor in Canada at Point Aconi.

Description The company, with headquarters in Halifax, has operations that provide over 95% of the generation, transmission and distribution of electric power throughout Nova Scotia. It links its network through New Brunswick to the North American power grid.

Various sources, principally US and South America, provide coal and petroleum coke for NSPI's four units at Lingan (total capacity 612 MW), two at Trenton (314 MW); one at Point Tupper (152 MW) and one at Point Aconi. (173 MW).

The company is a member of the Canadian Clean Power Coalition (Org 1.1 and Proj 11.1), which proposes the development, construction and operation of full-scale demonstration projects, which will remove GHG and other emissions of concern from greenfield coal-fired power facilities.

Contact

Doug Campbell
Nova Scotia Power Inc.
902-428-6221
douglas.campbell@nspower.ca
The company's web site is at www.nspower.ca

Org 5.2 New Brunswick Power Generation Corporation

What is it? New Brunswick Power Generation Corporation (Genco) owns and operates the non-nuclear generating facilities for the provincial electrical utility.

Role Played in Canadian Clean Coal Activities Genco is a potential customer for clean coal technologies.

Description Genco, with headquarters in Fredericton, is one of the New Brunswick Power group of companies, a provincial Crown Corporation.

Genco generates electricity at fourteen oil, coal, hydro and diesel-powered facilities. These stations have an installed capacity of over 3,000 MW, of which some 60% is thermal. Coal-fuelled thermal stations are Belldune (458 MW) and Grand Lake (57 MW). The company owns two subsidiaries: NB Power Coleson Cove Corporation, which owns and operates the Coleson Cove Generating Station, and NB Coal Limited, which mines coal to supply the Grand Lake Generating Station.

Contact

Arden Trenholm
New Brunswick Power Generation
Corporation
506-458-4385
atrenholm@nbpower.com
The company's website is www.nbpower.com

Org 5.3 Ontario Power Generation

What is it? Ontario Power Generation (OPG) is an Ontario-based electricity generation company whose principal business is the generation and sale of electricity in Ontario.

Role Played in Canadian Clean Coal Activities OPG monitors the status and development of a variety of energy technologies, including clean coal technologies.

Description OPG is a public company whose shares are wholly owned by the Government of Ontario. It is responsible for approximately 70% of the electricity generation in the province.

The company's generating portfolio has a total capacity of over 22,000 MW making it one of the largest power generators in North America. Generating assets include three nuclear generating stations, four fossil generating stations, 64 hydroelectric generating stations and three wind generating stations.

Coal-fired generating stations are:

- Lambton (4 x 500 MW)
- Nanticoke (8 X 500 MW)
- Atikokan (230 MW)
- Thunder Bay (2 X 160 MW)

The company maintains its awareness of the development of clean coal technologies through such low cost collaborative activities as: membership in the CETC-O Oxy-Fuel R&D Consortium (developing oxy-fuel combustion technologies for CO_2 capture and storage) [Proj 8.5]; graduate student development support at the University of Waterloo; and co-funding through CEATI [Org 1.5] of the International Energy Agency's Greenhouse Gas R&D Programme [Org 2.11] and the IEA's Clean Coal Centre [(Org 2.8].
To manage its existing fleet performance, OPG also participates in the collaborative work of the Electric Power Research Institute's [Org 2.5] Integrated Environmental Control Program and post-combustion NOx programs.

Contact
Blair Seckington
Ontario Power Generation
Toronto, Ontario
416-592-5191
Blair.seckington@opg.com
The company's website is www.opg.com

Org 5.4 Manitoba Hydro

***What is it*?** Manitoba Hydro is a provincial Crown Corporation, providing electrical energy and natural gas throughout the province.

Role Played in Canadian Clean Coal Activities Like other Canadian utilities, the Corporation is a potential customer for clean coal technologies.

Description The Corporation, headquartered in Winnipeg, is the province's major energy utility and is governed by the Manitoba Hydro-Electric Board, whose members are appointed by the Lieutenant-Governor in Council.

Almost all of Manitoba Hydro's electric generation is from hydro. About 5% of its supply is from thermal generation at its Brandon (coal and natural gas) and Selkirk (natural gas) stations and from power imported from the US. Manitoba Hydro also operates small diesel-electric generating stations to serve four northern communities that are not connected to the provincial transmission grid.

The Brandon Generating Station has a capacity of 365 MW consisting of a 105 MW coal-fired steam turbine and two 130 MW gas turbines (natural gas as primary fuel with diesel as a backup fuel). The coal-fired unit's fuel is low sulphur, low ash Powder River sub-bituminous coal from Montana-Wyoming.

Contact

Jason Doering
Manitoba Hydro
204-474-4647
jtdoering@hydro.mb.ca
www.hydro.mb.ca

Org 5.5 SaskPower

What is it? SaskPower, a provincial crown corporation with headquarters in Regina, supplies, transmits and distributes electricity to most of the province of Saskatchewan.

Role Played in Canadian Clean Coal Activities The corporation is one of the most active in Canada in supporting the development of clean coal technologies SaskPower provided the industry lead for the development of the Clean Coal Technology Roadmap (Doc 1.1) and is very active in the development of mercury removal technology.

Description SaskPower has a generating capacity of over 3,200 MW from 17 generating facilities. About one-half comes from three coal-fired base load facilities: Shand (279 MW capacity), Boundary Dam (813 MW) and Poplar River (562 MW). All are pulverized coal units with lignite supplied from mines in the Estevan and Coronach areas of southern Saskatchewan.

In the summer of 2007, SaskPower will make a decision on whether to proceed with construction of a clean coal plant which would cost "in excess of $1 billion" when ready for commissioning in 2011. SaskPower is currently working with the following partners on the design of this project:

- Neill and Gunter - Owner's engineer [Org 8.23]
- Marubeni Canada/Hitachi Canadian Industries - Steam Turbine Generator Set [Org 8.19]
- Air Liquide - Air Separation Unit and CO_2 Compression Unit [Org 8.3]
- Babcock and Wilcox - synthetic air boiler [Org 8..5]

SaskPower is involved in the following activities, found elsewhere in this Clean Coal Compendium

- Close links to the International Test Centre, Regina [Org 4.4]
- The Canadian Clean Power Coalition [Org 1.1, Proj 11.1]
- Leader of the Saskatchewan Clean Coal Project [Proj 11.3]
- Injection of activated carbon for removal of mercury [Proj 4.3]
- Non-thermal plasma multi-pollutant control and flue-gas cleanup [Proj 6.12]
- Oxyfuel R&D consortium [Proj 8.5]

The Company is also a collaborative partner in the new Saskatchewan Poly-Generation engineering study.

Contact

Bob Stobbs
SaskPower, Regina, Saskatchewan
306-566-3326
bstobbs@saskpower.com
The Saskpower web site is at www.saskpower.com

Org 5.6 ATCO Power

What is it? ATCO Power Ltd. (ATCO Power) is a Calgary-based owner and operator of independent power projects in Alberta and elsewhere in Canada and abroad.

Role Played in Canadian Clean Coal Activities ATCO Power is participating in the development of mercury capture technology for implementation on existing coal-fired units by 2011. The company is also carrying out emission reduction studies to evaluate existing and new control technologies as well as studying fuel optimization and efficiency improvements. ATCO Power is also pursuing clean coal technologies for new projects in Canada.

Description ATCO Power is owned by the ATCO Group, a large Canadian-based, international group of companies engaged in utilities, power generation and global enterprises. The Group owns and operates independent hydroelectric, coal, and natural gas-fired power plants. It includes ATCO Power and ASHCOR Technologies.

In Alberta, ATCO Power operates two major coal-fired generating stations: Battle River and Sheerness. The Battle River station has a 670 MW capacity. The Sheerness Generating station has a 760 MW capacity and is jointly owned by ATCO Power and TransAlta Utilities. Both stations are northeast of Calgary and are supplied by nearby coal mines.

ASHCOR Technologies markets coal combustion products produced by ATCO Power's generating stations to the ready-mix concrete and oil well cementing sectors.

Contact

Dwight Redden
ATCO Power Ltd.
Calgary, Alberta
780-209-6902
dwight.redden@atcopower .com
www.atcopower.com

Org 5.7 EPCOR Utilities Inc.

What is it? EPCOR Utilities Inc. (EPCOR), wholly owned by the City of Edmonton, is a large provider of energy and energy-related services and products. The company operates a multi-unit coal-fired power station (Genesee) and many combined cycle, small hydro and wind-generating stations.

Role Played in Canadian Clean Coal Activities In a joint venture with TransAlta, EPCOR operates a commercial-scale, supercritical coal-fired power plant. The two companies are also jointly developing another. EPCOR is also the lead utility in the front-end design of a proposed new IGCC plant.

Description EPCOR has operations ranging from generation to distribution to distributed power purchasing in several Canadian provinces and in other countries, including the United States.

In Canada, the company's main power generating facility is the large, three-unit coal-fired plant at Genesee, of which one unit is the supercritical Genesee 3 plant. This supercritical pulverized coal combustion unit is the first of its kind in Canada, with emission levels (including GHGs) much better than conventional technologies. (Proj 11.10). Two smaller plants (Clover Bar and Rossdale) are gas-fired. All are in the vicinity of Edmonton. Also, EPCOR will be part owner, with Transalta, of the proposed Keephills 3 supercritical coal-fired generating plant (Proj 11.11).

The company is a major player in the Canadian Clean Power Coalition (CCPC), providing its current Chairman [Org 1.1]. It is also the utility lead on the Front End Engineering Design of a proposed Alberta-based IGCC plant, sponsored by the CCPC. This plant could be Canada's first coal-fired IGCC plant operating with near-zero emissions.

Contact

David Whitten
EPCOR
Edmonton, Alberta
780-412-3414
dwhitten@epcor.ca

EPCOR's web site is at www.epcor.ca

Org 5.8 Maxim Power Corporation

What is it? Maxim is a Calgary-based independent power producer operating plants in Western Canada and abroad.

Role Played in Canadian Clean Coal Activities Maxim Power's subsidiary, Milner Power Inc., operates a single coal-fired power plant in Alberta. The company recently acquired this plant from ATCO. It has not yet engaged in any clean coal projects.

Description The company's stated strategy is to own and operate innovative and environmentally responsible power projects using commercial technology to generate electric and thermal energy for customers.

The company owns and operates 24 power plants in Western Canada, the United States and France, with a total nameplate capacity of 481 MWe.

Maxim's Canadian coal-fired power station is the H.R. Milner plant (operated by Milner Power Inc., a subsidiary of Maxim), a 144 MW station located near Grande Cache, Alberta. The plant is fuelled with highly volatile bituminous coal from the Coal Valley mine. (See the Alberta section in Part D of this Compendium.).

Contact

Pat Lucas
Maxim Power Corp.
Calgary, Alberta
403-263-3021, extension 308
plucas@maximpowercorp.com
The web site of Maxim is www.maximpowercorp.com

Org 5.9 TransAlta Corporation

What is it? TransAlta Corporation is a power generation and wholesale energy marketing company operating in Canada and internationally. The company owns and operates coal-fired and gas-fired plants, hydro plants and plants running on other renewable energy sources.

Role Played in Canadian Clean Coal Activities The Corporation is a founding member of the Canadian Clean Power Coalition. TransAlta supports the development of clean coal technologies.

Description The corporation is one of three major power producers in Alberta (the others are ATCO and EPCOR).

TransAlta supplies approximately one-half of Alberta's total electric energy needs and is well positioned in other markets where the demand for electricity is growing - Eastern Canada, the United States, Mexico and Australia.

TransAlta's Canadian operations include a number of plants in Alberta and Ontario and a proposed wind farm in New Brunswick. In Alberta, TransAlta is the owner and operator of Keephills (766 MW), Sundance (2,020MW) and Wabamum (279 MW) coal-fired plants. TransAlta is also joint owner of Genesee 3 (450 MW – with EPCOR) and Sheerness (770 MW-with ATCO) coal-fired plants. These plants all use Alberta sub-bituminous coals.

For a complete list of TransAlta's operations, visit the website at www.transalta.com.

Contact

Joel Thompson
TransAlta
Calgary, Alberta
403-267-7330
joel_thompson@transalta.com
The TransAlta Corporation web site is at www.transalta.com

6. REGULATORY AGENCIES

Regulatory Agencies – Overview

Section D of this Compendium provides an overview of the current regulatory regime and commercial practice for clean coal in Canada. Information on this page is taken from Section D.

The federal and provincial governments share responsibility for environmental standards related to air pollution under the Canadian Environmental Protection Act (federal) and the relevant provincial/territorial environment acts and associated regulations. The federal government also has responsibilities under international agreements.

The federal government is moving toward national standards for most air pollutants and is engaged with provinces and territories through the Canadian Council of Ministers of the Environment (CCME; Org 1.3) in a national process to define Canada-Wide Standards (CWS) which set out consensus-derived emission limits, monitoring requirements and implementation timetables.

The federal role in regulating air emissions from coal-fired power plants is under the jurisdiction of Environment Canada [Org 9.1], which administers the Canadian Environmental Protection Act 1999 (CEPA). There are as yet no CEPA regulations covering the emissions of interest for this Compendium. However, Environment Canada did issue *New Source Emission Guidelines for Thermal Electricity Generation* under CEPA 1999. These guidelines are intended to serve as the basis for provincial regulations and standards.

The provinces, for their part, set mandatory emission levels through environmental legislation administered by provincial environment departments. For those provinces that use coal for electricity generation, the relevant agencies are:

- Nova Scotia: The Department of Environment and Labour (www.gov.ns/enla) administers Air Quality Regulations which fall under the Environment Act.
- New Brunswick: The Department of Environment (www.gnb.ca) administers the Clean Air Act and associated Air Quality Regulations.
- Ontario: The Ministry of the Environment (www.ene.gov.on.ca) administers the Environmental Protection Act.
- Manitoba: The Department of Conservation (www.gov.mb.ca/conservation) administers the Environment Act.
- Saskatchewan: The department of Environment (www.se.gov.sk.ca) administers the Saskatchewan Clean Air Act.
- Alberta: Alberta Environment (www.environment.gov.ab.ca) administers the Environmental Protection and Enhancement Act.

Org 6.1 Environment Canada - Canadian Environmental Protection Act 1999

What is it? The Canadian Environmental Protection Act 1999 (CEPA 1999) is part of Canada's federal environmental legislation. It is aimed at preventing pollution and protecting the environment and human health in order to contribute to sustainable development - development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

Role Played in Canadian Clean Coal Activities Under CEPA 1999, regulations are developed to control specific emissions. There are as yet no CEPA regulations covering the emissions of interest for this Compendium, specifically SO_2, NO_x, mercury, and particulate matter (<10 microns) from coal combustion.

Description CEPA 1999 came into force on March 31, 2000 following an extensive parliamentary review of the former CEPA. The CEPA 1999 Act:

- makes pollution prevention the cornerstone of national efforts to reduce toxic substances in the environment;
- sets out processes to assess the risks to the environment and human health posed by substances in commerce;
- imposes timeframes for managing toxic substances;
- provides a wide range of tools to manage toxic substances, other pollution and wastes;
- ensures the most harmful substances are phased out or not released into the environment in any measurable quantity;
- includes new provisions to regulate vehicle, engine and equipment emissions;
- strengthens enforcement of the Act and its regulations;
- encourages greater citizen input into decision-making; and
- allows for more effective cooperation and partnership with other governments and Aboriginal peoples.

Contact
Inquiry Centre
Gatineau, Quebec
1-800-668-6767 or 819-997-2800
enviroinfo@ec.gc.ca
The CEPA web site is at www.ec.gc.ca/CEPARegistry/the_act/

Org 6.2 National Energy Board

What is it? The National Energy Board (NEB) is a federal regulatory agency with a range of powers related to energy exports, pipelines and power lines as well as oil and gas related activities in Canada's north.

Role played in Canadian Clean Coal Activities In 1998 the NEB approved the Canadian portion of a CO_2 pipeline from North Dakota to the Weyburn, Saskatchewan enhanced oil project. Future interprovincial and international pipelines, carrying emissions from thermal-generating stations, would also be subject to NEB approval and regulation.

Description The regulatory powers granted to the National Energy Board (NEB) under the *National Energy Board Act* include:

- authorization of exports of oil, natural gas, and electricity;
- authorization of the construction of interprovincial and international oil, gas, and commodities pipelines and international power lines;
- setting of tolls for pipelines under federal jurisdiction; and
- regulation of oil and gas activities on Canada's lands in the north.

As a result of the *Canada Transportation Act*, which came into force on 1 July 1996, jurisdiction over interprovincial and international commodity pipelines in Canada was transferred from the National Transportation Agency to the NEB. At that time, the definition of "pipeline" in the *National Energy Board Act* was broadened to include pipelines transporting commodities other than oil or gas (excluding municipal sewer and water lines).

Canada's Energy Outlook, last published by the NEB in 2003, used a scenario-based approach to examine various possible energy futures for Canada to the year 2025. A "techno-vert" scenario was used to represent a world in which technology advances rapidly and Canadians show a preference for environmentally-friendly products and cleaner-burning fuels. Forecasts based on the techno-vert scenario assumed significant use of "clean coal" technologies well-suited for carbon capture and storage. An updated Energy Futures document will be released in the fall of 2007.

Contact

Robert Steedman
National Energy Board
403-299-3178
rsteedman@neb-one.gc.ca
The National Energy Board web site is at www.neb-one.gc.ca

7. ENVIRONMENTAL NON-GOVERNMENTAL ORGANIZATIONS (ENGOs)

Org 7.1 Energy Probe

What is it? Energy Probe is a consumer and environmental think tank focused on promoting resource conservation, economic efficiency, and effective utility regulation. It is active in analysis of nuclear economics, nuclear weapons proliferation regulation, renewable energy options, conventional fuels, conservation program analysis, and energy market analysis.

Role Played in Canadian Clean Coal Activities In recent years, Energy Probe has published environmental benchmarking analysis for all the large coal-fired electric plants in NAFTA and has published several newspaper columns on cleaner coal options for Ontario.

Description Energy Probe is a national consumer and environmental charity based in Toronto, but active nationally. The organization is funded by donations from private citizens and receives no funds from government, energy companies, or unions.

Contact

Tom Adams
Energy Probe
416-964-9223, extension 239
tomadams@nextcity.com
Energy Probe's web site is at www.energyprobe.org

Org 7.2 Ontario Clean Air Alliance

What is it? The OCAA is a diverse, multi-stakeholder coalition of approximately 90 organizations. Members include cities, health associations, environmental and public interest groups, public utilities, unions, faith communities and individuals.

Role Played in Canadian Clean Coal Activities The Alliance is an advocacy group dedicated to, among other goals, the phase out of all coal generating stations.

Description The OCAA's short-term goal is to achieve the complete phase-out of Ontario's four coal-fired power plants (Lambton, Nanticoke, Atikokan and Thunder Bay).

The Alliance's long-term goal is to ensure that all of Ontario's electricity needs are met by ecologically sustainable renewable sources. Its strategy to achieve its goals consists of conservation, renewable energy sources and the use of natural gas as a transition fuel.

Contact

Jack Gibbons
Ontario Clean Air Alliance
416-926-1907, extension 240
jack@cleanairalliance.org
The Alliance's web site is at www.cleanair.web.net

Org 7.3 Pembina Institute

What it is? The Pembina Institute is an independent, not-for-profit environmental policy research and education organization that focuses on energy and the environment.

Role played in Canadian Clean Coal Activities The Pembina Institute's major policy research and education programs include the environmental impacts of the energy industry, including climate change.

Description The Institute has a multidisciplinary staff of approximately 40 with offices in Calgary, Drayton Valley (Alberta), Edmonton, Ottawa, and Vancouver. It operates major policy research and education programs in the areas of sustainable energy, climate change, environmental governance, ecological fiscal reform, sustainability indicators, and the environmental impacts of the energy industry.

With respect to clean coal, the Institute's views find some expression in a submission (February 2007) to the House of Commons Legislative Committee on Bill C-30 (*The Clean Air Act*) and the *Canadian Environmental Protection Act.* The submission (co-authored with Sierra Legal [a separate organization from the Sierra Club] and the Canadian Environmental Law association) is available at:
http://www.pembina.org/pdf/publications/Bill_C30Subm_plus_chart.pdf

Clean coal is also discussed in both the *Power for the Future* study http://www.pembina.org/pubs/pub.php?id=166 and the more recent paper on combustion options for electricity generation
http://www.pembina.org/pubs/pub.php?id=1345

For more information, especially on carbon dioxide capture and storage, refer to the Pembina project page (Proj 12.2).

Contact

Mark Winfield
The Pembina Institute
416-978-3486
markw@pembina.org
The Pembina Institute web site is at www.pembina.org.

Org 7.4 Pollution Probe

What is it? Pollution Probe, with headquarters in Ottawa, is a donor-based Canadian environmental organization with major programs in air, water, climate change and energy. Pollution Probe defines environmental problems through research, promotes understanding through education, and presses for practical solutions through advocacy.

Role Played in Canadian Clean Coal Activities: Pollution probe advocates the following hierarchy for a sustainable electricity future:

1. Energy efficiency and conservation
2. Green power that meets the criteria for EcoLogo certification;
3. Ecologically sustainable larger-scale hydro and other renewables;
4. Combined heat and power using natural gas; and
5. The cleanest and safest technologies among the remaining options.

The organization has also looked at a sustainable energy future from the perspective of linkages between climate change mitigation and adaptation.

Description: Founded at the University of Toronto in 1969, Pollution Probe currently has 21 staff (full-time including interns) at offices in Ottawa and Toronto. The organization, under the banner Green Power, prepares reports on current conditions and identifies opportunities to encourage emission reductions. Some significant reports include: (i) A Green Power Vision and Strategy for Canada, September 2004; (ii) Report on the Green Power in Canada Workshop Series, August 2004; and (iii) Promoting Green Power in Canada Report, 2002 http://www.pollutionprobe.org/whatwedo/greenpower/index.html.

Pollution Probe is considering developing a Primer on coal technologies as part of its Environmental Primer Series. Primers on electricity and coal include the Smog Primer, Climate Change and Human Health, Mercury, Acid Rain, and Bioproducts. Primers can be found at: http://www.pollutionprobe.org/Publications/Primers.htm

Pollution Probe has also commented on legislation and policy, including those pertaining to energy and electricity:
http://www.pollutionprobe.org/Publications/commentpaperssubject.htm

Contact

Ken Ogilvie, Executive Director
Pollution Probe
Toronto, Ontario
416-926-1907
kogilvie@pollutionprobe.org

Rick Findlay
Pollution Probe
Ottawa, Ontario
613-237-8666
rfindlay@pollutionprobe.org

Pollution Probe's web site is at www.pollutionprobe.org

Org 7.5 Sierra Club of Canada

What is it? The Sierra Club of Canada (SCC), with headquarters in Ottawa, is a Canadian volunteer-based environmental organization.

Role Played in Canadian Clean Coal Activities SCC has a general campaign on fossil fuels to influence public opinion in general and, in particular, to change regulations and emission levels. Over and above this, the Club pushes its agenda of an overall reduction in fossil fuel use.

Description The SCC consists of five chapters – Atlantic, Quebec, Ontario, Prairies and British Columbia. This pan-Canadian organization is governed by a nine-member Board of Directors drawn from across the country. The organization claims membership of about 10,000 in Canada.

The SCC has identified smog and air pollution as responsible for a higher incidence of respiratory diseases and death, and acid rain for its contamination of other ecosystems such as watersheds and forests. It cites an overdependence on fossil fuels for causing release of greenhouse gases such as carbon dioxide, methane and nitrous oxide.

The SCC supports efficiency and renewables as the solution to current air quality problems.

Contact

National Office
Sierra Club of Canada
Ottawa, Ontario
613-241-4611
info@sierraclub.ca
The Sierra Club's web site is at www.sierraclub.ca

8. PRIVATE SECTOR COMPANIES

Note on Private Sector Companies

This section includes many of the Canadian companies offering equipment, services and consulting in support of the clean coal industry. In particular, it tries to capture companies with a key role in projects, such as the Clean Coal Power Coalition, that are in the forefront of allowing the use of coal and other solid fuels as a sustainable energy source.

Major private sector companies operating as electric utilities are classified under Section 5 of the compendium, Canadian Coal-Burning Utilities.

Org 8.1 AESWapiti

What is it? AESWapiti is a joint enterprise between a power company and a coal producer, formed to develop a coal and biomass-fired power station in northeastern British Columbia.

Role Played in Canadian Clean Coal Activities The enterprise plans to develop a 184 MW coal and biomass-fired power generation facility. These plans pre-date the recent British Columbia government Speech from the Throne that stated the requirement for CO_2 capture and storage from coal-fired plants in British Columbia.

Description This joint enterprise brings together a long-time British Columbia coal producer, Hillsborough Resources Limited, and AES Corporation, a global power company which among other things develops and deploys clean coal technologies. AES operates 122 power generation facilities on five continents.

Hillsborough, in addition to the Wapiti thermal coal development, is 20% owner of the newly formed Peace River Coal Inc., which, along with Anglo Canada (60% owner) and NEMI Northern Energy and Mining Inc. (20% owner) operate the Trend open-pit coal mine located south of Tumbler Ridge, British Columbia.

A description of the AES Wapiti project is in this Compendium [Proj 11.13].

Contact

Ed Beswick
Hillsborough Resources Limited
Vancouver, British Columbia
604-684-9288, extension 231
edbeswick@hillsboroughresources.com
The website is www.aeswapiti.com

Org 8.2 Airborne Clean Energy

What is it? Airborne Clean Energy is a Calgary-based company formed to develop and commercialize an emissions reduction process for coal-fired power stations.

Role played in Canadian Clean Coal Activities The company is commercializing its process in Canada and elsewhere to reduce the costs of removing SO_x, NO_x and mercury from coal-fired power station emissions.

Description Formed in 1995, Airborne developed and patented a process that reduces the multiple forms of pollution caused when burning high sulphur fuels to generate electricity (the Airborne Process). The process is the only multi-pollutant technology recognized for award in either round 1 or round 2 of the US Department of Energy's Clean Coal Power Initiative.

The company states that by employing the Airborne Process, power producers not only reduce their polluting emissions but can transform pollutants, through Airborne's proprietary regeneration process, into a high-quality granular fertilizer. Airborne's technology uses a combination of dry sodium bicarbonate injection, wet sodium carbonate scrubbing and advanced chemical oxidants to scrub regulated pollutants (SO_2, SO_3, NO_x and Hg) from flue gas while turning the SO_2, SO_3 and NO_x into a marketable fertilizer.

The company asserts that the recovery of SO_2, SO_3, NOx and Hg with the Airborne system is the highest guaranteed in coal-fired energy, including IGCC systems. The capital and operating costs for pollution control are significantly less than traditional systems.

The company has entered into strategic alliances with Peabody Energy, the Potash Corporation of Saskatchewan (for sales and marketing of fertilizer), HPD (for sodium bicarbonate regeneration systems), and Icon Construction (for fertilizer granulation systems). The company has also entered into advanced discussions to commercialize the technology in China.

Current Projects include the Mustang Generating Station, USA, Saskatchewan Minerals, Canada and an ethanol production facility for a confidential Canadian client.

Contacts

Murray Mortson
Airborne Clean Energy
Calgary, Alberta
403- 253-7887
m.mortson@airbornecleanenergy.com
The company's web site is at www.airbornecleanenergy.com

Org 8.3 Air Liquide Canada Inc.

What is it? Air Liquide Canada is a branch of Air Liquide of France, a major international provider of industrial and medical gases and related services.

Role Played in Canadian Clean Coal Activities The company is a partner in the Front End Engineering Design (FEED) project, to design a super-critical, oxy-fuel clean coal plant in Saskatchewan [Proj 11.3]. Air Liquide is also an international supplier of oxygen separation technology, often a key component in clean coal plants.

Description Air Liquide Canada, with general management in Montreal, has offices across the country.

Air Liquide can be found in this Compendium as a project contractor (Separation Unit and CO_2 Purification Unit) for the SaskPower clean coal project - Front end engineering design. [Proj 11.3].

Contact

Alain Delisle
Air Liquide Canada
Edmonton, Alberta
780-992-5835
alain.delisle@airliquide.com
The Air Liquide Canada web site is at www.ca.airliquide.com.

Org 8.4 Alstom Canada Inc.

What is it? Alstom Canada Inc., a subsidiary of the large multinational French conglomerate of the same name, supplies a wide range of industrial equipment and services for Canadian industry, including power generation.

Role Played in Canadian Clean Coal Activities Alstom, through its power division, is engaged in some of the clean coal activities found in this Compendium.

Description Servicing the industrial and utilities industries, the Power Service Sector of Alstom offers a complete portfolio of products and services for boilers, turbines, generators and environmental equipment.

Projects in this Compendium with some support provided by Alstom are:

- Zero emissions hydrogen production via gasification [Proj 7.3]
- SO_2 and CO_2 capture using limestone-derived sorbents [Proj 10.6]

Contact
John Randall
Alstom Canada Inc.
Burlington, Ontario
905-333-2025
john.randall@power.alstom.com
The company's web site is at www.power.alstom.com

Org 8.5 Babcock & Wilcox Canada

What is it? Babcock & Wilcox Canada is a private company and wholly owned subsidiary of the Babcock & Wilcox Company (USA).

Role Played in Canadian Clean Coal Activities The company is one of the leading providers of fossil-fuelled boiler systems, engaging in several projects.

Description Babcock & Wilcox Canada is engaged in extensive research and development in the areas of materials and corrosion research, critical materials manufacturing, thermal and structural design, field service and repair work as well as advanced materials development. The company maintains a broad R&D program aimed at design improvements, cost reductions, increasing the long-term reliability of products and the development of new products and services.

