Partnership's Introductory Statement

The Canadian Natural Gas Partnership for Energy and Environment (the Partnership) represents 12 industry members with a focus on the downstream end of natural gas delivery. Included are natural gas transmission companies and distributors.

With governments and the general public clearly focusing on air issues and associated environmental concerns, particularly those of climate change and smog, the Partnership recognized the need for a detailed inventory and audit of Greenhouse Gas (GHG) emissions from Canada's natural gas delivery system.

The *"GRI Canadian Natural Gas Companies 2000 GHG Inventory Report and Validation by Audit"* was produced in response to this need. The study was undertaken by ICF Consulting under the direction of the Partnership, the environmental technology research arm of the natural gas industry. It builds on the "1995 Air Emissions Inventory of the Canadian Natural Gas Industry" and improved methodology results from knowledge gained through research undertaken by the gas industry in Canada, the United States and internationally. Lastly, the study also includes a comparison of 2000 emissions against the 1995 data to clearly demonstrate where the improvements have been made and where further actions are required.

The inventory and audit should be regarded as work in progress, showing the industry's evolving understanding of emission sources and quantities. It is expected that further refinement will be made to the GHG emissions inventory as the Partnership continues to work to improve the accuracy of emission estimates undertaken by the Partnership. The study confirms the relatively low emissions of carbon dioxide, methane and nitrous oxide from natural gas transmission, storage and distribution.

The Partnership considers that an independent third party audit is one approach to gaining recognition of GHG emission inventories as credible, and a beginning point in good environmental management practice. Recognizing this, the Partnership commissioned ICF Consulting Canada, Inc. to develop a GHG audit process intended to generate an audit attest statement for the year 2000 GHG inventory.

This report and the information contained herein should be viewed as the best estimate the industry has its GHG emissions from natural gas transmission and distribution. We also believe that the most appropriate technical information on the gas delivery system in Canada has been used in this compilation and therefore this report provides the credible information required for future GHG inventory work.

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Canadian Natural Gas Companies 2000 Greenhouse Gas Inventory Report and Validation by Audit

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Foreword

GRI Canada has commissioned ICF Consulting Canada, Inc. to:

- Issue an inventory statement of greenhouse gas (GHG) emissions for the year 2000.
- Develop and carry out an audit process that will generate a GHG audit attest statement for the year 2000.

The audit project is the first of its kind for a major industrial sector in Canada. This report provides the results of the 2000 GHG inventory compilation and some background to the audit process, presents the audit opinion and discusses the implications.

For more information on the work discussed in this report please contact Jasmine Urisk.

Contents

Executive Summary

In early 2002, twelve Canadian natural gas transmission and distribution companies submitted estimates of their year 2000 and 1995 greenhouse gas (GHG) emissions to ICF Consulting for review. The review included an on-site audit, by ICF Consulting, of each company's 2000 GHG information and management systems. Audit findings identified during the review were addressed by the participating companies and their GHG information revised and re-reported to ICF Consulting for inclusion in an inventory of the 12 companies' GHG emissions. This report is not intended to update the 1995 Inventory of the Canadian Natural Gas Industry[1]. This inventory is intended to represent the GHG emissions of those 12 companies that participated in the study and not the entire industry. However all major Canadian transmission and distribution companies that were operating in 2000 participated.

Participating companies employed a variety of approaches to estimate GHG emissions including both company-specific and/or sectoral emission factors coupled with entity level activity data. The results of the 2000 emissions inventory include all carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions. A summary of results in tonnes of CO_2 equivalent are shown in Table ES-1. Table ES-1 also provides a 1995 inventory which includes GHG information from the same 12 participating companies. Unless relevant activity data, available in 2000, were unavailable for 1995 the same approaches were employed for estimating GHG emissions at the company level. This ensured the highest possible degree of comparability between the 2000 and 1995 information.

Table ES-1. 2000 and 1995 Canadian Natural Gas Transmission and Distribution Company Emissions

Segment	1995 CO_2eq (t/yr)	2000 CO_2eq (t/yr)	Change 2000 – 1995 (t/yr)	% change
Transmission	16,363,529	14,701,158	(1,662,371)	-10%
Storage	143,115	128,562	(14,553)	-10%
Distribution	1,165,714	1,146,981	(18,733)	-1.6%
Other Direct	143,241	133,458	(9,783)	-6.8%
Total Direct	**17,815,599**	**16,110,160**	**(1,705,439)**	**-9.6%**
Indirect	499,066	915,899	416,833	+83%
TOTAL	**18,314,666**	**17,026,059**	**(1,288,607)**	**-7.0%**

Conclusions

Total (direct and indirect) GHG emissions from the 12 companies participating in this study reduced from 1995 to 2000 by almost 1.3 million tonnes of CO_2 equivalent. Those emissions associated with the transmission segment alone reduced emissions by 1.6 million tonnes while increasing the total length of the pipeline by 6% and increasing the volume of gas transmitted (for domestic use and export) by 18%[2].

At the same time those emissions associated with the distribution segment reduced emissions slightly while increasing the total length of the pipeline by 9%, increasing the volume of gas distributed by 8%, and increasing the total number of customers by 2.4%[3].

[1] Prepared by Radian International LLC for the CGA Standing Committee on the Environment. 1997, **1995 Air Emissions Inventory of the Canadian Natural Gas Industry**.

[2] Canadian Gas Association (2001) - Canadian Gas Facts 2000, Prepared by Canadian Gas Association (CGA) – Research Department

[3] Canadian Gas Association (2001) - Canadian Gas Facts 2000, Prepared by Canadian Gas Association (CGA) – Research Department

1.0 Introduction

In 1994[4] the Canadian gas industry estimated and reported its greenhouse gas (CO_2, CH_4, and N_2O) emissions for 1990. In 1997,[5] the 1990 inventory was updated and an inventory compiled for 1995.

Over the past several years Canadian natural gas transmission and distribution companies have undertaken research through GRI Canada (formerly Gas Technology Canada) to estimate the GHG emissions from their facilities. This work has encompassed:

- Studying GHG emissions of sectoral importance (developing methodologies and technologies for source measurement),
- Developing methodologies for the estimation of fugitive, vented and combustion related GHG emissions,
- Developing a consistent national approach to developing inventories and GHG inventory calculation tools,
- Preparation of GHG inventories and reporting of annual emissions,
- Continuously improving reported GHG inventory completeness, accuracy and consistency.

The GRI Canada sponsors hold that an independent third party audit is one approach to gain recognition of GHG emission inventories as credible and a beginning point in the continuous improvement process of good environmental management practice. Recognizing this, the sponsors – comprised of 12 natural gas transmission and distribution companies – commissioned ICF Consulting Canada, Inc. to:

- Issue an inventory statement of greenhouse gas (GHG) emissions for the year 2000.
- Develop a GHG audit process that will generate a GHG audit attest statement for the year 2000 inventory.

[4] CGA, 1994, 1990 Air Emissions Inventory of the Canadian Natural Gas Industry. Prepared by Gas Technology Canada for the CGA standing committee on the Environment.

[5] Radian International LLC, 1997, 1995 Air Emissions Inventory of the Canadian Natural Gas Industry (see footnote 1)

Acknowledgements

GRI Canada and ICF Consulting Canada, Inc. thank the following companies for participating in this process:

AltaGas Utilities Inc.
ATCO Gas
ATCO Pipelines
BC Gas Utility Ltd.
Manitoba Hydro (Centra Gas Manitoba Inc.)
Enbridge Gas Distribution
Foothills Pipe Lines Ltd.
Gaz Metropolitain
SaskEnergy Inc.
TransCanada PipeLines Limited
Duke Energy Gas Transmission Canada
Union Gas Limited

We also thank URS-Radian for providing technical support to this project.

2.0 GHG Audit Opinion

GRI Canada, commissioned ICF Consulting to provide an independent audit of twelve Canadian natural gas transmission and distribution companies greenhouse gas (GHG) emissions. The objective of this audit was to:

- Provide an independent opinion of the 2000 GHG emissions data;
- Identify any weaknesses and deficiencies in the internal GHG emissions data control, management, and reporting systems that could affect the reliability of the data; and
- Provide input to the process of issuing an independent opinion of the Canadian natural gas industry's 2000 GHG emissions data.

The audit conducted included 12 companies consisting of the following natural gas industry segments:

- transmission, and/or
- distribution, and
- storage.

As of December 2000, 358,017 km of pipeline were available in Canada to carry natural gas; 81,340 km for transmission; and 276,667 km for distribution. In the year 1999, these pipelines supplied natural gas equivalent to 2683 PJ of energy or 26% of Canada's total primary energy demand[6]. The audit covered all GHG sources but focused on the entity-level source categories identified through a risk assessment. Common categories covered in the audit included:

- Fugitive emissions from pipelines, compressor stations and M&R stations;
- Vented emissions from pipeline blowdowns; and
- Combustion emissions associated with compressor unit fuel.

Through the audit process it was clear that the industry has devoted significant resources and effort to quantifying their GHG emissions and developing, implementing and improving effective GHG emissions management and reporting systems. However, our audit identified specific issues that affected the quality of the 2000 GHG emissions data. The main issues of sectoral significance that were identified during the audits performed June through August, 2002 are detailed in section 8.0 "Risks to the Canadian Natural Gas Companies GHG Information".

An omission or misstatement of GHG information can result from either an error or inherent uncertainty. Full quantitative analysis of the degree of potential misstatement (due to identified errors and/or inherent uncertainty) is not part of an audit. However, a subjective assessment of the combined company 1995 GHG information is provided in Appendix D and relied upon for the purposes of issuing this audit opinion on the 2000 GHG information. The analysis conservatively assumes that all companies participating in this study utilized sector-level vs. entity level emission factors. Results indicate the errors in reported emissions were in the region of minus 12% to plus 28% (all +/- provided are within 95% confidence limits)[7] for the transmission segment, minus 15% to plus 18% for storage, and minus 8% to plus 299% for distribution. The combined error for all segments was estimated to be in the region of minus 10% to plus 41%. The error associated with fugitive emissions was estimated to be minus 5.8% to plus 80%, vented emissions minus 12.4% to plus 135%, and combustion emissions minus 21.8% to plus 22%.

[6] Canadian Gas Association (2001) - Canadian Gas Facts 2000, Prepared by Canadian Gas Association (CGA) – Research Department

[7] The methodology selected for uncertainty assessment considered the source of the activity data and emission factors applied. It was consistent with the first method (Tier I) in the *IPCC Good Guidance and Uncertainty Management in National GHG Inventories*. Individual source uncertainties were drawn from GRI-GHG Calc Version 1.20 and the *IPCC Good Guidance and Uncertainty Management in National GHG Inventories*.

In conclusion, our audit has shown that the companies have adhered to best practice and provided the most reliable estimate of GHG emissions for the year 2000 (summarized in Table 2.1). Where findings were identified, companies made relevant corrections where practicable following our audit.

Combustion related emissions made up 71.0% of the Canadian gas companies' total GHG inventory of direct emissions for 2000. It is our opinion that combustion related GHG emissions, as reported in the 2000 inventory, are free of material misstatement.

Fugitive (21.9%) and vented (7.2%) emissions combine to make up 29.0% of the total GHG inventory of direct emissions for 2000. Based on audit results, GHG estimation methodologies applied, and third party uncertainty assessment[8] it is our opinion that the methodology used to estimate the fugitive and vented GHG emissions, as reported in the 2000 inventory, are more rigourous than normally expected of a National Inventory[9].

Table 2.1. 2000 Canadian Natural Gas Transmission and Distribution Industry Emissions*

	CO_2eq (t/yr)			
Segment	**Fugitive**	**Vented**	**Combustion**	**Total**
Transmission	2,564,411	954,857	11,181,891	14,701,158
Storage	71,258	15,651	41,653	128,562
Distribution	890,679	182,876	73,426	1,146,981
Other Direct	-	-	133,458	133,458
Total Direct	**3,526,348**	**1,153,384**	**11,430,428**	**16,110,160**
Indirect	-	-	915,899	915,899
TOTAL	**3,526,348**	**1,153,384**	**12,346,327**	**17,026,059**

*Only those emissions from the 12 companies participating in the full inventory and audit process are included.

The conclusions reached regarding the uncertainty estimates above are based on the conclusion of one consultant based on 1995 industry data and the conservative assumption that all Canadian natural gas companies relied upon sector-level (GHG-Calc)[10] emission factors. Uncertainty may be able to be reduced substantially through the further study of fugitive emissions, the sharing of information between participating companies, and the development of company-specific emission estimation methodologies. At the time of the audit, there was little value added from the Canadian natural gas companies' business perspective, to quantify or reduce uncertainty. However, in the future there may be reason (e.g. emission trading) to add value by spending more resources on developing the most accurate estimation of GHG emissions possible.

[8] **GRI Canada (2001) -** Prepared by Clearstone Engineering Ltd., Assessment of the Accuracy of Carbon Dioxide Estimates from Natural Gas-Fired Equipment at Natural Gas Transmission, Storage and Distribution Facilities

[9] **Environment Canada (2001)**, Canada's Greenhouse Gas Inventory 1990-1999

[10] GRI Canada (2001), GRI-GHG Calc Version 1.20 [Software]

3.0 The GHG Inventory Project

Objective

Since the 1995 air emissions inventory was compiled, consolidation within the industry has taken place, and participating companies have undertaken entity-level analysis and developed ever more complete, accurate and dependable inventories. To ensure these improvements are accounted for, a revised inventory was compiled for 2000.

In addition, to add credibility to the 2000 inventory an audit of the entity level data compiled to produce this inventory was carried out for the first time (see sections 4.0 The GHG Audit Project and 5.0 The Audit Process).

