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PETROLEUM TECHNOLOGY ALLIANCE CANADA

Facilitating innovation, collaborative research and technology development, demonstration and deployment for a responsible Western Canadian upstream hydrocarbon energy industry.

Upstream Oil and Gas
Fact Finding Report on Fugitives

March 2006

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Acknowledgements and Disclaimer

About the Industrial Energy Audit Incentive (IEA) and PTAC.

Industrial Energy Audit Incentive - The Government of Canada has been working with industry for more than 25 years to promote energy efficient industrial practices. Building on the success of this partnership, Natural Resources Canada (NRCan) has a financial incentive to help industrial companies identify ways to increase energy efficiency, improve production processes and cut costs. This incentive is designed to help defray the cost of hiring a professional energy auditor to conduct an on-site audit at an industrial facility. Funding is available for up to 50 percent of the cost of an energy audit to a maximum of $5,000. This is an exclusive service for companies that are registered with NRCan's Industrial Energy Innovators Initiative (IEII). By using energy more efficiently in the extraction, refining and delivery of natural resources and in the manufacture of products, industry can become more competitive and help reduce greenhouse gases.

Petroleum Technology Alliance Canada - PTAC is a not-for-profit association that facilitates collaborative research and technology development to improve the financial, environmental and safety performance of the Canadian upstream conventional oil and gas industry. The purpose of PTAC is to provide a mechanism that facilitates collaboration on R&D to the benefit of those involved. PTAC acts as a matchmaker between those that have problems or opportunities and those that have potential R&D solutions. PTAC brings stakeholders together to identify areas where R&D will make a difference, and to launch specific projects to address these problems or opportunities. PTAC promotes industry participation in the resulting R&D and assists with securing funding from a variety of sources. PTAC also facilitates the transfer of commercial technologies from other industrial sectors for application in the upstream oil and gas industry.

Acknowledgements

The author would like to acknowledge funding provided by Natural Resources Canada and the Office of Energy Efficiency. Thanks as well to all those who have provided in-kind support for this project by attending and contributing to content, attending the technology information session, and by responding to questions.

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Disclaimers

This document is **intended as an overview of fugitive emissions and mitigation options**. Any technologies discussed or referred to are intended as examples of potential solutions or solution areas and have not been assessed in detail or endorsed as to their technical or economic viability. Any incentive or other motivating factors for reduction of fugitive emissions are also speculative and are not intended as recommendations.

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1. Executive Summary

Varying definitions for “fugitives”, related to estimation and calculation of GHG emissions, have caused some confusion for the industrial personnel involved with tracking and mitigating emissions, as the IPCCC definitions are not consistent with other definitions applied to other non-GHG air emissions. The IPCCC “fugitives” might better be characterized as “non-fuel related GHG emissions”. By the IPCCC definition, almost 60% of the estimated 101 $MtCO_2eq$ upstream oil and gas GHG emissions (excluding oil sands) are “fugitives” whereas only about 17% would be classified as “fugitives” using standard definitions used for other types of air emissions.

True “fugitive” sources are difficult to control and measure, and require substantial efforts in monitoring, leak detection and maintenance. Other upstream sources, including reported and unreported venting, flaring and storage losses, can be more easily measured and economically controlled. A large number of options are available to reduce the “by design” emissions, and are gradually being implemented in Canadian operations in response to higher gas prices, and regulatory pressure to control Criteria Air Contaminant (CAC), Hydrogen Sulphide (H_2S) and large volume methane losses.

Meanwhile, increasing demands for natural gas and oil are forcing producers to direct more and more of their capital, manpower and growing cash flows to further development, rather than allocating those resources to improving energy efficiency. Increased regulatory, public and/or shareholder pressure is needed to adjust the balance between development of new resources and efficient production of established mature production. Some emissions can be reduced by improved design, while other, true “fugitive”, emissions require increased measuring, monitoring and incentives to increase maintenance activities in upstream operations.

The industry has been rapidly reducing controllable emissions over the last 5-10 years, and there is significant potential for further reductions in the near future if the appropriate motivation can be provided to producers.

2. Current Situation Assessment

2.1 Definitions of Fugitives

Fugitive emissions come from many sources and can contain a wide range of gases. Definitions of what constitutes a *"fugitive emission"* can vary considerably depending on what concern is being addressed. The following are some common descriptions from various sources:

Generic Fugitives Definitions – The generic definitions of "fugitives" can vary widely and are often not limited to a specific set of air contaminants, but are still relatively consistent in defining them as emissions which are difficult to track and control. Some example industry definitions for fugitives are:

- *"Emissions not caught by a capture system which are often due to equipment leaks, evaporative processes and windblown disturbances."* Source California Air Resources Board."[1]
- *"Emissions from facilities or activities that could not reasonably pass through a stack, chimney, vent, or other equivalent opening."*[2] – Business and Legal Reports
- *"Air pollution derived from human activities that does not emanate from a particular point, such as an exhaust pipe or stack. Roadway dust and VOCs from refinery valves are examples of fugitive emissions."*[3] – Environment Canada CAC Glossary.

Global Reporting GHG Fugitives - Currently the global focus is on Greenhouse Gas emissions (GHGs), which are thought to potentially impact global warming. The Intergovernmental Panel on Climate Change (IPCC) and UNFCCC use definitions that reflect the reporting process being implemented to monitor and track GHG emissions to meet the needs of the Kyoto Accord. The main focus is on non-water GHG species, which might impact global warming.

[1] Taken from European Environment Agency website http://glossary.eea.eu.int/EEAGlossary/F/fugitive_emission
[2] Taken from Business and Legal Reports website http://enviro.blr.com/topic.cfm/topic/178/state/155
[3] Taken from Environment Canada website http://www.ec.gc.ca/pdb/cac/cac_gloss_e.cfm

- "*Fugitive emissions from fossil fuels are intentional or unintentional releases of GHGs from the production, processing, transmission, storage and delivery of fossil fuels. Released gas that is combusted before disposal (e.g. flaring of natural gases at oil and gas production facilities) is considered a fugitive emission. However, if the heat generated during combustion is captured for use (e.g. heating) or sale, then the related emissions are considered fuel combustion sources."* Canada's Greenhouse Gas Inventory 1990-2003 Final Submission.[4]
- Pros – Easier to manage and tabulate across industries and countries for GHG emissions tracking, as fuel streams are generally accurately measured. Fugitive emissions are often based on emissions factors to minimize need for direct measurement.
- Con's – Assumes all fuel combustion is optimized, producing a consistent exhaust stream. Doesn't inform how controllable the fugitive emissions are.