This Compendium includes Babcock and Wilcox Canada in these activities:

- CETC-O Oxy-Fuel R&D Consortium: development of oxy-fuel combustion technologies for CO_2 capture and storage [Proj 8.5]
- SaskPower clean coal project - Front end engineering design [Proj 11.3]

Contacts

Richard Worden	Bryan Stone	John Fleming
B&W Canada	B&W Canada	B&W Canada
519-621-2130	519-621-2130	519-621-2130
raworde@babcock.com	bbstone@babcock.com	jfleming@babcock.com

The Babcock & Wilcox Company web site is at www.babcock.com

Org 8.6 Bantrel Co.

What is it? Bantrel, a subsidiary of Bechtel Co. (U.S.), is an Alberta-based provider of engineering, procurement, construction, and construction management (EPC) services.

Role Played in Canadian Clean Coal Activities. Bantrel has contributed to the early steps of the Canadian Clean Power Coalition's plan to develop two major clean coal demonstration projects [Org 1.1, Proj 11.1]. It is also a major EPC company, with a particularly large presence in oil sands processing plants; as such, it is likely to be involved in the proposed oil sands gasification plants [Proj 11.7].

Description Bantrel is a major engineering, procurement and construction contractor (EPC) in the oil sands business. With over 3,000 personnel deployed on a select group of mega projects, Bantrel is the lead contractor on some of the most significant oil sands projects in Alberta today.

Bantrel offers turnkey capability, including the performance of feasibility studies, front-end and detailed engineering, procurement, project management, construction, commissioning and start-up, risk management, loss prevention and operations assistance.

Bantrel is engaged in energy projects, including bitumen upgrading and integrated gasification combined cycle technologies.

Contact

David Liderth
Bantrel Inc.
403-290-5000
Email liderthd@bantrel.com
The Bantrel company website is www.bantrel.com

Org 8.7 Cansolv Technologies Inc.

What is it? Cansolv Technologies Inc. (CTI) is an international company headquartered in Montreal that designs and builds gas separation systems based on the patented Cansolv technology.

Role played in Canadian Clean Coal Activities Cansolv is developing a project to construct and operate a plant to extract CO_2 from the flue gases of a coal-fired plant in Western Canada.

Description CTI offers its clients high efficiency air pollution and capture solutions for the removal of SO_2 and CO_2 from gas streams in various industrial applications.

This Compendium describes a proposed three-phase Cansolv project: a pilot plant, a commercial demonstration plant and a full-scale plant. [Proj 11.8].

Contact

Dr. Leo Hakka
Cansolv Technologies Inc.
Montreal, Quebec
514-382-4411, extension 26
hakkal@cansolv.com

The Cansolv Technologies Inc. web site is at www.cansolv.com.

Org 8.8 CO2 Solution Technologies Inc.

What is it? CO2 Solution is a Canadian company, based in Quebec. It is a high tech firm involved in recycling carbon dioxide (CO_2).

Role Played in Canadian Clean Coal Activities The generic nature of the technology allows multiple applications. One of the primary focuses is the use of the technology in the coal power plant sector, where it could enable a large reduction of CO_2 emissions allowing the use of coal in an environmentally acceptable way.

Description CO2 Solution carries out research agreements and designs develops and markets goods and services related to CO_2 management and removal by means of an enzyme conversion-based technology. Having developed a technology since 1997 for the capture and sequestration of CO_2 in the context of climate change, CO2 Solution is now at the stage of seeking to demonstrate a coal based pilot plant operation that may be adapted to thermal power plants. [Proj 11.9]

Contact

Sylvie Fradette
CO2 Solution
418-842-3456
sylvie.fradette@co2solution.com
The web site is at www.co2solution.com

Org 8.9 Colt Engineering

What is it? Colt Engineering, with headquarters in Calgary, is a large private contractor providing services to energy companies across Canada and internationally.

Role Played in Canadian Clean Coal Activities Colt has worked on Canada's first super-critical, coal-fired generating unit.

Description This employee-owned company has over 4,000 employees with offices in Calgary, Edmonton, Sarnia, Toronto and Anchorage.

Colt conducts major project activities with long-term client relationships, and establishes and manages strategic alliances. The company has been engaged in project development, leading to full-scale implementation, on energy and pipeline projects for Canadian and US clients. This includes front-end and detailed engineering, project and construction management, construction and plant commissioning. It also includes revamps, debottlenecks, overhauls and upgrades on existing facilities.

As for its clean coal activities, Colt helped develop Genesee 3 [Proj 11.10], Canada's first super-critical coal-fired generating unit, a venture of EPCOR [Org 5.7] and TransAlta [Org 5.9].

Contact

Paul Huizinga
Colt Engineering
Calgary, Alberta
403-258-8000
huizinga.paul@colteng.com
The Colt website is www.colteng.com

Org 8.10 Compliance Energy Corporation

What is it? Compliance is a new Canadian energy company engaged in the development of coal resources in the Tulameen coal basin in south-central British Columbia.

Role Played in Canadian Coal Activities The Company plans to develop the Princeton Power Project, producing electricity from locally produced wood residue and possibly coal.

Description The Corporation, with its head office in Vancouver, was formed in response to the British Columbia Government's 2002 Plan to encourage new electricity sources.

Compliance's main power activity would be its planned Princeton Power Project [Proj 11.12]. As originally proposed, the Project would generate 49 MW of electricity from local coal and wood residue with emissions levels that meet British Columbia's 2005 Coal-Fired Plant Emission Guidelines. However, this project is likely to be affected by the recent statement by the British Columbia government that all coal-fired plants in British Columbia must include CO_2 capture and sequestration. Compliance Energy is now considering a design that would burn only wood.

Contact

John Tapics
Compliance Energy Corporation
Vancouver, British Columbia
604-689-0489
john@complianceenergy.com
Compliance's web site is at www.complianceenergy.com

Org 8.11 Delta Energy

What is it? Delta Energy is a private company based in Thunder Bay, Ontario that is planning on developing electricity generation based on biomass gasification.

Role played in Canadian Clean Coal Activities The company is planning to construct and operate a biomass-fuelled gasification plant, to produce electricity connected to the local grid, that will meet increasingly stringent emission levels. While not strictly within the scope of this clean coal compendium, it is included because of the gasification stage.

Description Delta Energy has $48 million in financing in place to build two biomass co-generation plants (one 4 MW, the other 10 MW) adjacent to the FibraTECH Manufacturing mill near Thunder Bay.

If the approval process goes as hoped, the company will be ready to start building in April 2007 and produce power before the end of the year. The power plants would be the first in Ontario to use a gasification process that turns the wood wastes that fuel the system into a gas before burning them. Delta Energy will use a system developed by Primenergy (www.primenergy.com) of Tulsa, Oklahoma. In addition to producing power, the system will produce synthetic gas, steam, compressed air and heat that FibraTECH (an adjacent panelboard plant) will be able to use in its operations. It could also produce heat for a 'district' heating system.

Delta has applied under the Ontario's standard offer program to sell the electricity the plant produces to the provincial grid.

Contacts
Lynn Engler
Delta Energy
Thunder Bay, Ontario
807-344-8055
lengler@tbaytel.net
Delta Energy does not yet have a website.

Org 8.12 Ergo Exergy Technologies Inc.

What is it? Ergo Exergy is a Quebec-based company that specializes in the technologies needed for the underground gasification of coal.

Role played in Canadian Clean Coal Activities Ergo Exergy is leading the commercial development of Underground Coal Gasification (UCG) technology. Coal deposits in Nova Scotia and Alberta are being examined for their suitability for the proprietary technology of Epco Exergy referred to as ***ε***UCG™. Together with Ergo Exergy's Canadian licensee Laurus Energy Inc. [Org 8.22], Ergo Exergy is developing commercial projects targeting power generation in an IGCC configuration as well as production of synthetic natural gas (SNG) by methanation of the ***ε***UCG™ gas produced from otherwise unusable coal deposits in Canada.

Description Ergo Exergy has brought together international UCG experts with practical experience of commercial UCG operations. Ergo Exergy provides access to UCG technology for prospective commercial UCG projects worldwide. Together with international energy companies, Ergo Exergy advances current and potential UCG projects around the globe. Its technology has been applied to UCG projects in South Africa, India, Australia, New Zealand and the United States.

The Ergo Exergy process produces a syngas variant that can be used to co-fire existing coal-fired plants or repower natural gas fired plant, although the most efficient and environmentally friendly way of generating electricity using the syngas is the Integrated Gasification Combined Cycle (IGCC). The syngas can also be converted to chemicals and liquid fuels.

Contacts

Michael Blinderman
Ergo Exergy Technologies, Inc.
Montreal, Quebec
514-993-6416
info@ergoexergy.com
The company web site is at www.ergoexergy.com.

Org 8.13 ESI Ecosystem International Ltd.

What is it? ESI Ecosystem International Ltd. (ESI) is a privately-held, Montreal-based company that develops and implements a variety of environmental technologies, especially clean and renewable energy sources, in Canada and abroad.

Role played in Canadian Clean Coal Activities The company has developed a process for the mild gasification of coal. The process produces a synthetic gas. The coal to gas transformation is achieved using steam and heat from an existing power plant. The process gas is stored and can be used in a gas turbine to generate electricity and provide power to the grid. The process reduces CO_2 and, even more so, emissions such as NO_x, SO_x, and mercury.

Description ESI identifies international environmental projects, to ensure their development, to organize their financing, and to provide project management. ESI has a number of projects in Poland, in the field of small hydro and smokeless coal. In Canada, they have proposed the use of their mild gasification process as a means of continuing to use Minto high sulphur coal in New Brunswick Power's Grand Lake generating facility.

Contacts

Adalbert Goraczko
ESI Ecosystem International
514-697-1690
esiltd@esiltd.ca
The company web site is at www.esiltd.ca.

Org 8.14 Fluor Canada Ltd.

What is it? Fluor Canada, with headquarters in Calgary, is a large engineering, procurement, construction and maintenance service company.

Role Played in Canadian Clean Coal Activities The company has conducted studies on CO2 capture with proprietary solvents and has been a supporter of solvent capture research at University of Regina.

Description The Canadian company is a wholly-owned subsidiary of Fluor Corporation, one of the world's largest, publicly owned companies in the field.

Fluor Canada's projects have focussed on amine scrubbing and oxyfuel evaluation as part of the early planning and design work under the Canadian Clean Power Coalition [see Org 1.1 and Proj 11.1].

Contact

P. James McLean
Fluor Canada
Calgary, Alberta
403-537-5063
james.mclean@fluor.com
Fluor Canada's website is www.fluor.com/canada.

Org 8.15 Fossil Power Systems Inc.

What is it? Fossil Power, located in Dartmouth, Nova Scotia, is a privately held service company providing hardware and software systems and services to the international steam power industry.

Role Played in Canadian Clean Coal Activities The company offers boiler control, combustion management and hardware for the steam power industry and therefore can be instrumental in meeting increasing restrictions on emissions.

Description Fossil Power System's main thrust is the supply of control devices and control systems, mainly for large boilers (over 200,000 lbs per hour).

Fossil Power is active in the research and development of new and existing products.

Contact

Trevor Siteman
Fossil Power Systems Inc.
Dartmouth, Nova Scotia
902-468-2743, extension 235
sitemant@fossil.ca
The web site of Fossil Power is www.fossil.ca

Org 8.16 Foster Wheeler Canada Ltd.

What is it? Foster Wheeler Canada Ltd. is a subsidiary of Foster Wheeler Ltd. (U.S.), a global conglomerate with a focus on engineering, construction and procurement.

Role Played in Canadian Clean Coal Activities The company has worked on Nova Scotia Power's circulating fluidized bed Point Aconi power station, fuelled by pet coke and bituminous coal.

Description Foster Wheeler's centres for work on clean coal are located outside Canada, mainly in Clinton, New Jersey and Helsinki, Finland. Its main Canadian operation, in Niagara-on-the-Lake, Ontario, includes an engineering centre that provides engineering, fabrication and construction of industrial steam generators and heat transfer equipment.

The Niagara-on-the-Lake office would probably have some supporting role in any Foster Wheeler participation in Canadian clean coal projects.

Contact
Paul Kelso
Foster Wheeler Canada Ltd.
Niagara-on-the-Lake, (St. Catharines), Ontario
905-688-4434
paul_kelso@fwc.com
The web site is at http://www.fwc.com.

Org 8.17 Greenfield Research Incorporated

What is it? Greenfield Research is a research and development company providing services for fluidized bed boilers in the chemical and power industries.

Role Played in Canadian Clean Coal Activities. The company's unique technology would result in a practical means of firing biomass in an existing fossil fuel fired power plant to reduce both CO_2 and NO_x.

Description The company, located in Halifax, Nova Scotia, is built on the potential to commercialize a technology being developed by Dr. Prabir Basu at Dalhousie University who has determined that certain types of old pulverized coal-fired boilers can be modified to operate as environment friendly circulating fluidized bed boilers (Proj 3.2).

Overall, this research and development company provides services for:

- Fluidized bed boilers, gasifiers, incinerators and process equipment
- Feasibility studies for fluidized bed projects
- Training courses on fluidized bed boilers and reactors
- Software for evaluation of boiler design and financial analysis of power projects
- Bubbling and circulating fluidized bed boiler operation & maintenance
- Innovative processes

Contact
Dr. Prabir Basu
Greenfield Research Incorporated
902-422-9426
Prabir.Basu@greenfieldresearch.ca
The web site is at www.greenfieldresearch.ca.

Org 8.18 Greenhouse Gas Separation Systems Inc.

What is it? Greenhouse Gas Separation Systems Inc. (GGSSI) is a Canadian environmental technology and training company established primarily to commercialize a new patent pending process for the reduction (separation, capture, and sequestration) of GHG emissions such as CO_2, NO_x, and CH_4.

Role played in Canadian Clean Coal Activities GGSSI offers its separation and capture technology to Canadian CO_2 emitters. The technology could be applied to large emitters where geological storage is an option.

Description GGSSI was founded in 2000. It is built on designs and processes of a confidential and proprietary nature relating to the separation, capture, and sequestration of GHG emissions. In particular, the company has a patent pending for the Cerenzie Process, a GHG separation and capture technology.

The Cerenzie Process uses a combination of pure O_2 combustion, membrane separation, and ozonation scrubbing. The Canadian government-sponsored Environmental Technology Verification Program has independently verified that the pure O_2 combustion component of the Cerenzie Process can capture up to 92% of CO_2 from flue gases. In addition to the Cerenzie Process, GGSSI offers products and services in the following areas:

- Identification and monitoring of gas composition;
- GHG emissions reduction credit certification under the Kyoto Protocol;
- Training of environmental monitors; and
- Training of workers in the oil and gas industry.

The company notes that the GGSSI oxy-fuel technology increases fuel efficiency and reduces environmental impact. By applying the Oxy-Fuel Process and eliminating the oxidation of the air source nitrogen, the production of this greenhouse gas is greatly reduced to where the only NOx formed is from the fuel-born nitrogen.

Contact

Albert Cerenzie
Greenhouse Gas Separation Systems Inc.
403-506-0759
albertggssi@shaw.ca
The GGSSI web site is at www.ggssi.ca

Org 8.19 Hitachi Canada and Hitachi Canadian Industries

What is it? Hitachi Canada, a subsidiary of Hitachi American and Hitachi Japan, markets and manufactures a broad range of electronics and provides industrial equipment and services throughout Canada. Hitachi Canada has a Power and Industry Division in Calgary. Hitachi Canadian Industries Ltd., with headquarters in Saskatoon, is an independent company wholly owned by Hitachi Ltd. of Japan.

Role Played in Canadian Clean Coal Activities As Hitachi's primary contact/liaison office in Canada, Hitachi Canada has been involved in all aspects of the engineering, manufacturing and construction of generation facilities in Canada related to clean coal including construction of the first super-critical coal-fired unit in Canada.

Description Hitachi is a Japanese-based conglomerate that manufactures and markets a broad range of consumer, medical and industrial services and equipment. It has supplied a number of Canadian power plants with a variety of heavy electrical equipment. Currently Hitachi is one of the participants for the front end engineering design (Power Train engineering, manufacturing and construction) of the SaskPower clean coal project [Proj 11.3]. Hitachi also performed the engineering, manufacturing and construction of the Power Island for the Genesee 3 super-critical power plant (EPCOR/ TransAlta) [Proj 11.10]. In the past, Hitachi participated in studies for the Canadian Clean Power Coalition [Org 1.1 and Proj 11.1]. The studies, evaluating amine scrubbing and oxyfuel combustion were steps towards CCPC's objective to develop a major clean coal demonstration project.

Contact

Taite Purnell
Hitachi Canada Ltd.
403-225-5265
taite.purnell@hitachi.ca
Hitachi's website is www.hitachi.ca.

Org 8.20 HTC Purenergy

What is it? HTC Purenergy facilitates the deployment of CO_2 management projects that require the design, deployment and management of CO_2 source, supply and storage programs.

Role played in Canadian Clean Coal Activities HTC Purenergy is commercializing CO_2 capture and storage technology, to meet GHG and other emission reduction targets. HTC is also involved in carbon sequestration, enhanced oil recovery, risk assessment and carbon credit validation.

Description HTC Purenergy is the commercial business name of Saskatchewan-based HTC Hydrogen Technologies Corp. The Corporation works through product development, technology aggregation and partnership agreements with organizations such as the University of Regina's International Test Centre for CO_2 Capture [ITC; Org 4.3]. It is able to provide a range of technologies, experience and resources to support the engineering, procurement and construction of CO_2 management programs of large carbon emitters such as coal and natural gas power plants from its offices in Regina, Sydney, Australia, and Beijing, China.

The product development centre of HTC Purenergy is based at the ITC. The technologies have been developed through a Collaborative Research Agreement with the university and a Clean Air-CO_2 Sponsor Agreement with the ITC.

HTC Hydrogen Technologies has developed and aggregated intellectual property including patent rights and technology rights in the areas of CO_2 capture and capture solvents as well as other work in the handling of CO_2, as well as H2 production and handling.

In addition HTC works in conjunction with the Petroleum Technology Research Centre in designing enhanced oil recovery, CO_2 sequestration risk assessment, and carbon credit validation engineering projects world-wide.

Contact

Jeff Allison
HTC Purenergy Corp
Regina, Saskatchewan
306-352-3263
jallison@htcenergy.com
The HTC Purenergy web site is at www.htcenergy.com.

Org 8.21 Jacobs Consultancy Inc. (USA)

What is it? Jacobs Consultancy is a US consulting firm that offers services that include strategy development, economic analysis, and technical consulting to the energy and utilities industries. The company has an office in Calgary.

Role Played in Canadian Clean Coal Activities Jacobs has the capability to provide a range of economic and technical services in the clean coal area.

Description Jacobs has contributed to the early steps of the Canadian Clean Power Coalition's plan to develop a major clean coal demonstration project [Org 1.1, Proj 11.1]

Contact

Denise Bennett
Jacobs Consultancy
Calgary, Alberta
403-258-6533
denise.bennett@jacobs.com
Jacobs web site is at www.jacobsconsultancy.com.

Org 8.22 Laurus Energy Inc..

What is it? Laurus Energy Inc is a Quebec-based company that develops commercial projects based on Ergo Exergy UCG (***ε***UCG^{TM}) technology in Canada. Laurus Energy was established to develop, own and operate commercial ***ε***UCG^{TM} gas production facilities in Canada.

Role played in Canadian Clean Coal Activities Laurus Energy has examined coal deposits for their suitability for the proprietary technology of Ergo Exergy [Org 8.12], referred to as εUCG^{TM}, in every Canadian province and has created an inventory of coal applicable to εUCG^{TM} technology.

Description Laurus Energy's strategic objective is to manufacture syngas from proprietary coal leases and sell it to end-users as clean and cost effective fuel for power generation and/or as a chemical feedstock. Laurus Energy has examined energy demand and infrastructure, regulatory and environmental framework at the provincial and regional level to complement its characterization of coal deposits. Supported by Ergo Exergy, Laurus Energy Inc. is developing commercial projects targeting power generation in an IGCC configuration as well as production of synthetic natural gas by methanation of the εUCG^{TM} gas generated from otherwise unusable coal deposits in Canada. Laurus Energy is developing a project in Alberta that will produce an alternative to natural gas for oil sands developments.

Contacts

Simon Maev, Director
Laurus Energy Inc.
Montreal, Quebec
514-241-8381
simon.maev@laurusenergy.com

Org 8.23 Neill & Gunter

What is it? Neill & Gunter is a Canadian-based design and consulting engineering firm with 13 offices throughout North America. Its 650 staff members are comprised of engineers, technicians, and support staff. This multi-sector company has specific expertise in power generation and emissions control.

Role Played in Canadian Clean Coal Activities Neill & Gunter's experience in assessing state-of-the-art power plant emission control technologies has given the company a database of these emission control systems, including effectiveness, limitations, and costs. Its numerous clean coal projects include studies of emission control of SO_x, NO_x, Hg, volatile organics and particulates. It has participated in projects with SaskPower [Org 5.5] and Ontario Power Generation [Org 5.3] and the CANMET Energy Technology Centre-Ottawa [Org 3.1] and is a member of the International Test Centre for CO_2 Capture [Org 4.4].

Description Study objectives have included: establishing target emissions for coal-fired plants; due diligence review of developing control technologies; database development; identifying retrofit costs, including performance, lifecycle, and risks related to new technologies. Technologies reviewed included pre-combustion, combustion and post combustion, supercritical CFB and PF boilers, and covered all emission control methodologies including CO_2 capture. Fuels included coal, lignite, pet coke, Orimulsion®, and other oil production by-products.

Representative studies include: reduction of mercury emissions for a +2000MW coal-fired power plant, power plant CO_2 capture using ceramic membrane technology; and, for CCPC [Org 1.1] (i) evaluation of retrofit emission control options and (ii) amine scrubbing/oxyfuel balance of plant. With respect to SaskPower, the utility is assessing its options for a new 300 MW coal-fired plant. Neill and Gunter completed a pre-feasibility study for a CO_2 capture-ready coal-fired plant examining both post-combustion capture and oxyfuel options for CO2 capture. N&G is now the prime consultant for the front-end engineering design with the oxyfuel capture option.

The company has also worked on the Coleson Cove Conversion Project (2 x 500MW) FGD units with wet electrostatic precipitators - carried out as Coleson Power Group, a company co-owned by Neill and Gunter.

Contact
David Cameron
Neill & Gunter
Regina, SK
306-522-0688
dcameron@neillandgunter.com
Neill & Gunter's web site is at www.neillandgunter.com

Org 8.24 Nexen Inc.

What is it? Nexen is a large Canadian company with a core business to explore, develop, produce and market crude oil, natural gas and power.

Role Played in Canadian Clean Coal Activities Nexen is one of two partners in a new facility that will open in 2007, producing hydrogen, heat and power from gasifying oil sands by-products. It also supports some of the R&D activity described in this Compendium.

Description Nexen, with headquarters in Calgary and over 3,000 employees worldwide, is a publicly traded company primarily in the oil and gas business but also is a special retail provider of customized electricity.

The company is a partner with OPTI Canada Inc. [Org 8.25] in the Long Lake Integrated Bitumen and Upgrading Project, near Fort McMurray, Alberta [Proj 11.6]. This project includes gasification units and a gas purification system.

Nexen contributes funding for a project at the University of Saskatchewan [Proj 7.5] on gasification in a fluidized bed membrane reactor. Nexen also supports the University of Regina's International Test Centre Consortium Program [Org 4.4, Proj 6.2].

Contact

Carla Yuill
Nexen Inc.
Calgary, Alberta
403-699-5800 (head office)
carla_yuill@nexinc.com
Nexen's web site is at www.nexeninc.com.

Org 8.25 Opti Canada Inc.

What is it? OPTI Canada Inc. is a Calgary-based company that develops major integrated bitumen and heavy oil projects in Canada.

Role Played in Canadian Clean Coal Activities OPTI is a partner in the Long Lake bitumen project [Proj 11.6] which, when it opens in 2007, will be the first Canadian gasification plant to utilize oil sands derived by-products to produce hydrogen, power and steam for use in the upgrading process. OPTI is the lead on the gasification plant construction and operation.

Description OPTI Canada Inc. was established in 1999 to develop major integrated bitumen and heavy oil projects in Canada using its proprietary, next-generation OrCrude™ process.

The company is a partner with Nexen Inc. [Org 8.24] in the Long Lake Integrated Bitumen and Upgrading Project, near Fort McMurray, Alberta (Proj 11.6). This project includes gasification units and a gas purification system.

Contact

Alison Trollope
OPTI Canada Inc.
Calgary, Alberta
403- 218-4705
atrollope@opticanada.com
OPTI's web site is at www.opticanada.com.

Org 8.26 SFA Pacific Inc. (USA)

What is it? SFA Pacific is an employee-owned company, headquartered in California, specializing in evaluation services in the oil refining, power generation, petrochemical, and environmental control industries.

Role Played in Canadian Clean Coal Activities SFA conducted the original pre-screening study sponsored by the Canadian Clean Power Coalition in 2002, to help identify the most appropriate technology for a Canadian clean coal plant. [Proj 11.1].

Description SFA Pacific's emphasis is on technology and process evaluation, market analysis, economic analysis, and business strategy. It has no business ties to the development of technology or plant construction, and no position in product markets. The SFA Pacific professional staff conducts proprietary technical consulting work for individual client companies and conducts multi-client sponsored programs and produces reports.

Contact

Dale Simbeck
SFA Pacific Inc.
Mountain View, California
650-969-8876
simbeck@sfapacific.com
The company's website is www.sfapacific.com

Org 8.27 Sherritt International Corporation

What is it? Sherritt is an international, diversified resource company involved in the production of nickel, cobalt, oil and electricity, and the development of coal as an energy resource.

Role Played in Canadian Clean Coal Activities Sherritt is now Canada's largest coal company and one of the largest coal producers in North America, providing predominantly thermal coal to electric utilities and industrial customers. The company is undertaking a multi-phase project that could result in Canada's first commercial coal gasification facility with CO_2 capture and storage.

Description Directly and through its subsidiaries, Sherritt has interests that include thermal coal production, oil and gas exploration, development and production, and electricity generation. In particular, through its partnership with the Ontario Teachers' Pension Plan Fund, Sherritt holds an indirect interest in Prairie Mines & Royalty Ltd. This operating company is the largest thermal coal producer in Canada, mining 94% of all the thermal coal produced in 2005. The former Western Canadian coal producer, Luscar, is now owned by Sherritt.

Sherritt has begun preliminary engineering on its Dodds-Roundhill coal gasification project [Proj 11.5] which could be the first coal-fired plant in Canada to incorporate CO_2 capture and storage.

Sherritt is the lead on two R&D projects in the compendium: development of coal cleaning technologies for Western sub-bituminous and lignite coals [Proj 2.2], and gasification characteristics for Western Canadian feedstocks [Proj 7.1]. Sherritt/Luscar is a member of the Canadian Clean Power Coalition [Org 1.1, Proj 11.1].

An earlier plan to build a gasification pilot plant to evaluate hydrogen production from Western Canadian feedstocks has been supplanted in favour of building a full commercial plant [Proj 11.5]. The company had announced its intent to build a two-unit 1000 MW coal-fired power plant and associated coal mine facility near Bow City, Alberta, using the best available technology. However, this is now on hold.

Contact

Dr. Amar Amarnath
Sherritt Coal
780-420-5810
aamarnath@sherrittcoal.com
The company's website is www.sherritt.com.

Org 8.28 SNC-Lavalin Inc.

What is it? SNC-Lavalin, based in Montreal, is one of the world's major groups of engineering and construction companies and a leader in the ownership and management of infrastructure.

Role Played in Canadian Clean Coal Activities The company's areas of experience include cogeneration and power plants.

Description Founded in 1911, SNC-Lavalin has been active internationally for nearly 40 years, establishing a multicultural network that spans every continent. The SNC-Lavalin companies have offices across Canada and in 30 other countries around the world and are currently working in some 100 countries.

Services provided by the company include:

- Certificates of approval and permit applications
- Air emission inventory compilation
- Compliance status assessments
- Greenhouse gas reduction relating to climate change
- Air quality modeling
- Environmental baseline studies
- Evaluation, equipment design or process modification to reduce emissions
- Source testing, ambient air monitoring and fugitive emissions monitoring
- Regulatory report preparation
- Indoor air quality studies and industrial hygiene services
- Expert testimony and evidence

Contact

SNC-Lavalin Group Inc.
Montreal, Quebec
514-393-1000
SNC-Lavalin's website is www.snclavalin.com.

Org 8.29 Suncor Energy Inc.

What is it? Suncor, an integrated energy company, is one of Canada's largest producers of synthetic crude oil from the oil sands deposits of the Western Sedimentary Basin with both mining and in-situ bitumen extraction as well as Fort McMurray based upgrading operations.

Role played in Canadian Clean Coal Activities The company is developing technologies and commercial applications aimed at capturing CO_2 emissions from oil sands processing for long-term storage to avoid emission to the atmosphere.

Description Suncor, although it is an oil sands company, does explore technologies for capturing CO_2 from processing operations.

The company is one of eight major international oil companies sponsoring the CO_2 Capture Project to develop new breakthrough technologies to reduce the cost of CO_2 capture [Org 2.4].

Suncor is working on its Voyageur Upgrader and potential gasifier, part of a plan to increase capacity at Suncor's synthetic crude oil operations [Proj 11.7].

Contacts

Stephen Kaufmann
Suncor Energy Inc.
403-269-8195
skaufman@suncor.com

Cal Coulter
Suncor Energy Inc.
403-269-8616
ccoutler@suncor.com

The Suncor web site is at www.suncor.com.

Org 8.30 TransCanada Energy

What is it? TransCanada Energy is the energy segment of TransCanada Corporation. TransCanada Energy includes power operations, natural gas storage and liquefied natural gas (LNG).

