4 - Uncertainties under the microscope

This section is a summary of a paper prepared by CONCAWE as a contribution to the 4th meeting of the Stakeholder Expert Group on the EU Air Policy review. The study is based on the results of extensive sensitivity analysis undertaken by CONCAWE using their in-house Integrated Assessment Model. This is largely founded on the data developed by IIASA to support their policy scenario analysis undertaken in the context of the revision of the Gothenburg Protocol (energy scenario PRIMES 2009).

The illustrative sensitivity analysis focussed on six key issues: Policy vulnerability to under-delivery of Euro VI/6 NOx emission reductions, Policy dependency on NH_3 emission reductions from Agriculture, Policy need to consider multiple time horizons, Policy vulnerability to a single energy scenario, the Policy benefit of more fully accounting for short lived climate forcers and finally, the Policy implications of differentiating the toxicity of primary and secondary components of the overall PM mix.

4.1 Uncertainty in the real world performance of Euro VI/ 6

Policy scenarios leading to revised Thematic Strategy on Air Pollution (TSAP) targets must account for uncertainties in the reductions in road transport NOx emissions associated with the introduction of Euro VI/6 standards in 2014/17.

If real-world vehicle performance results in higher than expected NOx emissions, the sensitivity analysis indicates that, at a given ambition level, this would result in significant increases in costs to the non-transport sector or even in unachievable targets.

A sensitivity analysis shows that if under real life driving conditions EURO VI only delivers a 50% improvement over Euro V and Euro 6 achieves only a Euro 5 emission level, then a factor of 3 cost increase for non-road transport sectors is possible, from 7 to 20 b€/year.

In the past, real world NOx emissions from the road transport sector have been substantially greater than forecast from the regulated emission limits (from Euro II/2 to Euro V/5), due to a significant difference between performance under actual driving conditions and performance under the standardized driving cycle that forms on which the regulation is based. This has led to substantial problems in achieving obligations under the current National Emission Ceiling Directive (NECD) and Ambien Air Quality Directive (AAQD) in a number of Member States.

The importance of this is illustrated by Figure 2 which shows the forecasted evolution in NOx emissions from Road Transport in EU-27 from 1995 out to 2030 and beyond. This is derived from CONCAWE's in-house road transport emissions forecasting model developed for and used extensively to support the European Auto Oil programmes[4].

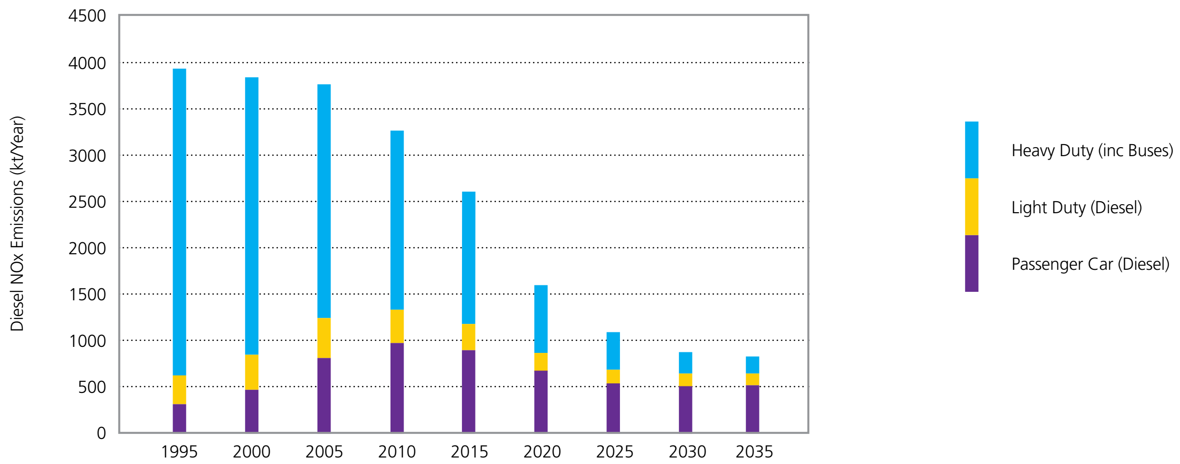
It is important to highlight the critical dependence of overall policy on the forecast transport NOx emissions. To illustrate this we compare two emissions forecasts: one based on all vehicles achieving emissions per kilometre as estimated with COPERT 4 and the other assuming higher emissions per kilometre from the Euro VI/6 diesel fleet component.

Design of sensitivity scenarios: If sensitivity scenarios are to provide insights into the influence of uncertainties on the robustness of policies they of course must have a clear basis for their design. With this in mind the following sensitivity scenarios were constructed:

Sensitivity Scenarios:
Sensitivity Scenario a: For Euro VI (heavy duty vehicles): the fleet averaged Euro VI real world NOx emission/km would be half the emissions achievable using the Euro V emission factors[5] in COPERT. **Sensitivity Scenario b: For Euro 6 (light duty vehicle):** the fleet averaged Euro 6 real world NOx emissions would be at the same level as the Euro 5 emissions represented in COPERT.

[4] The emission algorithms (e.g., COPERT 4 emission relationships) and exogenous assumptions (e.g. fleet numbers, fleet starting vintages and turnover rates) are entirely consistent with the current version of TREMOVE used to support the transport elements of GAINS.
[5] Emission factors derived from tests on marketed vehicles.

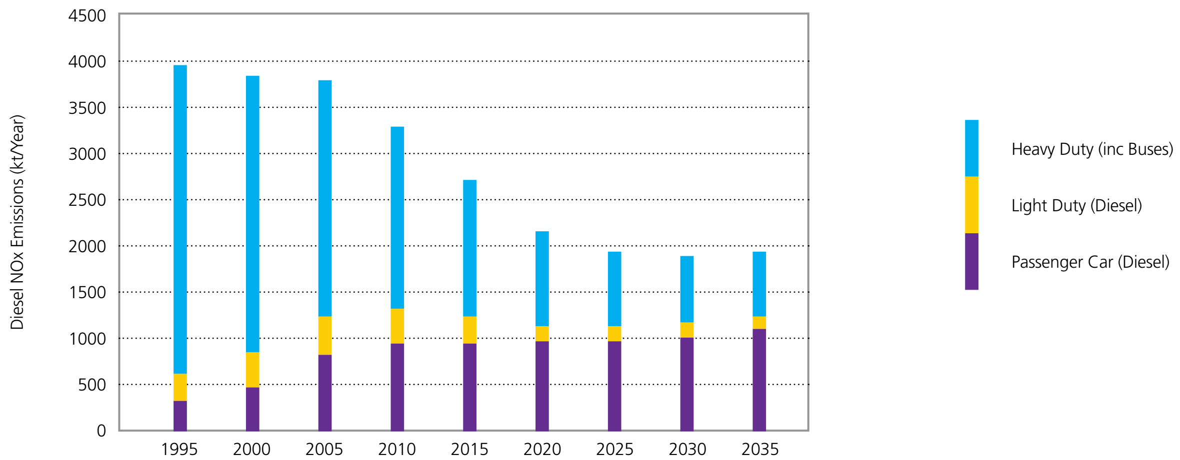
Figure 2
Evolution of NOx Emissions from Road Transport in EU-27: Base Case (COPERT 4)
Source: CONCAWE STEERS Model



Between 1995 and 2010 NOx emissions from diesel vehicles have not fallen as fast as NOx emissions from gasoline vehicles. This is in part due to growth from the dieselisation of the light duty vehicle (LDV) fleet and the general increase in vehicle kilometres driven. However, an important reason for this slower than expected reduction has been the disappointing real world performance of Euro II/2 to Euro IV/4 vehicles.

Between 2010 and 2015 with the 'real world' performance for Euro V/5 already reflected in COPERT 4, this trend is not significantly changed. In contrast by 2030 LDV diesel NOx is forecast to halve and heavy duty vehicles (HDV) NOx reduce by eightfold from the introduction of Euro 6/VI in 2015/16 when replacement of the pre 2015/16 fleet is complete.

Figure 3
Evolution of NOx Emissions from Road Transport in EU-27: Sensitivity Case.
Source: CONCAWE STEERS Model



If higher than expected emissions from Euro VI/6 vehicles do occur (sensitivity case a + sensitivity case b), NOx emissions will be double over the base case 2025 i.e. emissions would be some 1Mt/y higher. This will by far not deliver targets and may bring some Member States to a non-compliance situation.

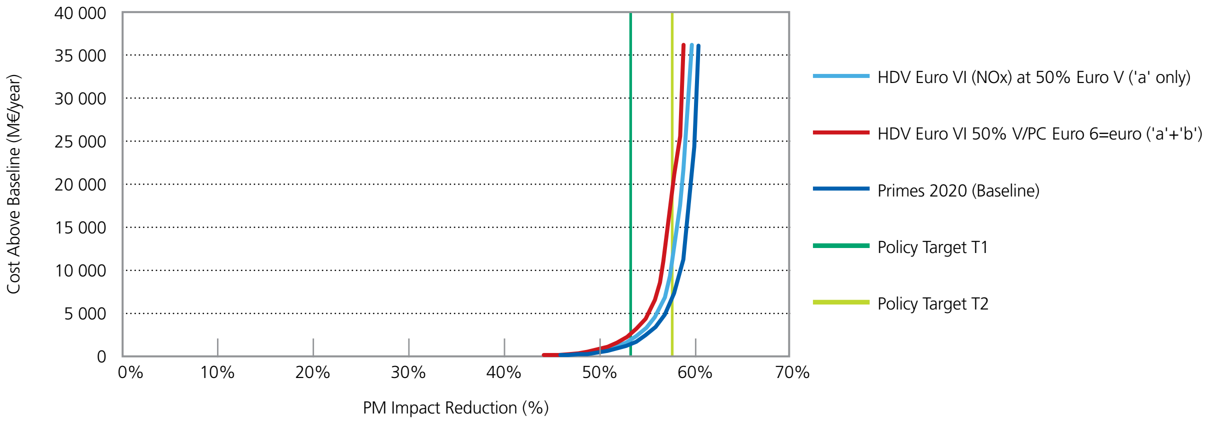
To illustrate the policy implications of this under-achievement of the Euro VI/6 program, the sensitivity case and the base case were tested under two optimisation scenarios to deliver further health impact improvement beyond the baseline (current legislation) in PM (50% gap closure[6]: Policy Target T1, 80% gap closure: Policy Target T2). The optimisations were carried out using CONCAWE's in-house Integrated Assessment Model (IAM)[7].

[6] GAP CLOSURE the reduction in impacts, expressed as a percentage, of the maximum further impact reduction achievable in moving from Current Legislation scenario to Maximum Technical Feasible Reduction.
[7] CONCAWE integrated Assessment Model utilises identical source-receptor functions, cost functions and impact algorithms to those used in GAINS to support IIASA's recent work for the revision of the Gothenburg Protocol.

