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REPORT ON AVAILABILITY, QUALITY AND QUANTITY OF MARINE FUELS SOLD IN CANADA

FINAL REPORT

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BMT DOCUMENT QUALITY CONTROL DATA SHEET

PROPOSAL/REPORT: Report on Availability, Quality and Quantity of Marine Fuels Sold in Canada

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EXECUTIVE SUMMARY

Background and Objectives

Sulphur oxides (SO_x) in engine emissions have been identified as substances of concern. These compounds can have adverse effects on humans, animals, vegetation and even on buildings. Environment Canada has been monitoring the levels of sulphur in liquid fuels refined and imported into Canada for over ten years; however, Environment Canada's inventory does not include data on the quality of fuels sold specifically to marine vessels in Canada.

The present study conducted a survey of Canadian refineries and fuel suppliers in order to fill in the knowledge gaps in this area. The report focuses on commercial ships and provides a comprehensive picture of the current sulphur levels in marine fuels (distillates and residuals), the quantities of marine fuels currently being produced and sold in Canada, and the future availability of the various grades of marine fuels at Canadian ports.

Regulatory Review

International
The *International Convention for the Prevention of Pollution from Ships*, known as MARPOL 73/78, is the main international convention covering prevention of pollution of the marine environment by ships. MARPOL Annex VI, *Regulations for the Prevention of Air Pollution from Ships*, entered into force on May 19, 2005. It applies to all ships of the flag states that have ratified the 1997 MARPOL Protocol. Additionally, the Annex VI requirements apply to ships of non-signatory states while operating in waters under the jurisdiction of parties to the 1997 Protocol.

Although Annex VI establishes a global sulphur cap of 4.5% for marine fuels, the real impact of Annex VI will be the designation of SO_x Emission Control Areas (SECAs) with more stringent fuel quality standards.

The European Union
In June 2004, the European Union (EU) Environment Council agreed to reduce SO_2 emissions from ships operating in the EU by more than 500 000 tonnes per year beginning in 2007. The greatest effect of this agreement was the decision to impose a 1.5% sulphur limit for marine fuels used by all ships in the North Sea, English Channel and Baltic Sea (aligned with MARPOL Annex VI sulphur limits within SECAs).

United States
In May 2004 the United States Environmental Protection Agency (U.S. EPA) enforced the *Clean Air Nonroad Diesel Rule*, which prescribes a two-step sulphur standard for non-road, locomotive and marine (NRLM) diesel fuels that will achieve significant SO_2 and sulphate particulate matter (PM) emission reductions. Beginning June 1, 2007, refineries will be required to produce NRLM diesel fuels with a maximum sulphur content of 500 ppm (mg/kg). The sulphur content of locomotive and marine diesel fuel will be reduced to 15 ppm (mg/kg) beginning June 1, 2012.

These regulations do not apply to the marine residual fuels typically burned by larger marine vessels/engines, since it is not possible to ensure that lower-sulphur fuels are used by ships that are able to buy fuel in other countries. Thus, in conjunction with development within Canada, the U.S. EPA is currently investigating the designation of North America (or parts thereof) as a SECA pursuant to MARPOL Annex VI.

Canada
In an international context, Canada acceded to MARPOL 73/78 in 1992, but has yet to ratify Annex VI. The *Canada Shipping Act* (CSA), currently being updated by Transport Canada, includes a new set of regulations that reflect the requirements of MARPOL Annex VI, including the recognition of SECAs.

Environment Canada's *Regulation Amending the Sulphur in Diesel Fuel Regulations* has recently come into force under the authority of the *Canadian Environmental Protection Act, 1999*. The Canadian regulations on marine diesel fuels are aligned with the U.S. EPA rules: a maximum sulphur level of 500 ppm (mg/kg) beginning in 2007, which reduces to 15 ppm (mg/kg) in 2012. As with the U.S. regulations, these do not apply to residual fuels.

The Marine Sector and Marine Fuels in Canada

The Marine Sector
Forty-one percent of Canada's international marine transportation originates from, or is destined for, the U.S. The next two largest trading areas are Europe and Asia/Oceania, both with about 20% of the share. The West Coast handles the largest amount of cargo by tonnage, closely followed by the Atlantic Provinces and Quebec. Ontario handles less cargo due partly to the seasonal restrictions of the St. Lawrence Seaway.

There are only about 450–600 Canadian-flagged, self-propelled commercial vessels with a gross registered tonnage over 500 tonnes. Most trade is carried by foreign-flagged vessels.

Marine Fuels
In Canada, historical sales of marine heavy fuel oils (residual and intermediate fuels) vary from 50% to 70% of total marine fuel sales to domestic and foreign consumers. Moreover, data from Statistics Canada indicate that the majority of marine fuel sales (distillates and heavy fuel oils) are to domestic consumers, ranging from 50% to 80% of total sales per year.

Fuel is a major expense to ship owners, since it is burned both at sea and while in port, and bunker costs range from 60% to 95% of a vessel's operating costs. Although domestic sales are fairly stable, Canadian sales to foreign ships are more variable and are subject to price volatility, since these consumers have the option to bunker at various ports along their international routes.

As residual fuels can be considered as essentially a "by-product" of the refining process, residuals sell for less than the cost of the crude oil from which they are derived. Understanding this is important to understanding how the move to low-sulphur fuels is likely to affect the supply and cost of marine fuels in the future.

Supply and Influences from Other Industries

The production and supply of marine fuels in Canada generally follow a complex path: some residual fuel produced in Canada may be transferred to the United States for additional processing before being imported back by a Canadian fuel supplier. However, the actual volume of fuel in the marine supply chain does not, at present, show any signs of a bottleneck or limit.

Fuel that is sold as "marine fuel" was often originally produced for use in a completely different market, emphasizing the fact that marine fuels are not a primary refinery product. The markets with the most influence on the marine residual fuel supply are the land-based industrial heating and power generation plants. As regulations in these markets demand higher-quality products, there will be a knock-on influence on the marine market. Similarly, as demand increases for higher-quality distillates, heavy-fuel producers may choose to increase their production of these higher-value products, thus (all other things being equal) reducing the supply of residual fuels.

Marine Fuel Quality

Canadian refineries, importers and marine fuel suppliers from across the country provided data on their 2004 fuel sales and quality. The fuel quality data presented in detail in Section 6 are reproduced here as Table 1.

Table 1: Volume-weighted Sulphur Content of Canadian Marine Fuel Sales in 2004

	Volume-weighted Average Sulphur Content (%)				
Fuel Grades	**Atlantic**	**Quebec**	**Ontario**	**Western**	**Canada**
DMA	0.125	0.226	0.489	0.145	0.207
DMB	**	0.054	0.226	0.211	0.144
Other marine distillates	0.172	**	**	**	0.224
< IFO 180	**	1.468	1.974	**	1.763
IFO 180 – IFO 380	3.632	1.306	2.230	1.666	1.819
IFO 380 – IFO 640	**	1.492	2.313	1.587	1.672
> IFO640	**	n/a	**	n/a	1.806
All Distillate Fuels	**0.144**	**0.134**	**0.313**	**0.233**	**0.201**
All Residual Fuels	**2.505**	**1.331**	**2.162**	**1.627**	**1.760**

Notes: ** Information withheld to protect confidential data
DMA = marine distillate fuel, grade A; DMB = marine distillate fuel, grade B; IFO = intermediate fuel oil, with number indicating viscocity (in centistrokes)

Comparing the above data for residual fuel quality to the global average of 2.7% sulphur content, and considering that only 5% of the global supply of heavy fuel oil (HFO) is below 1.5%, it becomes obvious that the Canadian fuels are of a much higher quality.

Should Canada implement a SECA, the current state of production suggests that Canada is in reasonably good shape to accommodate a cap of 1.5% sulphur content. This is not to imply that there would not be challenges to doing so or that there could not be changes to the longer-term availability and quality of marine fuels.

Future Availability of Low-Sulphur Fuels

Processing light crudes (< 0.7% sulphur) can produce low-sulphur (< 1.5%) residual fuels using normal refining processes. When those light crudes are unavailable, additional desulphurization processes must be introduced, which are naturally accompanied by price premiums that will be passed on to the consumer. Although predictions of such premiums are difficult to quantify accurately, estimates range from $20 to $90 per tonne depending on the fuel product.

Some of these desulphurization processes could also be accompanied by changes in the supply of marine fuels. For example, blending low-sulphur residuals (~1%) with medium-sulphur residuals (~2%) to produce SECA-compliant products is a short-term solution given the current decline in light sweet crudes. This could lead to a limited future availability of SECA-compliant products. Additionally, refiners have indicated that rather than simply desulphurizing residual fuels, which does not increase yields of higher-value distillate products, there would be a preference for combining the process with conversion and upgrading. This would increase the price premium for the low-sulphur marine residual fuels and would weaken the availability of marine HFO in general since, all things being equal, production volumes would decline.

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1 INTRODUCTION

1.1 Background

Air pollution as a result of exhaust emissions from marine vessels plays an increasing role in the total emissions from the transportation sector in Canada. Of particular concern are the emission levels of sulphur oxides (SO_x). Estimates indicate that in 2000, the marine sector accounted for 40% of the SO_x emission inventory from the entire transportation sector in Canada. As a result of current and upcoming regulations to control sulphur levels in gasoline, and in on- and off-road diesel fuels, the relative contribution from the marine sector is expected to rise to 54% by 2030.

Marine fuels are generally categorized as either residual fuels or distillates. Mixtures of these basic types, commonly termed intermediate fuel oils (IFO), also exist. Distillate fuels are those fractions of crude oil that can be separated by the refinery boiling process of distillation. The portions of the crude oil that did not boil are what are referred to as residual fuels.

Modern marine vessels are mainly powered by diesel engines. These engines have favourable fuel consumption rates compared to steam and gas turbine plants. Diesel engines are typically operated on heavier fuels that have a higher sulphur content. These engines also possess inferior criteria air contaminant (CAC) release characteristics than their steam and gas turbine plant counterparts. Since the 1973 oil crisis, crude oil has been processed to provide a maximum quantity of refined products (gasoline, diesels, kerosene and gases). This has resulted in increased concentrations of contaminants such as sulphur, ash, ashpaltenes and metals in residual, intermediate and, to some extent, marine diesel fuels.

Most large (deep-sea) vessels traversing Canadian waters operate on residual fuel oils. In its report *Setting Canadian Standards for Sulphur in Heavy and Light Fuel Oils*, Environment Canada (2003b) indicated that the average 2001 sulphur level in residuals sold in Canada was 1.7% by weight (17 280 mg/kg). By comparison, the sulphur level in on-road diesel fuel will be regulated at 0.0015% (15 mg/kg) in 2006. Worldwide, as reported to the International Maritime Organization (IMO), the average marine fuel sulphur content (distillates and residuals) has been estimated to be 2.7% (Hirst 2002).

The *Sulphur in Liquid Fuels* report, published annually by Environment Canada (Environment Canada 2002), provides sulphur levels of fuels refined in and imported into Canada; however, it does not adequately reflect the quality of fuels used in marine vessels in the Canadian market. Thus, this report sets out to expand on the *Sulphur in Liquid Fuels* report, i.e., to accurately portray the availability of the various marine fuel grades, their quality, and quantities sold. Preliminary marine fuel sales statistics exist for the year 2002 (CPPI 2005; see Figure 1.1), and this report will update and refine these statistics to reflect a 2004–2005 basis.

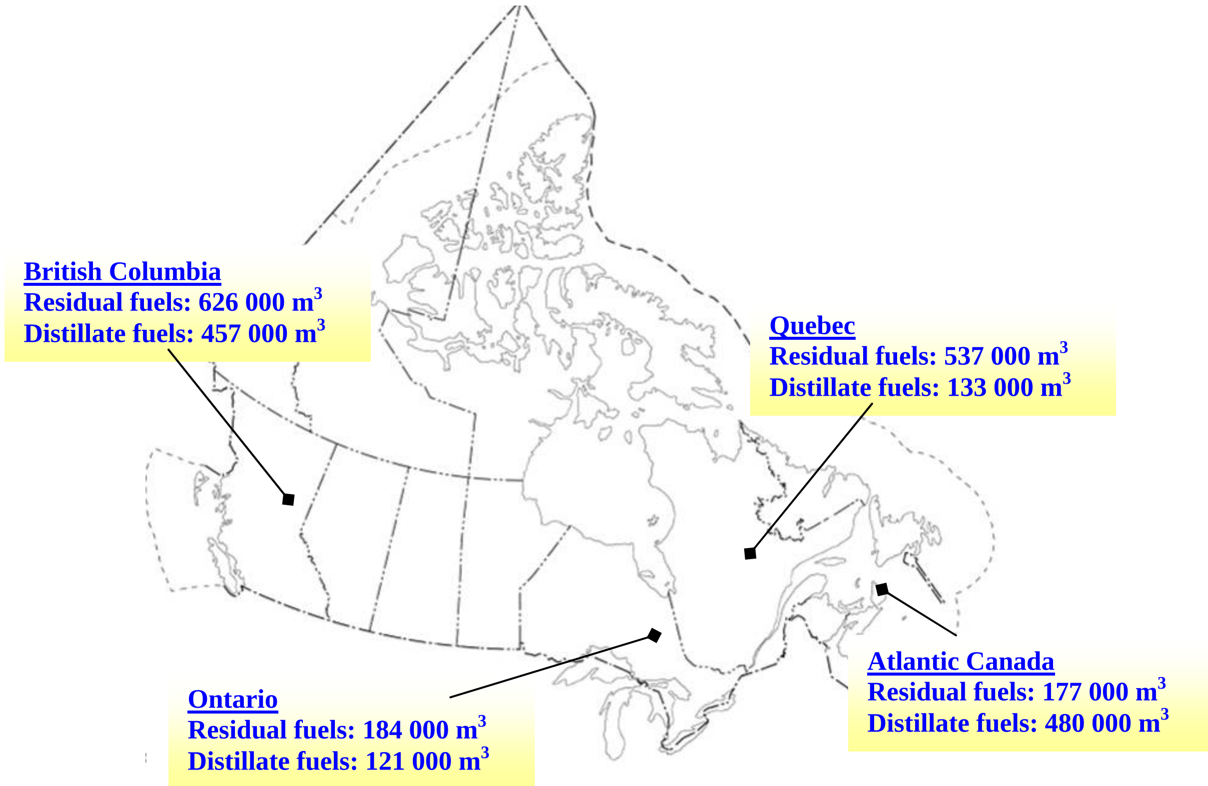

Figure 1.1: 2002 Marine Fuel Sales in Canada

1.2 Objective

The objective of this study has been to develop a comprehensive report detailing the availability, quality and quantity of marine fuels sold in the Canadian market. For the purpose of the report, marine vessels are defined as ships with compression-ignition engines rated above 37 kilowatts (kW) used for propulsion and auxiliary power production. These engines are used on commercial vessels in a variety of applications, including deep-sea vessels (freighters, tankers and other large ships normally operating offshore or in the Great Lakes), cruise ships, ferries, government vessels (i.e. Canadian Coast Guard / Fisheries and Oceans Canada and the Department of National Defence), fishing vessels and inshore workboats and tugboats.

The report will discuss various aspects of the marine fuels sold in Canada, such as, but not limited to the following:

- an overview of the various types and grades of marine fuels (distillates and residuals)
- a review of the sulphur content of marine fuels
- a review of the current and future availability of the various types and grades of marine fuels sold at Canadian ports and bunkering stations
- a review of the quantity of the various types and grades of marine fuels available

1.3 Scope

The stated objective has been achieved by an in-depth review of the Canadian marine fuel supply chain. The path from refineries to suppliers and consumers is described in detail. The quality, quantity and availability of fuels has been determined for residual and distillate marine fuel grades by regions and by bunkering ports/agents.

The scope of this study encompasses the following steps:

- determining current marine fuel supply, demand and cost
- identifying and describing the path from fuel producer/importer to consumer
- ascertaining residual and distillate marine fuel qualities by supplier and consumer demographics
- evaluating the influence of potential low-sulphur fuel regulations
- determining current and future availability of low-sulphur fuels in view of potential regulations and demand
- assessing the cost to producers and consumers

The preferred methodology employed has been of a "bottom-up" type, defining the following factors at the supplier or source-specific level:

- current and forecasted marine fuel sales
- current fuel qualities and marine fuel specifications
- current residual and distillate fuel costs
- availability of low-sulphur fuels
- upstream sources/suppliers and supply chains
- current fuel blending practices
- customer/consumer bases
- assessments of future low-sulphur marine fuel availability

Where sufficiently detailed data are unavailable, the bottom-up approach has been supplemented by a top-down approach. Fuel availability has been assessed in view of potential management options and strategies employed (at refinery and bunker agent levels) to ensure a supply of lower sulphur fuels. The cost of low-sulphur fuels will also be determined.

In co-operation with the Canadian Petroleum Products Institute (CPPI), the project team prepared questionnaires that were distributed to industry stakeholders. Two questionnaires were developed: one for refineries and importers, and the other for marine fuel agents/resellers. Examples are included in Annex A of this report.

The questionnaires requested detailed data and information on current production and sales (by grade), fuel quality (sulphur content) and blending practices. In addition, consultations with refineries and suppliers were held to identify operational changes required in order to meet future fuel standards.

When requested, confidentiality agreements were executed, describing how the project team could use the reported information from each participating organization. These agreements also outlined steps for the project team to take to ensure that information was properly safeguarded. Instructions for returning or destroying confidential information were also included. In all cases, BMT executed agreements supplied by the stakeholders, which differ from each other in some aspects and provisions. A relatively detailed example (stakeholder name deleted) is provided in Annex B.

1.4 Organization of this Report

Section 1 serves as a general introduction to the project and introduces key terminology and background information on marine fuels and marine propulsion systems. The remainder of this report is organized as follows:

- *Section 2 - Regulatory Review* assesses existing and proposed regulations controlling sulphur levels in marine fuels in Canada, the United States and the European Union. The review considers international conventions, federal/national regulations and regional (state/provincial) standards. In particular, sulphur emission control areas (pursuant to the IMO) and options for Canada to align its fuel standards to those set out by the U.S. EPA are assessed.

- *Section 3 - General Overview of the Marine Sector in Canada* provides a profile of the marine shipping industry in Canada. It includes an identification of shipping activities by region and ports according to vessel type, size, service (liner/tramp) and their demand for various grades of marine fuels.

- *Section 4 - Technical and Operating Issues* provides a brief review of any concerns the shipping industry might have related to the operation of ships on low-sulphur fuels. These concerns include assessments of fuel characteristics (e.g. density, viscosity), lubricity requirements, fuel switching practices, ship/engine impacts and associated operating and safety concerns.

- *Section 5 - Overview of Marine Fuels Sold in Canada* profiles domestic refinery processes and practices and the various grades of residual and distillate marine fuels available in the Canadian market. Major differences in fuel characteristics are assessed by grades, including assessments of crude-oil qualities. The cost associated with the various grades of fuels is provided by region and source.

- *Section 6 - Overview of Marine Fuel Quality in Canada* identifies the sulphur content in various grades of marine fuels sold in Canada. Current and historical levels of fuel qualities are assessed, and future trends are identified by regulatory options.

- *Section 7 - Canadian Marine Fuel Supply Chain* profiles the marine fuel supply industry in Canada, including refineries, importers, marketers and marine fuel retailers / bunker agents. The path from producer to consumer is identified by region, and includes assessments of current blending practices and influence of demand from consumers.

- *Section 8 - Availability of Marine Fuels Across Canada* identifies sources of supply, current and forecasted marine fuel supply/sales trends, fuel quality (sulphur content and variability), and current low-sulphur fuel availability by regions.

- *Section 9 - Future Low-Sulphur Fuel Availability and Costs* identifies marine fuel availability across Canada. Broken down by regions/ports, the analyses determine future availability of low-sulphur residual and distillate fuels. The analyses assess refinery/importer capability to provide low-sulphur fuels and the technology/practices needed to produce the required fuel of higher quality. The cost associated with reducing the sulphur content in marine fuels is also assessed.

Supporting documentation and information is provided in the Annexes, as identified and referenced throughout the report.

1.5 Clarification of Terminology for Marine Fuels

Subsequent sections of this report refer to the following marine fuel types and grades:

Table 1.1: Marine Fuel Types and Grades

Fuel Type	Example Fuel Grades	Common Industry Name
Distillate	DMX, DMA, DMB, DMC	Marine Gas Oil (MGO) or Marine Diesel Oil (MDO)
Intermediate	IFO 180, IFO 380, IFO 420	Intermediate Fuel Oil (IFO)
Residual	RMA - RML	Fuel Oil or Residual Fuel Oil

The marine industry commonly refers to distillate fuels as marine gas oil (MGO) or marine diesel oil (MDO), residual fuels as residual fuel oil, and intermediate fuels as intermediate fuel oil (IFO). In terms of land-based automobile and truck usage, “diesel fuel” is 100% distillate, whereas in the marine industry “marine diesel fuel” typically refers to a blend of distillate and residual oils. The 100% distillate fuel used in the marine industry is called MGO, which indicates that it was boiled into a gas prior to being condensed into a liquid oil. The non-boiling fractions of the crude are the residual fuel oils. Different grades of residual fuels are created by different refinery distillation processes (variations in pressure and temperature), which can result in slightly larger or smaller quantities of gas oil remaining in the non-boiling fractions. Thus it is possible to obtain intermediate grades of oil directly from the distillation process; alternatively, intermediates are made by blending residual with distillate (US EPA 1999:4).

The predominant standard for marine fuels worldwide is the International Organization for Standardization (ISO 8217). Other sources/organizations with fuel property standards include (among others) the American Society for Testing and Materials (ASTM), the International Council on Combustion Engines (CIMAC), *Platt’s Guide to Petroleum Specifications* and certain (major) petroleum refining and marketing companies (e.g. Shell and Mobil). There are standards for marine distillate fuels (DMX, DMA, DMB and DMC) and for the most widely used intermediate fuels.

DMX and DMA would normally be considered representative for MGO, while DMB and DMC would normally be considered as MDO—a heavier distillate fuel that sometimes contains a portion of residual oil. The sulphur content, viscosity and density specifications in ISO 8217 are summarized in Table 1.2.

Marine fuels employ a series of letters that identify them (1) as either distillate (D) or residual (R) fuel; (2) as a marine fuel (M); and (3) by grade (A, B, C). Thus, DMA is "marine distillate fuel A," which is the most common fuel used in small and medium compression-ignition marine engines. DMB generally comes from DMA that has picked up a limited amount of contamination during storage or transfer. DMB is not an intentionally manufactured product; as such, it is not available in all ports.

DMC may be manufactured from the heavier fractions of distillate or may be a blend of DMA and residual fuels created in marine fuel terminals. The ISO specifications list DMC as a "distillate" fuel; however, it may be considered to be an intermediate-type fuel given that the specifications allow blending with residual oil (US EPA 1999:9). The limitation on the amount of heavy fuel oil that can be blended into DMC is normally limited by the DMC viscosity specification, depending on the quality of the residual fuel used for blending.

Table 1.2: Selected ISO 8217:1996 Specifications for Marine Fuels

	MARINE FUELS						
	Distillate			Intermediate		Residual	
Characteristics	**DMX**	**DMA**	**DMB**	**DMC**	**RME/F 25**	**RMG/H 35**	**RML 55**
Density at 15°C, kg/m^3	890		900	920	991	991	1010
Kinematic viscosity, cSt, at 40°C	1.4 5.5	1.5 6	11	14	25 at 100°C	35 at 100°C	55 at 100°C
Flashpoint (°C)	43	60	60	60	60	60	60
Pour Point (°C), upper	-	-6	0	0	30	30	30
Carbon residue (%)	0.3µ	0.3µ	-	-	15/20	22	22
Ash (%), max	0.01	0.01	0.01	0.05	0.1/0.15	0.15	0.2
Water (%), max	-	-	0.3	0.3	1	1	1
Sulphur (%), max	1	1.5	2	2	5	5	5
Vanadium (mg/kg)	-	-	-	100	200/500	300/600	600
Aluminium (mg/kg)	-	-	-	25	80	80	80
Total sediment (mg/kg)	-	-	-	0.1%	0.1	0.1	0.1

International specifications identify 15 different residual fuels with individual grades designated by letters A through L, along with a number to signify the viscosity limit in centistrokes (cSt). Therefore, “Residual Marine Fuel A” with a viscosity of 10 cSt at 100°C would be codified as RMA10. IFO 180 and IFO 380 are the most common intermediate fuels, and the numbers refer to the viscosity limits at the common fuel-handling temperature of 50°C. These values are equivalent to viscosities of 25 and 35 cSt, respectively, at 100°C. Therefore, the official specification for IFO 180 is RME25 or RMF25, and that for IFO 380 is RMG35 or RMH35. As stated previously, intermediate marine fuels may be manufactured with or without blending with heavy distillates. The diversity of intermediate and residual marine fuels reflects the various properties of residuum from global crude oil sources, as well as the variety of engine design specifications (US EPA 1999).

Viscosity is traditionally the main, and often the only, characteristic quoted in the purchase of marine fuels. In addition to this property, which describes the oil’s resistance to flow, there are several physical properties important to marine fuels. As indicated in Table 1.2, these include flashpoint, density, water content, carbon residue, asphaltenes, wax, sulphur, ash, sediment by extraction, aluminium, silicon, sodium, vanadium, specific energy or calorific value, colour, sodium, additives, acids, ignition quality, stability and compatibility.

Table 1.3 provides a further description of some of the physical characteristics of marine fuels (European Commission 2002a:11–12).

Engine type dictates the type of marine fuel used on board ships. For much of the 1960s, steam turbines were the most common engine used in the marine industry. Environmental impacts were not an issue, and fuel resources were considered “infinite.” These inefficient machines were therefore widely used; they could burn low-quality, high-viscosity fuels and were relatively cheap to maintain.

With the fuel crisis of the 1970s, fuel economy had a much greater influence on machinery selection, and ship owners moved towards the use of diesel engines for main propulsion as well as auxiliary electrical power. Diesels are more sensitive to fuel quality than steam turbines. Propulsion diesels typically run on intermediate fuel oil (IFO), and diesel generators run on distillate fuels such as MDO and MGO. The reliability and economy of diesel engines is such that they are now the most common propulsive machinery used at sea, and with advances in design (such as high-pressure common fuel rail engines) they are also becoming much more environmentally friendly.

Table 1.3: Physical Properties of Marine Fuels

Property	Units	Definition	Significance
Viscosity	cSt	Resistance to flow	Amount of preheating for pumping processes. Higher viscosity means poorer ignition and combustion
Flashpoint	°C	Temperature at which vapours ignite	Minimum temperature at which vapour is produced; safety measures; the lower the value, the easier the oil ignites
Density	kg/m^3	Relation between mass and volume	Less dense bunkers provide higher energy unit/mass; prices are often quoted in $/tonne, and deliveries are measured in volume (m^3); fuel purification processes in the ship use density differential
Water content	% vol	Water content	The more water, the less calorific value in the fuel; water can cause problems in the injectors; water forms emulsion and sludge that blocks filters and interrupts the flow
Carbon residue	% wt	Carbon left after total combustion	Leads to late burning and high exhaust temperatures (damages moving parts); indicator of carbon depositing tendency and the combustion properties
Asphaltenes	% wt	High-molecular-weight hydrocarbons	Play a role in the stability and compatibility of a fuel; they are a slow-burning material
Wax	°C	Amount of wax in fuel	High-wax bunkers can not be easily pre-heated; even if high-wax bunker has good calorific value, it can cause problems for pumping and storage
Sulphur	% wt	Amount of sulphur in the fuel	Fuels with higher sulphur content tend to have lower energy content; sulphur forms corrosive acids on the engine and exhaust system
Ash, silicon, sodium, aluminium, vanadium	% wt	Inorganic material in the fuel	Residue that damages moving parts; highly abrasive material that causes engine damage; forms salts resulting in deposits
Calorific value	Cal/g MJ/kg	Heat released	The higher the number, the more energy developed per unit of fuel
Ignition quality	Cetane no.	Ease of ignition	The higher the number, the more “easily” the engines can be started
Stability	-	Phase changes	Suspension or sludge formation, incompatibility with other fuels

Traditionally, fuel choice was a matter of operational performance, but the evolving technology and price increases have recently had much influence on the selection of the bunker for a specific vessel. While in large cargo vessels there is a trend toward switching to residual fuels even to drive generators and auxiliary machinery (uni-fuel concept), other fleets (e.g. passenger vessels, fishing boats) are still constrained by the space needed for, or the engine weight penalties associated with, operation on residual fuel. Similarly, the decision on whether to burn residual fuels or distillates in cruise ships is not straightforward.