Scope

An inventory, combining the GHG emissions of the major Canadian natural gas transmission and distribution companies, was compiled based on twelve companies' reported and audited entity-level GHG inventories for 2000. In 2000, these twelve companies (see Acknowledgements) comprised over 95% of the Canadian natural gas transmission system and approximately 85% of the natural gas distribution system[11].

As these participating companies comprised such a significant portion of the national sector and as the data available for the non-participating companies could not be independently verified, it was decided that only those companies participating in the audit process would be included in the Canadian natural gas transmission and distribution companies inventory.

The scope of the inventory included all 6 gases identified under the Kyoto Protocol however only three were of significance to the gas transmission and distribution industry, CO_2, CH_4, and N_2O.

[11] Canadian Gas Association (2001) - Canadian Gas Facts 2000, Prepared by Canadian Gas Association (CGA) – Research Department

Characterization

For the purposes of this exercise, the Canadian natural gas transmission and distribution systems were defined as all infrastructure, within Canada, used to transport, store and distribute natural gas to the end user. The following segment descriptions were adopted when developing the GHG inventories:

- **The transmission segment** moves natural gas from the gas plant or directly from the field production to local distribution companies. The transmission segment consists of large diameter pipelines, compressor stations, and metering facilities.
- **The storage facilities** serve to store natural gas produced during off-peak times allowing gas to be delivered during peak demand in the winter. Facilities can be above ground (liquefied natural gas) or below ground (spent gas production fields, aquifers, or salt caverns). Facilities consist of piping, flow control, meters, filters and may include a compressor station and dehydrators.
- **The distribution segment** receives high pressure gas from transmission pipelines, reduces the pressure and delivers the gas to residential, commercial and industrial customers. This segment includes pipelines, measurement and regulation (M&R) stations, and customer meters but does not include any emissions downstream of the customer meters.

Where these industry segment definitions did not accurately describe operations of a participating company, that company included those emissions within another segment along with an explanation of why.

Emission Types

Emissions from the end use of the gas were not considered except where the gas was consumed as part of the transmission, storage, and distribution segments. There are 5 main categories of emissions from natural gas transmission, storage and distribution operations;

- **Fugitive emissions** from piping and associated equipment components. These emissions include unintentional leaks from underground pipeline, seals, packings or gaskets. Primarily CH_4 emissions.

- **Vented emissions** are intentional releases to the environment (by design or operational practice). Sources include equipment and pipeline blowdowns and purging, M&R station control loops, and gas operated devices that use natural gas as the supply medium. Emission associated with accidental third party dig-ins are also included in this section, despite the fact that they neither occur by design or operational practice, as the associated emissions are quantified in a similar fashion to blowdowns or purges. Primarily CH_4 emissions.
- **Process combustion emissions** include CO_2, CH_4, and N_2O emitted from the combustion of fossil fuels to fire station engines, turbines and pipeline heaters. Primarily CO_2 emissions.
- **Other (miscellaneous) direct emissions** include emissions from mobile sources and domestic fuel consumption for building heating. Primarily CO_2 emissions.
- **Indirect Emissions** include CO_2, CH_4, and N_2O emissions associated with the utility that generated the electricity consumed by the reporting entity. Primarily CO_2 emissions.

Reporting

The twelve participating companies reported information in a consistent format (see Appendix B for sample template) using an agreed upon template and source categories (as defined in GHG inventory handbooks). The entity level GHG information for 2000 was reported in early 2002. This data formed the basis for the GHG audits, conducted in the summer of 2002. Any findings identified during the audit process were addressed and revised (final) results for 2000 and 1995 were re-reported by November 2002. Please refer to Section 4.0 and 5.0 for more detail on the audit project and process.

The 2000 Inventory vs. Previous Inventories (1995 Air Emissions Inventory of the Canadian Natural Gas Industry[12])

Every five years, since 1990, inventories of GHG emissions from the Canadian natural gas industry have been compiled. Previous years inventories included not only transmission, storage, and distribution segments but production and processing as well. However, due to the fact that comparable, detailed sectoral-level, information was not available for the production and processing segments at the time this inventory was compiled, and in order not to take away from the detailed, audited/verified nature of the transmission, storage, and distribution segments' GHG information the scope of the 2000 inventory has been limited to these segments. In addition, this report is not intended to update the 1995 Inventory of the Canadian Natural Gas Industry as no attempt was made to account for those companies that did not participate in this 2000 report.

The scope of previous inventories was limited to emissions that result directly from industry operations, indirect emissions resulting from the gas industry's electrical energy use (where electricity was generated at a power plant) and emissions from mobile sources were not consistently included. The 2000 inventory has included these emissions. Table 3.1 compares and contrasts the main sources of GHG emissions covered in the scopes of the 1995 and 2000 inventories.

Table 3.1 Comparison of GHG Emissions Included the 1995 and 2000 inventories.

	Inventory	
Source	**1995 (Radian, 1997)**	**2000**
Production	X	
Processing	X	
Transmission	X	X
Storage	X	X
Distribution	X	X
Non-participating companies[13]	X	
Mobile		X
Indirect		X

[12] CGA, 1994, 1990 Air Emissions Inventory of the Canadian Natural Gas Industry. Prepared by Gas Technology Canada for the CGA Standing Committee on the Environment.

[13] Those companies involved in Canadian natural gas transmission, storage, or distribution segments but not providing GHG information or participating in the audit/verification process.

4.0 The 2000 GHG Inventory

This section provides the results of the 2000 emissions inventory for the 12 Canadian natural gas transmission and distribution companies. Detail concerning the entity-level GHG emissions estimation methodologies (emission factors and activity data) is provided in Section 6.0 Status of Company-level GHG Information and Management Systems.

Tables 4.1 and 4.2 and Figures 4.1 though 4.3 provide the results of the 2000 and 1995 emissions inventory and include CO_2, CH_4, and N_2O emissions and highlight trends between 1995 and 2000 inventories. For additional detail figures on the 2000 GHG data please refer to Appendix A.

Table 4-1. 2000 Canadian Natural Gas Transmission and Distribution Industry Emissions*

Segment	CO_2 (t/yr)	CH_4 (t/yr)	N_2O (t/yr)	CO_2eq (t/yr)
Transmission	10,931,584	170,281	625	14,701,158
Storage	40,295	4,169	2	128,562
Distribution	75,247	51,009	2	1,146,981
Other Direct	120,015	428	14	133,458
Total Direct	**11,167,141**	**225,887**	**643**	**16,110,160**
Indirect	914,583	7	4	915,899
TOTAL	**12,081,724**	**225,894**	**647**	**17,026,059**

Table 4-2. Revised 1995 Canadian Natural Gas Transmission and Distribution Industry Emissions*

Segment	CO_2 (t/yr)	CH_4 (t/yr)	N_2O (t/yr)	CO_2eq (t/yr)
Transmission	11,633,653	215,209	679	16,363,529
Storage	46,430	4,553	4	143,115
Distribution	82,245	51,564	2	1,165,714
Other Direct	129,552	434	15	143,241
Total Direct	**11,891,879**	**271,760**	**700**	**17,815,599**
Indirect	497,306	9	5	499,066
TOTAL	**12,389,185**	**271,769**	**705**	**18,314,666**

*Only those emissions from the 12 companies participating in the full inventory and audit process are included.

Figure 4.1: GHG Trend Between 1995 and 2000 GHG (CO_2 equivalent) Emissions by Industry Segment (tonnes)

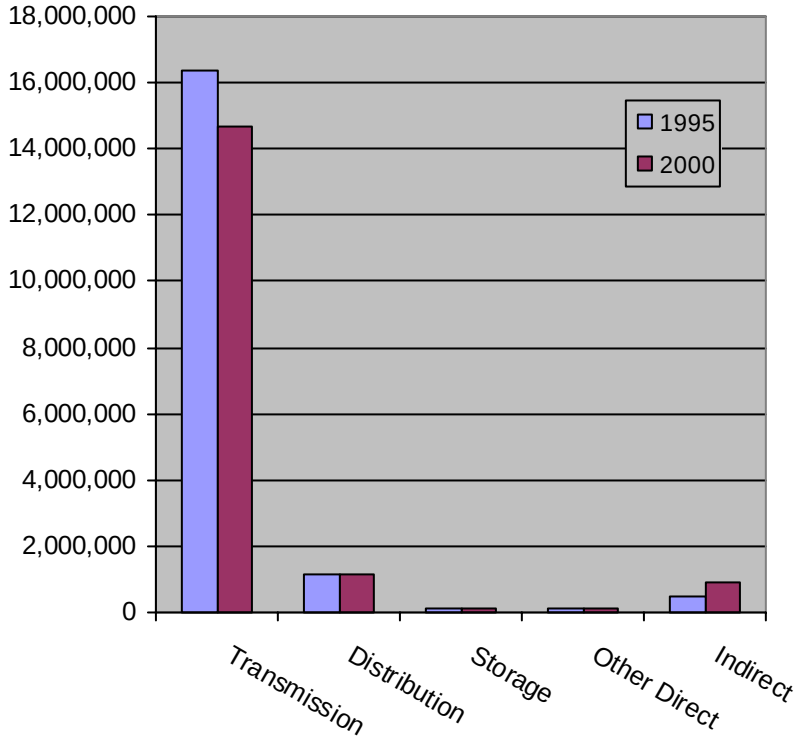


Figure 4.1 details the trends in GHG emissions between 1995 and 2000 for the transmission, distribution, and storage segments as well as other (miscellaneous) direct, and indirect sources. Of merit is the fact that transmission related GHG emissions fell by 1,662,371 tonnes (or 10%) while indirect emissions increased by 416,833 tonnes (or 84%) between 1995 and 2000.

Figure 4.2: GHG Trend Between 1995 and 2000 Direct GHG (CO_2 equivalent) Emissions by Specific GHG Emission (tonnes)

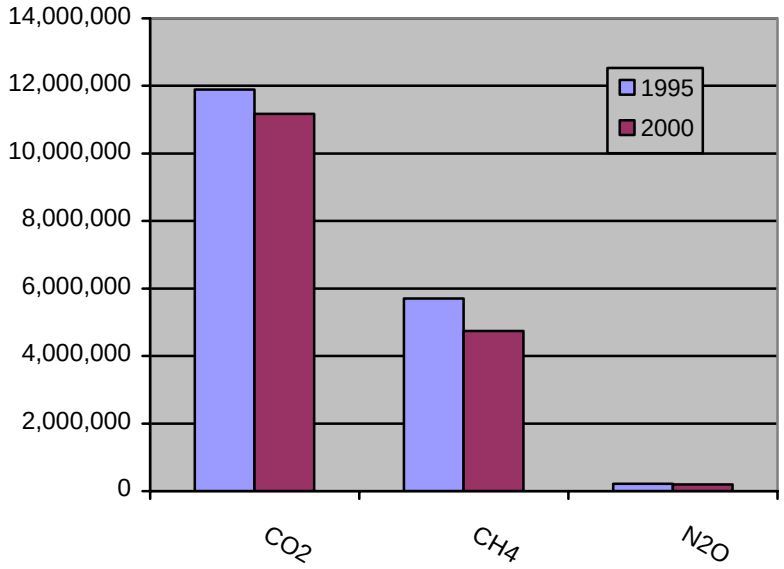
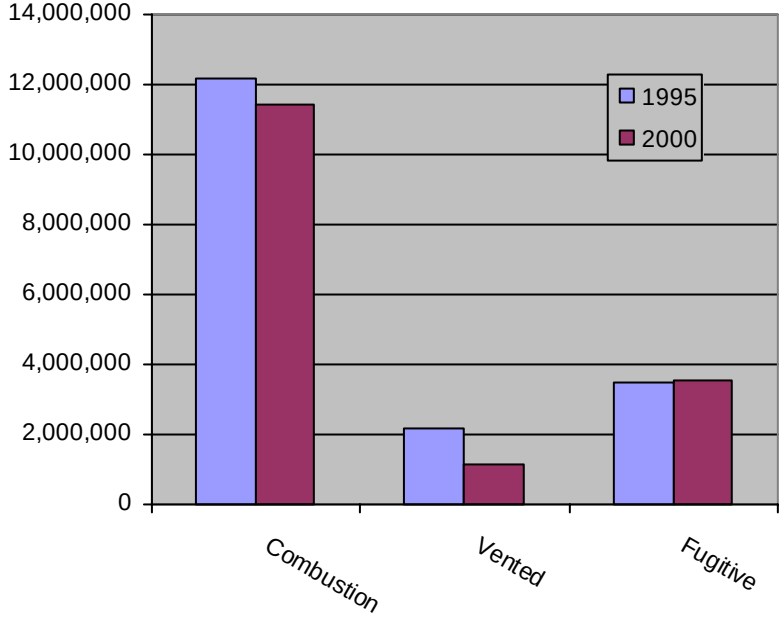


Figure 4.2 details the trends in direct GHG emissions between 1995 and 2000 for the three GHG gases of importance (CO_2, CH_4, and N_2O). Of merit is the fact that CO_2 related GHG emissions fell by 724,738 tonnes (or 6%) while CH_4 related GHG emissions fell by 963,333 tonnes CO_2 equivalent (or 17%) between 1995 and 2000.

Figure 4.3 details the trends in direct GHG emissions between 1995 and 2000 for the three GHG emissions types (combustion, vented and fugitive). Of merit is the fact that combustion related GHG emissions fell by 763,885 tonnes (or over 6%) while vented related GHG emissions fell by 997,191 tonnes CO_2 equivalent (or 46%) between 1995 and 2000.