The 'optimisation driver' was confined to PM health impacts to simplify the analysis and aid transparency.

Transport emissions lie outside the optimisation as they are determined by the forecast fleet development, mileage driven and technical abatement measures in place i.e. they are input data. The resulting optimised costs are for the additional stationary source abatement measures needed to achieve further PM impact reductions. Note that PM impact is related to the concentrations of total $PM_{2.5}$ in the air and this comprises both directly emitted 'primary' particles and 'secondary' particles ($PM_{2.5}$ formed in the air by chemical reaction). NOx, NH_3 and SO_2, contribute to secondary $PM_{2.5}$. The results are shown in Figure 4 below.

Figure 4
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture).
Source CONCAWE IAM (PRIMES 2009)



Three baseline starting points were examined, all derived from the PRIMES 2009 energy scenario (central scenario for the revision of the Gothenburg Protocol).

'Base Case'- dark blue line

Energy scenario: actual baseline PRIMES 2009.

Euro VI/6: Full delivery as determined using COPERT 4 (Euro VI delivering 8 times lower emissions than Euro V and Euro 6 half of Euro 5)

With optimised delivery of a given EU-27 PM reduction target in 2020.

'Sensitivity Scenario 'a' only- light blue line

Euro VI/6: Euro VI only delivers a 50% improvement over Euro V and Euro 6 delivers as in the base case. In this case the baseline NOx emissions were adjusted in each Member State (MS) to account for the greater transport NOx emissions before the optimisation scenarios were run.

'Sensitivity Scenario 'a' and 'b'- red line

Euro VI/6: Euro VI delivers a 50% improvement over Euro V and Euro 6 performance is the same as Euro 5. Again, for this case, baseline NOx emissions were adjusted in each member state to account for the 'under-delivery' of Euro VI/6 before the optimisation scenarios were run.

The vertical lines represent two different control scenarios considered as percentage of PM impacts gap closure (GP).

Policy Target 1: 50% Gap Closure- dark green line:

Should Euro VI/6 under-deliver the implications for further investments in stationary sources (including ammonia abatement measures in agriculture) to make up for the greater than expected NOx emissions from road transport are already clearly significant. For the worst case considered in the sensitivity scenarios (sensitivity case a+b red line) Figure 4 shows annual costs doubling from some 1.5 b€/y to 3b€/y.

Policy Target 2: 80% Gap Closure- light green line:

Costs escalate since here policy would be hitting the steep part of the cost curve. In this case annual costs rise from some 7b€/y (base case, dark blue line) to almost 20b€/y (sensitivity case a+b, red line). It is also important to note that in case of under-delivery of Euro VI/6 at the higher ambition targets, in some Member States, the NOx ceilings will become unachievable even at Maximum Technically Feasible Reductions (MTFR). Such situations have already been experienced in the case of the current NECD 2010 ceilings.

It is necessary to explore the reductions that would be required from other sectors to compensate for a lower than expected delivery of Euro VI/6. Particularly in a context where the economies of the EU will increasingly struggle to compete in the global market place, these potential unintended consequences should be well understood. Certainly, the implications of such uncertainties (via sensitivity scenarios around the central policy case) need to be explored throughout the entire policy process.

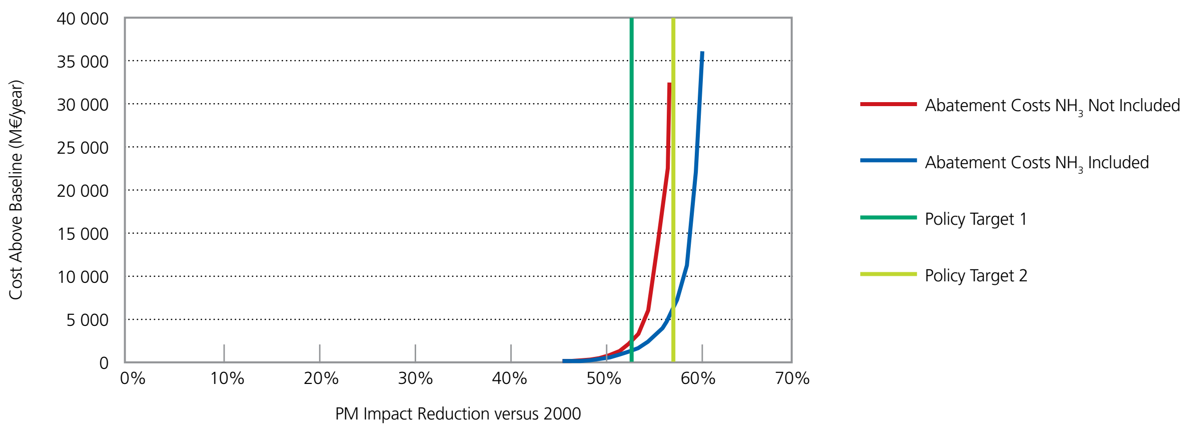
4.2 NH_3 from agriculture

Ammonia is a key pollutant; if emissions of ammonia are not reduced the scope for compensation by controls on NOx is extremely limited. It is not possible to meet ambitious acidification, eutrophication or human PM exposure targets if ammonia emissions are not reduced.

The Clean Air For Europe (CAFE) programme which underpinned the current Thematic Strategy on Air Pollution, clearly identified the reduction in ammonia emissions from agricultural sector as an important component of cost-effective policy designed to deliver improved air quality in Europe. Through earlier policy initiatives, such as the NECD and Gothenburg Protocol, the need for agriculture to be part of the solution to Eutrophication and Acidification was already well established. What was new and important in CAFE was the understanding that reductions in ammonia emissions from agriculture were central to cost-effective reductions in human exposure to fine particulates. This section illustrates why this remains crucial for any policy initiatives resulting from the review process.

CONCAWE has carried out a sensitivity analysis using its in-house integrated assessment model to identify the least-cost measures to deliver further improvements (beyond the baseline) in PM health impacts in the EU in 2020 if different NH_3 emission reduction measures are considered.

Figure 5
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture)
Source: CONCAWE IAM, based on PRIMES 2009



Case 1- blue curve: optimised (least-cost) curve of cost versus reduction in long term health impacts of PM in the EU assuming all further abatement measures identified within the GAINS model (version used to support the GP revision work) are available for selection, including ammonia abatement measures.
Case 2- red curve: optimised (least-cost) curve of cost versus reduction in long term health impacts of PM in the EU assuming no further ammonia abatement measures are available. In other words, ammonia emissions remain at 2020 Baseline levels.

The important, even essential contribution of reductions in ammonia in achieving optimised delivery of a given PM target is evident in Figure 5.
Policy Target 1: 50% PM impact Gap closure[8]: The cost of the control scenario without ammonia abatement measures (red curve intersection with dark green line) is 3 b€/y that is essentially double of the cost with ammonia abatement measures (blue curve intersection with dark green line) that is 1.5 b€/y.
Policy Target 2: 80% PM impact Gap Closure the difference between scenarios dramatically increases from some 7 b€/y (blue curve intersection with light green line) to the Maximum Technically Feasible Reduction (MTFR) point for all the 'beyond baseline' abatement measures for stationary sources of Primary $PM_{2.5}$, NOx and SO_2 at a cost of some 32 b€/y (red curve intersection with light green line).

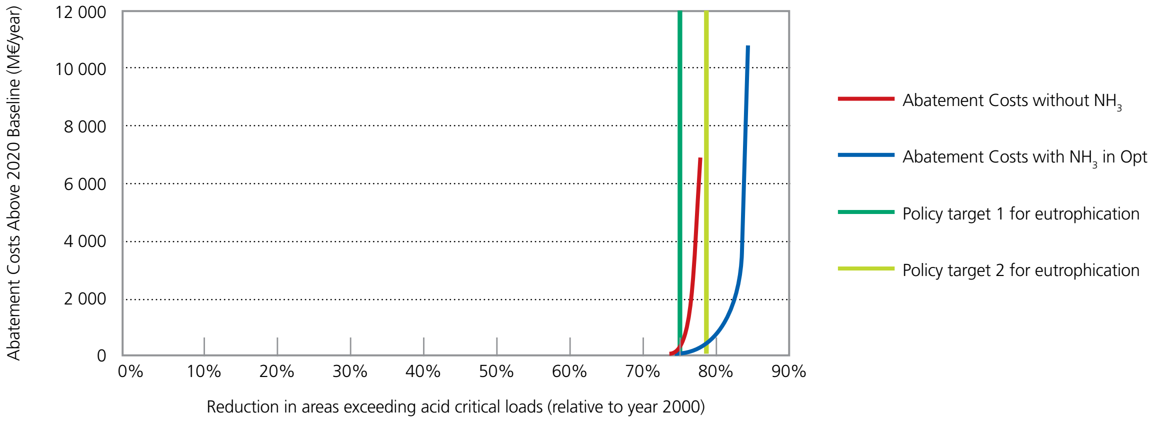
From a policy point of view, it is also worth noting that at the 7b€/y cost, the best achievable gap closure for PM[9], should ammonia emissions remain at the 2020 Baseline, is 60%. Without limit on the cost, the best achievable gap closure, as implied above, would be 80% (i.e. MTFR for SO_2, NOx and Primary PM emissions).

[8] GAP CLOSURE: the reduction in impacts, expressed as a percentage, of the maximum further impact reduction achievable in moving from Current Legislation scenario to Maximum Technical Feasible Reduction.
[9] i.e. The best achievable further health impact improvement beyond the baseline.

As already noted, ammonia reductions have long been recognised as the priority for achieving cost-effective further reductions in the areas of ecosystems exceeding acidification or eutrophication critical loads.

Figure 6 (acidification) and Figure 7 (eutrophication) show the optimised cost of further abatement measures versus reduction in the ecosystem areas exceeding their critical loads.

