

Low Sulphur Fuel Oils

***Preliminary Estimated Costs to Canadian Industry
based on European Data***

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Introduction

The purpose of this paper is to present and discuss information on costs related to reducing sulphur in fuel oils. European Commission and United Kingdom cost assessments of reducing the sulphur level of both LFO and HFO are reviewed. These are used to develop preliminary “high-level” estimates of the potential costs to Canadian industry of implementing similar sulphur requirements in Canada.

Environment Canada is undertaking additional work to refine these preliminary cost estimates. This work will assess potential costs of reducing sulphur dioxide emissions resulting from the combustion of fuel oils based on available technical options to fuel oils users, including reducing sulphur content in fuel oils, fuel switching, improved energy efficiency and pollution abatement. It is expected that this information will become available later in 2002.

European Union Council Directive 99/32/EEC

Countries of the European Union are subject to its Directive 1999/32/EC requiring them to reduce sulphur in heavy fuel oil (HFO) to 1% wt. by January 1, 2003 and sulphur in light fuel oil (LFO) to 0.1% wt. by January 1, 2008. Some countries such as Austria, Denmark and Finland already have in place a limit of 1% wt. sulphur (or less) for HFO. The current EU sulphur limit in LFO is a maximum of 0.2% wt.

The EU Directive forms part of an overall European strategy to combat acidification. In November 2000¹, the European Union Council adopted national emission ceiling limits (to be met by 2010) for certain atmospheric pollutants including SO₂. Accordingly, some flexibility is built in the Directive (such as described below under bullets 4 and 5) to “*reflect the conclusions from the integrated assessment [for the acidification strategy] and to avoid non cost-effective expenditure...*”.

The EU Directive includes the following flexibility:

1. The 1% wt. sulphur limit for HFO does not apply for fuel used in combustion plants that
 - are equipped with effective desulphurisation technologies (as per Directive 88/609/EEC on large combustion plants);
 - have thermal input below 50 megawatts where the emissions of sulphur dioxide are at concentrations less than or equal to 1700 mg/Nm³ (in flue gas with oxygen content 3% by volume on dry basis at standard temperature and pressure); or

¹ Official Journal of the European Communities, Common Position (EC) No. 51/2000 adopted by the Council on 7 November 2000 with a view to adopting Directive 2000/C375/01 of the European Parliament and of the Council of European Communities on national emission ceilings for certain atmospheric pollutants, December 28, 2000.

- are part of refineries where monthly average emission limits do not exceed 1700 mg/Nm³.

According to the Commission, these flexibilities recognize that for power stations and certain industries it would be more cost effective to remove SO₂ from emissions using technology such as flue gas desulphurisation rather than using low sulphur HFO. The Commission considers that the emission standard of 1700 mg SO₂/Nm³ “*is approximately the equivalent, in terms of emissions, of burning heavy fuel oil with a 1% [wt.] sulphur content.*”

2. The requirement for sulphur in HFO does not apply to fuels for marine use.
3. While the sulphur requirement for light fuel oils applies to marine gas oils (i.e. distillate fuels intended for marine use), it allows for a derogation for these fuels in Greece, the Spanish Canary Islands, the French Overseas Departments, and the Portuguese archipelagoes of Madeira and Azores, since low sulphur levels “*may present technical and economic problems*” for these countries.
4. The EU Directive allows a member state to authorize HFO with sulphur levels between 1% wt. to 3% wt. to be used in part or the whole of its territory if air quality standards for SO₂ are respected and where emissions do not contribute significantly to acidification in any member state. The Directive specifies that to avail itself of this possibility, a member state has to inform the European Commission and the public at least 12 months beforehand. The Directive establishes a process where proposed measures are reviewed by the Commission which then makes a decision. According to the Directive, the Commission’s decision is to be reviewed every eight years on the basis of information to be provided to the Commission by member states.²
5. The Directive allows a member state to authorize, up to the end of 2012, LFO with sulphur levels between 0.1% wt. to 0.2% wt. to be used in part or the whole of its territory if air quality standards for SO₂ are respected and where emissions do not contribute significantly to acidification in any member state. To avail itself of this possibility, a member state would follow the process identified above for HFO.

