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sulphur emissions from small stationary oil combustion plant and the availability of low sulphur fuel oil in the EEC

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ABSTRACT

This report deals with sulphur emissions from combustion plant of capacities less than 50 MW_{th} and the possible effect the implementation of the EEC Large Combustion Plant Directive could have on these emissions. The availability of low sulphur fuel oil in the EEC up to year 2000 is also discussed and the differences between the Northern and Southern member countries highlighted. Some information is given on the sulphur grades of fuel oil available in the 12 EEC member countries, in order to ascertain whether some standardisation would be possible.

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SUMMARY

Although the proposed EEC Large Combustion Plant Directive (LCPD) does not apply to small combustion plant of less than 50 MW_{th}, the Commission is concerned that indirectly there could be an increase of small plant emissions if low sulphur fuel availability were limited by implementing of the LCPD. CONCAWE has carried out a study on this effect in the case of fuel oil. The study also surveys the range of fuel oil sulphur grades available in the EEC-12 and compares the long term availability (up to year 2000) of 1% sulphur heavy fuel oil with the demands of key end-use sectors of the fuel oil market.

The study assumes that by the year 2000, sulphur emissions from both coal- and oil-fired plant (LCP) will each have to be reduced by 60 per cent of their 1980 levels and that, based on earlier CONCAWE studies (Report 5/86), fuel oil sulphur emissions will in fact be reduced by the required 60%. The composite oil supply/demand outlined for EEC-12 has been analysed, under the simplifying assumption that the Region's total oil processing capacity can be regarded as a single large refinery, providing products for a large homogeneous market. Some attempt has been made to identify differences in conditions that can occur between countries.

Main conclusions are:

1. In most scenarios considered, the introduction of the LCPD would have little effect on the anticipated reductions in sulphur emissions from small plants. However, some scenarios can be identified in which adverse effects are possible due to a scarcity of low sulphur fuel oil, resulting from the implementation of the LCPD. Such effects are most likely to be in terms of a switch from fuel oil to alternative low sulphur fuels, such as gas or low sulphur coal with attendant higher consumer costs.

2. By the year 2000 there are significant uncertainties concerning the quantities of low sulphur fuel oil that can be produced. Under any realistic set of supply/demand assumptions, the total supply capability for 1% fuel oil will be inadequate to meet the entire fuel oil consumption in the small plant sector. (Some 23 million t/yr or 25% of total fuel oil consumption).

3. The quantity of 1% S fuel oil will be spread unevenly over the countries because of different low sulphur crude access and use, different fuel oil consumption and different refining structure.

   Production and use of larger than average amounts of low sulphur fuel oil in certain Member States would imply the use of worse than average quality fuel oil pools in some other areas. Significantly the oil industry itself will have

very little flexibility to increase the availability of this grade of fuel oil. However, increased use by power stations of very high sulphur fuel oil together with Flue Gas Desulphurisation could indirectly increase the availability of low sulphur fuel oil.

4. Because of the above mentioned different conditions pertaining across the Community, country specific studies would he required to obtain a better insight into their individual situations with respect to both the availability of low sulphur fuel oil and the effect of the LCPD on the small user sector sulphur emissions.

5. The fuel oil grade structures in Member States vary widely as a result of tailoring to meet market requirements with limited coincidence of common grades. Consequently it would be difficult to formalise the existing broad range into standard community-wide low, medium and high sulphur grades. The benefits of doing so are in any case not likely to be significant in terms of emission control.

1. INTRODUCTION

EEC proposals to regulate the sulphur emissions from stationary combustion plant of capacity greater than 50 MW_{th} (Large Combustion Plant Directive or LCPD) have been under discussion for some time. The Commission is now giving some attention to sulphur emissions from the less than 50 MW_{th} stationary combustion plant, and the possible effect on such plant of the implementation of the LCPD.

After discussions with the Commission, CONCAWE has studied three aspects viz.

- whether implementation of the LCPD would cause a shift of sulphur emissions into the small plant sector;
- what principal sulphur grades are currently being marketed in EEC-12 countries and whether standard community-wide grades could be established;
- what quantity of 1% sulphur fuel could be manufactured in the EEC-12 in year 2000.

In addition to information from the market, CONCAWE has made use of the data generated for Report No. 5/86 "Sulphur emissions from combustion of residual fuel oil based on EEC energy demand and supply 1980-2000".

2. ENERGY BALANCE

Report 5/86 was based on a total energy mix for the EEC-10 countries using both oil industry and EEC forecasts. The analysis of these data is relevant for the EEC-12 also.

