Assessment of the UK 15 min Sulphur Dioxide Objective

1. Summary

In response to concerns raised, this paper considers the costs and benefits of removing the existing UK 15 minute objective on sulphur dioxide (SO_2). If the objective were to be removed, some installations could potentially increase their emissions while maintaining compliance with other regulatory SO_2 constraints. The costs industry could save by doing that have been compared with the estimated monetised health disbenefits arising from the resulting additional sulphur emissions using assessment methodologies consistent with the rest of the AQSR evidence base.

The main effects of the removal of the objective would be felt in the power generation and refinery sectors, and our assessment focuses on these. IPPC regulators have had regard to the objective in their deliberations on BAT, but there is no legal requirement to meet the objective. We are considering amending the IPPC guidance in England and Wales to make this clearer.

It is recognised that industry have incurred large costs in controlling SO_2 over the years, but we have evaluated only the additional costs of meeting the 15 min mean objective that might be avoided by its removal. Only the health disbenefits of the resulting potential additional emissions have been calculated to maintain internal consistency.

The results of this analysis suggest the removal of the SO_2 15 min mean objective would provide a net disbenefit of **£11m - £41m per annum** for the period up to 2015. The health disbenefits included in this calculation cover only those associated with chronic effects. Other effects which would increase this disbenefit have also been described and quantified (e.g. acute affects on sensitive individuals), but are not included in this estimate as they are either less certain or difficult to monetise.

2. Issue

The 1997 UK National Air Quality Strategy adopted an air quality objective based on a 15 min averaging period to guard against the short term effects of SO_2. This objective has no direct equivalent in European legislation. It is more stringent than 1999/30/EC, which sets Limit Values with averaging periods of 1 hour and 24 hours.

In recent years, some UK industries have suggested the 15 min SO_2 objective is an example of ‘gold plating’. This paper sets out work undertaken so far by Defra, the devolved administrations and the HPA to consider whether the objective should be retained.

3. Background

Directive 1999/30/EC sets two air quality limit values for SO_2 for the protection of human health to be achieved from January 2005: the 1 hour mean of 350 $\mu g/m^3$, which is not to be exceeded more than 24 times per year; and the 24 hour mean of 125 $\mu g/m^3$, not to be exceeded more than 3 times per year. The UK Air Quality Strategy has set an additional objective for SO_2 of a 15min mean of 266 $\mu g/m^3$ (100 ppb), not to be exceeded more than 35 times per year. This is derived from a Standard recommended by Expert Panel on Air Quality Standards (EPAQS) in 1995 (set at the same concentration and averaging time, but without any exceedences).

EPAQS concluded that a short averaging time was desirable as the effects of SO_2 on the lung's airways could occur very rapidly (over a period of a few minutes). EPAQS felt that it was unlikely that significant effects will occur in the majority of people with asthma exposed to concentrations below 200 ppb in ambient air. A 15 minute averaging time was decided upon as a sensible compromise between the desire to match the response time for sensitive individuals and the practicality of measurement. They agreed that a more easily measured 15 minute average could conceal short lived peaks[1]. They recommended a lowering of the 200 ppb figure by a factor of 2 to allow for the possibility of shorter peaks being concealed within the 15 minute period, as well as the need to ensure an adequate margin of safety for individuals more severely affected with asthma.

The World Health Organisation (WHO) has also produced a short-term guideline for SO_2 of 500 $\mu g/m^3$ over a 10 minute averaging time (with no exceedences). Their rationale, based on a rapid response to short term exposures, was similar to EPAQS. However they did not consider the possibility of short lived peaks within the averaging period in the same detail as EPAQS. It is worth noting that while the EPAQS 15 min *standard* is likely to be more stringent than the WHO 10 min guideline, the 15 min *objective* is likely to be less stringent than the WHO 10 min guideline.

WHO have recently recommended a new guideline for SO_2 of 20 $\mu g/m^3$ averaged over 24 hr. A preliminary analysis of the relative stringency of the different guidelines, standards and objectives has been carried out by examining monitoring data for 2005 from the national monitoring networks. This analysis suggests that WHO's new guideline of 20 $\mu g/m^3$ over 24 hours is considerably more stringent than the UK 15 min standard (no exceedences of 266 ug/m^3) and objective (no more than 35 exceedences of 266 ug/m^3). WHO also proposed two interim 24 hr guidelines of 50 $\mu g/m^3$ and 125 $\mu g/m^3$. The higher of these interim guidelines is roughly equivalent to the 15 min objective; the lower is roughly equivalent to the 15 min EPAQS standard. So an important consideration in the debate on the objective is that there is a general international move amongst health professionals towards tighter SO_2 standards.