The newer generations of these vessels can be driven by compact and powerful gas turbines that can free up passenger space on board the ship. Some operators also value the perceived environmental benefits of gas turbines, which have low visible emissions. However, compared to diesel engines, gas turbines have significantly inferior fuel efficiency characteristics. Many naval vessels use gas turbines due to their high power density and fast response times.

The following table comments on the possible uses of marine distillate fuel categories.

Table 1.4: Marine Distillate Fuel Categories

ISO 8217	Type	Viscosity at 40°C (max)	Uses/Notes
DMX	MGO	5.5	Suitable for use when the ambient temperature is low. High cetane number and reduced flashpoint. Used for emergency machinery external to main machinery spaces. In the merchant marine, its use is limited to lifeboat motors and emergency generators.
DMA	MGO	6.0	High-quality distillate generally used for auxiliary engines.
DMB	MDO	11.0	Distillate mixed with some residual. Intended for use in diesel engines that are not designed for combustion of residual oil.
DMC	MDO	14.0	Higher viscosity diesel oil. Largely used by fishing fleets. Not suitable for machinery and fuel oil treatment plants that are not designed for residual fuel.

Similarly, residual marine-grade fuels are further summarized as follows:

Table 1.5: Marine Residual Fuel Categories

ISO 8217	Viscosity at 50°C (max)	Uses/Notes
RMA10 to RMB10	40	Suitable for use at low ambient temperatures in installations without preheating facilities in the storage tank, where a pour point lower than 240–300°C is necessary. RMA10 generally has the lower specific density and a minimum viscosity to improve ignition properties.
RMC10 to RMH55	40 to 700	Fuel oils requiring on board treatment/purification in ordinary purifier/clarifier extraction systems.
RMK35 to RML55	380 to 700	Fuel for use in installation with separators specially designed for the treatment of fuel oils with higher specific densities.

2 REGULATORY REVIEW

2.1 Review of Applicable Regulations Worldwide

Subsequent sections introduce existing and proposed regulations related to marine engines and marine fuel sulphur limits. Regulations are summarized by jurisdiction in Table 2.1.

Table 2.1: Marine Fuels Regulatory Summary

Jurisdiction	Key Elements	Effective Date
International (IMO)	4.5% global sulphur limit (MARPOL Annex VI)	May 19, 2005
	1.5% sulphur limit in designated SECAs	May 19, 2006
United States	500 mg/kg (ppm) sulphur limit in marine diesel	June 1, 2007
	15 mg/kg (ppm) sulphur limit in marine diesel	June 1, 2012
Canada	500 mg/kg (ppm) sulphur limit in marine diesel	June 1, 2007
	15 mg/kg (ppm) sulphur limit in marine diesel	June 1, 2012
European Union	0.2% sulphur limit for MGO/MDO	Effective
	1.5% sulphur limit in the Baltic Sea	August 11, 2006
	1.5% sulphur limit for passenger vessels to/from EU	August 11, 2006
	1.5% sulphur limit in the North Sea	August 11, 2007
	0.1% sulphur limit for inland water vessels and ships in port	Jan. 1, 2010 - Proposed

2.1.1 International Administrations

On an international scale, the *International Convention for the Prevention of Pollution from Ships*, known as MARPOL 73/78, is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978, respectively, and updated by amendments through the years. MARPOL is overseen by the International Maritime Organization (IMO), a specialized agency of the United Nations that is responsible for international shipping measures. The Treaty includes six "annexes" (Annex VI deals with air pollution from ships), which cover a number of different pollutants and/or shipboard operations that affect air quality (including NO_x, fuel oil quality, SO_x, incinerators, ozone-depleting substances and volatile organic compounds).

MARPOL Annex VI, *Regulations for the Prevention of Air Pollution from Ships*, is included within the 1997 MARPOL Protocol which was adopted by the 1997 MARPOL Conference. The Annex entered into force on May 19, 2005, having met the ratification requirement—a minimum of 15 States which control a combined merchant gross tonnage of not less than 50 percent of the world total. The Annex applies to all ships of the flag States which have ratified the 1997 MARPOL Protocol. Additionally, the Annex VI requirements also apply to ships of non-signatory States while operating in waters under the jurisdiction of parties to the 1997 Protocol. In the case of those flag States which ratify the 1997 MARPOL Protocol after the entry into force date, the Annex requirements will take effect three months from the date of their signing (American Bureau of Shipping 2005:1).

In order to limit SO_x emissions, Annex VI establishes a global sulphur fuel content cap of 4.5% for marine fuels, irrespective of fuel grade or the type of combustion machinery in which they are to be burned (IMO 2004b). In addition, Annex VI designates SO_x Emission Control Areas

(SECAs) with more stringent fuel quality standards. Since 1999, the Marine Environmental Protection Committee (MEPC) has operated a sulphur monitoring program. This has been performed in conjunction with fuel oil testing programs performed by third-party agencies (e.g. American Bureau of Shipping, Det Norske Veritas and Lloyd's Registry). To date, this has covered nearly 300 000 deliveries representing some 280 million tonnes of residual fuel oil. Results indicate that the number of instances of sulphur contents in excess of 4.5% has been negligible, and that the average sulphur content value is 2.7% (IMO 2004a; see Figure 2.1).

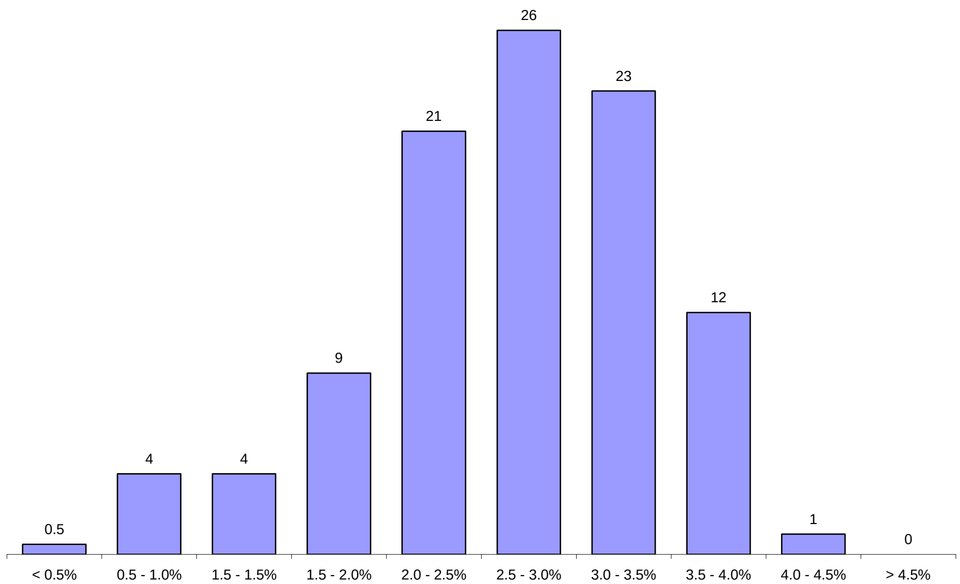

Figure 2.1: Summary of MEPC Sulphur Monitoring Program, 1999–2003 (% of Samples)

As shown by the monitoring program, the 4.5% limit does not represent any significant restriction on current fuel supplies; however, it is lower than the maximum limit currently given for most of the residual fuel oil grades in the ISO 8217 specification (see Section 1.5). Thus, the real impact of Annex VI will be within designated SECAs.

The Baltic Sea was the first area designated as a SECA pursuant to the IMO. Moreover, at MEPC 44 in March 2000, it was agreed that the North Sea (including the English Channel) had met the necessary criteria to be declared a SECA after the entry into force of the Annex.

Within a SECA, the requirement is either a maximum limit of 1.5% sulphur content in respect of all fuel oils as bunkered or the use of an exhaust gas cleaning system, or equivalent, which results in an overall emission value of 6.0 grams SO_x/kWh or less (Agren 2003a:3). In the short term, it is expected that the majority of existing ships will seek to comply with the SECA requirements by means of limiting the sulphur content of fuel oils as the primary control option. Exhaust cleaning systems are currently being tested by a small number of ship operators. In the longer term, the preferred compliance approach will depend on the costs, reliability, design and operational impacts of different control options.

Whether this will be achieved by the use of either low-sulphur residual fuel oils or gas oils (which inherently have sulphur contents below the limit value) will depend on such factors as a ship's projected operating profile, bunker tank and transfer systems, and the price differential between the various grades. In any case, the MEPC guidelines for the approval of exhaust gas cleaning systems, or alternative primary control options such as on board blending, have only just been adopted in July 2005.

The SECA requirement will not be applied to vessels operating in a SECA during the first year after the Annex VI entry into force date or, where such areas are declared after that date, the first year after their designation. Therefore, based on the Annex VI entry into force date of August 11, 2005, the Baltic SECA will take effect from August 11, 2006. The North Sea SECA was formally accepted by MEPC 53 in July 2005, and will come into force November 21, 2006 with full implementation 12 months later.

2.1.2 Regulations in the United States

In May 2004, the U.S. Environmental Protection Agency (EPA) published an "Advanced Notice of Proposed Rulemaking (ANPRM), announcing its intent to propose more stringent [NO_x and HC] emission standards for Category 1 and 2 marine diesel engines" (US EPA n.d.). Under the U.S. EPA, Category 1 and 2 marine diesel engines refer to engines with per-cylinder displacements between 2.5 and 30 litres. These engines are typically used for propulsion of smaller vessels such as tugboats, supply vessels, fishing boats and other commercial and government captive fleet vessels. They are also used as stand-alone generators for auxiliary electrical power. Category 3 engines are those with a per-cylinder displacement greater than 30 litres. These engines are typically used on board larger ocean-going vessels.

Acknowledging the need to reduce emissions beyond current standards, the ANPRM emphasized the use of advanced emission control technologies (e.g. selective catalytic reduction) on locomotive and marine diesel engines. Moreover, the U.S. EPA noted that the use of such technologies will not be feasible without changes to the fuel quality (i.e. lower levels of sulphur).

At the same time (May 2004), addressing fuel quality issues, the U.S. EPA enforced the *Clean Air Nonroad Diesel Rule* (US EPA 2004c). For historical reasons, the U.S. EPA uses the term "nonroad" while Canada (Transport Canada and Environment Canada) uses the term "off-road". The terms are considered identical herein. The final rule prescribes a two-step sulphur standard for non-road, locomotive and marine (NRLM) diesel fuels that will achieve significant SO_2 and sulphate particulate matter emission reductions, removing 99% of the sulphur in diesel fuels by 2010 (US EPA 2004a,b).

Beginning June 1, 2007, refineries will be required to produce NRLM diesel fuels with a maximum sulphur content of 500 ppm (mg/kg). Then, beginning June 1, 2010, the sulphur content will be reduced to a maximum of 15 ppm (mg/kg) for non-road diesels. The sulphur content of locomotive and marine diesel fuel will be reduced to 15 ppm (mg/kg) beginning June 1, 2012 (US EPA 2004b).

These regulations do not apply to the marine residual fuels typically burned by larger marine vessels/engines (US EPA 2003c:ES-2). Fuel controls are only for marine distillate fuels burned by Category 1 and Category 2 engines; these include engines used to provide propulsion power on coastal and inland water vessels and as stand-alone generators for auxiliary electrical power on many types of vessels.

Through extensive option assessments and regulatory analysis, the U.S. EPA concluded that refineries can feasibly meet the 500 ppm (mg/kg) and 15 ppm (mg/kg) sulphur cap standards for NRLM diesel fuels. The U.S. EPA projects that refineries will use conventional desulphurization technology for complying with the 2008 standard, which is the same technology currently used to produce 500 ppm (mg/kg) sulphur highway diesel fuels. Drawing on the experience gained from the 1993 highway sulphur standard, the 2007 deadline is perceived to offer refineries sufficient lead time for compliance. To comply with the 15 ppm (mg/kg) sulphur caps, refineries will be able to use the experience gained from complying with the comparative highway diesel fuel standard which takes effect in 2006 US EPA 2004b:ES-6).

With regard to the residual fuels used by Category 3 engines, the U.S. EPA is concerned that "regulating fuels sold in the U.S. will not necessarily ensure that lower-sulphur fuel is used in U.S. waters, since ships could purchase their fuel in other countries" (US EPA 2003a:9751) Thus, in conjunction with development within Canada, the U.S. EPA is currently investigating the designation of North America (or parts thereof) as a SECA pursuant to the international (IMO) process for consumption of lower-sulphur residuals.

In addition to the federal EPA, several states have looked at their own cleaner fuels regulations, with California and Alaska showing the most progress. The California Air Resource Board (CARB) has implemented a number of programs that are aimed at, or include, marine vessels. Within the context of the present study, California enacted legislation (Bill 2135, August 2000) wherein all passenger ferries carrying more than 75 passengers must use on-road diesel (< 500 ppm) after January 31, 2002. Aligned with the U.S. EPA's non-road fuel regulations, CARB is also investigating future amendments that will require the use of ultra-low sulphur fuel, i.e., < 15 ppm (Genesis Engineering 2003:90; Esplin 2002).

In Alaska, a voluntary agreement between the State and oil tanker operators (Polar Tankers Inc and Phillips Petroleum Corp.) ensures that vessels operate on very-low-sulphur bunker (< 0.5%) while entering or alongside the port of Valdez.

2.1.3 Regulations in Canada

Transport Canada: The *Canada Shipping Act* (CSA), administered by Transport Canada, provides authority to regulate ship stack emissions. The *Regulations Respecting Air Pollution from Ships*, adopted under the CSA, establishes smoke density limits on "any fuel burning installation on a ship". However, these regulations are of limited applicability since they are only applicable within one mile of shore (Melious 2004:50).

In an international context, Canada acceded to MARPOL 73/78 in 1992, but has yet to ratify Annex VI. Through its "regulatory reform project," Transport Canada is currently updating the existing CSA, to be called the *Canada Shipping Act, 2001* (CSA 2001), which includes bringing into force a new set of regulations by 2006. Under the proposed "Regulations for the Prevention of Pollution from Vessels and for Dangerous Chemicals, Division 6 - Air", the CSA 2001 reflects the requirements of MARPOL Annex VI, i.e., a 4.5% sulphur cap on fuel and the adoption of the IMO NO_x standards (Transport Canada 2004:82–86).

As such, Canadian regulations will be aligned with the international context. Recognizing the IMO designation of SECAs, the CSA 2001 includes requirements for Canadian flagged vessels operating within such designated control areas.

Annex VI regulations are adopted in full, recognizing exhaust gas cleaning systems as an alternative to low-sulphur (1.5%) fuel; any exhaust gas cleaning system (e.g. seawater scrubber) will require approval by the Minister of Transport. The Minister will also be responsible for approving criteria for possible waste stream discharges into enclosed ports, harbours and estuaries.

Environment Canada: The *Canadian Environmental Protection Act* (CEPA), administered by Environment Canada, was extensively revised in 1999 (CEPA 1999) to "contribute to sustainable development through pollution prevention and to protect the environment, human life and health from the risks associated with toxic substances" (Environment Canada n.d.).

In February 2001, the federal government published a comprehensive 10-year Federal Agenda on Cleaner Vehicles, Engines and Fuels (the Federal Agenda) in the *Canada Gazette*. As part of this federal agenda, Environment Canada is developing regulations under CEPA 1999 that align Canadian emission standards for a broad range of on-road and off-road vehicles and engines with those of the U.S. EPA (and to some extent, standards developed in the European Union) (Canada 2002). For instance, Part 7 of CEPA 1999 contains powers to regulate emissions from fuels (Division 4), and vehicles and engines (Division 5). These emissions regulations are aligned with U.S. EPA rules. It should be noted however, that these regulations do not apply to marine vehicles or engines (Canada 1999). Emissions from marine engines are regulated through the *Canada Shipping Act*.

Similarly, in May 2004, Environment Canada published the *Off-Road Compression-Ignition Engine Emission Regulations* (Canada 2004a), which introduce exhaust gas emission standards for diesel engines used in off-road applications, e.g., construction, mining, farming and forestry machines. The Regulations establish Canadian emission standards aligned with the U.S. EPA rules for non-road diesel engines. However, diesel engines (greater than 37 kW or 50 hp) installed in marine vessels are excluded.

The Regulations apply to engines of the 2006 and later model year, and encompass the U.S. EPA Tier 2 and Tier 3 standards for off-road engines. Environment Canada also considers maintaining alignment with the U.S. EPA Tier 4 (2008) rules for off-road diesel engines (Canada 2004a). Recognizing that Tier 4 off-road diesel engine emission standards will not be feasible without accompanying fuel changes, Environment Canada (2003a) issued a discussion paper in August 2003 regarding the reduction of sulphur in Canadian off-road diesel fuel. In contrast to the above regulations, these fuel standards encompass marine diesel fuels (see further discussion following).

A set of proposed regulations were published in the *Canada Gazette* in October 2004 (Canada 2004b). The *Regulation Amending the Sulphur in Diesel Fuel Regulations* has since come into force under the authority provided by sections 140 and 330 of CEPA 1999. Key elements related to marine diesel fuels include the following:

- As of June 1, 2007, sulphur in off-road, rail and marine diesel fuels that are produced or imported for use or sale in Canada will be limited to a maximum of 500 mg/kg.
- As of October 1, 2007, sulphur in off-road, rail and marine diesel fuels that are sold or offered for sale in Canada will be limited to a maximum of 500 mg/kg.
- As of June 1, 2012, sulphur in off-road rail and marine diesel fuels that are produced or imported for use or sale in Canada will be limited to a maximum of 15 mg/kg; diesel fuel that is sold or offered for sale in locomotives or marine vessels will remain subject to the 500 mg/kg sales limit.

The Canadian regulations on marine diesel fuels are aligned with the U.S. EPA *Clean Air Nonroad Diesel Rule*, setting a maximum sulphur level of 500 ppm (mg/kg) in 2007. The second step takes effect in 2012, when the sulphur limit is further reduced to 15 ppm (mg/kg). It should be noted however, that (after 2012) diesel fuel *produced* or *imported* for use in locomotives and marine vessels is subject to the 15 ppm (mg/kg) limit, whereas the *sale* of diesel fuel for these uses is subject to a 500-mg/kg limit. The difference is because contamination of some diesel fuel will occur in the distribution system, and a sales outlet for such volumes is needed.

Considering the general introduction to marine fuels in Section 1.5, it is useful to clarify which marine diesels are covered by the sulphur standards. The basic approach is that the standard applies to any diesel fuel used or intended for use in marine diesel engines. However, marine diesel engines can use a wide variety of fuels, ranging from No. 1 and No. 2 diesel to residual and residual fuel blends, which are used in the largest engines. The new standards are not intended to cover all such fuels, and *residual fuels (all RM grades) are not subject to the sulphur standards*.

Canadian regulations are fully harmonized with the U.S. EPA standards. Comparing the regulations with ISO 8217 classifications for marine fuels, it becomes clear that *the regulations apply to all DMX and DMA fuel grades*. As previously discussed, DMB grades are allowed to have a trace of residual fuel, which can be high in sulphur. This contamination with residual fuel usually occurs due to the distribution process, when distillate is brought on board a vessel via a barge that has previously contained residual fuel, or using the same supply lines as are used for residual fuel. DMB is produced when fuels such as DMA are brought on board the vessel in this manner. The regulations apply to the distillate that is used to produce the DMB, for example the DMA distillate, up to the point that it becomes DMB. *However, DMB itself is not subject to the sulphur standards*.

DMC is a grade of marine fuel that may contain some residual fuel and is often a residual fuel blend. It is produced by blending a distillate fuel with residual fuel, for example at a location downstream in the distribution system. The regulations apply to the distillate that is used to produce the DMC, up to the point that it is blended with the residual fuel to produce DMC. *However, DMC itself is not subject to the sulphur standards* (US EPA 2004c:39041).

2.1.4 The European Union

The main regulation affecting emissions from seagoing ships in the EU is *Directive 1999/32/EC* on the sulphur content of liquid fuel oils. This directive requires member states to ensure that marine gas oils[1] used within their territory do not exceed a prescribed 0.2% sulphur limit (Commission to the European Parliament 2002a). It requires that member states ensure that if ships are using distillate fuels in the Community (territorial waters, including seas 12 nautical miles from shore and inland waterways), the sulphur content of those marine distillate fuels must be 0.2% or less. The directive also sets sulphur limits for inland heavy fuel oils and gas oils, whereas marine heavy fuel oils are regulated by IMO regulations.

In other words, ships must ensure that if they are using distillate fuels, the sulphur content of those fuels must be within the prescribed limit. However, provisions with regard to the sulphur content of marine residual fuels are limited. It has been suggested that this omission has accelerated the pre-existing trend towards “unifuel” operation on heavy fuel oil at all times in the interests of economy. Thus, since November 2002, the European Commission has devoted significant effort to developing amendments to the 1999 Directive in an effort to reduce ships’ emissions of sulphur dioxide and particulate matter (Commission to the European Parliament 2002b).

Political agreement was reached in June 2004, when the environment ministers of the 25 member states agreed on the European Commission’s proposed amendments to the existing Directive.

In summary, the Environment Council agreed “to reduce ships’ SO_2 emissions in the EU by over 500 000 tonnes per year from 2007, with reductions targeted to deliver the greatest possible benefits around populated ports and coasts and in acid-sensitive ecosystems” (EUROPA 2004). The main provisions of the 2004 agreement included amendments to the 1999 Directive as follows:

- a 1.5% sulphur limit for marine fuels used by all ships in the North Sea, English Channel and Baltic Sea (aligned with MARPOL Annex VI sulphur limits within SECAs)
- a 1.5% sulphur limit for marine fuels used by passenger vessels on regular services to or from any Community port (aimed to improve air quality around ports and coasts, and create sufficient demand to ensure an EU-wide supply of low-sulphur fuel) (Agren 2003b:4)

[1] In the Directive, marine gas oils are defined to include all marine distillates fuels: DMX and DMA grades, which are known as MGO, but also DMB and DMC grades, which are known as MDO

- a 0.2% sulphur limit on all marine fuel (not just distillate fuels) used by inland vessels and by seagoing ships at berth in EU ports. A tighter 0.1% limit (initially proposed for January 2008) was delayed until January 2010 to allow single-fuel ships time to adapt their fuel tanks.

With regard to monitoring and enforcement, "Member States shall take all necessary measures to ensure that marine fuels are not used in the areas of their territorial seas, exclusive economic zones and pollution control zones falling within SO_x Emission Control Areas if the sulphur content of those fuels exceeds 1.5% by mass. This shall apply to vessels of all flags, including vessels whose journey began outside the Community" (Council of the European Union 2004:13). Member states are also responsible for enforcing marine fuel limits, at least in respect of (i) vessels flying their own flag; and (ii) in the case of member states bordering SECAs, vessels of all flags while in their ports. The same applies to the passenger vessel regulation, which requires that member states enforce the 1.5% standard for vessels flying their flags and for all vessels of all other flags while in their ports. Member states will require the correct completion of ships' logbooks, including fuel-changeover operations, as a condition of ships' entry into Community ports.

Moreover, they will ensure that the sulphur content of all marine fuels sold in their territory is documented by the supplier in a bunker delivery note, accompanied by a sealed sample, and they will ensure that marine diesel fuels (distillates) are not placed on the market in their territory if the sulphur content exceeds 1.5% (Council of the European Union 2004:14). Directive 1999/32/EC is enforceable upon fuel users. It does not apply directly to suppliers, meaning that distillates with higher sulphur grades (up to 1.5%) can be, and are, still made available at ports throughout Europe (European Commission 2002b:75).

Effective January 1, 2010, Member States will take all necessary steps to ensure that the following vessels do not use marine fuels with a sulphur content exceeding 0.1%:

- inland waterway vessels
- ships at berth in Community ports, allowing sufficient time for the crew to complete any necessary switch from, or to, other fuels as soon as possible after arrival at berth and as late as possible before departure

However, the 0.1% regulation does not apply in the following situations:

- whenever, according to published timetables, ships are due to be at berth for less than two hours
- to inland waterway vessels that carry a SOLAS 1974 certificate, while those vessels are at sea

As an alternative to using low-sulphur marine fuels, member states may allow ships to use approved abatement technologies, provided that these ships:

- achieve emissions reductions that are (at least) equivalent to those that would be achieved through the fuel sulphur limits specified; and
- document thoroughly that any waste streams discharged into enclosed ports, harbours and estuaries have no impact on ecosystems, based on criteria communicated by authorities of port states to the IMO (Council of the European Union 2004:17).

2.2 Identification of Impact on Domestic Industries

The various regulations above will affect the refinery and fuel supply sub-sectors as well as the domestic and international shipping industry.

As discussed in greater detail in subsequent sections, the off-road low-sulphur rule will likely keep distillate supplies tight (Purvin & Gertz 2004:II-6). As refineries are required to meet the various low-sulphur fuel specifications for on-road diesel (2006), off-road diesel (2007), and possibly furnace oil (2010), some refineries have indicated that they do not plan to make any changes in their distillate production. Others, though, have plans to reduce production, particularly of furnace fuel oil, as they implement the low-sulphur steps (Purvin & Gertz 2004:III-8).

As municipal and provincial authorities reduce the maximum allowable sulphur content in the heavy fuel oils used in land applications (such as industrial, institutional and power generation uses), the tendency will be for more low-sulphur HFO to flow towards these markets. The natural assumption is that, all things being equal, more of the higher-sulphur HFO will be steered towards the marine and export markets.

Whereas production of high-quality products (gasoline, jet fuel, etc.) will increase according to demand, lower-quality diesel (furnace fuel oil, marine diesel, etc.) production will stagnate and possibly decline as capital investments required to produce lower-sulphur products will be used to produce incremental gasoline as a result of the change in production (see Section 5). These forecasts consider the shutdown of Petro-Canada's Oakville refinery (the high costs of converting the Oakville refinery to produce low-sulphur fuels resulted in a decision to close the refinery and to bring in supplies from Quebec).

As derived from assessments in Europe, the supply of low-sulphur (< 1.5%) residual fuels could be achieved in two branches. These include increased blending practices and, subsequently, investments in refinery facilities for desulphurization of the residual fuels. The costs of production of low-sulphur residual fuels will likely increase with the amount of bunkers produced.

At low levels of production, costs will be relatively low, as there is likely to be some flexibility within the current refinery production to free up some low-sulphur bunkers. As production increases in view of regulations and this flexibility is fully utilized, refinery investments will be needed to desulphurize the residual blending components to meet the higher demand for low-sulphur bunkers. The amount of required investments will depend on crude-oil runs, existing facilities and the current quality of marine residuals produced (varying by region and refinery across Canada). At present, Canada appears to be well-positioned to meet a sulphur limit of 1.5% for residual fuels given the current national average of 1.76%. These data are presented and discussed further in Section 6.

As indicated by some refineries, the large investments needed to desulphurize will likely result in significantly tighter supply; economic justification stipulates that refineries will combine desulphurization with increased conversion of residues to lighter products. Refinery processes for desulphurization of residual fuels are expensive due to the nature of the feedstock involved, and the costs of these processes are far too high to justify construction of such a plant only to convert high-sulphur residue to low-sulphur residue (European Commission 2002a:7–8). Accordingly, some domestic refineries indicate that a SECA would require significant import of compliant low-sulphur fuels.

Lower-sulphur distillate and residual marine fuels will fetch a significantly higher price. The availability and cost of domestic fuel supply is provided in detail in subsequent sections, noting here that global bunker studies have indicated potential price premiums ranging from $30 to $130 per tonne of low-sulphur marine fuel. Premiums will vary by fuel type and demand.