Upstream Oil and Gas Industry – For oil and gas producers, and the residents living near producing operations, the main emissions of concern are those that are toxic emissions or emissions of materials which have a positive economic value if conserved. These emissions are generally controlled and reported through federal, provincial and/or municipal regulations. Toxic emissions of greatest concern are hydrogen sulphide (H2S), sulphur dioxide (SO2), Volatile Organic Compounds (VOC's), and benzene, toluene and ethyl-xylene (BTEX). Other sulphur or aromatic compounds may not be toxic, but may cause odours of concern to local residents. Finally, there are hydrocarbon emissions, which are mainly of concern as the loss of a valuable resource such as methane, ethane and other hydrocarbon liquids, many of which (except methane and ethane) are also included under VOC's. Regulations, or voluntary best production practices, set standards for emissions of toxic substances by site, sometimes adjusted for

[4] "Canada's Greenhouse Gas Inventory 1990-2003" page 52, Section 3.2 Fugitive Emissions (CRF Category 1.B) http://www.ec.gc.ca/pdb/ghg/inventory_report/2003_report/2003_report_e.pdf

proximity to residences or sensitive areas. Most intentional, large emission volumes are reported and periodically reviewed by regulators to determine if control measures are appropriate.

For GHG emissions the industry prefers to separate emissions that are intentional from those that are unintentional[5]. The definitions below are taken from the latest CAPP report.

- Vented Emissions – *"emissions to atmosphere by design or operational practice."*
- Fugitive Emissions – *"unintended releases of GHGs to the atmosphere. This category includes fugitive equipment leaks and accidents and equipment failures. Fugitive equipment leaks are emissions from equipment components that leak as a result of wear, poor design or improper installation."*
- Pros – Reflects emissions that are important to all stakeholders from a local to an international level. Differentiates between emissions which are intentional and measurable (as part of the oil and gas production process) and those that are unintentional releases.
- Con's – Not directly comparable to the UNFCCC definition.

2.2 Best Available Data on Industry Fugitive Emissions

Currently the best data/estimates available on fugitive emissions from the upstream oil and gas industries are a series of reports prepared for the Canadian Association of Petroleum Producers (CAPP)[6], by Clearstone Engineering Ltd of Calgary[7]. An earlier set of reports, based on 1995 data, was released in 1999 and has been used extensively for estimating and forecasting emissions. This analysis has recently been redone using data from 2000 and issued in 2004. The most recent analysis generally follows IPCC protocols but also includes inventories of other, non-GHG emissions (CACs and H_2S) and incorporates

[5] See CAPP Report 2005-0015 page 24, 1.4 Emissions Terminology, Vented Emissions and Fugitive Emissions.
[6] CAPP Reports are available for free download at www.capp.ca publications.

improvements in methodology, estimation methods and measurement, adopted since the 1999 report. The report is titled ***"A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry"*** and is published in several volumes, which are available for download from the CAPP website (www.capp.ca):

- CAPP 2005-0011 – Volume 1, Overview of the GHG Emissions Inventory – September 2004.
- CAPP 2005-0012 – Volume 2, Overview of the CAC Inventory – September 2004.
- CAPP 2005-0013 – Volume 3, Methodology for Greenhouse Gases – September 2004.
- CAPP 2005-0014 – Volume 4, Methodology for CAC and H2S Emissions – September 2004.
- CAPP 2005-0015 – Volume 5, Compendium of Terminology, Information Sources, Emission Factors, Equipment Schedules and Uncertainty Data – September 2004.
- Additional reports are due to be issued soon on emissions from Oil Sands operations.

While the above report is the most comprehensive and detailed assessment available, the results are based on estimates that are, in turn, based on reasonable assumptions, but may vary significantly from actual results in any given facility. The main variation will likely be in one or two significantly larger than estimated emissions, due to equipment failure, that are large enough on their own to exceed the estimated emissions for an entire facility.

[7] Clearstone Engineering Ltd. contact – Dave Picard website www.clearstone.ca

2.3 What are the Key Streams of Concern?

The CAPP reports for conventional upstream oil and gas operations separate the emissions into specific types of emissions of GHGs and CACs, as shown in Figures 1 and 2. As indicated earlier, GHG emissions are normally not a major concern to local residents, and therefore, not of concern to regulators unless they were economic to recover. Most regulations prior to Kyoto focused almost exclusively on reducing CAC, H2S and odour emissions, while methane and CO2 are colourless, odourless and non-toxic gases, which are only hazardous in extremely large volumes or in enclosed, inadequately ventilated spaces, where they may cause a reduction in oxygen content.

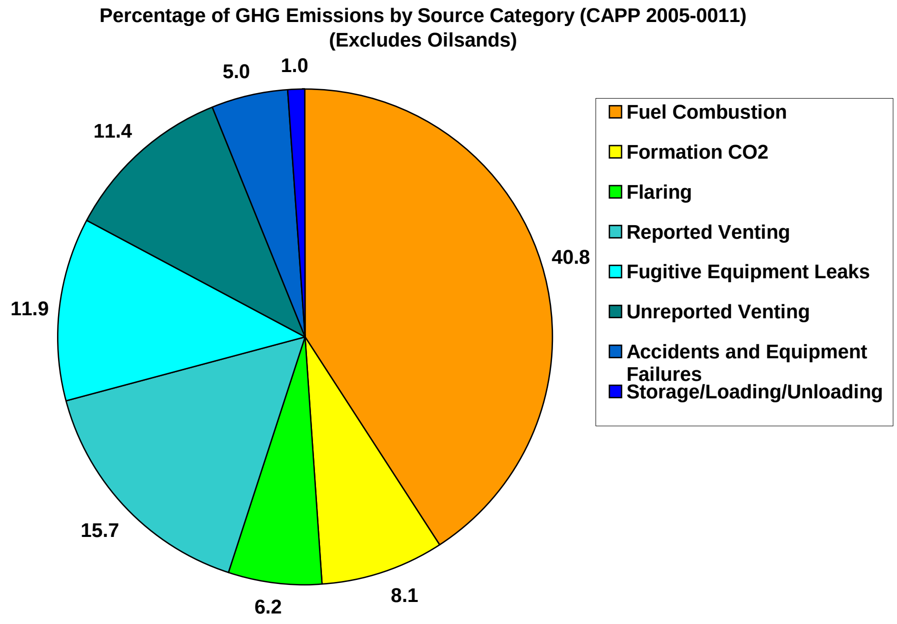

Figure 1 – GHG Emissions by Type of Source

GHG emissions are mainly methane from vents, leaks and failures, and from combustion sources, as shown in Figure 1. Fuel combustion includes contributions of NO_x, CO_2 and incomplete combustion products based on vendor standards using commercial natural gas. Formation CO_2, is carbon dioxide produced from the ground with the natural gas, and removed in a gas plant, which is then vented, or emitted through an incinerator stack if it is produced with hydrogen sulphide. Flaring combustion efficiencies vary widely depending on composition of the gases being burned, local wind and weather conditions, and the design of the flare system, but will mainly be combustion gases. The remaining 45% of the CO_2eq emissions are due mainly to methane emitted from various oil and gas production sources. Methane should be a high priority for reduction as, with a warming potential of 21 tCO_2eq/tonne of methane it is a much more powerful GHG gas, and also has a significant economic and energy value.