The EC legislation has been derived from the recommendations of the WHO using a 1 hour limit value for SO_2 derived from the 10 min short term guideline (although by including 24 allowed exceedences the LV is in fact far less stringent). An averaging time of 1 hour will conceal exceedences and potential effects which may occur over shorter periods.

There are other legislative constraints on sulphur emissions within the UK, such as the National Emission Ceilings Directive, the Integrated Pollution Prevention and Control (IPPC) Directive and the Large Combustion Plants Directive (LCPD). Sulphur emissions may also be relevant to the requirements of other Directives.

It is important to recognise that there are very few remaining exceedences of the 15 min objective within the UK. By 2006, 15 Air Quality Management Areas (AQMAs) had been declared based on failure of the 15 min SO_2 objective. Of these, two are related to refineries, eight to industrial installations, one to shipping, one to a steam railway and three to domestic coal burning. Some of these sources are controlled under IPPC, others as part of Local Air Quality Management (LAQM). IPPC regulators must have regard to the objective in their deliberations on BAT. LAQM Action Plans must pursue the achievement of the objective. But there is no legal requirement to meet the objective in either case and we are considering amending the IPPC guidance in England and Wales to make this clearer.

[1] This factor was derived from monitoring data from areas where exceedences were likely. In those days monitors tended to incorporate chart recorders, so they could actually look at the occurrence of peak levels within the 15 min means to validate this assumption.

4. Approach

In order to carry out this analysis, an assessment has been carried out of the effects on health of **removing** this objective. This assumes that industry would only need to comply with the 1 hour and 24 hour objectives for SO_2 and some installations, in particular those using lower sulphur fuels to meet the 15min objective, could therefore theoretically increase their emissions. The impact on health of this increase in emissions can be quantified, both in terms of the effects of SO_2 and secondary particulate matter (which is partially derived from atmospheric reactions involving SO_2). These health effects can be monetised and compared with the financial benefits of removing the objective.

We have focused on the two industry sectors where we believe the removal of the objective would have the largest effect in terms of both health benefits foregone and industry costs saved – coal fired power stations and oil refineries.

The following scenarios have been modelled using a base year of 2004 and projections to 2010, 2015 and 2020 were produced:
(a) DTI UEP21 energy baseline with the current 15 min SO_2 objective in place (2004 and 2010 only);
(b) DTI UEP21 energy baseline without the current 15 min SO_2 objective in place (2004 and 2010 only);
(c) DTI UEP26 energy baseline with the current 15 min SO_2 objective in place;
(d) DTI UEP26 energy baseline without the current 15 min SO_2 objective in place.

5. Assumptions

A number of assumptions have been made in this modelling.

- The emissions for scenario (a) were projected based on site specific information prepared by DTI for UEP12 and adjusted by the projected emissions for the electricity supply industry for UEP21. At the start of the work to review the 15 min SO_2 objective, this was the current set of energy projections published by DTI. UEP21 has now been superseded by UEP26.
- For scenario (b) site specific corrections were made for power stations based on their flue gas desulphurisation (FGD) and LCPD status. The emissions from power stations with FGD and within the National Emission Reduction Plan (NERP) were kept constant. This is based on two conservative assumptions: that the operation of a plant at less than optimum abatement conditions is not BAT and therefore unlikely to be allowed by the permit, and; that within the NERP the increase in emissions by one source would be cancelled by the decrease in emissions from another source. Hence the annual total emissions would remain constant.[2]
- Annual emissions from ‘opted out’ coal fired power stations were increased by a factor of 1.5 (based upon the lower end of factors arising from modelling results from the Environment Agency – see Annex A).
- Virtually all LCPD sources in the refinery sector have opted into the NERP. So, even if their emissions increase individually under trading, there will be no overall increase in emissions since the NERP in effect has a fixed maximum “bubble”. The refinery

[2] There is limited capacity within the NERP for one of the major sources to increase their emissions significantly as the majority of operators within the NERP have relatively small emissions to trade. If the 15 minute objective were removed, operators which are part of the NERP would need to decide whether it was cost-effective to purchase additional SO_2 quota to enable an increase in site specific emissions whilst complying with the requirements of the reduction plan.

emissions from non-LCPD sources (currently 60% of the sector total) were increased by a factor of 1.5 giving an overall 30% increase. Further detail can be found in Annex A.