Figure 4.3: GHG Trend Between 1995 and 2000 Direct GHG (CO_2 equivalent) Emissions by Emission Type (tonnes)



It is difficult and not included in the scope of this study, to quantify those activities undertaken by the 12 companies that led to the reduction in emissions. However, through the audit process some key emission reduction activities were identified and confirmed with sufficient and appropriate evidence. These activities include but are not limited to:

- Cast iron pipeline replacement,
- Efficiency improvement of transmission station turbines,
- Improvement in pipeline maintenance and inspection (leak detection and repair), and
- Pipeline system improvements aimed at reducing the amount of gas vented and number of events.

5.0 The GHG Audit Project

The primary objective of the GHG audit was to provide an independent opinion on the participating companies' consolidated 2000 emissions data. In addition, the audit identified any weaknesses and deficiencies in the internal company-specific GHG emissions data control, management, and reporting systems that could affect the reliability of the data.

The audit project began in September 2001 and was designed around four key stages as shown in Figure 5.1. In the absence of generally accepted standards for the auditing of GHG inventories, the audit team first worked with representatives from each of the 12 companies participating in the project to gain an understanding of the entity level GHG source emission quantification methodologies, data reporting and control systems. Similarities were identified and a consistent data reporting format and replicable methodology for the audit were developed.

The audit methodology has incorporated features of both financial and environmental management system (ISO 14000 series) auditing standards. Due to the timeline and number of companies involved in the project, a risk-based approach has been adopted drawing on an understanding of both individual company and sectoral risks and controls as they relate to GHG emissions information.

This approach has enabled the auditors to assess critically how the Canadian natural gas transmission and distribution sector is managing risks related to reporting its GHG emissions data and the level of reliance that can be placed on data reporting systems. Audit testing focused on those entity-level sources that were considered to present the greatest risk of materially misstating the reported data.

To provide a balance of skills and capabilities, audit teams possessed knowledge of GHG issues, technical processes, environmental audit techniques, and financial audit concepts.

Figure 5.1: Stages in the Audit and Inventory Attestation Project

Project planning	Gain agreement on audit scope, objectives, responsibilities, criteria and outputs
Development of audit process	Develop audit plan, schedule, risk assessment methodology, definitions and working documents.
Audit of entity level 2000 data	Audit participating company inventories, issue company specific audit reports, ensure findings are addressed and inventories revised.
Consolidation of inventories and audit findings	Consolidate industry level findings and revised inventories, issue revised industry level inventory and audit attest statement.

Currently there is no single, established, and accepted approach to GHG emissions inventory audit. The approach employed in this project included:

- A confirmation of emission estimates and a confirmation of the appropriateness of key assumptions;
- An evaluation of the applicability of the activity data and the data management system for inventorying and reporting GHG emissions; and
- The identification of findings to be addressed through methodology and inventory modifications (as applicable);

6.0 The Audit Process

In order to understand the Canadian natural gas companies' GHG emissions data issues and risks the team of auditors undertook the following activities (detailed in Figure 6.1):

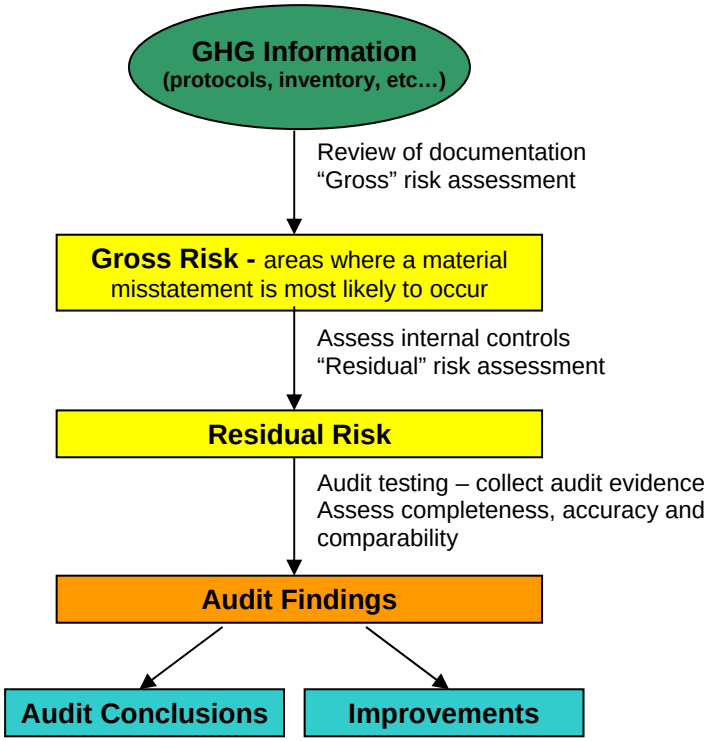
- A full day workshop with key representatives from each of the 12 participating companies to discuss the audit process and identify key risk areas;
- Developed a consistent reporting template to aid in risk analysis and identification and comparison of different entity estimation methodologies source categories;
- Review of existing GHG protocols, including handbooks for estimating methane and combustion related emissions from Canadian natural gas systems, historic industry level inventories (1990 and 1995), current (2000) and historic entity-level GHG inventories (annual 1990 through 1999), and the results of previous audits.

This information was used to identify the significant sources of **gross risk** (areas where the risk of errors in monitoring or reporting of GHGs has a material impact on the reported emissions) for each individual entity level audit. The audits were planned to obtain the information and explanations considered necessary to provide sufficient evidence to form the audit opinion. The audit work included detailed testing of data estimation techniques for those emission sources representing the greatest risk of misstatement.

The following were examined:

- Evidence supporting the reported data by the participating company;
- GHG estimation methods, assumptions and reporting procedures;
- Whether GHG protocols applied were appropriate to the circumstances and whether they were consistently applied.

Figure 6.1: Process for Auditing GHG Emissions Inventory



In the absence of a standard for corporate GHG auditing, a misstatement of 10% of sectoral emissions was considered to be material. A standard of 5% is commonly applied to financial information; however, this represents a challenging standard when applied to environmental data that have a higher level of inherent uncertainty.

7.0 Status of Company-level GHG Information and Management

The purpose of this section is to provide the user of the 2000 GHG inventory with a better understanding of the reliability and consistency of the company-specific information compiled. This section is separated into two sections; the first describing the methodologies employed by the participating companies to estimate GHG emissions and the second describing the management systems employed to ensure the quality of the current GHG information and continuous improvement going forward.

7.1 GHG Estimation Methodologies

The Canadian natural gas companies through GRI Canada have developed a set of sector specific tools that include; protocols (peer reviewed handbooks) for estimating CH_4 emissions and combustion related emissions (CO_2, CH_4 and N_2O); as well as a calculator tool (GHG Calc 1.2). The tools provide a variety of approaches but encourage companies to use the most complete and accurate method available for GHG emissions estimations, relevant to their own operations and level of reliable activity data. As a result of the broad adoption and consistent implementation of these tools by the companies participating in this process, entity-level source coverage is very good and GHG information is comparable and can therefore be collected and compiled to form a group inventory. The following provides additional information on those methodologies typically employed in the estimation of each emission type (fugitive, vented, combustion, and indirect).

In many cases, a company did not fit perfectly into one of the methodology categories discussed below. Where this was the case, ICF Consulting made an educated decision as to which best described each company's status.

Fugitive Emissions

Fugitive emission estimation techniques employed by the participating companies can be divided into the following categories, as presented in order of increasing sophistication and accuracy;

- Those companies (42%) that relied on station or facility level emission factors developed at the industry level and entity level station and facility counts to estimate fugitive emissions.
- Those companies (33%) that undertook component counts at their stations and facilities, and relied on component specific emission factors developed at the industry level to estimate fugitive emissions.
- Those companies (25%) that developed component specific emission factors (based on equipment supplier information or actual measurements of emissions) and entity level component counts to estimate fugitive emissions.

Vented Emissions

The assessment of gas volumes released from process venting or purging activities requires a range of approaches depending on the type of venting being considered. For large volume emitting sources, such as a blow down (depressurization) of a large section of pipe, all companies employed a similar event-specific methodology based on the volume and pressure of piping depressurized.

For common small to medium sized emitting sources such as gas operated devices and instrument control loops, the methodologies employed included, in order of increasing sophistication and accuracy;

- Those companies (33%) that relied on average emission factors for standard instrument control loops (developed at the industry level and based on actual measurements at gas transmission and distribution facilities) and entity level component counts to estimate vented emissions.

- Those companies (42%) that developed an event-specific methodology based on entity-level emission factors for standard instrument control loops (duration, volume and pressure based engineering estimates) and annual counts or estimates of the times each component vented.

- Those companies (25%) that developed an event-specific methodology based on entity-level emission factors for standard instrument control loops (based on actual measurements) and annual counts or estimates of the times each component vented.

Process Combustion Emissions and Other Direct Emissions

All companies employed a similar methodology to estimate combustion related GHG emissions based on the carbon content of the fuel (for CO_2) and combustion technology characteristics (for CH_4 and N_2O). For 2000, all companies relied upon metered activity data (typically facility-level natural gas usage).

Indirect Emissions

Indirect emission estimations were limited to those associated with electricity usage at entity owned facilities. All companies employed a similar methodology based on the greenhouse gas intensity of the power (CO_2, CH_4 and N_2O per kWh) as reported by the provincial utility or electricity generator and entity-level metered electricity usage.

7.2 GHG Management Systems[14]

The following section describes GHG related management systems employed by the companies participating in this study. For the purposes of this study the following elements are addressed:

- development of a documented GHG protocol;
- quality assurance and quality control;
- uncertainty management; and
- continual improvement.

GHG Measurement and Reporting Protocol

A measurement and reporting protocol is a procedure that provides comprehensive documentation of emission sources, calculation methodologies, sources of activity data and emission factors. It should also include information such as the organizational and operational boundaries, assumptions and responsibilities of key employees.

All companies have made an excellent beginning in the development of this documented procedure aimed at ensuring the consistent, effective, efficient and transparent development of periodic GHG inventories. However, only a few companies (25%) measurement and reporting protocol included all the information described above.

Quality Assurance and Quality Control (QA/QC)

Quality control (QC) is a system of routine technical activities to measure and control the quality of the GHG inventory. QC activities include general methods such as accuracy checks on data and calculations and the use of approved standardized procedures for calculating, archiving and reporting GHG information. Quality assurance (QA) activities include a system of review procedures aimed at ensuring the inventory represents the best possible estimate of GHG emissions given the state of scientific knowledge and data available. Reviews can be conducted by internal staff (typically not involved in the inventory compilation/development process) and by independent third parties.

Most companies employed some review function aimed at ensuring the quality of the data. Typically employees tasked with assembling the GHG inventory carried out data checks and investigated when anomalies were found in data. Several companies (25%) had undertaken an internal audit of GHG data (i.e. activity data, emission factors and emission estimates) through the use of counterparts from peer companies; however, the audit portion of this project was the

[14] **IPCC (2000)**, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Available on-line at: http://www.ipcc-nggip.iges.or.jp/gp/report.htm

first third-party review and assessment for the majority of the companies (75%).

Uncertainty Management

Uncertainty estimates are an essential element of an emissions inventory. Uncertainty information is not intended to dispute the validity of inventory estimates, but to help prioritize efforts to improve future accuracy and guide decisions on methodological approach. In order to analyze GHG information users must be able to understand the actual reliability of the total inventory and the component parts (sources).

The Canadian natural gas companies' sector specific tools for estimating CH_4 emissions and combustion related emissions (CO_2, CH_4 and N_2O) and the GHG-Calc software tool provide uncertainties for some commonly applied sectoral-level GHG emission estimation factors. Those companies that have developed their own entity-level emission factors based on field measurement or analysis have generally not quantified the uncertainty associated with their own factors.

No company had, at the time of the on-site audit, undertaken a full uncertainty estimate. However, a subjective assessment of the 1995 GHG information was undertaken (and is detailed in Appendix D) in 2003 and is relied upon for the purposes of issuing an audit opinion (see Section 2.0) on the 2000 GHG information.

Continual Improvement

All the companies participating in the 2000 inventory have undertaken many efforts to improve their inventories since the 1995 inventory was compiled in 1997. Fewer are relying on sectoral-level emission factors and more have developed entity-level factors based on own facility component counts and measurement programs.

Through the audit process, non-conformances and opportunities for improvement were identified. All material findings were addressed and several companies submitted plans to address the opportunities for improvement in 2003/2004.

8.0 Risks to the Canadian Natural Gas Companies' GHG Information

There are many different factors that could result in misstatement of the Canadian natural gas companies' GHG emissions data. The following summarizes those that should be addressed to ensure the reliability and continual improvement of the GHG inventory.

- There is a lack of understanding of uncertainty of the overall inventory and at the individual source level required internally, to make decisions aimed at managing GHG emissions, and externally, to ensure GHG information is interpreted properly. A better understanding of company-level uncertainty help prioritize efforts to improve future accuracy and guide decisions on methodological approach.

- For estimating emissions from fugitive and vented sources, most companies rely on national/sectoral-level emission factors taken from industry studies (GRI, GTC, Radian, Clearstone) based on a sampling of national sectoral data. Considerable effort and expense has been applied by the Canadian natural gas industry to develop these factors and ensure they are the best available. However, the uncertainty associated with these factors can run as high as several thousand % due to small data sets and the attempt to extrapolate the results to a broad spectrum of companies. Uncertainty may be able to be reduced substantially through the further study of fugitive emissions, the sharing of information between participating companies, and the development of company-specific emission estimation methodologies.

- Emission factors are drawn from reliable sources such as industry studies (GRI GHGCalc, Radian, Clearstone, etc…), VCR, IPCC, etc. Many of these factors are being revised and updated periodically based on new and more-in-depth studies. There is no formal system in place to ensure that emission factors relied upon continue to be current and the best available.