The larger local concerns with oil and gas production operations are with other non-methane and non-CO_2 emissions of CACs and H_2S, which are shown in Figure 2.

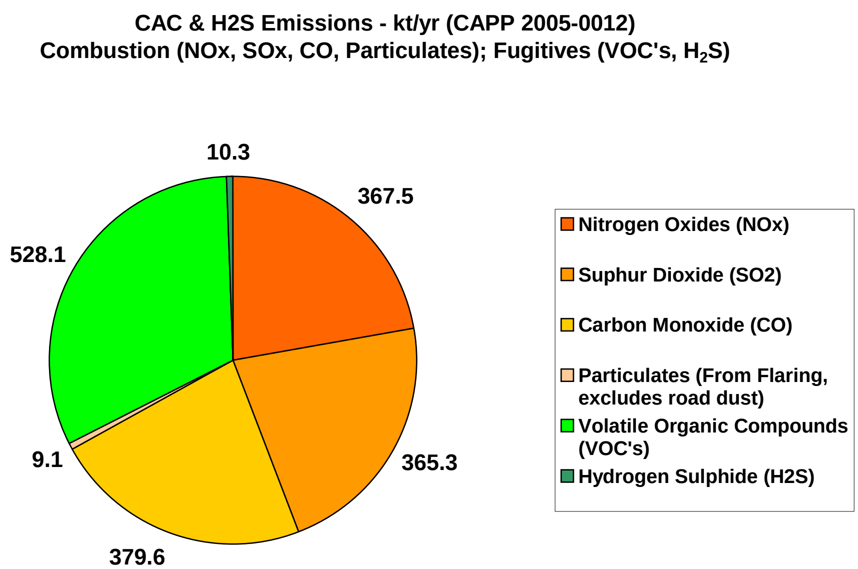

Figure 2 – CAC and H2S Emissions (excluding oil sands)

Nitrogen oxides, sulphur dioxide and carbon monoxide are known to impact plants growing near emission sources, and are of concern for human health (employees and nearby residents), especially those with asthma or respiratory problems. Particulates can also cause respiratory and health problems. Particulates from road dust are not included in the above chart but are significant as most oil and gas traffic is on gravel or unimproved rural roads, and dust also contributes to road safety hazards. Many VOC's are carcinogens, highly volatile and flammable, and also contribute to odours from operations. Hydrogen sulphide emissions, while low in volume, are of great concern as this gas can cause severe respiratory problems and even death at parts per million concentrations, and is detectable by odour at parts per billion levels. Over one third of the natural gas produced in Canada is considered to be "sour", and contains significant concentrations of H_2S.

2.4 Energy and GHG Intensity Indicators Focus

Energy and GHG intensities vary by upstream oil and gas sector, however, some sectors have greater opportunity for GHG reduction depending on the relative amounts of GHGs being emitted. Figure 3 shows the Production Energy Intensity (PEI) by sector while Figure 4 shows a similar comparison for Production Carbon Intensities (PCI) for GHG emissions from four oil production sources.

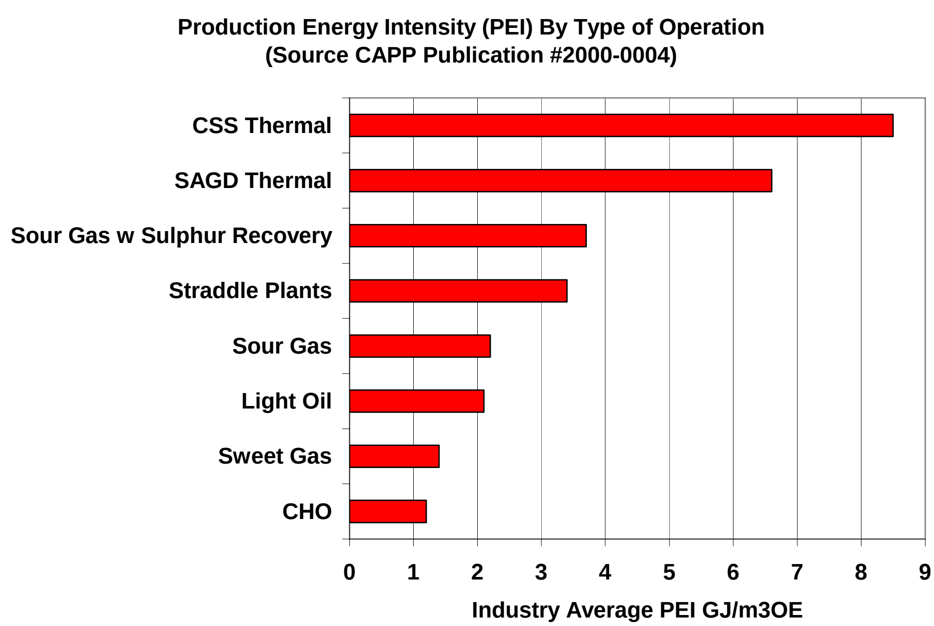

Figure 3 – Energy Intensities by Sector

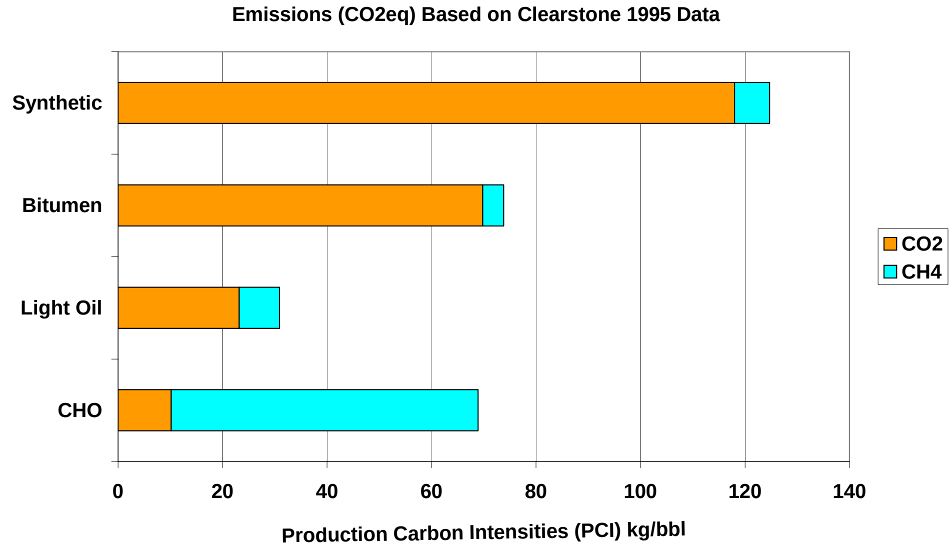

Figure 4 – GHG Intensities by Oil Production Type

As can be see from the above charts a focus on energy efficiency would tend to focus on reducing energy use in oil sands operations, and achieve some reductions in GHG emissions. However, to achieve the highest relative reduction in GHG emissions the focus would be on conventional heavy oil in Alberta and Saskatchewan where reported venting of methane represents 77% of the emissions of that type so could potentially reduce total GHG emissions by 12.5%.