- While smaller operators in other sectors may also be impacted by the removal of the objective possibly allowing the increase in emissions this was considered insignificant on a national scale compared to the uncertainties in the emission projections which are of the order of 20%.
- Emissions estimates for scenario (b) were only calculated for 2010. Following advice from the Environment Agency it was assumed that the opted out power stations would be unlikely to emit in 2015 and this scenario would therefore be identical to scenario a.
- Site specific information was obtained from DTI for UEP 26 for coal fired power stations. This was used for a UEP26 baseline (c) for each year. UEP26 predicts more power stations with FGD than UEP21. As a result SO_2 emissions are lower, despite a greater use of coal, and both the costs and benefits of removing the objective are reduced.
- As the DTI UEP26 estimates show opted out power stations continuing to operate in 2015 (the last year in which they are able to) and non-LCPD sources at refineries operating through to 2020, emissions for scenario (d) were calculated for 2010, 2015 and 2020 using the assumptions described above.

6. AQ modelling results

The monetisable benefits for this analysis focus on the chronic effects arising from the assumed additional SO_2 emissions. These are calculated on the basis of changes in the annual average population weighted concentrations described in the tables below. Other effects which would increase this benefit have also been described and quantified (e.g. acute affects on sensitive individuals), but are not included in the main estimate as they are either less certain or difficult to monetise.

Table 1 shows a summary of the key results of this modelling assessment. Key results of the health impact assessment are shown in Table 2.

Table 1: Predicted UK population weighted mean concentrations

	a	b	difference
SO_2 2010 ($\mu g/m^3$)	2.755	3.010	0.255
PM_{10} 2010 ($\mu g/m^3$, gravimetric)	18.233	18.353	0.120

	c	d	difference
SO_2 2010 ($\mu g/m^3$)	2.495	2.632	0.138
SO_2 2015 ($\mu g/m^3$)	2.359	2.469	0.110
SO_2 2020 ($\mu g/m^3$)	2.224	2.297	0.073
PM_{10} 2010 ($\mu g/m^3$, gravimetric)	18.163	18.214	0.051
PM_{10} 2015 ($\mu g/m^3$, gravimetric)	17.453	17.496	0.043
PM_{10} 2020 ($\mu g/m^3$, gravimetric)	16.880	16.900	0.020

The GIS-based air dispersion models used in this assessment were of the same type as those in the April 2006 AQS review consultation. The health impact assessment of the resulting changes in SO_2 and PM_{10} concentrations were calculated using methods fully consistent with the Third Report of the Interdepartmental Group on Costs and Benefits (IGCB)[3]. The assessment of the change in life expectancy due to the long-term effect of PM has been based on a 5 year change in concentration, with the impact of this change followed for 100 years.

[3] 'An Economic Analysis to Inform the Air Quality Strategy Review Consultation'. Defra (2006). Available at http://www.defra.gov.uk/environment/airquality/strategy/igcb/index.htm

Table 2: Results of the health impact assessment

	Deaths brought forward	Additional respiratory hospital admissions	Additional cardiovascular hospital admissions
SO_2 2010 (b – a)	88	73	-
PM_{10} 2010 (b – a)	40	42	42

	Deaths brought forward	*Additional respiratory hospital admissions*	*Additional cardiovascular hospital admissions*
SO_2 2010 (c-d)	48	39	-
SO_2 2015 (c-d)	38	31	-
SO_2 2020 (c-d)	25	21	-
PM_{10} 2010 (c-d)	17	18	18
PM_{10} 2015 (c-d)	14	15	15
PM_{10} 2020 (c-d)	7	7	7

The life table calculations carried out for the AQSR used changes in concentration for 5, 20 or 100 years and 5 years is the most appropriate for the assessment of the combined impact of the increases in emissions from power stations and refineries between 2010 and 2015. After 2015 the emissions from power stations for scenario d are the same as for scenario c (the UEP26 baseline). The emissions from refineries are, however, predicted to remain higher for scenario d than for scenario c for the foreseeable future. However, for the main analysis we have focused on the 5 year impact. We have also separately assessed the impact of the change in emissions (and therefore ambient concentrations) over a 100-year period.