Role played in Canadian Clean Coal Activities TransCanada Energy is the lead proponent in assessing the feasibility of an IGCC polygen plant in Saskatchewan [Proj. 11.4].

Description TransCanada Energy concentrates on power generation and marketing, gas storage and LNG regasification terminals. Its existing power portfolio encompasses nuclear power, natural gas, coal, hydro and wind generation. TransCanada owns or is constructing approximately 7,700 megawatts of power in Canada (Alberta, Ontario, Quebec, New Brunswick) and the US (Vermont, New Hampshire, Massachusetts and Rhode Island). TransCanada also conducts wholesale and retail electricity marketing and trading in Alberta, Ontario and the north-eastern U.S.

Contacts

John Jenkins
TransCanada Energy
Calgary, Alberta
403- 920-5086
john_jenkins@transcanada.com
The company web site is at www.transcanada.com.

Org 8.31 Zeton Inc. (Canada)

What is it? Zeton Inc. is a Canadian company specializing in the design and construction of pilot and semi-works scale plants for scaling up existing and new process technologies.

Role played in Canadian Clean Coal Activities The company has the capability to develop pilot plants for the reduction of emissions from coal-fired power plants. Specific and relevant experience for CANMET and others includes:

- coal to liquids via Fischer-Tropsch technology
- coal gasifiers to syngas for clean coal applications
- coal liquor filtration for clean methane from coal

Description Zeton can provide state-of-the-art lab scale reactor systems, pilot plants, demonstration plants and small scale commercial plants as well as design/build know-how in scale-up of technologies and plants for the process industries worldwide. The company focuses on the important stage from innovation through early market development. Applications and industries served include modular small scale commercial plants, oil refining, petrochemicals, synfuels/GTL, polymers, fine/specialty chemicals, pharmaceuticals and food additives, as well as nuclear, mineral upgrading and environmental applications.

Contacts

Peter Smith
Zeton Inc. (Canada)
Burlington, Ontario
905-632-3123
psmith@zeton.com
The company web site is at www.zeton.com .

9. GOVERNMENT AGENCIES (NON-RESEARCH)

Org 9.1 Environment Canada

What is it?. Environment Canada is the federal Department responsible for most environmental regulations and standards under federal jurisdiction.

Role played in Canadian Clean Coal Activities Environment Canada supports clean coal technologies and recognizes that they can play a key role as one of Canada's future options for near-zero emission electricity. As part of this support, EC maintains a research program on clean coal technologies that seeks to ensure that the development of these technologies considers environmental objectives as a top priority.

Description Consistent with its vision of clean coal, Environment Canada's efforts on research and development, largely funded by the Program of Energy Research and Development (PERD, Org 10.3), helps develop sector expertise on clean coal technologies. This in turn contributes to Environment Canada's ability to provide technical advice on government policies and programs related to the energy sector.

Additionally, Environment Canada's technological capacity to apply new and improved research instruments, monitoring devices and environmentally friendly technologies is part of a team effort that helps the Department fulfill its legislated responsibilities and encourages Canadians and Canadian industry to reduce their impact on the environment.

Contact

Lorie Cummings
Electricity and Combustion Division
Environment Canada
819-953-9714
email: lorie.cummings@ec.gc.ca
Environment Canada's web site is at www.ec.gc.ca.

Org 9.2 Industry Canada

What is it? Industry Canada is the federal department with primary responsibility for the support of industry.

Role played in Canadian Clean Coal Activities The Department supports the energy industry and its services industries to ensure they have the capability to remain competitive and sustainable, domestically and internationally, by adapting to changing circumstances (such as globalization, environmental regulations).

Description Industry Canada plays a role in advancing the commercialization and deployment of emerging energy technologies by developing relevant sector analysis and tools that have resulted in increased understanding of sector trends, and awareness of Canadian sector capabilities. Initiatives include this compendium of clean coal activities, produced in collaboration with Natural Resources Canada and Environment Canada, as well as support for Canada's Clean Coal Technology Roadmap.

Industry Canada develops sector expertise and provides policy input into government initiatives related to the energy sector. Efforts include maintaining sector expertise, and monitoring and continuing to provide advice to program managers (e.g. within federal funding organizations) and other government departments in relation to research, demonstration, deployment and commercialization of energy technologies including hydrogen and fuel cells, renewable energy, and carbon capture and storage.

In order to advance development and commercialization of emerging energy sectors, including next generation clean processes for conventional resources, Industry Canada works with other government departments, industry associations and other stakeholders. This collaboration supports research, development, demonstration and commercialization of innovative energy technologies within conventional sectors (including carbon capture and storage in Canada) and emerging energy sectors.

Contact

Catherine Kerr
Industry Canada
613-954-3264
Kerr.catherine@ic.gc.ca
Industry Canada's web site is at www.ic.gc.ca.

Org 9.3 Natural Resources Canada – Office of Energy Research and Development

What is it? The Office of Energy Research and Development (OERD), located in Ottawa, coordinates the government of Canada's energy science and technology activities. Its role includes funding allocations, policy development, and representation of the federal government in Canada and abroad.

Role Played in Canadian Clean Coal Activities OERD supports the development and implementation of S&T initiatives related to clean coal activities at the federal, national, and international levels.

Description OERD manages the Program of Energy Research and Development (Org 10.3), the new ecoEnergy Technology Initiative (Org 10.2) and the Technology and Innovation Research and Development Initiative [Org 10.7). For the most part, OERD does not award contracts directly. Contract award is the responsibility of other federal government organizations (such as the CANMET Energy Technology Centres) that receive funds through OERD.

OERD also coordinates Canada's involvement in international energy S&T activities through linkages with the U.S. Department of Energy, the International Energy Agency, the European Union, the Asia-Pacific Economic Cooperation (APEC) and the North American Energy Working Group. These linkages support contacts with clean coal research elsewhere.

OERD, from its strategic position within Canada's energy S&T community, supports the investigation of clean coal, such as the commissioning of this Compendium.

Contact

Mary Preville
Office of Energy R&D, NRCan
613-995-3590
mpreville@nrcan.gc.ca
The Office of Energy Research and Development web site is at www.nrcan.gc.ca/es/oerd

Org 9.4 Natural Resources Canada – Renewable and Electrical Energy Division

What is it? The Renewable and Electrical Energy Division (REED), based in Ottawa, plays an economic analysis, policy development and program delivery role regarding renewable and electrical energy, while respecting the jurisdiction that provinces and territories have in this area.

Role Played in Canadian Clean Coal Activities REED has a role in providing economic and policy analysis regarding clean coal technologies for the federal government.

Description REED works collaboratively with Natural Resources Canada's Office of Energy Research & Development [Org 9.3], CANMET Energy Technology Centre [Org 3.1], and Petroleum Resources Branch (PRB) and industry to explore policy opportunities for the federal government in CCT and CCS areas. REED also provides senior management with policy advice and economic analysis relating to clean coal technologies.

REED also manages two programs, namely the ecoENERGY Renewable Power Program and the ecoENERGY Renewable Heat Program. REED also has a role in collaborating with other government departments, the U.S. government, and industry to implement a policy and regulatory framework of mandatory and enforceable reliability standards.

Contact

Chris Padfield
Renewable and Electrical Energy Division,
NRCan
613-947-5101
cpadfiel@nrcan.gc.ca
The website for REED is http://www2.nrcan.gc.ca/es/erb/erb/english/View.asp?x=68.

Org 9.5 Alberta Environment

What is it? Alberta Environment is responsible for protecting that province's land, air, and water.

Role played in Canadian Clean Coal Activities The department's responsibilities include addressing climate change.

Description Alberta Environment published *Albertans and Climate Change: Taking Action*, which establishes a framework to reduce GHG emissions. The action plan champions CO_2 capture and storage.

Toward this goal, the government supports:

Technology development

- Innovative Energy Technologies (does not include clean coal in its mandate)
- Alberta Energy Research Institute (AERI) [Org 10.1]
- Alberta Research Council (ARC) [Org 3.3]

Partnership and Collaboration

- Integrated CO_2 Network (ICO_2N)
- Climate Change Central (C^3)

Regulatory and Risk Management

- CO_2 monitoring program

Contact

Christeen Finzel
Alberta Environment
780-415-6654
christeen.finzel@gov.ab.ca
The Alberta Environment web site is at www.environment.gov.ab.ca.

10. GOVERNMENT PROGRAMS

Org 10.1 Alberta Energy Research Institute

What is it? The Alberta Energy Research Institute (AERI) is a component of the Alberta government's Ministry of Advanced Education and Technology. It provides strategic direction to the government and invests in research and technology in support of the province's energy industry.

Role played in Canadian Clean Coal Activities AERI supports several clean coal projects.

Description The Ministry of Advanced Education and Technology Innovation promotes science, research, and development by providing strategic leadership, by managing and funding strategic investments, and by coordinating government initiatives for science and research in the province. AERI has offices in Calgary and Edmonton.

The Clean Coal projects it supports include:

- Canadian Clean Power Coalition [Org 1.1, Proj 11.1]
- Coal cleaning technologies [Proj 2.2]
- Gasification characterization of western Canadian feedstocks [Proj 7.1]
- Dodds Roundhill coal gasification plant for hydrogen production [Proj 11.5]
- Support of the Advanced Coal Combustion Chair at the University of Alberta [Proj 4.6]
- Fluid coke as a sorbent for mercury [Proj 4.6]
- CETC-O Oxy Fuel R&D Consortium [Proj 8.5]
- University of Regina – International Test Centre Consortium [Proj 6.2]
- Hollow fiber membranes for CO_2 separation [Proj 9.1]
- Front End Engineering Design for Alberta IGCC Plant (EPCOR/CCPC) [Proj 11.2]

AERI continues to look for opportunities to advance emissions reduction through clean coal technologies.

Contact

Alice Hedges
AERI Head Office
403-297-8650
alice.hedges@gov.ab.ca
The AERI web site is at www.aeri.ab.ca.

Org 10.2 ecoEnergy Technology Initiative, Natural Resources Canada

What is it? The ecoEnergy Technology Initiative is a new federal government program aimed at accelerating the development and market-readiness of technology solutions in clean energy, and fostering the next generation of clean technologies needed to break through to emissions-free energy production and reduced energy use.

Role Played in Canadian Clean Coal Activities One of the program's six priority areas is Clean Integrated Electricity in which clean coal and carbon capture and storage are sub-components.

Description The ecoENERGY Technology Initiative is a new strategic approach to undertaking and funding energy science and technology (S&T) activities. ecoENERGY will be delivered as a single, integrated research, development, and demonstration (RD&D) program coverings the innovation spectrum from basic research to near-commercialization of technologies. The $230M, four year initiative will focus on priority technology areas to support the development and demonstration of the next generation of clean energy technologies - technologies that currently do not exist, or that are at a very early stage of development. The following are the Initiative's Eight Portfolios in six strategic areas:

- Clean Fossil Fuels
- Clean Integrated Electricity
  - Clean Coal and Carbon Capture & Storage
  - Distributed Power Generation
  - Next Generation Nuclear (Generation IV)
- Bio-based Energy Systems
- Low Emission Industrial Systems
- Clean Transportation Systems
- Built Environment

The initiative will also provide the new knowledge that will be essential to support the regulatory approach to the government's Clean Air Regulatory Agenda.

The Initiative is scheduled to come into effect in April 2007 and will run for a period of four years.

Contact

Mary Preville
Natural Resources Canada, Ottawa
613-995-3590
mpreville@nrcan.gc.ca
The web site for ecoENERGY is www.ecoenergy.gc.ca

Org 10.3 Program of Energy Research and Development, Natural Resources Canada

What is it? The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both our economy and our environment. It directly supports energy R&D conducted/managed by the federal government departments, and is concerned with all aspects of energy supply and use.

Role played in Canadian Clean Coal Activities One of the program's strategic directions is to provide S&T to reduce emissions and the associated environmental impacts from centralized, combustion-based electric power generation and large industrial emitters. This includes electric power generation from renewable energy sources, cleaner conversion of coal to electricity, small-scale or distributed generation (with an emphasis on combined heat and power applications), and CO_2 capture and storage.

Description PERD is a long-standing fund devoted entirely to energy R&D, with an annual budget of about $50 million. PERD directly funds federal partner departments and agencies, which then team up with federal laboratories, private sector (industry, research institutes, companies, consortia and alliances, individuals), associations, universities, provincial and municipal governments and research organizations, international organizations, and other funding agencies.

PERD supports a number of the projects in this compendium, including many of those conducted by the CANMET Energy Technology Centre [Org 3.1].

PERD is managed by the Office of Energy Research and Development, Natural Resources Canada [Org 9.3].

Contact

Mary Preville
Natural Resources Canada, Ottawa
613-995-3590
mprevill@nrcan.gc.ca
PERD information is available through the OERD web site at www.nrcan.gc.ca/es/oerd.

Org 10.4 Innovative Research Initiative, Natural Resources Canada

What is it? The Innovative Research Initiative (IRI) for Greenhouse Gas Mitigation was a fund designed to stimulate the initiation of high-risk exploratory scientific and technical ideas in natural sciences and engineering.

Role played in Canadian Clean Coal Activities Clean coal projects, with elements of greenhouse gas mitigation, were eligible for funding.

Description The IRI program was completed in 2006. The IRI was aimed at government scientists in the provincial, territorial, and federal scientific community. It was a Climate Change Action Plan 2000 program, an outcome of the Technology Issues report on Enhancing Technology Innovation for Mitigating Greenhouse Gas, which recommended that Canadian capacity for advanced research in this field be stimulated through the government scientific community.

The IRI was complementary to the Natural Sciences and Engineering Research Council's Novel Next generation Technology Initiative in Energy Research and Technology Related to Greenhouse Gas Mitigation, which targeted the university community. It has also been completed.

The IRI was intended to advance solutions to the climate change problem, and to yield other benefits such as increased energy efficiency, improved productivity, improved air quality, and reduced emissions of other effluents.

IRI-funded projects in this compendium include:

- High selectivity gas separation by mixed-matrix polymer–zeolite membrane (NRC) [Proj 9.5]; and
- A novel method for capturing CO_2 from flue gas (SRC) [Proj 10.14].

The IRI was managed by the Office of Energy Research and Development, Natural Resources Canada.

Contact

Karen Huynh
Office of Energy Research and Development
Natural Resources Canada
613-947-3483
kahuynh@nrcan.gc.ca

Org 10.5 Natural Sciences and Engineering Research Council of Canada

What is it? The Natural Sciences and Engineering Research Council of Canada (NSERC) is the federal government's main vehicle for direct funding of university research at the individual project level.

Role played in Canadian Clean Coal Activities The vast majority of university-based R&D in clean coal is funded in whole, or in part, by NSERC.

Description NSERC is the national instrument for making strategic investments in Canada's capability in university-based S&T. NSERC supports basic university research through discovery grants and project research through partnerships among universities, governments, and the private sector. It also supports the advanced training of highly qualified people.
The NSERC projects listed in this compendium are too numerous to repeat in full here. They are instead grouped by Project section classification.

1. Generic Modeling and Characterization [Proj 1.3]
2. Coal Beneficiation and Cleaning [Proj 2.1]
3. Biomass Co-Firing [Proj 3.1]
4. Emission Reduction (without CO_2 capture) [Proj 4.1, 4.2, 4.3, 4.6]
5. CO_2 Capture – General [Proj 5.1, 5.2, 5.3]
6. CO_2 Capture - Solvents [Proj 6.1, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11]
7. CO_2 Capture – Oxy-Fuel [Proj 8.4]
8. CO_2 Capture - Membranes [Proj 9.2, 9.3, 9.4, 9.7]
9. CO_2 Capture - Other [10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.10, 10.12,]

Contact
For the university scientists, refer to the name on each project page.

For NSERC itself

NSERC
Discovery Grants
613-995-5829
www.nserc.gc.ca

Org 10.6 Sustainable Development Technology Canada

What is it? Sustainable Development Technology Canada (SDTC) is a not-for-profit foundation that finances and supports the development and demonstration of clean technologies that provide solutions to issues of climate change, clean air, water quality and soil.

Role Played in Canadian Clean Coal Activities SDTC-funded projects are drawn from all major Canadian economic sectors, including energy exploration and production, power generation, energy utilization, transportation, agriculture, forestry, wood products and waste management.

Description SDTC was established by the Government of Canada in 2001 and commenced operation in November of that year. SDTC's mission is to act as the primary catalyst in building a sustainable development technology infrastructure in Canada. The Foundation reports to Parliament through the Minister of Natural Resources Canada.

There is an SDTC-supported project in this compendium, namely Integration of Mercury into Pollutant Removal Units of Coal-Fired Power Plant (Proj 4.5)

Contact SDTC for information about the foundation and the application process.

Contact

Sustainable Development Technology
Canada
613-234-6313
applications@sdtc.ca
The SDTC web site is at www.sdtc.ca.

Org 10.7 Climate Change Technology and Innovation Research & Development Initiative, Natural Resources Canada

What is it? The Climate Change Technology and Innovation Research and Development Initiative (CCTII R&D) is a federal program to help achieve greenhouse gas reduction in the longer term.

Role played in Canadian Clean Coal Activities Clean Coal & Carbon Capture and Storage (CCCCS) is one activity area within CCTII R&D.

Description CCTII R&D is a $115M federal R&D funding initiative. The Initiative commenced in 2003 and is set to be complete in March 2008.

The program includes the following Technology Areas:

- cleaner fossil fuels;
- advanced end-use efficiency technology;
- decentralized energy production;
- biotechnology; and
- hydrogen economy.

The cleaner fossil fuels technology area is itself divided into three programs:

- bitumen and heavy oil;
- unconventional gas supply; and
- clean coal and carbon capture and storage.

This CCCCS R&D program strives to advance energy technologies incorporating Clean Coal, CO_2 Capture and Storage that will be essential to developing a transformed energy economy in Canada. The research projects are carried out in partnership with stakeholders from within and outside of the federal government.

Contact

Mary Preville
Natural Resources Canada, Ottawa
613-995-3590
mprevill@nrcan.gc.ca
T&I information is available through the OERD web site at www.nrcan.gc.ca/es/oerd

Org 10.8 Canada ecoTrust for Clean Air and Climate Change

What is it? The Canada ecoTrust for Clean Air and Climate Change is a third-party trust established by the federal government to provide more than $1.5 billion to provinces and territories that identify major projects that target real reductions in greenhouse gas emissions and air pollutants.

Role played in Canadian Clean Coal Activities Of the 8 announcements made as of 22 March 2007, 2 provinces have expressed interest in pursuing coal-related projects/programs as a result of ecoTrust funds. In Alberta, two initiatives have been mentioned, including CO_2 capture, transportation and storage or use for EOR (in conjunction with the joint Canada-Alberta ecoENERGY Carbon Capture and Storage Task Force), and a Clean Coal Front End Engineering Design (FEED) project. New Brunswick intends to examine the use of zero emission technology for clean coal energy generation in Belledune.

Description The Canada ecoTrust for Clean Air and Climate Change will provide provinces and territories with the flexibility to draw down the funds over three years or according to their respective schedule and priorities, upon passage of legislation. The Canada ecoTrust for Clean Air and Climate Change will be allocated on a per capita basis and will provide a minimum of $15 million per province and $5 million per territory to support efforts to develop technology, improve energy efficiency, and undertake other projects that will result in significant environmental benefits. As of 22 March 2007, ecoTrust announcements have been made for 2 territories and 6 provinces. The program will co-fund with the provinces technology development, energy efficiency, and other projects that will provide results on the reduction of air pollution and greenhouse gas emissions.

Contact

Not available at time of printing this report

Information on ecoTrust can be found on at www.ecoaction.gc.ca.

PART B: PROJECTS (S&T, ECONOMICS, IMPLEMENTATION AND OUTREACH)

1. GENERIC MODELING AND CHARACTERIZATION

Proj 1.1 Characterization of fuels for and products of clean coal technologies (CETC-O)

Goal To develop a comprehensive database of fuel properties (and associated products such as slags, ash and pollutants) for all coal and related fuels (e.g. pet coke) being considered for use in Canada

Significance of project The first comprehensive source of data on properties of fuels and associated waste products for Canadian users.

Project description This project will include all fuels in use or being considered for use in Canada and those proposed for use in advanced cycles. While aspects of this work have been underway for some time, this initiative is being planned to complete a more comprehensive matrix of fuels, characteristics and test conditions. The scope of work will depend on funding levels but the full scope would include:

- A broad range of fuels: bituminous, sub-bituminous and lignite coals, petroleum coke, bitumen, refinery bottoms, as well as dry-fed and slurry-fed blends of these fuels.
- A broad range of properties: kinetics, heat transfer, ash characteristics, slagging/fouling behaviour and pollution formation characteristics.
- Properties measured in a variety of chemical and physical conditions that simulate existing combustion technology, improved technologies (e.g. low NO_x and other emerging burner designs) as well as advanced cycles (e.g. gasification, oxygen enrichment, increased pressures).
- Expanded and upgraded facilities for carrying out the needed experiments.

Duration 2007- 2011

Who is involved CANMET Energy Technology Centre – Ottawa (Org 3.1) and interested Canadian utilities.

Funding Level & Funders Approximately $2M over four years: NRCan (requested) and interested utilities.

Contact

Mr. Pat Hughes
CETC-O
613-996-0827
phughes@nrcan.gc.ca

Proj 1.2 Advanced modeling techniques for clean coal technologies (CETC-O)

Goal To develop more sophisticated modelling techniques, to incorporate into these models a broader range of combustion conditions and coal and combustion product characteristics and to apply these models to optimization of existing plant and advanced cycles.

Significance of project Both researchers and industry have become more reliant on models to identify overall cycle options, to optimize processes and flow sheets, to understand the physical chemistry taking place in specific unit operations and to support the design of specific components.

Project description Two types of models are included in the scope of this project: process models that simulate the macro behaviour of combustion systems (e.g. flow sheets, process efficiency, process optimization, model-based control systems, model-based decision support) and Computational Fluid Dynamics (CFD) models that can examine specific aspects in great detail (e.g. fluid flow and particle behaviour in the burner region). Elements of this Activity include:

- Upgrading of existing and defining new models to incorporate additional fuel and product characterization data (see previous project).
- Enhancing modelling, scale-up and visualization techniques by inclusion of nanoscale phenomena, transient behaviour, advanced reaction kinetics and improved heat transfer and radiation calculations.
- Creating new modeling tools to complement investigations of pollutant formation and development of effective control strategies.
- Application of enhanced models to explore the impacts on existing plant of introducing new components, new pollution control strategies and new fuels.
- Developing and validating approaches for simulation of advanced cycle conditions (gasification, oxygen enrichment, higher temperatures, higher pressures, and other emerging approaches).
- International joint work on model development and their application to technologies under commercial development to determine their applicability to Canadian conditions.

Duration 2007 – 2011.

Who is involved CANMET Energy Technology Centre – Ottawa, NRCan (Org 3.1).

Funding Level & Funders Approximately $2M over 4 years: NRCan (requested)

Contact

Dr. Eddy Chui
CETC-O, NRCan
613-943-1774
echui@nrcan.gc.ca

Mr. Bruce Clements
CETC-O, NRCan
613-943-8881
clements@nrcan.gc.ca

Proj 1.3 Mathematical modeling of a Circulating Fluidized Bed (CFB) lignite combustor (Saskatchewan)

Goal To model a circulating fluidized bed combustor (CFBC) with the aim of better understanding sulphur capture efficiency and the influence of particle size distribution in CFBCs.

Significance of project It will identify the advantages and optimize performance of CFBC technology for removal of sulphur prior to solvent-based CO_2 capture.

Project description This project will develop models for the CFBC process to address issues of reproducibility and predictability associated with most fluidized bed processes. This should add to the power generation industry's fundamental understanding of the process in order to optimize CFBC efficiency and its environmental performance. Some of the advantages of CFBCs include fuel flexibility, high carbon utilization, reduced NO_x emissions arising from staged oxygen addition, and the capacity for dry scrubbing with limestone injection to capture sulphur dioxide. Additionally, advancements in construction materials have allowed the implementation of a supercritical steam cycle, resulting in higher efficiency.

In the present research, modeling of the fluid mechanics of CFBs using phenomenological and computational fluid dynamics (CFD) approaches is combined with existing kinetics models for coal combustion and sulphur capture available in the open literature. The model also incorporates particle size distribution effects as well as the influence of alternating oxidation/reduction zones on sulphur capture. Significant strides toward a single comprehensive technical model of industrial-scale CFBCs are anticipated.

Duration 2005-2007.

Who is involved University of Saskatchewan (Org 4.1) and SaskPower (Org 5.5).

Funding Level & Funders $25K per year for two years from NSERC and $50K from SaskPower for a total project budget of $100K over two years.

Contact
Dr. Todd Pugsley
University of Saskatchewan
306-966-4761
todd.pugsley@usask.ca

2. COAL BENEFICIATION & CLEANING

Note: Proj 4.6 also involves coal cleaning, but as the work is focused on mercury removal, it is catalogued with other projects aimed at reducing emissions other than CO_2.

Proj 2.1 Coal reverse flotation, a new method of improving flotation column throughput and coal- water slurry technology (UBC)

Goal Wider utilization of flotation to upgrade finer fractions of sub-bituminous and oxidized coals.

Significance of project Since sub-bituminous coals and oxidized coals are difficult to process using flotation, the fine fractions of these coals are not processed at all and are either used without cleaning, or are lost to tailings. This process could lead to wider utilization of this material in the form of coal/water slurries.

Project description Flotation of coal strongly depends on coal rank; while bituminous coals used to make coke are very hydrophobic and float easily, low-rank subbituminous and oxidized coals float poorly. The reverse flotation process is effective in cleaning subbituminous/oxidized coals when quaternary amine is used to float gangue. Since coal reports to the flotation "tailings", this product is then ideal for coal-water slurries. Because in the process only about 30 % of the material is floated, instead of 70% floated in traditional coal flotation, column flotation capacity limitations are alleviated, making a wider use of columns possible. The results are available in the following publications:

K. Ding and J.S. Laskowski, "Coal Reverse Flotation. Parts 1 & 2," *Minerals Eng.*, 2006, Vol. 19, pp. 72-86, and K. Ding and J.S. Laskowski, "Zero Conditioning Time Concept and Its Application in Flotation," *Proc. 23rd Int. Mineral Processing Congress*, Istanbul, 2006, Vol. 2, pp. 1111-1117.

Duration 2000-2004.

Who is involved University of British Columbia (Org 4.5).

Funding Level & Funders $81.7Kper year: NSERC.

Contact
Dr. Janusz Laskowski
University of British Columbia
604-822-4949
jsl@mining.ubc.ca

Proj 2.2 Coal cleaning technologies for western sub-bituminous and lignite coals (Sherritt)

Goal To test and evaluate various coal cleaning strategies to upgrade western Canadian coals by reducing ash, moisture and other impurities.

Significance of project Identifies cleaning options to address barriers to the use of Western Canadian coals as a feedstock for gasification plants.

Project description This project consisted of four main elements:

i) Coal Characterization. All coals from Luscar (a Sherritt subsidiary) analysed for full mineral content.
ii) Mechanical Separation. Fluid bed separation of heavy minerals was tested to determine effectiveness of ash reduction and impact on recovery.
iii) Wet Pyrolysis. Tests were conducted at various scales, up to 2 litre batches, on the impact of wet pyrolysis on moisture and sodium reduction, ability of product to form a stable slurry at high solids loading, and calorific value.
iv) Solvent extraction. Using coal tar solvents, a 99.8% ash-free coal pitch was obtained from sub-bituminous and lignite coals.

Duration 2004-2006

Who is involved Sherritt Coal (Org 8.27), Lehigh University, University of Alberta (Org 4.1), National Centre for Upgrading Technology (NRCan/ARC), Dynatech, EERD(USA).

Funding Level & Funders Amount not disclosed: Sherritt and AERI.

Contact
Dr. Amar Amarnath
Sherritt Coal
780-420-5810
aamarnath@sherrittcoal.com

3. BIOMASS CO-FIRING

Proj 3.1 Clean energy from coal and biomass (Dalhousie)

Goal To identify ways of improving the emissions and economic performance of fluidized bed furnaces.

Significance of project Developing and testing (at lab and pilot scale) strategies for reducing emissions from and costs of FBC.

Project description This is a multifaceted project covering the following aspects:

- Examining the financial viability of any new or combination of existing options for power generation. A comprehensive financial analysis model is being developed to examine the financial viability of power generation projects and to examine the impact of clean technology options
- Exploring the feasibility of reducing CO_2 emissions from FBC plants firing high sulphur coal by such approaches as chemical looping.
- Removing some practical limitations of FBC boilers, such as agglomeration, to allow them to burn biomass while continuing to use the ash for cement production.
- Addressing knowledge gaps in the heat transfer and hydrodynamics of FBC and novel gas-solid separators for sub-compact less expensive FBCs.

Some of the experiments would be carried out at a pilot-scale fluid bed furnace sited at a power plant.

Duration 2005-2010.

Who is involved Dalhousie University (Org 4.1).

Funding Level & Funders $35Kper year: NSERC.

Contact
Dr. Prabir Basu
Dalhousie University
902-494-3227
Prabir.Basu@Dal.ca

Proj 3.2 Clean power with circulating fluidized bed combustion (Greenfield Research)

Goal To develop a practical means of firing biomass in an existing fossil fuel-fired power plant to reduce both CO_2 and NO_x emissions.

Significance of project Current biomass co-firing technology developed in Europe is effective but interferes with operation of the existing fossil fuel-fired boilers. The present effort is to develop a stand-alone fuel flexible means of supplementing the steam in the power plant from biomass.

Project description The project involves development of a subcompact circulating fluidized bed boiler that could burn any fuel starting from biomass to waste coal or even oil, to supplement the steam generation in the coal-fired plant. This will lead to the development of a unique means for co-firing biomass in existing power plants.

Duration 2005-2008.