- All 12 companies participating in this study rely on a handful of staff to assemble activity data, calculate emissions, and compile the annual inventory. At the entity level, there is generally a lack of sufficient documented company-specific procedures (GHG Measurement and Reporting Protocol) describing emission sources, calculation methodologies, sources of activity data, emission factors, organizational and operational boundaries, assumptions and responsibilities of key employees. Therefore, should the companies lose the use of these key staff the level of effort to assemble the inventory would be significant.

- Employees tasked with assembling the GHG inventory also carry out data checks and investigate when anomalies are found in data. However, in the process of the audit, transcription errors and calculation errors were identified throughout the inventories completed by all companies. Where identified, these errors were addressed and GHG information revised. No formal QA/QC process has been implemented including an internal audit or management review of GHG data (i.e. activity data, emission factors and emission estimates).

9.0 References

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Appendix A – 2000 GHG Information (Detailed Analysis)

Figure 3.3: 2000 GHG (CO_2 equivalent) Emissions by Industry Segment – TOTAL EMISSIONS = 17,026,059 CO_2 equivalent

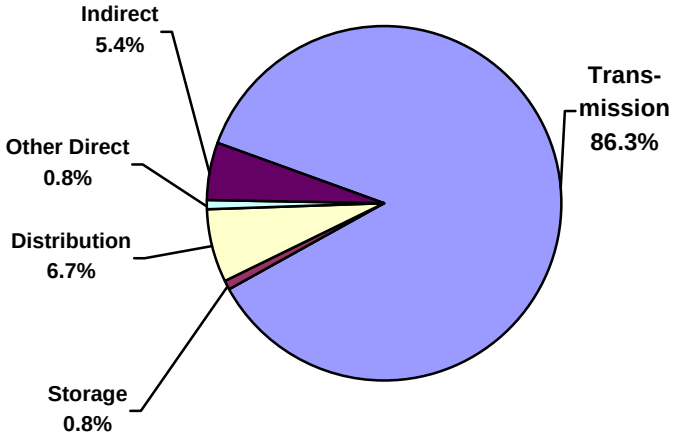


Figure 3.3: 1995 GHG (CO_2 equivalent) Emissions by Industry Segment – TOTAL EMISSIONS = 18,341,666 CO_2 equivalent

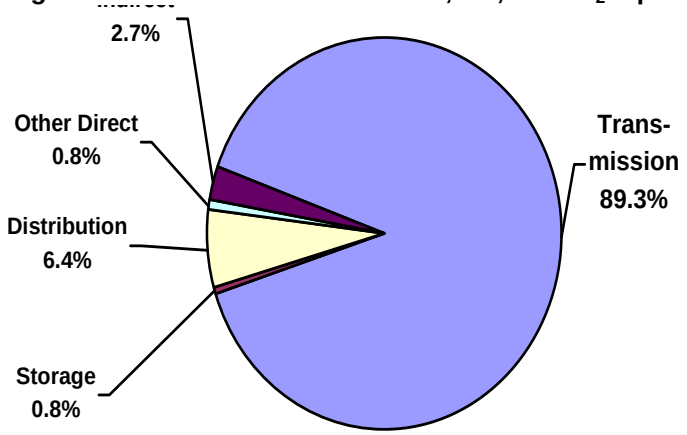


Figure 3.2: 2000 Direct GHG (CO_2 equivalent) Emissions by Emissions Type – TOTAL EMISSIONS = 16,110,160 T CO_2 equiv.

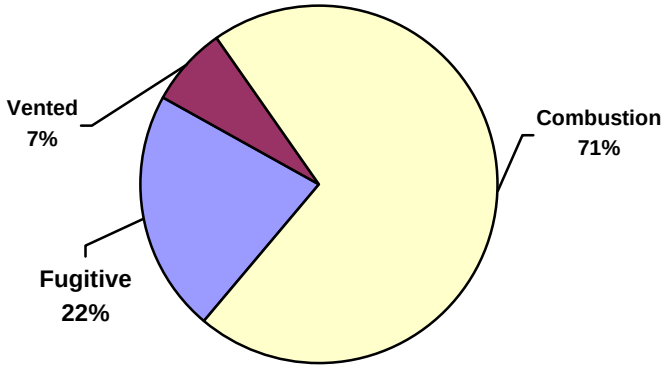


Figure 3.2: 1995 Direct GHG (CO_2 equivalent) Emissions by Emissions Type – TOTAL EMISSIONS = 17,815,599 T CO_2 equiv.

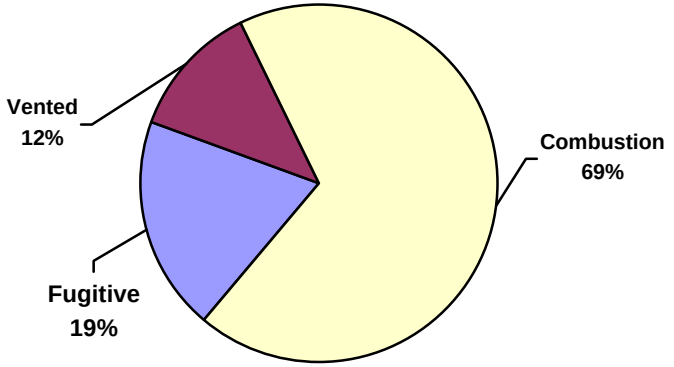


Figure 3.3: 2000 CO_2 Emissions by Industry Segment

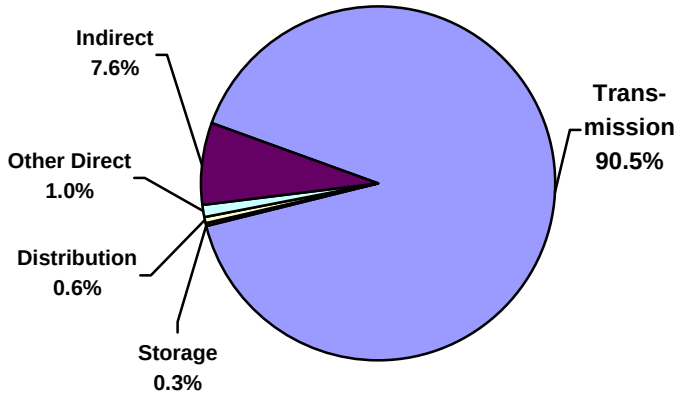


Figure 3.4: 2000 CO_2 Emissions by Emissions Type

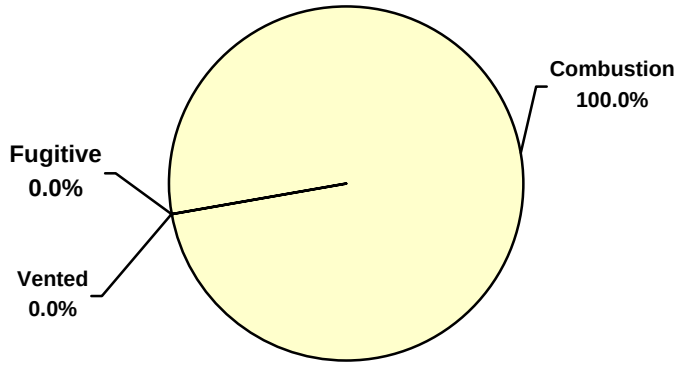


Figure 3.5: 2000 CH_4 Emissions by Industry Segment

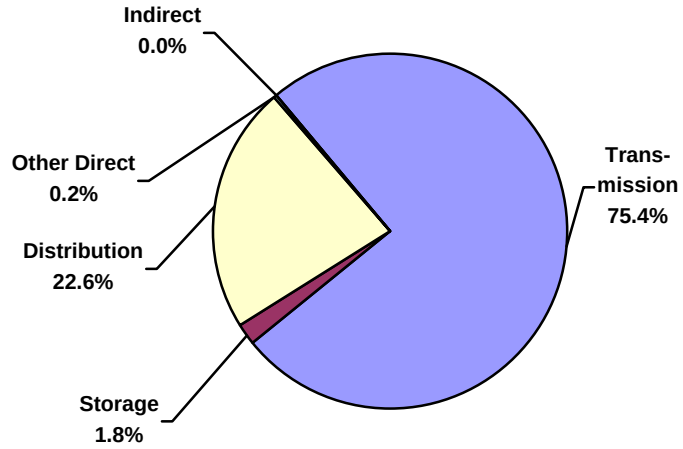


Figure 3.6: 2000 CH_4 Emissions by Emissions Type

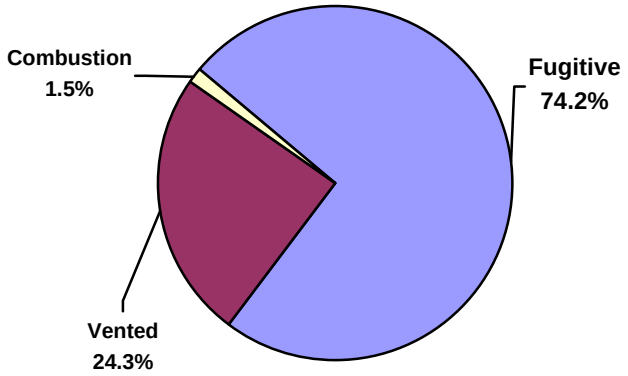
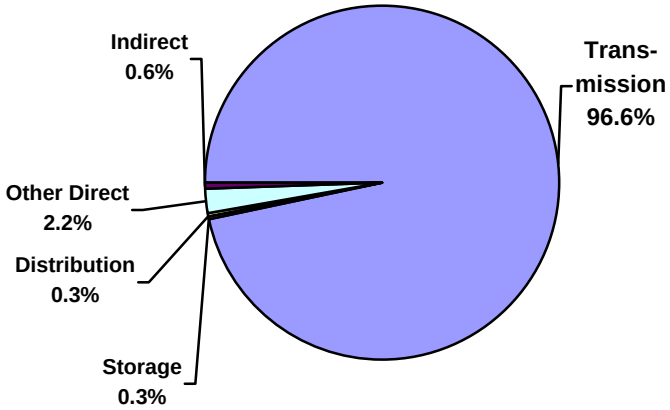


Figure 3.7: 2000 N_2O Emissions by Industry Segment



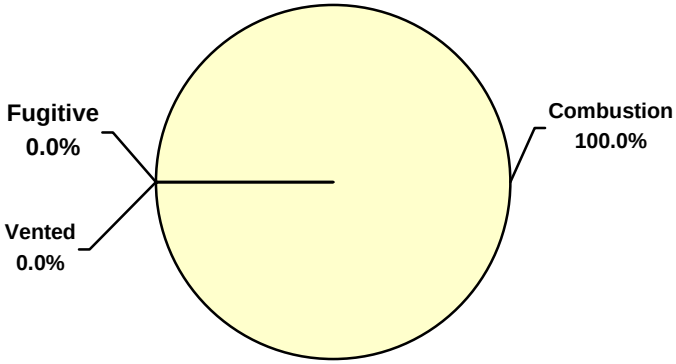


Figure 3.8: 2000 N_2O Emissions by Emissions Type

Appendix B – Sample GHG Data Reporting Template

2000 National Greenhouse Gase Emissions Inventory

	2000 GHG Emissions, t/yr				
PROCESS SEGMENT					
Emissions Type					
Source	t CH_4/yr	t CO_2/yr	t N_2O/yr	t CO_2E/yr	Methodology
Direct Emissions					
TRANSMISSION					
Fugitives Emissions					
Pipeline Leaks					
Unprotected Steel	0.0	0.0	NA	0.0	
Protected Steel	0.0	0.0	NA	0.0	
Compressor Stations					
Station	0.0	NA	NA	0.0	
Reciprocating Engine	0.0	NA	NA	0.0	
Turbine Engine	0.0	NA	NA	0.0	
Electric Drive	0.0	NA	NA	0.0	
M&R Stations					
Industrial Sales Meter Station	0.0	NA	NA	0.0	
TRANS/TRANS Interchange	0.0	NA	NA	0.0	
Farm Taps	0.0	NA	NA	0.0	
Receipt/Sales Meter Station					
Sweet Receipt Meter Station	0.0	NA	NA	0.0	
Sour Receipt Meter Station	0.0	NA	NA	0.0	
Sales Meter Station	0.0	NA	NA	0.0	
Border Meter Station	0.0	NA	NA	0.0	
Total Fugitives Emissions	**0.0**	**0.0**		**0.0**	

		Vented Emissions							
			Normal Operations						
				Dehydrator Vents		0.0	NA	NA	0.0
				Pneumatic Devices					
					Compressor Station Isolation Valves	0.0	NA	NA	0.0
					M&R Station Isolation Valves	0.0	NA	NA	0.0
					Compressor Station Control Loops	0.0	NA	NA	0.0
					M&R Station Control Loops	0.0	NA	NA	0.0
					Mainline Block Valves				
			Routine Maintenance/Upsets						
				Pipeline Venting (Blowdowns)		0.0	NA	NA	0.0
				Compressor Station Venting (Blowdowns)		0.0	NA	NA	0.0
				M&R Station Venting (Blowdowns)		0.0	NA	NA	0.0
				Upsets		0.0	NA	NA	0.0
		Total Vented Emissions				**0.0**			**0.0**
		Combustion Emissions							
				Dehydrator Reboilers		0.0	0.0	0.0	0.0
				Compressor Exhaust					
					Engines (fuel use)	0.0	0.0	0.0	0.0
					Turbines (fuel use)	0.0	0.0	0.0	0.0
				Generators					
					Engines (fuel use)	0.0	0.0	0.0	0.0
					Turbines (fuel use)	0.0	0.0	0.0	0.0
			Other (fuel use)			0.0	0.0	0.0	0.0
				Pipeline Heater Fuel		0.0	0.0	0.0	0.0
		Total Combustion Emissions				**0.0**	**0.0**	**0.0**	**0.0**
	Transmission Total					**0.0**	**0.0**	**0.0**	**0.0**