The number of additional life years lost due to the long term effect of PM is estimated to be 25,310 (no lag) to 26,779 (40 year lag) or ~0.1 days per person for the difference between scenarios a and b (UEP21) in 2010 (5-year change in concentrations). For the difference between scenarios c and d (UEP26) in 2010 the number of additional life years lost is 10,775 – 11,401 (5-year change in concentrations). A coefficient of 6.0% per 10 $\mu g/m^3$ change in PM has been used in these calculations.

7. Cost-Benefit analysis

This section sets out the assumptions and results of the cost-benefit analysis carried out to assess the impacts of the SO_2 15 min objective.

7.1 Benefits

Monetisable benefits arising from avoided chronic effects

Quantified benefits of the SO_2 15 min objective have been based on the agreed IGCB methodology and on expert advice from the Committee on the Medical Effects of Air Pollutants (COMEAP) who recommended a 6% reduction in hazard rate (per 10 $\mu g/m^3$) for $PM_{2.5}$ health effects. COMEAP also stated that the 6% coefficient should apply equally to all components of $PM_{2.5}$, including sulphate. This has been applied to the secondary particulate benefits of this objective, on the basis that virtually all the sulphate created by the extra SO_2 emissions will be in the finer size fraction. Table 3 sets out the quantified health benefits of the SO_2 15 minute mean based on UEP 21 (scenarios a and b) and UEP26 (scenarios c and d).

Table 3: Quantified health impacts of SO_2 15 min mean objective in the UK

	PM life years saved ('000s) – 6% (2010–2109[4])	PM – RHA[5] (2010, p.a.)	PM – CHA[6] (2010, p.a.)	SO_2 as gas – mortality (2010, p.a.)	SO_2 as gas – RHA (2010, p.a.)
Scenario (b-a)	25 – 27	42	42	88	73
Scenario (c-d)	11	18	18	48	39

These values have been discounted to generate a Present Value (PV) in 2005 prices of the different impacts and then annualised. The results are presented in Table 4.

Table 4: Annual PV of health impacts of SO_2 15 min objective in the UK

	PM life years saved – 6%	PM – RHA[3]	PM – CHA[4]	SO_2 as gas – mortality	SO_2 as gas – RHA
Scenario (b-a)	£86-127m	£0.1-0.4m	£0.1-0.4m	£1.3m	£0.1-0.7m
Scenario (c-d)	£37-54m	£0.2m	£0.2 m	£0.7m	£0.1-0.4m

The main analysis therefore suggests an annualised benefit of **£37m – £54m per annum** from the retention of the 15 min mean SO_2 objective for the period to 2015.

Other benefits not included in main analysis

We have also estimated the additional benefits derived from changes in concentrations arising from additional refinery emissions beyond 2015. These are more uncertain because of the difficulty in making assumptions about abatement in the longer term. Initial estimates suggest these additional impacts are likely to exceed an annualised benefit of £10m.

Chamber studies indicate SO_2 also acts to irritate the airways and exposure can lead to breathing difficulties through broncho-constriction. Given the reduction in population-weighted mean concentrations of SO_2 (set out in Table 1) evidence suggests the 15 minute mean objective is likely to generate some benefits in reduced occurrences of breathing difficulties, particularly among sensitive groups of the population such as asthmatics. However current studies are insufficient at present to allow formal monetised quantification of these avoided impacts to take place. This effect is therefore not included in the main analysis, even though there is strong evidence of its existence.

A formal quantification is not currently possible because of the absence of an established cost-benefit approach for this health endpoint. In the absence of such a method, the following steps can be used to derive the 'worst-case' number of additional episodes of broncho-constriction:

- Determine the number of exceedences of the 100 ppb 15 min averages per year for each emission scenario;
- Determine the population size in each 1km grid square;
- Make an assumption about the proportion of the population who are asthmatics;
- Make a further assumption that asthmatic symptoms (i.e. broncho-constriction) will be produced in the proportion of asthmatics (previous step) once an exceedence of the 100 ppb 15 min average has occurred;
- Calculate the possible impact in terms of the number of episodes of broncho-constriction using the different emission scenarios.

[4] These long term changes in health outcomes only relate to changes in concentrations over a 5 year period.
[5] RHA – Respiratory Hospital Admissions saved.
[6] CHA – Cardiovascular Hospital Admissions saved.