Who is involved Greenfield Research Incorporated (Org 8.18) and Dalhousie University (Org 4.1).

Funding Level & Funders $40K per year: Industrial Research Assistance Program (IRAP).

Contact
Dr. Prabir Basu
Greenfield Research Incorporated
902-422-9426
Prabir.Basu@greenfieldresearch.ca

4. EMISSION REDUCTION (without CO_2 capture)

Proj 4.1 Development of integrated electrostatic air pollution control system for a small-scale combustion based power generators (McMaster)

Goal Development of an integrated pollution control system based on a dust flow separator type electrostatic precipitator for $PM_{2.5}$ control and plasma catalyst system for simultaneous NO_x, SO_x and hydrocarbon control.

Significance of project While the focus of this project is for diesel combustion and micro-gas turbine based small power generators, the technology developed under this work can be used for small coal boiler multi-pollution control and for a micro-gas turbine power generator based on gasified coal.

Project description The present project has tested the process on a 100kW micro-gas turbine and a 5 kW diesel power generator. In principle, this technology can be used up to 200kW power generation. An economic evaluation showed that electrostatic precipitation combined with non-thermal plasma-catalyst system can be cost effective compared with many separate series-connected pollutant control devices.

Duration 2001-2004.

Who is involved McMaster University (Org 4.1), Ford Motor Company, Dofasco, CETC-O (Org 3.1), Elliot Energy Inc.

Funding Level & Funders $171.5Kper year: NSERC and partners (shown above).

Contact
Dr. JenShih Chang
McMaster University
905-525-9140, extension 24924
changj@mcmaster.ca

Proj 4.2 Electrohydraulic discharge and energetic atmospheric plasma processes in multi-phase flow systems (McMaster)

Goal To develop plasma based processes for multipollutant reduction strategies in combustion systems by electrohydraulic discharge.

Significance of project Plasma-based processes can significantly reduce the cost of multi-pollutant control systems.

Project description This project is providing fundamental physics, chemistry and engineering baseline data for non-thermal plasma gaseous pollution control and electrohydraulic discharge thermal plasma water treatments. This study includes examining the ability of non-thermal plasmas to convert SO_2, NO_x and other acid gases to an agricultural fertilizer. The technology developed under this project has been tested in pilot-scale coal boilers in multi-pollutant emission control studies in several research centres such as CANMET in Canada, Los Alamos Labs in the US, SEPRI in China, Ebara Co. in Japan, and Hitachi Plant Technology Co. in Japan. In a different project, coal-steam plasma reforming gas was enriched for the higher heating value products by non-thermal plasmas.

Duration 2002-2007.

Who is involved McMaster University (Org 4.1).

Funding Level & Funders $38K per year: NSERC.

Contact
Dr. JenShih Chang
McMaster University
905-525-9140, extension 24924
changj@mcmaster.ca

Proj 4.3 Injection of activated carbon for removal of mercury from coal combustion flue gas (SaskPower)

Goal To demonstrate, at an operating plant, a promising technology for mercury removal from coal-fired plants.

Significance of project This technology would dramatically reduce mercury emissions at a significant cost advantage over other proposed mercury control technologies.

Project description This project is complemented by the two subsequent projects (Proj 4.4 and 4.5). In this project, a number of activated carbon sorbents are being injected into the flue gas at various points in the gas cleanup system (before and after the ESP and before the baghouse) to determine the optimum design for mercury removal. Tests are being run on SaskPower's Emission Control Research Facility and at their Poplar River Generating Station. At the latter, tests have been run on both a slip stream and at full scale. The test system is flexible enough to study a wide range of operating parameters (e.g. type of activated carbon, carbon injection rate, baghouse air-to-cloth ratio, temperature, and levels of other flue gas constituents).
This project has the support of key regulatory agencies developing the Canada Wide Standard for mercury. In addition to controlling mercury, the technology can also substantially reduce emissions of particulate matter (PM), ensuring that the flue gas will be sufficiently free of PM and mercury should a downstream control facility for CO_2 be required. If the technology can be shown to work at Poplar River, which burns lignite, a fuel high in elemental mercury, it is expected to be applicable to all coal-burning plants.

Duration 2003 – 2008.

Who is involved SaskPower, Alstom Canada, the University of North Dakota Energy and Environmental Research Center (EERC), CANMET Energy Technology Centre-Ottawa, the University of Regina, Saskatchewan Research Council and the University of Saskatchewan.

Funding Level & Funders $10.4 M, SaskPower (Org 5.5), Alstom Canada (Org 8.4), Sustainable Development Technology Canada (Org 10.6) and CANMET Energy Technology Centre-Ottawa (Org 3.1), US DOE, EPRI (Org 2.5), North Dakota Industrial Commission, Basin Electric Power Cooperative, Great River Energy, Minnkota Power, Montana-Dakota Utilities, Otter Tail Power (the last eight all being US based)

Contact

David Smith
SaskPower
306-566-2290
dsmith@saskpower.com

Proj 4.4 Novel biochar and coal char sorbents for the removal of mercury from coal combustion flue gas (Saskatchewan)

Goal To develop novel biochar and coal char sorbents for the removal of mercury from coal combustion flue gases.

Significance of project An effective and low cost activated carbon based adsorbent technology for removal of mercury from coal combustion flue gas.

Project description In this project, activated carbon sorbents are prepared from coal char and biochars by physical (steam) and chemical (impregnating with various additives including KCl, KBr, KI, $FeCl_3$, $ZnCl_2$, $CuCl_2$, etc.) activation methods and studied in laboratory and plant scales. The prepared sorbents are characterized by surface area, pore volume, pore size distribution and elemental analysis. The activity, breakthrough and stability screening test for mercury adsorption is done using inert nitrogen gas. As the actual composition of the flue gas affects the sorption performance of the activated carbon significantly, the most promising sorbents will be tested in a simulated flue gas stream. The used sorbents are to be characterized by TGA, TPD, EXAFS, XANES, and SEM. A mathematical model will be developed. Based on the results obtained at laboratory scale, the technical and economic feasibility of using high performance carbon sorbents for mercury removal will be evaluated using the operating conditions of the Poplar River Power Station as a typical power plant base case. Finally, the sorbents with desirable performance will be evaluated under actual operating conditions using SaskPower's Emission Control Research Facility at the Poplar River Power Station.

Duration 2005-2009.

Who is involved University of Saskatchewan (Org 4.1), Saskatchewan Research Council (Org 3.2), SaskPower (Org 5.5), Advanced Biorefinery Inc.

Funding Level & Funders $95K per year: NSERC ; $34K per year: Advanced Biorefinery Inc.

Contact

Dr. Ajay Dalai
University of Saskatchewan
306-966-4771
ajay.dalai@usask.ca

Proj 4.5 Integration of mercury into pollutant removal units of coal-fired power plant (Regina)

Goal To evaluate the integration of activated carbon injection for mercury control with amine scrubbing for CO_2 removal from lignite flue gas.

Significance of project Evaluating and optimizing the integration of activated carbon injection for mercury control with amine scrubbing for CO_2 removal from lignite flue gas.

Project Description This project will evaluate and optimize a variety of options for integrating the activated carbon injection for mercury control with amine scrubbing for CO_2 removal from lignite flue gas.

Duration 2005-2006.

Who is Involved University of Regina International Test Centre (Org 4.4)

Funding Level & Funders $40,000 a year for two years; SDTC & SaskPower.

Contact
Dr. Raphael Idem
University of Regina
306-585-4470
raphael.idem@uregina.ca

Proj 4.6 Fluid coke as a sorbent for mercury (Alberta)

Goal To develop a material (activated coke) that can capture mercury in effluent gases from coal-fired power plants.

Significance of project A means of achieving required mercury emission reductions at lower cost than can be achieved with current mercury sorbents.

Project description This project will develop treatment procedures for coke, produced in the production of synthetic crude from the Alberta oil sands, which will produce a material (activated coke) than can capture mercury in effluent gases from coal-fired power plants. The approach is to develop procedures that increase the surface area of the fluid coke for about 20 m^2/g to several hundred m^2/g and to modify the resultant high surface area cokes so that they will be active for capturing mercury at temperatures above 150 C.

Duration 2005 - 2008.

Who is involved University of Alberta (Org 4.1), Syncrude Canada and EPCOR (Org 5.7).

Funding Level & Funders Approximately $230K: Province of Alberta (AERI).

Contact
Dr. Sieg Wanka
University of Alberta
780-492-3817
sieg.wanke@ualberta.ca

Proj 4.7 Mercury emission control from coal-fired power plants (Alberta)

Goal To establish effective, integrated options for reducing hazardous emissions per unit energy produced by coal-fired power plants. The initial focus is mercury using pre-combustion physical coal cleaning and fuel upgrading (moisture removal) and post-combustion flue gas pollutant adsorption and catalytic conversion.

Significance of project Evaluates, at lab scale, options for removing mercury from coal prior to combustion/gasification and the effectiveness of novel, recyclable sorbents at lab scale with exploratory full scale testing.

Project description This project integrates three approaches offering mercury emissions reduction:

- Dry physical coal cleaning – using an Air Dense Medium Fluidized Bed separator to reduce ash content (and associated mercury content) of sub-bituminous coal feedstocks. The project has examined the effect of coal particle size and fluidization velocity on level of ash removal and on overall yield. Wet coal cleaning options and next generation triboelectrostatic separation were evaluated in parallel studies;
- Thermal upgrading – a rapid thermal upgrading process was tested at lab scale, measuring the dependence of moisture and mercury removal on temperature and the overall energy implications of such a process;
- Sorbent-based – tested various novel nanosilver-based sorbents, exchanged onto a zeolite support. Testing included the effect of temperature, silver loading and silver species on mercury absorption; joint collaborations with China's State Key Laboratories involve the development of acid gas catalysts.

Duration 2002 – ongoing.

Who is involved University of Alberta (Org 4.1; NSERC/EPCOR/AERI Industrial Research Chair in Advanced Coal Cleaning and Combustion Technology) and EPCOR (Org 5.7); State Key Laboratories of Coal Conversion and Coal Combustion, China.

Funding Level & Funders Over $2M: NSERC, EPCOR, AERI, U of A (total cost of project over 5 years).

Contact

Dr. Zhenghe Xu
University of Alberta
780-492-7767
Zhenghe.Xu@ualberta.ca

5. CO_2 CAPTURE – GENERAL

Proj 5.1 Optimisation of integrated CO_2 capture, transportation and storage in Canada (Waterloo)

Goal To propose optimal national solutions to implement carbon dioxide reduction, capture, transportation, and storage.

Significance of project Development of regionally sensitive models to identify the most cost-effective combination of technologies/practices to reduce CO_2 emissions.

Project Description In this project, optimization models will be developed, implemented, and integrated to aid in finding optimal solutions for CO_2 capture, additional treatment, transportation, and storage. These models will offer a multi-region, multi-technology decision framework that will make it possible to reach the target carbon dioxide reductions in a cost-effective way. They will also account for predictable trends and interactions that occur in a dynamic setting of a country as a whole. The following tasks will be included: i) understand and quantify both the current and projected releases of CO_2 to the environment in a selected region; ii) assemble a data base of CO_2 capture options available, their cost, comparison, and effectiveness; iii) model the CO_2 processing and transportation problem; iv) determine storage options, maximum capacity, and associated costs; v) model the different decision scenarios using mathematical programming techniques and taking interactions into account; vi) test the model on a case study of OPG fossil fuel boilers; vii) develop a solution strategy for the mathematical programming model; and viii) implement the solution strategy and illustrate it on different case studies.

Duration 2005-2008.

Who is involved University of Waterloo (Org 4.2).

Funding Level and Funders Total $467K; NRCan (CCT&I via CETC-O's Clean Coal CO_2 Capture & Storage Strategy; Ontario Power Generation; University of Waterloo (NSERC); International support for 2 graduate students.

Contact

Dr. Peter L. Douglas
University of Waterloo
519-888-4567, extension 2913
pdouglas@uwaterloo.ca

Proj 5.2 Development of a generalised systems scheduling framework for the operation of generating stations with CO_2 constraints in Canada (Waterloo)

Goal To develop a decision framework that will provide optimal strategies for operating a fleet of electric generating stations with CO_2 mitigation constraints.

Significance of project A Systems Scheduler that would allow a utility to optimize its fleet of generating assets to implement carbon dioxide reduction.

Project Description This research project will develop and test a Systems Scheduling framework, the context for which is the solution passed down from the Regional Planning problem (a fleet of generating stations using a variety of fuels with CO_2 capture and storage identified for specific boilers) and determine the optimal operation and cost over a period of time. The inputs have already been developed for the Regional Planning problem; this project will develop the additional inputs needed to solve the Systems Scheduling problem.

- Phase 1 focuses on gathering the necessary information to develop the simulator and perform the Ontario case study. Most of the data necessary to model power plants, CO_2 capture processes and sequestration systems is already developed; the operation of the electricity markets and CO_2 trading credits will be the main focus of Phase 1.
- Phase 2 involves the development of models (unit operation, economic and scenario models) and their incorporation into the simulator. The simulator will be developed using GAMS, a model developed for the World Bank.
- Phase 3 will apply the simulator to the Ontario electric utility sector. In this phase, the robustness of the developed model will be investigated to ensure that the model is comprehensive enough. The model will be validated by comparing results from the simulation using a scenario representing the last three decades.

Duration 2005-2008.

Who is involved University of Waterloo (Org 4.2).

Funding Level and Funders $560K: CETC-O (NRCan - CCT&I), Ontario Power Generation, University of Waterloo(NSERC), governments of Malaysia and Saudi Arabia (graduate students)

Contact:

Dr. Peter L. Douglas
University of Waterloo
519-888-4601
pdouglas@uwaterloo.ca

Proj 5.3 CO_2 capture and mitigation technologies for Canada's power generation system (Waterloo)

Goal To develop advanced capture processes specifically suited to the recovery of CO_2 from fossil fuel power plants.

Significance of project Will investigate combinations of separation processes and power plant configurations to help identify which is best for CO_2 capture.

Project description This project will investigate the integration of separation processes, such as physical and chemical absorption, cryogenic distillation and membranes with various power plant configurations such as coal-fired, natural gas, integrated gasification combined cycle and fuel cells. The project will determine optimum means of incorporating capture processes into practical CO_2 recovery schemes.

Duration 2001-2005.

Who is involved University of Waterloo (Org 4.2) in collaboration with NRCan (CANMET Energy Technology Centre-Ottawa) (Org 3.1), TransAlta Utilities (Org 5.9), Air Liquide (Org 8.3) and the IEA Greenhouse Gas R&D Programme (Org 2.11).

Funding Level & Funders $242K: NSERC.

Contact
Dr. Peter Douglas
University of Waterloo
519-888-4601
pdouglas@uwaterloo.ca

Proj 5.4 Improvements in efficiency and process modifications for CO_2 capture in western Canadian hydrogen plants (Waterloo)

Goal To develop, optimize and cost process schemes for hydrogen production at oil sands plants in Alberta, based on hydrogen plants, combined with solid oxide fuel cells and/or turbines with CO_2 capture.

Significance of project Will help identify the most effective strategy for producing hydrogen from a range of fuels (including pet coke) for oil sands upgrading while capturing CO_2.

Project description This project is comprised of three tasks. Task 1 will develop the overall approach and integrate the results of the other two tasks. Task 2 will simulate and optimize a solid fuel-based hydrogen plant. AspenPlus models will be developed for IGCC using a wider range of fuels (pet coke, heavy oil residue), and alternative CO_2 capture strategies will be assessed. Task 3 is similar to Task 2, except the focus will be on natural gas fed hydrogen plants. Again, AspenPlus models will be developed for alternative reforming processes and CO_2 capture options from existing and new hydrogen plants will be assessed. These results will be fed back into Task 1 where the integration of various hydrogen plants with various power systems, such as combined cycle, solid oxide fuel cell and SOFC/turbine configurations. Both solvent-based and oxyfuel strategies will be examined. This will provide a portfolio of options, with the capital and operating costs compared to current practice.

Duration 2004-2007.

Who is involved University of Waterloo (Org 4.2).

Funding Level and Funders $212K: Natural Resources Canada (CETC-O).

Contact:
Dr. Peter L. Douglas
University of Waterloo
519-888-4601
pdouglas@uwaterloo.ca

Proj 5.5 Integrated economic model for CO_2 capture and storage (ARC et al.)

Goal To develop a computer model to simulate the economics of connecting CO_2 emission point sources to ECBM coal beds and aquifers to induce incremental production of oil and gas and store CO_2 in reservoirs and aquifers.

Significance of project This model will allow the overall economic costs associated with CO_2 capture and geological storage initiatives to be compared.

Project description An evaluative numerical tool is being developed to assess storage options both from a business perspective (e.g. project value, CO_2 credits), and from a policy perspective (e.g. emission reductions, taxes and royalties). This integrated model will be able to handle the four distinct businesses – CO_2 capture, CO_2 transport, injection/energy production and CO_2 storage/credits. It will be able to evaluate individual project proposals and groups of projects (for province-wide impacts). The fiscal regime treatment and evaluation will depend on proper greenhouse gas accounting to generate credits, conventional injection/production economics, CO_2 capture economics, and scenario analysis and risk assessment. The integrated model will have an extensive list of capture options to choose from, a wide range of storage options, a range of business considerations, and a friendly user interface with tables and graphics outputs.

Duration 2005 - 2008

Who is involved Alberta Research Council (Org 3.3), Alberta Energy and Utilities Board, Energy Navigator, SNC Lavalin (Org 8.28), and the Computer Modelling Group.

Funding Level & Funders $500,000: NRCan, Energy Navigator Inc. (in-kind contribution - software development); SNC Lavalin Inc. (in-kind contribution – process engineering); AERI (proposed).

Contact

John Faltinson,
Alberta Research Council
780-450-5405
faltinson@arc.ab.ca

6. CO_2 CAPTURE – SOLVENTS

Proj 6.1 High efficiency gas testing systems for CO_2 (greenhouse gas) capture and separation (Regina)

Goal To improve separation processes for recovery of CO_2 from industrial sources at the lowest possible capital and operating costs with minimum operating problems.

Significance of project Will examine ways of improving the performance of solvent-based CO_2 capture systems.

Project description Work under this project investigated the mass transfer processes in high efficiency structured as well as membrane packings and studied the CO_2 absorption-reaction characteristics of new formulated solvents. On the basis of these studies, new structured and membrane packings and new solvent formulations were identified. Process integration and optimization analyses of CO_2 capture and separation from industrial sources including coal-fired power plants were performed to examine the impact of using the high efficiency column packings, membranes and formulated solvents developed in the project.

Duration 2000-04

Who is involved University of Regina (Org 4.3).

Funding Level & Funders NSERC; $34.8k per year

Contact:
Dr. Paitoon Tontiwachwuthikul
University of Regina
306-585-4160
paitoon.tontiwachwuthikul@uregina.ca

Proj 6.2 University of Regina International Test Centre Consortium Program (Regina)

Goal To develop technical solutions that reduce dramatically the costs of solvent-based CO_2 capture from gas streams.

Significance of project Will provide the basis for comparing the performance of solvent-based CO_2 capture systems and will optimize the solvent capture approach.

Project description This research program incorporates a number of projects that establish baselines for the current performance of solvent-based systems and develop improved solvent chemistry and process design to reduce capital costs, solvent degradation, corrosion and parasitic energy loses. The work is carried out at the laboratory scale and at the pilot plant scale at a dedicated facility at the University of Regina and at semi-commercial scale at the Boundary Dam facility. Phase I of the program was completed in 2005 (establishing the university facility and upgrading/refurbishing the Boundary Dam plant, establishing baseline performance and costs, testing mixed solvents, work on packings, degradation and corrosion). Phase II is just beginning with a program that will evaluate and test new solvents, optimize the overall process and its integration into power systems, including product delivery and transport, conduct a detailed cost analysis of an integrated design and develop training and innovation standards and training materials for operating a solvent-based CO_2 capture facility.

Duration Phase I: 2002-2005; Phase II: 2005-2009.

Who is involved University of Regina's CO_2 Capture Group (Org 4.3) with Universities of Waterloo (Org 4.2), British Columbia (Org 4.5) and Calgary.

Funding and Funders Phase I: $14M for facilities (Western Economic Diversification, Canadian Foundation for Innovation, SaskPower [Org 5.5], Government of Saskatchewan); Approximately $3M operating (governments of Canada, Saskatchewan and Alberta, SaskPower [Org 5.5], TransAlta [Org 5.9], EPCOR [Org 5.7], Nexen [Org 8.24], EnCana, Petrobas, Fluor Daniel [Org 8.14] and Luscar/Sherritt [Org 8.27].

Phase II: Approximately $3M for operations: NRCan (CCT&I), Sask Energy & Mines, AERI, EnergyiNet, Sask Power, EnCana, EOn (UK), Saudi Aramco, RITE (Japan), B&W [Org 8.5], NTC Purenergy [Org 8.20], KIER (S. Korea), Univ. of Regina, Univ. of Waterloo, Imperial College.

Contact:

Dr. Paitoon Tontiwachwuthikul
University of Regina
306-585-4160
paitoon.tontiwachwuthikul@uregina.ca

Malcolm Wilson
University of Regina
306-337-2287/2296
malcolm.wilson@uregina.ca

Proj 6.3 Capture of CO_2 from combustion flue gases using amines (Regina)

Goal To reduce the cost of CO_2 capture with solvents through improved formulations, reduction of energy requirements, better operating practices and better corrosion inhibition.

Significance of project Will identify a number of ways to reduce the cost and improve performance of solvent-based CO_2 capture systems.

Project description This project will address the cost issue of amine-based CO_2 solvents by using a combination of strategies including efficient use of conventional solvents (such as higher MEA loadings), formulation of a new energy efficient solvent (such as concentrated MEA/MDEA blends), reduction of heat for regeneration, as well as optimization and integration. New operating techniques will also be tested in order to obtain a substantial reduction in the cost of CO_2 capture. Presently, there are no data regarding CO_2 absorption rates, vapour/liquid equilibrium, corrosivity, degradation characteristics, heat of absorption, heat of regeneration, etc. of highly concentrated CO_2-loaded MEA solutions or MEA/MDEA blends. In addition, because of the high cost and toxicity of current inhibitors, there is the need to develop less expensive and less toxic, environmentally friendly corrosion inhibitors.

Duration 2004-2006.

Who is involved International Test Centre for CO_2 Capture, University of Regina (Org 4.4).

Funding Level & Funders $83K per year for each of two years: Natural Resources Canada.

Contact:
Dr. Raphael Idem
University of Regina
306-585-4470
raphael.idem@uregina.ca

Proj 6.4 Fundamental studies of mass transfer with chemical reaction for CO_2 separation processes (Regina)

Goal To develop operational and design strategies to reduce the cost of solvent capture of CO_2.

Significance of project Pilot scale testing and modeling of key steps in solvent capture to reduce costs.

Project description This project will carry out a series of absorption and regeneration experiments in pilot scale columns fitted with structured packings. The project will also develop mechanistic models to predict mass transfer parameters and fluid dynamic phenomena in both absorber and regenerator. The models will incorporate all crucial mechanistic components of gas absorption and regeneration, including thermodynamics, kinetics, fluid dynamics and packing geometry. By combining the experimental results with the mechanistic models, overall process simulation and optimization will be carried out. The project objectives are: i) to provide insight into mass transfer and fluid dynamic behaviour in structured packings in absorbers and regenerators; ii) to develop rigorous predictive models for gas absorption and solvent regeneration; iii) to provide a cost-effective operational and process design strategy; and iv) to evaluate the cost reductions due to the proposed strategy.

Duration 2003-2007.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders NSERC: $21.0K per year.

Contact
Dr. Adisorn Aroonwilas
University of Regina
306-337-2469
Adisorn.Aroonwilas@uregina.ca

Proj 6.5 Separation of CO_2 from flue gases: alkanolamine degradation prevention studies (Regina)

Goal To understand the amine degradation process during CO_2 capture from flue gas streams and use this understanding to prevent amine degradation.

Significance of project Identifying ways to reduce solvent degradation, thereby improving performance and reducing costs.

Project description The project involved studies of the mechanisms of amine degradation under a variety of conditions typical of CO_2 capture processes.

Duration 2000-04.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders $21,500 per year for each of four years; NSERC.

Contact
Dr. Raphael Idem
University of Regina
306-585-4470
raphael.idem@uregina.ca

Proj 6.6 CO_2 capture from coal-fired power plant flue gases using formulated amines: degradation prevention studies (Regina)

Goal To develop an "optimum degradation inhibitor" that will enable any formulated amines to be used for multi-component capture involving coal combustion flue gases (containing O_2, CO_2, SO_2, N_2, NO_X and Hg) with the minimum possible degradation.

Significance of project Identifying ways to reduce solvent degradation due to flue gas impurities, thereby improving performance and reducing costs of solvent capture processes.

Project description This project will perform a comprehensive study of the degradation of mixed amines formulated for CO_2 capture from coal-fired power-plant flue gases (i.e. containing O_2, CO_2, SO_2, N_2, and NO_X). The project will elucidate the degradation behaviour and mechanism in CO_2 capture in a system using mixed (formulated) amines that contain a corrosion inhibitor. The aim is to develop a framework or strategy for preventing or minimizing degradation by developing an understanding of the mechanism of degradation prevention using scavengers and chelating agents and by developing formulations of effective amine degradation inhibitors for use with flue gas that contains CO_2, O_2, N_2, SO_2 and NO_x with formulated amine solvent (starting with MEA-MDEA) that contains a corrosion inhibitor.

Duration 2005-09.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders $26,500 per year for each of five years; NSERC.

Contact
Dr. Raphael Idem
University of Regina
306-585-4470
raphael.idem@uregina.ca

Proj 6.7 High pressure solubility studies in acid gas removal (Regina)

Goal To measure the solubility of CO_2 in promising physical solvents and non-alkanolamine solutions, and develop new models.

Significance of project Bench-scale testing and model development of alternative solvents for CO_2 capture**.**

Project description This project involved a screening study of fourteen glycol ethers in terms of their capacity for CO_2 absorption and hydrocarbon co-absorption. The solubilities of CO_2 in three promising non-alkanolamines were measured in a high-pressure cell up to 6500 kPa. A model correlated then predicted the experimental data well. The reaction rates of CO_2 in non-alkanolamine aqueous solutions were measured in a stopped-flow cell, and the results were compared to those of MEA. Calorimetric and viscosity measurements shed new light on the interactions between water and the physical/alkanolamine solvents in terms of complex formation and the strength of the intermolecular forces involved.

Duration 2002 -2006.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders $24,750 in each of four years; NSERC.

Contact
Dr. Amr Henni
University of Regina
306-585-4960
Amr.henni@uregina.ca

Proj 6.8 Solubility, kinetics and calorimetric studies in acid gas removal (Regina)

Goal To measure the solubility and the absorption rates of CO_2 in promising aqueous and non-aqueous polyamine solutions, and develop new models.

Significance of project Bench-scale testing and model development of alternative solvents for CO_2 capture. The calorimetric studies dealing with the heat of mixing allow for a better understanding of the molecular interactions.

Project description This project involved a screening study of fifteen diamines/alkanolamines in terms of their capacity for CO_2 absorption and hydrocarbon co-absorption. The solubilities of CO_2 in polyamines are measured in a high-pressure cell up to 6500 kPa. The screening was done in a low pressure glass reactor. A model correlated then predicted the experimental data well. The reaction rates of CO_2 in polyamines solutions were measured in a stopped-flow cell, and the results were compared to those of MEA, DEA or MDEA. The first six amines studied outperformed the amines considered as industry standards. Calorimetric, volumetric and viscosity measurements shed new light on the interactions between water and the amines solvents in terms of complex formation, self-association, and the strength of the intermolecular forces involved. A correlation was found between the heat of mixing and the speed of reaction with CO_2. Computational chemistry models are used to study the mechanism of the reactions with CO_2 in order to better understand the reactions and to be able to predict the structure of more promising amines.

Duration 2006 -2011.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders NSERC: $24,450 in each of five years.

Contact

Dr. Amr Henni
University of Regina
306-585-4960
Amr.henni@uregina.ca

Proj 6.9 Molecular design and solvent development of cost-effective processes for CO_2 capture from industrial gas streams (Regina)

Goal To develop novel absorption solvents that can capture carbon dioxide (CO_2) from industrial flue gas at much lower costs in comparison with the conventional processes.

Significance of project Design, modeling and evaluation (bench scale) of alternative CO_2 solvents.

Project description This project involves:

- the design, synthesis and molecular modeling of new, structurally relevant amines (especially amino alcohols) for stripping CO_2 from flue gases;
- thermodynamic solubility, physical and transport property measurement and kinetics***;***
- their speciation and kinetic properties during degradation;
- an investigation of their corrosion properties and stability; and
- an evaluation of the performance of these solvents in an absorber.

The data will be used to develop tools to aid in the refinement and optimization required in the design and development of synthetic reactive solvents for CO_2 recovery.

Duration 2003-2006.

Who is involved University of Regina (Org 4.4).

Funding Level & Funders $172K per year plus in-kind support from a consortium of industry and governments; NSERC.

Contact
Dr. Paitoon Tontiwachwuthikul
University of Regina
306-585-4160
paitoon.tontiwachwuthikul@uregina.ca

Proj 6.10 Fundamental studies of CO_2 (greenhouse gas) capture and separation using extra-high concentration formulated solvents (Regina)

Goal To develop improved (lowest cost and reduced operating problems) separation processes for CO_2 recovery from industrial gas streams.

Significance of project Laboratory scale testing of alternative CO_2 solvents at high concentrations.

Project description This project will: i) study the CO_2 absorption-reaction characteristics of newly formulated solvents (up to 5 compounds) at extra high concentration (up to 10 kmol/m^3); ii) examine the reaction kinetics and absorption mass transfer of these high efficiency solvents; and iii) perform process integration and optimization analysis of CO_2 capture and separation from industrial sources (including coal-fired power plants) based on these new solvents.