Objective and Benefits of EU Directive

The objective of the EU Directive is to reduce emissions of SO₂ across the European Union. According to the European Commission, it “*is an integral part of a cost-effective strategy designed to combat acidification as well as reducing atmospheric pollution by sulphur dioxide and particulate matter.*”

The European Commission estimated that the introduction of the 1% wt. sulphur limit for HFO “*will reduce SO₂ emissions in 2010 by approximately 1 million tonnes as compared*

² The authors are not aware of any applications by member states for the use of high sulphur fuel oils.

to what would be the case in the absence of the Commission's proposal". In considering benefits to human health, the Commission estimated that, "on average, the economic costs of the damage resulting from 1 tonne of SO₂ emissions in the [European] Community is approximately 4000 ECU³ [CAN\$ 6,000]; the majority (80% +) of these costs being attributed to damage to human health." Accordingly, the EU estimated the overall economic cost of the damage resulting from 1 million tonnes of SO₂ emissions to be approximately 4 billion EURO (CAN\$ 6 billion).

European Union Cost Estimates

In 1997, the European Commission developed cost estimates⁴ associated with the implementation of the Directive which was then at the proposal stage. At that time, the proposal included 1% wt. sulphur requirements in 2003 for HFO and did not address sulphur requirements for light fuel oil. The final Directive includes sulphur requirements for both heavy and light fuel oils as described above.

The Commission estimated the total cost of the proposed Directive at 0.8 billion EURO per year (CAN\$1.2 billion per year) to achieve a reduction of over 1000 kt SO₂. This cost equates to approximately 700 EURO (CAN\$1000) per tonne of SO₂. The estimate included costs to refineries (capital and operating cost to produce low sulphur fuel oils), as well as costs to users including power generation, transport and other industries.

The estimated costs assumed that power plants and large boilers in industry and in refineries will, whenever it is cheaper, choose the flue gas desulphurization option rather than use low sulphur fuel oil. The figures did not take into account the fact that the Directive allows for derogation in those regions where air quality standards for SO₂ are respected and where emissions do not contribute significantly to acidification.

The cost assessment further specified that "*There are clearly significant differences between the Member States, with Italy, Spain, France, Greece and Ireland and to a lesser extent UK, Germany and Belgium showing a significant dependence on heavy fuel oil as a source of heat and power. Furthermore, the estimated average sulphur content of the heavy fuel oil used across the Community also show considerable variations with many Member States having average figures of 1% [wt.] sulphur or less whereas in others some categories of heavy fuel oil have average sulphur concentrations as high as 3.5% [wt.]*".

Table 1 provides the estimated annual cost of the EU 1% wt. HFO directive to produce the lower sulphur fuel or install emission control equipment, as estimated in 1997. The total annual cost to all industrial sectors is estimated at 759.4 million EURO per year (CAN\$1.1

³ ECU: European Currency Unit or EURO. Conversion rate used in this report: 1 EURO = CAN\$1.5.

⁴ European Union, Explanatory Memorandum to the proposal for a Council Directive relating to a reduction of the sulphur content of certain liquid fuels and amending Directive 93/12/EEC, March 1997. Available upon request to the authors of this report.

billion per year). Across the European Union approximately 20% of the cost is borne by the refining industry, 38% by the power generation industry, and 42% by other industries.

For illustrative purposes, we have calculated (using the Canadian consumption for HFO) what the costs would be if Canadian industry were to face the same average costs (refer to Table 1). In this context, the cost to Canadian industry of reducing sulphur in HFO in line with European requirement is on average CAN\$123 million, with a range up to 393 million depending on to which European country the comparison is made. In terms of unit cost, the estimate is on average 1.5 CAN cents per litre, with a range up to 4.6 CAN cents per litre.

The cost report recognized that some refineries will have to change their refinery processes, install new process units, or undertake blending operations to achieve the required sulphur content. It also found that proven technologies used to reduce sulphur content in HFO are available.

Table 1: European Union Cost Estimates to All Industrial Sectors in European Countries for Implementation of 1% wt. Sulphur HFO or Emission Controls – 1997

Country	Annual consumption in 1995 (kt)	Converted consumption in 1995 ⁵ (million litre)	Average sulphur content (% wt.)	Cost to All Industrial Sectors (million EURO/year)	Total Cost (million CAN\$ / year)	Cost using Canadian consumption (million CAN\$ / year) ⁶	Annual cost per unit (¢ CAN/L)
Belgium	1,976	1,996	1.0	37.4	56.1	239	2.8
Denmark	811	819	1.0	1.2	1.8	19	0.2
Germany	7,012	7,085	1.2	43.3	65.0	78	0.9
Greece	2,677	2,705	2.7	35.1	52.7	166	2.0
Spain	8,222	8,308	1.0 to 3.5	178.1	267.2	273	3.2
France	7,275	7,351	2.1	72.7	109.1	126	1.5
Ireland	1,284	1,297	2.0	39.9	59.9	393	4.6
Italy	30,586	30,904	1.53	99.6	149.4	41	0.5
Luxembourg	98	99	NA	0.1	0.2	17	0.2
Netherlands	1,176	1,188	2.2	0.4	0.6	4	0.1
Austria		940	0.96	0.5	0.8	7	0.1

⁵ Converted using the Canadian average HFO density of 989.7 kg/m³ (Source: *Sulphur in Liquid Fuels report – 2001*).