Depending on how the regulations are implemented (domestic and international), the price premiums could change bunker supply competitiveness. Because of the substantial contribution that fuel costs make to the overall expense of ship operations, decisions regarding when and where to bunker are made with close attention to relative fuel prices at different ports. Due to relatively large fuel storage capacities, deep-sea vessels have considerable flexibility in their scheduling of obtaining bunker. This is particularly true for ships on liner trades. In view of the new regulations, domestic fuel sales to foreign ships could decrease, since these ships could source cheaper fuel elsewhere; however, sales could increase as more SECAs come into force globally given the relatively low sulphur content of current Canadian residual fuels (1.76% vs. 2.7% globally). It is assumed that fuel sales to the captive domestic fleet would remain relatively unchanged. Changes in sales patterns will depend on the regulatory regime adopted in the U.S. and, for residual fuels, internationally.

In addition to increased fuel costs, ship owners/operators have raised concerns related to operation and safety (fuel compatibility, lubricity, etc.) and fuel availability. These technical and operating issues are further described in Section 4.

2.3 Jurisdictional Assessment and Impact

Formally codified in 1982, the United Nations Convention on the Law of the Sea (UNCLOS)[2] is the most significant "source" from which to determine national administrations' jurisdictional scope for establishing marine vessel air emissions regimes. UNCLOS "entails the predominance of international rules and standards over national regulations…in respect of standard-setting and enforcement measures relating to pollution from vessels" (Rosenne and Yankov 1991:13). Under the Convention, states operate in three capacities: flag, port and coastal states.

- **Flag states**: In international customary maritime law, it is incumbent upon any state which allows the registration of vessels under its flag to effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag. The flag state is required to take such measures for ships flying its flag as are necessary to ensure safety at sea with regard to construction, maintenance, seaworthiness, manning, labour conditions and crew training, among others.

  Specifically in relation to the monitoring of condition of vessels under the flag, such measures shall include those necessary to ensure that each ship is appropriately surveyed as to construction, design, equipment and manning (CDEM). Article 94.5 of UNCLOS then imposes a duty on flag states to take any steps that may be necessary to secure observance with "generally accepted international rules and standards" (GAIRAS). With regard to air pollution, this is achieved by the flag state's authority to impose MARPOL Annex VI.

The roles of the other jurisdictions, "while growing, have traditionally been more limited" (Davies et al. 2000:13). The authority of non-flag states to regulate shipping and emissions is summarized as follows (Harrison et al. 2004:3; Hare 1994):

- **Port states**: UNCLOS guarantees port states the right to establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for entry of foreign vessels into their ports or internal waters. In addition, the Convention gives a port state the authority to control emissions in port through the right of the state to exclude vessels from its ports or place conditions upon their entry.

- **Coastal states**: A state having a coastline is entitled under international law to take certain limited steps to protect its own interests. UNCLOS recognizes four main zones of varying jurisdiction: (i) internal waters (bays, ports and similar enclosed areas of the sea); (ii) territorial waters (extending 12 miles to seaward of defined "baselines" along the shore); (iii) a contiguous zone (covering the territorial waters and a further 12 miles to seaward); and (iv) the exclusive economic zone (EEZ, extending to 200 miles). A coastal state's powers range from full sovereign powers within internal waters, to rights limited to the exploitation of natural resources on and beyond the EEZ. There are limitations on the seemingly wide power of the coastal state. First, Article 94.5 of UNCLOS imposes an obligation on inspecting authorities to conform to GAIRAS. Second, there must be no

[2] Available at http://www.un.org/Depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm

discrimination against any one state by another (Article 227). Third, the state must not violate one of the cornerstones of international maritime law: the right of merchant ships to innocent passage across the seas.

All states have the right of free passage of their ships through the high seas, the continental shelf zone and the EEZ. A similar right is enjoyed for the outer 12 miles of the contiguous zone. In the territorial sea, the sovereignty of the coastal state is subject to the right of innocent passage by foreign ships (Article 24).

Innocent passage is defined by UNCLOS as navigation through the territorial sea whether or not actually entering internal waters or calling at a port facility. To be innocent, a ship's passage must not be prejudicial to the peace, good order or security of the coastal state. But international law, through Article 21, allows states specific powers to adopt laws and regulations in conformity with international laws which limit the right of innocent passage through the territorial sea (though by implication therefore not beyond the EEZ). They may thus regulate maritime traffic; protect navigational aids, cables and pipelines; conserve living resources and generally protect the environment; prevent, reduce or control pollution; and prevent the infringement of customs, fiscal or immigration laws.

States may not, however, impose conditions relating to construction, design, equipment or manning (CDEM) of foreign ships unless they are giving effect to GAIRAS. And they must give due publicity to measures being taken by them to enable foreign ships to comply.

As far as pollution is concerned, Article 211 sets out the state's authority: "in the exercise of their sovereignty within their territorial sea, [coastal states may] adopt laws and regulations for the prevention, reduction and control of marine pollution", provided they do not hamper the right of innocent passage of foreign vessels. They may include the EEZ in these measures, provided they conform to and give effect to GAIRAS.

Considering the provisions under UNCLOS, SO_x emissions from international shipping is best controlled through implementation of GAIRAS. MARPOL Annex VI is considered GAIRAS, and designating Canada as a SECA would lead to cost-effective reductions of SO_x (and to some extent, particulate matter) emissions in Canadian waters (BMT 2005). As discussed in Section 2.1.1 of this report, a SECA designation pursuant to IMO would apply to all ships (international and domestic), reducing the sulphur content in all fuels consumed to below 1.5% from a worldwide average of about 2.7%. If the planned applications to designate Canada (and the U.S.) as SECA(s) were rejected, the administration would face numerous challenges in order to convince international stakeholders that an alternative clean fuel regulation could be regarded as imposing emission, rather than CDEM, rules and standards.

Although a regulation could, potentially, be regarded as an emission standard (argued on the ground that there is a direct correlation between sulphur content and emissions and that the emissions standard can be met simply by burning low-sulphur fuel), recent experience with Bill C-15 (the *Migratory Birds Convention Act, 1994*) indicates that regulations that go beyond

GAIRAS/UNCLOS will face fierce opposition from the international shipping community. As such, the U.S. EPA has indicated that it will control emissions from foreign-flagged ships through regulations pursuant to the IMO.

Considering the captive fleet and ships that trade across international boundaries, Environment Canada's *Regulations Amending the Sulphur in Diesel Fuel Regulations* will effectively reduce SO_x emissions from domestically flagged vessels. By limiting the rule to diesel fuel suppliers, not consumers, CEPA 1999 provides legal authority to enforce such a rule. Moreover, consultations with industry indicate that the refinery and fuel supply industry is supportive of regulations that limit the sulphur content in marine distillates.

3 GENERAL OVERVIEW OF THE MARINE SECTOR IN CANADA

3.1 Makeup of the Marine Sector

The world's ships can be divided into five general categories based on the cargo the ships carry and the type of work performed by the vessel. The first category is tankers, which includes oil tankers, chemical tankers and liquefied gas carriers. While other categories of ships contain more ships by number, the size of the tankers, particularly the supertankers (VLCC and ULCC),[3] cause the vessels to make up 35% of the world's total ships by tonnage. The second category of ships is the bulk cargo ships, which are designed to hold large amounts of loose cargo such as grain and coal. These ships make up 7% of the total ships by number and 29% of the ships by tonnage. The third category includes container and Ro-Ro (roll-on, roll-off) ships, which are cargo ships designed to carry their cargos in large packed containers or on wheels. This category of ships includes 23% of the ships by number and 16% of the ships by tonnage. The fourth category of the ships is fishing vessels, which includes both fishing and mobile fish processing units. A considerable number of these ships exist. There are over 23 000 "high seas" units in the world, accounting for 28% of the world's ships by number; however, they account for only 2% by tonnage because of the small average size of these vessels. The fifth category consists of the remainder of the ships, including tugs, icebreakers, scientific research vessels, ferries and cruise ships (Johnson 2001).

While it may seem at first glance a straightforward exercise to quantify vessel movements taking place within a defined marine area over a given period of time, or the number of visits to ports within that area, this is generally not the case. One problem in a Canadian (nation-wide) context is the lack of comprehensive or comparable data readily available from port authorities, pilotage authorities and governmental sources/agencies. However, subsequent sections provide a brief profile of international and domestic trade, by region, across Canada.

3.1.1 International Trade

Figure 3.1 shows the share of international trade for 2002 to various regions worldwide. Results are based on the cargo tonnage imported and exported to various ports across Canada. As indicated, the majority of international marine transportation (41%) originates from, or is destined to, the U.S. (mostly on the East Coast and the Great Lakes). Other large trading areas include Europe (20%, mostly from Ontario, Quebec and the Atlantic Provinces) and Asia/Oceania (20%, mostly from West Coast ports). Moreover, Figure 3.2 indicates the distribution of cargo handled (loaded and unloaded) at various regions across Canada. The West Coast handles the largest amount of tonnage, closely followed by the Atlantic Provinces and Quebec. Ontario handles less cargo due to the seasonal restrictions of the St. Lawrence Seaway and their knock-on effects on marine trade patterns (Statistics Canada 2004a).

Although the West Coast, Quebec and the Atlantic Provinces handle (close to) the same amount of international cargo, the level of shipping activities varies significantly. Whereas the West

[3] VLCC: Very Large Crude Carrier, and ULCC: Ultra Large Crude Carrier

Coast handles a lot of containers (volume-specific shipping), ports in eastern Canada handle mostly dry and liquid bulk cargoes (mass-specific shipping). Thus, the level of shipping activities is significantly higher on the West Coast (see Figure 3.3), i.e., there are more port calls (vessel movements) per unit tonnage.

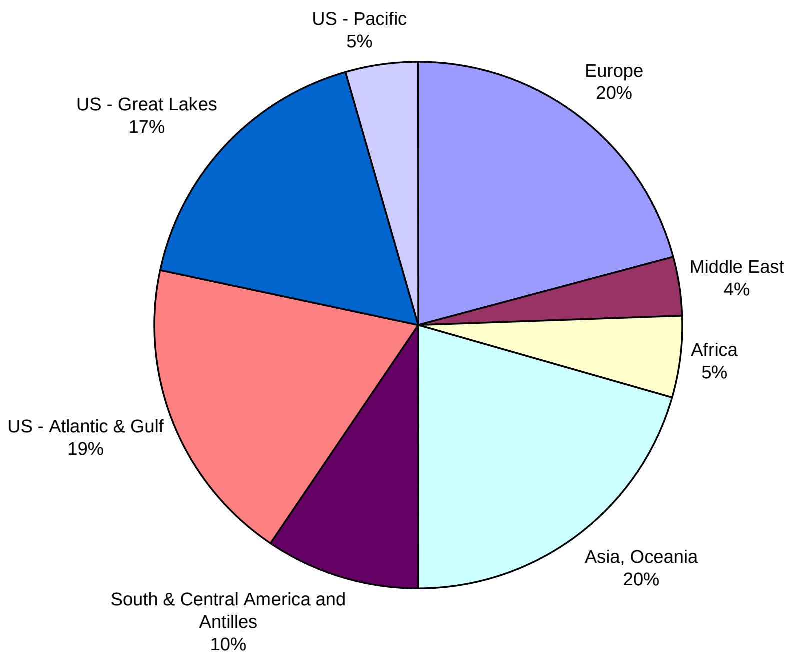

Figure 3.1: International Shipping for 2002, by Tonnage and Foreign Region (from Statistics Canada 2004a)

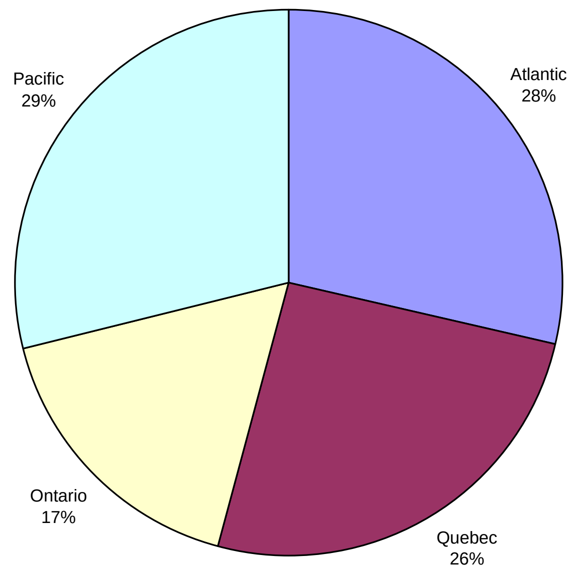

Figure 3.2: International Shipping, by Tonnage and Canadian Region (from Statistics Canada 2004a)

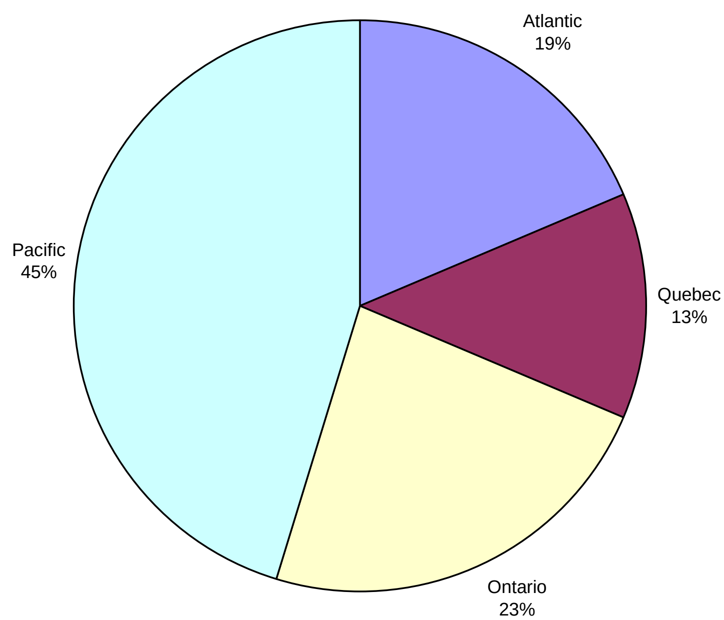

Figure 3.3: International Shipping Movements, by Region (from Statistics Canada 2004a)

Figure 3.3 indicates that the West Coast experiences (at least) 45% of the international shipping movements (port calls) in Canada. In particular, the Port of Vancouver handles close to half of all container ship movements in Canada (liner trades). Moreover, due to export of coal, grain and wood products, the amount of bulk carrier traffic in Pacific ports is significant (tramp trade). Other measurable trades include imports of automobiles, export of sulphur and potash, and trade of fuel oils and chemicals. Table 3.1 provides a summary of major commodities traded across

Canada, by region. Results are presented in descending order on a tonnage basis, and they cover internationally traded (exported and imported) commodities only.

Table 3.1: Internationally Traded Commodities, by Region (from Statistics Canada 2004a)

Western	Ontario	Quebec	Atlantic
Coal (E)	Coal (I)	Iron ore/concentrates (E)	Crude petroleum (I)
Grains (E)	Iron ore/concentrates (I)	Crude petroleum (I)	Crude petroleum (E)
Sulphur (E)	Stone/sand/gravel (E)	Alumina (I)	Gasoline/jet fuel (E)
Potash (E)	Salt (E)	Grains (E)	Minerals (E)
Wood/forest products (E)	Limestone (I)	Bauxite (I)	Fuel oils (E)

Notes: (E) denotes export
(I) denotes import

Table 3.2 provides an overview of which vessel types make up the international shipping sector in Canada. It is based on the amount and type of cargo handled at Canadian ports, the number of annual ship arrivals (by type) at major ports (Vancouver, Hamilton, Montréal, Halifax and St. John's), vessel visitation frequencies, and liner shipping and tramp trade patterns. Results are presented by region and indicate the share of vessel arrivals by ship type, i.e., in 2004, 30% of all commercial cargo ship visits to western region ports were performed by container ships.

Table 3.2: Vessel Arrivals by Region and Ship Type (from Statistics Canada 2004a)

Type / Region	Container	Bulk Carrier	Dry Cargo	Tanker	Other
Atlantic	18.4%	14.8%	8.5%	55.7%	2.7%
Quebec	23.1%	42.2%	6.3%	20.7%	7.6%
Ontario	6.8%	76.4%	1.4%	5.7%	9.7%
Western	30.1%	37.3%	10.9%	6.6%	15.0%

Results in Table 3.2 omit passenger vessels (ferries and cruise ships) that travel internationally (mostly between Canada and the U.S.). Passenger traffic is port specific, and including these types of vessels would significantly skew the regional breakdowns. For example, due to passenger ferry services between British Columbia and Washington State, the port of Victoria has 4–5 port calls daily from "international" ferries (1800 movements per year). The same applies to passenger and short sea-shipping routes across the Great Lakes, and passenger services between Nova Scotia and Maine.

Container ships usually trade on a liner basis and typically operate with a 35-day turnaround time for Pacific services. In the western region, container ships will generally visit two or three ports in the Far East and then cross the Pacific to call at both the Vancouver and Seattle port authorities. Typically, individual vessels from the same company will make these trips, usually under a contract of affreightment or (occasionally) on a spot charter basis. Deep-sea container ships are relatively large units (deadweight capacities ranging from 30 000 to 60 000+ tonnes), with high service speeds and significant propulsion powers (20 000 to 60 000+ kW). Feeder ships, providing domestic and coastal services, are smaller units that distribute the cargo between major hubs and smaller ports.

Bulk commodities (coal, grains, iron ores, sulphur, potash, etc.) are typically carried on a "one ship, one cargo" basis, generally using *bulk carriers*. They usually operate on a time charter or spot charter basis, and go directly from Canadian ports to their destination port. Where trade flows are predictable—servicing a steel mill, for example—fleets of ships exist for the specific trade. Some shipping companies (especially in the western region) also run bulk shipping services geared to the transport of special cargos such as forest products. Ships employed for such trades are typically referred to as *dry cargo* ships, and operate on semi-liner/assigned trading routes. For trades such as grain, where the quantities and routes are unpredictable, tonnage is drawn from the tramp market. Bulk carriers and dry cargo ships vary significantly in size, capability and performance.

Tankers comprise three types of vessels: (i) chemical tankers to load methanol and similar products, (ii) product tankers for imports and exports of refined products, and (iii) crude-oil tankers. Whereas chemical and product tankers are relatively small units that trade on a semi-liner basis or under long-term charter agreements, crude-oil carrier operations are similar to that of bulk carriers (i.e. tramp market or time charter operations). As above, the various tanker categories vary significantly in size, capability and performance.

Other ships refer to specialized cargo vessels such as reefers, car carries (roll-on, roll-off), combination (ore-bulk-oil), offshore, and fishing vessels and miscellaneous tonnage that cannot easily be grouped into the above categories.

3.1.2 Domestic Trade

Table 3.3 indicates the share of intraprovincial marine transportation and the trade between provinces. Results are derived from the total tonnage transported per year, and show that most goods (on a tonnage basis) are transported within the Atlantic Provinces (due to Newfoundland's offshore oil fields) and between various ports in British Columbia (due to transportation of wood chips, logs and other forest products). The greatest share of interprovincial transportation occurs between Quebec and Ontario, indicating the significance of the Great Lakes bulk carrier fleet.

Table 3.3: Domestic Transported Tonnage (%), by Origin and Destination (from Statistics Canada 2004a)

From \ To	Atlantic	Quebec	Ontario	Western
Atlantic	29%	5%	1%	0%
Quebec	1%	7%	10%	0%
Ontario	0%	7%	14%	0%
Western	0%	0%	0%	25%

The major commodities traded are crude petroleum, wood and forest products, various grains, and fuel oils. Commodities are transported by numerous types of ships, including tankers, bulk carriers, dry cargo ships and a significant number of barges.

According to the Canadian Ship Registry (Transport Canada 2005), there are approximately 3000 Canadian flagged commercial vessels/barges with a gross registered tonnage over 500 tonnes. The majority of the registered units are barges, with only 15–20% of the total being self-propelled commercial vessels. Barges are mainly designed to carry various types of dry and liquid bulk cargoes. However, the number of specialty barges has been slowly increasing over the last decade. For example, barges are being converted to carry rolling freight for short sea shipping services. Of the self-propelled commercial vessels, the majority are registered as ferries, bulk carriers (Great Lakes fleet), fishing vessels, dry cargo and tankers. The number of container ships, Ro-Ro (roll-on, roll-off), and other specialty ships is very limited.

The majority of domestic transportation in the western region is provided by tug and barges. Great Lakes trade and transportation between Ontario and Quebec is mainly conducted by bulk carriers and tankers registered in the two provinces, supplemented by tug and barge operations. Within the Atlantic Provinces, the majority of trade is performed by various types of tankers (crude, product and chemical), shuttle tankers and other specialty cargo ships.

3.2 Overview of Fuels Sold to the Marine Sector

Marine fuels were introduced in Section 1.5, broken down by distillate and residual oils, and providing international standards and specifications for fuels supplied to commercial shipping. Based on these definitions, the following provides a brief overview of marine fuels sold worldwide and across Canada. Additional details on Canadian sales are provided in Section 5.

In 2001, the world marine bunker market was estimated at 140 million tonnes per year. With more than 25 million tonnes of sales, the U.S. is the world's leading country regarding bunker sales. Over the 1990–1999 period, world bunker sales grew at an average of 3.4% per year. However, they only reached their previous record (1973) volume sales figure 0f 126 million tonnes in 1997 (European Commission 2002a:31).

Heavy fuel oils (residual and intermediate fuels) constitute the majority of the marine bunkers sold worldwide. In 2001, the market share of sales of HFO was 80%, declining from 89% in the early 1970s as a result of an increasing share of smaller types of vessels and the fact that modern engines are less constrained by the type of fuel they burn.

In Canada, historical sales of marine fuels indicate that the market share of sales of HFO varies from 50% to 70% of total marine fuel sales to domestic and foreign consumers (Statistics Canada n.d.; see Figure 3.4). Moreover, data from Statistics Canada (n.d.) indicate that the majority of marine fuel sales (distillates and heavy fuel oils) are to domestic consumers, ranging from 50% to 80% of total sales per year (see Figure 3.5). Domestic marine sales indicated below cover sales of marine fuels to ships of Canadian registry (flag), including commercial fishing vessels. However, domestic figures exclude sales to Canadian Coast Guard / Fisheries and Ocean Canada (CCG/DFO) and Department of National Defence (DND) ships, all of which run on diesel distillates.

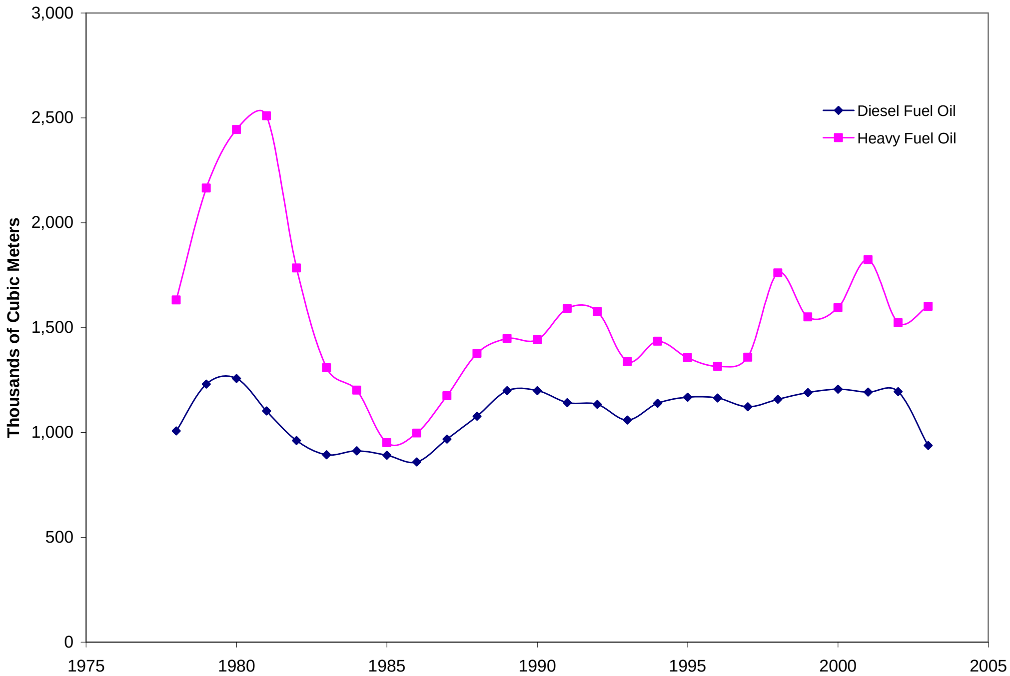

Figure 3.4: Historical Marine Fuel Sales in Canada, by Grade (1978–2003)

Whereas total domestic sales are fairly stable, varying between 1 500 000 and 2 000 000 cubic meters per year since 1979 (except for "peaks" in 1980–1981), sales to foreign ship owners are more variable and are subject to price volatility. Foreign consumers have the option to bunker at various ports along their international routes; in addition to product quality and availability, the port and the bunker price are major determinants when selecting a place to bunker. Fuel is a major expense item for a ship owner. It is both burned at sea and while in port, and bunker costs range from 60% to 95% of the vessel's operating costs (international context), the higher end of the range being more typical of old Very Large Crude Carriers (VLCC) with fuel-inefficient engines. Thus, when prices in Canada are high, foreign consumers choose to bunker elsewhere. Figure 3.5 indicates a decrease in foreign sales since 2001, reflecting the higher price for fuel at Canadian ports compared to alternative bunker locations such as Rotterdam and Singapore (see Section 5.5).

From 2002 to 2003, sales in Canada to foreign ships fell by 48% for marine diesel and 42% for marine heavy fuel oils. Whereas the western region saw a sharp decrease in marine diesel sales (86%), the sale of heavier products fell by only 20%. In eastern Canada (Quebec and the Atlantic Provinces) the opposite took place, with foreign heavy fuel oil sales plummeting by 80% and 89%, and marine diesel fuel sales decreasing by 47% and 15%, respectively. Overall, Quebec experienced the largest loss of foreign marine fuel sales—a total reduction of 78%. Conversely, total sales to foreign consumers increased by 25% in Ontario. However, due to the relatively low level of international shipping in the Great Lakes, the foreign sales figures are small compared to the other regions in Canada. Moreover, due to the draft/loading restrictions of the Seaway system, ships often opt to arrive to the Great Lakes with limited amount of bunker on board; i.e., operators are willing to pay the higher Canadian fuel price so that they can transport greater amounts of cargo into the Great Lakes.

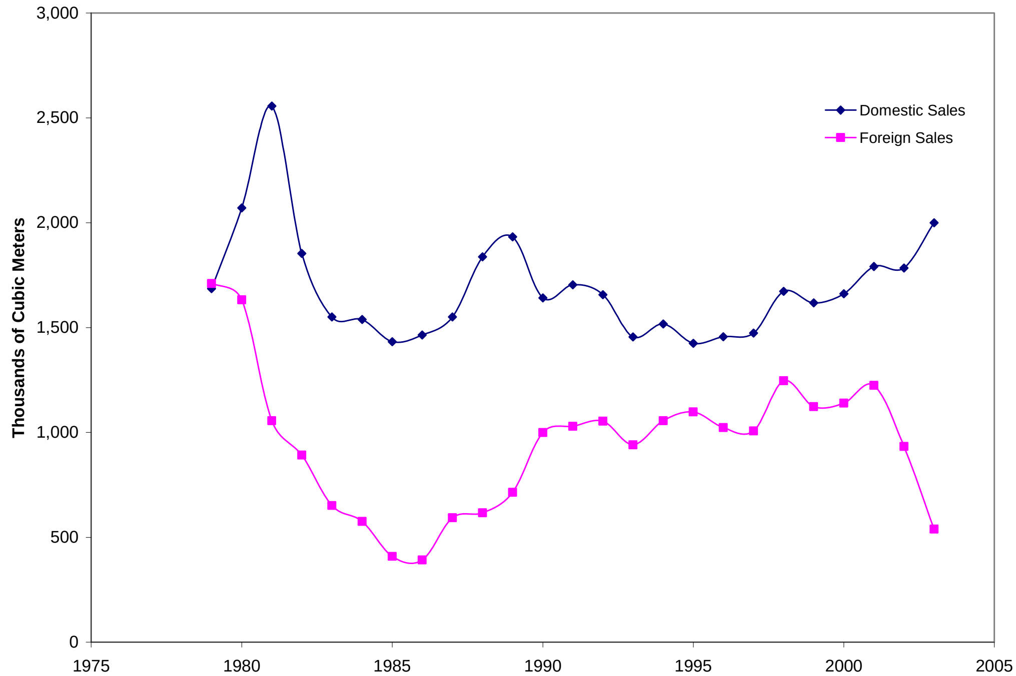

Figure 3.5: Marine Fuels Sales in Canada, by Consumer Base (1979–2003)

Table 3.4 provides an overview (by region) of typical characteristics of the various qualities of marine fuel supplied throughout Canada. Values presented are based on sampling performed by Det Norske Veritas (DnV) in 2004, and are presented on a sampling rather than a volume-averaged basis. Additional assessments of fuel quality and sulphur contents are presented in Section 6.