Duration 2004-09.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders NSERC: $35K per year.

Contact
Dr. Paitoon Tontiwachwuthikul
University of Regina
306-585-4160
paitoon.tontiwachwuthikul@uregina.ca

Proj 6.11 Comprehensive corrosion studies and development of low toxicity corrosion inhibitors for CO_2 separation process (Regina)

Goal To conduct a comprehensive study of corrosion behaviour, to identify the corrosion mechanism and develop a predictive model and to search for low-toxic chemical compounds that can replace the current toxic corrosion inhibitors used in CO_2 separation processes.

Significance of project Will identify less toxic corrosion inhibitors for use in solvent-based CO_2 capture processes.

Project description This project focuses on the development of low toxicity corrosion inhibitors to respond to environmental concerns and to reduce the cost of waste disposal as well as prepare for more stringent regulations for chemical use. Corrosion experiments will be carried out to examine the influence of process parameters on corrosion behaviour. The results will be used to test various corrosion mechanistic models. The performance of low-toxic corrosion inhibitors will be experimentally evaluated under static and dynamic conditions. The minimum dosage or injection rate for each low-toxic inhibitor will be determined. In addition, their long-term performance will be evaluated in order to determine the frequency of dosage addition or injection needed for satisfactory inhibition.

Duration 2000-2007.

Who is involved University of Regina (Org 4.3).

Funding Level & Funders NSERC grants and scholarship: $61,900 (2000-01); $61,900 (2001-2002); $61,900 (2002-2003); $65,000 (2003-2004); $65,000 (2004-2005); $25,000 (2005-2006); $25,000 (2006-2007).

Contact

Amornvadee Veawab
University of Regina
306-585-5665
amy.veawab@uregina.ca

Proj 6.12 Non-thermal plasma multi-pollutant control technology for flue gas pre-cleaning before amine-CO_2 scrubbing operation (CETC-O)

Goal To develop an effective means of removing pollutants from flue gases prior to amine stripping of CO_2.

Significance of project Development plus lab-scale and field testing of a technology to remove SO_2, NO_x and mercury from a hot flue gas stream.

Project description: This research project will explore the use of radical shower plasma-generating technology as a flue gas cleaning technology prior to feeding the flue gas to an amine-based CO_2 separation process. In the radical shower plasma mode, reagent and pollutants are charged and excited locally at low electricity input to trigger chemical reactions and convert pollutants to harmless solid substances that can be captured by particulate control devices. The plasma technology is designed to remove SO_2, NO_x and Hg from the coal-fired flue gas. A plasma radical shower reactor will be designed and tested on a coal-fired flue gas stream to determine its effectiveness in controlling levels of pollutants in the flue gas. Operating conditions such as flue gas temperature, plasma discharge voltage and reagent utilization rates will be investigated.

This technology will be tested in the lab prior to a proposed test on a flue gas slip stream from an operating coal-fired power plant.

Duration 2004-2007.

Who is involved Initial work on the radical shower plasma technology was done by Dr. Chang at McMaster University (Org 4.1). This project will be carried out at the CANMET Energy Technology Centre-Ottawa (Org 3.1). Subsequent field testing is tentatively planned by SaskPower (Org 5.5) at their Boundary Dam or Poplar River plant, in conjunction with the International Test Centre at the University of Regina (Org 4.4).

Funding Level and Funders $570,000 over three years; Natural Resources Canada (Climate Change Technology & Innovation), SaskPower, Ontario Power Generation and Nova Scotia Power.

Contact

Dr. Quan Zhuang
CANMET Energy Technology Centre-
Ottawa
Natural Resources Canada
613-943-0977
QZhuang@nrcan.gc.ca

7. CO_2 CAPTURE - GASIFICATION

Proj 7.1 Gasification characteristics of Western Canadian feedstocks (Sherritt)

Goal To select the best gasification technology for feedstocks of interest in Western Canada and to evaluate performance of these feeds in the chosen design.

Significance of project Identifies the preferred gasification technology for low rank coals and pet cokes and an optimum strategy for operating an economically viable gasifier with Western Canadian feedstocks.

Project description This project is a continutation of earlier work by Sherritt (Proj 2.2) in which the impact of coal cleaning on improving the gasification of Western Canadian coals was assessed. This current project evaluated various gasifier designs to determine which would work best with these same low-rank coals and other feedstocks of interest (e.g. pet coke). From this analysis, the entrained flow-quench gasifier design of Future Energy was chosen. Proof-of-concept tests using the feedstocks of interest were run at Future Energy's test facilities in Germany. These tests examined carbon conversions, cold gas efficiencies, mass flow and slagging characteristics and slag leachabilities.

Duration 2005-2006.

Who is involved Sherritt International/ Luscar (Org 8.27); Future Energy.

Funding Level & Funders Amount not disclosed; Sherritt and AERI.

Contact
Dr. Amar Amarnath
Sherritt Coal
780-420-5810
aamarnath@sherrittcoal.com

Proj 7.2 Emission-free coal and carbon energy technology with integrated CO_2 capture (ZECA)

Goal To develop and commercialize an integrated zero emission technology for converting carbon-based fuels to power and/or hydrogen.

Significance of project While no longer active, this initiative sought to develop a very advanced, efficient and clean concept for clean coal.

Project description ZECA Corporation (ZECA) was a private carbon management venture that embodied a U.S.-Canadian collaboration that succeeded the Zero Emission Coal Alliance (The Alliance) in 2001. Technical and business plans to design, construct and operate a pilot plant within a five year period were developed.

ZECA was the exclusive world licensee (from the University of California) of patented Emission-Free Coal and Carbon Energy Technology (E-F Technology) that was identified at Los Alamos National Laboratory (LANL) and Louisiana State University. This technology uses hydrogasification and calcium oxide reforming to produce hydrogen from coal, petroleum coke, bitumen, heavy oil, biomass etc. while simultaneously producing "pure" carbon dioxide for sequestration. The hydrogen may be used for upgrading (oil sands), production of electricity or off-site sales. Initially hydrogen-fueled turbines may be used for generating electricity but, ultimately, development of a robust, sulphur tolerant, solid oxide fuel cell was seen as important to achieve "water-free", zero emission electricity production using this technology.

ZECA's work continues under the auspices of individual participants.

Duration 2000-2005

Who is involved ZECA's shareholders included Canadian and American utility, mining, manufacturing and coal interests and was managed from Calgary, Alberta.

Funding Level & Funders Approximately $1.0-1.5M: From shareholders, Natural Resources Canada, AERI, and industrial participants.

Contact
Alan Johnson,
ZECA Corporation
403- 239-0730
Johnson.rjz@gmail.com

Proj 7.3 Zero emissions hydrogen production via gasification (CETC-O)

Goal To develop the scientific and engineering knowledge for an advanced fossil fuel-fired technology for producing hydrogen and electricity with no CO_2 or other air emissions.

Significance of project Will investigate, at small pilot scale, the potential for chemical looping combustion to provide a more attractive approach to clean coal.

Project description The project will entail the fundamental research and process simulation required for basic engineering for a chemical looping gasification process featuring enhanced hydrogen production and CO_2 capture. Simultaneously, a hot gas clean-up module along with in-situ syngas monitoring will be designed and installed. The approach will use dual fluid beds for the carbonation/gasification and sorbent regeneration steps. Hydrogen production would be integrated into the gasification process achieving both production of hydrogen and separation of impurities simultaneously. The project will also address the effective control of particulate and gas-phase contaminants at high temperature and high pressure through the use of cyclones and barrier filters. Fixed-bed reactors will be examined to capture alkali species with a regenerable sorbent.

The project would evaluate existing Canadian fuels and sorbents using an entrained flow gasifier, would research high temperature, multi-pollutant sorbents, develop an engineering design package for a typical plant in the WCSB, develop an in-situ optical measurement system to measure component concentrations and develop partnerships and tools for commercialization.

Duration 2004-2008.

Who is involved CANMET Energy Technology Centre-Ottawa, Natural Resources Canada (Org 3.1).

Funding Level and Funders $2.1M (over 4 years). Natural Resources Canada - Climate Change Technology & Innovation [Org.10.7]; CCPC [Org 1.1]; Alstom [Org 8.4]; University of Toronto, University of Ottawa [Org 4.1], University of British Columbia [Org 4.5] ; Instituto de Carboquimica (Spain).

Contact

Dr. Ben Anthony
CANMET Energy Technology Centre-
Ottawa, Natural Resources Canada
613-996-2868
banthony@nrcan.gc.ca

Proj 7.4 Feasibility of integration of membrane reactor with gasification for clean coal application (CETC-O)

Goal To evaluate CANMET's ceramic hydrogen permselective membrane (H-membrane) in a water-gas-shift (WGS) membrane reactor for producing a pure H_2 stream, as well as a stream highly concentrated in CO_2, from the product stream of the gasification of coal.

Significance of project Will test, at laboratory scale, the ability of a proprietary H-membrane to increase hydrogen production and enrich the CO_2 stream from the water gas shift reaction.

Project Description Membrane reactors offer a new industrial paradigm as they combine reaction and separation in one step. WGS membrane reactors can circumvent the thermodynamic limitation found in conventional WGS reactors as they can separate H_2 as it is produced. Removal of H_2 results in an increase in CO conversion and production of H_2 with increased purity and an enriched high pressure CO_2 stream. CANMET's proprietary H-membranes will be evaluated for viability in a WGS membrane reactor, treating pre-combustion streams obtained from the gasification of coal. Actual coal gasification streams obtained from the CANMET coal gasifier (see Proj 5.2) will be used in the evaluations. WGS membrane reactor studies will be carried out at atmospheric pressure on facilities separate from the coal gasifier. Membrane reactor operating parameters, such as water to CO ratio, catalyst placement and product sweep rate will be studied. Membrane reactor compatibility with various coal gasification product streams and membrane reactor efficiency for CO conversion, H_2 removal and CO_2 concentration will be determined. CANMET H-membranes will also be evaluated by industry (Engelhard and KTI) for water-gas shift/reformer applications. Completion of this project would provide a logical decision point and risk analysis of an integrated coal gasification/membrane reactor study, with an estimate of process requirements, and any economic gains. This will position CETC-O to form strategic business alliances for further process development leading to commercial realization.

Duration 2005-2008.

Who is involved CANMET Energy Technology Centre-Ottawa (NRCan) (Org 3.1).

Funding and Funders $375K: CETC-O (NRCan - CCT&I), Englehard and KTI.

Contact

Dr. Jan Galuszka
CANMET Energy Technology Centre-
Ottawa, Natural Resources Canada
613-995-1585
galuszka@nrcan.gc.ca

Proj 7.5 Gasification in a Fluidized Bed Membrane Reactor (Saskatchewan)

Goal To develop a new process for the gasification of asphaltenes, biomass, and coal in which hydrogen permeable membranes are immersed in a fluidized bed gasifier.

Significance of project Will examine the degree to which a fluidized bed membrane reactor (FBMR) represents an alternative to conventional gasifier technology with the potential to have gasification and product purification taking place in a single reactor.

Project description The research will study the use of FBMR technology for gasification in a pilot-scale system. The FBMR has been studied on a lab scale for the steam reforming of methane, but the technology has never been considered for gasification. The FBMR is a fluidized bed into which hydrogen-permeable membranes are immersed. The hydrogen formed by gasification passes through the membranes to create a concentrated hydrogen stream. The remaining gas that does not permeate through the membrane is mostly CO, which could be fed to a CO boiler to produce an essentially pure stream of CO_2. The heat released during the combustion of the CO could be used for heat integration and the pure CO_2 could be sequestered or otherwise utilized in a chemical complex. It may also be possible to add limestone to the fluidized bed for the purpose of dry sulphur capture.

The pilot FBMR will be 0.2 m ID and approximately 2 m tall and housed in the Chemical Engineering pilot plant at the University of Saskatchewan. Presently the gasification of the meat and bone meal (MBM) left over from the cattle rendering process is being studied. The switch to coal and coke fuels and then asphaltenes will follow. The influence of temperature, pressure and fluidizing gas velocity will be studied for each fuel. The long-term objective is to follow up the pilot-scale study with a large-scale demonstration project of the FBMR for the gasification of coal, coke or asphaltenes.

As the name implies, the gasification and product purification takes place all in one reactor.

Duration 2005-2008.

Who is involved University of Saskatchewan (Org 4.1), Nexen (Org 8.24), and the Province of Saskatchewan (through Sask-Ag and Food for the MBM project).

Funding Level & Funders $240 K from Nexen and $145 K from Sask Ag and Food.

Contact
Dr. Todd Pugsley
University of Saskatchewan
306-966-4761
todd.pugsley@usask.ca

Proj 7.6 Increasing gasifier availability via improved refractory and injector designs (CETC-O)

Goal To develop suitable gasifier fuel injector designs and refractory lining materials by improving the technology associated with these components that are the largest contributors to gasifier planned and unplanned shutdowns.

Significance of project Will address key barriers to adoption of IGCC through materials selection, modeling, component design and pilot-scale testing.

Project Description The project will develop improved gasifier fuel injector designs and refractory lining materials for the gasification of western Canadian coals for power generation and hydrogen production. The approach will include better fundamental understanding of the failure processes and a new computational fluid dynamics model (pilot plant proven). New designs will be evaluated using a variety of fuels including petroleum coke, asphaltenes, a mixture of petroleum coke and lignite from Saskatchewan and sub-bituminous coal from Alberta. This project consists of the following activities:

- Investigation of refractory materials under slagging gasification conditions;
- CFD modeling of the fuel injectors and combustion zone for dry fuels;
- Process simulation with ASPEN Plus;
- Engineering design and manufacture of new fuel injectors for feeding dry fuels;
- Engineering design and manufacture of new slagging gasifier vessel;
- Installation of the injector, gasifier and shell temperature monitoring instrumentation into the CETC-O pilot-scale gasification plant;
- Pilot plant evaluation of the refractory materials selected by the Albany Research Center and CETC-O;
- Pilot-scale evaluation of the dry fuel injector designs for the selected feedstocks; and
- Demonstration of a fibre optic temperature-sensing device in conjunction with LxSix, a Canadian fibre optic manufacturer.

Duration 2005-2008.

Who is involved CANMET Energy Technology Centre-Ottawa (NRCan) (Org 3.1), Albany Research Centre, LxSix Photonics.

Funding and Funders Approximately $1.5M: CETC-O (NRCan - CCT&I), Albany Research Centre, LxSix Photonics.

Contact

Dr. Ben Anthony
CANMET Energy Technology Centre-
Ottawa, Natural Resources Canada
613-996-2868
banthony@nrcan.gc.ca

8. CO_2 CAPTURE- OXY-FUEL

Proj 8.1 ThermoEnergy Integrated Power System (TIPS) process (CETC-O)

Goal To develop a next generation power cycle based on pressurized combustion.

Significance of project The TIPS cycle may offer significant thermodynamic efficiency advantages over other combustion-based approaches to clean coal technology.

Project description Phase 1 of this project involved a feasibility analysis of the TIPS cycle based on process models in order to optimize thermodynamic efficiencies. The study consisted of detailed modeling of the TIPS system using CETC proprietary models. The study included design layout and also sized and costed equipment. Phase 3 has been proposed and includes construction of a pilot plant, an experimental program and cycle/equipment development.

The TIPS cycle has the potential to:

- Increase steam cycle and boiler efficiency compared with ambient pressure combustion technologies;
- Reduce auxiliary power consumption of ambient pressure combustion cycles using an air separation unit (ASU), flue gas recycle (FGR) and a product recovery train (PRT);
- Reduce the cost of multi-stage compression and refrigeration used within ambient pressure combustion technologies;
- Improve burnout;
- Reduce furnace, scrubber, flue gas condenser and heat exchanger sizes;
- Maintain efficiency for high moisture fuels (*e.g.* lignite, biomass); and
- Improve effectiveness of scrubbing for air pollution control.

Duration Phase 1: 2004 – 2006; Phase 2: 2007-2008; Phase 3+: 2007-2012.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1), ThermoEnergy Corporation (US), others being recruited.

Funding Level & Funders Phase 1- USDOE (via ThermoEnergy); Phase 2 - $500K USDOE (via ThermoEnergy) and $250K NRCan (proposed); Phases 3 and beyond - $12M (proposed).

Contact

Bruce Clements
CANMET Energy Technology Centre –
Ottawa (NRCan)
613-943-8881
clements@nrcan.gc.ca

Proj 8.2 Closed gas turbine cycle project (Waterloo/Carleton)

Goal To evaluate advanced power cycles involving oxy-fuel combustion for their ability to produce power and capture CO_2.

Significance of project Looks at the most cost-effective means of producing electrical power while capturing CO_2

Project description This project evaluates the technical and economic performance of various closed gas turbine and fuel cell based cycles utilizing oxy-fuel combustion to produce power and capture CO_2. The work program includes simulation activities and primary research.

Work on the Raven Zero Emission Gas Turbine is focused on the design and construction of a 70 KWe natural gas-fired generator set using pure oxygen combustion with CO_2 re-circulation. Design parameters and concepts learned from the pilot-scale work will be used to model the operations of a 100 MWe industrial scale facility. Work is underway to develop a simulation of a solid oxide fuel cell (SOFC), which can be integrated with a gas turbine bottoming cycle. A particular aspect of the work on SOFC is the operation with syngas that could originate from biofuel or from coal syngas. In this project the focus has been on evaluating the effect of the CO concentration in the syngas on the SOFC performance.

Duration April 2002 - March 2006.

Who is involved Carleton University (Org 4.1) is doing the work on the Raven Zero Emission Gas Turbine; University of Waterloo (Org 4.2) is doing the SOFC simulation work.

Funding Level & Funders $850K: Climate Change Action Plan (CCAP) Program through the CANMET Energy Technology Centre- Ottawa .

Contacts

Dr. Eric Croiset
University of Waterloo
519-888-4567, extension 6472
ecroiset@cape.uwaterloo.ca

Dr. Donald Gauthier
Carleton University
613-520-5690
dgauthie@mae.carleton.ca

Proj 8.3 Advanced Brayton-cycle-based zero emission power plants burning fossil fuels (Carleton)

Goal To design a 100MW plant utilizing a Brayton-cycle-based semi-closed zero emission design fueled with an O_2/CO_2/gaseous fuel.

Significance of project Will identify the process/design/material changes needed to optimize combustion turbines for oxy-fuel use.

Project Description This work extends that of Proj 8.2. Four major elements are proposed:

- Continue to study the implementation of a Brayton-cycle-based semi-closed zero emission design for a nominal 100-MW plant, supplemented by new models to assess the performance and the relative cost of the options available.
- Continue to study the utilization of working fluids other than air in gas turbine turbomachinery, including the development of design tools. The design tool will be validated using a commercially available computational fluid dynamics code (probably CFX) and turbomachinery rig testing as applicable.
- Continue to study combustion systems for O_2/CO_2/gaseous fuel (natural gas and syngas) utilization, include the development of design tools. The design tool will include non-equilibrium models for the composition of products leaving the combustor. The design tool will be used for a preliminary combustor design and to provide estimates of performance parameters such as temperature profiles and pressure loss across the combustor. The design tool will be validated using commercially available state-of-the-art computational fluid dynamics and chemical kinetics codes.
- Initiate the study of new materials and coatings required for this design through identifying the expected failure modes and proposing solutions. Coatings specifically designed for this project will be manufactured and tested in a test rig that will be designed and manufactured.

Duration 2006-2008.

Who is involved Carleton University (Org 4.1).

Funding Level and Funders $470K: CETC-O (NRCan - CCT&I) and Carleton University.

Contact:
Dr. Donald Gauthier
Carleton University
613-520-5690
donald_gauthier@carleton.ca

Proj 8.4 Decarbonization of fossil fuels for CO_2 mitigation (Waterloo)

Goal To advance and optimize the efficiency of the oxy-fuel process for carbon-based combustion.

Significance of project Using a modeling approach, will examine ways of increasing the overall energy efficiency of oxyfuel combustion processes.

Project description This research project examines oxy-fuel combustion as an alternative to post-combustion capture of CO_2 by chemical solvents. The approach is to burn the fuel in a mixture of air and oxygen and recycle part of the flue gas in order to increase the concentration of CO_2 in the flue gas. The goal is to optimize the overall efficiency of such a power plant, using simulation, by trading off the penalties associated with the production of oxygen against the penalties inherent in conventional CO_2 separation.

Duration 2000 -2004

Who is involved University of Waterloo (Org 4.2).

Funding Level & Funders $86K: NSERC.

Contact
Dr. Eric Croiset
University of Waterloo
519-888-4567, extension 36472
ecroiset@chemengmail.uwaterloo.ca

Proj 8.5 CETC-O Oxy-Fuel R&D Consortium: development of oxy-fuel combustion technologies for CO_2 capture and storage

Goal To develop oxy-fuel combustion as a cost-effective technology for CO_2 capture from fossil-fired processes.

Significance of project A very extensive pilot-scale investigation and development of oxyfuel combustion for clean coal.

Project description The research program is aimed at improving the understanding of oxy-fuel combustion with a wide range of fossil fuels and its impact on plant design and pollutant abatement technologies. Pilot-scale testing under the program is carried out in a 0.3 MWth vertical combustor capable of firing coal, oil, and natural gas with varying degrees of O_2 concentration in a flue gas re-circulation stream to produce a near pure stream of CO_2 that can be readily captured by direct compression. Oxygen combustion and the performance of the down stream clean up technologies including electrostatic precipitators, bag houses, scrubbers, and condensing exchangers are being studied under the guidance of an industry/government consortium management committee. Elements of the program included the development of a novel low NO_x oxy-fuel burner, and novel integrated mercury, sulphur and particulate control technology options for a variety of fossil fuels. Integrated flue gas pre-treatment for CO_2 purification and removal and for multi-pollutant capture mechanisms are also being studied in a condensing heat recovery and scrubbing environment. Boiler simulation tools are being developed for use in a HYSYS and other commercial software. Outputs of the program are confidential to partners; however, several papers are in the public domain. The research program also includes developing a semi-closed-cycle micro gas turbine, a conceptual design of a zero emission 100 MW industrial gas turbine, and investigating the integration of Solid Oxide Fuel Cells (SOFC) into a gas turbine cycle to generate power while producing a CO_2 rich stream for capture.

Duration Program started in 1994, currently in Phase 8.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1) plus consortium members including: (present) SaskPower (Org 5.5), Ontario Power Generation (Org 5.3), IEA GHG R&D Programme (Org 2.11), US Department of Energy, Alberta Government (AERI – Org 10.1), Babcock & Wilcox (Org 8.5); (past) EPCOR (Org 5.7), TransAlta (Org 5.9), NSPower (Org 5.1), and Air Liquide (Org 8.3).

Funding Level & Funders Approximately $1Mper year: Consortium members and NRCan (PERD).

Contact

Dr. Kourosh Zanganeh
CANMET Energy Technology Center -
Ottawa, Natural Resources Canada
613-996-3916
kzangane@nrcan.gc.ca

Proj 8.6 Oxy-fuel field demonstration project (CETC-O)

Goal To enhance market acceptance of oxy-fuel combustion with CO_2 capture as a commercial viable and attractive near-zero emissions technology.

Significance of project Helps prepare the oxyfuel technology for commercial demonstration.

Project description The oxy-fuel process includes fossil fuel combustion in an oxygen rich environment, integrated flue gas treatment, CO_2 compression, CO_2 pipeline and storage, and its use in enhanced oil, gas and coal bed methane recovery. This project is aimed at identifying, promoting, and fostering opportunities for the commercial demonstration of oxy-fuel combustion as means of reducing CO_2 and other air emissions. Elements of this project comprise process modelling, feasibility engineering and cost studies to address technology gaps and needs in order to support site-specific commercial demonstrations. Efforts are also focused on developing novel processes for CO_2 capture and compression that could be used in commercial demonstration, increasing awareness of the latest oxy-fuel technology developments, soliciting interest in technology demonstration, developing partnerships and project proposals for commercial demonstrations.

Duration 2001-2006.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1) and a number of industrial partners.

Funding Level and Funders $1.38 M: Government of Canada (Climate Change Action Plan), currently seeking industrial partners for additional projects in areas described above.

Contact

Dr. Kourosh Zanganeh
CANMET Energy Technology Centre -
Ottawa, Natural Resources Canada
613-996-3916
kzangane@nrcan.gc.ca

Proj 8.7 Zero-emission oxy-fuel combustion technologies for clean fossil fuels (CETC-O)

Goal To develop a new generation of oxy-fuel combustion processes and compact combustor/boiler systems that will further improve plant efficiency and reduce CO_2 capture cost.

Significance of project Examines variants of the oxyfuel approach to improve costs and efficiency.

Project description This project will investigate new variants of oxy-fuel combustion processes by minimizing the flue gas recycle and controlling the flame temperature through other means. The oxy-steam combustion approach will be investigated as a means of moderating the boiler temperature to allow conventional materials to be used in the design while offering improved heat transfer. These developments may lead to smaller boilers and greatly reduced flue gas volume. The reduction in flue gas volumes will in turn reduce the size of the flue gas treatment equipment, leading to lower capital and operating costs for plants with CO_2 capture.

Another area of investigation will be performance optimization of the CO_2 compression train (for flue gas compression) and CO_2 purification using new processes.

The project also includes process modeling and experiments to investigate the advantages of hybrid cycles in the oxy-fuel process to help improve overall fuel-to-electricity efficiency.

The project involves pilot-scale testing and process simulation, CFD modeling and costing to assess the scale-up of the technologies.

Duration 2004-2008.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1), Carleton University (Org 4.1) and industrial partners being solicited.

Funding Level and Funders Approximately $3M: Natural Resources Canada (Climate Change Technology & Innovation); CETC-O Oxy-Fuel Consortium; Carleton University.

Contact

Dr. Kourosh Zanganeh
CANMET Energy Technology Centre-
Ottawa, Natural Resources Canada
613-996-3916
kzangane@nrcan.gc.ca

Proj 8.8 Novel oxy-fuel burner with in-situ emissions multi-pollutant & CO_2 control (CETC-O)

Goal To develop i) a novel oxy-fuel burner that utilizes fuel and oxidizer streams to suppress pollutants, enhance and control heat transfer, and increase combustion efficiency and ii) a mercury capture sorbent technology.

Significance of project Design, development and pilot-scale evaluation of a new oxyfuel burner. Also, the development and pilot-scale testing of a novel nanostructure TiO2 sorbent for Hg removal from flue gases in oxyfuel processes.

Project Description The first part of this work seeks to improve heat transfer and flame quality via the development of a novel oxy-fuel burner design that exploits the oxy-fuel flame structure, namely the temperature and combustion radical profiles. By aligning these profiles, soot and NO_x can be dramatically reduced, along with other pollutants, and a lower flame temperature can be realized while the radiant heat transfer can be maintained or increased. If successful, this design would increase combustor efficiency, reduce gas stream pollutants, and reduce the flue gas re-circulation ratio needed to cool the oxy-fuel flame. The second part of this work proposes a multi-pollutant and mercury capture technology, which further increases the CO_2 concentration in the flue gas and reduces the load on downstream pollution control systems. By adding nanostructure TiO_2 based sorbents to the fuel stream or introducing them slightly downstream of the combustor, pollutants such as trace toxic metals, mercury, and other species may be eliminated. The two technologies will be tested in tandem and separately. Tasks will include equipment design and construction, testing in CETC-O's "vertical combustor facility" and optimization and scale-up incorporating both economic and technical aspects.

Duration 2006-2008.

Who is involved CANMET Energy Technology Centre – Ottawa (NRCan) (Org 3.1) and Washington University (St. Louis, Missouri).

Funding Level and Funders $440K: CETC-O (NRCan - CCT&I), Ameren, Washington University.

Contact

Carlos Salvador
CANMET Energy Technology Centre –
Ottawa (NRCan)
613-992-3428
csalvado@nrcan.gc.ca

Proj 8.9 Integrated high efficiency oxy-fuel combustion process for CO_2 capture comprising slagging combustor, air separation, and gas turbine technologies (CETC-O)

Goal To develop second-generation oxy-fuel combustion to improve the efficiency and further reduce CO_2 emissions by integrating the oxy-fuel combustion with reduced or no CO_2 recycle, gas cooled slagging combustor and gas turbine technologies.

Significance of project Modeling based identification of alternative oxyfuel concepts with improved cost and efficiency.

Project Description This project builds upon the work under Proj 8.3, 8.5 and 8.7. The project has two principal tasks - design of an advanced gas cooled slagging cyclone combustor and design of an efficient gas turbine using the by-product gas stream from an Air Separation Unit (ASU) as the working fluid. The project will include the following elements:

- Development of efficient and optimised process models for second-generation oxy-fuel combustion.
- CFD analysis, modeling and design of the gas cooled slagging combustor and N_2 turbine for the second-generation oxy-fuel combustion.
- Identification of critical operating parameters and the optimum operating range of the system.
- Feasibility studies on the individual components and the overall system.
- Development of new control schemes for operation of a gas cooled slagging combustor, N_2 turbine and the overall system.

Duration 2006-2008.

Who is involved CANMET Energy Technology Centre – Ottawa (Org 3.1), Carleton University (Org 4.1), Federal Institute for Materials Research and Testing (FIMRT - Germany).

Funding Level and Funders $287K: CETC-O (NRCan - CCT&I), Carleton University and FIMRT.

Contact

Kourosh Zanganeh
CANMET Energy Technology Centre –
Ottawa (NRCan)
613-996-3916
kzangane@nrcan.gc.ca

Proj 8.10 Electrical power production from circulating fluidized bed combustor (CFBC) boilers with CO_2 capture (CETC-O)

Goal To test CO_2/O_2 firing of a circulating fluidized bed boiler to verify low conventional emissions and a nearly pure stream of CO_2.