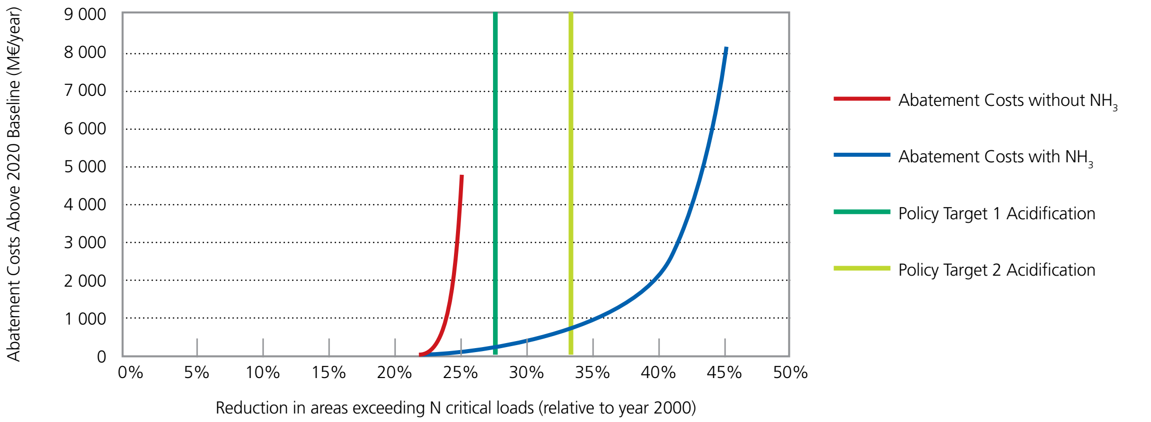
Figure 6
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus Reduction in the Area of Forest Ecosystems Exceeding Acid Critical Loads. Source: CONCAWE IAM (PRIMES 2009)



In the case of further progress in reducing acidification, the maximum further improvement is severely limited if measures are confined to SO_2 and NOx.

Case 1- blue curve: all further abatement measures are available, including ammonia abatement measures.
Case 2- red curve: ammonia emissions remain at 2020 Baseline levels.

Figure 7
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus Reduction in the Area of Ecosystems Exceeding Eutrophication Critical Loads Source: CONCAWE IAM (PRIMES 2009)



In the case of eutrophication, no significant progress can be achieved without a focus on ammonia.

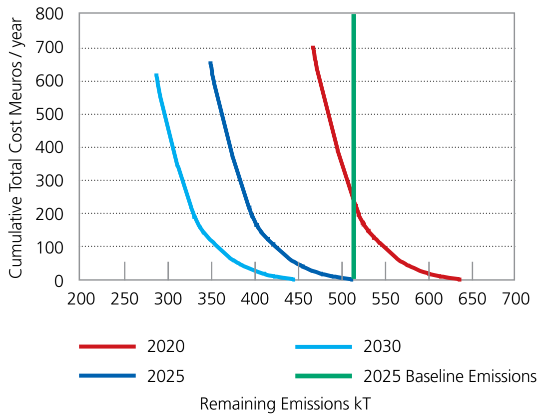
To highlight the significant challenge to the policy process of ensuring the required reductions of ammonia emissions from the agricultural sector are realised, it is worth noting, in the context of the Gothenburg Protocol (GP) that ammonia emissions in the 2020 Baseline are predicted to fall by less than 2% between now and 2020. Although a new agricultural baseline scenario is under preparation, the optimisation undertaken in this 'GP PRIMES 2009' scenario, foresees the cost-effective contribution to the 50% PM GC target to result in a 17% reduction from 'today's' level and a 29% reduction in the case of an 80% PM GC target.

4.3 Multiple time horizons

Policy horizon years are critical. The structural changes (e.g. changing energy use) and the on-going emission reductions resulting from already agreed legislation, has significant effects on emissions with time. This introduces the question of what is the appropriate timing for compliance with any new policy initiatives in a changing world. Investing heavily in abatement technology to achieve emissions reductions that will be reached by other means just a few years later could lead to unnecessary additional financial pressures and regret investment.

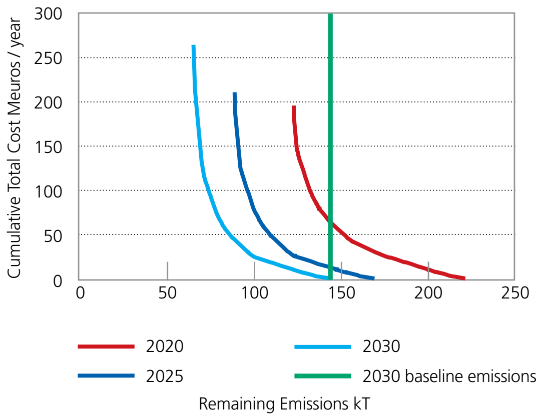
CONCAWE has carried out an analysis based on IIASA-GAINS data (IIASA report #10, (IIASA 2013)), developed for their work on the revision of the TSAP, to illustrate the economic importance of several policy horizon years.

Figure 8
National NOx Cost Curves for Three Policy Horizon Years for One Example Member State.
Source: IIASA for 2012 TSAP (PRIMES 2010)



Comparison of national cost curves for further abatement measures on NOx in one example Member State of the EU for three policy horizon years: 2020, 2025 and 2030.
In each case, the continuing effects of base case changes in emissions are clearly seen. This has significant implications for the cost of achieving further impact reductions as a function of time.
Example:
If the revised TSAP targets required this Member State to reduce its baseline NOx emission to 515kt/y, then the additional cost burden for NOx reducing measure would be:
+250M€/y, if the compliance year is 2020
+0M€/y, if the compliance year is 2025, i.e. Baseline measures achieve the objective.

Figure 9
National SO_2 Cost Curves for Three Policy Horizon Years for One Example Member State
Source: IIASA for 2012 TSAP (PRIMES 2010)



Comparison of national cost curves for further abatement measures on SO_2 in one example Member State of the EU for three policy horizon years: 2020, 2025 and 2030.
As for the NOx case, the continuing effects of base case changes in emissions are clearly seen.
Example:
If the revised TSAP targets required this Member State to reduce its baseline SO_2 emission to 144kt/y. then the additional cost burden for SO_2 reducing measure would be:
+ 60M€/y, if the compliance year is 2020
+10M€/y, if the compliance year is 2025
+0M€/y, if the compliance year is 2030, i.e. Baseline measures achieve the objective.

Of course in looking at future policies designed to make further progress in air quality in the EU it is also important to recognise the on-going costs of already agreed measures which are delivering these continued reduction in baseline emissions (with their associated further improvements in air quality) with time. For this example Member State, for NOx alone, GAINS indicates the cost of already mandated measures in 2010 to be some 2.8 b€/y, rising to 5.3 b€/y in 2020 and reaching 6.7 b€/y by 2030.

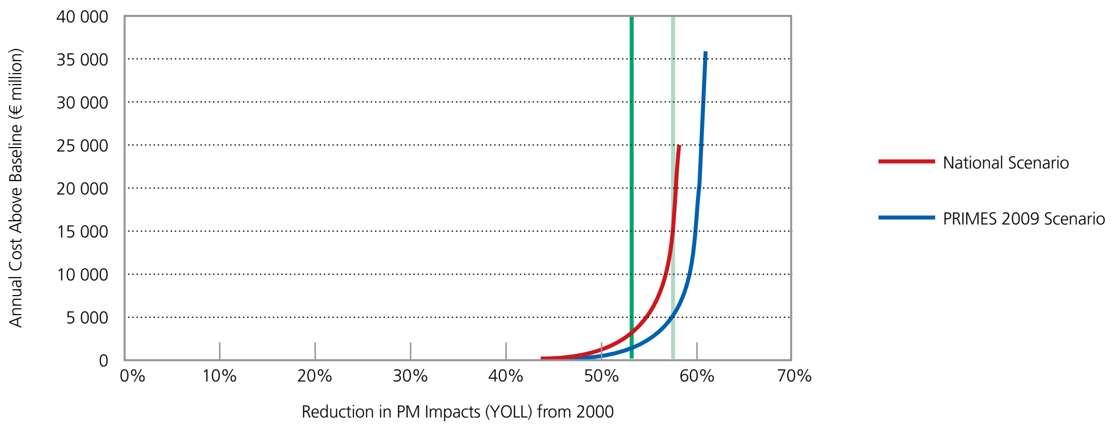
4.4. Range of Energy scenarios

Given the uncertainties in defining the 'future world' it is vital to ensure that ambition levels (expressed as revised national emission ceilings) based on one energy scenario do not result in significant escalation in compliance costs or non-achievability in a different actual future energy world. The current difficulties in some Member States in meeting 2010 NOx ceilings illustrates the vital need to include such energy uncertainties in policy development.

The need for consistency/coherency in the central assumptions used in the development of interrelated policy initiatives (e.g. Air Quality and Climate Change) is well recognised. However, this should not be interpreted as a need to base policy on a single view of the 'future world' that the policy is designed to influence. History serves as a constant reminder that actual developments can be quite different from the projections made a few years earlier. Sensitivity scenarios around a central view to test the robustness of future business plans are essential to the business world. In CONCAWE's view such sensitivity analysis is also essential in the policy arena.

In this regard, along with a number of other stakeholders, CONCAWE has requested that a range of energy scenarios, around the central PRIMES scenario, should be used in appropriate sensitivity scenarios to test policy options. In this short section, the databases used for the revision of the Gothenburg Protocol have been used to support this call.

Figure 10
Annual Abatement EU-27 Costs for Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus PM Impact Reduction: Comparison of PRIMES and National Energy Scenarios Source: CONCAWE IAM



Although only twelve Member States submitted their alternative national energy scenarios during the Gothenburg Protocol review process, the consequence of moving from a PRIMES based world to this alternative 'National Energy Scenario' world is already significant. Figure 10, shows the optimised curves of cost beyond the baseline versus further reductions in PM impacts for each energy scenario. The two vertical lines indicate a medium (target 1, yellow, gap closure[10] 50%) and high (target 2 red, gap closure 75%) improvement target. The implications of arriving in the 'National energy future world' having designed policy with a sole focus on the PRIMES world are obvious: costs, justified only for the PRIMES world, double at the medium ambition level and triple to close to Maximum Technically Feasible Reduction (MTFR) costs at the high ambition. In the latter case, at an individual Member State level some individual pollutant ceilings set solely based on PRIMES would likely, at this ambition, be unachievable. Given the binding nature of the NECD, this would force Member States to consider measures that would otherwise not be justifiable and could have undesirable economic consequences. Such a situation would be avoided with the inclusion of suitable sensitivity analysis.

[10] GAP CLOSURE: the reduction in impacts, expressed as a percentage, of the maximum further impact reduction achievable in moving from Current Legislation scenario to Maximum Technical Feasible Reduction.

4.5. Short Lived Climate Forcers (SLCF)

The sensitivity scenarios in this section demonstrate how attributing a CO_2 credit or debit to SO_2, and Black Carbon emissions (based on carbon price) and including them in the optimization strategy can give an entirely different perspective to control policies and shift the policy emphasis away from NOx and SO_2 controls on stationary sources, even at relatively low carbon prices and long-time horizons.

One key recent development in the context of the revision of the Gothenburg Protocol (GP) was the inclusion of considerations over the influence of short lived climate forcers (SLCF) in the policy process with a particular focus on Black Carbon (BC). As a consequence, the GAINS team have begun to incorporate such considerations in a quantitative way into GAINS.