This is a very crude means of calculating the possible impact and we acknowledge the debatable intrinsic assumptions. Using this method, we have estimated the number of episodes of broncho-constriction at 90,000 for scenario c and 160,000 for scenario d. This implies a worst case estimate of 70,000 additional episodes of broncho-constriction could be associated with the removal of the objective.

A reduction in SO_2 concentrations is also expected to lead to a reduction in damage to materials and ecosystems through acidic deposition as set out in the Third Report of IGCB. This benefit has not been quantified or monetised although it is likely to be small.[7]

7.2 Costs

The assumptions used in the cost analysis are presented below. The analysis focuses on those costs borne by both coal-fired power stations and oil refineries in meeting the 15 min mean that would be avoidable in its absence. These costs capture the estimated incremental cost of meeting the 15 min mean (as opposed to the 1 hour limit value) and assumptions used are based on discussions with both EA and industry stakeholders. Costs have been modelled over a five year period (2005-2009) for coal-fired power stations[8] and oil refineries on a consistent basis with the benefits modelling above.

Non-FGD equipped coal-fired power stations

EA have looked at coal power stations on a case-by-case basis and estimated the level of sulphur content in coal that would be required to achieve compliance with the SO_2 15 minute objective (as opposed to the next most stringent AQS objective) assuming the 2005 level of electricity generation. This is based on the current average sulphur content of fuel, load factors and estimates of the sulphur content of coal power stations could use in order to individually achieve AQS objectives. This can then be used to estimate the additional low sulphur coal required to meet the 15 minute mean only. Based on these assessments, this equates to an additional estimated 10Mt p.a. of low sulphur coal being used between 2005-2007 and an estimated 4Mt p.a. between 2008-2009 (the former period is higher as it includes the additional low sulphur coal being used by plants fitting FGD to meet the 15 minute mean before LCPD requirements in 2008).[9]

The cost of coal is based on DTI figures (estimated to be between £30 - £37 per tonne, 2005 prices) with a 3% - 7% premium applied to account for extra cost of low-sulphur content coal (based on International Energy Agency (IEA) findings).[10] When these cost assumptions are applied to the additional estimates above, results suggest additional annualised costs of **£15m – £20m per annum** for coal-fired power stations to meet the SO_2 15 minute mean.

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[7] The benefits of a reduction in SO_2 on materials and crops is discussed in section 2.6 and section 4.11 (respectively) of the IGCB third report. Analysis carried out for AQS measures that lead to a reduction in SO_2 emissions suggest that these monetised benefits are small compared to the health benefits (as shown in Table 4 above). Available at http://www.defra.gov.uk/environment/airquality/publications/stratreview-analysis/index.htm

[8] Only non-FGD coal-fired power stations have been considered in this cost analysis. Our assessment of remaining plants indicates that plants were either already fitted with (or commissioned) FGD before the introduction of the SO_2 15 minute mean in 2000, or are currently planning or in the process of fitting FGD in time for 2008 (to meet the requirements of LCPD).

[9] The range in estimated additional low sulphur coal needed is driven by the lack of data of available data to estimate the additional coal usage for the Scottish power stations (Cockenzie and Longannet). The range assumes additional low sulphur coal needed to meet the 15 min mean at these power stations is between 0 tonnes (0%) and the total individual coal usage at each station (100%).

[10] Evidence is mixed on the presence of a low sulphur premium. For the purposes of this analysis we have taken a conservative estimate of 7% premium, based on the high end estimate of the premium range suggested by IEA.

Oil refineries

The cost estimate from UKPIA suggested that costs, per refinery, could be up to £10m p.a. in order to switch to sweeter (lower sulphur grade) crude oil. Current cost assumptions pro-rata this according to refining capacity across the nine refineries. EA believe there are only three refineries which have any realistic issue with the 15 minute mean using current crude oil input. They also suggest the sulphur issue could be better (and more cost-effectively) dealt with by fitting abatement equipment to the refinery – allowing them to continue using current crude supplies – as opposed restricting crude oil choice.