Significance of project Pilot-scale testing and evaluation of a CFBC oxyfuel concept.

Project description This project will demonstrate CO_2/O_2 firing in a CFBC (circulating fluidized bed combustion) boiler using the 1MWt CETC pilot-scale CFBC boiler. The existing facility will be upgraded to allow O_2 firing with flue gas recycle and create a test platform capable of verifying the concept of O_2 firing in a CFBC boiler. Subsequent phases include testing CO_2/O_2 firing with a variety of Canadian coals and biomass to verify that the pilot-scale CFBC can be run in this mode. A number of optimized long-term tests will be done to ensure that agglomeration and other issues are not potential showstoppers. An overall economic evaluation of oxy-fuel CFBC will be carried out. The program will allow the concept to be fully tested at a reasonable pilot scale level, verifying that low conventional emissions (NO_x, SO_x, CO, mercury and unburned hydrocarbons) can be achieved alongside the production of a near pure CO_2 stream for sequestration.

Duration 2005-2008.

Who is involved CANMET Energy Technology Centre –Ottawa (Org 3.1), with CANMET Materials Technology Centre, National Research Council Institute for Chemical Processing and Environmental Technology (Org 3.4) and Terra International.

Funding Level and Funders Total $700K - NRCan (CCT&I via CETC-O's Clean Coal CO_2 Capture & Storage Strategy).

Contact

Dr. Ben Anthony
CANMET Energy Technology Centre-
Ottawa, Natural Resources Canada
613-996-2868
banthony@nrcan.gc.ca

9. CO_2 CAPTURE – MEMBRANES

Proj 9.1 Hollow fibre membranes for CO_2 separation (ARC)

Goal To develop and implement micro-porous hollow fibre technology in CO_2 separation.

Significance of project Will develop and evaluate hollow fibre technology as a means of improving performance of solvent-based CO_2 capture concepts.

Project description This project is pursuing new ways to improve the efficiency of CO_2 separation from synthetic flue gas using micro-porous hollow fibre technology. Using micro porous hollow fibres as the absorber in a packed tower has the following advantages compared to conventional packings: i) high gas/liquid contact area; ii) gas and liquid flow rates may vary in a wide range without flooding; iii) hollow fiber membrane contactors may be operated in any orientation; and iv) low operating pressure. This project is also examining inorganic-salt based solvents, which offer advantages such as low cost, resistance to oxidation and degradation, as well as lower desorption energy. The objectives of this project are 1) development of a technology using micro-porous hollow fibre membrane modules as gas-liquid contactors to achieve efficient low cost CO_2 capture from flue gas 2) apply this technology for post-combustion CO_2 capture and the pre-combustion gas cleaning, 3) advance the potential of incorporating this technology with current available liquid processes in next 5-6 years. To date, the project has developed a micro-porous hollow fiber membrane module, including the selections of materials and the design, which overcomes the wet-ability changing issue and achieves much more practical operation time and CO_2 absorption efficiency. It also exhibits excellent CO_2 absorption efficiency when an inorganic salt-based solvent was employed. Recently, the ARC membrane based gas liquid contactor has also demonstrated the capability to remove high concentration SO_2 from simulated flue gas. Studies of this technology to separate CO_2 from biogas streams will be conducted over the next two years through the funding support from Alberta Innovation.

Duration 1999 – 2007.

Who is involved Alberta Research Council (Org 3.3) & University of Waterloo (Org 4.2).

Funding Level & Funders $1.1M (Alberta Research Council Inc; Natural Resources Canada; University of Waterloo; Alberta Newsprint Company; AERI (proposed).

Contact
Hangqi Yuan,
Alberta Research Council
780-450-5391
yuan@arc.ab.ca

Proj 9.2 Novel CO_2 separation processes for CO_2 mitigation (Waterloo)

Goal To develop reactive chemical membranes capable of separating CO_2 selectively from gas mixtures.

Significance of project Will explore whether membranes combined with chemical solvent technology could provide a better process for CO_2 separation.

Project description This research is aimed at developing novel techniques for capturing CO_2 from gaseous streams based on i) chemical sorption of CO_2 by mixed solvents and ii) selective separation of CO_2 in reactive membranes. Specific aspects to be studied are mass transfer enhancement by mixed solvents and facilitated transport of CO_2 in reactive membranes.

Duration 2003-2008.

Who is involved University of Waterloo (Org 4.2).

Funding Level & Funders NSERC; $46,600 per year for each of five years.

Contact
Dr. Amit Chakma
VP Academic and Provost
University of Waterloo
519-888-4766
provost@admmail.uwaterloo.ca

Proj 9.3 Gas permeation properties of commercial polyphenylene oxide and cardo-type polyimide hollow-fibre membranes (Ottawa)

Goal To investigate the effect of operational parameters on the performance of commercial polyphenylene hollow fibers and Cardo-type polyamide hollow fibres.

Significance of project Evaluating under laboratory conditions, the ability of commercial hollow fibre membranes to separate gas mixtures of interest in clean coal plants.

Project description Based on pure N_2, O_2, CH_4 and CO_2 permeation experiments, it was concluded that these hollow fibre membranes are good candidates for O_2/N_2 and CO_2 / CH_4 separations with an average O_2/N_2 permselectivity of 3.9 and 5.7 for PPO and Cardo-type polyimide hollow fibres, and average CO_2/CH_4 permselectivity of 16.4 and 36.0 for PPO and Cardo-type polyimide hollow fibres respectively. The CO_2 permeance has an increasing trend with feed pressure with values of 210 and 110 GPU at 100 psig for PPO and Cardo-type polyimide hollow fibres. Gas mixture transport was determined by three different concentrations of CO_2 in CO_2-CH_4 gas mixtures (5%, 10% and 24.6% CO_2-balance CH_4) at room temperature and three different stage-cuts for each feed concentration. The feed side and permeate side pressures were 100 psig and atmospheric respectively. It was concluded that at stage-cuts proportional to feed CO_2 concentrations (vol.%), the obtained separation factors were approximately equal.

Duration 2004-2005.

Who is involved University of Ottawa (Org 4.1).

Funding Level & Funders $30K: Sharif University, Iran; NSERC; University of Ottawa.

Contact
Dr. Takeshi Matsuura
University of Ottawa
613-562-5800, extension 6114
matsuura@eng.uOttawa.ca

Proj 9.4 Pressure swing permeation and integrated membrane/adsorption processes for enhanced separation of gases (Waterloo)

Goal To integrate membrane permeation with pressure swing adsorption for improved separation of gases.

Significance of project Evaluated the benefits of combining pressure swing adsorption with pressure swing permeation (of a membrane) as a strategy to separate CO_2 from flue gases.

Project description A dynamic membrane process, called pressure swing permeation, was developed so that it can be operated in a cyclic fashion similar to pressure swing adsorption, having the ultimate objective of synergistically integrating the two processes to enhance the overall separation efficiency. The idea was to use the pressure swing to increase the pressure of the permeate from the membrane unit by pressurization with the high pressure feed. This will facilitate the subsequent adsorption separation for further purification.

Duration 2000-2004.

Who is involved University of Waterloo (Org 4.2).

Funding Level & Funders NSERC; $24,000/yr for each of four years.

Contact
Dr. Xianshe Feng
University of Waterloo
519-888-4567, extension 6555
xfeng@cape.uwaterloo.ca

Proj 9.5 High selectivity gas separation by mixed-matrix polymer-zeolite membranes (NRC)

Goal To investigate inorganic-organic mixed matrix membranes that exhibit selective gas separation performance in excess of the performance limits for typical polymeric membranes.

Significance of project Preparing high-selectivity membranes based on polymer-zeolite composites and laboratory testing of their ability to separate a variety of gases, including CO_2 from flue gases.

Project Description This project seeks to explore avenues for the preparation of zeolite-based mixed-matrix composite membranes and to improve the performance of these membranes by eliminating defects and void spaces occurring at the polymer-zeolite interfaces. These membranes combine the highly gas selective rigid pore-channel structure of inorganic zeolites with the processability of polymer matrices. A number of gas separations of industrial interest are being investigated including O_2/N_2, acid gas removal from natural gas, H_2/CO_2, and CO_2 capture from flue gas.

Duration 2002 – 2006.

Who is involved National Research Council of Canada - Institute for Chemical Process and Environmental Technology (Org 3.4), National University of Singapore.

Funding Level & Funders $650K - National Research Council of Canada as part of an international collaborative agreement with Singapore; NRCan (Innovative Research Initiative).

Contact
Dr. Michael Guiver
National Research Council
613-993-9753
michael.guiver@nrc-cnrc.gc.ca

Proj 9.6 Direct $C0_2$ reductions from industrial emissions using membranes (NRC)

Goal To evaluate two classes of novel high permeability membranes as a process element in CO_2 capture.

Significance of project Developing novel polymeric membranes appropriate for capturing CO_2 economically from flue gas in various industries.

Project Description Ultrahigh flux membranes with good CO_2/N_2 selectivity are viewed as a key enabling technology for CO_2 capture from flue gases and other industrial streams. This project will evaluate two promising classes of membrane polymers, one type that was recently discovered at NRC-ICPET, and has initially demonstrated the ability to significantly improve flux while maintaining gas selectivity, and another type which has not been investigated before. Initial work on selected structures 'in-house' suggests that the CO_2 permeability is approximately double that reported elsewhere. The aromatic polymer structure, combined with the contorted chains, provides the very high free volume leading to high CO_2 permeability. The rigid and inflexible chain structure provides for high gas selectivities. Another class of membrane polymers being developed 'in-house', via polyimides – bismaleimide interpenetration polymer networks (PI-IPN) with tuneable properties have shown high permeability and selectivity, combined with practically no tendency to CO_2 swelling. One novel aspect of this project is using nano-structured IPN and polymers of intrinsic microporosity (PIM) materials to prepare superior membranes with a high productivity. A major, though not entire portion of the emitted CO_2 can be captured without compression of the entire stream.

Duration 2005 – 2008.

Who is involved National Research Council of Canada - Institute for Chemical Process and Environmental Technology (Org 3.4).

Funding Level & Funders $600K - NRC and industrial partners (not yet announced).

Contact
Dr. Michael Guiver
National Research Council
613-993-9753
michael.guiver@nrc-cnrc.gc.ca

Proj 9.7 Membrane screening and development for CO_2 absorption in a membrane contactor (Regina)

Goal To develop a small pilot-scale membrane absorber and test its performance in the one-tonne per day CO_2 pilot plant facility located at the ITC.

Significance of project Smaller, more efficient membrane contactors could one day replace the large and expensive packed columns that are currently used in industry.

Project Description This research program is focused on membrane stability by developing affordable membranes that resist wetting. In *Task 1* various membrane-solvent relationships will be analysed to identify system characteristics that optimize performance. *Task 2* is devoted to manufacturing flat and hollow fibre membranes that possess these desirable characteristics. *Task 3* then tests these membranes in contactors to assess the overall performance of the system, and compare the CO_2 capture results with existing packed-column technology. The long-term goal of this work is to develop a pilot plant scale membrane contactor that can be tested in an industrial setting.

Duration 2006 – 2010.

Who is involved International Test Centre for CO_2 Capture -University of Regina (Org 4.4).

Funding Level & Funders $82K: NSERC; $30K: ITC.

Contact
Dr. David deMontigny
University of Regina
306-337-2277
david.demontigny@uregina.ca

10. CO_2 CAPTURE - OTHER

Proj 10.1 New solid sorbents for carbon dioxide capture (UQAM)

Goal To identify and prepare solid CO_2 sorbents.

Significance of project Evaluation at laboratory scale of the ability of solid sorbents to improve CO_2 capture processes.

Project description This project seeks to identify an efficient solid sorbent for CO_2 characterized by high rates of CO_2 capture at 2 mmol/g of sorbent, long-term regeneration capacity and a small difference in adsoption and desorption temperatures. Sorbents will be prepared by grafting amino groups on a high surface area support such as activated carbon or silica.

These sorbents will be characterized by a variety of physical and chemical techniques and their usefulness for CO_2 adsorption will be evaluated.

Duration 2004 -2007.

Who is involved Université du Québec à Montréal (Org 4.1).

Funding Level & Funders $256K (2004-2007); NSERC.

Contact
Dr. Daniel Bélanger
Université du Québec à Montréal
514-987-3000, extension 3909
belanger.daniel@uqam.ca

Proj 10.2 CO_2 scrubbing – the dry route (Ottawa)

Goal To identify and test new solid adsorbents for CO_2 scrubbing that address shortcomings of liquid-based scrubbing systems.

Significance of project Evaluates solid CO_2 sorbents to determine their advantages over liquid solvent concepts.

Project description This project will develop technology based on recyclable solid adsorbents and direct interaction of CO_2 with amines grafted on the pore walls of very high surface area honeycomb-like nanoporous silica. This dry scrubbing approach would not be accompanied by corrosion nor does it generate any contaminated water. With the amine groups protruding from the pore walls, their reaction with gas phase CO_2 should be quantitative and faster than in conventional liquid phase systems because of diminished mass transfer resistance. The developed adsorbents will be tested with QuestAir Technologies' Pulsar process, which features adsorbent-coated laminates instead of fixed bed columns.

Duration 2001-2004.

Who is involved **:** University of Ottawa (Org 4.1).

Funding Level & Funders NSERC; $136,160 (2001-02); $106,160 (2002-03); $108,160 (2003-04).

Contact
Dr. Abdelhamid Sayari
University of Ottawa
613-562-5483
abdel.sayari@science.uOttawa.ca

Proj 10.3 Novel adsorbents for acid gas removal (Ottawa)

Goal To provide CO_2 adsorbents with greater adsorption rates and capacities than present commercial adsorbents.

Significance of project Evaluating alternative adsorbents that could overcome the current limitations of commercial adsorbent materials.

Project description During the laboratory scale, research-intensive phase of the project, several materials types and morphologies were identified and explored. This has led to three main types of adsorbents, namely, (i) amine supported on hydrophobic periodic nanoporous materials (PNMs), (ii) amine-grafted or coated PNMs, and (iii) amine-impregnated PNMs. Within each class of materials lies the ability to adsorb CO_2 and/or water to various extents when exposed to ppm level or higher CO_2 contents, either from dry or humid inlet gas. Further, extremely high single-pass capacities have been obtained; up to 1.5 times higher than the optimal uptake of 13X at 5% CO_2 feed, 1.0 atm total pressure. The rate of adsorption on these materials is systematically higher than that of optimally regenerated 13X; the best observed maximum being 2.5 times as high as 13X zeolite.

Duration 2004 -2005.

Who is involved University of Ottawa (Org 4.1).

Funding Level & Funders NSERC; $125,000 (2004-05).

Contact
Dr. Abdelhamid Sayari
University of Ottawa
613-562-5843
abdel.sayari@science.uottawa.ca

Proj 10.4 CO_2 separation technology in combustion systems (UBC)

Goal To establish a facility to assess chemical looping combustion as an approach to providing a high concentration CO_2 stream.

Significance of project Pilot testing of a specific chemical looping combustion process that offers a means of capturing CO_2 different from solvents, gasification or oxyfuel approaches.

Project description Using a chemical looping combustion (CLC) unit, this project will examine the feasibility of a unique CLC reactor configuration that combines a fluidized bed process with the reduction-oxidation mechanism of metal oxides. (CLC is a process where the air required for combustion never mixes with fuel. Instead, the oxygen is supplied by metal oxides that circulate between two separate air and fuel reactors.) This configuration produces a relatively high concentration of CO_2, which can be separated from other flue gas components and captured with relative ease, thereby reducing the cost of separation and increasing process efficiency.

Duration 2004 – current.

Who is involved University of British Columbia (Org 4.5).

Funding Level and Funders $350K: Canadian Foundation for Innovation, British Columbia Knowledge Development Foundation, NSERC.

Contact
Dr. Naoko Ellis
University of British Columbia
604-822-1243
nellis@chml.ubc.ca

Proj 10.5 Experimental and numerical studies of fluidized bed and their application to chemical looping combustion (UBC)

Goal To develop reactor models for chemical looping combustion in fluidized bed systems.

Significance of project Will provide basic information to allow chemical looping combustion systems to be designed.

Project description Based on FBC technology, this project examined the hydrodynamics of chemical looping combustion in hot and cold models and developed a reactor model through studying the effect of solid loading and circulation rate on pressure balance, voidage distribution and gas mixing. This project also examined aspects of the use of liquid biofuels (unrelated to clean coal).

Duration 2003-2006

Who is involved University of British Columbia (Org 4.5).

Funding Level & Funders $22Kper year: NSERC.

Contact
Dr. Naoko Ellis
University of British Columbia
604-822-1243
nellis@chml.ubc.ca

Proj 10.6 SO_2 and CO_2 capture using limestone-derived sorbents (UBC)

Goal To improve the ability of calcium based sorbents to capture SO_2 and CO_2 during combustion of coals.

Significance of project Increased effectiveness of limestone and dolomite in reducing SO_2 emissions and investigating the potential for associated CO_2 capture.

Project description For several years this work has been studying means of improving the ability of calcium-based sorbents – limestone and dolomite – to capture and store sulphur oxides during combustion of coal and other sulphur-containing fuels. As part of this, a dual-environment thermal gravimetric reactor was constructed. Results have demonstrated that the capacity of certain sorbents for capturing sulphur can be greatly enhanced by exposure to steam over a certain temperature range. This technology is being used in commercial circulating fluidized bed combustors, providing improved environmental compliance.
The reactor set-up provides a vehicle for studying the capacity of calcium-based sorbents to capture carbon dioxide, in addition to sulphur. This reaction can be used as part of a cycle to concentrate CO_2 to the point where it can be sequestered by other processes. Work has been undertaken on the ability to carbonate CaO at different temperatures and partial pressures, with and without SO_2 present. Causes of loss of sorbent regeneration ability have been identified. The kinetics of the carbonation reaction have been investigated. Various dopants that might improve the process have also been tested. In addition, lithium silicate has been studied as a possible alternative sorbent and exhibits less loss of activity due to cycling. The role of particle attrition in these processes is also being studied. Alternative schemes for incorporating sorbents into combustion and gasification processes have been simulated.

Duration 2000 – ongoing.

Who is involved University of British Columbia (Org 4.5); Alstom Power (Org 8.4).

Funding Level & Funders $700K: NSERC, Alstom Power, Canada Foundation for Innovation.

Contact
Dr. John Grace
University of British Columbia
604-822-3121
jgrace@chml.ubc.ca

Proj 10.7 Chemical looping combustion using CaO for CO_2 capture (CETC-O)

Goal To investigate the use of metal oxides as CO_2 sorbents in combustion processes.

Significance of project Pilot testing of a specific chemical looping combustion process that offers a means of capturing CO_2 different from solvents, gasification or oxyfuel approaches.

Project Description This project will define operating conditions for a looping cycle based on $CaO/CaCO_3$ in two linked fluidized beds. In the high temperature bed, $CaCO_3$ will be introduced into an oxy-fuel fired combustion reactor, with the gas leaving the bed enriched in CO_2 from both the combustion process and the decomposition of the $CaCO_3$. In the second reactor, a lower temperature air-fired combustion reaction will allow the lime to combine with the CO_2 formed during combustion, stripping CO_2 from the combustion gas and generating the $CaCO_3$ for recycle (looping) back to the first reactor. It is expected that this cycle will reduce by 2/3rds the oxygen demand of an oxy-fuel cycle. The work will be conducted at two scales – in a 100KW twin fluidized bed pilot unit and in a separate 1 MW twin bed unit, both located at the CANMET Energy Technology Centre-Ottawa. The work is divided into two principal areas: sorbent modification and improvement and commissioning and operation of the pilot plant looping cycle combustors.

Duration 2003-2006.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1) and University of British Columbia (Org 4.5).

Funding and Funders 200K: Natural Resources Canada (PERD) and NSERC.

Contact

Dr. Ben Anthony
CANMET Energy Technology Centre-
Ottawa
Natural Resources Canada
613-996-2868
banthony@nrcan.gc.ca

Proj 10.8 Chemical looping combustion using $Na_2CO_3/NaHCO_3$ for CO_2 capture (CETC-O)

Goal To investigate a looping cycle based on sodium carbonates as an alternative method of capturing CO_2 in combustion processes.

Significance of project Pilot testing of a specific chemical looping combustion process that offers a means of capturing CO_2 different from solvents, gasification or oxyfuel approaches.

Project Description This project will define operating conditions for a CO_2 looping cycle based on $Na_2CO_3/NaHCO_3$ in two linked fluidized beds. In the first reactor, Na_2CO_3, CO_2 and H_2O combine to form $NaHCO_3$, separating the CO_2 from flue gas generated by a combustor. In a second reactor, the $NaHCO_3$ sorbent is heated causing the release of CO_2 and H_2O. The Na_2CO_3 that is formed in the second reactor is then recycled to the first reactor. It is expected that this process will allow the capture of CO_2 from existing coal-fired power plants at a cost competitive with amine scrubbing. The work will be conducted at two scales – in a 100kW twin fluidized bed pilot unit and in a separate 1 MW twin bed unit, both located at the CANMET Energy Technology Centre-Ottawa.

Duration 2005-2007.

Who is involved CANMET Energy Technology Centre-Ottawa (Org 3.1) and the Research Triangle Institute.

Funding and Funders $550K: Natural Resources Canada and the Research Triangle Institute.

Contact

Dr. Ben Anthony
CANMET Energy Technology Centre-
Ottawa
Natural Resources Canada
613-996-2868
banthony@nrcan.gc.ca

Proj 10.9 Direct carbon fuel cells (CETC-O)

Goal To generate experimental data needed for designing direct carbon fuel cells (DCFC) by building a small experimental unit and testing the performance of direct carbon conversion in catalytically activated molten carbonate mixtures.

Significance of project Bench scale testing of a DCFC to determine its feasibility as an alternative to combustion of carbon-based fuels.

Project description This project will design, construct and test a small (approximately 10W) DCFC. The project will examine the DCFC performance using coal derived carbon (high ash carbon), petroleum coke (high S carbon), and NG-derived carbon (clean carbon). These are commercially useful carbon feeds and tests will reveal the effect of impurities such as ash and sulphur on carbon conversion. Work will also include the fundamentals of electrochemical oxidation of carbon in various molten salts. DCFC development will utilize much of the work done to date on molten carbonate fuel cells. A DCFC would produce electrical power at high conversion efficiency and a pure CO_2 waste stream suitable for storage.

Duration 2005-2008.

Who is involved CANMET Energy Technology Centre-Ottawa, Natural Resources Canada (Org 3.1), Institute for Chemical Process and Environmental Technology, National Research Council of Canada (Org 3.4) and GenCell Technologies (Connecticut).

Funding Level and Funders Total $450K; NRCan (CCTII via CETC-O's Clean Coal CO_2 Capture & Storage Strategy, PERD and A-Base); GenCell Technologies.

Contact

Dr. Michio Ikura,
CANMET Energy Technology Centre-
Ottawa
Natural Resources Canada
613-996-0505
mikura@nrcan.gc.ca

Proj 10.10 Solid oxide fuel cell (SOFC) power generation systems (Waterloo)

Goal To simulate syngas-based (e.g. coal syngas) SOFC and investigation of the possibility of capturing CO_2 at reduced cost.

Significance of project Will provide an estimate of the efficiency benefits and economic costs of using SOFC's as part of a CO_2 capture strategy.

Project description This research project will develop a robust SOFC model capable of predicting cell performance and loss in cell performance over time for a variety of operating conditions, in particular feed composition (including hydrocarbons or light alcohols). Sub-tasks of this project are: 1) determination of the kinetics of carbon deposition and its effect on the anode microstructure; 2) implementation of a carbon deposition model; 3) simulation of industrial tubular and planar cells operating with syngas; and 4) overall process simulation of SOFC base power generation with CO_2 capture.

Duration 2004-2009.

Who is involved University of Waterloo (Org 4.2).

Funding Level & Funders $108K: NSERC.

Contact
Dr. Eric Croiset
University of Waterloo
519-888-4567, extension 6472
ecroiset@cape.uwaterloo.ca

Proj 10.11 Development of zero-emissions direct ammonia fuel cells for efficient combined heat and power (CETC-O)

Goal To develop a zero-emissions solid electrolyte fuel cell that operates directly on ammonia.

Significance of project Will evaluate the economic and technical feasibility of using an ammonia fuel cell as a carbon free source of energy, with the ammonia produced from coal or other feedstocks,

Project description This project will build on earlier work to develop a solid electrolyte fuel cell that utilizes ammonia directly as a carbon-free fuel source. The novel fuel cell converts ammonia to hydrogen and nitrogen, and protons are the active charge carriers. Water and nitrogen at the cathode and anode, respectively, are the only chemical products of the fuel cell. This project will focus on accelerating the development and eventual deployment of ammonia fuel for applications in decentralized electricity production and combined heat and power. Ammonia can be produced from natural gas or coal or as a by-product of oils sands upgrading and the process yields a high purity CO_2 waste stream. This project includes marketing studies, an early field trial using a conventional fuel cell running on ammonia (in a combined heat and power or ammonia refrigeration application), fuel cell performance testing (lab scale) and materials development and compatibility assessments.

Duration 2005-2008.

Who is involved CANMET Energy Technology Centre –Ottawa (Org 3.1) with CANMET Materials Technology Centre, National Research Council Institute for Chemical Processing and Environmental Technology (Org 3.4), and Terra International.

Funding Level and Funders Total $2.1M; NRCan (CCT&I via CETC-O's Clean Coal CO_2 Capture & Storage Strategy, PERD and A-Base) - $1.8M; Terra International - $300K.

Contact

Dr. Andrew McFarlan
CANMET Energy Technology Centre-
Ottawa
Natural Resources Canada
613-995-2376
anmcfarl@nrcan.gc.ca

Proj 10.12 Advanced greenhouse gas mitigation based on hydrates (UBC)

Goal To provide basic thermodynamic and kinetic data for the conceptual design of carbon dioxide separation processes based on hydrate crystallization.

Significance of project Basic assessment of the ability of gas hydrate crystallization to offer an improved approach to separating flue gases.

Project description Gas hydrate crystallization offers an opportunity for the development of innovative technology for CO_2 separation from CO_2/N_2 or flue gases ("*post-combustion capture*"). Moreover, carbon may be removed prior to combustion through the separation of CO_2 from CO_2/H_2 mixtures in integrated gasification-combined cycle power plants ("*pre-combustion capture*"). The principle is that the CO_2 concentration in the gas hydrate crystal is greater than that in the gas. The approach, based on laboratory data, proposes a hybrid concept. For separation of CO_2 from flue gases, this consists of three hydrate crystallization stages coupled with another separation process (e.g. membrane) and yields a 99% CO_2 stream. For separating CO_2 from a H_2/CO_2 mixture, the concept would employ two crystallization stages and one membrane separation, yielding a 98% CO_2 steam with a separate H_2 stream.

Further work is needed to test these concepts at pilot scale.

Duration 2003-2006.

Who is involved University of British Columbia (Org 4.5)

Funding Level & Funders $225K: NSERC

Contact
Dr. Peter Englezos
University of British Columbia
604-822-6184
englezos@interchange.ubc.ca

Proj 10.13 Hydrate technology for gas separation and CO_2 capture (NRC)

Goal To develop a new approach to gas separation, especially for capturing CO_2 from flue gas using hydrate technology.

Significance of project Laboratory testing of separation of CO_2 from simulated flue gas by hydrate formation.

Project Description This work complements that of Proj 10.12, and involves setting up a laboratory facility to serve as a template for scaling up the process based on the concept of hydrate formation in water dispersed in a porous medium. Earlier work showed that, on a small scale, the separation of CO_2 from flue gas using hydrate formation based on this concept is quite efficient with drastically improved kinetics of hydrate formation. The major portion of the work is in the design, fabrication, setting up and testing of the equipment. Optimum operating conditions will be chosen based on previous thermodynamic work but the operating mode of the facility (semi-batch or batch) and the scale of the process (flow rate of CO_2) based on emissions from a typical power plant have yet to be determined. A model flue gas mixture (17 % CO_2 and the balance N_2) will be chosen for the work. These researchers are also pursuing the design, synthesis and characterization of completely new classes of materials for gas adsorption.

Duration 2006-2008.

Who is involved National Research Council –Ottawa (Org 3.4) and University of British Columbia (Org 4.5).

Funding Level and Funders $406K: CETC-O (NRCan - CCT&I), NRC, UBC and an industrial partner not yet named.

Contact

Dr. John Ripmeester
National Research Council
613-993-2011
john.ripmeester@nrc-cnrc.gc.ca

Proj 10.14 A novel method for capturing CO_2 from flue gas (SRC)

Goal To determine the feasibility of capturing CO_2 from flue gases using a process based on the formation of CO_2 clathrate hydrates.

Significance of project Laboratory testing of the formulation of clathrate hydrates from flue gas to establish process parameters. Clathrates can be understood as gas-saturated ice and provide a compact form of storing gas without requiring high compression. The process takes advantage of the low temperatures prevalent in Canadian winters to reduce energy consumption.

Project Description This project examines the feasibility of using clathrate hydrates as a means of separating CO_2 from a simulated gas stream (N_2/ CO_2 mixture). Following a literature review, available data and predictive thermodynamic models were used to assess the overall concept. Experiments using available equipment were conducted on the effect of process parameters such as temperature, pressure, and CO_2 concentration on the efficiency of the process. The ability of clathrates to improve water quality was also assessed.

Duration 2005-2006.

Who is involved Saskatchewan Research Council (Org 3.2).

Funding Level and Funders $75K: NRCan (Innovative Research Initiative); Saskatchewan Research Council.

Contact
Dr. Selim Sayegh
Saskatchewan Research Council
306-787-9328
sayegh@src.sk.ca

11. DEMONSTRATIONS/ COMMERCIAL IMPLEMENTATION

Proj 11.1 Canadian Clean Power Coalition (Org 1.1)

Goal To promote the development and commercialization of clean coal technologies in Canada and abroad.