⁶ Converted using the Canadian annual consumption for 2001 of 8500 million litres divided by the individual European country's consumption.

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Portugal	3,335	3,370	NA	33.6	50.4	127	1.5
Finland	1,678	1,695	1.1	0.0	0.0	0	0.0
Sweden	1,930	1,950	0.3	0.0	0.0	0	0.0
United Kingdom	9,028	9,122	2.18	217.5	326.3	304	3.8
TOTAL	78,018	78,830	N/A	759.4	1,139.1	123	1.5

United Kingdom Cost Estimates

In July 2000, the United Kingdom (U.K.) published its Regulatory and Environmental Impact Assessment⁷ including cost estimates for implementing the final council Directive reducing sulphur level in HFO to 1% wt. in 2003 and in light fuel oil to 0.1% wt. in 2008. It included the flexibility for facilities that meet prescribed emission limits.

The assessment indicated that the industry sectors likely to be affected by the implementation of the Directive included petroleum refining, power generation, metal industries, sugar manufacturing, other manufacturing (breweries, dairies, building materials manufacture), agriculture (grain drying), quarrying (roadstone coating processes), shipping (fishing vessels, ferries and naval vessels) and railways.

The assessment estimated the total annualized refinery costs for the production of HFO and gas oils (LFO) to meet the sulphur limits in the Directive to be in the range of £55 to 125 million (CAN\$132 to 300 million⁸) per year. Of these costs, £39 to 109 million (CAN\$94 to 262 million) per year are expected to arise from the increased operating costs of switching to low sulphur crude oils to produce the low sulphur fuel oils, with £16 million (CAN\$38 million) per year arising from annualized capital costs. There is an additional £12 million (CAN\$29 million) in regulatory compliance costs for the refiners. The U.K. estimates that the costs to consumers of fuel oils is £0 to 39 million (CAN\$0 to 94 million), depending on how much of the cost of producing low sulphur fuel oils is past on by refiners.

For illustrative purposes, we have calculated (using the Canadian consumption for LFO and HFO) what the costs would be if Canadian industry were to face the same average costs (refer to Table 2). In this context, the cost to Canadian industry of reducing sulphur in fuel oils in line with European requirements (based on U.K. data) is between CAN\$123 and 321 million. In terms of unit cost, the estimate is between 1.2 and 3.2 CAN cents per litre.

⁷Regulatory and Environmental Impact Assessment, United Kingdom, July 2000. Available upon request to the authors of this report.

⁸Conversion rate used in this report: £1 = CAN \$2.4.

Table 2: United Kingdom Cost Estimate – July 2000

Item	Total Cost (million £/year)	Total Cost (million CAN\$/year)	Cost using Canadian consumption (million CAN\$/year) ⁹	Annual cost per unit (¢ CAN/L)
Production Operation Costs	39 to 109	94 to 262	72 to 199	0.7 to 2.0
Annualized Capital Costs	16	38	29	0.3
Refinery Compliance Costs	12	29	22	0.2
Cost to Other Consumers	0 to 39	0 to 94	0 to 72	0 to 0.7
Estimated Total Cost	67 to 176	161 to 422	123 to 321	1.2 to 3.2

Potential Cost to Canadian Industry

This section examines European cost estimates in order to develop preliminary “high-level” potential costs to the Canadian industry if Canada were to reduce sulphur in fuel oils to European levels.

The 1997 EU document provides little information on the assumption used in the calculations. It does not provide segregated capital and operating costs nor amortization period used. It also accounts only for the costs associated with reducing sulphur in HFO since LFO was not considered at the time. On the other hand, the 2000 U.K. cost estimate was prepared in respect of the final EU Directive reducing sulphur level in both LFO and HFO. It is also most recent and provides more information on the assumptions used in the calculations. Further the situation in Canada is probably more similar to that in the U.K. than to countries that have already reduced a significant portion of their fuel oils to low sulphur fuel oils. It should also be noted that the 2000 U.K. estimates (CAN\$123 to 321 million) are within the range of the 1997 EU annualized cost estimates (CAN\$0 to 393 million). Due to these considerations, Environment Canada favours using the U.K. estimates as the basis of the preliminary “high-level” costs presented in this report.