What this work by IIASA has provided is a helpful bringing together of quantified data on the direct global warming potential (GWP) of all the key SLCFs and was first presented by IIASA in Dublin in May 2010[11]. The following data for GWPs have been abstracted from this presentation:

Table 1
Global Warming Potentials relative to CO_2 (GWP CO_2=1) (a negative value represents a net cooling effect)

	20 year GWP	100 year GWP
SO_2	-140	-40
Black Carbon	2200	680
Organic Carbon	-240	-75

The availability of these relative GWPs allow the "CO_2 compensation costs" implied for a unit reduction in each of the three SLCF to be computed for a given carbon price e.g. the currently anticipated long-term price of €30/t CO_2e. The carbon compensation cost here is the cost involved in sustaining 'no change' in Baseline GWP by introducing compensating measures.

Table 2
Carbon compensation costs for SO_2 and BC

	Carbon compensation costs (€/tonne) Considering a carbon price of 30€/tCO_2	
	20 year integration period	100 year integration period
SO_2	4200	1200
Black Carbon	-66,000	-20,400

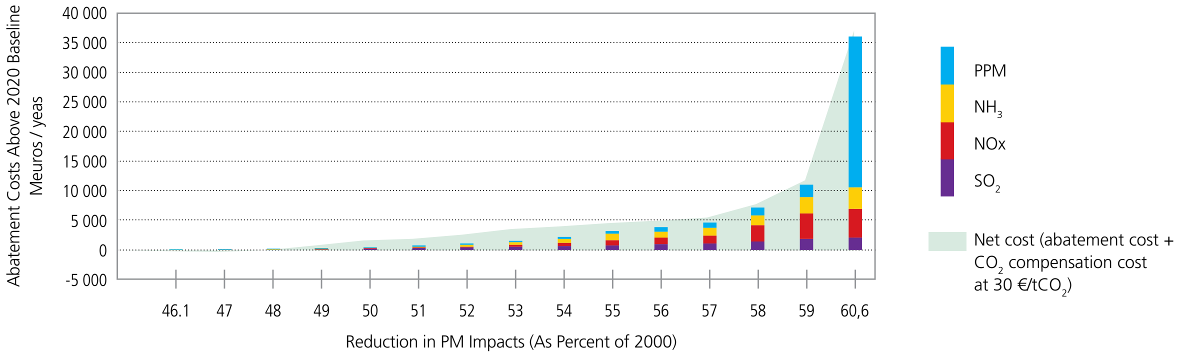
Table 2 shows that removing the beneficial climate cooling effect of sulphates derived from SO_2 emissions has to be compensated by additional climate mitigation measures. Conversely, in the case of black carbon, reductions in emissions of this powerful climate warmer result in savings in the climate mitigation costs of the baseline.

Based on detailed data made available by the GAINS team in the context of the Gothenburg Protocol revision process, CONCAWE have recently built this capability into their in-house IAM. What follows are some first results which indicate the importance of taking the full implications of SLCF into account in developing future policy. Importantly, the work clearly indicates that the inclusion of the considerations into the optimisation strategy significantly shifts the policy emphasis away from further controls for SO_2 and NOx on stationary sources, even at relatively low carbon prices and long-time horizons.

[11] First presented by Markus Amann at the 38th session of the UN-ECE TFIAM meeting in Dublin, May 17-19, 2010

Annual Abatement Costs for EU-27 by Pollutant For Stationary Sources (Including Agriculture) Above the 2020 Baseline versus PM Impact Reduction Including Carbon Compensation Cost for SLCFs

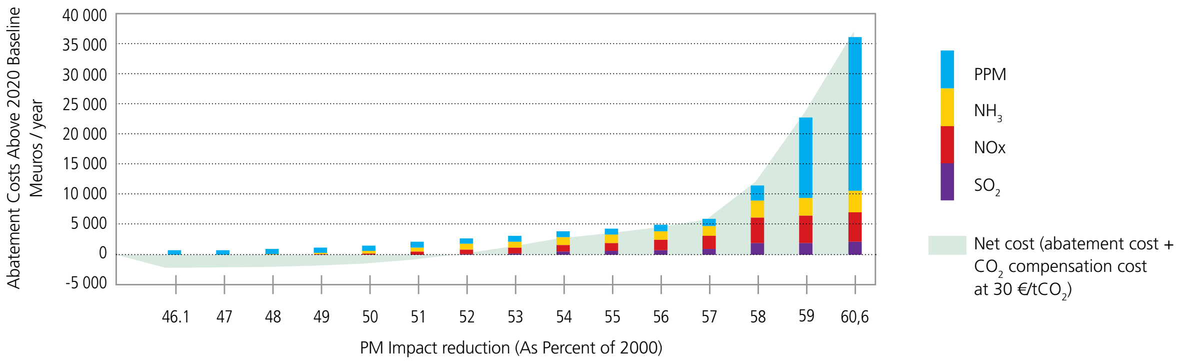
Figure 11
Case 1: PRIMES 2009 Scenario: Without SLCF in Optimisation



Case 1: Compensation cost not in the Optimisation Strategy

- Up to the 54% improvement target:
  Abatement measures on SO_2, NH_3 and NOx rather than on primary $PM_{2.5}$. As may be seen this results in a significant additional cost of measures to compensate for reductions in SLCF (here mainly SO_2).
- At the 54% improvement target point:
  Net Cost = ~1.5b€/y abatement measures + ~ 2.1b€/y CO_2 compensation cost = 3.6 b€/y
- Beyond 58% improvement target point:
  Most SO_2 measures have been exhausted and the optimiser picks Primary $PM_{2.5}$ measures. Since these emissions include a black carbon component, their reduction results in savings in the cost of climate mitigation measures included in the baseline, and the difference between abatement cost and net overall costs reduces.

Figure 12
Case 2: PRIMES 2009 Scenario: With SLCF in Optimisation



Case 2: Compensation cost not in the Optimisation Strategy

- Up to the 53% improvement target:
  Abatement measures on primary $PM_{2.5}$ with a high fraction of BC component rather than on SO_2, NH_3 and NOx.
  Net cost is negative (compensation costs > abatement cost), but abatement costs in Figure 12 themselves are clearly higher than those shown in Figure 11. In other words, as well as moving away from measures controlling secondary sources of $PM_{2.5}$, the overall abatement burden on some sectors would increase.
- Beyond 58% improvement target point:
  Most $PM_{2.5}$ measures have been exhausted and the optimiser picks SO_2, NH_3 and NOx measures.

In CONCAWE's view, these first results serve to demonstrate the importance of accounting for SLCF in the context of the current Air Policy review process as a way of properly exploiting synergies between climate change and air quality progress.

4.6. Differentiated PM toxicity

Is the assumption of ‘equal toxicity’ for all components of particulate matter precautionary from a Policy Perspective? Sensitivity Scenario Analysis Suggests not.

Addressing the health concerns from human exposure to fine particulates continues to be a priority concern in European air quality policy and a number of research projects have been completed in this area. Despite the recent review of evidence led by the World Health Organisation (WHO) in the project REVIHAAP (WHO, 2013), the WHO has not yet provided guidance on how to differentiate the impacts of the different components of the PM mix e.g. primary and secondary components.

As a consequence, currently all PM components are given ‘equal impacts potency’, under the premise that this is a precautionary assumption until the epidemiological community can provide sufficient data to support a different view.

While this continues to point to the need for more research to fill the knowledge gap, appropriately designed “uncertainty scenarios” can provide important policy input to minimise/avoid regret measures.

In all the scenario analyses carried out by the GAINS team in support of the current Air Policy review, the assumption that all components of fine particulates are equally harmful to human health has been retained. As we shall see in this section, the retention of such an assumption has profound implications for the policy outcome (e.g. a revised NECD); given that all measures to reduce PM concentrations are considered equally effective in reducing the PM impact on human health.

However, through suitably designed ‘sensitivity scenarios’ we can examine what the effect on policy might be if particles from some sources are more ‘potent’ and others less ‘potent’ in their effect on human health. To ensure the health impact of the overall PM mix is kept constant, if the potency of secondary particulates is reduced there is a compensating increase in the potency of primary particles.

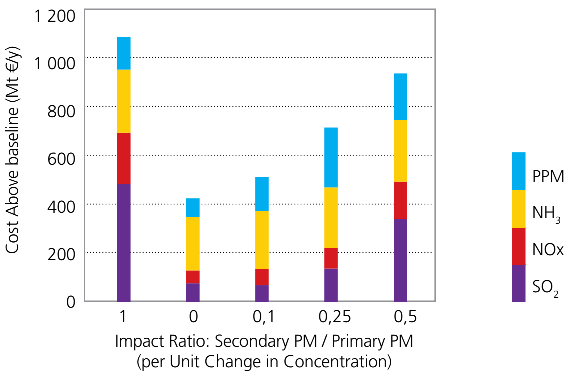
Sensitivity case- PM toxicity differentiation Primary and Secondary particles

If primary particles (derived from combustion) have more impact on human health than secondary particles, this will have implications in the control techniques selected by the integrated assessment model results because it will select emission control strategies focussed preferentially on reduction of primary particles.

- Secondary particles control: SO_2, NOx and NH_3
- Primary particle controls: particle matter (PM)

Figure 13

EU-27: Optimised Cost above Baseline (by Pollutant) to Achieve 50% Gap Closure[12] for Various Impact Ratios of Secondary/Primary PM per Unit Change in Concentration. In all cases, the overall potency of the mix is kept constant in terms of the impact on human health.



In this example, the costs of achieving a 50% PM Impact Gap Closure are shown[13]. The bars show the additional costs for the EU-27 (expressed the annualised cost in millions of euros) above the baseline cost of CLE, based on different assumptions on the relative potency of primary and secondary particulates.

- The 100% bar shows the case where all PM, both primary and secondary, are assumed to be equally potent in their effect on human health (i.e. the assumption used in the Air Policy review). Cost above the baseline near **1.1 b€/year**.
- The 0% bar shows an extreme case where all harmful particle effects are assigned to primary $PM_{2.5}$ alone. Cost above the baseline near **0.4 b€/year**.

[12] GAP CLOSURE the reduction in impacts, expressed as a percentage, of the maximum further impact reduction achievable in moving from Current Legislation scenario to Maximum Technical Feasible Reduction.

[13] To ensure consistency, the so called ‘come along’ benefits on reduced health impacts from Ozone and reduced Acidification/Eutrophication, as a consequence of achieving a 50% PM impacts Gap closure are also retained in each sensitivity case.

The overall cost of mitigation measures is markedly lower in the 0% bar. This is because the potency of primary PM in this case has been substantially increased to maintain a constant overall potency of the particulate mix, so each tonne reduction has a much greater impact reduction potential. Expenditure on measures to reduce SO_2, NOx is substantially reduced; Expenditure on NH_3 is similar as a consequence of sustaining the ‘come along’ benefits for acidification and eutrophication achieved under the ‘equal potency’ scenario. The remaining three bars in Figure 13 show the effect of re-introducing the attribution of harmful effects to secondary particles.