A significant proportion of SO_2 releases on a refinery can be from the Fluid Catalytic Cracker unit (FCC). Other sources are the onsite combustion plant which are covered by LCPD. It is possible to fit tail gas cleaners to the FCC in order to reduce SO_2 emissions and comply with the 15 minute mean. EA estimates this leads to an annualised cost of £1.4m per annum per refinery. There are two issues here:

1. The PPC TGN shows FCC gas scrubbing as candidate BAT technique and this will be assessed for each refinery during the PPC determination. It is therefore likely that this would be fitted irrespective of the 15 min mean. Therefore there may be no cost incurred in meeting the 15 minute mean.
2. EA experts are concerned that fitting a 'standard size' tail gas cleaner might not fully meet the 15 min mean. A worst case assumption would be that tail gas would need to go through a bank of two scrubbers. It may be less expensive to improve the efficiency of one unit rather than install a second. EA estimate that the cost of a scrubber would be £1.4m per refinery (annualised cost) depending on the size of refinery.

In light of this the additional cost borne per refinery by the 15 minute mean is estimated at between £0m per annum (assuming a single scrubber enables the 15 minute mean to be met) and £1.4m per annum (assuming a second scrubber is required). This equates to a total cost to the refinery industry of **£0m-£7m per annum**[11] (based on costs to 7 refineries – of the remaining two, one refinery (Stanlow) already has some abatement on the FCC and another (Teesside) does not have a FCC unit due to the nature of refinery).

Table 5: Annual present value of costs to non-FGD coal-fired power stations and oil refineries

Cost to non-FGD coal power stations	Cost to oil refineries
£15-20m	£0-7m

7.3 Summary of costs and benefits

The analysis of benefits and costs set out above suggest that removal of the SO_2 15 minute mean objective would provide a net disbenefit of **£11m - £41m per annum** until 2015. This is based on the more recent UEP26 scenario (scenario (c-d)) results.

This is a conservative analysis. There would be other effects resulting from a removal of the objective, although their magnitude is less certain:

- An illustrative calculation suggests that removal of the objective could result in 70,000 additional episodes of broncho-constriction as a result of increased SO_2 concentrations.

[11] For the analysis of the longer term impact of additional refinery emissions we have made the conservative assumption that these costs will be maintained beyond 2015.

- We have also estimated costs and benefits associated with increased refinery emissions beyond 2015 resulting from the removal of the objective. These are uncertain, but likely to exceed a net disbenefit of £3m pa.

Potential increase in annual emissions from 'opted out' coal fired power stations

Opted out power stations will be able to manage their emissions by altering the proportion and times at which they buy lower sulphur coal. The operating hours used are based on DTI estimates of behaviour and clearly are subject to the commercial decisions of individual operators.

Within Scenario (b) Annual emissions from 'opted out' coal fired power stations were increased by 50%. No physical abatement equipment is assumed to be fitted in any of the scenarios. This factor arises from three concurrent studies; analysis based on plume dispersion theory suggests that a plant emitting sufficient to exactly meet the 15 minute objective could increase its emission by between 100% and 300% if allowed to increase its emissions until it just meets the 1 hour objective.

Reanalysis of measurement data from sites impacted by plumes from major point sources suggested that an increase of between 30% and 450% in emissions would be allowed depending on the meteorological conditions and the relative location of other sources.

Ground level concentrations are linearly related to emissions. Modelling carried out for a generic power station with and without flue gas desulphurisation shows that, in the absence of the 15 minute objective, emissions could be increased by 80% before meeting the next regulatory constraint (the 1 hour EU Limit Value). Further work on a range of generic sources gave increases of 52% for a refinery, 64% for a municipal waste incinerator, 50% for a hazardous waste incinerator and 57% for a cement works using the dry process and burning 25% tyres.

Hence 50% was a conservative value to take into account that operators are cautious in approaching regulatory limits since they may be subject to action for breach of permit if they were to exceed an objective. If necessary, the resulting emission was constrained to the station specific limit ('A' limits in England and Wales, a bubble for Longannet and Cockenzie in Scotland).

Potential increase in refinery emissions from non-LCPD sources

The 60% of refinery emissions from non-LCPD sources are presently permitted based on the attainment of the 15 minute objective. In the absence of this objective, the regulator would no longer be able to take into account the short term health effects of sulphur dioxide in permit determinations. It is therefore assumed that removal of the objective will lead to operators applying for revised permits.

In Scenarios (b) and (d) it is assumed that operators will seek the most economic approach to emission management which would be to increase emissions from these sources. This could involve moving releases from LPCD sources on site and hence making available the possibility of a trading gain for the operator. This would lead to an increase in the national total. These non-LCPD sources were increased by a factor of 1.5 for the reasons given above leading to an overall 30% increase at refineries.