2.5 Direct Human Impacts Focus

As discussed earlier, if direct human impacts are the key focus, as they are for provincial regulations, then the primary regulatory direvers will be on reducing total emissions of CACs and hydrogen sulphide. This indeed has been the case, especially over the last 15-20 years, and emissions of all CACs have been reduced. Fortunately, most actions to reduce CACs also reduce GHG emissions, but may or may not impact energy use, depending on the solution selected for emissions being controlled. E.g. incineration involves adding energy to ensure complete destruction of the CAC and H_2S. Therefore, while the global focus as a result of Kyoto is on GHGs and energy, the major environmental driver locally has been on toxic emissions of CACs and H_2S.

3. Technology Options for Control of Fugitives

Options for detecting, measuring and controlling fugitives are all highly dependent on the characteristics of the emission source, and the availability of some outlet for the emission, if it is hydrocarbon, or disposal for non-hydrocarbons, such as carbon dioxide or hydrogen sulphide. Generally hydrocarbons will have an economic value, which significantly enhances the motivation and ability to conserve the emissions.

3.1 Options Available by Type of Source

A number of studies have been done on mitigation options, particularly for methane and hydrocarbon emissions. Most of these options do not require new technologies, just the application of currently available technologies. The preferred solution for any source is going to be the option that provides the highest net economic benefit, which usually means the lowest capital cost option. As most fugitive sources are relatively small, they require simple solutions that can be easily incorporated into new designs (preferred), or retrofitted to existing operations if they are to remain in service for a number of years. For older facilities, which may soon be retired, the best solution may be just to let them operate until they are reclaimed, as modifications may result in higher emissions or economic/environment/safety risk than the emissions are worth.

New Paradigm Engineering Ltd prepared some reports, containing one-page option description sheets, and tools to assist in selecting the most economic options first, through a series of Joint Industry Projects conducted between 2000 and 2002. Many of these options are being used to reduce emissions as provincial regulations, and industry best practices, provide increased motivation for producers to take action. Key reports by sector focus are listed below:

a. ***"Vent Options for Oil and Gas Production Facilities"*** – New Paradigm 2001. Provides flow sheets to help prioritize economic options to consider for various vent streams from field gas dehydration, oil battery, instruments and other controlled sources. This report may be viewed on the PTAC website: http://www.ptac.org/links/EnergyEfficiencyKC/eekc0505.pdf.

b. ***"Vent Options for Gas Plant and Compression Facilities"*** New Paradigm 2001. This document discusses ways of detecting and mitigating fugitive leaks. This report may be viewed on the PTAC website: http://www.ptac.org/links/EnergyEfficiencyKC/eekc0506.pdf

c. ***"Heavy Oil Vent Gas Mitigation Options"*** New Paradigm 2000. This document discusses options to reduce methane venting from heavy oil wells by using vent gas to displace outside energy, generate power, provide energy for small scale hot water flooding, or gas for sale. This report may be viewed on the PTAC website: http://www.ptac.org/links/EnergyEfficiencyKC/eekc0504.pdf

d. ***"Thermal Heavy Oil Energy Conservation Options"*** New Paradigm 2001. This document discusses options to assess and reduce energy use in thermal heavy oil operations, mainly focused on cyclic injection or continuous flooding, however, many options also apply to SAG-D operations, and includes reduction of vent and flare streams. This document is available on the PTAC website at: http://www.ptac.org/links/EnergyEfficiencyKC/eekc0503.pdf

3.2 Reported Venting

Generally reported venting consists of streams from sources where there are no facilities (pipelines and/or compressors) in place to recover the gas economically.

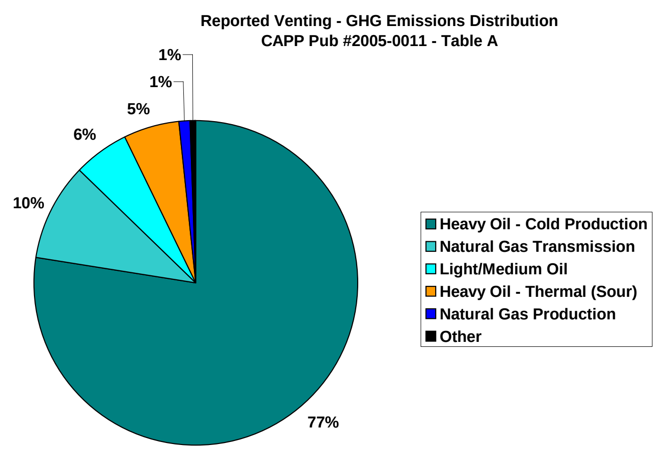

Figure 5 – Reported Venting Distribution by Sector

With the recent increase in natural gas prices ($1/GJ → $6-8/GJ) more of the gas is now economic to recover. As shown in Figure 5, most of the gas is methane vented from primary or cold heavy oil sites, where oil is being trucked from the producing wells, so gas gathering requires separate pipelines to each well. The stream emitted is mainly methane (95-97% dry analysis), but is water wet and low pressure (0 to 100 kPa) so must be dried, compressed and pipelined to market, used on-site to back out other energy sources, or used in local oil recovery processes.

Options - Preferred options are to first of all reduce use of outside energy sources (natural gas ($6/GJ), propane ($19/GJ) and electrical power ($23/GJ)) and substitute use of vent gas. At current gas prices most of the capital required for this option should payout in less than a year. Most cold production heavy oil operations will have more vent gas than they can use in their own facilities, so the next step will be to try and sell surplus volumes of low-pressure gas to local gas users, such as municipalities or pipelines. Producers may still have some uneconomic vent gas from isolated or hard to access wells or facilities, for which the only GHG reduction option will likely be to flare or convert the methane to CO_2 with a lower net global warming potential (21 tCO2eq/tonne of methane → 2.75 t of CO2), this could likely be economic with a GHG credit of $5-15/t$CO_2$eq.

Trends/Issues - Vent volumes have been rapidly dropping in Alberta and the majority of the producers are now recovering or utilizing most of the produced gas. A few producers are well behind the others, (e.g. one company was responsible for 23% of Alberta reported vent gas in 2004, but had improved significantly from 2003 when it was responsible for 30% of the vented gas). In Alberta, a new regulation will come into force in 2006 (AEUB Guide 60), which will force all producers to recover any gas that is economic, and even if it is slightly negative present value. Large producers will be required to assist smaller operators in gathering and marketing vent gas, and the AEUB mandates economic calculation methodology. In Saskatchewan, producers have been required to at least test vent gas from each well for 24-hours, once per year, and this should encourage conservation in that province as well.