The impact on the cost of delivering the 50% Gap closure scenario, if differentiated toxicity is assumed (especially at the low end of secondary toxicities considered) is evident from Figure 13; costs are halved. However, ensuring the right pollutants are addressed is also it is important. Table 3 shows the corresponding emission reductions by pollutant for each of the impact ratio assumptions.

This indicates the significant implications for the National Emission Ceilings Directive if a differentiated toxicity assumption were adopted.

Table 3
Emission reductions by pollutant for each impact ratio secondary/primary particles

Emission Reduction as Percent of Baseline

Impact Ratio	SO_2	NOx	NH_3	PPM
100%	23%	6%	14%	20%
0%	7%	3%	14%	18%
10%	7%	3%	14%	20%
25%	12%	4%	14%	22%
50%	20%	5%	14%	21%

4.7. Short Lived Climate Forcers (SLCF) and PM toxicity

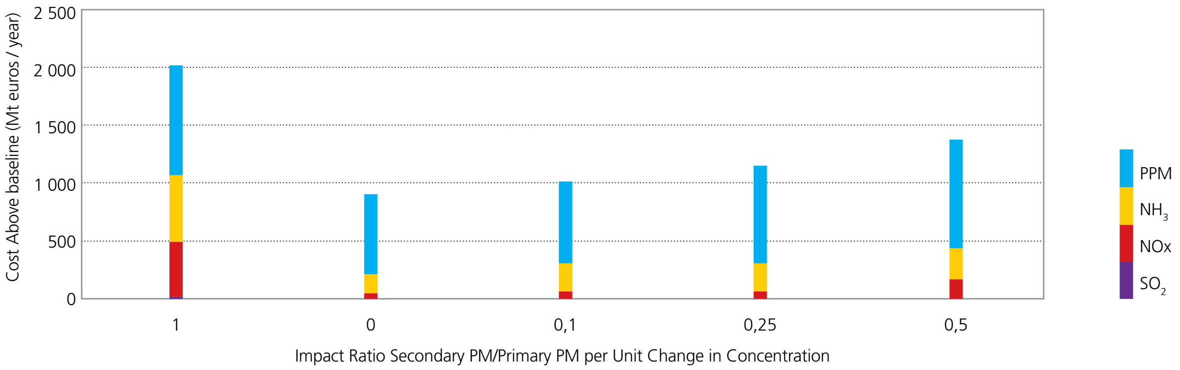
When both differentiated toxicity and SLCF are accounted for in designing an optimum policy response, even at a modest differentiated toxicity assumption, there is a profound change to the resulting package of measures and the attendant costs.

The influence on outcome of incorporating short lived climate forcers (SLCF) into the optimisation of costs for a given policy ambition was separately explored in an earlier chapter of this Review. In the scenarios depicted in Figure 13, SLCF were not incorporated in the optimisation.

To further explore the sensitivities depicted in Figure 13, further scenarios were run with SLCF inside the cost-optimisation strategy with a carbon price set at 30€/tCO_2. The results are shown in Figure 14.

Sensitivity case: Both differentiated toxicity and SLCF are accounted for in designing an optimum policy response

Figure 14
EU-27: Optimised Cost above Baseline (by Pollutant) to Achieve 50% Gap Closure[14] for Various Impact Ratios of Secondary/Primary PM per Unit Change in Concentration



Emission Reduction as Percent of Baseline

Impact Ratio	SO_2	NOx	NH_3	PPM
100%	1%	9%	19%	28%
0%	1%	2%	12%	18%
10%	0%	3%	14%	21%
25%	0%	3%	14%	25%
50%	0%	5%	14%	28%

[14] GAP CLOSURE the reduction in impacts, expressed as a percentage, of the maximum further impact reduction achievable in moving from Current Legislation scenario to Maximum Technical Feasible Reduction.

When both differentiated toxicity and SLCF are accounted for in designing an optimum policy response, even at a modest differentiated toxicity assumption, there is a profound change to the resulting package of measures and the attendant costs:

Table 4
Net costs when CO_2 compensation costs are accounted for

Impact Ratio	100%	0%	10%	25%	50%
Net cost M€	-840	-1835	-1770	-1720	-1545

The negative figures shown in Table 4 are the net costs when the CO_2 compensation costs are accounted for.

- Taking the 25% Impact ratio case in Figure 14 and comparing it to the 100% (the approach used for the Air Policy review work) case of Figure 13, starkly illustrates the extent of shift in measures/costs to deliver the policy.
- In the case of Figure 13, most money is spent on precursor emissions for secondary PM, abatement costs are some 1,100 €M/y but when CO_2 compensation costs are added, the net cost for this 50% Gap Closure essentially doubles to 2,300 €M/y.
- In contrast, Figure 14 indicates, by accounting for SLCFs and with a 25% PM impact ratio assumption, the emphasis shifts to primary PM measures, particularly those that are 'rich' in black carbon content. Given that the 'come along benefits' associated with the 'current approach' (Figure 13, 100% Impact Ratio) expenditure continues on NH_3 since this delivers Eutrophication and Acidification benefits without incurring CO_2 compensation penalties. The overall cost of abatement measures is similar but by spending on primary PM abatement and not spending on SO_2, the CO_2 'compensation' costs are negative compared to the baseline i.e. savings in CO_2 mitigation costs. Overall, this results in a saving in costs over the base case of some 1,700 €M/y compared to the 'current approach' outcome with additional costs over the baseline (including CO_2 compensation costs) of 2,300 €M/y.

Appendix 1: Uncertainties Under the Microscope

Uncertainties under the Microscope
IAM Sensitivity Scenario Analysis Can Provide a Powerful Policy Lens

A CONCAWE contribution to the AQPR

Introduction:

In the European arena a key tool that has been at the centre of air quality policy development over the past two decades has been IIASA's RAINS/GAINS Integrated Assessment Model. Both in the UN-ECE and EU context this has provided the all-important link between environmental/health impacts and cost-effective mitigation policies.

Although substantial progress has been made to make greater use of this powerful tool to explore the complete policy envelope, in CONCAWE's view more needs to be done. The purpose of this paper is to illustrate, via a number of examples, the 'policy benefits' of a thorough sensitivity analysis. Today, perhaps more than at any time in recent history, it is imperative to ensure, to the best of our abilities, that we do not unwisely expend precious economic resources in any policy arena. In the context of the current EU Air Quality Policy Review, making full use of the policy lens that GAINS provides will contribute to such a goal.

Summary of findings:

This paper was prepared as a contribution to the 4th meeting of the Stakeholder Expert Group on the EU Air Policy Review as the review enters its scenario/policy development phase. The paper is based on the results of extensive sensitivity analysis undertaken by CONCAWE using their in-house Integrated Assessment Model. This is largely based on the data IIASA developed to support their policy scenario analysis recently undertaken in the context of the revision of the Gothenburg Protocol.

The illustrative sensitivity analysis was targeted to support five contentions. Each is addressed in detail in the main section of the paper; here we provide a brief summary of the key findings:

Why the emission reductions expected of Euro VI/6 must be achieved: Policy scenarios leading to revised TSAP targets must account for uncertainties in the reductions in road transport NOx emissions associated with the introduction of Euro VI/6 standards in 2015/16. Should real-world vehicle performance result in higher than expected NOx emissions, the sensitivity analysis indicates that, at a given ambition level, this would result in significant increases in costs to the non-transport sector or even in unachievable targets. A realistic sensitivity example based on the gap closure concept as used in the CAFE 2005 program for $PM_{2.5}$ impacts, shows a factor of 3 cost increase is possible, from 7 to 20 b€/year.

Why Cost-Effective Reductions in Ammonia Emissions from Agriculture are important: Ammonia is a key pollutant; if emissions of ammonia are not reduced the scope for compensation by controls on NOx is extremely limited. It is not possible to meet ambitious acidification, eutrophication or human PM exposure targets if ammonia emissions are not reduced.

Why Multiple Time Horizons are Vital in Policy Scenarios: Policy horizon years are critical. The structural changes (e.g. changing energy use) and the on-going emission reductions resulting from already agreed legislation, have significant effects on emissions with time. This introduces the question of what is the appropriate timing for compliance with any new policy initiatives in a changing world. Investing heavily in abatement technology for the industry to achieve emissions reductions that will be reached by other means just a few years later could lead to unnecessary additional financial pressures and regret investment for industry.

Why a Range of Energy Scenario Is Important for Robust Policy: Given the uncertainties in defining the 'future world' this sensitivity analysis highlights the need for policy to be tested for a range of energy scenarios. This is vital to ensure that ambition levels (expressed as revised national emission ceilings) based on one energy scenario do not result in significant escalation in compliance costs or non-achievability in a different actual future energy world. The current difficulties in some Member States in meeting 2010 NOx ceilings illustrates the vital need to include such energy uncertainties in policy development.

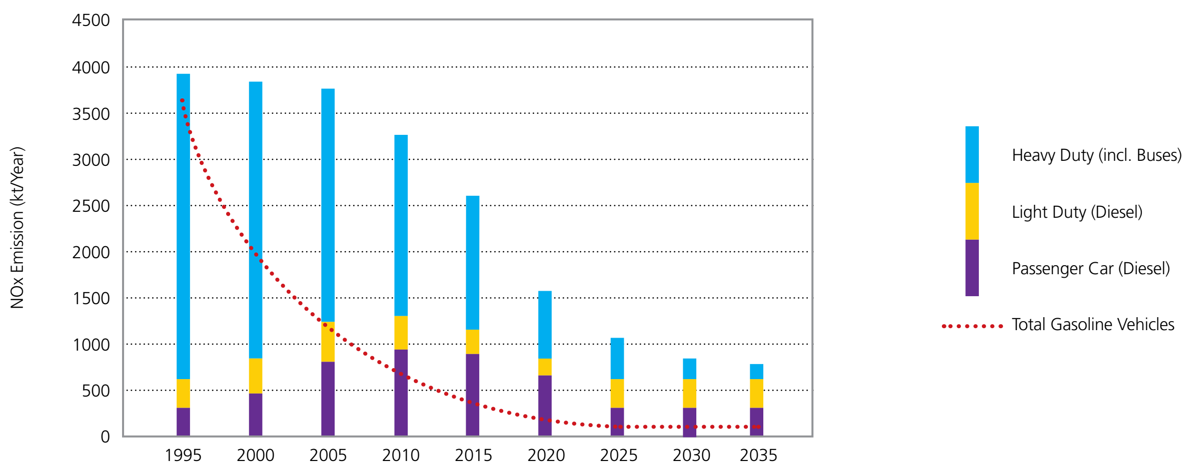
Why the influence of short Lived Climate Forcers should be more fully examined: Climate impacts of air policy need to be properly accounted for. In the context of the revision of the Gothenburg Protocol the influence of short lived climate forcers (SLCF) began to be examined in the policy process with a particular focus on Black Carbon. Other emissions such as sulphates from SO_2 and Organic Carbon are also recognized to be SLCFs. The sensitivity scenarios in this chapter demonstrate how attributing a CO_2 credit or debit to all three of these SLCF emissions (based on carbon price) and including them in the optimization strategy can give an entirely different perspective to control policies and shifts the policy emphasis away from NOx and SO_2 controls on stationary sources, even at relatively low Carbon prices and long-time horizons.