In 1980, oil represented the main component (54%) followed by coal (23%) and natural gas (17%). By year 2000, oil is predicted to fall by some 15-26% of the 1980 level, coal and gas show a significant growth and nuclear power a spectacular 4-fold growth. This still leaves oil as the main component but now only some 38% of the total. The details are shown in Appendix I.

Within the oil demand, product splits were derived and are shown in Appendix II.

The striking point from the data is that while total oil demand is forecast to decrease by 15-26% of the 1980 level over the period 1980-2000, fuel oil demand is expected to decrease by some 50-55% of the 1980 level over the same period.

Since these data were generated, two events have taken place which have an impact on energy demand and the energy mix. These are the dramatic fall in oil prices and the Chernobyl incident. The possible implications are clear: low oil prices may encourage an increased use of energy with an overall increase in the use of oil; Chernobyl may delay or even reduce the use of nuclear energy for electricity generation. This energy demand is likely to be met by fossil fuel. Many studies have been made and are continuing to quantify the possible effects. The current view is that although there has already been some additional growth in oil demand which may continue for some time, this is mainly confined to the transport sector. Furthermore, it is expected that oil prices will increase again in the 1990s to reflect a tightening of availability at the end of the century. Based on this, there is no reason to expect that the energy level or mix will be significantly different to that shown above for 2000.

3. FUEL OIL DEMAND PER END-USE

In Report 5/86, a split is made for EEC-10 countries of the amount of fuel oil used in the three sectors viz, power stations, large users above 50 MW_{th}, and small users below 50 MW_{th}. Assuming a similar pattern for the EEC-12, the following sector position is obtained:

Table 1 EEC-12 fuel oil demand per end-use category (million t/yr)

Sector	1980	1983	2000	
			HI	LO
Power	74	45	28	24
Large users (a)	72	53	46	39
Small users	48	30	24	22
Total EEC-12	194	128	98	85

(a) Includes refinery own fuel consumption

The above shows the very large drop anticipated in the use of fuel oil in the power sector reflecting the high expection for nuclear and coal in this sector. The split between large and small users in 1980/1983 is based on actual oil company data, but the projections for year 2000 are sensitive to economic activity and the penetration of alternative energy forms such as natural gas, middle distillates and electricity.

4. SULPHUR EMISSIONS

Report 5/86 derived the sulphur content of the average inland fuel oil ex EEC-10 refineries and assumes that imports are at 3.5% sulphur.

These data have been adjusted to EEC-12 by the following procedure.

- Demand per product, crude oil composition, quantity of feedstocks and imports have been reassessed for EEC-12. (Appendix IV).
- Refinery processing capacity for each process has been reassessed for EEC-12. (Appendix V).
- CONCAWE Report No. 9/75 "The sulphur grid method" has been applied to assess the sulphur content of the additional fuel produced and thus the additional sulphur emissions.
- Based on the additional amount of LS crude processed and the results of above-mentioned calculation, an estimate was made of the additional amount of LS fuel oil that could be produced.

The overall impact of these changes is small. The calculated fuel oil sulphur contents and the resulting sulphur emission from EEC-12 inland fuel use are shown below:

Table 2

	1980	1983	2000	
			HI	LO
Inland fuel demand[(a)] (million t/yr)	194	128	98	85
Sulphur content average (% wt) (incl. imports)	3.2	2.6	2.9	2.5
Sulphur emissions (million t/yr)	6.2	3.35	2.85	2.1
(%) of 1980 level	100	54	46	34

(a) Includes total refinery consumption

The above shows a significant sulphur emission reduction of 54-66% over the period 1980-2000. This trend closely reflects the reductions previously identified for EEC-10.

The main cause of these reductions is the 50% decrease in fuel oil quantity and a smaller effect due to the lower fuel oil sulphur content in year 2000.

The actual sulphur content of the small user fuel oil is uncertain but it will not be higher than the average of the overall fuel oil pool and almost certainly lower since the higher sulphur fuels tend to be used in the power generation sector. The contribution to fuel oil sulphur emissions by the smaller user sector will therefore be about 20-25% of the total emissions, in line with its share of total fuel oil demand.

5. THE POSSIBLE EFFECT OF THE IMPLEMENTATION OF THE LCPD

The draft directive requires that sulphur emissions from the combustion of fossil fuels in existing large plant be reduced by 60% by 1995 or thereafter taking 1980 as a base year. Since this report is only concerned with oil combustion, the simplifying assumption is made that sulphur emissions from coal and oil each have to be reduced by 60% of their respective 1980 level.