Table 3.4: Characteristics of Marine Fuels Sold in Canada for 2004[4]

	Density [kg/m^3]	cSt at 50°C	Sulphur [%]	Ash [%]	Vanadium [mg/kg]	Energy [MJ/kg]
Heavy Fuel Oils						
Western Canada	981.94	283.77	1.73	0.05	67.85	40.71
Ontario	982.74	310.43	1.82	0.03	61.62	40.67
Quebec	981.62	343.74	1.31	0.03	51.97	40.87
Atlantic	983.83	367.72	2.31	0.04	96.26	40.48
Diesel Fuels						
Western Canada	864.78	3.66	0.28	n/a	n/a	42.74
Ontario	n/a	n/a	n/a	n/a	n/a	n/a
Quebec	865.08	3.17	0.22	n/a	n/a	42.78
Atlantic	854.35	3.04	0.20	n/a	n/a	42.93

Comparing the above characteristics to ISO 8217 standards (Table 1.2), results indicate that the majority of distillates sold in Canada are of DMX and DMA quality. Similarly, the majority of

[4] Data provided by Det Norske Veritas.

heavy fuel oils sold in Canada are IFO 380 (RMG/H 35), whereas IFO 180 (RME/F 25) is provided in lower volume at selected ports according to demand.

3.3 Overview of Major Environmental Concerns

Throughout a vessel's life cycle there are a great many environmental drivers that should be considered. Environmental concerns relate to construction, operation and disposal; however, only operational concerns will be discussed in this report. Construction and disposal activities fall outside the scope of this study, and focus will be on environmental concerns related to operation, and on air emissions in particular. During the operation of a marine vessel, there are many broad areas of potential concern, including:

- energy use and air emissions
- antifouling coatings
- ballast water
- discharges

Since the last three items on this list are outside of the scope of this project they will only be briefly mentioned in the interest of providing a complete picture of the environmental concerns that relate to ship operations.

Energy and air emissions are currently the primary focus, worldwide, relating to shipping and the environment. Today's merchant fleet, unlike the sailing fleet of just 150 years ago, exclusively burns fossil fuel to propel itself. For the last 70 years, this fuel has been predominantly oil, and burning it in engines, turbines and boilers creates significant levels of criteria air contaminant emissions. Modern ships are typically powered by diesel engines (see Table 3.5), and noxious emissions arise as most of the marine fuels burned are residual and intermediate fuels.

Table 3.5: Global Engine Profile

Machinery Type	No. of Ships	%
Slow-speed diesel	56 628	65.7%
Medium-speed diesel	27 758	32.2%
Steam/gas turbine	1820	2.1%
Total	**86 208**	**100%**

Steam vessels have significantly higher fuel consumption than diesel engines; consequently, the proportion of steam vessels is small and is declining. Steam vessels tend to use the lowest grade of residual fuel, with a typical nominal viscosity of 500 cSt. However, the remaining steam vessels tend to be large tankers, where steam propulsion has remained popular as it also provides a power source for running cargo pumps while in port. Thus, steam-propelled vessels burning low-grade fuel are still significant users of low-grade fuel and potentially create a high level of in-port pollution. There are still a few steam-driven naval ships, but this is attributable to the higher average age of naval vessels and the perceived need for a low acoustic signature that is better for rotating (turbines) rather than reciprocating (diesel) machines.

Sulphur is naturally present in liquid and solid fuels such as oil and coal. Most marine fuels contain sulphur. The combustion of fuels containing sulphur gives rise to emissions of sulphur oxides (SO_x) and particulate matter, including primary soot particles and secondary inorganic sulphate particles formed as a result of atmospheric oxidations of SO_2. Nitrogen oxides (NO_x) are also emitted when fuels are burned, both as a result of incomplete combustion and, to a lesser extent, the nitrogen content of the fuel (Commission to the European Parliament 2002b).

SO_2 emissions can damage human health and the built environment, contribute to acidification, and damage sensitive ecosystems. Particulate matter (PM) emissions can damage human health. NO_x emissions contribute to acidification and to the formation of ground-level ozone, which can harm human health and vegetation. Both short-term and long-term exposure to air pollutants gives rise to health impacts in terms of effects on mortality and on morbidity (illness, including exacerbation of asthma, increased incidence of bronchitis and heart failure).

Antifouling coatings constitute another area of environmental concern. The use of TBT (tributyltin) paint is now being phased out following legislation by the IMO, which has outlawed its use by 2008; this in response to the assessment of its impact on aquatic organisms. Hence, paint manufacturers are now developing alternatives.

It has been argued (Abbott et al. 2000) that while eliminating the use of TBT will allow certain areas of the marine ecology to recover, the ban may adversely affect other areas of the environment. This is mainly because of the possible increase in the use of fossil fuel by shipping due to the replacement antifouling coatings not being as effective at providing a self-polishing underwater hull. Any reduction in underwater hull smoothness will reduce the hull efficiency through the water, thus increasing fuel consumption.

Moreover, little is currently known and published about the possible effects on the marine environment of the alternative compounds that are now being used. Most of the compounds being proposed are organic booster biocides, which are highly toxic when used to kill agricultural pests (Evans et al. 2000). As ship hull fouling is liable to increase with the phasing out of TBT, a problem that may increase is the introduction of non-native marine life that is transported on the fouled hull. It is often thought that the main method of introducing invasive species to a region is through ballast water, but research indicates that a fouled hull can be a significant vector (Ridley and Hutchinson 2004).

Ballast water is currently an environmental driver of significant concern in North America. It has been suggested that there have been thousands of non-indigenous species (NIS) introduced into North America over the past hundred years. International shipping has provided a vector for some of these invasions. Some have been intentional, such as food or for pest control, and some unintentional, as in the case of ballast discharge. In particular, the waters of the Great Lakes and the St. Lawrence have unintentionally become the new habitats for several species.

In 1995, the number of NIS in the Great Lakes was counted at 139, with the most notable being the zebra muscle and the ruffie. The economic cost of ballast water–related introductions to

North America is estimated in the billions of dollars, and the ecological impacts are not yet fully understood.

Discharges cover the intentional and accidental discharges of oil, oily water, sewage, and garbage and solid waste. Although major oil spills make the headlines, oil generally enters the marine environment through more frequent minor oil spills and the intentional discharge of oil. Ship-related operational discharges of oil include the discharge of bilge water from machinery spaces, fuel oil sludge, and oily ballast water.

Before international regulations were introduced to prevent oil pollution from ships, the normal practice for oil tankers was to wash out the cargo tanks with water and then pump the resulting mixture of oil and water into the sea. Also, oil cargo or fuel tanks were used for ballast water and, consequently, oil was discharged into the sea when tankers flushed out the oil-contaminated ballast water to replace it with new oil. When ships discharge oily water, they release a toxic mix of oil, nutrients and other pollutants into the marine environment. Many of these pollutants dissipate over time. However, the amount of traffic in some shipping areas and the level of enclosure in many ports worldwide allow the contaminants to accumulate.

4 TECHNICAL AND OPERATING ISSUES

The following section provides a brief overview of issues raised from an operating perspective. It is based on consultations with domestic ship owners/operators[5] and a review of published literature on issues related to international regulations and operation on low-sulphur fuel.

4.1 Regulatory Concerns

With respect to regulations, the major concerns are mainly logistical and relate to operation within a SECA (or equivalent control area). In view of SECA designations, there will be ships that will never enter, or alternatively never leave, the controlled area. For the latter, the situation will be relatively straightforward; they will have to meet the prescribed sulphur limit without exception.

4.1.1 Ship Operating Concerns

The complication arises for ships that burn residual fuel and operate, or may operate, for only a portion of their time within a SECA. Outside the SECA, such ships will utilize fuel oils of sulphur content typically around 2.0–3.5% (see Figure 2.1). Once inside the SECA, however, they will have to burn fuel with, at most, 1.5% sulphur. In these instances, it will be necessary for those ships to have both a segregated bunker capacity and the means to change to the lower-sulphur fuel prior to entry into a SECA (American Bureau of Shipping 2005:9).

The effect of this changeover requirement will differ from ship to ship, but certainly, it can be seen that some ships will require a substantial capacity for segregated low-sulphur fuel oil. Installing extra tanks is a potential solution for new builds. However, installing new tanks is significantly more problematic for existing ships where the space would come at the expense of cutting into the cargo holds or other revenue-generating spaces. On larger vessels, such as oil tankers, while it may be technically feasible, the loss of cargo capacity is a significant cost issue for commercial vessels and is described as the "cardinal sin" by builders and operators.

In those instances, ship owners will need to consider their options prior to the entry into force of these requirements (August 2006 in the Baltic Sea) and take the necessary steps to arrange for the necessary subdivision or addition and segregation of bunker, settling, and service tanks; the relative sizes of each of these tanks; and the associated transfer and service piping systems. Ships burning residual fuel oil that intend to enter a SECA, but that do not have the capability for two segregated fuel oil grades, will thus need to operate continuously on lower-sulphur fuel oils.

The principal direct cost of splitting tanks would be the installation of extra pipes, including vents, filling points, gauges and maintenance hatch access, as well as the significant costs of testing the tanks. There would be indirect costs associated with more frequent refuelling stops (and reduced flexibility in sourcing cheap bunkers), in addition to the higher cost of the low-sulphur fuels.

[5] The following ship owners/operators provided guidance to the project: *Seaway Marine Transportation, Anglo Eastern Ship Management, Fednav International, and Diesel Injection Sales and Service.*

For an existing vessel, the installation of new tanks could potentially be considered as a “major conversion” as well. When an existing vessel undergoes what is considered to be a major conversion, it is reclassified as a new ship and must be upgraded to the specifications required of new ships under all relevant international conventions. Thus, unless exemption was granted by the flag state, the costs of installing extra fuel tanks could be increased significantly.

Considering dual-fuel storage and use, MARPOL Annex VI Regulation 14 (IMO 2002) states: “Those ships using separate fuel oils to comply with paragraph [(4)(a)] of this regulation shall allow sufficient time for the fuel oil service system to be fully flushed of all fuels exceeding 1.5% m/m sulphur content prior to entry into SO_x emission control areas.”

This flushing time can range from one to six days depending on the engine size, day tank volume, and the fuel supply system (Skjolsvik 2004_. Thus, in order to comply with the regulations, operators on short-haul or feeder trades will need to assess in detail the feasibility of dual-fuel operation. For example, switchover during a voyage between two SECAs in close proximity (e.g. Canada and Europe) would not be a realistic option if the switchover time approaches 6 days (i.e. close to the duration of the voyage). Again, these issues are more significant for tramp ship operators than liner trade ships.

4.1.2 Fuel Sourcing Concerns

Another important concern relates to fuel availability at ports outside the controlled area(s); even with segregated fuel oil tanks, operators might not be able to load compliant (low-sulphur) fuels at ports outside the SECA(s). Limited availability of compliant fuels in the non-SECA ports might require additional port calls in order to bunker lower-sulphur products. In turn, this will lead to increased travel time between ports, delays, and increased operating expenses.

Compliant products could be loaded and carried when departing from a SECA for consumption upon re-entry to a SECA. However, this will impact vessel routing and, potentially, the client base. In particular, due to uncertainties related to routing, operation and the next consignment, it may not be feasible for ships on tramp trade to carry redundant low-sulphur fuel in the event that the next port of call will be in a controlled area.

As more SECAs are implemented there will be an increased call for sweet crudes by the refineries that supply these SECAs in order to meet the demand for low-sulphur marine fuels. All other things being equal, this will reduce the availability of sweet crudes in non-SECA regions, and will quite likely have an impact on the price of these crudes and the resulting fuels.

Internationally, increasing economic growth will bring about a demand for more fuels and require that these be environmentally cleaner fuels. As more crude is produced to meet demand, refineries will be forced to rely more on sour crudes; thus the HFO that comes from this production will have incrementally higher sulphur content as the supply of sweet crude is either diverted (to SECAs) or depleted. This could lead to an increase in the price differential between low- and high-sulphur HFO.

Canadian synthetic crude, the majority of current production, does not yield black oil for HFO production. Unless the crude that comes from the Atlantic offshore can meet the national demand for residual products, Canada could well find that the quality of its import supply is reduced as more SECAs are implemented outside of North America.

There are also seasonal fluctuations in the quality of the crude and resulting HFO that could have an effect on the availability of low-sulphur fuel. In summer, many refineries will source heavier crude in order to produce asphalt for the road construction industry, thus affecting the availability of low-sulphur HFO for the marine sector. Conversely, shipping through the St Lawrence Seaway that closes during the winter reduces the direct demand for marine fuels from refineries in Ontario (Purvin & Gertz 2003). The crude being used at these refineries would likely be lighter in winter to better meet the regulations for land-based heating oil. Thus, Ontario refineries could have a (relative) surplus of higher-quality HFO during winter.

The preceding is a very simplistic scenario, and it is unlikely that refiners would resort to stockpiling their higher-value products, but it does illustrate the seasonal fluctuations in fuel oil quality. Fortunately, for ships operating year-round in Canadian waters there are no significant additional fuel-related operating concerns that stem from cold weather, mostly because the HFO needs to be heated in order to flow regardless of the outside air temperature.

4.2 Safety and Operating Concerns

Historical shipping practice for vessels entering ports for manoeuvres was to operate on a different fuel, often distillates. The advantage of this was more reliable engine control with the diesel fuel and less general degradation of the engines. More recently, the trend has changed to maintaining use of residuals throughout the operation—the “uni-fuel” concept.

Advances in engine technology and improved fuels have made this a more feasible option for shipping operators. A significant number of ships currently being built have the capacity to switch to distillates for the purposes of starting engines as well as manoeuvring in port (European Commission 2002b), and issues surrounding low-sulphur fuels may support this approach. There are however, a number of technical challenges and potential problems that need to be taken into account (Walker 2003).

Switching over from HFO to low-sulphur HFO or MDO can lead to thermal shock of fuel system components. For example, low-speed diesel-engine fuel pump bodies are large pieces of metal designed to contain the extreme pressures of fuel injection. Introducing diesel or gas oil at 40°C into a fuel system operating on HFO at temperatures close to 140°C (to lower viscosity) can cause components to crack and fail. Alternatively, the high-temperature components can cause the gas oil to boil. In turn, this causes the system to gas up, resulting in the loss of engine power and thus manoeuvrability (Walker 2003).

Moreover, injecting diesel or gas oil (with a lower flashpoint than HFO) into preheated engine components could likely lead to accidental combustion, engine failures and possibly engine room fires.

Possible loss of power can also result from shipboard fuel-blending practices. These practices can be deliberate, as in the case of diluting residual fuels with distillates or other components in storage or settling tanks, or accidental, as sometimes occurs in fuel lines and pumps during switchover. Dilution of a thermally cracked residue with a concentration of a paraffinic diluent such as gas oil can result in unstable fuels.

Consequently, it is necessary to ensure that the aromaticity of any diluent is high enough to keep the asphaltenes dispersed. Unfortunately this often leads to other problems, as fuels with high aromaticity often have poor ignition and combustion properties. Mixing even two stable fuel oils can result in a product with a low stability reserve. This means that even small variations in temperature (e.g. from changing external conditions) will cause fuel coagulation or heavy sludge formation, leading to clogging of fuel separators and filters. This can lead in turn to choking off of the fuel supply and engine shutdown (MARTOB 2004).

4.3 Technical and Operating Issues

A number of issues in running an engine on low-sulphur fuels are related to lubrication. Lubricating oils contain calcium, which protects the engine from fuel emissions from heavy fuel oil by neutralizing acidic emissions such as those from high-sulphur fuel grades. If the fuel supply changes to a low-sulphur distillate, the distillate will not neutralize the calcium content of the lube oil, resulting in white calcious deposits on the cylinder rings. This in turn will cause scuffing of the cylinders and tearing of the cylinder liners. There would therefore be a need to install an extra cylinder oil tank. It is unlikely that this would be too great a space issue in larger vessels, but could be problematic for smaller ships depending on the available space in the engine room and its original design (European Commission 2002b; Wärtsilä 2005). There are obviously costs that would be incurred in such a process, as well as an increase in the complexity of safe operations of the engines.

Lubricity is an estimate of a fuel’s ability to protect systems against wear. Sulphur is a naturally lubricating trace element; removal of this element leads to bore-polish and subsequently hampers the creation of the necessary oil film on the liner surface, eventually resulting in accelerated wear. Wear can lead to fuel pump leakage, reducing fuel line pressure and leading to ignition delays and poor engine timing. All of these result in low engine performance. At the opposite end of the spectrum, use of high base number (BN) cylinder lubricating oils can result in over-lubrication, leading to cylinder liner lacquering and scuffing (MAN B&W Diesel A/S 2005).

Thus, the lack of lubricity in low-sulphur fuels might require retrofitting of engine components, such as anti-polishing rings, and adjustment or modification of fuel systems (pre-heaters, fuel lines, separators, etc.) to account for fuel viscosity changes and lowered flashpoints.

Based on the issues raised above, ships with continuous or long-term operation within SECA(s) will face numerous technical issues related to dual fuel/lube oil storage (possibly conversions), fuel/lube oil switchover, machinery retrofits, and flushing and fuel mixing/blending. Moreover, additional training of crew will be required. For example, the bunkering of two grades of distillate will require different operational procedures than those currently in place, requiring personnel to ensure that the correct fuel is bunkered in the correct tanks according to sulphur content (which is distinct from ISO 8217 grade) as opposed to all distillates being bunkered in the same tanks. This will require a degree of retraining on behalf of the personnel responsible for bunkering operations and raises the possibilities of human error in terms of ensuring that the correct fuels are bunkered in the appropriate tanks. Clear marking to distinguish between low- and high-sulphur distillates may also be required.

Considering vessel operations, the major concerns relate to fuel availability and cost. As described in Section 4.1, the limited availability of compliant fuels at non-SECA ports is a major concern. Moreover, for ships visiting SECAs infrequently, the operators are concerned about the costs required to bring an existing fleet of ships into compliance with low-sulphur fuel regulations; retrofitting is required to be able to operate on dual fuels. The increased cost of low-sulphur fuels (see Section 5.3) is also a concern. Depending on the frequency of visits to controlled areas, and the amount of time spent traversing these areas, the premium related to operation on distillates and/or low-sulphur residuals compared to conventional bunkers can significantly increase the annual operating budget. While the overall effect of increased cost of operation on compliant products may be substantial, a regulation will not affect the bottom line of vessels trading exclusively within a given SECA; i.e., the costs will be felt by all the parties involved, and there will be a tumble-down effect with distribution of costs to the end user. However, concerns arise for international shipping, as the cost of trading between SECA and non-SECA ports could pose a competitive disadvantage for vessels trading exclusively outside controlled areas.

There are various other significant, though less important, issues involved in changing fuel quality and grade. Higher-quality fuels tend to provide savings in fuel consumption and maintenance efforts. The typical heat value for MDO is about 42 MJ/kg, while for HFO it is about 40 MJ/kg (see Table 3.4). In theory, this difference could represent a reduction in fuel consumption of approximately 5% (Croner 2002). Furthermore, diesel oil properties of a lower viscosity and less particle content leads to reduced friction in the engine's moving parts, which in turn leads to reduced fuel consumption and lower maintenance for pistons, separators, turbochargers, fuel valves and exhaust valves.

Other benefits of burning MDO relate to a reduced volume of sludge, longer service intervals between overhauls, reduced lube oil consumption and better working environments. The volume of sludge (e.g. waste products, sediments, oil residues and water from the separators, settling tanks, scavenging air installations) is heavily dependent on fuel quality; higher-quality fuels result in reduced volumes of sludge. In addition to less "wasted" fuel (sludge), the reduction in sludge volumes leads to a better working environment, less labour on board and reduced costs of transferring the sludge to a waste reception facility.

A switch to MDO will also lead to better conditions for, and a reduction in, cleaning labour. The properties of diesel oil, such as the lower viscosity and reduced particle content, is such that it is possible to reduce the quantity of detergent and to use less strong, more environmentally friendly detergents. This applies to all oil handling equipment, such as separators, pumps, filters and heaters. Moreover, a lower release of soot and particles leads to reduced cleaning efforts of decks, superstructure and machinery accessories.

5 OVERVIEW OF MARINE FUELS SOLD IN CANADA

5.1 General

Crude oil consists of hydrocarbons or molecules made up of carbon and hydrogen atoms. These hydrocarbons vary in length according to the number of carbon atoms in the chain. In order to produce economically viable and profitable products, the hydrocarbon chains are separated by length through the refining process. This transforms crude oil into a variety of petroleum products that can be used for fuels, petrochemical feed stocks, lubricants and asphalt. Simply stated, petroleum refining combines distillation processes (separation into various fractions) with other processing operations that alter the molecular structure of hydrocarbons.

Crude oils typically contain 35% to 50% (by weight) of residuals that remain after distillation of the crude oil at atmospheric conditions, which is the first processing step in almost all refineries. However, as Canadian demand for lighter products has grown and overall heavy fuel oil demand has declined, heavy fuel oil demand for both marine and land-based uses now represents less than 10% of the overall Canadian market (CPPI 2005; see Figure 5.1). Canadian refineries are configured primarily to meet the demands of the Canadian and the very similar U.S. markets. Therefore, they must utilize a variety of refining methods to generate a product mix tailored to demand.

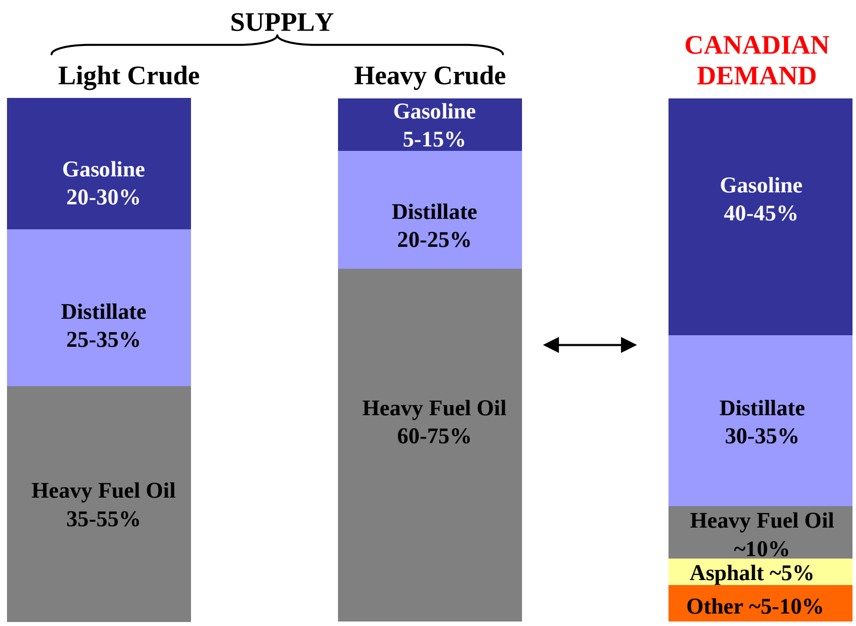

Figure 5.1: Crude Oil Types vs. Domestic Demand

5.2 Refining Processes

A typical oil refining process can be seen in Figure 5.2.[6] Stages of different separations are used to slowly isolate and purify each different length of hydrocarbons (Favennec 2001:199–122). Once separated, these constituents can be converted through catalytic cracking, coking and visbreaking processes. These larger fractions, in turn, can be reformed or combined to produce higher-value molecules of similar or larger size. Treating processes can remove undesirable impurities such as sulphur, nitrogen and oxygen through hydrodesulphurization, hydrotreating, chemical sweetening and acid gas removal. The shorter-chain-length fuels are the most valuable products (e.g. gasoline, propane, jet fuel and liquefied petroleum gases).

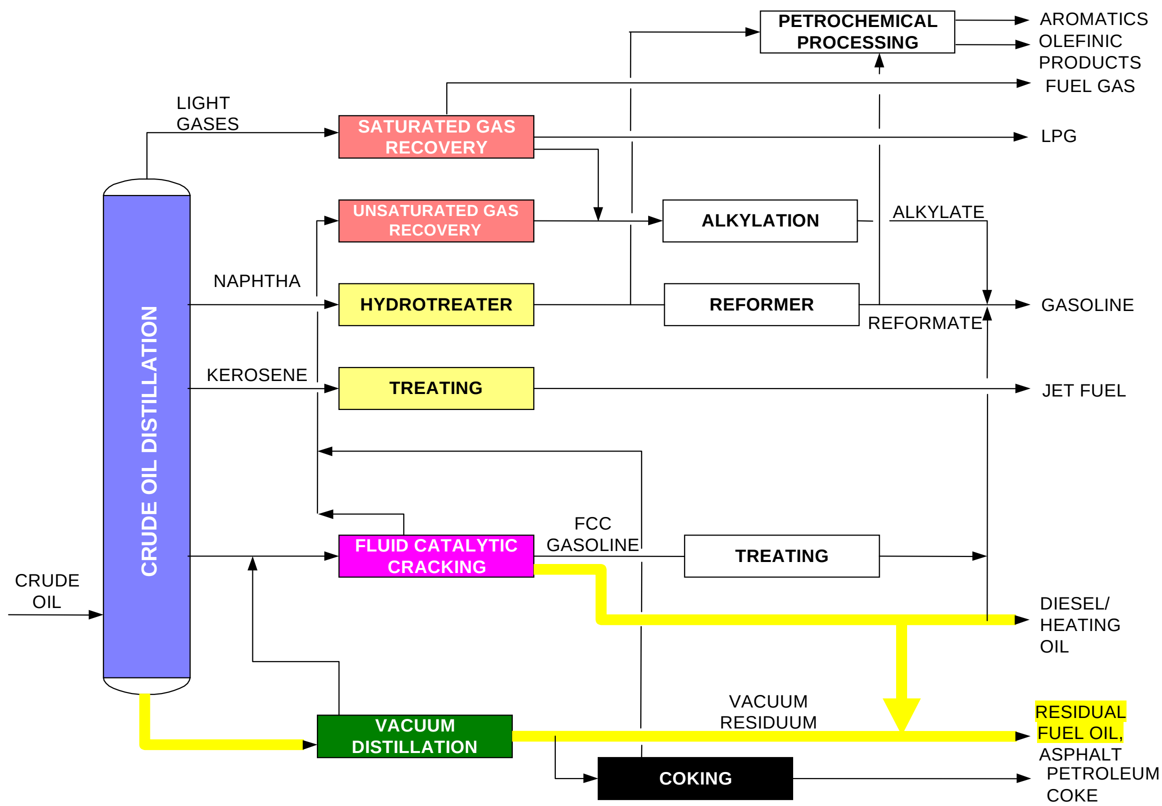

Figure 5.2: Oil Refining Process Flow Diagram

Distillation, the first stage of refining, is able to separate the crude oil into various hydrocarbon chain lengths. The shorter the chain length, the lighter the oil and the higher it goes in the distillation column. Distillation occurs by having a number of stages in a column separated by trays. Each stage remains at a constant temperature. The more volatile (lower boiling point) or lighter oils boil and rise to the higher stages. The less volatile (higher boiling point) or heavier oils condense and drop to the lower stages. At certain stages in the column, some of the oil is extracted, separating the oil into streams.

[6] Adopted from National Petroleum Council (June 2000) and CPPI (2005)

Two forms of distillation are present in the refining process: atmospheric and vacuum. Atmospheric distillation is performed at atmospheric pressure and requires very high temperatures in order to encourage hydrocarbon separation. Vacuum distillation is usually performed after atmospheric distillation and only on the heavier streams. Vacuum distillation uses lower pressures and higher temperatures to achieve separation.