1 - Why the emission reductions expected of Euro VI/6 must be achieved:

The road transport sector remains an important contributor to overall emission levels of regulated pollutants in the EU. As such, they continue to be a priority policy target for further reductions, especially in the case of NOx. However, particularly in the case of NOx emissions derived from diesel power trains, history stands as a stark reminder of how, from Euro II/2 through to Euro V/5, real world emissions have been substantially greater than forecast from the regulated emission limits. This has led to substantial problems in achieving obligations under the current National Emission Ceiling Directive (NECD) and Ambient Air Quality Directive (AAQD) in a number of Member States.

In the context of the current Air Quality Policy Review (AQPR) process this has resulted in strong calls for Policy Makers to ensure that the planning around the Euro VI (HDV)/6 (LDV) standards is robust enough to ensure legislated limits can be met under real world driving conditions.

Figure 1
Evolution of NOx Emissions from Road Transport in EU-27: Base Case (COPERT 4)
Source: CONCAWE STEERS Model



The importance of this is illustrated by Figure 1 which shows the forecasted evolution in NOx emissions from Road Transport in EU-27 from 1995 out to 2030 and beyond. This is derived from CONCAWE's in-house road transport emissions forecasting model developed for and used extensively to support the European Auto Oil programmes. The emission algorithms (e.g., COPERT 4 emission relationships) and exogenous assumptions (e.g. fleet numbers, fleet starting vintages and turnover rates) are entirely consistent with the current version of TREMOVE used to support the transport elements of GAINS. For clarity, the trend in NOx emissions from diesel powered vehicles is shown in the stacked bars while the trend in NOx emissions of all gasoline powered vehicles is shown separately as the over-plotted red line.

What is evident from this Figure is that between 1995 and 2010 NOx emissions from diesel vehicles have not fallen at anything like the rate at which gasoline vehicle NOx has fallen. This of course is in part due to growth from the dieselisation of the light duty vehicle fleet and the general increase in vehicle kilometres driven. However, an important reason for this slower than expected reduction has been the disappointing real world performance of Euro II/2 to Euro IV/4 vehicles. Between 2010 and 2015 with the 'real world' performance for Euro V/5 already reflected in COPERT 4, this trend is not significantly changed. In contrast, by 2030 LDV diesel NOx is forecast to halve and HDV NOx reduce by eightfold from the introduction of Euro 6/VI in 2015/16 when replacement of the pre 2015/16 fleet is complete. Given past experience how can we be sure Euro VI measures will deliver such significant improvements and what are the implications of under delivery?

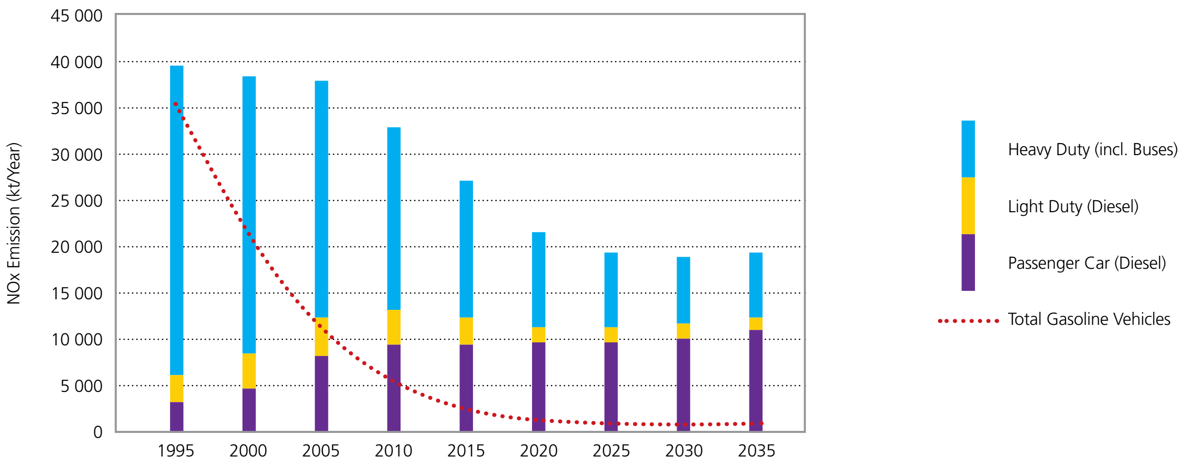
The purpose of this article is to illustrate the critical dependence of overall policy on the forecast transport NOx emissions. To undertake this we compare two emissions forecasts: one based on all vehicles achieving emissions as estimated with COPERT 4 and the other assuming higher fleet integrated emissions from the Euro VI/6 diesel fleet component. In so doing, this article does not attempt to go into any detailed considerations of how "future world" emissions from Euro 6/VI will look, especially considering the huge effort being devoted to ensuring that today's "real world" is reflected in the type approval process.

A key advantage of Euro VI/6 diesel power trains is that the standards are premised on the application of Selective Catalytic Reduction (SCR) technology which incorporates the injection of an ammonia reagent[26] to enable SCR on lean burn engines. This NOx after treatment system removes a constraint on the NOx level at the outlet of the engine, and hence allows simultaneous optimisation of engine fuel consumption through a higher thermal efficiency. The application of SCR with its NOx reduction potential (in excess of 90% for HDV and up to 75% for LDV) is thus foreseen to facilitate the simultaneous delivery of higher fuel efficiency with very low exhaust NOx. Coupled with the use of particulate filters this will also reduce dramatically primary PM from road transport.

Design of sensitivity scenarios: If sensitivity scenarios are to provide insights into the influence of uncertainties on the robustness of policies they of course must have a clear basis for their design. With this in mind the following sensitivity scenarios were constructed:

- **For Euro VI:** We have taken a sensitivity case where the fleet averaged Euro VI real world NOx emission/km would be half the emissions achievable using the Euro V emission factors in COPERT
- **For Euro 6:** We have taken a sensitivity case where the fleet averaged Euro 6 real world NOx emissions would be at the same level as the Euro 5 emissions represented in COPERT.

Figure 2
Evolution of NOx Emissions from Road Transport in EU-27: Sensitivity Case.
Source: CONCAWE STEERS Model



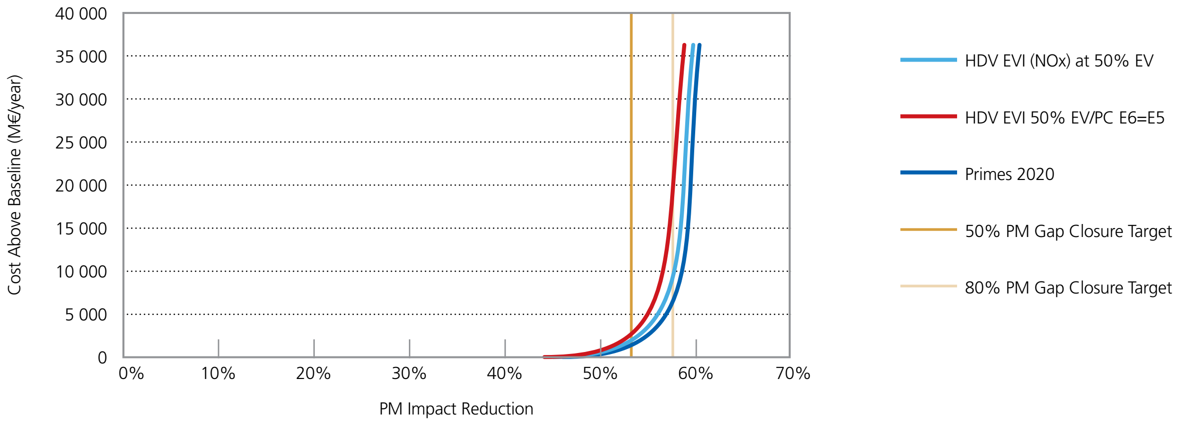
Policy Implications (e.g. Revised NECD) for higher than expected emissions from Euro VI/6 vehicles:
Figure 2 above shows the implications of the Euro VI/6 sensitivity scenario discussed above on the evolution of NOx emissions from road transport in the EU. In the 2025-2030 world of 'full penetration' of Euro VI/6, NOx emissions double over the base case, i.e. increase by some 1Mt/y.

What does this imply for NOx ceilings that are set based on the assumption that the Euro VI/6 measure does deliver forecast emission reductions?

To illustrate the policy implications, multiple optimisation scenarios were carried out using CONCAWE's in-house Integrated Assessment Model (IAM) which utilises identical source-receptor functions, cost functions and impact algorithms to those used in GAINS to support IIASA's recent work for the revision of the Gothenburg Protocol. The 'optimisation driver' was confined to PM health impacts to simplify the analysis and aid transparency. Transport emissions lie outside the optimisation as they are determined by the forecast fleet development, mileage driven and technical abatement measures in place. i.e. they are input data. The resulting optimised costs are for the additional stationary source abatement measures needed to achieve further PM impact reductions. The results are shown in Figure 3 below Note that PM impact is related to the concentrations of total $PM_{2.5}$ in the air and this comprises both directly emitted particles and secondary particles ($PM_{2.5}$ formed in the air by chemical reaction). NOx and NH_3 which we examine in the ammonia study below, contribute to secondary $PM_{2.5}$.

[26] Currently foreseen to be Urea

Figure 3
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus PM Impact Reduction
Source: Concawe IAM



Three baseline starting points were examined, all derived from the PRIMES 2009 energy scenario used as the central scenario for the revision of the GP. For the 'Base Case' the actual baseline PRIMES 2009 was used. This is shown as the dark blue line on Figure 3 and is consistent with optimised delivery of a given EU-27 PM reduction target in 2020 assuming the Euro VI/6 emissions calculated with COPERT 4. The light blue line shows the results recalculated assuming Euro VI only delivers a 50% improvement over Euro V. In this case the baseline NOx emissions were adjusted in each Member State (MS) to account for the greater transport NOx emissions before the optimisation scenarios were run. Finally, the red line shows the results assuming a future Euro VI delivers a 50% improvement over Euro V and Euro 6 is the same as Euro 5. Again, for this case, baseline NOx emissions were adjusted in each MS to account for the 'under-delivery' of Euro VI/6 before the optimisation scenarios were run.