TRANSMISSION STORAGE					
Fugitives Emissions					
Storage Wells	0.0	NA	NA	0.0	
Compressor Stations					
Station	0.0	NA	NA	0.0	
Reciprocating Engines	0.0	NA	NA	0.0	
Turbine Engine	0.0	NA	NA	0.0	
Electric Drive	0.0	NA	NA	0.0	
Total Fugitives Emissions	**0.0**			**0.0**	
Vented Emissions					
Routine Maintenance/Upsets					
Storage Station Venting	0.0	NA	NA	0.0	
Total Vented Emissions	**0.0**			**0.0**	
Combustion Emissions					
Normal Operations					
Compressor Exhaust					
Engines (fuel use)	0.0	0.0	0.0	0.0	
Turbines (fuel use)	0.0	0.0	0.0	0.0	
Other	0.0	0.0	0.0	0.0	
Total Combustion Emissions	**0.0**	**0.0**	**0.0**	**0.0**	
Transmission Storage Total	**0.0**	**0.0**	**0.0**	**0.0**	

LNG FACILITIES					
Fugitives Emissions	0.0	0.0	0.0	0.0	
Vented Emissions	0.0	0.0	0.0	0.0	
Combustion Emissions	0.0	0.0	0.0	0.0	
LNG FacilitiesTotal	**0.0**	**0.0**	**0.0**	**0.0**	

DISTRIBUTION										
	Fugitives Emissions									
			Pipeline Leaks							
					Mains - Cast Iron	0.0	0.0	NA	0.0	
					Mains - Unprotected Steel	0.0	0.0	NA	0.0	
					Mains - Protected Steel	0.0	0.0	NA	0.0	
					Mains - Plastic	0.0	0.0	NA	0.0	
					Services - Unprotected Steel	0.0	0.0	NA	0.0	
					Services - Protected Steel	0.0	0.0	NA	0.0	
					Services - Plastic	0.0	0.0	NA	0.0	
					Services - Copper	0.0	0.0	NA	0.0	
			Meter/Regulator							
					Gate Station	0.0	NA	NA	0.0	
					District Regulator Station	0.0	NA	NA	0.0	
					Industrial Meters	0.0	NA	NA	0.0	
					Farm Taps	0.0	NA	NA	0.0	
					Receipt/Sales Meter Station	0.0	NA	NA	0.0	
			Customer Meters							
					Residential	0.0	NA	NA	0.0	
					Commercial/Industry	0.0	NA	NA	0.0	
	Total Fugitives Emissions					**0.0**	**0.0**		**0.0**	
	Vented Emissions									
		Pneumatic Devices								
					Pneu. Oper. Isolation Valves	0.0	NA	NA	0.0	
					Pneu. Oper. Control Loops	0.0	NA	NA	0.0	
		M&R Station Purge								
		Routine Maintenance							0.0	
			Pipeline Blowdowns			0.0	NA	NA	0.0	
			Station and Meter Vents			0.0	NA	NA	0.0	
			Other - Gas Sampling & Odorant Inj.			0.0	NA	NA	0.0	
		Dig-ins (third party damage)				0.0	NA	NA	0.0	
	Total Vented Emissions					**0.0**	**0.0**		**0.0**	

Combustion Emissions					
Compressor Exhaust					
Engines (fuel use)	0.0	0.0	0.0	0.0	
Turbines (fuel use)	0.0	0.0	0.0	0.0	
Other (fuel use)	0.0	0.0	0.0	0.0	
Pipeline Heater Fuel	0.0	0.0	0.0	0.0	
Total Combustion Emissions	**0.0**	**0.0**	**0.0**	**0.0**	
Distribution Total	**0.0**	**0.0**	**0.0**	**0.0**	
Other Direct Emissions					
Vehicles	0.0	0.0	0.0	0.0	
Domestic Gas Use (Buildings)	0.0	0.0	0.0	0.0	
Other Direct EmissionsTotal	**0.0**	**0.0**	**0.0**	**0.0**	
Total direct Emissions	**0.0**	**0.0**	**0.0**	**0.0**	
Indirect Emissions					
Electrical Usage	0.0	0.0	0.0	0.0	
Total Indirect Emissions	**0.0**	**0.0**	**0.0**	**0.0**	
COMPANY TOTAL EMISSIONS	**0.0**	**0.0**	**0.0**	**0.0**	

Appendix C – Audit Team Resumes

The Audit Team was comprised of four auditors. Each company audit involved two auditors. Duncan Rotherham led the audit process and participated in all twelve company audits. Ravi Kantamaneni participated in seven company audits, Kevin Lok participated in three, and Don Robinson in two.

Attached are the resumes of the four auditors.

DUNCAN ROTHERHAM – Lead Auditor
Project Manager

EDUCATION

1997	Graduate Diploma, Ecotoxicology, Concordia University
1995	B.Sc., Biology, University of Victoria

PROFESSIONAL LICENSES
Registrar Accreditation Board (RAB) accredited Lead Environmental Management System (EMS) Auditor
Canadian Environmental Auditing Association (CEAA) accredited Environmental Management System (EMS) Auditor

EXPERIENCE
Duncan Rotherham is a Project Manager with ICF Consulting working in the Energy Group's, Environment Practice. He has five years experience providing a wide range of services to the oil and gas, utility, forest products, manufacturing, and chemical sectors. Duncan has acted as an auditor in support of bp's (formerly BP Amoco's) project to verify their 1990, 1999 and 2000 inventories of GHG emissions. He was a member of the team of environmental and financial auditors, providing both the technical GHG expertise to evaluate the effectiveness and credibility of bp's emissions reporting activities and the required environmental management system (EMS) auditing expertise. He is currently leading an audit team that will develop a GHG audit process, and conduct over 15 company GHG verification audits aimed at generating an industry wide GHG audit attest statement for the Canadian Natural Gas Industry. He has planned and carried out GHG emission (PFC) emission quantification and management protocol development for Alcan's Kitmat facility. For the past two years he has lead the ICF team's efforts aimed at verifying emissions reduction project at 3 of DuPont's North American facilities. For the World Banks Prototype Carbon Fund he was part of the ICF team undertaking an independent third party assessment of the Chilean Chacabuquito Hydropower project design, baseline and monitoring and verification protocol aimed at validating the project. Duncan Rotherham is a certified EMS lead auditor with extensive auditing experience in the private sector.

Duncan has played key roles in baseline, emissions inventory and protocol development, assessment, and implementation for Nexfor, JD Irving, Algonquin Power Corporation, Primary Power, Alcan and Manitoba Hydro. In addition Mr. Rotherham has designed, built, deployed and audited environmental management systems and processes for many major corporations including Sunoco, Ontario Hydro Nuclear, Ontario Power Generation, SaskPower, Manitoba Hydro, Tembec and CXY Chemicals.

Emissions Inventory Verification/Auditing

Audit Process Development, Implementation and Validation of the Canadian Natural Gas Industry, 2000 GHG Inventory. Duncan Rotherham is currently leading a team in the development and implementation of an audit process to determine the validity of the GHG inventory as reported in the "Canadian Natural Gas Industry Report". The audit process involves the development of an audit protocol, working documentation and checklists specific to the gas industry, more than 15 full on-site verification audits. Based on the results Duncan will over see the development of a summary attestation report, summarizing findings and best management practices along with a set of individual reports outlining the detailed audit findings from each member company.

Emissions Protocol Development and Baseline Verification – Alcan. Mr. Rotherham undertook a gap analysis at Alcan's Kitimat primary aluminum production facility to determine the status and verifiability of GHG information pertaining to PFC emissions. Based on the analysis he presented opportunities for improvement to management and developed an emission protocol aimed at ensuring the verifiability of GHG emissions and associated reductions. The protocol will be implemented at the Kitimat facility and adapted to be implanted at Alcan's operation worldwide. The comparative analysis resulted in recommendations concerning the utility of the existing database. The protocol will then be used to establish the baseline for the PFC emission reduction project and as the basis for an Emission Reduction Credit Creation Report and opinion letter to substantiate the creation of the credits.

Verification of GHG Emissions Reductions for 3 of DuPont's Projects. Duncan Rotherham led a the ICF Consulting team in the planning, undertaking and report writing of the verification of emission reductions associated with emission reduction projects at 3 of Dupont's North American facilities. The projects included nitrous oxide emission reductions at Dupont's Sabine Texas and Brockville Ontario plants and HFC-23 emission reductions at the Louisville Kentucky plant. As no accepted standard was available for the verification of emission reductions at the project level ICF Consulting developed their own approach based on the best available practices.

GHG Inventory Auditor – bp (formerly BP Amoco). Duncan Rotherham audited the GHG inventories of 5 North American based facilities of BP Amoco. The audit included an intensive 3 day training program on BP Amoco's climate change strategy and the role of the GHG audit; GHG reporting methods and protocols issued by BP Amoco for use by its business units; the requirements of the GHG audit process. The 5-week GHG emissions audit was against the GHG Protocol and was designed to conclude, whether or not, the reported business unit and corporate level emission data for CO2 and CH4 were free of material misstatement.

Verification of GHG Emissions Reductions for the Chilean Chacabuquito Hydropower Project: Duncan Rotherham worked on the ICF Consulting team and DNV undertaking an independent third party assessment of the Chilean Chacabuquito Hydropower project design, baseline and monitoring and verification protocol aimed at validating the project. The assessment confirmed that the project, as designed and documented, was in compliance with Article 12 of the Kyoto Protocol; all relevant rules, requirements, regulations, modalities, criteria, guidelines and principles governing the use of Article 12; and requirements of Chile (host country). As the rules for validating CDM projects were not yet completely agreed upon ICF Consulting/DNV utilized the PCF Preliminary Validation Manual to plan the validation exercise and incorporated expert knowledge to reduce risks associated with uncertain requirements at the time of validation.

Validation of GHG Emissions Reductions for Toronto Renewable Energy Cooperative Wind Turbine Project: Duncan Rotherham and MacLeod Dixon LLP conducted an independent third party validation of potential GHG emission reductions associated with the development of Toronto Renewable Energy Cooperative (TREC) and Toronto Hydro Energy Services Inc. (THESI) Waterfront Windmill project. The project entailed the construction of two utility-scale wind turbines (Lagerwey 750kW/58 model), one at the Exhibition Place and one at the Ashbridges Bay Treatment Plant, both in Toronto, Ontario. The validation was performed as a desktop review of a number of well-elaborated documents presented by TREC and THESI. In addition consultations with TREC and THESI as well as with other information sources were used to establish a validation opinion. This enabled the validation team to perform an extensive risk-based review of issues with impact on future claims of emission reductions from the project. The final validation report summarised the results of the project validation, performed on the basis of currently existing and emerging requirements for validation under; the Ontario Emission Trading Code and Ontario's Emission Trading Regulation made under the Environmental Protection Act (for SOx and NOx emission reductions), and pertinent elements of the Clean Development Mechanism (CDM) in the Kyoto Protocol.

Emissions Baseline Inventory / MVP Protocol Development

Emissions Inventory Assessment Revisions and Protocol Development – JD Irving. Duncan Rotherham is currently working with JD Irving to meet their greenhouse gas (GHG), nitrogen oxides (NOx) and sulphur dioxide (SO2) emissions management needs for their Irving Forest Products division. The Forest Products division manufactures pulp, tissue, paper and corrugated medium from its six pulp mill operations in New Brunswick (4), the US (1) and Ontario (1). ICF Consulting is developing a baseline (1990) and annual inventories (years 1991 through present) for GHG and current baselines for NOx and SO2 emissions given the probability of their near term regulation. Going-forward ICF Consulting will work with JD Irving on the development of a process (multi-pollutant protocol) for the efficient and accurate quantification of emissions. The over all objective of the project is to ensure that the data being collected is comprehensive and accurate so that past (for GHG) and future emission abatement projects implemented at the pulp mills will yield GHG, NOx and SO2 emission "assets" marketable upon the implementation of a provincial, national or international emissions trading scheme.

Greenhouse Gas Inventory Assessment and Protocol Refinement – Nexfor. Mr. Rotherham and his team are currently engaged in the examination of the existing greenhouse gas (GHG) data set and measurement methodologies for Nexfor, a forest products company, to determine if they have been adequately structured, documented and measured to accurately quantify and qualify for future credits. Based on this assessment, ICF will offer an opinion on the existing GHG measurement and reporting protocol and identify opportunities for improvement in measurement methodologies and reduction of associated uncertainty.

CDM Capacity Building for the Solid Waste Management Sector in Argentina. Duncan Rotherham is leading ICF Consulting's efforts in support of a Conestoga Rovers project to build a landfill gas recovery project in Argentina. ICF's role in the CIDA funded project is to work with the Argentinean CDM office, the Argentinean solid waste management sector and Canadian entities interested in participating in methane recovery from landfill projects in Argentina, to develop training workshops and tools to identify, foster investment and facilitate the execution of future projects. The project runs from March 2002 through 2005.

Emissions Inventory Development – Algonquin Power Corp. and Primary Power Inc. Mr. Rotherham and his colleagues conducted a detailed operations assessment, and prepared a comprehensive emissions inventory encompassing all the GHG, nitrogen oxides (NOx), and sulphur dioxide (SO2) emissions from Algonquin Power Corporation's small hydroelectric generation stations in Canada and the US and Primary Power Inc.'s biomass fired generating stations. The emissions baselines and inventories were developed in accordance with guidelines of the government registry programs: Voluntary Challenge Registry (VCR) in Canada and Climate Wise in the US. This process is integral in applying for and achieving recognition as a green power provider under the Environmental Choice Program's EcoLogo. Based on the inventory he undertook a detailed analysis of the identified assets and identified opportunities for gaining market recognition.