As previously discussed, refineries focus on the production of fuels that are mainly used for automobiles, aviation and home heating. Heavy-gas oils can be converted into these more profitable, straight-run gasolines through the cracking of heavier to lighter hydrocarbons. Cracking simply breaks apart the long carbon chains in the heavy hydrocarbons, whereas coking is used to break down even heavier chains into the lighter fuels. These processes are expensive and they are not perfectly efficient. A combination of efficiency and economics determines the range of products derived from cracking and coking.

The number of impurities in the oil increases as the boiling point ranges increase (Energy Information Administration 2005). As a result, the middle distillate fuels, heavy oils and residual oils all contain a high amount of impurities, notably sulphur. In order to reduce these harmful impurities, a purification process is introduced. Hydrotreating purifies the oil by reacting the impurities with hydrogen gas under catalytic conditions. Hydrogen gas reacts with the SO_x impurity to produce hydrogen sulfide (H_2S) gas. This gas is then separated from the oil and is further reacted to produce liquid sulphur and water.

The final stage of the refining process is customer-specific and can vary from barrel to barrel of crude. It involves the production of specific products that are a combination (blend) of the fuels produced.

Canadian refineries are grouped into two major categories based on process capacity: skimming and conversion (see Table 5.1). Refinery complexity, capital intensity, operating flexibility and value added all increase as one moves from left to right in the following table from one refinery type to the next. Nearly all refineries in Canada are based on catalytic cracking, although a few deep conversion refineries use hydrocracking in place of catalytic cracking (Purvin & Gertz 2004:III-9).

Table 5.1: Refinery Classes

	Skimming		*Conversion*		
Category	**Topping**	**Hydro-skimming**	**Thermal Cracking**	**Catalytic Cracking**	**Deep Conversion**
Atmospheric distillation	√	√	√	√	√
Treating	√	√	√	√	√
Blending	√	√	√	√	√
Upgrading		√	√	√√	√√
Conversion			√	√√	√√√

Note: Number of √ represents increasing complexity

Skimming refineries are relatively simple, comprising crude distillation, treating, upgrading (catalytic reforming, in hydro-skimming only), and blending. Skimming refineries produce refined products in proportions determined mainly by the proportions of boiling range fractions in the crude oil mix. Refineries in Canada that produce only asphalt are skimming refineries with only vacuum distillation units.

Conversion refineries are relatively complex, comprising crude distillation, treating, upgrading (at least catalytic reforming and usually other processes as well), conversion (at least one conversion process and often more than one), and blending. The definition of a deep conversion refinery is one that has residual catalytic cracking, hydrocracking or thermal cracking processing units and therefore high conversion of the heavier parts of crude oil. Conversion refineries produce more light products and less heavy products than indicated by the distribution of boiling range fractions in the crude oil mix. Some deep conversion refineries produce an all-light slate containing no residual products. Conversion refineries shift the product slate toward light products by cracking (converting) heavy crude oil fractions into gasoline blendstocks, distillate blendstocks and refinery gases. As the industry has gone deeper into the residue to convert more crude oil to light products, the quality of the heavy fuel oil produced has in some respects reduced, as impurities become concentrated in the residuals.

5.3 Marine Fuels

Marine fuels are a mix of medium distillates and residual oils. Depending on the product required, the residual oils are blended with the heavy and medium distillates to produce a final heavy product with specific viscosity and flashpoint, whereas distillates are derived from the medium distillate fuel column.

As discussed in Section 1.5, marine fuels are broadly categorized into MGO, MDO, IFO and residuals. MGO is produced from refinery middle distillate blending components which can also be used for the production of road diesel and heating gas oil with additional processing if required. The specifications for MDO are such that some heavy fuel oil can be blended with the middle distillate components.

Residual fuel is produced from refinery streams also used for the production of light and heavy fuel oil sold for inland use. However, the higher permissible sulphur content of marine bunkers, as compared to most inland heavy fuel oil product, allows the use of components produced from crude oils of a higher sulphur content. Sulphur is one of many differentiators of crude oil quality (and therefore cost), as discussed below.

As residual fuels can be considered as, essentially, a “by-product” of the refining process, residuals (including many marine fuels) sell for less than the cost of the crude oil from which they are derived. Understanding this is important to understanding how the move to low-sulphur fuels is likely to affect the supply and cost of marine fuels in the future.

5.4 Crude Oil Properties and Prices

Every oil field yields crude oil with a unique mix of properties, which have been differentiated by the industry into a large number of categories. The world produces and trades more than 160 varieties of crude oil, which range widely in price While the United Kingdom’s Brent Blend averaged $43.04 in August 2004, Syrian Heavy averaged $29.97. Such large price differentials show why a single price cannot serve as a forecast for all crudes (World Bank Group 2004).

Crude oils differ from one another in a large number of chemical and physical properties, many of which play an important part in their refining and subsequent sale as petroleum products. Typically, statistical analyses of global price differentials have focused on two main properties: the specific gravity (lightness) measured in degrees API (a scale devised by the American Petroleum Institute) and the percentage of sulphur content by weight.

Lighter crudes (with higher API) produce a larger number of lighter products, such as gasoline, that have higher resale value. All other qualities being equal, lighter products are expected to sell at a premium over heavier crudes. By extension, if the prices of all petroleum products rise by the same percentage amount, the absolute price differential between heavy and light crudes (the discount) can be expected to grow.

High sulphur content has an adverse effect on the value of crudes because it leads to higher operating costs for refineries due to special processing and maintenance requirements. In addition, in many countries, new legislation mandates lower sulphur content for gasoline and diesels. So, high-sulphur (sour) crude is expected to sell at a discount relative to low-sulphur (sweet) crude of the same API. An increase in the share of high-sulphur crude in the world market, or a relative increase in the demand for low-sulphur products, is expected to result in larger discounts for high-sulphur crudes.

As mentioned above, the specific gravity and sulphur content varies by reservoir. However, density and sulphur content characteristics are not related; for example, some heavy crudes (e.g. South Africa) have relatively low sulphur content, whereas the oil fields in Canada (in a global perspective) produce medium-density crudes with medium sulphur contents.

Another important crude oil property is acidity. The recent emergence of West African and other new producers has led to an increase in the supply and number of crudes with high acidity, as measured by the total acidity number (TAN), an aggregate index that includes various types of acid. Some of these acids pose no particular problems in the refinery process. But above a certain limit, acidity has a corrosive effect on refineries. Blending low-TAN with high-TAN crude can deal with this problem, but it increases logistical costs. New refineries constructed using special materials can tolerate higher acidity, but these facilities are few in number. Thus, crudes with a high TAN (greater than around 0.5) are likely to be sold at a discount because they limit the options for refining.

Canada is currently the ninth-largest producer of crude oil in the world, with enough oil to both meet its domestic needs and supply export markets. Currently, Canada is the largest supplier of imported crude oil and refined products to the U.S., exporting 2.1 million barrels per day across the border. Oil production has traditionally come from conventional basins in western and northern Canada. In recent years, over 300 000 barrels per day come from offshore projects in Atlantic Canada. However, the biggest increase in production in the last decade has come from oil sands; this production continues to grow at a rapid pace (CAPP 2005).

In 2004, total Canadian crude oil production was in excess of 2.6 million barrels per day, where western Canada (British Columbia, Alberta, Saskatchewan, Manitoba and the Northwest Territories) produced more than 87% of all the crude oil. Atlantic Canada (Newfoundland and Labrador) produced the balance. Of the total production, the following products were supplied (indicating share of total production): conventional light and medium crudes (30%), conventional heavy crudes (24%), oil sands crudes (40%) and others (6%) (CAPP 2004:6). The distribution and domestic refinery consumption of Canadian crude oils is further described in Section 7.2.

Considering the production of marine fuels (distillates and residuals), crude oil quality is an important factor for the quality, sulphur content and cost of the final product. Refineries processing sour crudes will, with standard refinery processes, develop heavy marine fuel oils with high sulphur content. Similarly, unless refinery treatment systems are implemented, the quality of distillate fuels is derived as a function of the sulphur content of the crude. Thus, to produce low-sulphur marine fuels, refineries have the option to process sweet crudes and/or to invest in desulphurization technologies.

Typically, in order to produce heavy fuel oil with less than 1.5% sulphur content in a refinery with catalytic cracking configuration, a crude oil feedstock with sulphur content less than 0.7% is required (European Commission 2002a:42). This is typical of BC Light, Bonnie Glen, Federated, Pembina, Rainbow and Synthetic crude oil supplies in Canada; all are classified as light crude oils, fetching a $7 to $17 premium per barrel compared to heavy/sour crudes (2004–2005). Canadian supplies of heavy crude oil have a sulphur content in excess of 2%. Due to the price differential between low- and high-quality crudes, certain refineries have opted to invest in treatment technologies and incur higher operating costs. Depending on the price differential in crudes, the incremental costs of such investments can be justified for production and sales of high-value products (gasoline and diesel). However, investment in desulphurization technologies is not considered by the industry to be viable for production of low-sulphur heavy fuel oils in isolation. If the costs involved were applied only to the heavy products, their costs would increase to an unacceptable level.

5.5 Costs Associated with the Various Grades of Marine Fuels

The various marine fuel grades were introduced in Section 1.5 (global perspective), and an indication of the fuels supplied in the Canadian market was provided in Section 3.2. Additional assessments of Canadian products and sales are provided in Sections 6 and 7, while the following section provides an overview of historical and current marine fuel prices, by grade.

Bunker prices constantly fluctuate due to market forces and the cost of crude oil. Moreover, the bunker market is extremely price sensitive, with ships often basing decisions on where to bunker on the relative price of fuel available in respective ports. These bunkering decisions would therefore also be impacted by relative price premiums arising as a result of different fiscal policy across countries and regions, especially in terms of fuel taxes (European Commission 2002b:81).

More important perhaps, are typical differences exhibited between fuel types, including marine gas oil, marine diesel oil, and high-sulphur and low-sulphur heavy fuel oils. Considering comparative prices (quoted in U.S. dollars) by region, the following observations are made (see Figures 5.3 through 5.6)[7]:

- There is a fair amount of variation in price, particularly between fuel types, but also for the same type between ports. There is also fairly frequent variation due to changing supply and demand conditions.

- The long-term global price premium payable for MDO over HFO has tended to be in the range of $100 to $150 per tonne, although it is significantly higher at present.

- The historical price premium between low-sulphur and high-sulphur residual fuels has varied between $2 per tonne and $43 per tonne.

- Heavy fuel oil prices in Canada are generally higher than in the U.S. Prices are 10% higher on the East Coast, 2–5% higher on the West Coast, and are 15–20% higher than on the U.S. Gulf Coast (Houston).

- Marine diesel oil prices in Canada are generally higher than in the U.S. Prices are 2–5% higher on the East Coast and up to 10% higher on the West Coast, and are 20–30% higher than on the U.S. Gulf Coast (Houston).

- Excluding the U.S. Gulf Coast, prices in North America are generally 2–4% and 15–25% higher for HFO and MDO, respectively, than in Rotterdam and Singapore.

[7] Data obtained from Bunker World website (www.bunkerworld.com).

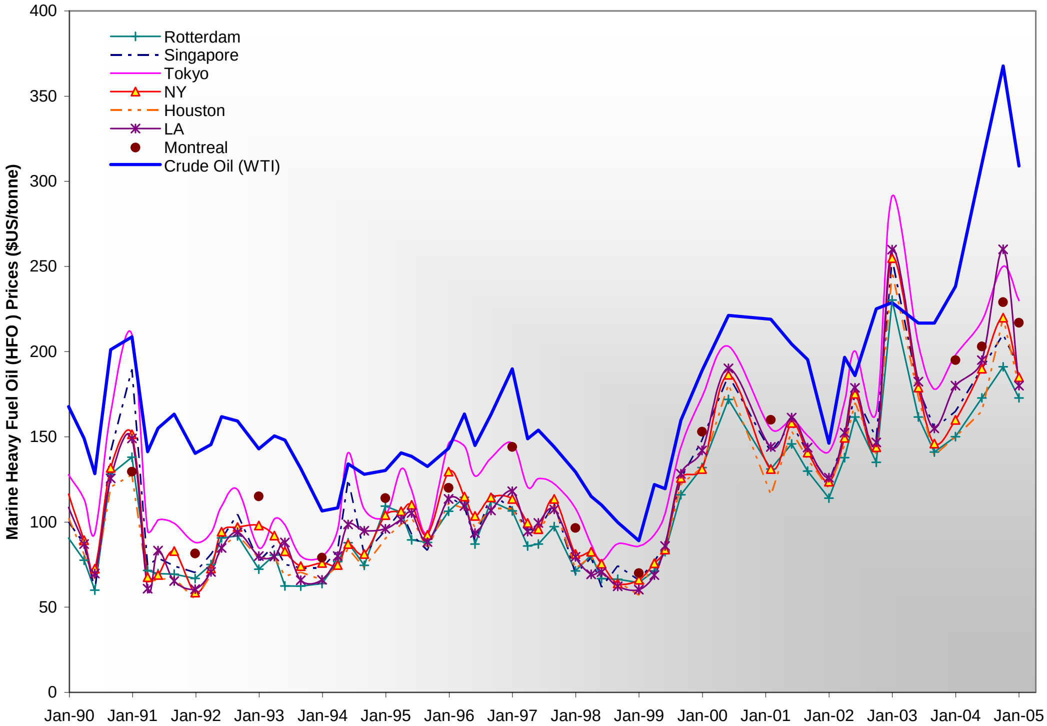

Figure 5.3: Marine Heavy Fuel Oil (HFO) Prices (1990–2005)

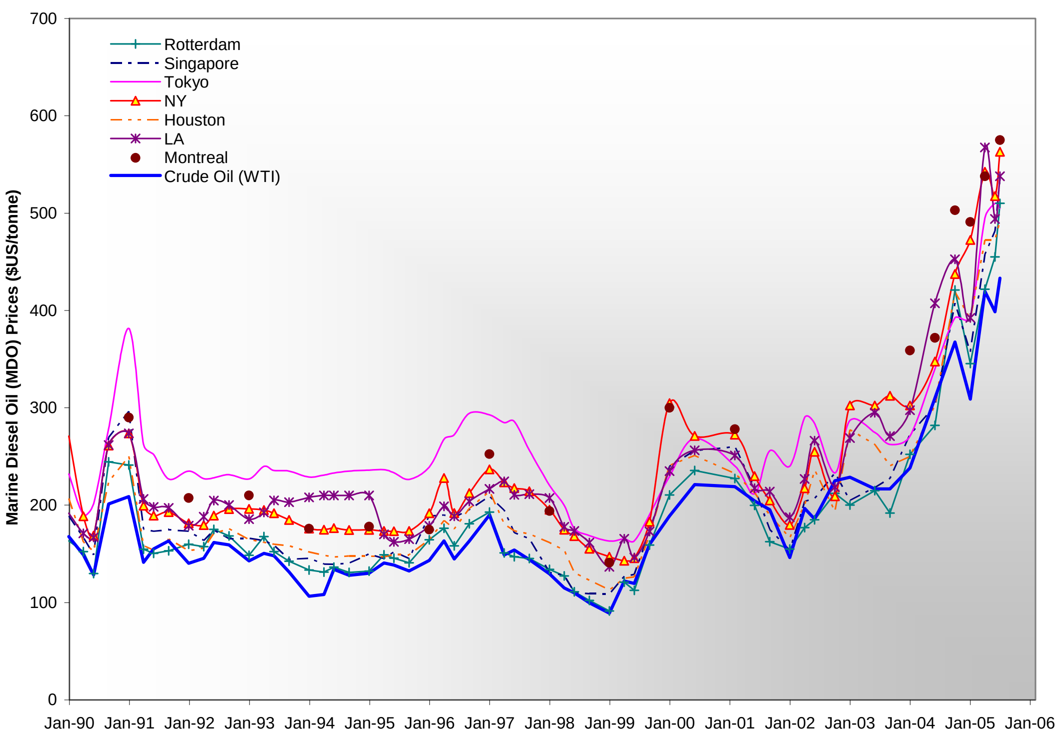

Figure 5.4: Marine Diesel Oil (MDO) Prices (1990–2005)

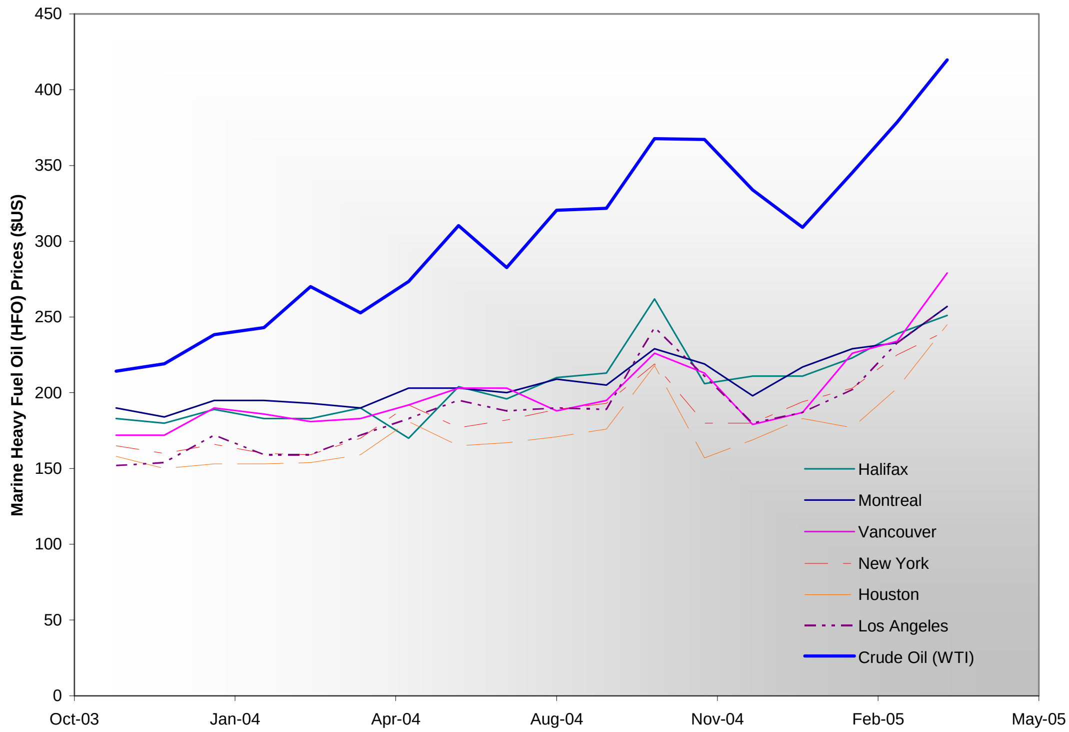

Figure 5.5: North American IFO 380 Prices (2003–2005)

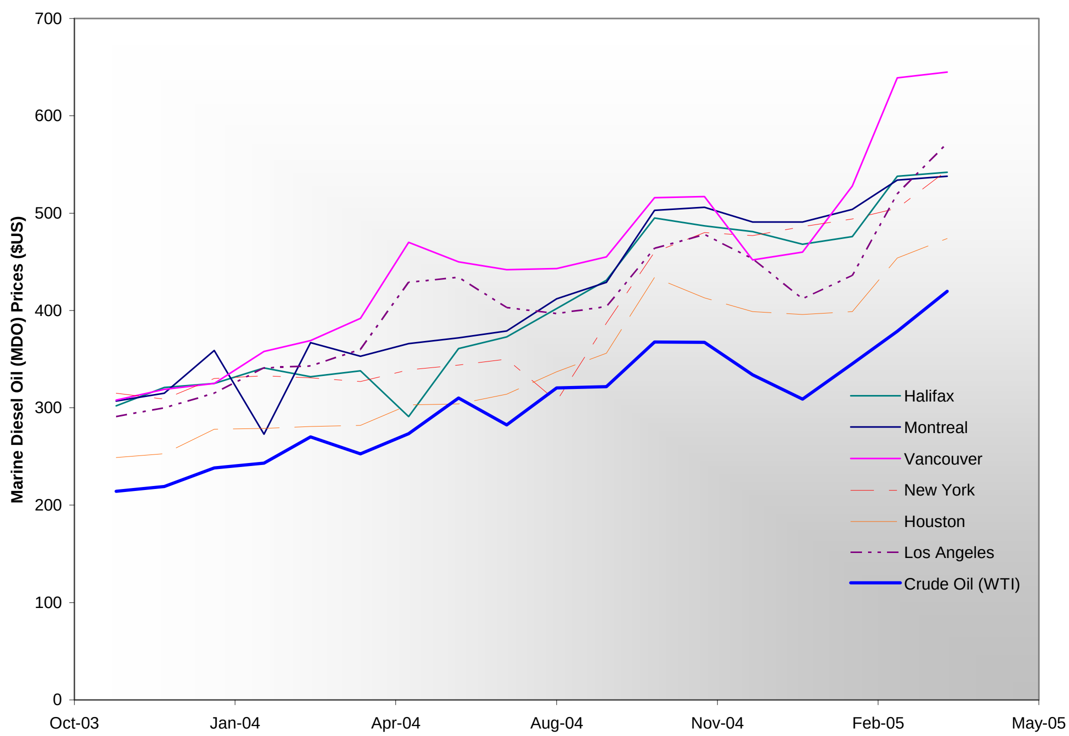

Figure 5.6: North American MDO Prices (2003–2005)

6 OVERVIEW OF MARINE FUEL QUALITY IN CANADA

6.1 Sulphur Content Levels of Marine Fuels in Canada

An overview of Canadian refineries, importers and marine fuel suppliers is provided in Section 7. The organizations identified were consulted and were requested to complete questionnaires on annual fuel sales and quality as part of this project. In addition, consultations were held with stakeholders to collect additional data on fuel quality variations and sulphur contents by fuel grades.

Responses were received from across the country. In cases where only a single refinery or supplier in a region sold a particular product, that data point has not been included in the regional total, since that would violate the terms of our confidentiality agreements. Similarly, the national total for that particular product has been withheld in cases where inclusion would allow readers to recreate the omitted regional data based on the sales in all of the other regions. To reduce the opportunity for readers to determine the withheld sales volume data, we have opted to not publish the number of regional sales agents of each product. These data are presented in Table 6.1 below.

The report handles the data for sulphur content results in the same fashion, with the exception of the national data, which have all been presented even for those products where the national sales volumes have not been reported. This was done because the sulphur content data are presented as volume-weighted averages so, without the national sales volumes, it is not possible to recreate the missing regional sulphur content data. These data are presented in Table 6.2 below.

Table 6.1: Volume of Canadian Marine Fuel Sales in 2004

	Fuels Sales for 2004 (m^3)				
Fuel Grades	**Atlantic**	**Quebec**	**Ontario**	**Western**	**Canada**
DMA	201 709	49 100	86 300	140 790	477 899
DMB	**	68 500	38 900	69 619	**
Other marine distillates	192 809	**	**	**	452 293
< IFO 180	**	9993	27 000	**	43 993
IFO 180–IFO 380	121 610	346 391	97 000	541 376	1 106 376
IFO 380–IFO 640	**	45 100	109 836	524 634	**
> IFO 640	**	0	**	0	91 000

Note: ** Information withheld to protect confidential data

Table 6.2: Volume-weighted Sulphur Content of Canadian Marine Fuel Sales in 2004

	Volume-weighted Average Sulphur Content (%)				
Fuel Grades	**Atlantic**	**Quebec**	**Ontario**	**Western**	**Canada**
DMA	0.125	0.226	0.489	0.145	0.207
DMB	**	0.054	0.226	0.211	0.144
Other marine distillates	0.172	**	**	**	0.224
< IFO 180	**	1.468	1.974	**	1.763
IFO 180–IFO 380	3.632	1.306	2.230	1.666	1.819
IFO 380–IFO 640	**	1.492	2.313	1.587	1.672
> IFO 640	**	n/a	**	n/a	1.806
All Distillate Fuels	**0.144**	**0.134**	**0.313**	**0.233**	**0.201**
All Residual Fuels	**2.505**	**1.331**	**2.162**	**1.627**	**1.760**

Note: ** Information withheld to protect confidential data

The results in Table 6.1 were adjusted to avoid double counting of the Canadian sales figures; i.e., at the fuel supplier level, domestically sourced fuels were not included in the above estimates, as these sales volumes were included in the refinery supply.

In order to verify the completeness of the reported volumes, imports, sales and fuel quality, results were compared to Statistics Canada (2003 and 2003, 2004b) and Environment Canada (2004) figures for 2003–2004. Comparing reported sales volumes in Table 6.1 to those presented in Figure 3.4, it becomes obvious that either the fuel usage practices of the marine sector have changed considerably between 2003 and 2004, or there has been some misreporting of data in one or both of the studies. The quantity of distillate fuel sales reported for the present study is on the order of 1.2 million cubic metres, which is approximately 400 000 cubic metres less than in 2003, or a decrease of about one third. The change in reported residual fuel sales is even more dramatic: from about 900 000 cubic metres in 2003 to just over 2 million cubic metres in 2004.

Without seeing the actual data from the Statistics Canada report that served as the basis for Figure 3.4, it is impossible to determine the source of the discrepancy. It is quite possible that neither dataset is incorrect, but rather that different questions were asked of sales agents and that different answers were therefore obtained.

With respect to the present study, not all questionnaires were returned from fuel suppliers despite repeated communications. Responses were obtained from all refiners that were contacted. However, in processing the data, there is some suspicion that certain respondents may not have included all of their marine products in their answers. Other respondents had such complicated processes of imports and exports and transfers between refineries that it was impossible to balance the production and sales data in the context of this study. It is the authors' impression that any omissions or inaccuracies in data are due to the very complex nature of the fuel production and sales business, where linear models of production and sales do not apply.

As indicated above, the sulphur content varies greatly by product and region. The volume-weighted average sulphur content for distillate fuels (as reported) was approximately

0.201% (2010 mg/kg), which is comparable to that reported for diesel fuels in Environment Canada's *Sulphur in Liquid Fuels* report for 2003 (Environment Canada 2004). The volume-weighted average sulphur content for residual fuels was approximately 1.76% (17 600 mg/kg), which was slightly higher than that reported by Environment Canada (1.541%). Environment Canada's average sulphur content covers all domestic heavy fuel oil produced in, and imported to, Canada, including consumption by energy utilities and industrial facilities. Heavy fuel oil sales to stationary facilities are regulated at regional and/or local levels, hence the difference in sulphur contents reported herein to that of previous studies.

An historical representation of sulphur contents in heavy fuel oil is presented by region in Figure 6.1.[8] Due to a lack of detail on specific refinery and supplier sales volumes, the results in this figure are based on discrete bunker samples taken by Det Norske Veritas (DnV). Since the mid 1990s, the average sulphur content has reduced in fuel supplied in western Canada, Ontario and Quebec, with the most significant reductions having occurred in Quebec. For western Canada and Ontario, the sulphur content has been reduced to a level comparable to that typical for the mid 1980s.

For the Atlantic Provinces, the average sulphur content has been relatively constant, but with a gradual increase noted since the mid 1990s. The increase is mainly driven by one refinery that supplies heavy fuel oils with sulphur contents in excess of 4% (the highest sulphur content in Canada for the data collected under the present study). Other refineries/suppliers in the Atlantic Provinces provide heavy fuel oils with sulphur contents comparable to that of the supply in Quebec. This is identified by the ranges provided in the figure below.

Figure 6.2 shows the trend of average sulphur content, by region, in distillate fuels sampled by DnV at various ports across Canada from 1990 to 2005.[9] The average values presented cover all types of marine diesels (DMA, DMB and DMC), as well as some low-sulphur non-marine fuels. As indicated, the sulphur content has generally reduced in the western and Atlantic regions, whereas the content in Ontario and Quebec has been relatively constant.