With the above regulatory and economic motivators, the volume of reported vent gas is expected to continue to rapidly drop in Alberta, and many companies are likely to apply the same criteria in Saskatchewan, even though regulations there are not as robust. Even though vent gas volumes are reported, it is suspected that there will be more gas recovered than estimated, as standards for vent measurement are relatively poor and inconsistent between producers.

3.3 Unreported Venting

Unreported venting is from the numerous small, designed in sources, where pressurized natural gas is used to power pneumatic instruments or pumps, and then the depressurized gas is vented to atmosphere. Most of the emissions are at individual gas or oil wells, or at small production facilities that usually have no outside power supply. Use of natural gas to drive pumps and instruments is common practice, as the pressurized gas is always available when the facility is operating and is the most economic, safe and environmentally suitable source of energy available. Economics, due to increasing gas prices and Kyoto, have changed the situation in recent years, to motivate use of equipment that still uses natural gas pressure, but doesn't result in as much venting of gas.

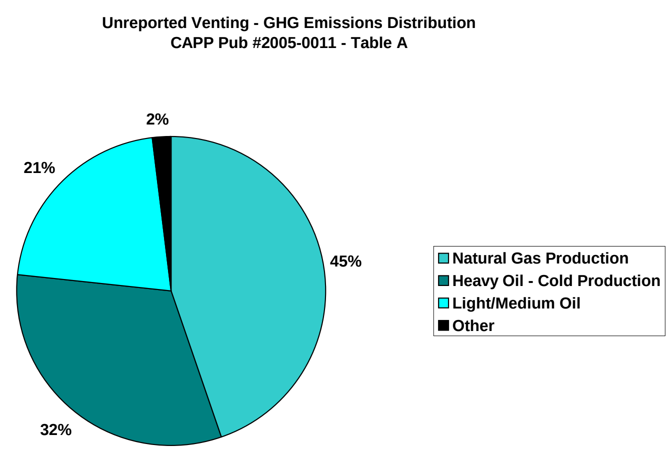

Figure 6 – Unreported Venting Distribution by Sector

Options – Today oil and gas facility designers can specify the use of low vent equipment, which requires lower volumes of gas to provide the same function. At lower gas prices the extra costs for these devices would not have been justified, however, at $6/GJ gas price they can payout quickly. Figure 7 shows the economic impact of low vent devices vs. standard devices, steady state and maximum values are shown, with most devices falling between these limits depending on how often they actuate or how variable the process is that is being controlled. Similar low vent options are also now available for injecting chemicals, such as corrosion inhibitors, methanol for freeze protection and circulating glycol for dehydration, so there is an incentive to reduce those volumes as well.

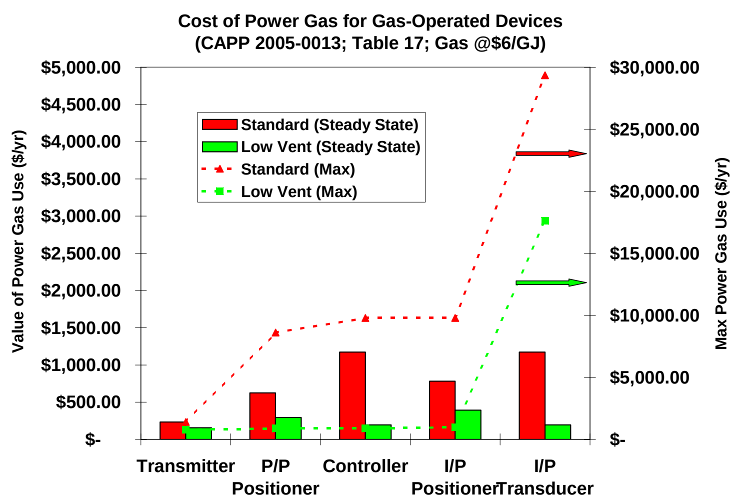

Figure 7 – Impact of Low Vent Instruments on Value of Emissions
(Source: CAPP Pub #2005-0013)

Trends/Issues – Much of the savings in this area will be achieved by shutting down older facilities, which are no longer required. Previously there was little incentive to conserve gas on producing leases, as fuel and instrument gas are not paid for by producers, and represented a very small fraction of the total gas production streams. As a result many companies have very little firm information on their actual gas emission rates from these types of sources. With higher demand for natural gas, producers are reviewing their operations, looking for ways of shutting down or consolidating facilities, as the producing pools are depleted and operating conditions change. Most new facilities are now installed with low or no vent options, however, asset turn-over is slow (often 20-50 years), so retrofitting of older facilities will have to be undertaken to reduce near-term emissions. Retrofitting is best done by skilled teams, as errors in conversion can potentially cause larger problems than GHG emissions, and, since most facilities operate 24 hours a day, and as close to 365 days of the year as possible, opportunities to make modifications are limited.

3.4 Storage and Other Sources

Emissions from storage and other sources are mainly Volatile Organic Components (VOC's) such as propane, butane, benzene, toluene and other hydrocarbons. Volumes can vary greatly between sites depending on the equipment installed, process conditions and more importantly the composition of the streams being processed. As shown in Figure 8, over half of the VOC's are from light/medium oil production, where the gas associated with the oil is much higher in heavier components, which often are sources of odour.

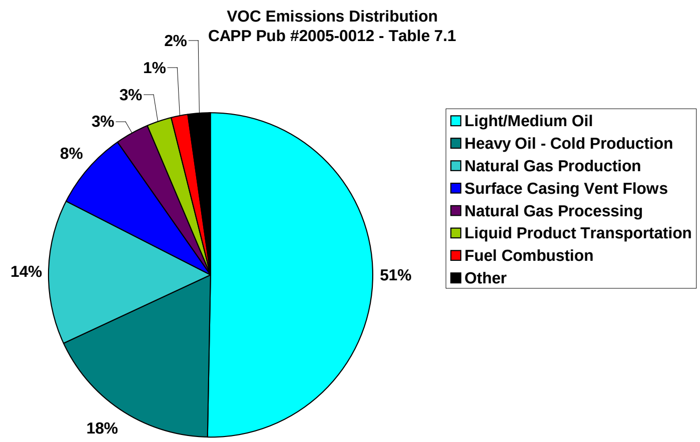

Figure 8 – VOC Emissions – Mainly from Storage and Other Sources

Aside from odour, many VOC's are carcinogens and much easier to ignite than methane, so health and safety issues are the primary motivation for reducing VOC's. Many VOC's also eventually react in the atmosphere to form GHGs so they do contribute to GHG emissions as well.