Greenhouse Gas Emission Measurement and Coverage for Entity Reporting Study. Mr. Rotherham and his team completed a study for Environment Canada to identify the greenhouse gas (GHG) emission sources that can be measured/estimated at the entity level (e.g., corporate, institutional, facility), as contrasted with the top-down national inventory. This project's focus was on entity-level greenhouse gas (GHG) emission estimation and reporting, which required an operational/sectoral approach to building practical credible reporting guidelines. Entity level GHG emission measurement must account for the complexity in boundaries, process estimation methods, data availability, measurement techniques, ownership patterns, and temporal effects on baselines and annual estimating/reporting. The report was written to assist Environment Canada to eventually prepare comprehensive guidance for entity level measurement/estimation that fully accounts for the broader diversity in conditions and resources at the entity level.

Emissions Trading System Analysis for TransAlta. Duncan Rotherham worked on the ICF Consulting team undertaking a detailed study of the major sources of SOX and NOX emissions in Alberta. The study was aimed at identifying the costs associated with abating SOX and NOX emissions for several key industries and based on the results develop a marginal abatement cost curve for the province.

EMS Auditing

Lead EMS Auditor – SASKPOWER. Duncan Rotherham acted as the Lead EMS auditor in auditing 3 fossil power stations, transmission and distribution services, fuel supply services and the corporate function of SASKPOWER. The 5 week EMS audit was conducted against the ISO 14001 standard and involved on the job training of several SASKPOWER internal auditors in conducting EMS audits.

Lead Auditor ODS Regulatory and Best Management Practices Audit – Air Liquide Canada Inc. He provided ALC a free of bias evaluation of its refrigerant environmental regulatory compliance over its HCFC R-22, and R-134a systems. In addition, a professional opinion was provided of its management practices, as well as its refrigerant management program relevant to the HCFC R-22, and R-134a systems, and how they compare to known industry practices.

EMS Auditing – Ontario Hydro Hydroelectric. Duncan Rotherham has audited 20 hydroelectric generating stations within 4 distinct plant groups throughout Ontario (Ottawa/St.Lawrence, Niagara, Northeast and Northwest). The 7 week EMS audit was conducted against the ISO 14001 standard under the guidance of a CEA certified lead auditor.

ISO 14001 EMS Auditor – Manitoba Hydro. He acted as an EMS auditor for an ISO 14001 based EMS audit conducted at Manitoba Hydro for a fossil electricity generating facility.

RAVI KANTAMANENI - Auditor

Senior Associate

EDUCATION

1995 M.S., Environmental Engineering, Washington State University
1993 M.S., Petroleum Engineering, Imperial College, London University, London, U.K.
1992 B.Sc., Civil Engineering, City University, London, U.K.

EXPERIENCE

Mr. Ravi Kantamaneni, a Senior Associate at ICF Consulting, has more than six years of consulting experience focusing on greenhouse gas (GHG) policy, inventory, mitigation and measurement issues. Currently, for United States Environmental Protection Agency (EPA), Mr. Kantamaneni is assisting with the management of several GHG voluntary programs (aluminum, magnesium and electric utility industrial partnerships). For these programs, he is involved in various activities, including, providing technical assistance to program partners and EPA, developing sector-specific U.S. emissions inventory estimates, and preparing technical documents. For the magnesium partnership, Mr. Kantamaneni is managing a measurement study to quantify sulfur hexafluoride (SF_6) emissions at magnesium production and processing operations. Results from the study will be used to develop emission factors, which will assist in re-evaluating company/national emissions inventories. Mr. Kantamaneni has also conducted studies to measure methane emissions at natural gas pipelines in the U.S. and Canada, and perfluorocarbon (PFC) emissions from aluminum production facilities. He has developed an in-depth knowledge of several industrial sectors, including iron and steel, cement, aluminum, and natural gas. Such expertise has been used in developing emissions inventories, analyzing the cost effectiveness of GHG mitigation options, and developing GHG protocol guidance documents. Specific projects are presented below:

Canadian Natural Gas Industry, Greenhouse Gas (GHG) Inventory Audit, 2002-present. For GRI Canada, Mr. Kantamaneni is assisting with a GHG inventory audit of several Canadian natural gas companies. The audit encompasses a review of their 2000 inventories to gain an understanding of the source data utilized, data collection techniques, emission estimation calculations and assumptions. The objective of the process is to issue a statement attesting to the validity of the reported GHG inventories, and the development of reports summarizing company and industry audit findings.

Southern California Gas (SCG) Company Health Risk Assessment Study, 2002. For the California Public Utility Commission (CPUC), Mr. Kantamaneni managed and conducted fugitive emissions measurements at SCG's Playa Del Ray storage facility. Measurements were conducted at the compressor facility, storage field well-heads, and in the processing plant. Hazardous air pollutants, such as benzene, toluene, hydrogen sulfide, and carbonyl sulfide were measured from leaking components to estimate total pollutant emission levels from the SCG facility and storage field. Using air dispersion modeling, these data will be used to estimate pollutant concentration levels for locations throughout the vicinity of the SCG facility.

SF_6 Emission Reduction Partnership for the Magnesium Industry, 2001-present. For EPA, Mr. Kantamaneni is managing a measurement study using Fourier Transform Infrared spectroscopy techniques to characterize the extent of sulfur hexafluoride (SF_6) destruction during magnesium production and casting operations. These data will be used to improve the U.S. inventory methodology, and determine industry-specific emission factors. Mr. Kantamaneni has also provided technical assistance to program partners, developed industry SF_6 emissions estimates for the U.S. GHG inventory, and for conferences/journals prepared technical documents to communicate partnership accomplishments/technical information on mitigation technologies.

Voluntary Aluminum Industrial Partnership, 1995-1997, 2001-present. For EPA, Mr. Kantamaneni conducted studies to measure fugitive and stack perfluorocarbon (PFC) emissions from aluminum smelters, using atmospheric tracer techniques and gas chromatography-mass spectrometry. He analyzed data to identify whether smelter characteristics and operating parameters could be used to predict PFC emissions. Currently, he is assisting with the development of a PFC measurement protocol to provide guidance towards a consistent approach to measure PFC emissions. He also contributed to the development of a methodology and statistical analysis to identify the potential costs associated with the process events (anode effects) that produce PFCs during aluminum production. Mr. Kantamaneni also assists with the development of PFC emissions estimates for the U.S. GHG inventory.

SF_6 Emissions Reduction Partnership for Electric Power Systems, 2001-present. For EPA, Mr. Kantamaneni has assisted with the development of a new methodology/model for estimating SF_6 emissions from utilities. EPA has utilized the results from this analysis to revise SF_6 emissions estimates in the U.S. GHG inventory. He has reviewed and validated program partner submissions of SF_6 emission estimates, and assisted EPA to resolve reporting errors by helping partners to better understand the submission methodology. To communicate partnership accomplishments and technical information on SF_6, he assisted with the preparation of the document *SF_6 Emissions Reductions Partnership for Electric Power Systems: Program Report – 2002.* Furthermore, Mr. Kantamaneni is assisting EPA in the recruitment of partners by identifying targeted lists of utilities, and developing recruitment strategies and materials.

International Cost Analysis of Non-CO_2 Greenhouse Gas Abatement, 2001-present. For EPA, Mr. Kantamaneni prepared estimates of the potential costs for reducing future emissions of high GWP gases (PFCs and SF_6). This involved the examination of technologically feasible mitigation options for industrial sources such as aluminium production, magnesium production, and electric utility systems. He developed baseline emissions data for the associated sectors, and assisted with the development of cost analyses for each mitigation technology.

Natural Gas STAR Program: Lessons Learned Updates, 2002-present. For EPA, Mr. Kantamaneni assisted in the review of the fourteen published Lessons Learned studies. The studies are used by companies to guide and facilitate the implementation of various cost-effective methane emission reduction management practices and technologies. Mr. Kantamaneni revised several studies by incorporating new information on concept changes, cost data, technologies and economics.

Estimating PFC Emissions from Aluminum Production: Standard Operating Procedure Development, 2001. For Alcan, Mr. Kantamaneni conducted an assessment and review of current perfluorocarbon (PFC) estimation processes, submitted a gap analysis, and developed a Standard Operating Procedure to provide a consistent approach to estimating PFC emissions at all of Alcan's worldwide aluminum production facilities.

Greenhouse Gas Inventory Protocol Development and Maintenance, 2001-present. For EPA (Climate Leaders program), Mr. Kantamaneni developed GHG protocol guidance and associated spreadsheet tools for the iron and steel and cement industrial sectors. Both protocol guidance documents build on those currently available (World Resource Institute (WRI) and World Business Council for Sustainable Development (WBCSD)), and provide a more comprehensive methodology to estimating direct GHG emissions.

State GHG Inventory Development, 2001. For the State of California's Energy Commission (CEC) and the Texas Natural Resource Conservation Commission (TNRCC), Mr. Kantamaneni supervised the development and preparation of emissions estimates and final documentation for all industrial sources, natural gas and petroleum systems, and wastewater and human sewage sector sources of the GHG inventory.

Natural Gas Transmission System Measurement Studies, 1997-2000. For several pipeline systems including, Tennessee Gas Pipeline, Southern Natural Gas Company (subsidiaries of El Paso Corp.), and Florida Gas Transmission, Northern Natural Gas Company (subsidiaries of Enron); Mr. Kantamaneni conducted studies to measure fugitive methane emissions. Mr. Kantamaneni analyzed the data to establish facility/company-specific emission factors, and identify opportunities to optimize natural gas savings at the compressor facilities.

Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations, 1995-1998. For Pipeline Research Committee International (PRCI), Gas Research Institute (GRI) and U.S. Environmental Protection Agency (EPA), Mr. Kantamaneni co-managed a multi-year methane emissions project. The project addressed the cost effectiveness of various leak mitigation options at transmission/distribution facilities; improved gas industry emission factors; identified key variables that affect emission levels; and compared the effectiveness of various leak detection and quantification methods, including EPA published emission factors, EPA method 21, "bagging" and high volume sampler measurements.

SELECTED PUBLICATIONS AND PRESENTATIONS

Howard T., R. K. Kantamaneni, G. W. Jones, "Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations", Compressor Research Supervisory Committee, PRC International, Report: PR-246-9526, December 1998.

R. Kantamaneni, G. Jones, M. Barna, P. Cooper, T. Howard, "Trends in Leak Rates at Metering and Regulating Facilities and the Effectiveness of Leak Detection and Repair (LDAR) Programs", Compressor Research Supervisory Committee, PRC International, November 1998.

B. P. Leber, Jr., A. T. Tabereaux, J. Marks, B. Lamb, T. Howard, R. Kantamaneni, M. Gibbs, V. Bakshi, E. J. Dolin, "Perfluorocarbon (PFC) Generation at Primary Aluminum Smelters", *The Metal Society (TMS)*, May 1998.

Kantamaneni R.K., G. Adams, L. Bamesberger, E. Allwine, H. Westberg, B. Lamb, C. Claiborn, "The measurement of roadway PM_{10} emission rates using atmospheric tracer ratio techniques", A*tmospheric Environment*, 30: 4209-4223, (1996), London, U.K.

Kantamaneni R.K., T. Howard, G.W. Jones, “The EPA/GRI/PRCI leak mitigation program”, EPA Natural Gas STAR Workshop, Houston, TX, 1998.

Kantamaneni R.K., C. Claiborn, G. Adams, B. Lamb, “Evaluation of PM_{10} emission rates from paved roads using a point source tracer release technique”, PNWIS/AWMA International Conference, Eugene, OR, 1994.

EMPLOYMENT HISTORY

ICF Consulting	Senior Associate	2001-Present
Indaco Air Quality Services	Project Engineer	1995-2001

DONALD R. ROBINSON - Auditor

Senior Manager

EDUCATION
M.S. Chemical Engineering, University of Southern California, 1968
B.S., Tau Beta Pi, Chemical Engineering, University of Southern California, 1967

HONORS/AWARDS
University of Southern California, 4-year, full tuition scholarship, 1963-67.
AIChE Award for Undergraduate Excellence in Engineering, 1965.
Tau Beta Pi, honorary engineering fraternity, 1967.
University of Southern California, full-expense graduate school fellowship, 1967-68.
Chevron Research Company, awards for volunteer leadership in Practical Politics program, 1969, 1970.
ARAMCO, selected for advanced management business training at Harvard University, 1977.
Mobil Oil Company, BOD Award for Excellence, 1988.
ICF Consulting "Employee Excellence" award, 2000.

EXPERIENCE

Mr. Robinson has over 33 years of oil and gas industry related experience, including 27 years with major oil and gas companies, both domestic and abroad, and 6 years with research, engineering and consulting companies. Assignments included process design, refinery, terminal and oil field technical services, operations and facilities planning, operation and engineering management, project management, environmental, health and safety management, computer control and information technology application management, and federal government support services. Mr. Robinson is currently a Senior Manager in ICF Consulting's Oil and Gas Practices. He has contributed to numerous technical reports and papers for the private sector, EPA and DOE, has developed and presented methane mitigation workshops for the oil and gas industry, both domestic and foreign, as well as GHG protocol critiques, audits and program development guidelines. Mr. Robinson is fully qualified as a project manager, chemical engineer and oil and gas industry consultant.

PROJECT EXPERIENCE:

2002-Present - Private Energy Company GHG Protocol Development: Mr. Robinson directs a staff of Chemical Engineers in developing and recommending key elements of a GHG emissions estimation protocol for a private energy company's worldwide natural gas gathering, processing, transmission and storage business units. Recommendations are also being developed on the most cost effective internal and external emission reduction opportunities specifically tailored for that company.