[8] Data obtained from Det Norske Veritas
[9] Data obtained from Det Norske Veritas

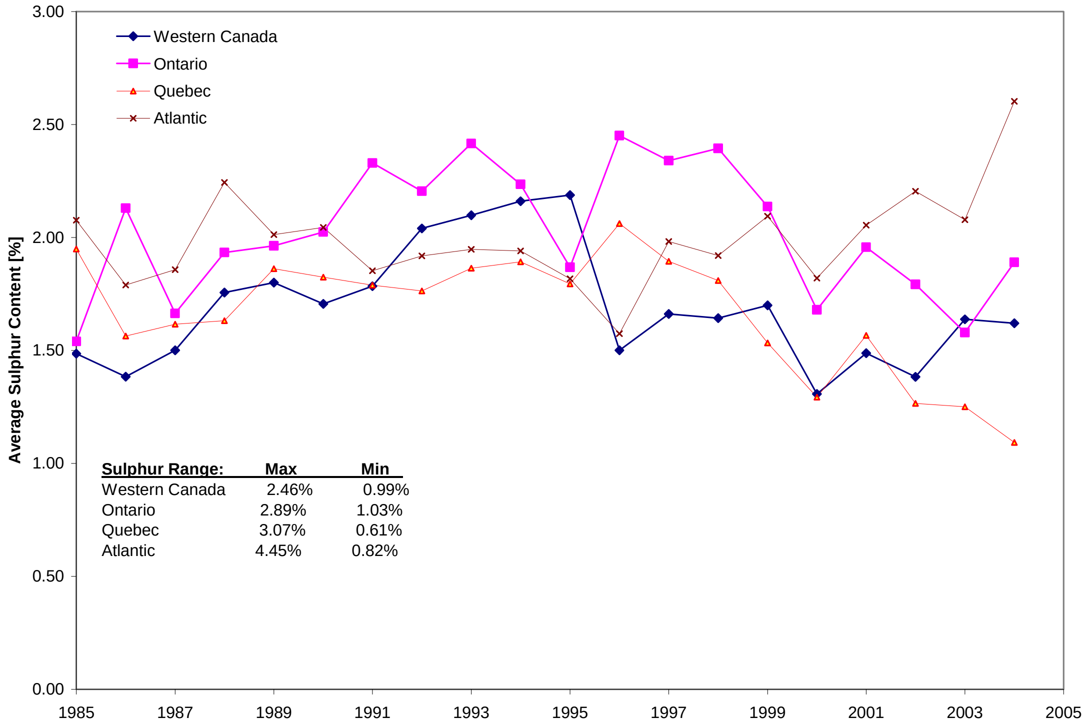

Figure 6.1: Historical Average Sulphur Contents in Residuals, by Region

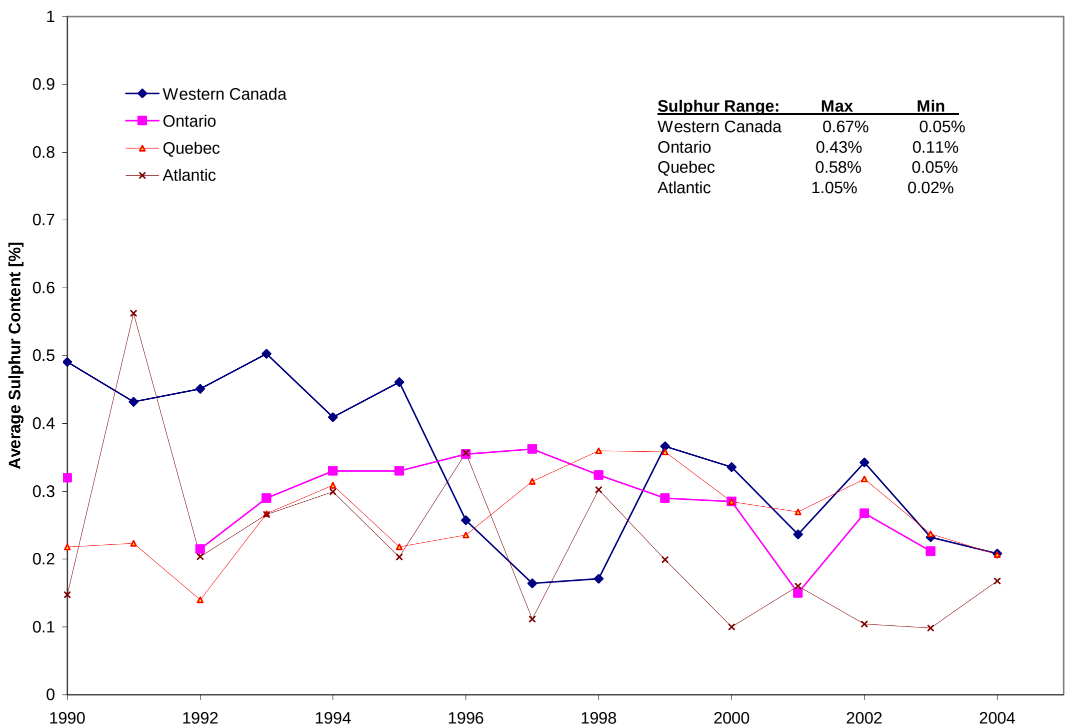

Figure 6.2: Historical Average Sulphur Contents in Distillates, by Region

6.2 Future Trends for Sulphur Content of Marine Fuels

The data in Table 6.1 (including that withheld for issues of confidentiality) indicate that on a national basis, 64% of the reported fuel sales are IFO 180 or heavier. Similarly, historical data presented in Section 3 showed that sales of marine heavy fuel oils have varied from 50% to 70% of total marine fuel sales since 1978. Moreover, as the sulphur content of heavy fuel oils is an order of magnitude greater than that for distillates, the majority of the domestic SO_x emissions inventory is related to the use of heavy fuel oil. This is also demonstrated in Environment Canada's *Sulphur in Liquid Fuels* report wherein heavy fuel oils constitute only 8% of production but almost 69% of the distribution of sulphur.

As discussed in Section 2, marine distillate fuels will be regulated to 500 ppm beginning in 2007, with limits of 15 ppm applied to marine fuels in 2012. Due to regulations aimed at both on-road and off-road diesel fuels in Canada, the domestic refineries are currently engaged in finalizing plans to produce on-road diesel with a sulphur content of 15 ppm. Each refiner is developing its own solution to meet the on-road regulation (by 2006), and as part of their current investments, many refineries are considering options to concurrently reduce the sulphur in off-road diesel (including rail and marine diesel fuels). For the most part, refineries are planning to add distillate hydrotreating capacity in order to meet the prescribed standards (Purvin & Gertz 2004:IV-4).

Regulations have also been proposed that set a 0.1% (1000 ppm) sulphur content limit for furnace fuels. As such, a number of domestic refineries have developed plans on how to produce low-sulphur furnace fuel at the same time as they implement other diesel sulphur reduction investments. The fuel would be produced through addition of hydrotreating capacity. However, desulphurizing light-fuel-oil components to produce 0.1% furnace fuels could prove problematic. After achieving ultra-low-sulphur diesel fuel, the remaining distillate stocks tend to be high-sulphur, cracked stocks that are more difficult to feasibly desulphurize. The same would apply to desulphurization of residuals/heavy fuel oils used for marine applications.

Through consultations with refiners, potential solutions were identified for production of low-sulphur residuals, ranging from re-blending fuels, sourcing low-sulphur crudes and/or blendstocks, and coking and hydrotreating residual oils. Refinery options to produce low-sulphur(1.5%) residuals are further discussed in Section 9.

In view of potential regulations, producers of heavy fuel oil will choose those alternatives that provide the highest-value product, which may in some cases also prove to be the lowest-cost option. Thus, if fuel standards are enforced such that additional desulphurization capacity must be implemented, the refinery industry has indicated that it would rather increase its production of lighter petroleum products. The reason is that hydrotreating residual fuel is not economically viable, but producing higher-quality distillates is. Assuming that the amount of crude processed is constant, the increased production of lighter products could thus lead to a reduction in the quantity of residual fuel oils available for sale.

In the future, those refineries that do not hydrotreat or hydro-crack residuals, but rather subject them to further cracking and coking to produce additional distillate products, will end up with a residual product with a higher concentration of sulphur than that which is currently produced.

7 CANADIAN MARINE FUEL SUPPLY CHAIN

7.1 Identification of Stakeholders in the Canadian Market

The Canadian refinery and marine fuel supply market consists of 21 refineries and numerous fuel supply agents at various bunkering ports across Canada. Nine of these refineries are located in western Canada (British Columbia, Alberta and Saskatchewan), another six are located in Ontario, and Quebec and the Atlantic Provinces are each home to three refineries. These 21 facilities are owned by 13 different petroleum companies, most of whom operate only one facility.

Of Canada's 21 refineries, 14 produce products that are known to be sold to the marine fuels market, either directly or indirectly. The remaining seven refineries do not supply fuels to the marine sector and have thus not contributed to this research. Figure 7.1 presents the geographic distribution of the Canadian refineries, identifying refineries relevant to this project.

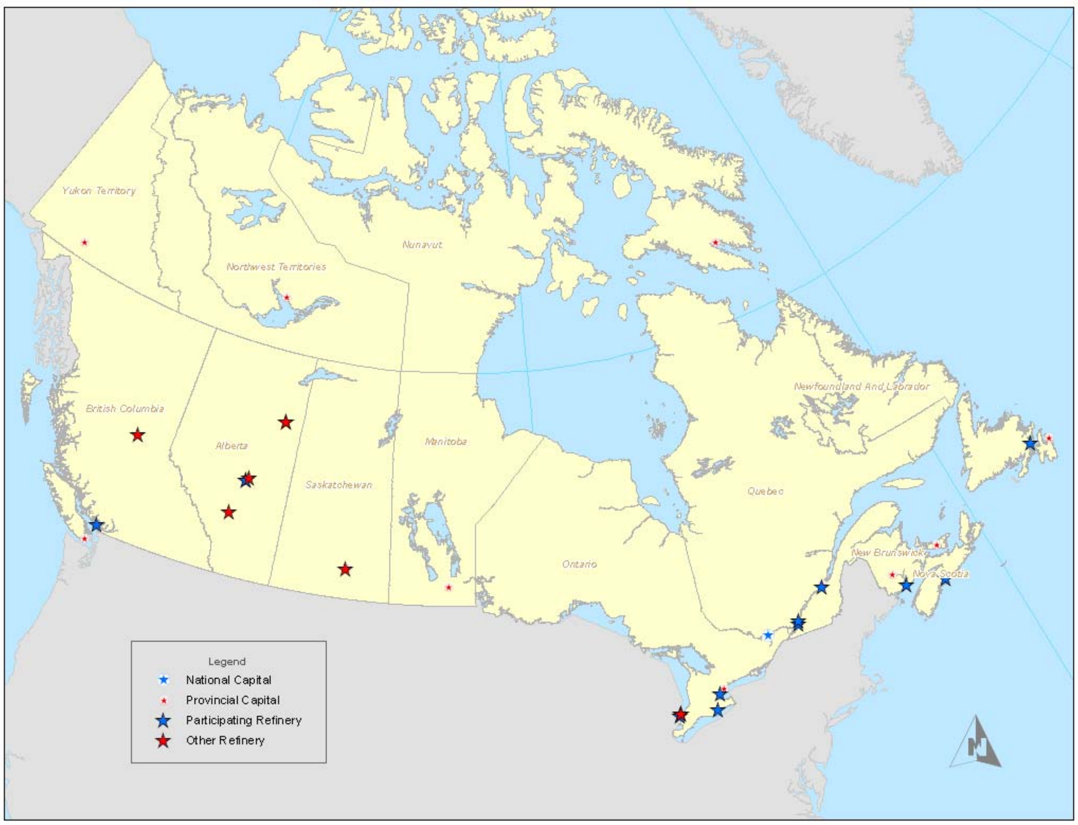

Figure 7.1: Distribution of Refineries in Canada

Fourteen different organizations have been identified to service the major bunkering ports across Canada, with anywhere from 1 to 7 fuel suppliers present at each individual port authority. On average, there are 2 to 3 suppliers at each major bunkering port. Figures 7.2 and 7.3 present the geographical distribution of the major domestic bunkering locations for eastern and western Canada, respectively. The various organizations are listed by port in Table 7.1.

Table 7.1: Marine Fuel Suppliers and Bunkering Ports

Organization	Ports Authorities Served
BP Marine Fuels	Montréal
ExxonMobil Marine Fuels Ltd	Halifax, Montréal, Port Cartier, Québec, Sarnia, Come By Chance, Vancouver
ICS Petroleum (Montréal) Ltd	Montréal
ICS Petroleum Ltd	Prince Rupert, Vancouver
Imperial Oil Ltd	Charlottetown, Halifax, Newcastle, Port Cartier, Québec, Come By Chance, Sarnia, St. John's, Vancouver
Irving Oil Ltd	Charlottetown, Dartmouth, Halifax, Saint John
Kildair Service Ltd	Montréal, Québec
Marine Petrobulk	Vancouver
Petro Canada Products Ltd	Québec
Provmar Fuels Inc	Hamilton, Toronto (Port Weller)
Shell Canada Products Ltd	Montréal, Québec, Sarnia
Statia Terminals Canada Inc	Halifax, Port Hawkesbury
Sterling Marine Fuels	Windsor
Ultramar Ltd	Québec

Notes: *The following major port areas are defined to cover surrounding bunkering locations as indicated*:
Halifax: Point Tupper, Shelburne
Montréal: Contrecoeur, Cornwall, Sorel, Trois-Rivières, Valleyfield
Port Cartier: Baie-Comeau, Sept-Iles
Québec: Bécancour, Port-Alfred, St-Romuald
Saint John: Canaport, Holyrood
Vancouver: Nanaimo, New Westminster, Port Moody, Victoria

Figure 7.2: Major Bunkering Ports in Eastern Canada

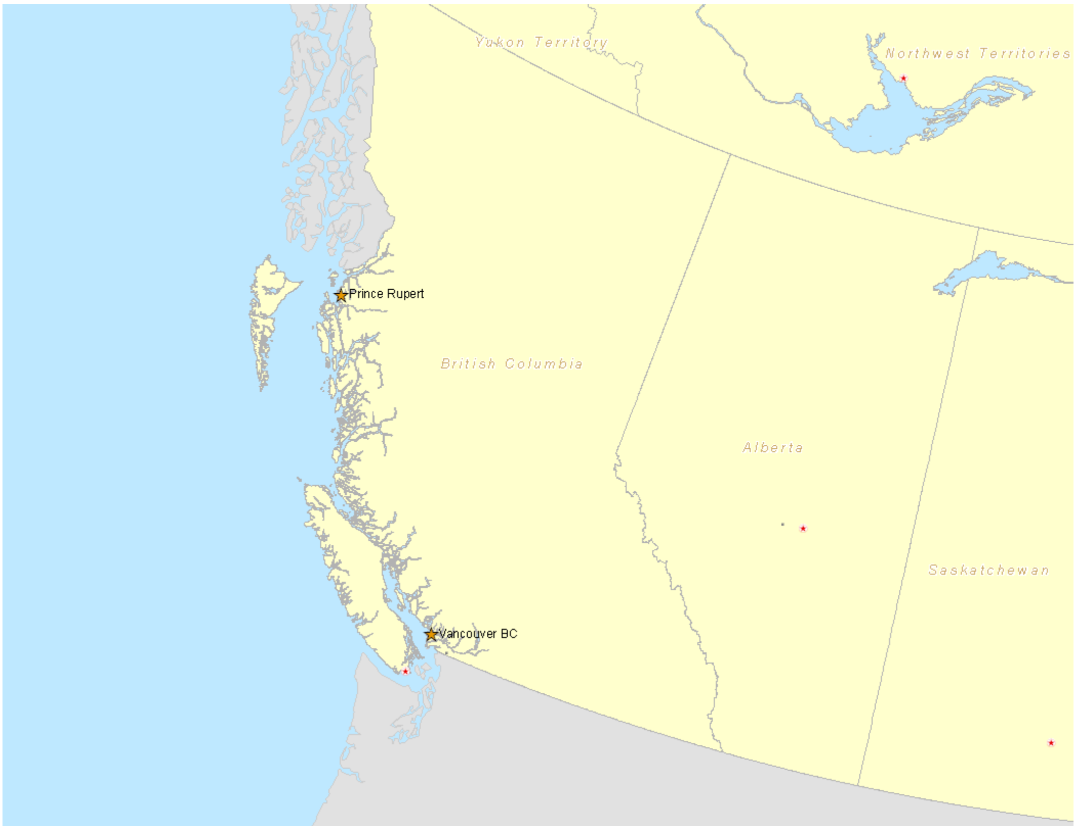

Figure 7.3: Major Bunkering Ports in Western Canada

As indicated, five domestic refineries act as fuel suppliers of their own branded products at various port authorities across Canada. The remaining nine independent marine fuel resellers source their products from domestic and international refineries and bunker agents.

7.2 The Canadian Marine Fuel Supply Chain

The supply of marine fuels in Canada does not follow a single set path from crude source to ship; rather, it can take several different paths depending on the capabilities of individual facilities. For example, a simple distillation refinery will transfer products to a cracking refinery before the product is sold to a supply agent, who in turn sells the product to the ship. There could also be a fuel blender added into the previous example either ahead of, or in lieu of, the supply agent. Furthermore, the different facilities within the chain are not necessarily all resident in Canada. For example, residual fuel produced in Canada may be transferred to the United States for additional processing before being imported back by a Canadian fuel supplier. The majority of imported marine fuels are obtained from the United States; however, specific suppliers also import their marine fuels from overseas. Similarly, crude oil may be sourced from Canada, the United States or offshore of North America. Figure 7.4 presents a schematic overview of the marine fuel supply chain in Canada. The complexity of this figure illustrates the many different paths that fuel products can take from crude source to end user.

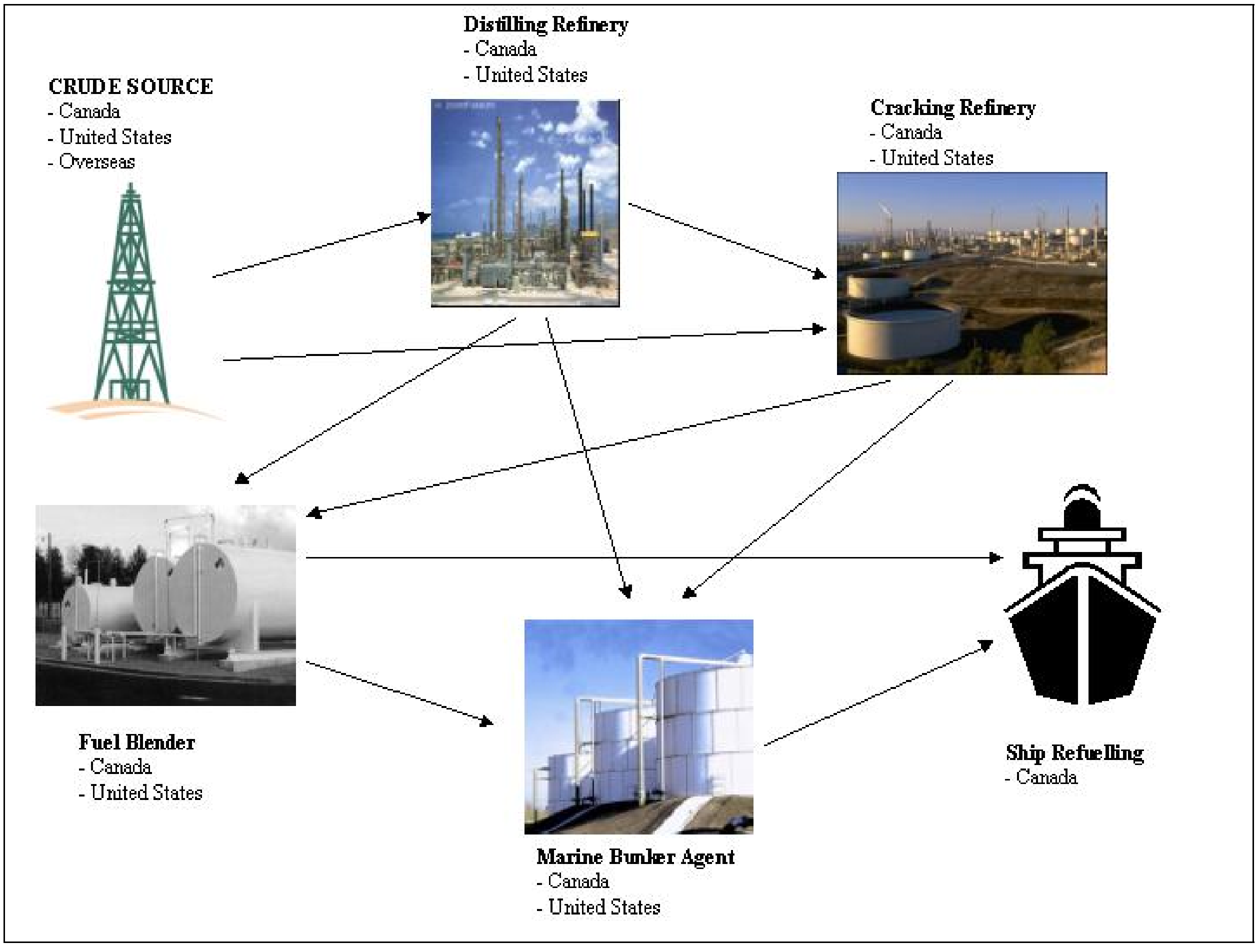

Figure 7.4: Marine Fuel Supply Chain in Canada

In addition to the complexity of the fuel production path, the actual fuel that ends up in a ship may have followed an equally convoluted route. Fuel blenders and suppliers may purchase fuel from a number of different sources, including imports, provided it meets their specifications. These different fuels can be stored in one single storage/collection tank, and the output is either sold directly to marine users, used as a blendstock, or both.

Similarly what is sold as a "marine fuel" may have originally been produced for use in a completely different market, emphasizing that marine fuels are not a primary refinery product. Figure 7.5[10] shows the variety of primary refinery products that may be used or sold as marine diesel fuels.

[10] Figure and information provided by Petro-Canada

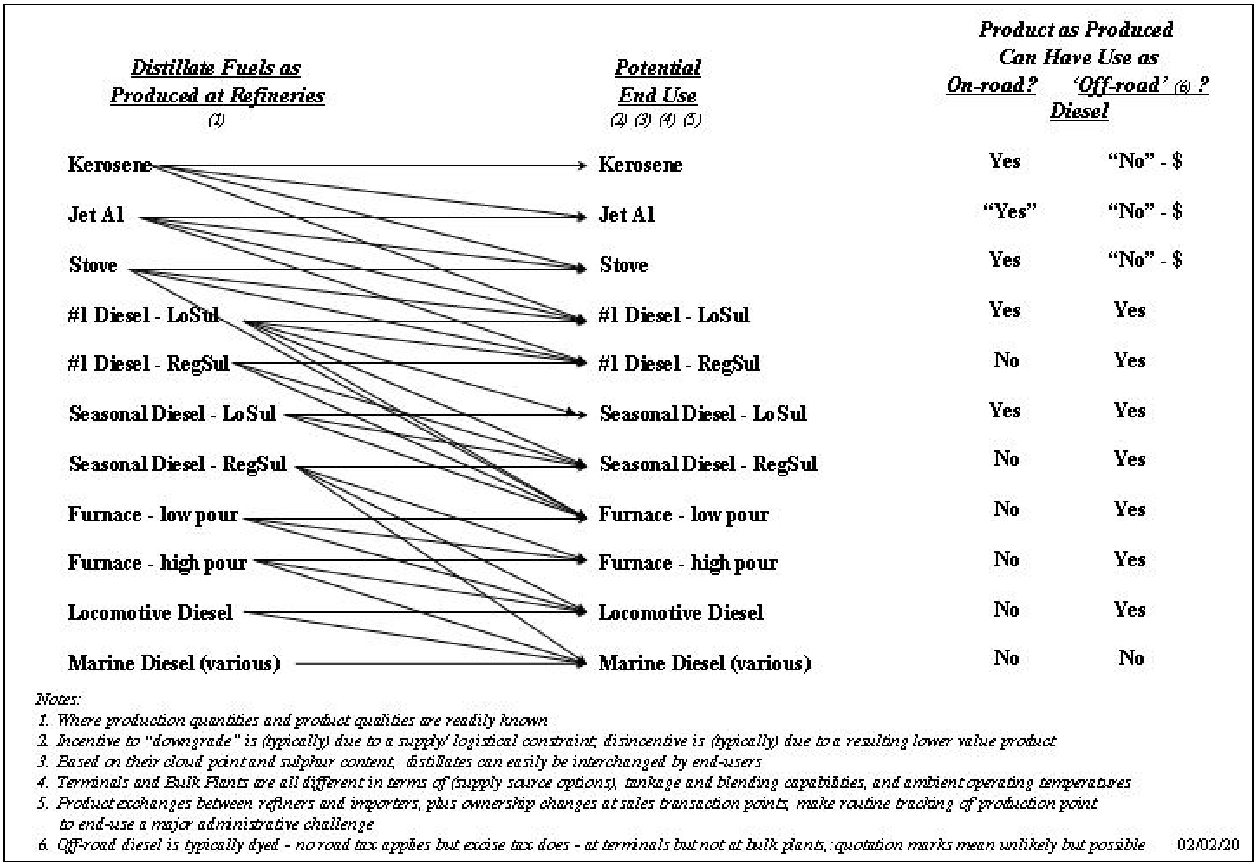

Figure 7.5: Interchangeability of Diesel Fuels

The actual volume of fuel in the supply chain does not, at present, show any signs of a bottleneck or limit of access to the marine market. Judging by current and historical sale of diesel fuel and heavy fuel oil in Canada, only a fraction is sold into the marine market.

Moreover, some refineries have indicated that the increased requirements for low-sulphur fuels in land-based markets (i.e. number 6 HFO) will result in a short-term increase in the availability of marine heavy fuels. This is because the availability of sweet crude oils is decreasing and the residual products from medium-sour crudes may be unacceptable to land-based markets. However, as the specification for sulphur content in marine fuels becomes more stringent, the future availability might diminish; i.e., the low value of the fuel could justify conversion to lighter fuels through additional processing.

7.3 Influence of Demand from Other Industries

The availability and price of natural gas and other market externalities has a direct impact on distillate and residual fuel sales. For example, in 2003, the differential between natural gas and fuel oil prices was sufficient to lead many commercial, industrial and utility end users to switch from gas to oil when the opportunity was presented. Accordingly, fuel switching boosted sales of both distillates (5%) and residual fuels (32%) compared to 2002.

However, sales to the marine industry did not reflect these overall sales figures. Marine residual sales incurred a slight (3%) increase, whereas marine distillate sales fell by 20%. Thus, although overall domestic sales of distillates and residuals increased, marine fuel sales decreased. In particular (as presented in Section 3.2), sales of marine fuels (distillate and residual) to foreign consumers decreased by more than 43% from 2002 to 2003.

The long-term trend toward lower sales of residual fuel remains, and it will continue to affect the Canadian markets, as it reflects the factors within the energy market and externalities. The principle reasons for the changing relationships are changing crude oil specifications; enhanced refinery sophistication, resulting in increased production of gasoline and distillates at the expense of production of heavier products such as residual fuels; environmental constraints and restrictions on fuel oil use; and the availability of abundant, relatively inexpensive natural gas, which has contributed to a diminished use of fuel oils. For residual fuel oil, although the overall trend is down, significant fluctuations in the amount of fuels sold will occur whenever the price differentials make switching attractive.

As evidenced in 2003, the amount of fuels sold to foreign-flagged ships will decrease when the price of bunkers increases. Volatility and high prices in the natural gas market will increase the demand (from land-based consumers) for distillates and heavy fuel oils. Due to inelastic supply, prices will increase to a level where foreign (ship) consumers will elect to bunker elsewhere.

With respect to future sulphur regulations, the natural gas market will exert other influencing factors on the fuel refining industry as well. Hydrogen is used by refineries to reduce the sulphur content of fuels by hydrotreating, and that hydrogen requires natural gas for its production, either as a resource or as a means to provide heat for the production process. Thus, if the price of natural gas increases, so too will the price of low-sulphur fuels. Similarly, an increase in the demand for low-sulphur fuels will influence the demand for natural gas, which can result in a rise in its price.

Thus, other markets and the demand from other industries already influence the level of marine fuel sales in Canada. As the demand for low-sulphur fuels increases, so too will these influences from other markets on the marine sector.