Significance of project The CCPC integrates the interests of most of the key stakeholders in clean coal in Canada and is accelerating technology implementation.

Project description The Coalition proposes the development, construction and operation of one or more full-scale demonstration plants by 2012. Phase I of the program (conceptual engineering and feasibility studies) began in September 2001, and completed in early 2004 with the assessment of technologies (gasification, amine solvent stripping and oxy-fuel combustion). Phase II (technology gap analysis and business plan development) commenced in spring 2004 and was completed in early 2007. The focus of Phase II was to investigate improvements to gasification technologies for low-rank coals (lignite and sub-bituminous). Phase III incorporates two Front End Engineering Design (FEED) studies that will determine how Integrated Gasification Combined Cycle (IGCC) and Super-Critical Pulverized Coal with Oxyfuel (SCPC) both with CO_2 capture (using, respectively sub-bituminous and lignite coal) can be applied to commercial scale power generation. These studies are the final step prior to committing to construction of two full-scale commercial CCT plants (SCPC with Oxyfuel by 2011 and IGCC by 2015) both with CO_2 capture. (see next two projects) Additional FEED studies with other utilities are being discussed.

Duration Phase I: 2001 - 2004; Phase II: 2004 - 2006; Phase III: 2007 - 2010.

Who is involved Phase I: ATCO Power (Org 5.6), EPCOR (Org 5.7), TransAlta (Org 5.9), SaskPower (Org 5.5), Ontario Power Generation (Org 5.3), NSPower (Org 5.1), Luscar (Org 8.27), EPRI (Org 2.5), IEA Coal Research (Org 2.8), IEA GHG R&D Programme (Org 2.11). Phase II: Basin Electric Power Cooperative joined; OPG and IEA drop out. Phase III: ATCO Power drop out; Luscar becomes Sherritt (Org 8.27).

Funding Level & Funders Phase I: $4.8M from Coalition members, Natural Resources Canada (NRCan), Provinces of Alberta, Saskatchewan & Nova Scotia; Phase II: $2.8M from Coalition members, Province of Alberta, and NRCan; Phase III: $60M from coalition members, Provinces of Alberta and Saskatchewan, NRCan (pending).

Contact
Bob Stobbs
Canadian Clean Power Coalition
306-566-3326
bstobbs@saskpower.com

Proj 11.2 Front-End Engineering Design for Alberta IGCC Plant (EPCOR/CCPC)

Goal To undertake a site-specific front-end engineering design (FEED) study for a 400 -600 MW net coal gasification (IGCC) demonstration facility using Alberta (Genesee) sub-bituminous coal with CO_2 capture.

Significance of project The results from the FEED study will provide greater accuracy in costing IGCC (+/- 15% versus +/- 35%) for Canadian sub-bituminous coals, thus allowing a decision on which gasification technology to apply to the next commercial power generation plant in Alberta.

Project description This project proposes to do an engineering design and costing assessment of a 400-600 MW net demonstration plant based on Integrated Gasification Combined Cycle (IGCC) technology fired with Alberta sub-bituminous coal. The assessment will be based on a specific site (co-sited with pre-existing Genesee coal-fired power plants) and will compare various IGCC variants and identify issues associated with using IGCC with Alberta coals. The assessment will include the costs of CO_2 capture as well as the possibility of offsetting revenues from sales of CO_2 for use in enhanced oil recovery. The ability of various designs to capture large fractions of other pollutants (NO_x, SO_2, PM, Hg) will also be assessed.

The results of the study will be a principal input to the decision, expected in 2009, to build an IGCC plant.

Duration 2006-2009.

Who is involved EPCOR (Org 5.7) and CCPC (Org 1.1).

Funding Level & Funders $33M: CCPC, Alberta Government (AERI), EPCOR, Canadian government (requested).

Contact
David Lewin
EPCOR
780-412-3196
dlewin@epcor.ca

Proj 11.3 SaskPower clean coal project – Front-end engineering design (SaskPower/CCPC)

Goal To prepare a business case, technical plan and execution plan to build and operate a 300 MW coal-fired electricity/CO_2 cogen facility with near-zero air emissions.

Significance of project This project could become the world's first commercial application of oxycoal technology, as well as one of the world's first near-zero emissions coal plants. It is one of a number of candidates under consideration for the next major increment to SaskPower's electrical base load capacity, along with the Saskatchewan poly-generation project (Proj 11.4).

Project Description This project is for front-end engineering, design and feasibility work for a potential near-zero emissions coal-fired electricity generating station in Saskatchewan. The design basis for the plant would be 300MW(e) net capacity, capable of near-zero emissions of greenhouse gases and pollutants normally associated with coal-fired thermal power plants, with an in-service date of 2011 and firing Saskatchewan lignite. SaskPower's Oxyfuel technology would be employed. The proposed plant would be at the same site as the existing Shand lignite-fired power plant. The project will also support design work needed to permit the use of captured carbon dioxide in enhanced oil recovery operations in Saskatchewan. Project contractors include Babcock & Wilcox (boiler) and Air Liquide (Air Separation Unit and CO_2 Purification Unit) and Marubeni Canada and Hitachi (for the turbine generator set), Neill & Gunter (engineering). Other contractors to be announced.

Duration 2006 – 2007.

Who is involved SaskPower (Org 5.5), B&W (Org 8.5), AirLiquide (Org 8.3), Marubeni Canada, Hitachi (Org 8.19), Neill & Gunter (Org 8.23), others to be announced.

Funding Level and Funders $20M from SaskPower and Canadian government (requested).

Contact
Max Ball
SaskPower
306-566-3231
mball@saskpower.com

Proj 11.4 Saskatchewan poly-generation project: technical and economic studies (TransCanada Energy)

Goal To assess the commercial feasibility of constructing a Saskatchewan poly-generation facility.

Significance of project Possibly the first solid-fuel-based polygeneration project in Canada. It is one of a number of candidates under consideration for the next major increment to SaskPower's electrical base load capacity, along with the SaskPower Clean Coal Project (Proj 11.3).

Project Description This project involves the front-end engineering, design and feasibility (technical and economic) of an industrial gasification and poly-generation facility near Belle Plaine, Saskatchewan. Several feedstocks have been considered and petroleum coke has been selected. The project seeks to deploy advanced technology to virtually eliminate emissions while producing hydrogen, nitrogen, steam and carbon dioxide to produce fertilizer, electricity and other commodities. The project also involves proposals for carbon dioxide pipelines for enhanced oil recovery. The decision on which of the two Saskatchewan initiatives is built first is expected in 2007. The intent is to build both, with the key decision being sequencing and timing.

Duration 2006 – 2010.

Who is involved TransCanada Energy [Org 8.30], a component of TransCanada Corporation, is the lead proponent.

Funding Level and Funders Not yet announced. Discussions have begun with federal and provincial governments.

Contact
John Jenkins
TransCanada Energy
403-920-5086
john_jenkins@transcanada.com

Proj 11.5 Dodds Roundhill coal gasification plant for hydrogen production (Sherritt)

Goal To build a commercial demonstration of a coal gasification unit with CO_2 capture and storage using western Canadian sub-bituminous or lignite coals and producing hydrogen for bitumen upgrading.

Significance of project This could be the first commercial coal gasification facility with CO_2 capture and storage in Canada.

Project Description Currently, a Feasibility Engineering Study is being carried out for a coal gasification plant to be located in the Dodds-Roundhill area in Alberta. Phase 1 of this project will produce 270MMscf per day of hydrogen and 12500t/d of high quality CO_2 that would be used for EOR.

Duration 2006 – 2011.

Who is involved Carbon Development Partnership (Sherritt and Ontario Teachers Pension Fund), Sherritt (Org 8.27), Linde/Siemens.

Funding Level and Funders not yet available

Contact

Dr. Amar Amarnath
Sherritt Coal
780-420-5810
aamarnath@sherrittcoal.com

Proj 11.6 Long Lake Integrated Bitumen and Upgrading Project (NEXEN/ OPTI)

Goal To build an integrated bitumen recovery and upgrading facility based in part on gasification of by-product asphaltenes to produce hydrogen for upgrading and fuel for power and steam.

Significance of project This is the earliest of a number of gasification projects proposed for oil sands upgrading. While it is not strictly clean coal, it is included to show that gasification technology is about to become widely used in Canada**.** Other proposed projects include North West Upgrading, Peace River Oil, Suncor and Synenco/Sinopec (see next entry).

Project description Long Lake is located some 40 miles south of Fort McMurray, Alberta. Phase 1 of the Long Lake Project will produce Approximately 60,000 bbl/d of high quality synthetic crude oil. The gasifier is the aspect of this project that relates to clean coal. This technology uses asphaltene residue to produce a substantial amount of the fuel gas required to supply the commercial SAGD operation, a cogeneration facility and the upgrader, as well as hydrogen to feed the hydrocracker. The Long Lake Project uses a Shell-licensed gasification system with four gasification trains, each with dedicated syngas coolers. Cooled syngas from all four gasification units is combined and treated in a single Selexol™ gas purification system. After treatment, most of the syngas is directed to a Linde PSA unit for recovery of hydrogen. Because hydrogen requirements are lower than the quantity of native hydrogen in the syngas, no CO-shift is required; consequently, the tail gas has low CO_2 concentrations. The Long Lake Project uses two GE 7EA gas turbines in a cogeneration system, producing roughly 120 MW of electricity, principally for on-site use. The gas turbines will operate on high pressure syngas, compressed PSA tail gas, or mixtures of both, natural gas, and mixtures of syngas and natural gas. NO_x suppression is provided by steam injection. Phase 2 of the Long Lake Project, which would add Approximately 70,000 bbl/d of SAGD capacity, is in the planning stages. CO_2 capture and storage is not part of the design.

Duration Startup of Phase 1 upgrader, including the gasifier, scheduled for third quarter 2007 with production of first synthetic volumes in the fourth quarter of 2007.

Who is involved Nexen (Org 8.24 - SAGD operation); OPTI (Org 8.25 - operation of upgrader/gasifier).

Funding Level & Funders $3.4 B: OPTI and Nexen.

Contact
Alison Trollope
OPTI Canada
403-218-4705
atrollope@opticanada.com

Proj 11.7 Four other proposed gasification plants for oil sands production

Goal To build and operate commercial plants to produce hydrogen, fuel gas, steam and power from bitumen and related by-products of oil sands processing for use in the production of synthetic crude.

Significance of project These plants will provide both construction and operating experience for gasification facilities in Canada. All use bitumen or processing by-products to produce a combination of H_2, fuel gas, steam and power. Two will assess the feasibility of CO_2 capture and storage.

Project description Four projects have been proposed but there is as yet insufficient public information to provide complete descriptions:

- North West Upgrading – has begun detailed engineering design for a plant north-east of Edmonton which will gasify the residue from a conventional distillation/hydrocracking upgrading process to produce hydrogen. The plant will be developed in three phases for a total feed capacity of 150,000 bbl/d bitumen. Phase 1 start-up is scheduled for 2010.
- Peace River Oil – Bluesky Project – proposes a 50,000 bbl/d upgrader in the Peace River district, in operation in 2011 at a cost of $2.5B, gasifying residues from upgrading to produce energy and hydrogen. The proposal includes plans for CO_2 capture for local EOR or other long term sequestration. Additional capacity will be added at a later date.
- Suncor (Org 8.29) – Voyageur Upgrader and potential gasifier – part of a plan to increase capacity at Suncor site to 500,000-550,000 bbl/d. Construction to begin in 2007 for startup in 2012.
- Synenco/Sinopec – Northern Lights Project – a 100,000 bpd (SCO) upgrader northeast of Edmonton which will gasify asphaltenes to produce H2. Construction to begin in 2008 with Phase 1 in operation in 2010 and Phase 2 in 2012. The project will assess CO_2 capture and sequestration opportunities.

Duration 2006-2012.

Who is involved See above.

Funding Level and Funders Not available except as above.

Contact
See individual company websites.

Proj 11.8 CO_2 capture, storage and enhanced oil recovery project in western Canada (Cansolv)

Goal To build and operate a commercial plant capturing CO_2 at a coal-fired facility in Western Canada by 2009.

Significance of project Could be the first semi-commercial demonstration of solvent-based capture of CO_2 from a coal-fired facility in Canada.

Project description Cansolv is developing a project to construct and operate a 5,000 ton/day carbon dioxide capture plant to extract CO_2 from the flue gases of a coal-fired plant in Western Canada. The project is proposed for development in three phases:

- conduct a pilot plant demonstration at a coal-fired facility, using Cansolv's mobile multipollutant pilot plant, while concurrently completing a project pre-feasibility study;
- install a commercial demonstration plant producing approximately 500 ton CO_2/day (by 2007), trucking the CO_2 to an oil field; and
- build, own and operate a full-scale plant with capacity of some 5000 ton CO_2/day (by 2009) and pipelining the CO_2 to oil fields in the region.

Duration 2006-2009.

Who is involved Cansolv (Org 8.7) and other partners (under consideration).

Funding Level and Funders Not yet available

Contact
Dr. Leo Hakka
Cansolv Technologies Inc.
514-382-4411, extension 26
hakkal@cansolv.com

Proj 11.9 Enzyme-based technology for the capture and sequestration of CO_2 (CO_2 Solution)

Goal To demonstrate a novel process for capturing CO_2 in flue gas streams using an enzyme reactor with subsequent treatment such as sequestration in the form of inert, bicarbonate compounds or desorption of the CO_2 for industrial use or geological sequestration.

Significance of project Demonstration at industrial facilities of CO_2 capture from flue gas streams using an enzyme reactor.

Project description This project seeks to demonstrate a novel technology for capturing CO_2 in flue gas from various industrial streams such as power plants, aluminum foundries, incinerators etc. The technology consists of an enzyme reactor designed to operate in an aqueous environment that captures the CO_2. The aqueous solution is then regenerated and recycled to the reactor. The presence of enzyme accelerates the absorption of CO_2 by converting it into bicarbonate ions. The ions are subsequently precipitated during the regeneration process. The technology was successfully demonstrated at the pilot scale at an aluminum refinery and at an industrial scale at a municipal waste incinerator.

Duration 2002-2006.

Who is involved CO_2 Solution (Org 8.8).

Funding Level and Funders Total cost not disclosed: private equity, Sustainable Development Technology Canada and consortium members: Laval University, L'agence de l'efficacité énergetique; Aluminum Association of Canada, CIFM (Centre intégré de fonderie et de métallurgie); CQRDA (Centre québécois de recherche et développement de l'aluminium) Elkem Metal Canada; Federation of Canadian Municipalities (Green Municipal Investment Fund); Fonderie industrielle Laforo inc.; Cascades; Place Bonaventure; Ville de Québec; Sita.

Contact
Sylvie Fradette
CO_2 Solution
418-842-3456
sylvie.fradette@co2solution.com

Proj 11.10 Genesee 3 super-critical power plant (EPCOR/ TransAlta)

Goal To construct and operate a cleaner coal-fired power plant in Alberta.

Significance of project This was the first (and to this point only) super-critical coal-fired power plant in Canada. Genesee 3 uses sub-bituminous coal.

Project description A joint venture between EPCOR and TransAlta utilities, the Genesee 3 plant is operated by EPCOR. It is located in Alberta at the site of two pre-existing coal-fired units. The coal is available from a mine on the same site. It went into commercial operation on 1 March 2005.

The Genesee 3 (G3) plant is a single 450 MW unit. Its overall efficiency is significantly higher than a conventional pulverized coal plant because its boiler operates at higher temperatures and pressures and it features a high efficiency steam turbine. This results in the GHG emissions from G3 being some 18% lower/unit of power produced than the average Alberta coal-fired plant. Moreover, the operators will purchase offsets so that the net CO_2 emissions from G3 are equivalent to those from a natural gas-fired plant. G3 also features fabric filters for reducing particulate matter (prevents 99.9 percent of particulate matter from reaching the atmosphere), flue gas desulphurization (reduces smog-related sulphur emissions by 77% over vintage coal-fired plants), and low NO_x burners (nitrogen oxide emissions reduced by 54%).

Duration Construction: 2001-2004
Operation**:** 2005 - ongoing

Who is involved EPCOR (Org 5.7), TransAlta (Org 5.9), Hitachi Canada (Org 8.19), Colt Engineering (Org 8.9).

Funding Level & Funders Approximately $700M (capital): EPCOR and TransAlta.

Contact
David Whitten
EPCOR
780-412-3414
dwhitten@epcor.ca

Proj 11.11 Keephills 3 Power Plant (TransAlta/EPCOR)

Goal To build a new 450 MW coal-fired power plant at the existing Keephills facility based on supercritical technology.

Significance of project This project builds on the success of the Genesee 3 supercritical plant which is also a joint project between EPCOR and TransAlta.

Project Description The project is to design and construct a 450MW electricity generating plant firing Alberta sub-bituminous coal. EPCOR would manage the construction and TransAlta would operate the plant.

Duration 2006-2011**.**

Who is involved TransAlta (Org 5.9) and EPCOR (Org 5.7).

Funding Level & Funders Approximately $1.5B (including mine development).

Contact
Don Wharton
TransAlta
403-267-7110
don_wharton@transalta.com

Proj 11.12 Princeton Wood Residue and Coal Power Generation Project (Compliance Energy)

Goal To develop a 56MW wood residue (and coal?) power generation facility in southern British Columbia.

Significance of project As originally proposed, this would have been the first Canadian electric power plant specifically designed to burn both biomass and coal at high biomass to coal ratios. In light of the more recent decision by the British Columbia government to require CO2 capture and storage for all coal-fired plants, it is now likely to burn only biomass.

Project Description The original design called for a circulating fluidized bed boiler, steam powered turbogenerator, water-cooled condenser, cooling towers, baghouse air emission control system and auxiliary systems. The boiler and baghouse air emission control technologies were to be selected to meet the most current air emission requirements. Limestone was to be injected into the boiler to control SO_x emissions, selective non-catalytic reduction utilized to control NO_x and Activated Carbon Injection to control mercury. Plant emissions were expected to be well below the British Columbia 2005 Coal-fired Plant Emission guidelines. The use of economically available "carbon neutral" wood waste were to be utilized to reduce greenhouse gas emissions. The plant was to be located at the site of a defunct copper mine (Similco) and using locally-produced wood residue and coal. The design would have allowed for the use of up to 50% wood residue feed. The plan called for an in-service date of 2010.

This project will be affected by the recent statement by the British Columbia government that all coal-fired plants in British Columbia must include CO_2 capture and sequestration. Project sponsors are now considering converting the project to 1005 wood fuel.

Duration Construction to begin: 2008
In service: 2010

Who is involved Compliance Energy Corporation (Org 8.10).

Funding Level & Funders Capital cost estimate approximately $200M.

Contact
Mr. John Tapics
Compliance Energy Corporation
604-689-0489
john@complianceenergy.com

Proj 11.13 Wapiti power development project (AESWapiti Energy)

Goal To develop a 184 MW coal and biomass-fired power generation facility in north-eastern British Columbia.

Significance of project Will employ state of the art, circulating fluidized bed, pollution prevention and control technologies.

Project Description The design calls for a hybrid circulating fluidized bed boiler, steam powered turbogenerator, air-cooled condenser, baghouse air emission control system and auxiliary systems. The CFB boiler and baghouse air emission control technologies will reduce emissions below current air emission requirements and regulations. The mine mouth feed plant will be sited with a new coal mine and will use locally-produced surplus wood residue. The design will allow for the use of up to 20% biomass feed. The plan calls for an in-service date of 2010. The plant site will be in north-eastern British Columbia, between Dawson Creek and Tumbler Ridge.

It is not yet clear how this project will be affected by the recent statement by the British Columbia government that all coal-fired plants in British Columbia must include CO_2 capture and sequestration.

Duration Construction to begin 2000;
In service: 2010

Who is involved The AES Corporation (US) and Hillsborough Resources Limited (Can) .

Funding Level & Funders Approximately $500M from AES Corp and Hillsborough Resources

Contact
Ed Beswick
AESWapiti
604-684-9288
edbeswick@hillsboroughresources.com

12. OUTREACH

Proj 12.1 Creation of a National Intelligence Centre on Near-zero Emissions Clean Coal Technologies (CETC-O)

Goal To establish a web based "National Intelligence Centre" to provide relevant up-to-date information on clean coal technologies to allow informed investment decisions to be made, and to accelerate the development and commercialization of clean coal technologies in Canada.

Significance of project A new means of keeping Canadian stakeholders abreast of the latest developments in clean coal technology and associated CO_2 capture processes, as recommended in the Clean Coal Technology Roadmap.

Project Description In an effort to avoid duplication and foster collaboration in advancing near-zero emission clean coal technology in Canada, the Clean Coal Technology Roadmap (see Doc 1.1) advised that a web-based "National Intelligence Centre" would be established to offer Canadian stakeholders access to screened information on clean-coal technology developments that are happening throughout the world and presented in a concise way as being relevant to Canada's clean coal strategic needs. The major tasks to be undertaken include:

- design and maintenance of the Centre's web site;
- monitoring and annual reporting on national and international developments in clean coal technology;
- identifying and providing information on national and international programs that support the development of clean coal technology;
- prepare profiles of key clean coal technology suppliers;
- report on developments that affect the key drivers and impediments to adoption of clean coal technology; and
- provide an annual update to Canada's Clean Coal Technology Roadmap.

Duration 2006-2008.

Who is involved CANMET Energy Technology Centre – Ottawa (NRCan) (Org 3.1).

Funding Level and Funders $249K: CETC-O (NRCan - CCT&I) and partners yet to be named.

Contact

Dr. Kourosh Zanganeh
CANMET Energy Technology Centre –
Ottawa (NRCan)
613-996-3916
kzangane@nrcan.gc.ca

Proj 12.2 Carbon Capture and Storage: An Arrow in the Quiver or a Silver Bullet to Combat Climate Change - A Canadian Primer (The Pembina Institute)

Goal To provide an overview of carbon capture and storage (CCS) for the public, outlining ways in which CO_2 can be captured and stored and the potential role of CCS as one tool in combating climate change.

Significance of project A layman's guide to the science, technologies and issues related to CCS and some aspects of CCT in Canada.

Project description The Primer provides a review of CO_2 capture technologies and transportation, followed by an examination of the potential for geological and ocean storage, as well as the issues of permanence and monitoring. The potential for geologic storage in Canada is described and illustrated with maps. The chapter on policy initiatives includes sections on the International Panel on Climate Change, the Carbon Capture Project, the Carbon Sequestration Leadership Forum and Canadian initiatives on CCS. The final chapter examines the role of CCS in a greenhouse gas reduction strategy.

The Primer was placed on the Pembina Institute's website in November 2005 and is available at www.pembina.org/climate-change/pubs/doc.php?id=584 . The Primer aims to provide information in a neutral manner. The Institute's position on CCS is described in a separate document, also available on their website. Also available is a more recent publication entitled *A Comparison of Combustion Technologies for Electricity Generation 2006 Update.*

Duration May 2005 - November 2005

Who is involved The draft report is written by Pembina Institute (Org 7.3) staff and has been reviewed by several members of the ENGO community as well as persons working within the oil and gas industry.

Funding Level & Funders This project was made possible through a contract with a private funder.

Contact
Mary Griffiths, Senior Policy Analyst
The Pembina Institute
780-433-6675
maryg@pembina.org

PART C: KEY STRATEGIC PLANNING DOCUMENTS

Doc 1.1 Canada's Clean Coal Technology Roadmap (2005)

What is it? *Canada's Clean Coal Technology Roadmap,* the product of a structured process, lays out a set of objectives and a strategy (championed by industry stakeholders) that will lead to the commercialization of clean coal technology (CCT) in Canada.

Role played in Canadian Clean Coal Activities The Roadmap focuses chiefly on technologies for the capture of CO_2 from coal-fired power plants, as well as plants operating on other carbon-rich fuels, a principal source of Canadian CO_2 emissions.

Description The Roadmap identifies technologies, strategies, processes, and pathways needed to allow coal to be used as a competitive, environmentally-clean energy source for the production of electricity. It focuses on identifying technologies and energy-system pathways for power-plant retrofits and mid-term new construction, but it also looks at technologies for the 2020 timeframe, where longer-term development, infrastructure planning, and implementation are required. The Roadmap features:

- a vision for the future use of coal in Canadian power generation;
- an outline of the critical challenges and expectations that confront coal's use;
- a detailed description of suitable performance standards for Canada's power industry;
- the identification of potential CCT pathways and highlights of other (global) CCT initiatives that may be of benefit to Canada;
- a review of the technology and innovation needed to develop these pathways in Canada;
- CCT objectives for Canada and a strategy for meeting those objectives; and
- a timeframe for developing the technology with recommended implementation targets.

Status The Roadmap was published in 2005.

Where to find it www.cleancoaltrm.gc.ca

Doc 1.2 Canada's CO_2 Capture and Storage Technology Roadmap (2006)

What is it? *Canada's CO_2 Capture and Storage Technology Roadmap* describes the product of a structured process that identifies technologies, strategies, processes, and integration system pathways needed if CO_2 is to be captured and stored in Canada.

Role played in Canadian Clean Coal Activities The Roadmap is seen as a common vision of requirements toward which all organizations conducting CCS-related activity can work.

Description The Roadmap exercise brings together Canada's experts from industry, academia, and government to:

- define the current state of CCS technologies;
- provide a vision of future technology needs and requirements; and
- map the various technology pathways and performance targets required to advance the technology to achieve the vision.

The intent is to have the tool developed and owned by the industry and supported by government and regulators. The Roadmap is expected to articulate a sound vision and to define clear performance targets and timelines. The Roadmap will address both a nearer-term market-transition timeframe, with consideration given to near-term growth and retrofit needs, and a 2015-and-beyond timeframe for technology pathways requiring longer-term development, infrastructure planning, and implementation.

Key elements include

- a survey of existing CCS technology roadmaps;
- a survey of industry issues and technology needs;
- preparation of a technology roadmap (TRM) strawman;
- development and maintenance of an interactive web site for communication purposes;
- workshops to bring stakeholders together to disseminate information, plan, and make decisions;
- studies by special advisory groups to identify technology pathways for key issues and needs; and
- preparation and publication of the TRM.

Status The Roadmap was published in 2006.

Where to find it www.co2network.gc.ca

Doc 1.3 CANiCAP (2005)

What is it? *CANiCAP* lays out planning options for technology and knowledge base development for the implementation of carbon capture and transportation research, development, and demonstration in Canada. It is a companion document to *CANiSTORE* [Doc1.3].

Role played in Canadian CCS CANiCAP has a double meaning. "CAN I CAPture CO_2" is directed at the NGO community and is meant to address environmental issues and consequences. The "CANada innovation (CO_2) CAPture" program focuses on identification of technology systems that are or may be capable of delivery of CO_2 in a concentrated form that renders it readily useable, transportable and storable, and a business plan to put such technology systems into place.

Description The document represents a culmination of provincial, national, and international review documents and valuable feedback from an initial strawman on CO_2 capture and transport (based on discussions with more than 25 companies from across Canada). The main part of the report outlines a pathway for CO_2 capture and transport research in Canada based on research, piloting, commercial demonstrations, and expanded commercial projects, and the construction of a CO_2 backbone pipeline connecting large CO_2 emissions hubs. The backbone is driven by the need for H_2 for upgrading oil sands, and the need for reduction in CO_2 emissions across Canada by CCS.

Financial projections and more detailed parts of the plan are contained in the appendices:

A: CO_2 Emission Hubs across Canada and the Proximity of Geological Sinks
B: CO_2 Capture Technologies and Capture Opportunities
C: Economics of CO_2 Capture from Power Plants Considering Near Term to Longer Term Breakthrough Technologies
D: A Selection of International Activities Related to Carbon Capture
E: Opportunities at Oil Sand and Heavy Oil CO_2 Emission Hubs
F: Opportunities at Electricity CO_2 Emission Hubs
G: Opportunities at Petrochemical CO_2 Emission Hubs
H: Opportunities at Multi-Industrial CO_2 Emission Hubs
I: Off-Gas from Oil Refineries and Bitumen Upgrading
J: Opportunities for a CO_2 Backbone Pipeline

Status Published in 2005.

Where to find it www.co2network.gc.ca

Doc 1.4 IPCC Special Report on Carbon Dioxide Capture and Storage (2005)

What is it? The *Special Report on Carbon Dioxide Capture and Storage* was prepared under the auspices of Working Group III (Mitigation of Climate Change) of the Intergovernmental Panel on Climate Change (IPCC) to assess the scientific, technical, environmental, economic, and social aspects of capture and storage of CO_2. The report was developed in response to an invitation of the United Nations Framework Convention on Climate Change (UNFCCC) at its seventh Conference of Parties (COP7) in 2001.

Role played in Canadian CCS A number of Canadians participated in the preparation of the IPCC Special Report as authors and reviewers. The report is a thorough review of current knowledge and potential and is especially important in moving toward acceptance of CCS by the international community and the UNFCCC as a recognized GHG mitigation option eligible for tradable credits.

Description The scope of the report includes the assessment of technological maturity, technical and economic potential to contribute to mitigation of climate change, and costs of CCS. It also includes legal and regulatory issues, public perception, environmental impacts and safety plus issues related to inventories and accounting of GHG emissions reductions. It identifies gaps in knowledge that would need to be addressed to facilitate large-scale deployment.

The structure of the report follows the components of a CCS system. An introductory chapter outlines the general framework for the assessment and provides a brief overview of CCS systems. Chapter 2 characterizes the major sources of CO_2 that are technically and economically suitable for capture so that the feasibility of CCS can be assessed on a global scale. Technological options for CO_2 capture are discussed extensively in Chapter 3, while Chapter 4 focuses on methods of CO_2 transport. In the next three chapters, each of the major storage options is addressed: geological storage (Chapter 5), ocean storage (Chapter 6), and mineral carbonation and industrial uses (Chapter 7). The overall costs and economic potential of CCS are discussed in Chapter 8, and an examination of the implications of CCS for GHG inventories and emissions accounting is given in Chapter 9.