1997- Present - EPA's Natural Gas STAR Program: Mr. Robinson functions as a senior manager for ICF Consulting's Energy Resources Group. Assignments include development of Lessons Learned summaries describing Best Management Practice technologies for economic methane emission reductions from Natural Gas Industry. Mr. Robinson also presents workshops for technology transfer to oil and gas operating companies, and assisted Southern Research, Inc. in organizing, planning and as a presenter and workshop facilitator in their kick-off meetings for the Environmental Technology Verification program for the Gas Industry. Associated with this program, Mr. Robinson participated in technical reviews of an EPA report on "Methane Emissions from the U.S. Petroleum Industry, 1996" and the joint EPA/GRI report "Methane Emissions From the Natural Gas Industry, 1996," identifying numerous opportunities for improvements in analyses of emissions ranging from well-head to refineries. He evaluated Best Management Practices for the Gas Processing sector, and re-analyzed default values for methane emission reduction for several BMPs.

2002 - DOE/NPTO Upstream Oil & Gas Environmental Research Objectives: Mr. Robinson participated with a team of contractors to perform background literature searches and telephone interviews with industry, research, regulators and academic people knowledgeable of oil & gas environmental needs and research. Mr. Robinson focused on the air issues. Following organization and presentation of the background to the client, Mr. Robinson participated in two workshops, in Houston and Denver, with the aim of obtaining end-user feedback on how DOE grant money should be spent in support of research that addressed the most critical oil & gas environmental issues, where solutions could enhance U.S. domestic oil and gas production and/or reserves.

2002 - EPA Study of Crude Oil and Refined Products Movement and Storage Facilities for On/Off-Road Diesel: This study provided EPA with background for rule-making on off-road ULSD diesel specifications. Mr. Robinson led ICF's efforts to characterize the quantity of off-road diesel usage in several industry and business sectors, and the product delivery and storage infrastructure, as it existed in the base year 2000. This involved updating of the 1983 and 1988 NPC studies of primary, secondary and tertiary petroleum infrastructure, and characterization of many industrial, commercial, educational and agricultural facilities for storing off-road distillate. Numerous EIA, Census, State, industry and other studies were evaluated, along with interviews of experts in industrial, pipeline, construction, railroad, mining, and agricultural sectors.

2001-2002 - API Study on Impact of Ultra Low Sulfur Diesel Regulations: This is primarily a linear program model study of the capital costs and market impacts of existing and proposed U.S. EPA rules on reducing the sulfur specification of highway and off-road diesel fuels. Mr. Robinson worked with the engineering and economics resources in ICF Consulting to research and set-up inputs to subcontractor EnSys Energy & Systems, Inc.'s WORLD LP Model. This model is set-up for this study to represent all five U.S. PADD regions and all foreign market regions (excluding Former Soviet Union, Eastern Europe and China). Worldwide refining industry capacities, technologies and product movements are normalized to year 2000 base case against actual refined product production and movements, then modeled forward to 2020 in various scenarios of diesel sulfur rule implementation. Mr. Robinson developed a simplified spreadsheet model of the U.S. refining industry gasoline and distillate production capability, refinery-by-refinery, and each refinery's relative capability to produce ultra-low sulfur distillate fuels. This model was used to group refineries by ULSD-capability for input into the WORLD model. Mr. Robinson was involved in analyzing the WORLD model output and drafting the report for the API client.

2000 - EPA and Russian Academy of Science "Second International Conference, Methane Mitigation Program" Novosibirsk, Russia: Mr. Robinson presented three papers describing cost effective methane emission reduction technologies practiced in the U.S., including pneumatic

instrumentation, compressor seals and glycol dehydrators. This elicited follow-up work helping Gazprom with a critique of their "Guidelines On Volumetric Measurement of Methane Emissions."

1998-2002 - EPA and API's Common Sense Initiative for Refinery Fugitive Emission Control: Mr. Robinson is providing senior consultant support to this initiative, including the development of reports on refining industry compressor and pressure relief fugitive emission control technologies and economics. These papers are suitable for a lay-audience with no technical understanding, explaining with text and graphics how compressors and pressure relief valves work, how fugitive emissions are and can be better controlled, and the economic impact on a refinery and the industry as a whole.

1999-2001 - BP-Amoco GHG Audit Services: Mr. Robinson functions on the ICF Consulting, KPMG, DNV team auditing BP-Amoco's GHG emissions. Direct services included critique of their CO_2 and methane emission estimating protocols, which led to Mr. Robinson redrafting their entire methane protocol. He presented a thorough GHG emissions check-list for oil and gas exploration and production, feed and product transportation and distribution, refining, and petrochemicals, which helped BP and other members of the audit team understand the totality of GHG issues, and make conscious choices on materiality, inclusions/exclusions, boundaries and "de-minimis" sources. Also, he trained auditors and participated in both upstream and downstream pre-audit site reviews to identify areas needing attention, then actual audits of refinery and petrochemical BUs.

1999 - EPA Study and Report on the Potential Impact on Small Refineries of Low Sulfur Gasoline: Mr. Robinson provided a generic model of small refinery gasoline production capability, applied to sixteen selected small refineries, to determine current facility capabilities and needs to product low sulfur gasoline. He also used literature and Internet data to develop a description of the markets that would be affected by potential closure of these refineries. These findings were incorporated with refinery financial data in a report to EPA.

1999 - DOE Best Environmental Management Practices Initiative: Mr. Robinson provided senior consulting support to ICF Consulting's services to DOE in developing a program patterned on EPA's Natural Gas STAR Program for oil and gas industry voluntary cooperation in improving technology application and transfer of the best environmental management practices. Mr. Robinson has contributed not only first-hand experience with the refining industry's views and requirements for such a program, but also has arranged direct input and support from a major oil company's "environmental best practices" coordinator.

1998-1999 - DOE Role in Critical Infrastructure Protection: Mr. Robinson developed a DOE briefing report for the President's Commission on Critical Infrastructure Protection, and a CIP Partnership Concept paper for the DOE Infrastructure Protection Task Force and the Infrastructure Assurance Center at Argonne National Laboratory. Mr. Robinson worked with a major oil and gas company and R&D companies developing plant automation technologies that are being prototype tested, and would be adaptable to infrastructure integrity monitoring and protection.

1998 - DOE Technical Objectives for NORM: Mr. Robinson developed and presented a novel format for capturing planning information on Naturally Occurring Radioactive Materials in the oil and gas production industry. This format includes the current situation and issues, R&D projects in progress and their outlook, continuing needs, leading to "themes" for DOE objectives satisfying the core un-addressed needs, and specific technical objectives and benefits from DOE funded projects.

1992-1995 - Environmental Technology Transfer Coordination: Mr. Robinson functioned as a team member on Mobil Oil Corporation's headquarters department for Technology Transfer Coordination. The team included Mobil Research and Development Corporation environmental technology development scientists and managers, and performed numerous environmental technology evaluations, emerging technology planning, regulatory analyses, refinery environmental "needs" workshops, analyses of and reporting on U.S. technology utilization, and development, justification and defense of the company's environmental research budgets and programs. A notable assignment included facilitation of a company-wide environmental vision development workshop including headquarters, Legislative and Regulatory Affairs, Research and Development, and field refinery representatives.

1984-1991 - Federal and State Environmental Policy Analysis and Response: In his role as Environmental Manager of Mobil's Beaumont, Texas, Refinery and EHS Manager of Mobil's Torrance, California, Refinery, Mr. Robinson directed, reported and coordinated with industry trade organization committees, such as Texas Mid-continent Oil and Gas Association and Western States Petroleum Association, analyses of proposed legislation and regulations from the refinery's impact perspective. A notable assignment included his participation in a team meeting with Texas Senator Jack Brook's staff on the impact of proposed regulations on Texas refining industry. This resulted in Mr. Robinson drafting a letter from Senator Brooks to the EPA Director outlining the Senator's position on the regulation.

1984-1991 - Refinery Environmental Management: Mr. Robinson functioned as the Environmental Manager for Mobil's largest refinery in Beaumont, Texas, and Environmental, Health and Safety Manager for Mobil's most challenged refinery in Torrance, California. Functions included total environmental compliance program development, implementation, reporting and personnel management for state and federal air, water and solid waste programs. Notable assignments included development of RCRA Hazardous Waste Part B Permit application and Closure Plans for seven land-based facilities and a dozen listed-hazardous wastes. This five-year assignment included analysis and presentation of the regulatory interpretations and justification, coordination of the engineering and political strategies, and negotiation of permit conditions with the Texas regulatory authority. Other significant assignments included negotiation of court ordered conditions with the Torrance Fire Department for refinery Risk Management and Prevention Plans for hydrofluoric acid and hydrogen sulfide, and negotiation of a settlement with the California Water Resources Board for groundwater contamination remediation in a Torrance drinking water aquifer. These assignments included representing Mobil's refinery on the Texas Mid-Continent Oil and Gas Association Environmental Subcommittee, and the Western States Petroleum Association Downstream Committee. Mr. Robinson was awarded a Mobil Board of Directors financial incentive bonus for some of this work.

SELECTED PUBLICATIONS AND PRESENTATIONS

Common Sense Initiative, Petroleum Refining Sector, Equipment Leaks Project: *Compressor Seal Controls and Costs*; U.S. Environmental Protection Agency and The Equipment Leaks Project Team, December 10, 1998.

Common Sense Initiative, Petroleum Refining Sector, Equipment Leaks Project: *Rupture Disks/Costs*; U.S. Environmental Protection Agency and The Equipment Leaks Project Team, June 1999.

Common Sense Initiative, Petroleum Refining Sector, Equipment Leaks Project: *Compendium of Sensing Technologies to Detect and Measure VOCs and HAPs in the Air*; U.S. Environmental Protection Agency and The Equipment Leaks Project Team, June 1999.

Petroleum Refining 101: ICF Resources “brown-bag” lecture on crude oil chemistry, unit operations, petroleum refining processes and economics; 1999-2002.

Lessons Learned From Natural Gas STAR Partners: *Using Hot Taps for In Service Pipeline Connections*; EPA 430-B-01-003 April 2001

Lessons Learned From Natural Gas STAR Partners: *Convert Gas Pneumatic Controls To Instrument Air*; EPA 430-B-01-002 April 2001

Lessons Learned From Natural Gas STAR Partners: *Options For Reducing Methane Emissions From Pneumatic Devices in the Natural Gas Industry*; EPA 430-B-97-008 August 1998

Lessons Learned From Natural Gas STAR Partners: *Installation of Flash Tank Separators*; EPA 430-B-97-008 October 1997

Lessons Learned From Natural Gas STAR Partners: *Reducing Emissions When Taking Compressors Off-Line*; EPA 430-B-97-010 October 1997

Lessons Learned From Natural Gas STAR Partners: *Replacing Wet Seals With Dry Seals in Centrifugal Compressors*; EPA 430-B-97-011 October 1997

Lessons Learned From Natural Gas STAR Partners: *Reducing Emissions From Compressor Rod Packing Systems*; EPA 430-B-97-012 October 1997

Lessons Learned From Natural Gas STAR Partners: *Installing Vapor Recovery Units on Crude Oil Storage Tanks*; EPA 430-B-97-032 October 1997

Presentations at the Second International Methane Mitigation Conference, Novosibirsk, Russia, June 18-23, 2000: Options for Reducing Methane Emission from Pneumatic Devices in the Natural Gas Industry; Options for Methane emission Reduction from Compressors: Dry Seal Installation, Rod Packing Maintenance, and Pressurisation Practices; Options for Reducing Methane Emissions and Improving Glycol Dehydrator Efficiency. (*www.ergweb.com/methane/papers*)

EPA Natural Gas STAR Technology Transfer Workshops for Gas Producers and Gas Processors: 14 one-day workshops in California, Colorado, Wyoming, New Mexico, Oklahoma, Texas, Louisiana, Alabama, West Virginia and Michigan; 1998-2002. (www.epa.gov/gasstar/workshops.htm)

EMPLOYMENT HISTORY

ICF Resources Incorporated	Sr. Manager	1998 - present
ICF Global Environmental Issues	Sr. Consultant	1997 - 1998
Mobil Oil Corporation	HQ Tech. Transfer Coordinator	1993 - 1995 (retired)
Mobil Oil Corporation	HQ Manager, Process Control	1991 - 1995

Mobil Oil Corporation	Torrance Refinery EHS Manager	1989 - 1991
Mobil Oil Corporation	Beaumont Refinery Env. Manager	1984 - 1989
Mobil Oil Corporation	Refinery Manager, Augusta Ref.	1983 - 1984
Mobil Oil Corporation	Augusta Refinery Technical Mgr.	1980 - 1983
Arabian American Oil Co.	Adm. Asst. to VP, Project Mgmt.	1979 - 1980
ARAMCO	Supt. Facilities Planning	1976 - 1979
ARAMCO	Sr. Supvr, Field Engineering	1976 - 1976
ARAMCO	Supt. Abqaiq Operations	1976 - 1976
ARAMCO	Supvr. Consulting Services	1975 - 1976
ARAMCO	Supvr. Terminal Engineering	1973 - 1975
ARAMCO	Process Engineer, Refinery & Term	1972 - 1973
Chevron Research Corp.	Process Engineer, Richmond Ref.	1968 - 1972
C.F Braun, Inc.	Research Assistant, HTRI	1967 - 1968
Union Oil Corp.	Process Engineer, Wilmington Ref.	1966 - 1966

KEVIN LOK - Auditor
Anaylst

EDUCATION
2000 BSc Environmental Science (Co-op) Graduate, B. Sc. (Hons.)

EXPERIENCE

Mr. Lok is an analyst with ICF Consulting in Toronto where he specializes in climate change impact analysis, GHG protocol and inventory development. He also has experience in emissions trading through his studies in emissions trading schemes in various countries and his participation in the Blue Circle's internal emissions trading program. He has two years of experience in environmental consulting and several years in data analysis as a research assistant for Prof. Gough during the third and fourth year at University of Toronto. Due to the nature of his projects, he uses programs such as Excel and Access extensively to collect, manipulate, analyse and present data. Other programs such as C language and Statistica are also useful tools for specific tasks.