Options – Most emissions from storage and other sources can be contained with improved process control, such as lower operating and tank temperatures, or vapour recovery systems on tanks to recover the gases. Heavier hydrocarbons are generally more valuable than methane, so there is a greater economic incentive to recover VOC's than to conserve the associated methane.

Trends/Issues – Often the largest sources of VOC emissions are from deviations in operation of controls (vessels operating at too high a temperature or pressure) or failure of some control device such as a level control valve, which may allow volatile liquids to bypass downstream equipment intended to stabilize the stream. Adding equipment such as coolers or vapour recovery systems to control VOC emissions is viable, however, these systems may cause other issues (e.g. create explosion hazards) if they are not properly designed. Normally the main motivator for change is complaints from local residents complaining of odours. The industry has widely implemented best practices and there are strict regulations to control the more hazardous compounds.

3.5 Fugitive Equipment Leaks

One of the two emission streams that have always been considered "fugitive" is from equipment leakage, mainly in processes handling natural gas. These volumes are estimated based on leakage factors per type of fitting, so estimates for a given facility can deviate widely from the actual losses. In sour gas plants, emissions are considerable less than for sweet gas operations, as the odour and hazards associated with hydrogen sulphide, trigger and force prompt actions to contain any leakage. Older plants tend to leak more than new plants due greater to wear and tear, and older style equipment being used.

Options – Most leakage can be repaired or leaking components replaced, the main problem is in detecting leakage. Methane is a colourless, odourless gas and cannot be continuously odourized as it is for downstream users. Also, since plants are noisy facilities, operators cannot easily detect the sound of a leak, to allow them to locate and repair it. Detection options include soap (similar to what home owners do to detect a leaking propane fitting on their bar-b-que) and a wide range of electronic gas detectors, based on infrared, sonic or other signals. Many producers periodically survey their facilities for leaks, and there are some options for detecting leaks inside buildings or from aircraft.

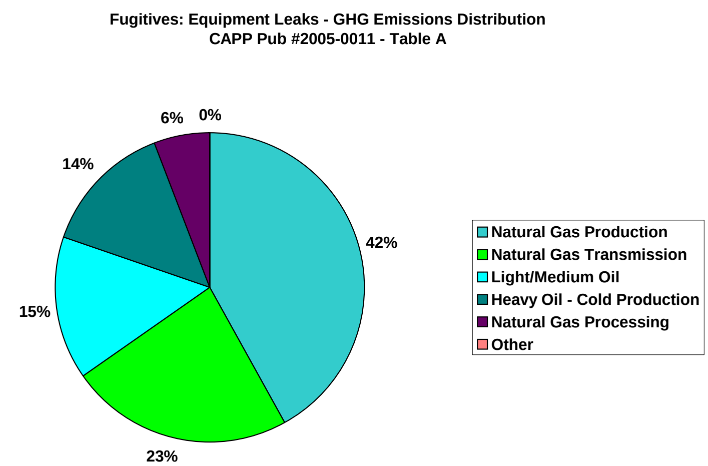

Figure 9 – Fugitives from Equipment Leaks and Wear and Tear

Trends/Issues – CAPP is believed to be preparing to issue a best practice for controlling fugitive emissions, however, a major concern is that many of these leaks will require plant or facility shutdowns to repair. Shutting down a facility can cause more equipment failures, accidents and emissions than occur with small stead-state emissions, so new options are needed to allow leaks to be contained, collected and mitigated without requiring facility shutdowns. In recent years this concern has become more pronounced as high, year-round gas demand allows few windows for maintenance, whereas previously most plants could be shutdown for maintenance in the summer when gas demand for home heating dropped.

3.6 Accidents and Equipment Failure

As can be seen in Figure 10, most emissions from “Accident and Failures” are attributable to well blowouts, or “surface casing vent flows”, and pipeline ruptures. While these events are rare their impact on emissions is very large, depending on the location, and conditions of the release and how long it takes to depressure, control and repair the failure. Each year there may be only 2-3 major well failures out of the 20,000+ producing wells, however, those wells may emit many millions of cubic meters of methane into the atmosphere before they are brought back under control. If a failure, or loss of control event, occurs, the main issue for the producers and regulators is to regain control as quickly and safely as possible. GHG emissions are not a consideration as the costs, financial and potential life, health and environmental impacts, are extreme.

Options – The main options are to avoid the incidents happening through rigourous monitoring, inspection and control procedures, and then to also have contingency plans in place that can be quickly implemented if an event occurs.

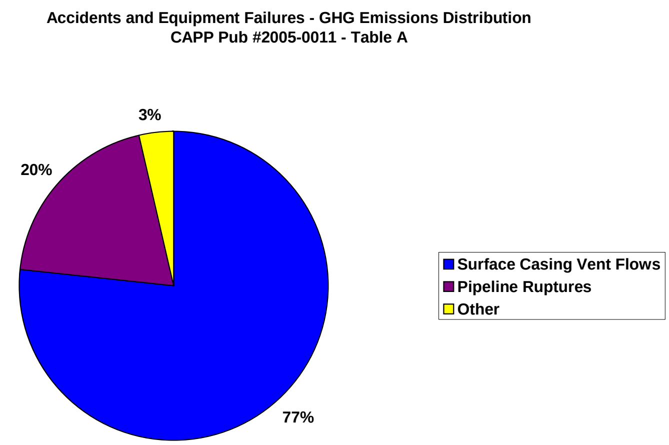

Figure 10 – Source of Accident and Equipment Failure Emissions

Trends/Issues – As in the case of other fugitives, the focus is on manpower intensive monitoring and inspection, and efforts must cover all operations of both large and small operators to have an impact. The trend towards corporate downsizing of staff, and selling off les profitable, "non-core", or mature operations to small producers is a concern to regulators as the smaller organizations will often have a greater challenge to properly manage the assets. Again greater demand for oil and natural gas is resulting in more of the available manpower being focused on growth, rather than maintenance activities.

3.7 Flaring and Incineration

Flaring volumes, in Alberta, have been reduced by over 70% since 1996, despite continued increases in production. Most of this has been achieved by operators paying closer attention to flares, due to public concerns with CAC emissions. As can be seen in Figure 11, most of the reduction has occurred at crude oil batteries where uneconomic to conserve gas was being flared. As with the reported vent streams, the increasing value of natural gas and natural gas liquids has provided additional motivation to reduce these volumes. Some sources, such as well testing and gas plant flaring, are less amenable to solutions. When wells are drilled they must be tested to determine the volumes that can be produced to allow for facility design, so most of the flaring is occurring before there are any facilities or pipelines in place to conserve the gas. In the case of gas plants, some gas is continually being flared to ensure that any emission streams, with potential to contain hazardous components, is properly burned rather than being released to the environment. Therefore, some flaring is required for public health and safety reasons.