7.4 Marine Fuel Blending Practices in Canada

Blending different fuel products is a primary means of producing marine fuel oils. While marine diesel engines are capable of burning very heavy fuels, many residual fuel oils need to be combined with at least a small amount of distillate fuel in order to meet the requirements of the marine industry. For example, refineries have indicated that, depending on the grade of the fuel, the amount of distillate streams used in the blend could be as high as 37%. Other important elements include the quality of the crude source and the capability of the individual refinery.

Whereas certain fuel suppliers perform their own blending of fuels, others source their blended fuel from the refineries, avoiding the blending step in their own processes. Table 7.2 presents a breakdown of the blended marine fuels supplied by refineries across the various regions of the country. As with the data presented in Section 6, product data that came from a single source in a particular region have been withheld to protect the confidential nature of that data. Based on the responses we received, blending is a practice that is generally much more likely to happen at the refinery end of the supply chain rather than at the fuel supplier end.

Table 7.2: Summary of Fuel Blending Practices Across Canada

Fuel Grades	**Ranges of Blendstock Products and Sulphur Contents**								
	Atlantic			Quebec			Ontario		
	Distillate	Residual	Sulphur	Distillate	Residual	Sulphur	Distillate	Residual	Sulphur
< IFO 180	**	**	**	10–35%	65–90%	0.7–1.9%	12–37%	63–88%	1.2–2.25%
IFO 180–IFO 380	5–21%	79–95%	1.2–4.9%	0–12%	88–100%	0.9–1.9%	5–13%	87–95%	1.2–2.4%
IFO 380–IFO 640	**	**	**	0–5%	95–100%	1.0–1.9%	0–15	85–100	0.99–2.5%
> IFO640	**	**	**	n/a	n/a	n/a	**	**	**

Fuel Grades	**Ranges of Blendstock Products and Sulphur Contents**					
	Western			Canada		
	Distillate	Residual	Sulphur	Distillate	Residual	Sulphur
< IFO 180	**	**	**	10–37%	63–90%	0.7–2.25%
IFO 180–IFO 380	5–12%	88–95%	1.2–1.9%	0–21%	79–100%	0.9–2.4%
IFO 380–IFO 640	0–5%	95–100%	1.33–1.9%	0–15%	85–100%	0.99–2.5%
> IFO 640	n/a	n/a	n/a			

Note: ** Information withheld to protect confidential data

The data in Table 7.2 indicate that there is considerable variation in the range across the country, which can likely be attributed to the variations in crude oil qualities and in the processing capabilities of the different refineries. The responses from refiners to the questions regarding marine fuel blending indicate that it is not something that occurs at all refineries, and it may differ from facility to facility within the same company.

Although not a defined practice, inadvertent fuel blending does occur at some fuel supply locations, where fuel oils from different sources may be combined into the same storage tank. This practice will restrict the accuracy of any estimates of the actual sulphur content of fuels being burned in ships.

8 AVAILABILITY OF MARINE FUELS ACROSS CANADA

Looking at the data for marine fuel sales in Table 6.1 (reproduced again here as Table 8.1), it is obvious that all but the heaviest of marine fuels are available in some quantity across the country. By far the most sought-after products are those which fall into the category of IFO 180–380, with the next-heavier range, IFO 380–640, as the second most popular. As discussed in the previous section, the blending practices that create these fuels result in sulphur contents (on a national basis) that range from 0.9 to 2.4% and from 0.99 to 2.5%, respectively. The volume-weighted national average sulphur contents for these two products are 1.82% and 1.67%, respectively.

Table 8.1: Volume of Canadian Marine Fuel Sales in 2004

	Fuels Sales for 2004 (m^3)				
Fuel Grades	**Atlantic**	**Quebec**	**Ontario**	**Western**	**Canada**
DMA	201 709	49 100	86 300	140 790	477 899
DMB	**	68 500	38 900	69 619	**
Other marine distillates	192 809	**	**	**	452 293
< IFO 180	**	9993	27 000	**	43 993
IFO180–IFO380	121 610	34 391	97 000	541 376	1 106 376
IFO380–IFO640	**	45 100	109 836	524 634	**
> IFO640	**	0	**	0	91 000

Note: ** Information withheld to protect confidential data

Although most, if not all, of the above fuel types are available nationally, it is important to look at the historical trend in fuel sales across the country in order to put the present data set into perspective. Figure 8.1 shows marine diesel fuel oil sales by region since 1978. As indicated, the western and Atlantic regions are the major suppliers of marine distillate products, having experienced steady and slightly increasing sales since the mid 1980s. Sales in Ontario and Quebec have experienced a decreasing trend since the late 1970s. Whereas sales in Quebec have been steady since the mid 1980s, sales in Ontario have seen slight variations. Except for Ontario, all regions experienced sharp declines in sales between 2002 and 2003. As introduced in Sections 3 and 5, and further discussed in Section 9, these declines were the result of the relatively high price of Canadian MDO compared to global bunker supply. Another interesting point is the sharp increase in sales in the western regions; subsequent to the elimination of a long-standing 7% sales tax on bunkers in 2000–2001, sales volumes experienced a measurable increase.

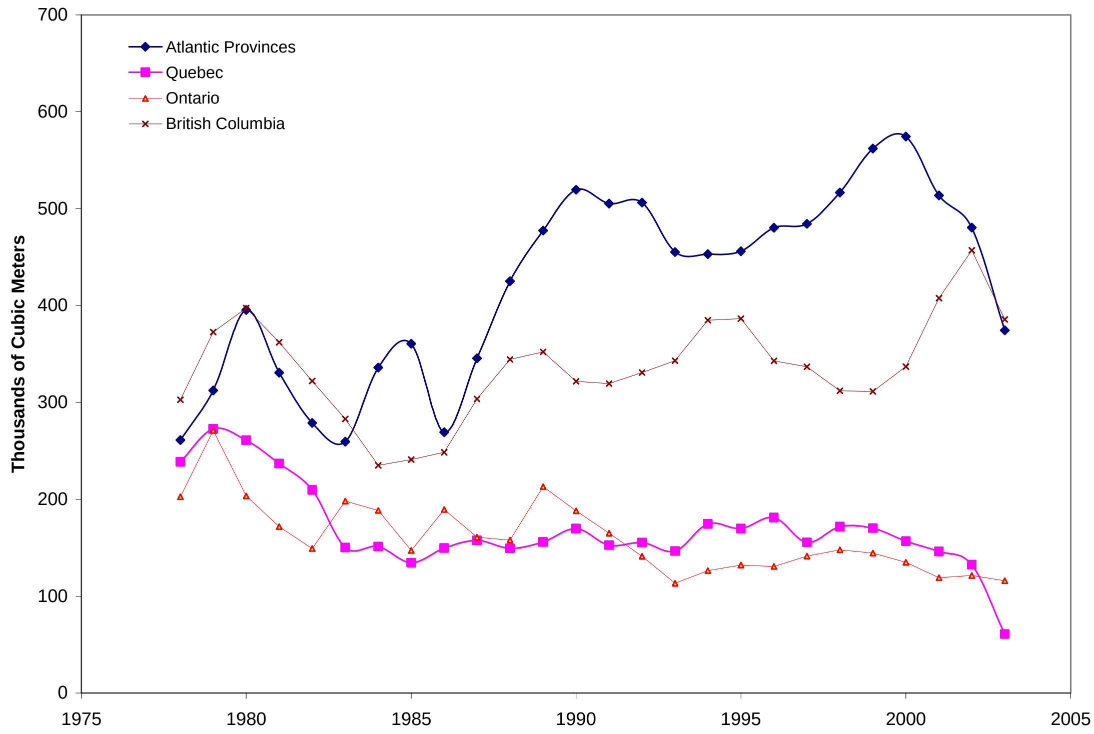

Figure 8.1: Marine Diesel Fuel Oil Sales, by Region, 1978–2003 (from Statistics Canada n.d.)

Figure 8.2 portrays marine heavy fuel oil sales, by region, since 1978. British Columbia and Quebec are the major supplying provinces, providing residual fuels to domestic and international consumers. Whereas the suppliers in Quebec provided most of their fuel to domestic consumers, the reverse was true in British Columbia. However, both provinces experienced significant declines in sales to foreign-flagged vessels in 2003—suppliers in Quebec saw their sales to foreign consumers diminish to 13.5% of total HFO sales volume. Sales in British Columbia have increased significantly since the mid 1990s, caused by a steady increase in domestic and international traffic as well as the removal of the bunkers sales tax.

Sales in Ontario have declined measurably compared to volumes experienced in the 1970s; however, due to a relatively steady shipping volume, sales have been relatively steady since the mid 1980s. Sales of heavy fuel oil in the Atlantic Provinces steadily increased from the mid 1980s to 1999. Subsequently, sales to foreign-flagged ships have steadily declined. Similarly, domestic sales declined between 1999 and 2002, after which domestic sales picked up due to the increasing domestic shipping activities related to the offshore oil and gas development of Newfoundland and Labrador.

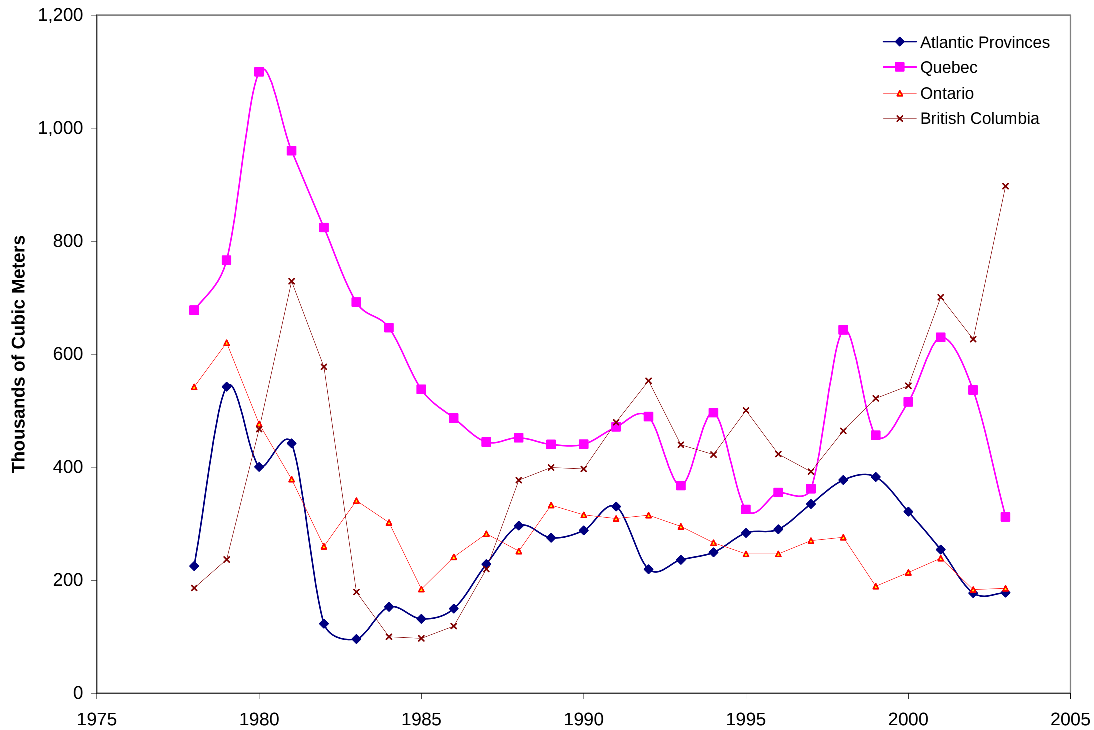

Figure 8.2: Marine Heavy Fuel Oil Sales, by Region, 1978–2003 (from Statistics Canada n.d.)

As discussed in Section 7, the availability of fuel to the Canadian marine sector is currently not experiencing any bottlenecks or limitations. As the requirements for higher-quality fuels in the land-based markets increase there will be an effect on the marine market supply, although it is not possible to predict with certainty what this effect will be. Some industry sources have indicated that the supply of HFO will not be appreciably changed. Instead, its sulphur content will be reduced, thus bringing about a price premium. Others are predicting that the supply of HFO will be streamed either towards the land-based markets or to off-road (including marine) markets, with the latter seeing a decrease in both supply and fuel quality from present figures. Still others suggest that supply of all HFO products will decrease as residual is upgraded to the higher-value distillate products. Section 9 discusses the future availability of low-sulphur marine fuels in more detail.

9 FUTURE LOW-SULPHUR FUEL AVAILABILITY AND COSTS

9.1 General

Three main factors will influence the availability of low-sulphur marine fuel in Canada and its costs relative to current pricing and world market prices. These factors are as follows:

- the crude oil slates being handled by Canadian refineries
- the desulphurization and cracking technologies used by Canadian refineries
- supply and demand for all petroleum products in the Canadian market

As with most predictions, there is considerable uncertainty as to how each of these factors will apply in the medium- and long-term future. However, certain trends can be projected with reasonable confidence.

9.2 Crude Oil Utilization

As noted in Section 5, the selection of crude oils processed by refineries is very complex and varies from refinery to refinery. The most important factors underlying the choice of crude sources are the market for products from the refinery, the refinery configuration and location (European Commission 2002a:40). Refineries must have access to the crude product (by pipeline or ship) and must also have a convenient means to deliver their products to their customers.

In Canada, total conventional crude oil production has been declining since 2000, and it is predicted that this trend will continue through to 2015. In 2003, the total conventional light- and heavy-crude-oil production was 1.12 million barrels per day, and forecasts indicate that by 2015 this production will decline to about 600 000 barrels per day (CAPP 2004). On the other hand, the production of oil sands crude has seen substantial growth and currently makes up close to half of total production. The same forecasts indicate that by 2015 it will account for 70–75% of all crude oil production. Synthetic crude oil has a low sulphur content (~0.1%), but also currently has a measurable price premium over conventional crudes, and the development of this price premium could affect the future quality, availability and price of fuel oils. More importantly, synthetic crude does not yield any black oil for the production of heavy fuel oil. It is probable that western Canadian refineries will increasingly work with Canadian synthetic crudes while eastern refineries will continue to be fuelled by imports and/or production from the Atlantic offshore sector. Central refineries currently served by pipelines from the West (e.g. the Enbridge line from Edmonton to Sarnia) could use either option. This scenario of future crude sourcing will not have a serious impact on the availability of HFO in western Canada, since it is already apparent that the majority of the supply is not produced locally; it is either sourced from the United States or elsewhere in Canada.

It is likely that the world demand for light, sweet crudes will continue to increase faster than that for heavier grades, and so the price premium will widen. As such, it is probable that more Canadian refineries relying on natural crudes will decide to invest in combinations of additional cracking and desulphurization technologies, with an additional push for this coming from the tightening of North American emission standards.

9.3 Sulphur Reduction Technologies

A number of desulphurization technologies were reviewed briefly in Section 5. As discussed, processing light (< 0.7% sulphur) crudes can provide low-sulphur (<1.5%) residuals (including marine heavy fuel oils) through normal refinery distillation and cracking processes. When lower sulphur levels are needed, additional desulphurization processes must be introduced.

Blending represents the lowest-cost option to reduce the sulphur content of heavy fuel oils. It includes blending a low-sulphur fuel stream into the existing HFO pool. Blending can either be performed with two different residuals (e.g. bunker fuel of less than 1.5% sulphur can be blended with the next-highest sulphur content fuel) or by adding a low-viscosity distillate stream to the HFO pool. The latter is usually less attractive on the basis of cost as was demonstrated in Table 7.2, where typical blending practices appear to use the least amount of distillate in order to meet the required product specification.

It should be noted that blending high- and low-sulphur fuels does not actually reduce total sulphur emission levels unless new streams are introduced to the overall supply pool.

9.3.1 Current Desulphurization Technologies

Refineries typically produce distillates from a blend of high-sulphur straight-run gas oil and light cycle oil. The cetane number and density of the light cycle oil is such that very little can be used to produce on-road diesel. However, it can be used to produce DMA due to its lower cetane and higher density specifications. The sulphur content of middle distillates is typically reduced using desulphurization processes—catalytic hydrotreating in particular—that have been widely used in the industry for many years. The sulphur that remains in the heavier fuels is mainly in the form of aromatic sulphur compounds, which require more extreme conditions to treat.

In order to achieve the 2012 standards of 15 ppm (deep desulphurization), current hydrodesulphurization units would need to be retrofitted with additional vessels. The added vessels will result in a two-stage hydrodesulphurization process. The first stage will reduce the sulphur content to around 250 ppm, without any major modifications. The second stage will further reduce the sulphur content to the 15 ppm standard. This stage will require further, more expensive modifications such as increasing the pressure, hydrogen supply rate or purity; and/or altering the catalyst to increase activity (Energy Information Administration 2005).

Current industrial processes used for deep desulphurization use a trickle bed reactor (where the heavy oils are passed over a bed of the catalyst) in a counter-current flow. The processes involve two reactors that contain different catalyst beds. The catalysts that form the beds vary depending on the degree of desulphurization required to take place.

Without the modification or addition of vessels, the desulphurization unit could be replaced with a thick-walled reactor, as the reactions would have to take place at greater pressures. Due to their extended fabrication time, thick-walled reactors would result in a significant increase in capital costs. Raising the pressure would also increase operating cost, as the consumption of pressurized hydrogen is the largest operating cost of hydrodesulphurization.

Due to the capital and operating costs involved, deep desulphurization is usually implemented in combination with hydro-cracking to convert (part of) the residual product into higher-value material. The severity of the process can be adjusted to control the level of conversion of the feed into higher-value products. Large quantities of hydrogen are used in this upgrading process, along with high temperatures and pressure to achieve a high degree of conversion. Through hydrotreating, over 60% of the feed can be converted into lighter naphtha, distillate and gas oil material with removal of over 50% of the sulphur in the feed (Energy Information Administration 2005:5–10).

The most common upgrading process is delayed coking, which is a severe thermal cracking process designed to maximize the conversion of residual product into lighter, higher-value products. The coking process concentrates the feed sulphur and carbon into a coke by-product. Sulphur in the liquid fractions is substantially lower than the feed and can be further desulphurized. These upgrading processes have high capital and operating costs, and typically require other supporting processes such as hydrogen production and amine treating, and require sulphur plants and utilities. However, the additional benefits of higher-value products could make these processes economical for the refinery, above a certain price threshold (Energy Information Administration 2005).

Processes for which the main objective is sulphur removal from residual products are available at lower capital and operating costs than the combined processes introduced above. Employing a once-through downflow reactor in which hydrogen and feed are introduced, the processes can remove sulphur (over 75%), nitrogen, asphaltene and metal contaminants from residual feeds. Although less costly than the combined desulphurization and upgrading plants, the cost of desulphurization would still add at least a $27 per tonne premium to the HFO prices. For refineries that currently process heavy sour crudes, the premium would be significantly higher. At present, this type of approach would represent pure cost to the refinery, as the current market would not pay a price premium for the treated fuel given the availability of regular HFO. In future, the segregation of marine (and land) heavy fuels into low- and high-sulphur categories may make dedicated desulphurization more attractive (Energy Information Administation 2005).

9.3.2 Future Technology Developments

In addition to the above desulphurization techniques, several new techniques are currently in the developmental phases, including Process Dynamics' IsoTherming technique and the Unipure Oxidation process. Moreover, laboratory testing is also being performed on zeolites and bacteria.

It is important to note that, as far as the authors were aware at the time of printing, technology developments have been demonstrated to be at a commercially economical stage. These technologies are presented here to provide insight on the directions being taken by research and development to find new methods of reducing the sulphur content of fuel products.

Process Dynamics employs current desulphurization technologies, but improves the interface between the hydrogen, feed and catalyst in the reactor. This is done by dissolving the hydrogen into the liquid phase prior to passing the liquid over the catalyst. The result is an increased contact surface between the reactants and allows for a greater amount of mass transfer between the fluids. Currently, Process Dynamics has a commercial-size (5000 barrels per day) demonstration unit, which has been in operation since 2003 (Process Dynamics 2005).

The oxidation technique does not employ classic hydrotreating methods. Instead, the gas and diesel oils are treated with hydrogen peroxide and formic acid. In the oxidation process, the sulphur compounds are oxidized to their corresponding sulfones, increasing the polarity of the compounds. A polar solvent is then introduced to the solution, causing the polar and non-polar compounds to separate. Subsequently, the non-polar (desired) compounds are isolated via liquid-liquid extraction. The concept is currently being tested in a small continuous-flow reactor. The technique may prove particularly useful for heavier oils, as it is deemed effective at removing sulphur from aromatic hydrocarbons, which are frequent components in heavy oils (Hao and Benxian 2004:1-11).

New high-performance catalysts are being tested as a method to reduce sulphur contents, with limited investments. These “drop in” catalysts are designed to meet future environmental standards without having to replace the entire process units currently installed at the refineries. Instead, they will simply replace the current catalysts present in the hydrodesulphurization units. The new catalyst technologies use molecular zeolites to increase the reactivity between sulphur and noble-metal catalysts (Naidu 2004). The use of zeolites will increase the production of hydrogen sulphide from alkyl and allyl sulphides. As such, a greater amount of sulphur can be removed from residual oils without having to modify the process specifications.

Bio-desulphurization is an emerging technology that uses bacteria as a catalyst to remove sulphur from heavy distillate fuels. In order to achieve sufficiently low sulphur content, a process combining current hydrodesulphurization techniques and bio-desulphurization would be necessary. The bio-desulphurization mechanism is similar to the oxidation process introduced above; however, it does not require the same large amounts of solvents to oxidize the sulphur compounds. Instead small bacteria cultures are introduced in the reactor. The bacteria will selectively oxidize and remove the sulphur atoms without degrading the carbon ring structure (Van Hamme et al. 2003). This concept has only been tested at bench scale, and there are various limiting factors that must be overcome before this process can be seen as a viable replacement to hydrodesulphurization.

9.4 Market Factors

As noted earlier, marine residuals are effectively a process by-product for most refiners, and sell at a discount to the crude-oil feedstock. When a refinery increases its ability to produce lighter fractions, it has to balance both costs and revenues. Desulphurization processes can generally be combined with cracking to take full advantage of the energy consumption involved. In the future, it is therefore highly probable that the proportion of residuals in most refineries’ output will continue to decrease.

The main markets for Canadian heavy fuels are land-based power generation and heating, domestic marine, and export marine, in descending order of product volume (though with regional variances).

The first of these markets competes with other domestic energy sources, and the first two both require compliance with national emission standards that will drive product quality faster than is the case on the international scene. International shipping will not be prepared to pay price premiums for any more fuel volume than is required to meet SECA access limits. It can therefore be expected that probable increases in Canadian bunkering costs will lead to considerable reductions in the volumes of bunker sales to international shipping.

9.5 Cost Associated with Reducing Sulphur Content Levels in Marine Fuels

Any future fuel regulations that demand high-quality fuels will lead to higher marine fuel production costs. The distribution of these incremental costs will depend on conditions in the international bunker market and the influence of demand from other domestic industries. In alignment with previous sections, the following section introduces costs for reducing the sulphur level in distillate and residual marine fuels—two distinct fuel categories with significantly different production requirements. Costs are developed in view of regulations introduced in Section 2, including regulations on ultra-low-sulphur diesel (15 ppm) and low-sulphur (1.5%) residual fuels.

9.5.1 Marine Distillate Fuels

Producing low- and ultra-low-sulphur distillate fuels will require a significant increase in hydrogen for desulphurization; this can be obtained from either third-party suppliers or through increased refinery production (using natural gas as hydrogen plant feedstock). Assessing current on-road and off-road distillate volume throughputs at Canadian refineries, previous studies have estimated the cost incurred by refineries to meet both on-road and off-road diesel specifications of 15 ppm (Purvin & Gerty 2004:IV-6; see

Table 9.1). The estimates are based on strategies planned and/or developed by domestic refineries in light of the upcoming regulations. The assessment covers capital and incremental operating costs.

Table 9.1: Capital and Operating Costs to Reduce Sulphur in Diesel

	Atlantic/Quebec	Ontario	Western Canada	Total Canada
Throughput (m^3/day)	34 000	13 500	30 800	78 300
Capital costs (¢/litre)	1.20	2.16	2.16	1.74
Operating costs (¢/litre)	0.53	0.54	0.52	0.53
Total costs (¢/litre)	1.73	2.70	2.67	2.27

The above costs indicate the incremental costs for producing 15-ppm sulphur diesels. However, they do not include any costs associated with infrastructure changes and increased distribution costs. In developing the above estimates, most refineries assumed that rail and marine diesel would be provided at 15 ppm. However, certain refineries provided costs on the assumption that they would leave rail and marine diesel fuels at 500 ppm. Thus, if all off-road fuels are desulphurized to 15 ppm, the total costs might prove slightly higher than shown in Table 9.1.

At an average cost of 2.27 cents per litre, current marine diesels (DMA and DMB) will incur a premium of around $20 per tonne. Considering current marine distillate price levels (e.g. $645 per tonne in Vancouver as of May 2005), the ultra-low-sulphur requirement will add a premium of 3–4%. However, considering historical MGO and MDO prices (approximately $200 per tonne), the premium could represent a 10% addition to long-term distillate fuel prices. The effect of these premiums on marine fuel sales and, possibly, distortion of port competition, should be further considered. For example, since the 7% sales tax on fuels sold to foreign ships was removed, marine fuel sales volumes have increased considerably in the western region (see Section 8).

Forced to invest in desulphurization technologies, refineries have indicated that their future investments will include provisions for increased conversion of fuels. By increasing the yields and sales of lighter (higher valued) products, refineries can recover some of their investments. These increasing rates of conversion could, eventually, reduce the availability of residual fuels.

9.5.2 Marine Residual Fuels

The cost of producing and supplying low-sulphur residual marine fuels will depend on the available crude stock and the strategy adopted by the various refineries, if any. Three options have been introduced, including blending, crude switching and desulphurization; these options have been listed according to their progressively increasing costs.

The cost of blending will depend on the availability of low-sulphur residuals and the future price spread between low- and high-sulphur HFO. On a global basis, the price spread for these products has been around $15–$20 per tonne (up to $40 at various bunkering ports worldwide); however, this price spread has been increasing and will likely continue to do so. Thus, if blending two residual products in order to meet the 1.5% sulphur limit, the premium, based on the current price spread, would be in the order of $10–$15 per tonne. This option assumes that low-sulphur heavy fuels (~1%) are blended with medium-sulphur residuals (< 2%) in order to produce SECA-compliant products. The availability of sufficiently low-sulphur residual fuels

(~1%) will likely be low given the declining global supply of light sweet crude, leading to a limited future availability of SECA-compliant products.

Thus, as an alternative, distillate streams could be added to produce the blended compliant product. However, the premium for this option will be high, reflecting the higher prices of MGO and MDO. At an estimated premium of $15–$25 per tonne, the cost could be comparable to that associated with desulphurization (with no conversion) of residuals (see Section 9.3). Additionally, given the small amount of distillate that is typically added to residuals, the range of sulphur reduction between the residual and the final HFO product may only be 0 to 0.15 %. Thus this option is likely the least favourable since it would provide limited improvements at a high cost.

In addition to the sulphur premium, production of two grades of bunker fuel (i.e. low sulphur for SECA purposes and high sulphur for consumption while in international transit) may require segregation of storage tanks at the refineries. Such infrastructure and distribution costs could possibly add an additional 10% to the premiums estimated herein.

The increased processing of lower-sulphur crudes will increase the costs of HFO in accordance with the cost of the higher-quality crude oils. For refineries that currently process heavy sour crudes, the change in crude runs could result in a $2–$5 premium per barrel to existing feed stocks (exceeding $10–$15 during periods of tight global crude oil supply). Considering the average crude-oil price differentials, refinery yield differentials and segregation costs, low-sulphur marine residuals could incur a premium of $50–$70 per tonne.

Accordingly, due to the increased feedstock costs, some refiners may choose to not produce any low-sulphur HFO. Instead, they would try to minimize their production of HFO, and aim to either export their high-sulphur HFO overseas or upgrade the residual to higher-value products. This could lead to reduced availability of low-sulphur marine products from domestic refiners.

The cost of desulphurization will depend on the strategy adopted by the various refineries. As introduced in Section 9.3, the cost of sulphur removal from residual products will be in excess of $27 per tonne. This low-cost option will not provide conversion and increased yields of lighter products. Based on refinery feedback, it is highly unlikely that any refineries would adopt this technology in the face of stricter marine fuel standards. Instead, it is likely that any desulphurization of residuals would occur in combination with upgrades and conversion. This would add significantly to the costs of marine residual fuels (approximately $50–$90 per tonne), and the availability of marine heavy fuel oils would be significantly weakened across Canada.