PROJECT EXPERIENCE

Emissions Inventory Assessment Revisions and Protocol Development – JD Irving
Kevin Lok and his colleagues assisted JD Irving in quantifying and managing the emissions of GHG, NOx and SO2 at the Irving Forest Products division. The Forest Products division manufactures pulp, paper, tissue and corrugated medium from its four mills in New Brunswick. Mr. Lok developed the baseline (1990) and annual inventories (years 1991 through present) for GHG and current baselines for NOx and SO2 emissions given the probability of their near term regulation. A multi-pollutant protocol was also prepared for the division as a guidance document for the efficient and accurate quantification of GHG, NOx and SO2 emissions from its operation. The overall objective of the project is to ensure that the data being collected is comprehensive and accurate so that past (for GHG) and future emission abatement projects implemented at the pulp mills will yield GHG, NOx and SO2 emission "assets" marketable upon the implementation of a provincial, national or international emissions trading scheme.

Multi-pollutant Emission Reduction Strategy Analysis Foundation Report for the Concrete Sector, Environment Canada
Mr. Lok was responsible for the gap analysis of the current PM, GHG, SO2 and NOx inventories for the concrete sector in the Environment Canada's database. He reviewed the available pollution control technologies for the sector and developed the multi-pollutant inventory for 2000 using the US EPA's emission factors and raw data from the concrete companies and the national association. Based on the projection of concrete production and the assumptions on the adoption of control equipment, he forecasted the various emissions for the sector from 2000 to 2020. He and his colleagues also identified the costs of Best Available Technologies/Practices for reducing particulate matter emissions from various activities in concrete manufacturing processes and calculating the cost-effectiveness of each technology/practice in terms of emission reduction capabilities based on US EPA emission factors.

GHG Emissions Verification and Reporting System Audit - Manitoba Hydro and Centra Gas
Mr. Lok, with the ICF Consulting team, is currently engaged in GHG Emissions verification for Manitoba Hydro and Centra Gas. A program was designed by the ICF team to audit and attest to Manitoba and Centra Gas's GHG emissions including an analysis of the potential GHG offsets that

could be generated from the three proposed landfill gas projects. A gap analysis and uncertainty assessment is also included in the program to improve the GHG data management system, emissions estimation methodology, and reporting system.

Multi-Pollutant Emissions Reduction Analysis - Environment Canada
ICF Consulting is currently using its proprietary IPM model (Integrated Planning Model) to conduct an analysis on a range of regulatory scenarios for SO2, NOx, PM and mercury. The IPM is modeling the five provincial market responses to Multi-Pollutant Emissions regulations. Kevin Lok is responsible for the synthesis of pollutant control technology performance and cost data.

Nitrous Oxide Emission Reduction Verification - Dupont
Dupont has achieved significant reductions in emissions of N_2O at the nylon facilities in Maitland, Ontario and Sabine, Texas and it will submit an emission reduction report to a registry. Mr. Lok, with the ICF Consulting team, is currently conducting an audit and verification of nitrous oxide (N_2O) emission reduction for the facilities. They will provide a letter of opinion confirming the validity of the emission reduction projects after site visits to the facilities and a review of all relevant documents.

HFC-23 Emission Reduction Verification - Dupont
Dupont has achieved significant reductions in emissions of HFC-23, a by-product of HFC-22 production, at the HFC-22 production facilities in Louisville, Houston and it will submit an emission reduction report to a registry. Mr. Lok, with the ICF Consulting team, is currently conducting an audit and verification of HFC-23 emission reduction for the facility. Mr. Lok and his colleagues will provide a letter of opinion confirming the validity of the emission reduction projects after site visits to the facilities and a review of all relevant documents.

Greenhouse Gas Inventory Report and Validation by Audit – Gas Research Institute
Mr. Lok and his team, is currently engaged in a project for Gas Research Institute (GRI) Canada to issue a Canadian natural gas industry wide inventory statement of GHG emissions for the year 2000 and to develop a GHG audit process that will generate an industry wide GHG audit attest statement as well as individual company specific reports for the year 2000.

Standard Operating Practice Development for PFC Emissions Estimation - Alcan
The objective of this project is to develop and implement a Standard Operating Practice (SOP) aimed at facilitating the application of the IPCC methodology for estimating PFC emissions. The SOP shall be applicable at all of Alcan's primary smelting production assets regardless of the specific technologies employed. To ensure its applicability and identify opportunities for improvement the guideline will be field tested at one of the Alcan's primary aluminum production facilities to verify estimated PFC emissions. Based on the assessment and the successful rectification of identified weaknesses ICF will issue an attestation letter validating the PFC emissions for an agreed upon period of time.

Probability of Generating Tradable Emissions Reduction Credits - TransCanada
ICF Consulting prepared for TransCanada a high level analysis of the likelihood of emission reduction credits being recognized for use in various circumstances. The analysis focuses on four major areas, Canadian domestic, the United States, Clean Development Mechanism (CDM) and Joint Implementation (JI). Within each of these groupings, ICF looked at direct, indirect, small and large-scale projects. Mr. Lok was responsible for drafting the section on CDM and JI.

Internal Emissions Trading Program – Lafarge (formerly Blue Circle Cement)
Assisted by ICF Consulting, an Internal Emissions Trading Program for Blue Circle Cement NA is at its final stage of development and will be effective in April 2001. It is based on projected improvements in emissions intensity that are equal to each plant contributing its share to the company meeting projected compliance target. Mr. Lok conducted models, under different emissions abatement options or projects, at the plant and corporate levels in order to project the attainable targets.

Greenhouse Gas Inventory and Data Analysis – Lafarge (formerly Blue Circle Cement)
Mr. Lok developed the greenhouse gas (GHG) inventory for Blue Circle Cement North America (NA), which has nine plants operating in Canada and the United States. The cement industry is a major emitter of CO_2, responsible for 5% of total global carbon dioxide emissions, and it is unique in terms of the emissions pattern because half of the emissions are emitted during the calcination process. ICF Consulting has been retained by Blue Circle Cement NA to develop a climate change strategy in its drive toward a more environmentally sustainable manufacture. The GHG impacts of the industrial process are quantified in the GHG inventory, which serves as the basis for calculating emissions projections, intensities, and balance sheets. Mr. Lok prepared reports that document emissions, emissions reductions, and projects for submission to the national voluntary reporting programs in Canada and the U.S. according to the guidelines.

Greenhouse Gas Inventory Assessment and Protocol Refinement - Nexfor
Mr. Lok examined the existing greenhouse gas (GHG) data set and measurement methodologies for Nexfor, a forest products company, to determine if they have been adequately structured, documented and measured to qualify for future credits. Based on this assessment, they offered an opinion on the existing GHG measurement and reporting protocol and identify opportunities for improvement in measurement methodologies and reduction of associated uncertainty. They are currently engaged in developing the GHG inventory for all the facilities world-wide.

Emissions Inventory Development – Algonquin Power
For Algonquin Power Corporation, Mr. Lok conducted an operation assessment and prepared a comprehensive emissions inventory encompassing all the GHG, nitrogen oxides (NOx), and sulphur dioxide (SO_2) emissions from all the small hydroelectric generation stations in Canada and the US. The emissions baselines and inventories will be developed in accordance with guidelines of the government registry programs: Voluntary Challenge Registry (VCR) in Canada and Climate Wise in the US. They are integral documents in applying for an EcoLogo in the Environmental Choice Program, the Canadian environmental certification program.

GHG Measurement and Coverage for Entity Reporting Study- Environment Canada
Mr. Lok and his team completed a study for Environment Canada on the available methods to estimate and measure greenhouse gas emissions at the entity level. The intention is that this information could be used to inform the discussions about and any development of a GHG emission monitoring and reporting handbook by Environment Canada for voluntary entity level reporting. Entity level GHG emission reporting will be required should Canada adopt a Domestic Emissions Trading (DET) system or include GHG emissions under Pollution Release Transfer Registry (PRTR) such as the National Pollutant Release Inventory (NPRI).

Review of Post-1990 Actions in Ontario with Significant Climate Change and Air Quality Benefits – Ontario Ministry of Transportation. This study will provide the Ministry of Transportation with a comprehensive review of post-1990 transportation actions in Ontario with significant climate change and air quality benefits. ICF team is currently developing quantitative estimates of the GHG reductions (avoided emissions) of post-1990 transportation actions, projects and programs. It will extract key lessons from past actions on how to improve the environmental benefits of future transportation projects.

Emissions Factors Development for a Public Transit Study – Transport Canada
Mr Lok and his team are developing emissions factors for different types of public transit. The emission factors are specific to the type of transit and they take into account of the actual driving conditions such as speed, acceleration, and idling.

Greenhouse Gas Inventory and Data Analysis – Imperial Tobacco Canada Ltd
Mr. Lok developed a GHG Emissions Baseline Report for Imperial Tobacco Canada Ltd. (ITCL), which has operations in Aylmer, Guelph, Joliette, and Montreal. The Emissions Baseline Report was comprised of an emissions inventory, emissions intensity indexes, projections, and balance sheets. He also prepared the Voluntary Challenge Registry (VCR) for ITCL.

Greenhouse Gas Inventory and Data Analysis – EMCO Building Products
Mr. Lok completed 1998, 1999 GHG Emissions Baseline Report and a VCR submission for EMCO Building Products, which has operations in Edmonton, LaSalle, and Pont-Rouge. The wood fibre recycling and the installation of an on-site oxidation facility were special scenarios that were taken into account in the report.

Greenhouse Gas Inventory Calculations Verification – Falconbridge Ltd
Mr. Lok reviewed and verified the data in the GHG Inventory and 1999 and 2000 VCR submission for Falconbridge Limited, which has Canadian mining and mineral processing facilities in Sudbury, Timmins of Ontario and Nunavik Region of Northern Quebec. All the energy data as well as the sources and consistency of the conversion factors were examined.

Greenhouse Gas Inventory and Data Analysis – P&H Food
Mr. Lok conducted an initial scoping study for P&H food. One of the challenges was to calculate the GHG emissions from the wastewater using the BOD and several other parameters. This calculation should be but is rarely included in the GHG inventories of private companies.

Hudson Bay Climatic Data Analysis – University of Toronto
Mr. Lok was responsible for analysing climatic data recorded at different sites in the Hudson Bay region using a statistical program, Statistica. The results were used in various models to assess the impacts of climatic change on the Hudson Bay's sea level. He was also responsible for the maintenance of the web page.

Appendix D – Uncertainty Assessment

Prepared by Clearstone Engineering Inc.(January 2003)

UNCERTAINTY ASSESSMENT

Atmospheric emissions of CH4 and CO2 from the Canadian natural gas transmission, storage and distribution system have been estimated by URS Radian (1998) to total 14,846 kilotonnes (kt) CO2E for the reference year 1995. Based on a subsequent analysis of the uncertainties in the emission factors and activity data used in the development of this estimate, the lower and upper 95-percent confidence limits on this value are 13,303 and 16,389 kt CO2E, respectively (or 14,846 kt CO2E minus 10.39 percent to plus 41.35 percent).

Tables 1 and 2 below summarize the estimated uncertainties by industry segment and by primary source category. Where the estimated confidence interval is balanced about the probable emission rate (e.g., combustion emissions in Table 2), it is because the uncertainties are generally assumed to be normally distributed. Where an unbalanced confidence interval occurs, it is because some of the uncertainties were greater than 100 percent, and therefore, were assumed to be log normal for the purposes of defining the lower confidence limit. While use of the log normal assumption results in a tighter confidence interval, it is conservative with respect to the potential amount of emissions since it results in greater estimated emissions at the lower confidence limit. Use of a normal distribution in these cases would result in a negative emission rate, which is meaningless, or, if the negative values are arbitrarily set to zero, an understatement of the lower probable emissions.

Table 1. 95% confidence limits for the 1995 emissions inventory summarized by industry segment.

Industry Segment	CO2E Emissions			Uncertainty Range	
	Probable (kt/y)	Lower Limit (kt/y)	Upper Limit (kt/y)	Lower (%)	Upper (%)
Transmission	12,941	11,404	14,478	-11.88	27.52
Storage	230	196	265	-14.90	18.19
Distribution	1,674	1,545	1,804	-7.74	298.61
Total	14,846	13,303	16,389	-10.39	41.35

Table 2. 95% confidence limits for the 1995 CGA emissions inventory sumnmarized by emission source category.					
Industry Segment	CO2E Emissions			Uncertainty Range	
	Probable (kt/y)	Lower Limit (kt/y)	Upper Limit (kt/y)	Lower (%)	Upper (%)
Fugitive	4,768	4,491	8,583	-5.80	80.01
Venting	3,385	2,966	7,965	-12.37	135.28
Combustion	6,693	5,234	8,163	-21.80	21.96
Total	14,846	13,303	16,389	-10.39	41.35

In all cases, the confidence limits have been estimated in accordance with the Tier-1 approached presented by IPCC (2000). This approach provides for the estimation of uncertainties by source using the error propagation equation based on the assumption of uncorrelated normally distributed uncertainties under addition and multiplication. Convenient analytic expressions are given by IPCC for determining the combined uncertainty in individual multiplication and addition steps of the inventory development process. The multiplication steps in the inventory development process occur when an emission factor and activity value are multiplied together to obtain a source emission estimate. The addition steps result from the aggregation of individual source emission estimates to determine the total emissions. For a given source category, the level of uncertainty will tend to decrease by a factor of 1/N0.5 where N is the number of sources.

The estimated uncertainties in individual emission factors and activity values have been taken from the recent report by Clearstone and Kestrel (2002). A detailed description of the uncertainty assessment approach is provided therein.