Status Published in 2005.

Where to find it www.ipcc.ch

PART D: CURRENT PRACTICE RELATED TO EMISSION CONTROL AT CANADIAN COAL-FIRED PLANTS

1. INTRODUCTION

This section of the compendium will provide an overview of the current regulatory regime and commercial practice for clean coal in Canada, as of roughly 1 January 2007. This section is meant to provide the backdrop against which the advances that are being developed and tested can be appreciated. The section will describe the measures that are in place at each of the coal-fired (again using the broadest definition of "coal") power plants in Canada to reduce air emissions and will place these measures in the context of the regulatory regime to which they are subject. The section is organized by province and, for those provinces with more than one coal burning utility, by utility as well. In addition, the federal regulatory regime is also summarized.

To date, Canada and some Canadian provinces and territories have existing or emerging regulatory regimes in place to limit the following air emissions from coal-fired power plants: oxides of sulphur and nitrogen, particulate matter and mercury. The limits and how they are defined differ from province to province although there is a trend towards widespread adoption of the Canada Wide Standards for these pollutants (see below). Limits on CO_2 emissions from coal-fired plants are also beginning to emerge. In Alberta, one particular unit (Genesee 3) has a net CO_2 emission limit (in kg/MWh) roughly ½ of that of other plants which is achieved via the purchase of offsets plus an improvement in plant efficiency. And a very recent British Columbia Speech from the Throne contained the following "Effective immediately, British Columbia will become the first jurisdiction in North America, if not the world, to require 100 per cent carbon sequestration for any coal-fired project". Note that to this point, there are no coal-fired plants in British Columbia although a number are proposed.

The federal and provincial governments share responsibility for environmental standards related to air pollution through the Canadian Environmental Protection Act (federal) and the relevant provincial/territorial environment acts and associated regulations. The federal government also has responsibilities under international agreements, such as the 1991 Canada-U.S. Air Quality Agreement, the 1994 UN-ECE Second Sulphur Protocol, and the Kyoto Protocol on climate change, as well as federal-provincial initiatives such as the Canada-wide Acid Rain Strategy Post-2000.

2. NATIONAL

Over the past decade, a federal/provincial/territorial mechanism has been established to collectively address national environmental issues and develop appropriate standards for their resolution. The Canadian Council of Ministers of the Environment (CCME- Org 1.3) reflects the shared jurisdiction over the environment that is a characteristic of the Canadian Federation. In 1998, the CCME, jointly with their respective Energy Ministers, developed the Canada-Wide Acid Rain Strategy for Post-2000, which was focused on addressing the problem of acid rain in Eastern Canada but also looked at ensuring that

emerging acid rain issues in Western Canada were addressed. The Acid Rain Strategy set SO_2 reduction targets and timetables for Ontario, Quebec, Nova Scotia and New Brunswick which will reduce their emission caps by 50% by 2010 (2015 for Ontario). Also in 1998, the CCME (except Quebec) ratified the Canada-Wide Accord on Environmental Harmonization and its Canada-Wide Environmental Standards Sub-Agreement. Under this Sub-agreement, the CCME set out to establish a series of Canada-Wide Standards (CWS), that member governments would implement by using their existing authorities in a coordinated manner. Among the CWS that have been set, two in particular relate directly to air emissions from power generation – particulate matter/ozone and mercury. The CWS for particulate matter and ozone, established in 2000, set a 2010 target for PM2.5 (considered to be the most important fraction in terms of its impact on public health) of 30 micrograms/cubic metre, measured over a 24 hour averaging time and an ozone limit of 65 ppb, averaged over 8 hours. Neither limit was used to derive explicit emission caps from electric power generation. This CWS requires that reviews be conducted in 2005 and 2010 on all aspects of particulate matter (including a recommendation on coarse particulate matter (2.5 – 10 µg CWS)) and ozone. The 2005 review would lead to revised limits as appropriate for 2015 and the 2010 review for target years beyond 2015. The 2005 review was completed and CCME decided to retain the current CWS. The 2010 review is currently underway.

Beginning in 1998, the CCME began to develop CWS for mercury. In 2006, a new CWS for mercury from electric power generation was endorsed by CCME. This CWS established emission caps from existing plant which represented 60% capture of mercury from coal burned (higher if credit for early action was included) and emission rates from new plants based on best available control technology, economically achievable. Using a baseline of measurements taken during 2002-2004, the CWS set out provincially-specific 2010 mercury emission caps from existing power plants for Alberta, Saskatchewan, Manitoba, New Brunswick and Nova Scotia which represented more than 45% reduction from observed rates (measured in kg/yr). The Ontario limits were not specified given that the whole future of coal-fired power in the province is under review. Again, these mercury emission caps are being incorporated into provincial regulations as they are updated (see below). For new plants, limits have been set based on best available technology economically achievable and depending on rank of coal used. For bituminous coals, the limit reflects capture of at least 85% of mercury in the coal burned; for sub-bituminous and lignite, that figure is 75%. A timetable for a possible review leading to revised caps for post 2018 was also set.

3. FEDERAL

The federal role in regulating air emissions from coal-fired power is under the jurisdiction of Environment Canada (EC), which administers the Canadian Environmental Protection Act 1999 (CEPA). Under CEPA 1999, regulations are developed to control specific emissions. There are as yet no CEPA 1999 regulations covering the emissions of interest for this study, although SO_2, NO_x, mercury, particulates (<10 microns) and even CO_2 are all designated as toxic substances. However, Environment Canada did issue *New Source Emission Guidelines for Thermal Electricity Generation* under CEPA 1999 which are to apply to new fossil-fired steam electricity generation after April 2003. This document includes emission limits (defined by 720 hour rolling averages) for NO_x (0.69kg/MWh), particulates (0.095kg/MWh - unspecified diameter) and for SO_2. The SO_2 limits are expressed as a function of the sulphur content and heat content of the fuel. These guidelines are intended to serve as the basis for provincial regulations and standards, and in the descriptions of provincial status that follows it can be seen that it has had this effect in some provinces.

Environment Canada (EC) also has the lead on a number of international agreements that address air quality issues, such as the 1991 Canada-United States Air Quality Agreement, which set reduction targets for acid rain and ground-level ozone-causing emissions. Canada is meeting its obligations under this Agreement for SO_2 and NO_x emission reductions.

The following acronyms and jargon are used in the tables below:

ESP	electrostatic precipitators; these reduce ash and fine particulate emissions;
FGC	flue gas conditioning, adding SO_3 and/or ammonia to control the resistivity and agglomeration nature of ash before the ash enters the electrostatic precipitators (ESPs). Often required to adjust ash characteristics when low-sulphur coal has replaced higher sulphur coal;
FGD	flue gas desulphurization;
Low NO_x burners	a burner design that limits oxidation of nitrogen (in combustion air);
OFA	overfire air, often used in conjunction with low-NO_x burners to further control NO_x formation; and
SCR	selective catalytic reduction to reduce NO_x emissions.

4. NOVA SCOTIA

Utility

Nova Scotia Power Inc, a wholly-owned subsidiary of Emera (Org 5.1)). Emera is a publicly-traded energy company with its head office in Halifax, Nova Scotia. NSPI supplies electricity to 460,000 customers and generates over 95% of the electricity consumed in the province.

Utility Fleet (coal-fired only)

Unit Name	Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Lingan #1	153	26	PC	Coal*	Cold-sided ESP	Low NO_x burners
Lingan #2	153	25	PC	Coal*	Cold-sided ESP	Low NO_x burners
Lingan #3	153	23	PC	Coal*	Low NO_x burners, cold sided ESP	FGD (on hold)
Lingan #4	153	22	PC	Coal*	Cold-sided ESP	Low NO_x burners; FDG (on hold)
Trenton #5	152	36	PC	Coal*	Cold-sided ESP	Bag house; Low NO_x burners
Trenton #6	162	16	PC	Coal*	Cold-sided ESP	Low NO_x burners
Pt. Tupper #2	152	34	PC	Coal*	Cold-sided ESP	Low NO_x burners
Pt. Aconi	173	13	CFBC	Pet coke*	Lime injection, fabric filter	
TOTAL	1253					

***** All units burn a blend of coal and petroleum coke. The fuel noted in the table is the larger fraction.

Regulatory Regime

Emissions from NSPI power plants are regulated by the Nova Scotia Environment and Labour, under the Air Quality Regulations which fall under the Environment Act. The regulations are expressed in terms of ambient air quality based on maximum permissible ground-level concentrations as well as explicit emission allocations for NSPI for NO_x,

SO_2 and Hg. For the species mentioned the explicit emission allocations tend to be more limiting.

The emission caps for NSPI for SO_2 were reduced to 108,750 tonnesper year effective 1 March 2005; this cap will drop to 72,500 tonnes per year as of 1 Jan 2010. For NO_x, a limit of 21,365 tonnes will come into effect in 2009. For mercury, the limit of 168 kg per year was put into effect as of 1 March 2005. The CWS for mercury, endorsed by Ministers in October 2006 would require that this limit, for existing plants, be 65 kg per year by 2010, but that is not yet reflected in provincial regulations. The CWS has a separate standard for new plants specified as a percent capture in coal burned or an emission rate, both based on the type of coal burned. The Environment Act makes reference to emissions trading but no scheme has yet been approved.

Environmental Performance

Nova Scotia Power has reduced sulphur dioxide by 25% in 2005 (137,000 tonnes to 103,000 tonnes) and has committed to an additional 25% by 2010. NSPI has achieved this reduction by fuel switching (to lower sulphur fuels). A proposal to install flue gas scrubbers at two Lingan units has been placed on hold to allow other options for emission reductions to be evaluated.

NSPI has initiated a program of installing low NO_x combustion firing systems on all its coal-fired plants which will allow it to reach the 2009 emissions limits.

Mercury emissions were reduced in 2005 to meet (actually exceed) the requirements of the regulations. By 2010 NSPI plans to reduce mercury emissions by 70% overall (to 65 kilograms), well below the current regulatory requirement. Analogous with SO_2, the principal strategy is using coals that are lower in mercury.

A project is planned to install a baghouse at Trenton Unit #5 to increase fuel flexibility; if approved by the Nova Scotia Utility and Review Board, the project will be complete in 2009.

Contacts:

NSPI - James Taylor, James.Taylor@Emera.com
NS Environment & Labour - Sharon Vervaet,902) 424 2548, vervaess@gov.ns.ca

5. NEW BRUNSWICK

Utility

New Brunswick Power Generation Corporation, a subsidiary of New Brunswick Power Holding Corporation (Org 5.2)

Utility Fleet (coal-fired only)

Unit Name	Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Belldune	458	13	PC	coal	Scrubber, ESP, Low NO_x burners	
Grand Lake	57	~ 40	PC	coal	ESP	
TOTAL	**515**					

Note: The Coleson Cove and Dalhousie plants operated on Orimulsion, a bitumen emulsion supplied from Venezuela until 2004. That fuel is no longer available and both these plants now use heavy fuel oil.

Regulatory Regime

NB Power is subject to the province-wide air quality standards as described in the New Brunswick Clean Air Act (1997) and the associated Air Quality Regulations. The regulations are defined in terms of maximum permissible ground level concentrations and for emissions from a coal-fired plant address SO_2, NO_x and particulate. The province-wide limits are reduced by a further factor of two in three regions of the province corresponding to high population densities. There is no reference to mercury in the regulations and there are no explicit emission limits for any species specific to NB Power. The New Brunswick Department of Environment also has an approval process within the Clean Air Act that further regulates industries. All NB Power plants have Approvals to Operate within which specific limits (i.e. for SO_2, NO_2 and particulate expressed as mass/unit energy input) for each facility are set.

Environmental Performance

A number of New Brunswick Power's plants were designed to burn Orimulsion, a bitumen emulsion imported from Venezuela. For a number of reasons, this fuel is no longer available. In the meantime, NBPower is burning much more expensive heavy fuel oil in these plants. New Brunswick has committed to meet its *Canada-Wide Acid Rain*

Strategy for Post 2000 SO_2 limits of 122.5 ktonnes per year by 2005 and 87.5 ktonnes per year by 2010. In 2004, a major refurbishment of Coleson Cove included the following improvements:

- Flue gas desulphurization equipment to reduce SO_2 emission rates by 77%;
- Boiler modifications to reduce NO_x emission rates by 70%; and
- Wet flue gas precipitator to reduce particulate release rates by 75%.

Because of the unavailability of Orimulsion, Coleson Cove continues to be fired on heavy fuel oil.

Contact:
NB Power - Arden Trenholm,(506) 458 4385, atrenholm@nbpower.com
NB Environment- Fiona Bragdon, (506) 444 2479, fiona.bragdon@gnb.ca

6. ONTARIO

Utility

Ontario Power Generation Inc. (Org 5.3)

Utility Fleet (coal-fired only)

Unit Name	Nominal Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Lambton Units 1&2	2 X 500	~35	PC	Low S Bit (US)	Low NO_x burners/OFA FGC; AI ESP	Closure in 2010+
Lambton Units 3&4	2 X 500	~35	PC	Med S Bit (US)	SCR; FGD; ESP	Closure in 2010+
Nanticoke	8 X 500	~30	PC	US Bit and sub-bit (PRB)	Low NO_x burners (all units); SCR (2 units); OFA (1 unit); FGC; ESP (8 units, 1 upgraded)	Uncertain – may close all or add some SCR + FGD or Baghouses + some closure 2010+ plus some biomass co-fire?
Thunder Bay	2 X 160	~20		Lignite (Can); sub-bit (PRB)	Hot side ESP	Close 2010+
Atikokan	230	~20	PC	Lignite	Low NO_x burners; ESP	Close 2010+
TOTAL	**6550**					

Regulatory Regime

The Province of Ontario regulates air emissions from OPG's fossil-fired power plants under the Ontario Environmental Protection Act. Several regulations apply, including Ontario Regulation 419/05: Air Pollution - Local Air Quality, which includes ambient air quality standards, averaged over specified averaging time periods, for several

contaminants. These standards represent maximum contaminant concentrations that are not to be exceeded at any point of impingent (generally located outside of a facility's property). The regulation requires facilities to model each contaminant emitted using specified air dispersion models, and that the predicted modeling results, as well as any ambient monitoring results, do not exceed the standards. Of the many contaminants specified in the regulations, only the following four are highlighted in this analysis: SO_2, NO_x, Hg and PM. Nonetheless, the regulations also contain limits for other heavy metals. Note that the regulation only includes a standard for Suspended Particulate Matter, defined as particles below 44 µm in size, but does not include standards for finer particulate matter (PM_{10} or $PM_{2.5}$).

Contaminant	Maximum Concentration (µgm/m^3) that apply to Target sectors for 2010 (e.g., Fossil fuel Electric Power Generation sector,)		
	Before 1 Feb 2010	After 1 Feb 2010	
	1/2 hour average	1 hour average	24 hour average
SO_2	830	690	275
NO_X	500	400	200
Mercury	5	-	2
Suspended Particulate Matter (< 44 µm)	100	-	120

In addition, under Ontario Regulation 153/99 (as amended by 192/05) OPG fossil-fired power plants are subject to emission caps for oxides of sulphur and nitrogen. The SO_2 cap is 175 tonnes per year and there is a combined cap for sulphur dioxide and nitrogen oxides together of 236 tonnes per year. Finally, under Ontario Regulation 397/01 (as amended by 193/05 - Emission Trading) OPG fossil-fired plants are awarded annual emission allowances and must retire on an annual basis allowances, or a combination of allowances and credits, equivalent to their annual emissions of nitrogen oxides and sulphur dioxide. If OPG does not receive enough allowances to meet their annual emissions, they must purchase additional allowances or emission reduction credits to balance their annual emissions and retirements.

During the second quarter of 2006, the Ontario Government put its plans to close all Ontario coal-fired plants on hold; it referred to the Ontario Power Authority the matter of how best to replace coal-fired generation in Ontario in the earliest practical time frame. This means that OPG's coal-fired plants will continue to operate past their previously mandated closing date.

Environmental Performance

In 2005, OPG met all the emission limit regulations, with substantial room to spare in the case of SO_2, both on gross and net basis. According to the National Pollutant Release Inventory, in 2005 OPG released approximately 106,000 tonnes of SO_2, 26,000 tonnes of

NO_x, (but net NO_x emissions, including emissions trading credits, met their overall target of 22.6 tonnes), 14,000 tonnes of particulate matter (of which 4750 tonnes was PM_{10} and 1580 tonnes was $PM_{2.5}$) and 300 kg of mercury. An extensive mercury monitoring campaign was underway in 2004 through 2006 at Nanticoke and Lambton and testing of mercury capture was conducted at Nanticoke, Thunder Bay and Lambton. Biomass co-firing tests were also conducted at these same three plants.

Contacts:

OPG - Blair Seckington, (416) 592 5191, blair.seckington@opg.com
Ontario Environment - Katherine Wilson, (416) 212 4457, Katherine.wilson@ontario.ca

7. MANITOBA

Utility

Manitoba Hydro, a provincial Crown Corporation (Org 5.4).

Utility Fleet (coal-fired only)

Unit Name	Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Brandon Unit 5	105	37	PC	US Sub-bit	ESP	
TOTAL	**105**					

Regulatory Regime

Electric power generation in Manitoba is subject to environmental licensing under the province's *Environment Act.* Manitoba has only one small coal-fired generating station that operates intermittently for system backup and security of supply. The facility was last licensed in 1994 and its environmental operating licence is currently under review. The Licence specifies limits, terms and conditions for air emissions (SO_2, NO_x and the requirement for an ESP for particulate matter removal), ambient air quality limits to be met off-site for SO_2, NO_x and suspended particulate, and monitoring and reporting specifications. Manitoba has agreed to a mercury cap of 20 kg per year for the Brandon facility (as per the CCME Council of Ministers endorsement of the Canada-wide Standard for mercury emissions from coal-fired electric power generation plants). Manitoba Conservation's Ambient Air Quality Criteria (updated July 2005) are expressed in terms of maximum time-based pollutant concentration levels. For SO2, the Maximum Acceptable Level concentration is 900 milligrams/m^3 averaged over 1 hour, 300 milligrams/m^3 (24 hour average) and 60 mg/m^3 (annual arithmetic mean). For NO_2, the corresponding numbers are 400, 200 and 100. The limits on $PM_{2.5}$ are set at the CWS level (30 µgrams/m^3 (24 hr avg)), with the PM_{10} level set at 50 µgrams/m^3 (24 hr avg).

Environmental Performance

Manitoba Hydro, during the Brandon Licence Review, has stated that it will not exceed the Ambient Air Quality Criteria (Maximum Acceptable levels) for $PM_{2.5}$, SO_2 and NO_x (with a minor potential exception to the last). Manitoba Hydro purchases coal based on an environmental screening process that limits the levels of mercury, selenium, sulphur, and ash found in the coal. Furthermore, in 2006 it implemented a voluntary 20 kg annual cap on mercury emissions (the anticipated CWS cap for 2010).

Contact:

Manitoba Hydro: Jason Doering, 204-474 4647; jtdoering@hydro.mb.ca
Manitoba Conservation: David Bezak, 204-945 7046; dave.bezak@gov.mb.ca

8. SASKATCHEWAN

Utility

SaskPower, a provincial crown corporation (Org 5.5)

Utility Fleet (coal-fired only)

Unit Name	Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Shand	1 X 279	~15	PC	Lignite	LIFAC*, Low NO_x burners, ESP	Upgrade LIFAC*
Boundary Dam	2 X 62 3 X 139 1 X 273	~45 ~35 ~28	PC	Lignite	ESP(6 units)	
Poplar River	2 X 281	~25	PC	Lignite	ESP (2 units)	Improved particulate capture, mercury controls
TOTAL	**1655**					

*LIFAC – Lime Injection into the Furnace and Activation of Calcium Oxide

Regulatory Regime

Emissions from fuel burning facilities in Saskatchewan are regulated under the Saskatchewan Clean Air Act (effective 1989) and associated Regulations. The Regulations specify Ambient Air Quality Standards in terms of maximum permissible concentrations averaged over defined time periods. For SO_2, the maximum concentration is 450 micrograms/m^3 averaged over 1 hour, 150 micrograms/m^3 (24 hour average) and 30 microg/m^3 (annual arithmetic mean). For NO_x, the one hour average limit is 400 micrograms/m^3 and the annual arithmetic mean limit is 100 micrograms/m^3. For suspended particulate (no diameter specified) the limits are 120 Micrograms/m^3 (24 hour average) and 70 micrograms/m^3 (annual geometric mean).

No limits are identified for mercury but Saskatchewan has developed an implementation plan for the CWS limits for mercury emissions. For 2010, this would require mercury emissions from Saskatchewan coal-fired plants to be reduced to 430 kg per year

(compared to the average of 710 kg per year released between 2002 and 2004). Early actions can be used to help meet the 2010 cap. Further reductions in the cap are contemplated for 2018. SaskPower is actively developing and testing innovative mercury-control technology.

Environmental Performance

Three years of air quality monitoring data from the areas surrounding SaskPower plants show that NO_2 concentrations are always well within regulatory limits, SO_2 concentrations exceeded the limits only once through that period (for reasons not related to the SaskPower plant), and while the limits for PM2.5 were exceeded several times, this was generally not due to plant operations. The SaskPower 2005 Environmental Report provides figures for CO_2, SO_2 and NO_x releases per unit of power produced for each year from 2001 through 2005, all of which show a small (but not steady) decline over the period.

Contacts:

SaskPower - Bob Stobbs, 306-566 3326, bstobbs@saskpower.com
Saskatchewan Environment – Jeff Paterson, 306-787 9764, jeff.paterson@gov.sk.ca

9. ALBERTA

Utilities

1. TransAlta Utilities, a principal operating subsidiary of TransAlta Corporation (Org 5.9).

TransAlta Fleet (coal-fired only)

Unit Name	Nominal Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Genesee 3[1]	1 X 450	~2	Super Critical PC	Sub-bitumin ous	Particulate filter (baghouse), FGD, Low NO_x burners, high efficiency plant	Mercury controls by 2010; SCR possible in 2015
Keephills	2 X 383	~23	PC	Sub-bitumin ous	ESP	Mercury controls in 2010
Sheerness[2]	2 X 378	~18	PC	Sub-bitumin ous	ESP	Mercury controls in 2010
Sundance	2 X 280 and 3 X 353 and 1X 400	~25-35	PC	Sub-bitumin ous	ESP	Mercury controls in 2010
Wabamun 4	1 X 279	~40	PC	Sub-bitumin ous	ESP	Planned to close April 2010
TOTAL[3]	**4270**					

Notes: 1. Co-owned (50%) with and operated by EPCOR (Org 5.7).
2. Co-owned (TransAlta L.P. has 50% share) and operated by ATCO (Org 5.6).
3. Some double counting in totals due to shared ownership in some plants.

2. EPCOR Utilities Inc., wholly owned by the City of Edmonton (Org 5.7).

EPCOR Fleet (coal-fired only)

Unit Name	Nominal Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Genesee 3[1]	1 X 450	~2	Super Critical PC	Sub-bitumin ous	Particulate filters (baghouse), FGD, Low NO_x burners, high efficiency plant	SCR by 2015
Genesee 1 & 2	2 X 384	~15	PC	Sub-bitumin ous		
TOTAL[2]	**1218**					

Notes: 1. Co-owned (50%) with TransAlta Utilities (Org 5.9).
2. Some double counting in totals due to shared ownership in some plants.

3. ATCO Power, a subsidiary of ATCO (Org 5.6)

ATCO Fleet (coal-fired only)

Unit Name	Nominal Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
Battle River	2 X 150 1 X 370	~25-38	PC	Sub-bitumin ous	Cold-side ESP	Hg reduction
Sheerness[1]	2 X 380	~16-	PC	Sub-	Cold-side	Hg reduction

	20	bitumin ous	ESP	

TOTAL[2] **1430**

Notes: 1. Co-owned (50%) with TransAlta LP (Org 5.9).
2. Some double counting in totals due to shared ownership in some plants.

4. Milner Power Inc., a subsidiary of Calgary based Maxim Power Corp (Org 5.8).

Milner Power Fleet (coal-fired only)

Unit Name	Nominal Unit Capacity (MW)	Unit Age (yrs)	Tech-nology	Fuel	Installed Emissions Controls	Planned Emissions Controls
H.R. Milner	1 X 144	~35	PC	High vol Bit.	Baghouse	
TOTAL	**144**					

Regulatory Regime

Air quality in Alberta is regulated under the *Environmental Protection and Enhancement Act* (EPEA, 1992). Under that Act, Alberta Environment has established ambient air quality objectives based on maximum permissible concentration limits averaged over specified times. For SO_2, the maximum concentration is 450 micrograms/m^3 averaged over 1 hour, 150 micrograms/m^3 (24 hour average) and 30 microg/m^3 (annual arithmetic mean). For NO_x, the one hour average limit is 400 micrograms/m^3, 200 micrograms/m^3 (24 hour average) and the annual arithmetic mean limit is 60 micrograms/m^3. For suspended particulate (no diameter specified) the limits are 100 micrograms/m^3 (24 hour average) and 60 micrograms/m^3 (annual geometric mean). No limits are identified for mercury.

For all power plants (a listed activity in the *Activities Designation Regulation*) an approval under EPEA is issued and would cover all environmental aspects of the operation. Air emission limits have long been a part of the approval and are based on the coal composition, capabilities of the installed air pollution control equipment, and meeting of the ambient air quality objectives as predicted by dispersion modeling. Monitoring and reporting requirements are also specified within the approval and include continuous, intermittent, and ambient air quality monitoring.

In an effort to improve environmental performance in the utility sector, as of 1 Jan 2006, Alberta Environment has created a new standard entitled *Alberta Air Emission Standards*

for Electricity Generation, based on recommendations of the Clean Air Strategic Alliance (CASA; Org 1.6) Electricity Project Team. These standards set an emission intensity limit for SO_2, NO_x, and particulate from, *inter alia*, Alberta coal-fired plants. Existing plants can continue to operate under "historic" emission limits until they reach the end of their design life; the dates at which each of the existing plants reaches its design life are specified in the standard (usually 40 years for coal-fired power plants or at the end of their power purchase agreement, whichever is later). Beyond that date, these plants must meet the standard of the day that is to be set on a five year interval based on pollution control technology capabilities. Presently, the SO_2 emission limit is 0.8kg/MWh, the NO_x emission limit is 0.69kg/MWh, and the particulate emission limit is 0.095 kg/MWh. New coal-fired plants must meet these same limits right away. These standards are scheduled for revision in 2008 with an effective date of 2011. In association with the *Alberta Air Emission Standards for Electricity Generation,* a NO_x and SO_2 emission trading program was implemented to give existing plant operators an incentive to reduce their emissions before the end-of-design life. Plants create credits if their emissions are lower than their historic emission intensity. Plants can extend their design life by up to 10 years by using credits.

While no mercury emission limits are yet in place, it is proposed that they will be by the end of 2011, with an initial proposed limit equal to 70% capture of mercury in the coal feed.

Environmental Performance

TransAlta

In 2005, TransAlta's emissions of SO_2 were just under 1.5 kg/MWh (roughly 20% higher than the average of the two previous years), while NO_x emissions were roughly stable at just under 1.5kg/MWh. Primary suspended particulate (diameter unspecified) was Approximately 0.12 Kg/MWh and mercury was 11 g/MWh, both down slightly from the average of the two previous years.

EPCOR

Recent plant manager updates for Genesee show that SO_2 and NO_x emission intensity limits for all units have been met by a significant margin. For the older units (G1/2) the limits are expressed as 3.25 tonnes/h SO_2 and 2.1 tonnes/h NO_x. Actual emissions averaged 1.6 tonnes/h SO_2 and 1.5 tonnes/h NO_x. For Genesee 3, the corresponding limits were 0.76 tonnes/h SO_2 and 0.53 tonnes/h NO_x and the emissions were 0.45 tonnes/h SO_2 and 0.24 tonnes/h NO_x. Genesee 3 also has a net GHG emissions limit of 0.418 tonnes/MWh (CO_2 equivalent).

ATCO

The emission intensity limits for both the Battle River and Sheerness plants are as follows:

	NO_x Emission Limit (t/h)	SO_2 Emission Limit (t/h)	2005 NO_x Emissions (t)	2005 SO_2 Emissions (t)
Battle River – Stack B	1.00	2.00	4133	9650
Battle River – Stack C	1.25	2.30	5793	13311
Sheerness	2.62	9.3	10287	39187

These emission limits have been consistently met by large margins. ATCO Power is participating in the development of mercury capture technology for implementation on existing coal-fired units by 2011. The company is also carrying out emission reduction studies to evaluate existing and new control technologies as well as studying fuel optimization and efficiency improvements. ATCO Power is also pursuing clean coal technologies for new projects in Canada.

Milner Power

Milner will continue to meet license limits for Nitrogen Oxides (NO_x), and Sulphur Dioxide (SO_2) through the end of its planned operating life (2020). Maxim Power Corp estimates that Milner will be neutral with respect to future Greenhouse Gas (GHG) emission limits, and that the facility is already in compliance with new Alberta mercury regulations to be implemented in 2010.

Contacts:
Alberta Environment: Randy Dobko, 780-427 6869, Randy.Dobko@gov.ab.ca
TransAlta: Don Wharton, 780-731 6000, don_wharton@transalta.com
EPCOR: Dave Whitten, 780-412 3448, dwhitten@epcor.ca
ATCO: Dwight Redden, 780-209 6902, dwight.redden@atcopower.com
Milner Power: Pat Lucas, 403- 263 3021, plucas@maximpowercorp.com