⁹ Converted using the Canadian annual consumption of LFO and HFO for 2001 of 13,215 million litres divided by the consumption of LFO and HFO in the U.K. In 1998, the estimated consumption of fuel oil (both LFO and HFO) in U.K. was 17,182 kt or 17,361 million litres. Conversion to litres uses the Canadian average HFO density of 989.7 kg/m³ (Source: *Sulphur in Liquid Fuels report – 2001*). Note: the U.K. HFO consumption is from the 1997 European Commission’s cost estimate document (9028 kt in 1995). The LFO consumption is estimated from the distillate fuel oil consumption (source: Energy Information Administration, U.S. DOE, www.eia.doe.gov.) minus the diesel fuel used for road transport, railways and water transport (source: U.K. Department of the Environment, Transport and the Regions, www.transtat.dtlr.gov.uk).

It is believed that actual Canadian costs are not likely to differ too widely from the estimates based on the U.K. data, since the refinery technology is roughly the same and current sulphur levels of HFO do not vary that markedly (2.18% wt. for the U.K. and 1.73% wt. for Canada), although they could be slightly higher due to the higher-sulphur crude oils that many Canadian refineries process and the fact that sulphur in LFO is not currently controlled in Canada (the Canadian 2001 *average* of 0.20% wt. being the same as the current *maximum* allowed in the U.K.).

It is recognized that the U.K. cost estimates reflect the unique industry structure (such as number of refineries, their sizes and configurations, etc.) in the U.K. as well as assumptions made by the authors of the study regarding the amortization period, energy prices and other factors. These assumptions are not all applicable to the Canadian context. However, it is believed that the extrapolation of U.K. cost estimates to Canada provides adequate preliminary “high-level” estimates.

Discussion

Preliminary “high-level” cost estimates to implement measures to reduce sulphur in fuel oils to European levels in Canada are in the range of CAN\$123 to 321 million per year, or a unit cost of 1.2 to 3.2 cents per litre.

These measures, which are estimated to reduce SO₂ emissions by 164,000 tonnes per year from 1999 levels¹⁰, would cost in the range of \$750 to \$1,960 per tonne of SO₂. This estimated cost per tonne of SO₂ is within the range of costs of other measures aimed at reducing sulphur dioxide emissions in Canada. The Canada-wide Standards Compendium of Cost information¹¹ estimated the average cost of SO₂ removal at \$930 per tonnes, with initiatives ranging from as low as \$352 to \$8,810 per tonne. The Compendium provides “high-level” cost estimates and included only direct costs largely based on using technology to reduce sulphur dioxide emissions. It does not include measures such as fuel switching and energy conservation.

A 1995 U.K. study¹² indicates that costs of desulphurization can vary widely, depending on the size of the refinery, the degree of desulphurization, the nature of the crude oil, and its price. This study cites a Norwegian study which estimates the cost of reducing sulphur in HFO from 2.15 to 1.0% wt. at \$US 333 (1985 \$) per tonne of SO₂ removed. In 2001 Canadian dollars, this cost is equivalent to \$807 per tonne, which is similar to the results based on the 2000 U.K. estimates. The study further indicates that due to the energy and

¹⁰Tushingam, M. and Bellamy, J., 2001. *Potential to Reduce Emissions of Sulphur Dioxide through Reducing Sulphur Levels in Heavy and Light Fuel Oils*. Environment Canada, March 22, 2001.

¹¹ Canada-wide Standards for Particulate Matter and Ozone, 1999. *Compendium of Cost Information*. May 17, 1999.

¹² Halkos, G., 1995. *Evaluation of the Direct Cost of Sulphur Abatement Under the Main Desulphurization Technologies*. Energy Sources, Vol. 17, pp. 391-412, 1995.

fuel requirement at oil desulphurization units, operating costs are very sensitive to changes in energy and oil prices. Desulphurization of HFO is associated with a fuel loss ranging from about 5% to 8%.

Environment Canada is undertaking additional work to refine these preliminary cost estimates. This work will assess potential costs of reducing sulphur dioxide emissions resulting from the combustion of fuel oils based on available technical options to fuel oils users, including reducing sulphur content in fuel oils, fuel switching, improved energy efficiency and pollution abatement. It is expected that this information will become available later in 2002.

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