The previous section has shown that in the LO 2000 case there would be a 66% reduction in sulphur emissions over the whole inland fuel consumption. Therefore, there should be no serious problem to meet the 60% reduction requirement and the effect on the sulphur emissions in the small sector should be very small.

In the HI 2000 case, the overall reduction in sulphur emissions would be 54%, and some additional sulphur removal would be required. A calculation has been made to show the effect on small plant sulphur emissions if the sulphur to be removed from the large sector were shifted to the small plant fuel oil. This calculation shows (Appendix III) that in the HI 2000 case the effect of introducing LCPD could be that sulphur emissions in the small sector will only reduce by 39% instead of 54%.

Although there is therefore a possibility that sulphur could be shifted into the small plant fuel oil with the implementation of the LCPD, constraints are imposed by existing or planned local regulations which will to some extent prevent an increase of the sulphur content of fuel oil in the small sector from present day values. This being the case, the more likely effect would be a further move away from fuel oil use in the large user/power sector to an alternative low sulphur fuel such as natural gas or even middle distillate. This would require some restructuring of refinery processing to reduce fuel oil production and with a consequent higher cost to the consumer.

If the oil sector were required to reduce sulphur emissions by more or less than the 60% assumed in this study, this would of course have a consequent effect on the calculation.

All the data derived in the previous sections are based on average EEC conditions. In fact there are significant differences between groups of member countries, as illustrated in the following table.

Table 3

	% share of LS crude availability	% LS crude on total crude	% fuel oil on total crude
N. Europe	65	65	15
S. Europe	35	37	31

The resulting fuel oil sulphur position in N. Europe is and will continue to be much easier than in S. Europe and there are further significant differences between individual countries such as energy mix and product mix and policies to meet sulphur reduction requirements. Therefore, global studies of the type carried out here cannot lead to reliable conclusions about rather small segments of the fuel oil market in individual countries. The national positions and their specific problems require more attention if these are to be taken account of in any EEC-wide solution.

Summarising therefore, introduction of the LCPD is not expected to have a significant overall effect on sulphur emission from small user plant, although situations can be identified where adverse effects are possible.

6. AVAILABILITY OF FUEL OIL GRADES BY SULPHUR CONTENT IN THE EEC-12

The Commission has indicated an interest in the sulphur content of individual grades available in the market of the Community countries. Based on information available to CONCAWE, the following qualitative picture can be given of the principal grades available. The current availability of low sulphur crudes means that in certain cases the "grade" may indicate current sulphur level rather than an official grade.

Table 4

Country	Inland Fuel Oil % S							
	0.5	1	1.5	2	2.5	3	3.5	4
Denmark		X	X					
Germany		X		X		X		
Netherlands				X				
Belgium/Luxembourg					X		X	
United Kingdom				X			X	
Ireland				X				
France		X		X				X
Greece	X						X	X
Italy		X				X		X
Spain		X		X			X	
Portugal							X	

In addition, bunker fuel oil is generally available and has a sulphur content in the 4-4.5% bracket.

Inspection of the data shows that whilst three broad sulphur brackets may be adopted for convenience viz. 1-1.5%, 2-2.5% and 3-4%, differences between countries are large due to tailoring to meet market requirements and significant problems can be expected in trying to establish community-wide standard grades.

There is a lack of consistent quantitative data for these three ranges but the best estimate is given below for 1983 EEC-12.

Fuel oil sulphur	% of total inland fuel oil
1-1.5%	10
2-2.5%	40
3-4%	50
	100

This would put the overall average sulphur content at about 2.8% with the medium/high sulphur average at 3%.

7. AVAILABILITY OF 1% SULPHUR FUEL OIL IN THE EEC-12, YEAR 2000

CONCAWE has carried out a study to assess the quantity of 1% sulphur fuel oil that could be produced by EEC-12 refineries in year 2000 based on crude intake quality, product demand and refinery processing structure and capacity, using the data generated for CONCAWE Report No. 5/86.

7.1 OUTLINE OF APPROACH

Report No. 5/86 was based on an LP computer modelled EEC-10 refinery situation, which generated a considerable amount of information. In order to maintain the basic position already reported, it was decided to use the same information for the additional study. The fuel oil pool generated consisted of some 15 to 20 components of varying quality e.g. sulphur, viscosity, density. The availability of low sulphur fuel oil (LSF) of a particular sulphur content e.g. 1%, will depend mainly on the quantities of fuel oil components below and around this level, and to a lesser extent on the sulphur contents of the other components and market segments. Also, forming a pool of LSF will inevitably mean an increase in sulphur content of the remainder of the fuel pool and some limit must be set so that this fuel will still be saleable under existing regulations.

Therefore the following framework was set up for investigation.