During the Clean Air for Europe Programme, the concept of further "impact gap closure" was adopted as an indicator of policy ambition level. The '100% impact Gap Closure' being defined as the additional reduction in impacts (beyond the baseline) by implementing Maximum Technically Feasible Measures. Thus a zero gap closure is equivalent to the Baseline and a 100% gap closure is equivalent to MTFR.

The vertical lines on Figure 3 indicate the 50% and 80% PM Impacts Gap Closure points. At 50% GC, the implications for further investments in stationary sources (including ammonia abatement measures in agriculture) to make up for the greater than expected NOx emissions from road transport, should Euro VI/6 under-deliver, are already clearly significant. For the worst case considered in the sensitivity scenarios, Figure 3 shows annual costs doubling from some 1.5 b€/y to 3b€/y.

At the higher PM GC target of 80%, costs escalate since here policy would be hitting the steep part of the cost curve. In this case annual costs rise from some 7b€/y to almost 20b€/y. It is also important to note here that at the higher ambition targets, in some Member States, the resulting NOx ceilings based on the assumption that Euro VI/6 will deliver, may become unachievable even at MTFR in case of under-delivery of Euro VI/6. Such situations have already been experienced in the case of the current NECD.

What then might be a wise way forward in a policy context? Clearly this work first serves to illustrate the importance of making every 'policy effort' to ensure the next round of Euro NOx standards deliver real world emissions consistent with these standards.

But this alone is surely not enough. It is wise to explore the reductions that would be required from other sectors to compensate for a lower than expected delivery of Euro VI/6. Particularly in a context where the economies of the EU will increasingly struggle to compete in the global market place, these potential unintended consequences should be well understood. Certainly, the implications of such uncertainties (via sensitivity scenarios around the central policy case) need to be explored throughout the policy process, but especially in the final stages including their documentation in the formal 'impact assessment'.

2 - Why Cost-Effective Reductions in Ammonia Emissions from Agriculture are Important:

The Clean Air For Europe (CAFE) programme which underpinned the current Thematic Strategy on Air Pollution clearly identified the reduction in ammonia emissions from agricultural sector as an important component of cost-effective policy designed to deliver improved air quality in Europe. Through earlier policy initiatives such as the NECD and Gothenburg Protocol, the need for agriculture to be part of the solution to Eutrophication and Acidification was already well established. What was new and important in CAFE was the understanding that reductions in ammonia emissions from agriculture were central to cost-effective reductions in human exposure to fine particulates. What follows illustrates why this remains an understanding for the current AQPR and any policy initiatives resulting from this review process.

Figure 4
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus PM Impact Reduction
Source: CONCAWE IAM

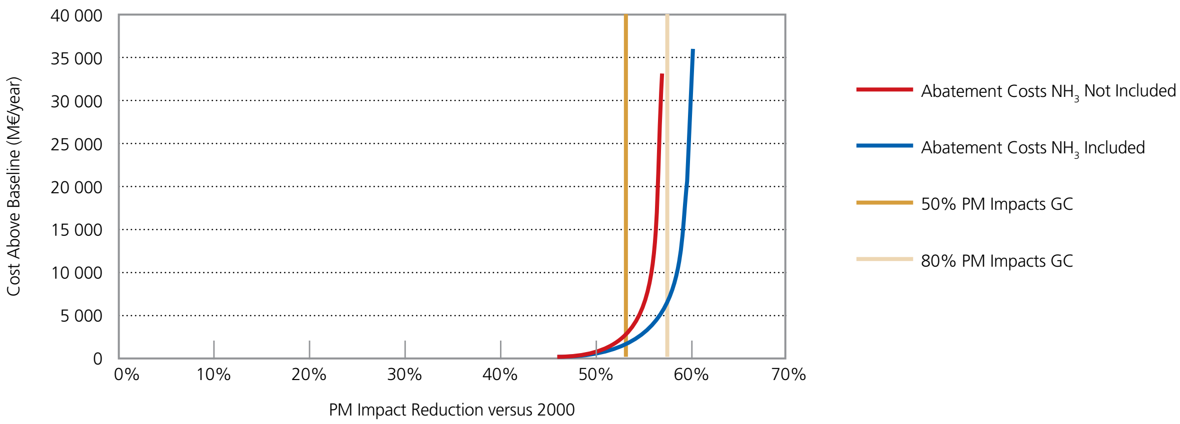


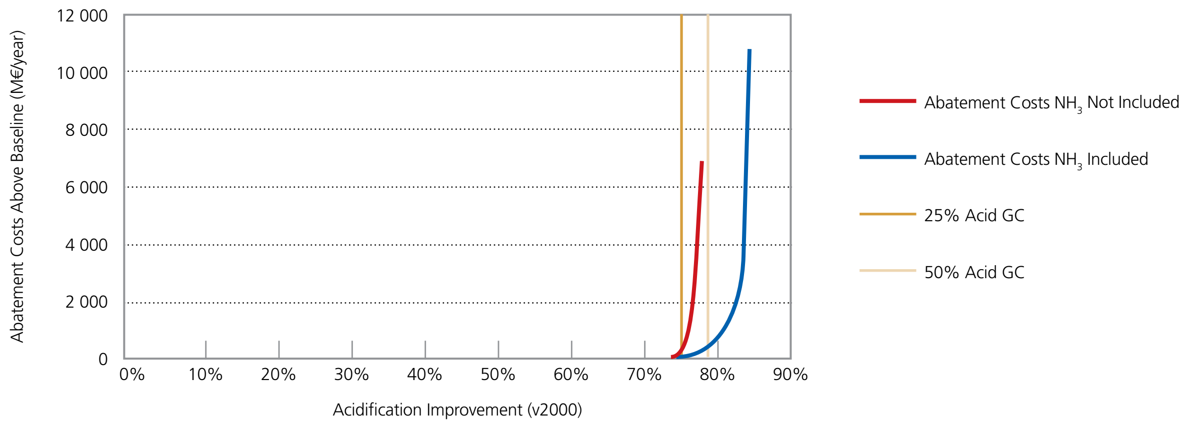
Figure 4 shows the results of integrated assessment modelling aimed at identifying the least-cost measures to deliver further improvements (beyond the Baseline) in PM health impacts in the EU in 2020. As in the work exploring the policy implications of under-delivery of Euro VI/6, this is based on the PRIMES 2009 energy scenario and associated baseline emissions that formed the central scenario for the recently completed revision of the Gothenburg Protocol.

The blue curve shows the optimised (least-cost) curve of cost versus reduction in long term health impacts of PM in the EU assuming all further abatement measures identified within the GAINS model (version used to support the GP revision work) are available for selection, including ammonia abatement measures. The red curve shows the equivalent curve but in this sensitivity case, assuming no further ammonia abatement measures are available to contribute to the cost-effective delivery of a given PM impact reduction target. In other words, ammonia emissions remain at 2020 Baseline levels.

The important, even essential contribution of reductions in ammonia in achieving optimised delivery of a given PM target is clearly evident in Figure 4. Without ammonia abatement measures, costs at the 50% PM impacts gap closure (GC) point essentially double from, some 1.5 b€/y to 3 b€/y. At the 80% GC point, this difference dramatically widens from some 7 b€/y to the MTFR point for all the 'beyond baseline' abatement for stationary sources of Primary $PM_{2.5}$, NOx and SO_2 at a cost of some 32 b€/y.

From a policy point of view, it is also worth noting that at the spend level of 7b€/y, the best achievable gap closure should ammonia emissions remain at the 2020 Baseline, is 60%. Without limit on the spend level, the best achievable gap closure, as implied above, would be 80% at MTFR.

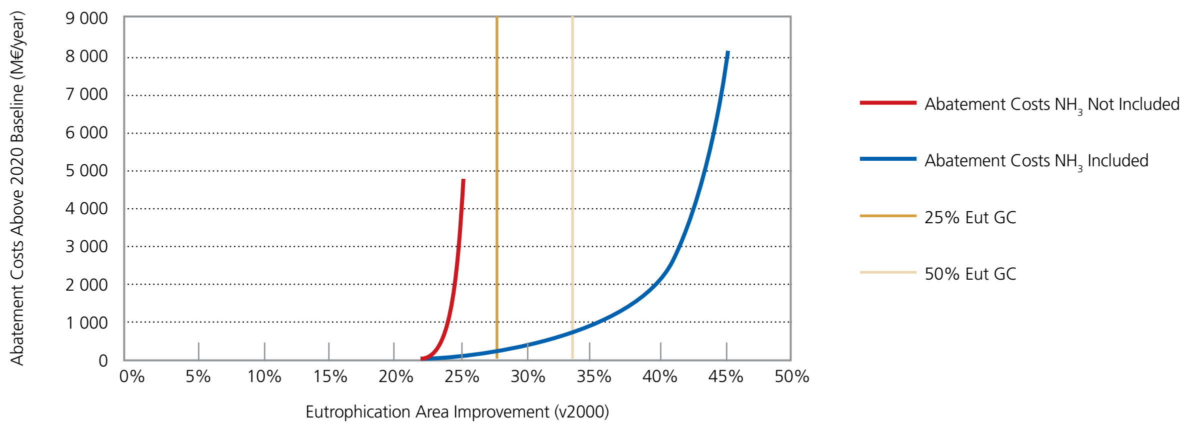
Figure 5
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus Reduction in the Area of Forest Ecosystems Exceeding Acid Critical Loads. Source: CONCAWE IAM



As already noted, ammonia reductions have long been recognised as the priority for achieving cost-effective further reductions in the areas of ecosystems exceeding acidification or eutrophication critical loads. The two curves showing the optimised cost of further abatement measure versus reduction in the ecosystem areas exceeding their critical loads in Figures 5 (acidification) and 6 (eutrophication) clearly show this.

In the case of further progress in reducing acidification (Figure 5), the maximum further improvement is severely limited if measures are confined to SO_2 and NOx. In the case of Eutrophication (Figure 6), no significant progress can be achieved without a focus on ammonia.

Figure 6
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture) Above the 2020 Baseline Versus Reduction in the Area of Ecosystems Exceeding Eutrophication Critical Loads Source: CONCAWE IAM



To highlight the significant challenge to the policy process of ensuring the required reductions of ammonia emissions from the agricultural sector are realised, it is worth noting, in the context of the Gothenburg Protocol that ammonia emissions in the 2020 Baseline are predicted to fall by less than 2% between now and 2020. Although a new agricultural baseline scenario is under preparation, the optimisation undertaken in this 'GP PRIMES 2009' scenario, foresees the cost-effective contribution to the 50% PM GC target to result in a 17% reduction from 'today's' level and a 29% reduction in the case of an 80% PM GC target. A challenge indeed!