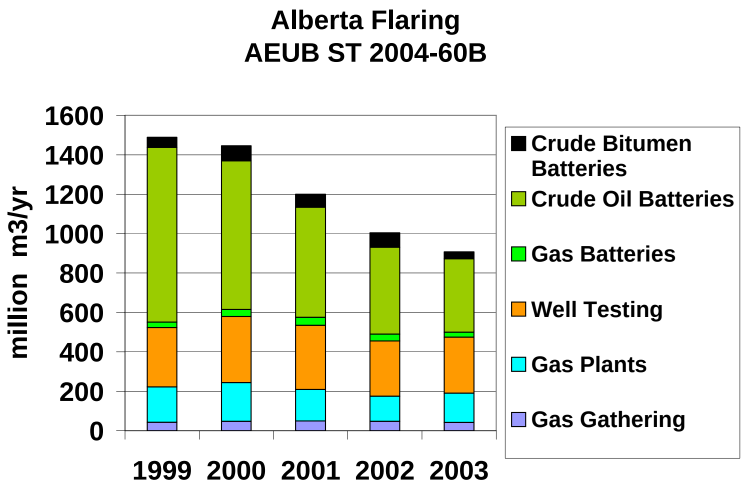

Figure 11 – Flaring Reductions in Alberta

Options – For crude oil batteries the options are similar to those for heavy oil well venting. There are far fewer options for other flare streams except to attempt to use as much of the energy generated as possible, however, economics generally don't favour installations, which may only operate at full capacity a few days a year, when the greatest volumes of gas are released.

Trends/Issues - The new Alberta Guide 60 will reduce crude oil battery flaring, as well as venting, as it will force companies to recover all economic gas and help smaller producers to recover their gas. Some work is being done to try and reduce well testing times, or collect well test volumes in portable gas storage, to reduce those sources. However, as long as natural gas is being produced some level of flaring will likely occur, to protect workers and the public from more serious releases. There is, however, a growing trend to replace simple flare stacks with more advanced incinerators and enclosed combustion devices to improve combustion efficiencies, while reducing the volumes of high quality gas needed to maintain the flare operation.

3.8 Oil sands Mining – Methane, VOC's

The new CAPP report on GHG and CAC emissions from oil sands mining operations, is not yet available, and is still under review. Fugitives from oil sands mining have traditionally been considered as minor, however, new information is being gathered which indicates a gradual change in that perception.

Methane emissions are generally from the mine face and the extraction processes, where methane gas is released from the oil sands, as it is from other oil streams, when they are depressured and heated. As bitumen contains fewer light hydrocarbon components and has a greater affinity for light hydrocarbons, these volumes will be relatively low per m3 of production, but with the rapid growth of oil sands production will soon become significant in total volume.

Another source of methane in mining operations is from biodigestion of oil in the tailings ponds. In warm water and hydrocarbon rich environments, natural bacteria can thrive and generate biogenic methane.

Finally, the industry uses light hydrocarbon solvents, anywhere from naptha to butane, to help separate and treat the produced bitumen. These solvents produce emissions of VOC's, which will also grow over time.

Options – Due to the vast scale of the mines, tailings ponds and extraction facilities, only limited work has been undertaken to look at methods of measuring, gathering and containing the above emissions, and it may be some time before any options are demonstrated which will be technically and economically viable.

Trends/Issues – The rapid growth of oil sands operations will cause significant increases in these fugitive emission sources in the next 20-30 years. Once mining and extraction operations are in operation, it may be difficult to retrofit gas containment equipment, if and when such options are developed.

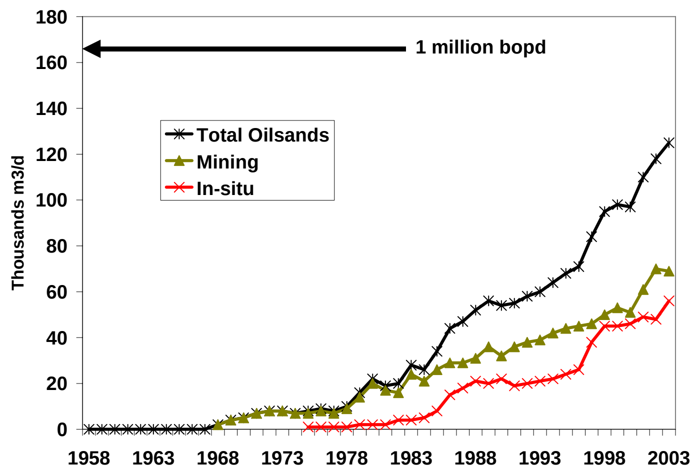

Figure 12 – Oil sands Production Growth (Source CAPP Statistical Handbook)

Applications for Mining/In-situ Projects total over 3.5 million barrels of oil per day

3.8 Oil sands In-situ

Most of the hydrocarbons used for in-situ oil sands operations, are used as fuel in the steam generators and any produced gas is usually recovered to reduce the need for purchased fuel. As most of the emissions are from combustion, there are few streams in in-situ oil sands operations, which are considered to be "fugitives" from a GHG point of view.

Trends/Issues – Some producers and researchers are discussing new processes, which may change the current emissions profile from in-situ operations. Recovery options such as solvent injection, in-situ combustion and in-situ upgrading or gasification, could result in more light hydrocarbons being used and produced in the processes, which will tend to increase the amount of potential fugitive emissions from these sources while reducing CO_2. As with oil sands mining, in-situ oil sands operations are rapidly expanding in Western Canada.

4. Implementing Options for Fugitives

While the previous sections have touched on the volumes and benefits to mitigating "fugitive" or non-fuel emissions, there still remain challenges in initiating and implementing changes to realize the potential benefits. As is shown in Figure 13, the total potential prize in conserving these streams (excluding oil sands and pipeline emissions) is over $600 M/yr. However, the total value of producer gas sales is over $78 billion/yr of which about $11 billion/yr goes to the provinces as royalties, so the emissions represent a relatively small percentage of the economic prize from new development, and must compete for the same capital and other resources.