	Sulphur % wt	Quantity
LSF	1 to 2	to be determined (b)
HSF	max 3	demand minus LSF (b)
Power stations	max 3.5	demand
Bunkers	max 4.0	demand
Refinery liquid fuel	3.5-4 (a)	as required for refineries

(a) In combination with refinery gas and coke on a fuel oil equivalent basis gives an average sulphur of 2-2.5% wt.

(b) LSF + HSF quantity equal to inland fuel oil demand minus power station demand.

The transformation of the EEC-10 to EEC-12 position has already been covered in Section 4.

7.2 LOW SULPHUR FUEL OIL AVAILABILITY

In calculating the quantities of LSF according to the framework shown above, it became clear that two refinery process factors have a significant effect on the quantities of LSF that can be produced.

These two factors are the quality of feedstock to the cokers and to the cat crackers.

- Coker feedstock
  This is normally vacuum residue. In the EEC, cokers have been mainly built to produce low metal, low sulphur coke which requires low sulphur residue as feed. This material is a 100% LSF component and the requirement to make high quality coke reduces the potential to produce LSF. In this study it is assumed that 70% of the 10 million t/yr EEC-12 coker capacity is fed with LS residue and 30% by HS residue.

- Cat cracker feedstock
  There is frequently an economic incentive to feed cat crackers with low sulphur atmospheric residue (LSR) instead of vacuum distillates. This incentive is based on the overall upgrading of the LSR and a lower requirement for vacuum distillation capacity from which only the distillate would be upgraded. The original study allowed 30% of the cat cracker feed to be LSR in year 2000 in order to recognise this aspect, and in fact the LP computer models fully utilised this possibility. In the EEC-10 this accounted for 21 million t/yr of LSR resulting in a loss of some 5-9 million t/yr of potential LSF. Since there is a possibility that not all cat crackers in year 2000 will in fact include LSR in the feedstock, a sensitivity has been calculated with zero LSR in CC feedstock.

As a sensitivity, a calculation was made of the increase in quantities of LS fuel when allowing the sulphur content to increase from 1 to 2% and also when allowing the sulphur content of the HS fuel to increase from 3 to 3.5%.

The following results were obtained for the EEC-12 situation.

Table 5 Availability[(a)] of low sulphur fuel oil - EEC-12 in year 2000

Sulphur content of LS fuel oil (%)	1		2	
Sulphur content of other fuel oil				
- bunkers (%)	4	4	4	4
- power sector (%)	3.5	3.5	3.5	3.5
- other (%)	3.0	3.5	3.0	3.5
Max high S conversion feedstock (million t/yr)	13	18	26	31
Max low S conversion feedstock (million t/yr)	7	10	15	19

(a) Availabilties are indicative and are averages of the 5 cases studied in year 2000. Other factors such as low sulphur crude processing and level of conversion can give at least ± 50% variation.

7.3 DISCUSSION

Reference to Table 5 shows that in year 2000 for EEC-12, an average 7-13 million t/yr of 1% sulphur fuel oil could be manufactured (based on maintaining HSF at 3% sulphur). The range depends upon how much LSR is taken up as cat cracker feedstock in EEC refineries. This is not in disagreement with the 1983 breakdown (see Section 6) which, based on an EEC-12 demand of some 100 million t/yr of inland fuel oil, would result in an availability of 10 million t/yr of 1% sulphur fuel oil. However, there are considerable differences between the five "year 2000" cases studied, e.g. for the above-mentioned case the lowest being zero and the highest 19 million t/yr of 1% S fuel. These differences are caused by different assumptions for LS crude processed, feedstock quantities and imports.

It must be stressed again that the calculated quantities are for global EEC and there will be an uneven spread between countries. It has already been pointed out in Section 5, Table 3 that between Northern and Southern European member countries there are large differences in fuel oil demand and use of LS crudes. Clearly if some countries claim a disproportionate share of 1% S fuel, there will be less for other countries.

The average amount of 1% sulphur fuel calculated in this study to be available in EEC-12 (some 10 million t/yr) would be insufficient to satisfy the small user sector completely (see Table 1).

The availability of LSF could be increased by allowing it to have a higher sulphur content, still maintaining 3% sulphur in HSF. The less than 50 MW_{th} sector could be satisfied at sulphur content of 2 to 2.5% wt. However, this would mean the elimination of 1% sulphur fuel oil which in practice would be difficult because of already existing national and local regulations. Here again, this is a global EEC calculation which should not be taken to reflect the position in any individual member country.