9.6 Implications of the Future Creation of a Canadian SECA

Section 6 presented data gathered from refineries and fuel suppliers which describe both the 2004 sales volumes of different fuel grades in Canada and the sulphur contents of these fuels. By examining the sulphur contents presented in Table 6.2 (reproduced here as Table 9.2) it becomes obvious that the Canadian HFO products, for the most part, are of a higher quality than the global average sulphur content of 2.7%. Additionally, only about 5% of the global supply of HFO is below 1.5% sulphur whereas, on average, all of the HFO available in Quebec is below

1.5% sulphur. Similarly, the national volume-weighted average is not substantially above this cut-off value for defining low-sulphur HFO.

Table 9.2: Volume-weighted Sulphur Content of Canadian Marine Fuel Sales in 2004

	Volume-weighted Average Sulphur Content (%)				
Fuel Grades	**Atlantic**	**Quebec**	**Ontario**	**Western**	**Canada**
DMA	0.125	0.226	0.489	0.145	0.207
DMB	**	0.054	0.226	0.211	0.144
Other marine distillates	0.172	**	**	**	0.224
< IFO 180	**	1.468	1.974	**	1.763
IFO 180–IFO 380	3.632	1.306	2.230	1.666	1.819
IFO 380–IFO 640	**	1.492	2.313	1.587	1.672
> IFO 640	**	n/a	**	n/a	1.806
All Distillate Fuels	**0.144**	**0.134**	**0.313**	**0.233**	**0.201**
All Residual Fuels	**2.505**	**1.331**	**2.162**	**1.627**	**1.760**

The data in the above table and the associated discussion have very important implications if Canada were to consider implementing SECAs. It indicates that, based on the present state of production, the Canadian market is already in reasonably good shape to comply with a maximum sulphur content of 1.5%. This is not to say that there would not be challenges for refineries and suppliers, as well as ship owners/operators, but compared to the global market, Canada may have fewer short-term difficulties in conforming to the requirements of a SECA. However, as discussed earlier, decreasing availability of light sweet crude will have an effect on the supply of low-sulphur HFO. Similarly, as more SECAs are implemented globally, the price and availability of low-sulphur HFO could both change considerably.

10 CONCLUSIONS

The production volume data collected during the present study indicate that there are no bottlenecks in the current supply of fuels to the marine sector in Canada. Furthermore, Canadian heavy fuel oil (HFO) is presently of a higher quality than the global average (1.76% sulphur content vs. 2.7%). However, the supply and quality of marine fuels are heavily influenced by the much larger land-based markets, primarily home and institutional heating, and power generation.

The most important consideration in looking at the supply and quality of residual fuels is that they are essentially a by-product of the refining process, and as such are sold for less than the cost of the crude from which they were produced. On top of this, marine fuels can be considered to be a by-product of the land-based markets. This is true for both distillate and residual marine fuel products. As such, the future supply of marine fuels will be determined as much by what happens in terms of regulations, supply and demand in the land-based markets as by the goings on of the marine market.

As demand from land-based distillate markets increases, producers may choose to increase production of the higher-value, light products by reprocessing (upgrading) residuals, thus reducing the overall supply of residual fuels. Similarly, as land-based HFO markets increase quality requirements, the supply of HFO to marine markets could (1) see a similar increase in quality since they are a secondary market; (2) see the lowest-quality residuals enter their supply, thus decreasing the quality from current levels; (3) see a decline in the availability of HFO regardless of quality; or (4) a combination of the above.

In the context of a North American Sulphur Emission Control Area (SECA), the necessary improvement in fuel quality from 1.76% to 1.5% sulphur content seems to suggest that the Canadian market is well positioned. This is not to suggest that such an incremental improvement would not present challenges to the refining industry. Moreover, this is only a snapshot of the current Canadian situation. Global supply of light sweet crude is known to be declining, and as more SECAs are implemented globally, there will be an increasing demand for this decreasing supply of premium crude. As this crude becomes less available, refineries that continue to produce residual fuel products (as opposed to those that choose to upgrade residuals to produce more distillates) will be required to increase the desulphurization technology in their processes. These additional refinery costs will be passed on to consumers, thus increasing the price of what is already a ship owner's most expensive operational outlay.

Although there is currently no shortage of marine fuels in Canada, there has been a decreasing trend in sales to foreign-flagged ships in the last few years. If a North America SECA were implemented, there would be a sudden increase in demand from foreign-flagged ships requiring this low-sulphur fuel to allow them to operate in Canadian/North American markets. There is no guarantee that there would be sufficient fuel supplies to meet a sudden spike in demand. Alternatively, the increased cost could prompt these ships to seek other, less expensive markets to load and off-load their goods.

11 REFERENCES

- Abbot, A., et al. 2000. Cost-benefit analysis of the use of TBT: the case for a treatment approach. *Science of the Total Environment*. Vol. 258, no. 1–2: 5–19.

- Agren, C. 2003a. Instead of low-sulphur fuel. *Acid News*. No. 3, September 2003.

- Agren, C. 2003b. Tighter limits for sulphur in fuels. *Acid News*. No. 1, February 2003.

- American Bureau of Shipping. 2005. *Understanding MARPOL Annex VI, A Guide for Ship Owners*. Houston (TX): American Bureau of Shipping.

- [BMT] BMT Fleet Technology Limited. 2005. *Management Options for Marine Vessel Air Emissions*. Report submitted to Environment Canada, Pacific and Yukon Region. March 2005.

- Canada. 1999. *Canadian Environmental Protection Act, 1999*. S.C., 1999, c. 33. Canada Gazette, Part III, vol. 22, no. 3. Ottawa: Queen's Printer. Available from: http://www.gazette.gc.ca/archives/p3/1999/g3-02203.pdf
-
- Canada. 2002. *Canadian Environmental Protection Act, 1999: Sulphur in Diesel Fuel Regulations*, P.C. 2002-1232, 17 July 2002, SOR/2002-254. Canada Gazette. Part II, vol. 136, no. 16, p. 1668–1677. Ottawa: Queen's Printer. Available from: http://www.ec.gc.ca/ceparegistry/documents/regs/g2-13616_r1.pdf

- Canada. 2004a. *Canadian Environmental Protection Act, 1999: Off-Road Compression-Ignition Engine Emission Regulations*. Canada Gazette, Part I, vol. 138, no. 19, p. 1450–1471. Ottawa: Queen's Printer. Available from: http://www.gazette.gc.ca/archives/p1/2004/2004-05-08/pdf/g1-13819.pdf

- Canada. 2004b. Canadian Environmental Protection Act, 1999: *Regulations Amending the Sulphur in Diesel Fuel Regulations.* Canada Gazette, Part I, vol. 138, no. 40, p. 2703–2729. Ottawa: Queen's Printer. Available from: http://www.gazette.gc.ca/archives/p1/2004/2004-10-02/pdf/g1-13840.pdf

- [CAPP] Canadian Association of Petroleum Producers. 2004. *Canadian Crude Oil Production and Supply Forecast*.

- [CAPP] Canadian Association of Petroleum Producers. 2005. *Canadian Crude Oil…a Reliable and Growing Supply of North American Energy*.

- [CPPI] Canadian Petroleum Products Institute. 2005. *Charting the Course, Marine Fuel Efficiency and Emissions, Marine Transport and Air Quality*, CPPI Perspectives, January 2005

- Commission to the European Parliament. 2002a. *A European Union Strategy to Reduce Atmospheric Emissions from Seagoing Ships*. Brussels, Belgium: Commission to the European Parliament. Vol. I, Nov. 2002. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52002DC0595:EN:HTML

- Commission to the European Parliament. 2002b. *Proposal for a Directive of the European Parliament and the Council Amending Directive 1999/32/EC as Regards the Sulphur Content of Marine Fuels*. Brussels, Belgium. Vol. II, Nov. 2002. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52002PC0595:EN:HTML.

- Council of the European Union. 2004. *Amended proposal for a Directive of the European Parliament and of the Council amending Directive 1999/32/EC as regards the sulphur content of marine fuels*. Political agreement. June 2004.

- Croner, P. 2002. *MDO vs HFO in Deep-Sea RoRo Service. Is there a Financial Break-even?*. Stokholm, Sweden: Wallenius Lines.

- Davies, M.E., et al. 2000. *Study on the Economic, Legal, Environmental and Practical Implications of a European Union System to Reduce Ship Emissions of SO2 and NOx*. A Report for the European Commission, August 2000. Teddington, Middlesex, England: BMT Murray Fenton Edon Liddiard Vince Ltd. Available from: http://ec.europa.eu/environment/enveco/taxation/ship_emissions/pdf/mainfinal.pdf

- Energy Information Administration. 2005. *The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects on Prices and Supply*. Washington, DC: Energy Information Administration. Available from: http://www.eia.doe.gov/oiaf/servicerpt/ulsd/pdf/ulsd.pdf

- Environment Canada. n.d. Acts, and Regulations and Agreements. Available from: http://www.ec.gc.ca/default.asp?lang=En&n=48D356C1-1

- Environment Canada. 2002. *Sulphur in Liquid Fuels – 2001*. Environment Canada; Oil, Gas and Energy Branch; Fuels Division. July 2002. Available from: http://www.ec.gc.ca/cleanair-airpur/caol/OGEB/fuels/reports/sulpur2001/sulphur_rpt_2001_e.htm

- Environment Canada. 2003a. *Reducing the Level of Sulphur in Canadian Off-Road Diesel Fuel. A Discussion Paper on Designing a Canadian Regulation to Align with the New U.S. Standard*. Environment Canada; Oil, Gas and Energy Branch; Fuels Division. August 2003. Available from: http://www.ec.gc.ca/cleanair-airpur/CAOL/OGEB/fuels/reports/OffRoadDiesel/SulphurOffRoadDiesel_e.cfm

- Environment Canada. 2003b. *Setting Canadian Standards for Sulphur in Heavy and Light Fuel Oils. Discussion Paper on Meeting Commitments of the Notice of Intent on Cleaner Vehicles, Engines, and Fuels*. Environment Canada; Oil, Gas and Energy Branch; Fuels Division. October 2002. Available from: http://www.ec.gc.ca/cleanair-airpur/CAOL/OGEB/fuels/reports/cnslt_rpts/disc_paper/toc_summ_e.htm

- Environment Canada. 2004. *Sulphur in Liquid Fuels – 2003*. Environment Canada; Oil, Gas and Energy Branch; Fuels Division. November 2004. Available from: http://www.ec.gc.ca/cleanair-airpur/CAOL/OGEB/fuels/reports/SulphurLiquid2003/toc_e.cfm

- Esplin, G. 2002. *Fuel Quality Options for the Reduction of Marine Vessel Emissions in the Georgia Basin*. Report prepared for Environment Canada. North Vancouver (BC): Genesis Engineering, Inc.

- EUROPA. 2004. *Clean ships get into gear after years of slow steaming*. Press release. Brussels, Belgium: European Commission. June 28, 2004. Available from: europa.eu/rapid/pressReleasesAction.do?reference=IP/04/810&format=PDF&aged=1&language=EN&guiLanguage=en

- European Commission. 2002a. *Advice on the Costs to Fuel Producers and Price Premia Likely to Result from a Reduction in the Level of Sulphur in Marine Fuels Marketed in the EU*. Study C.1/01/2002 by Beicip-Franlab. April 2002. Available at: http://ec.europa.eu/environment/air/pdf/020505bunkerfuelreport.pdf

- European Commission. 2002b. *Quantification of Emissions from Ships Associated with Ship Movements Between Ports on the European Community*. Prepared for the European Commission by Entec UK Limited. July 2002. Available from: http://ec.europa.eu/environment/air/pdf/chapter1_ship_emissions.pdf

- Evans, SM., Birchenough, AC., and Brancato, MS. 2000. *The TBT Ban: Out of the Frying Pan into the Fire*, Marine Pollution Bulletin. Vol. 40, no. 3: 204–211.

- Favennec, JP. 2001. *Refinery Operation and Management*. Petroleum Refining, vol 5. Paris, France: Editions TECHNIP. 624 p.

- Genesis Engineering. 2003. *Technologies and other Options for Reducing Marine Vessel Emissions in the Georgia Basin.* Draft report prepared for Environment Canada. North Vancouver (BC): Genesis Engineering, Inc. 187 p.

- Hao, L., and Benxian, S. 2004. *An Improved Desulphurisation Process Based on H2O2/Formic Acid Oxidation System Followed by Liquid-Liquid Extraction*. East China University of Science and Technology.

- Hare, J. 1994. Flag, Coastal, and Port State Control, Closing the Net on Unseaworthy Ships and their Unscrupulous Owners. *Sea Changes*. No. 16, p. 57.

- Harrison, D. Jr., Radov, D., and Patchett, J. 2004. *Evaluation of the Feasibility of Alternative Market-Based Mechanisms to Promote Low-Emission Shipping in European Union Sea Areas*. Prepared for the European Commission by NERA Economic Consulting. London (UK): NERA Economic Consulting. 135 p.

- Hirst, D. 2002. The Environmental Case for Seawater Scrubbing, Sept. 2002, updated October 2005. Available from: http://www.davidhirst.com/scrubb/SeawaterScrubbing(v102).pdf

- [IMO] International Maritime Organization. 2002. *International Convention for the Prevention of Pollution from Ships, 1973 and its Protocols of 1978 and 1997 Consolidated with all Amendments in Effect*. July 2002.

- [IMO] International Maritime Organization. 2004a. MARPOL 73/78 Annex VI – NO_x and SO_x Controls. August 2004. Available from: http://www.eagle.org/regulatory/noxsoxpaperaug04.pdf

- [IMO] International Maritime Organization. 2004b. Air pollution rules to enter into force in 2005. Press release, May 2004. Available from: http://www.imo.org/About/mainframe.asp?topic_id=848&doc_id=3620

- Johnson, JT. 2001. *Summary and Analysis of Results, Appendix O, Corrosion Costs and Preventive Strategies in the United States*, Sept. 2001

- MAN B&W Diesel A/S. 2005. *Emission Control, Man B&W Two-Stroke Diesel Engines*. Copenhagen, Denmark: Man B&W Diesel A/S. Available from: http://www.manbw.com/files/news/filesof4458/p9000.pdf

- MARTOB. 2004. *Operational Aspects of a Sulphur Cap on Marine Fuels*. Executive summary available from: http://martob.ncl.ac.uk/public%20docs/ES-WP5/Executive%20Summary%20on%20Operational%20aspects%20of%20a%20sulphur%20cap%20on%20marine%20fuels.pdf

- Melious, JD.. 2004. *Transboundary Air Quality Management Models: Options for Western Canada/ United States*, Report prepared for Environment Canada. June 2004.

- Naidu, A. 2004. The secrets of desulphurization. World Hydrocarbon. No. 2: 20–24.

- Process Dynamics. 2005. Diesel IsoTherming [information sheet on Internet]. Available from: www.processdyn.com/Diesel.html

- Purvin & Gertz Inc. 2003. *Technical Feasibility and Costs Associated with Reducing Sulphur Dioxide Emissions from Fuel Oil and Coal in Ontario*. April 2003

- Purvin & Gertz Inc. 2004. *Economic and Environmental Impacts of Removing Sulphur from Canadian Gasoline and Distillate Production*. August 2004

- Ridley, IG., and Hutchinson, KW. 2004. Life cycle cost drivers for marine vehicle concept design. Presented at defenceIQ: Whole Life Costing for Defence 2004. London, July 2004.

- Rosenne, S., and Yankov, A., eds. 1991. *United Nations Convention on the Law of the Sea 1982*, *A Commentary*. Vol. IV. London/Dordrecht/Boston: Martinus Nijhoff Publishers.

- Skjolsvik, KO. 2004. Application of low sulphur marine fuels – new challenges for the marine industry. Report. Marintek.

- Statistics Canada. n.d. CANSIM Online Data, *Supply and Demand of Primary and Secondary Energy*. Table 128-0002.

- Statistics Canada. 2002, 2003. *Report on Energy Supply-Demand in Canada*, Catalogue no. 57-003-XIB

- Statistics Canada, Transportation Division. 2004a. *Shipping in Canada 2002.* Catalogue 54-205-XIE.

- Statistics Canada. 2004b. *Refined Petroleum Products*. Catalogue no. 45-004-XIB.

- Transport Canada. 2004. *CSA 2001, Regulatory Reform Project – Phase 1, Prevention of Pollution from Vessels Regulations*, Rev. 7.

- Transport Canada. 2005. Canadian Ship Registry [online database]. Consulted March 2005. Available from: www.tc.gc.ca/ShipRegistry

- [US EPA] United States Environmental Protection Agency. n.d. Nonroad Engines, Equipment, and Vehicles. Diesel boats and Ships [Internet portal]. Available from: http://www.epa.gov/otaq/marine.htm

- [US EPA] United States Environmental Protection Agency. 1999. *In-Use Marine Diesel Fuel*. Fairfax (VA): ICF Consulting Group for the U.S. EPA. Catalogue no. EPA420-R-99-027. 20 p.

- [US EPA] United States Environmental Protection Agency. 2003a. *Control of Emissions from new Marine Compression-Ignition Engines at or Above 30 Litres per Cylinder; Final Rule*. Federal Register Part II, 40 CFR Parts 9 and 94, Feb. 2003.

- [US EPA] United States Environmental Protection Agency. 2003b. *Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel Proposed Rule*. Federal Register. Part II, 40 CFR Parts 69, 80. 89 et al. May 2003.

- [US EPA] United States Environmental Protection Agency. 2003c. *Draft Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines*. Federal Register, April. 2003. Catalogue no. EPA420-R-03-008.

- [US EPA] United States Environmental Protection Agency. 2004a. New Clean Diesel Rule Major Step in a Decade of Progress [press release]. May 2004. Available from:

http://yosemite.epa.gov/opa/admpress.nsf/7ebdf4d0b217978b852573590040443a/f20d2478833ea3bd85256e91004d8f90!OpenDocument

- [US EPA] United States Environmental Protection Agency. 2004b. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines.* Catalogue no. EPA420-R-04-007, May 2004.

- [US EPA] United States Environmental Protection Agency. 2004c. *Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel*. Federal Register. Part II, Vol. 69, No. 124, June 29, 2004, p. 39007–39056. Available from: http://www.epa.gov/EPA-AIR/2004/June/Day-29/a11293b.htm

- Van Hamme J., Singh, A., and Ward, OP. 2003. Recent advantages in petroleum microbiology. *Microbiology and Molecular Biology Reviews*. Vol. 67, no. 4: 503–549.

- Walker, S. 2003. A technical perspective: impact of low sulphur fuels on the end user. Paper presented at the 24th International Bunker Conference, Rotterdam, May 2003. Available from: http://www.bunkerworld.com/events/download/papers/rotterdam2003/Walker%20IBC%2003.pdf

- Wärtsilä. 2005. *Low Sulphur Guidelines*. Wartsila White Paper. Finland: Wärtsilä Corporation March 2005; updated January 2006. Available from: http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2323

- The World Bank Group. 2004. Crude oil prices. *Public Policy for the Private Sector*. Note no. 275, Oct. 2004.

ANNEX A

SAMPLE QUESTIONNAIRES

Fuel Refinery/Supply Data Collection Questionnaire

Environment Canada

Report on Availability, Quantity and Quality of Marine Fuels Sold in Canada

BMT Fleet Technology Ltd

PART A: GENERAL INFORMATION

A-1: Organization: ____

A-2: Location Address:____

City: ______________________ Postal Code: ________________

A-3: Parent/Corporate Owner:____

Street: ____

City: ________________ Province: ____ Postal Code: __________

Country: ________________ Website: http://____________________

A-4: Organization Description and Contacts:

Organization Description: ____

Primary Business: REFINING / IMPORT/ DISTRIBUTION / AGENT / SALES / OTHER

If Other; specify: ____

Contact: ______________________ Phone: ________________

E-mail: ______________________ Fax: ________________

PART B: MARKET BASE AND CLIENTS

B-1: What were the product volumes produced by the refinery in 2004 (see next page for details of fuel types)?

Refinery	Reg. S Diesel	Low S Diesel	Marine Diesel	Residuals (HFO)
__________	______	______	______	______
__________	______	______	______	______
__________	______	______	______	______

B-2: What volumes of fuels did this refinery sell in 2004 to:

Customer Type	Reg. S Diesel	Low S Diesel	Marine Diesel	Residuals (HFO)
Own branded Marine Direct Sales	______	______	______	______
Independent Marine Fuel Resellers	______	______	______	______
Other Non-Marine Use	______	______	______	______

PART C: MARINE PRODUCT SALES

Fuel Grades	**Year 2004 Sales**	**Sulphur Content**	**Remarks**
	cubic metres	% w/w	
Marine Diesel			
DMA			
DMB			
Marine Diesel Other Than Above (1)			
Intermediate			
< IFO 180			
IFO 180 to IFO 380			
Residual			
IFO 380 to IFO 640			
> IFO 640			

Note (1): includes No. 2 Diesel, DMX, DMC

PART D: BLENDING PRACTICES

D-1: What is the typical percentage range of components blended to produce the following marine fuels?

Supply / **Grades**	**Range of Distillate Component (%)**	**Range of Residual Component (%)**	**Sulphur Content Range (%)**
< IFO 180			
IFO 180 to IFO 380			
IFO 380 to IFO 640			
> IFO 640			

PART E: FUEL AVAILABILITY

E-1: On a company-wide basis, what factors influence the quality of the crude oil used in your refining process (e.g., other industries, source) and are these factors controllable (i.e., a specific choice of crude supplier) or are they driven by market demand?

E-2: What other industries, if any, have an influence on demand/availability of fuel types for use by the marine sector, and how do these influences affect the availability of fuel for use by the marine sector? *Please provide a general discussion only.*

PART F: FUTURE AVAILABILITY OF LOW SULPHUR FUEL

F-1: Are there any refining methods *other than hydro-treating* currently in place to achieve low sulphur distillate fuels?

F-2: What methods are (a) in place and (b) being developed to reduce sulphur in residuals?

Environment Canada

Fuel Supply Data Collection Questionnaire

Report on Availability, Quantity and Quality of Marine Fuels Sold in Canada

BMT Fleet Technology Ltd

PART A: GENERAL INFORMATION

A-1: Organization: ______________________________

A-2: Location Address: ______________________________

City: ______________ Postal Code: ______________

A-3: Parent/Corporate Owner:
Street: ______________________________

City: ______________ Province: ______ Postal Code: ______________

Country: ______________ Website: http://______________

A-4: Organization Description and Contacts:

Organization Description: ______________________________

Primary Business: REFINING / IMPORT/ DISTRIBUTION / AGENT / SALES / OTHER

If Other, specify: ______________________________

Contact: ______________ Phone: ______________

E-mail: ______________ Fax: ______________

PART B: MARKET BASE AND CLIENTS

B-1: What Port Authorities do you serve?

B-2: Primary customer base *(Please provide total sales volumes (cubic metres) for 2004)*:

Customer Type	Reg. S Diesel	Low S Diesel	Marine Diesel	Residuals (HFO)
Deep sea vessels (International)	________	________	________	________
Captive Fleet (Domestic)	________	________	________	________
Other (specify):	________	________	________	________

PART C: PRODUCT SALES

Fuel Grades	Year 2004 Sales cubic metres	Sulphur Content % w/w	Remarks
Marine Diesel			
DMA			
DMB			
Marine Diesel Other Than Above[(1)]			
Intermediate			
< IFO 180			
IFO 180 to IFO 380			
Residual			
IFO 380 to IFO 640			
> IFO 640			

Note (1): includes No. 2 Diesel, DMX, DMC

PART D: BLENDING PRACTICES

D-1: What is the typical percentage range of components blended to produce the following marine fuels?

Supply / Grades	Range of Distillate Component (%)	Range of Residual Component (%)	Sulphur Content Range (%)
< IFO 180			
IFO 180 to IFO 380			
IFO 380 to IFO 640			
> IFO 640			

D-2: Blending performed by self, refinery, importer, reseller, marketer? Specify:

D-3: Where are fuels sourced from (e.g. refinery, region, and/or country):

Reg. S Diesel ______________________________

Low S Diesel ______________________________

Marine Diesel ______________________________

Residuals (HFO) ______________________________

ANNEX B

SAMPLE CONFIDENTIALITY AGREEMENT

CONFIDENTIALITY AGREEMENT

Study of the Marine Fuel Supply Chain in Canada

Between:

____

and

BMT Fleet Technology Limited

BMT Fleet Technology Limited (BMT) is retained by Environment Canada to undertake a study of the marine fuel supply chain in Canada. In undertaking this assignment, BMT will be collecting and validating information from _________ related to production, sales, quality, distribution and locations. Such information will be treated as confidential as described below.

1. BMT understands that the nature of this assignment requires confidentiality provisions to be in place between BMT and ___________.

2. In this agreement, Confidential Information means:

   i) information disclosed by __________ to BMT relating to the business of __________ or any of its affiliates which, if disclosed in writing, is marked "Confidential", is disclosed in reports in such a manner that Company-specific information can be identified, or if disclosed orally is indicated to be confidential, and

   ii) correspondence with __________ specifically prepared utilizing Confidential Information in connection with this assignment.

3. However, Confidential Information does not include:

   i) reports prepared for CPPI, as we understand that all Confidential Information will be aggregated;

   ii) __________ specific information which __________ agrees in writing is no longer considered Confidential Information;

   iii) computer programs and methodology developed by BMT to assist it in performing this assignment;

   iv) market research and analyses of information in the public domain conducted by BMT;

   v) information which is or becomes generally available to the public other than as a result of a disclosure by BMT;

vi) information which is or becomes available to BMT on a non-confidential basis from a source other than __________, provided that the disclosing source, to BMT's knowledge or reasonable belief, is not bound by a duty of confidence to __________ or any of its affiliates or is otherwise, to BMT's knowledge or reasonable belief, prohibited from transmitting the information to BMT by reason of some contractual, legal or other form of obligation;

vii) information which is known to BMT on a non-confidential basis prior to disclosure to BMT by __________; and

viii) information which is independently developed by BMT through its employees who do not have access to the Confidential information.

4. The obligations of confidence contained in this letter do not apply to information BMT is required to disclose to a court of competent jurisdiction or any regulatory authority having jurisdiction, provided that BMT takes reasonable steps to maintain the confidentiality of the information and provided BMT provides __________ with immediate written notice of the request for disclosure.

5. BMT agrees to keep in confidence and not disclose without the prior written consent of __________, the Confidential Information in any manner whatsoever in whole or in part and will not use the Confidential Information directly or indirectly for any purpose other than the purposes of this assignment. All persons within BMT to whom Confidential Information is disclosed shall be bound by a secrecy agreement with BMT, and BMT shall use its best efforts to ensure that such parties do not use or disclose any Confidential Information contrary to the terms of this Agreement.

6. BMT shall keep a record of the location of the Confidential Information. At the end of the assignment, BMT shall deliver to __________ any Confidential Information furnished by __________, or any of its affiliates, and shall destroy all other copies of Confidential Information in its possession, or in the case of information stored in digital form, shall render that information inaccessible.

7. The report prepared by BMT for Environment Canada shall be the sole property of Environment Canada, but BMT may retain copies of such reports, summaries, correspondence and tables for its own records.

8. This Confidentiality Agreement shall be governed by the laws of the Province of Newfoundland and Labrador. It is agreed that for the purpose of obtaining injunctive relief, the parties hereto stipulate that (a) the Confidential Information has tangible value and constitutes trade secrets and is proprietary to __________, and (b) unauthorized disclosure of the Confidential Information will cause irreparable harm to __________ for which damages will not provide an adequate remedy.

9. BMT's obligations pursuant to this letter shall survive completion of this assignment, but shall terminate five years after the date of this agreement.

The parties hereby agree with the terms of this Confidentiality Agreement.

____________________________________ __________________________________
Name Signature

__________________________________ _______________________________
Position Date

BMT Fleet Technology Limited
__Andrew Kendrick__________________ ______________________________
Name Signature

__Vice-President___________________ ___30 May, 2005________________
Position Date