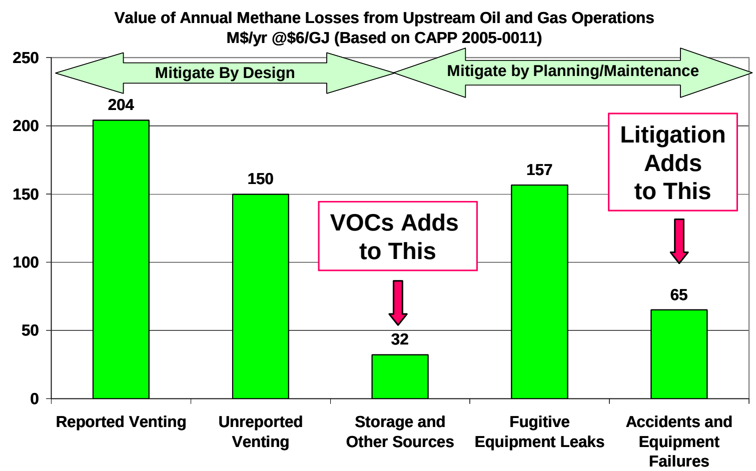

Figure 13 – Value of Upstream Oil and Gas Fugitive Emissions

4.1 Economic Range of Solutions

Depending on the situation and the capital costs, or facility downtime, to reduce a given emission, there is a wide economic range of solutions, which could be applied in many situations. Some solutions may require no capital investment, while others, such as power generation from waste gas or heat, may take many years to pay for the required investment. As the energy in the emitted streams is assessed on the corporate books as having no value when vented or flared, as it directly attracts no direct cost or benefit, this adds to the difficulty in assessing the economic value of a given action. The best economic options that demonstrate solid economics are those that result in a reduction of an energy purchase by the producer and therefore a reduction in operating costs. Suggested values of various energy streams are listed below:

- Purchased liquid fuel = \$23/GJ = \$0.80/l
- Purchased Power = \$14/GJe = \$0.05/kw-hr
- Oil Consumption = \$8/GJ = \$50/bbl
- Purchased Natural Gas = \$7.5/GJ
- Loss of a Gas Sale = \$6/GJ
- Fugitives CH4 Conservation (\$15/tCO2eq) = \$5.75/GJ
- Fugitives CH4 → CO2 Conversion (\$15/tCO2eq) = \$5.00/GJ
- Coal = \$1-2/GJ
- CO2 Reduction (fuel savings at \$15/tCO2eq) = \$0.75/GJ

Use of the relative energy source values and capital costs for facilities produce a range of project payouts from days to many years. Producers have the option of investing those same amounts of capital in development of new resources, which generates significantly greater returns for their shareholders, as shown in Figure 14. This relationship is discussed more in PTAC's Business Case for Energy Efficiency, see PTAC's website.

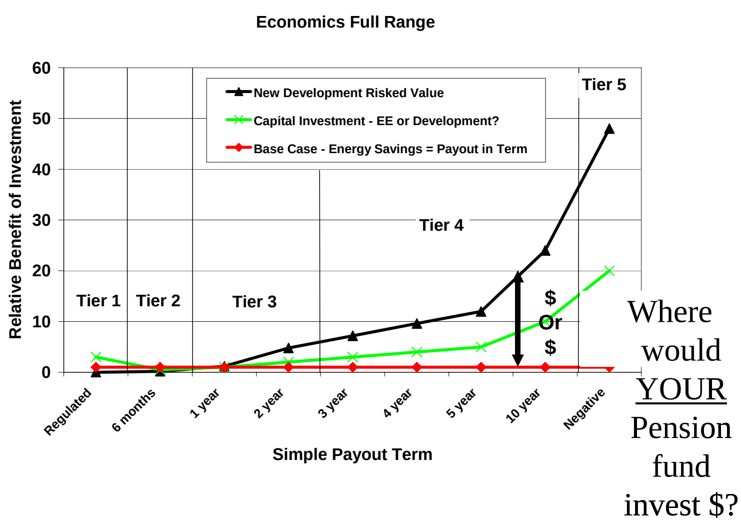

Figure 14 – Returns on Capital for Development vs. Energy Efficiency Projects

This economic hurdle is the main reason why many, not all, producers wait for regulations to implement mitigation measures to reduce fugitives. Even the "greenest" producers will rarely proceed with projects with payouts much longer than 2 years, unless there are safety, environment or other factors that also support the decision to proceed.

4.2 Barriers to Implementation of Solutions

Figure 15 illustrates a number of the barriers hindering implementation of emissions mitigation and energy efficiency measures in the oil and gas sector.

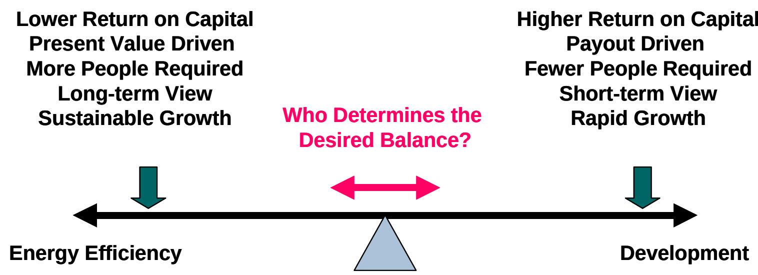

Figure 15 – Balancing Energy Efficiency vs. Development

In addition to low return on capital, discussed earlier, there are also issues with an acute shortage of experienced staff in oil and gas organizations after a couple of decades of "downsizing", followed by a boom in oil sands development which is draining manpower from all sectors. Market forces also tend to value short-term gains and rapid growth in assets or share value, over longer-term viability and sustainable growth. This puts the producers in a situation where voluntarily diverting funds to energy efficiency projects will penalize many small, share price focused companies, unless regulations level the playing field.

In the case of fugitives, another major hurdle is the lack of reliable and consistent measurement of the various vent and true fugitive streams. As these streams previously were perceived to have no value, there are few meters or measurement systems in place to quantify the losses to help justify action.

4.3 Incentives to Encourage Mitigation

The main incentives needed to encourage more rapid implementation of mitigation measures are either more regulations or incentives to invest in measurement devices and long-term investment in energy conservation technologies. This issue is not unique to upstream oil and gas as it impacts all primary energy industries where the input energy (coal, uranium or water) is assessed as having little or no book value.

5. Summary

In summary, the key issues covered in this assessment are that:

- **Definitions** - Definitions of "Fugitives" for GHG purposes, vary dramatically from definitions that have been used for other emissions, and can cause confusion and frustration to people unfamiliar with the differences.
- **Volumes** - New estimates of fugitives, prepared for CAPP, give indications of the relative size and distribution of these emissions, although as estimates they are still poor measures of actual performance in fugitive mitigation.
- **Focus on Methane** - One of the largest, and easiest to mitigate, emissions from upstream oil and gas operations are methane vent and flare streams, which contribute almost 50% of the upstream GHG emissions, 7% of Canada's emissions, and have a large and potentially growing economic value.
- **Sources** - The characteristics and properties of the emissions from each type of source and sectors must be assessed to determine the best option(s) for mitigation. However, there are a large number of options, which are already available that could be used to mitigate emissions.
- **Mitigation** - The key to mitigation is motivation, either through higher gas prices; lower capital costs, or increased regulation to encourage producers to divert resources from development to energy efficiency and conservation activities.
- **Measurement** – To allow increased management of emissions a first step is to encourage increased methods of measuring and reporting emissions.

Appendices

A. PowerPoint Presentation Materials (March 16th, 2006)