The allowed sulphur content of the remaining high sulphur fuel also has an effect on the quantity of LSF that can be produced. The sensitivity check has indicated that by allowing the HSF to increase from 3 to 3.5%, there would be an increase of some 3-5 million t/yr of 1% sulphur fuel over the EEC-12. This suggests that if e.g. power stations would go over to burning very high sulphur fuel oil together with the installation of FGD, there could be some scope to increase the availability of low sulphur fuel oil.

Finally it can be stated that LSF availability in the EEC is largely controlled by factors shown below and in general they are not easy for the oil industry to change or influence.

- LS crude availability and prices and product (in particular fuel oil) demand which are significantly influenced by the world-wide situation.

- Existing refinery process structure such as amount of conversion, quality of coker and cat cracker feedstocks which have been tailored to meet market demand.

- Existing fuel oil sulphur regulations.

Therefore the only flexibility to increase the availability of low sulphur fuel oil would be to encourage power stations to burn very high sulphur fuel together with FGD.

EEC-10 Total Energy Demand (million tonnes oil equivalent)

	Actual 1980	Actual 1983	Year 2000			
			EEC Estimates		Oil Company Estimates	
			Base Case	Range	Average	Range
Coal	223	212	264	223-309	275	259-300
Total oil (a)	523	438	439	281-539	380	360-420
Natural gas	170	165	196	196-256	205	195-210
Nuclear	43	76	215	150-235	160	135-175
Others	14	16	21	21- 29	40	35- 45
Total	973	907	1135	-	1060	-

(a) Including refinery fuel and bunkers

EEC-12 data are 8-10% higher for the total energy mix of which oil and coal are some 10-12% higher.

EEC-12 Total Oil Demand (million t/yr)

	1980	1983	2000 High Demand (EEC)	2000 Low Demand (Oil Companies)
LPG	18	19	22	18
Mogas	90	90	95	82
Naphtha	28	26	31	26
Kero	23	22	25	21
Gas Oil	180	160	172	150
Autodiesel	47	50	83	72
Other GO	125	103	82	72
Int. bunker	8	7	7	6
Fuel Oil	180	117	92	82
Inland	158	97	68	61
Int. bunker	22	20	24	21
Lube oil	4	5	7	6
Bitumen	13	11	13	11
Coke	3	7	6	6
Sulphur	2	2		
Sub total	541	459	463	402
Refinery consumption	37	30	31	25
Total	78	489	494	427

"Worst case" Impact of LCPD on Small Plant

	1980 (million t/yr)	2000 HI (million t/yr)
Sulphur emissions from large user/power sector	4.7	2.15
60% of 1980	2.8	-
Target 2000	-	1.9
Sulphur to be removed	-	0.25
Sulphur emission from small user sector	1.55	0.7
Sulphur transferred from large user/power sector	-	0.25
Revised sulphur emissions in small user sector	-	0.95
Reduction in small user sector		39%

Refinery Product Demand/Refinery Intake for EEC-12 (million t/yr)

	1980	1983	2000	
	EEC-12	EEC-12	EEC-12 HI	LO
LPG	14	13	20	17
Naphtha	19	18	18	1
Mogas	94	94	98	89
Kerosine	28	27	25	22
Gasoil	180	144	158	119
Inland fuel oil	152	94	65	52
Bunker fuel oil	23	20	19	11
Lube Oil	6	6	7	6
Bitumen	13	12	14	11
Coke	3	2	4	4
Refinery fuel and loss	37	30	31	25
	569	460	459	357
Crude Oil				
Low sulphur	185	210	193	143
Medium sulphur	158	145	189	132
High sulphur	216	86	77	57
Feedstock	10	19	NIL	25
	569	460	459	357

(a) Due to imports apparently exceeding demand. Assumed due to uncertain estimates.

Refinery Capacity for EEC-12 (million t/yr)

	1980 EEC-12	1983 EEC-12	2000 EEC-12
Crude distillation	920	728	601
Thermal cracker	17	18	10
High vacuum distillation	202	226	233
Cat cracker	59	75	77
Hydrocracker	6	7	10
Visbreaker (vacuum residue)	31	49	47
Coker	9	10	11
Residue hydro-conversion	NIL	NIL	3
Catalytic Reforming	102	88	82
Alkylation	3	5	5
Isomeration	4	4	5
Gas Oil HDS * (nominal)	151	141	115
(usuable)	128	118	103
% Desulphurisation			
Straight-run	75	75	85
Cracked	65	65	75
Lube Oil	7	7	7
Bitumen	31	25	24
Low sulphur residue in Cat Cracker	NIL	NIL	Up to 30%

* Max 20% light cycle oil + cracked gas oil