3 - Why Multiple Time Horizons are Vital in Policy Scenarios:

In the policy context of a revision of the TSAP with horizon years out to and possibly beyond 2030, the need to consider the on-going influence of already agreed policies (for example changes induced by structural change driven by climate policy, turnover of the vehicle fleet) is vital. This requires a focus on several policy horizon years. What follows is designed to illustrate the economic importance of such a focus and is based on recent GAINS cost curve data for 2020, 2025 and 2030.

Figure 7
National NOx Cost Curves for Three Policy Horizon Years for One Example Member State
Source: IIASA for 2012 TSAP

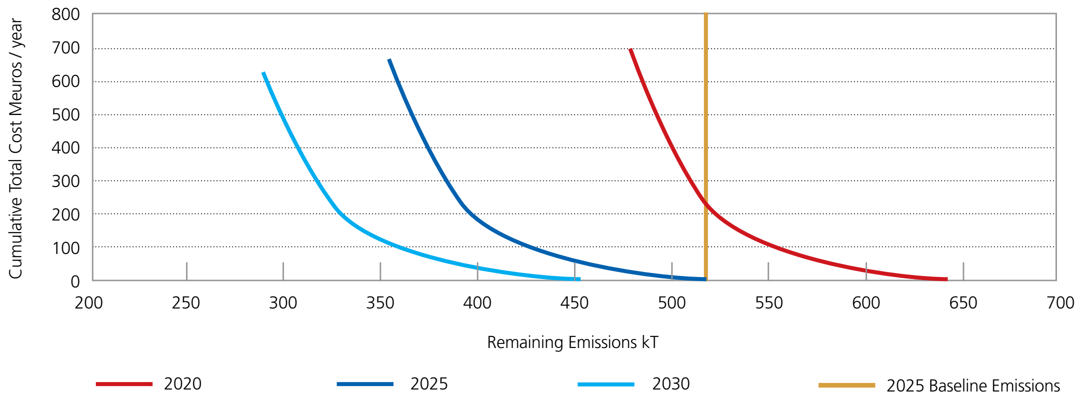
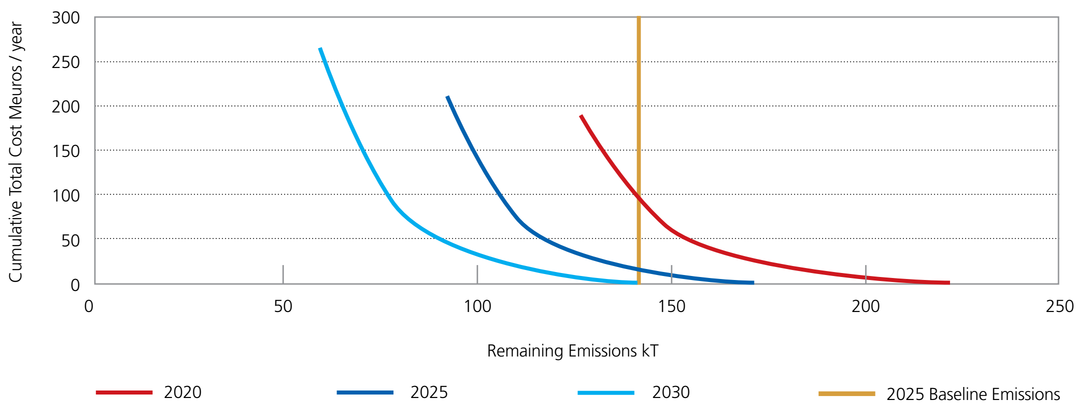


Figure 7 compare national cost curves for further abatement measures on NOx in one example Member State of the EU for three policy horizon years: 2020, 2025 and 2030. These are based on IIASA GAINS data developed for their current work on the revision of the TSAP. In each case, the continuing effects of base case changes in emissions are clearly seen. This has significant implications for the cost of achieving further impact reductions as a function of time.

If, for example, GAINS indicated that the revised TSAP targets required this Member State to reduce its baseline NOx emission to 515kt/y this MS would be faced with an additional cost burden for NOx reducing measures of some 250 M€/y if the targets were required to be met in 2020. However, should the time horizon for achieving the target be moved out by five years to 2025, baseline measures would deliver the ceiling without further burden to that MS.

This continuing influence of already agreed policies on emissions versus time is not confined to NOx as indicated by the corresponding cost curves for SO_2 in the same example MS given in Figure 8.

Figure 8
National SO_2 Cost Curves for Three Policy Horizon Years for One Example Member State
Source: IIASA for 2012 TSAP



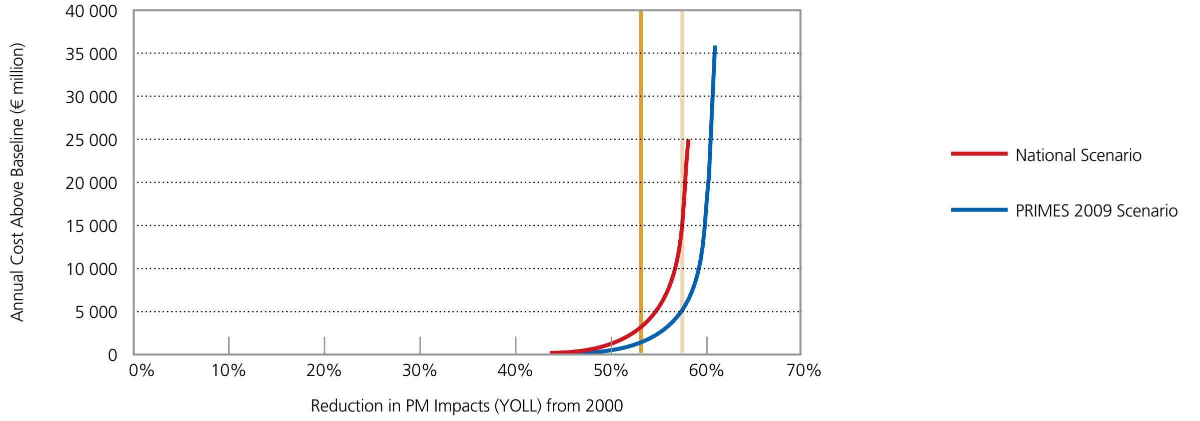
Of course in looking at future policies designed to make further progress in air quality in the EU it is also important to recognise the on-going costs of already agreed measures which are delivering these continued reduction in baseline emissions (with their associated further improvements in air quality) with time. For this example MS for NOx alone, GAINS indicates the cost of already mandated measures in 2010 to be some 2.8 b€/y, rising to 5.3 b€/y in 2020 and reaching 6.7 b€/y by 2030.

4 - Why a Range of Energy Scenarios Is Important for Robust Policy:

The need for consistency/coherency in the central assumptions used in the development of interrelated policy initiatives (e.g. Air Quality and Climate Change) is well recognised. However, this should not be interpreted as a need to base policy on a single view of the 'future world' that the policy is designed to influence. History serves as a constant reminder that actual developments can be quite different from the projections made a few years earlier. Sensitivity scenarios around a central view to test the robustness of future business plans are essential to the business world. In CONCAWE's view such sensitivity analysis is also essential in the policy arena.

In this regard, along with a number of other stakeholders, CONCAWE has requested that a range of energy scenarios, around the central PRIMES scenario, should be used in appropriate sensitivity scenarios to test policy options. In this short section, the databases used for the revision of the Gothenburg Protocol have been used to support this call.

Figure 9
Annual Abatement EU-27 Costs For Stationary Sources (Including Agriculture)
Above the 2020 Baseline Versus PM Impact Reduction: Comparison of PRIMES and 'National' Energy Scenarios Source: Concawe IAM



Although only twelve Member States submitted their alternative national energy scenarios, the consequence of moving from a PRIMES based world to this alternative 'National Energy Scenario' world is already significant. Figure 9, shows the optimised curves of cost beyond the baseline versus further reductions in PM impacts for each energy scenario. The two vertical lines indicate a medium (yellow) and high (red) improvement target. The implications of arriving in the 'National energy future world' having designed policy with a sole focus on the PRIMES world are obvious: costs, justified only for the PRIMES world, double at the medium ambition level and triple to close to MTFR costs at the high ambition. In the latter case, at an individual Member State level some individual pollutant ceilings set solely based on PRIMES would likely at this ambition be unachievable. Given the binding nature of the NECD, this would force Member States to consider measures that would otherwise not be justifiable and could have undesirable economic consequences. Such a situation would be avoided with the inclusion of suitable sensitivity analysis at the policy development phase.

5 - Why the influence of short Lived Climate Forcers should be more fully examined:

One key recent development in the context of the revision of the Gothenburg Protocol was the inclusion of considerations over the influence of short lived climate forcers (SLCF) in the policy process with a particular focus on Black Carbon. As a consequence, the GAINS team have begun to incorporate such considerations in a quantitative way into GAINS.

What this work by IIASA has provided is a helpful bringing together of quantified data on the direct greenhouse warming potential (GWP) of all the key SLCFs and was first presented by IIASA in Dublin in May 2010[27]. The following data for GWPs have been abstracted from this presentation:

Table 1
Global Warming Potentials relative to CO_2 (GWP CO_2=1)

	20 year GWP	100 year GWP
SO_2	-140	-40
Black Carbon	2200	680
Organic Carbon	-240	-75

The availability of these relative GWPs allow the "CO_2 compensation costs" implied for a unit reduction in each of the three SLCF to be computed for a given carbon price. The carbon compensation cost here is the cost involved in sustaining 'no change' in Baseline GWP by introducing compensating measures. In the case of SO_2, since this is a climate cooler, at a carbon price of 30€/tCO_2, this would imply carbon compensation costs of 4200 € for every tonne of SO_2 emissions reduced (assuming a 20 year integration period) and 1200 €/tSO_2 over a 100 year integration period. In other words, removing the beneficial climate cooling effect of sulphates derived from SO_2 emissions has to be compensated by additional climate mitigation measures. Conversely, in the case of black carbon (a powerful warmer), for the same carbon price the compensation cost would be -66,000 €/tBC and -20,400€/tBC over the two integration periods. In other words, reductions in emissions of this powerful climate warmer result in savings in the climate mitigation costs of the baseline.

The availability of these CO_2 compensation costs provides a means of more fully expressing the implications of air quality policies that results in further reductions in these pollutants. For example in the case of measures PM abatement measures, the reduction in CO_2 abatement costs implied by attendant reduction in the black carbon fraction of PM can be quantified. Similarly, for SO_2, the implied additional CO_2 compensation cost for removing this 'climate cooler' can be quantified.

By building these 'CO_2 compensation' costs in the form of adjustment algorithms to the basic cost curves derived from GAINS, these costs can then be accounted for in the optimisation strategy to derive a more complete 'least cost' set of measures that delivers the air quality objective accounting for the CO_2 compensation costs. Based on detailed data kindly made available by the GAINS team in the context of the GP revision process, CONCAWE have recently built this capability into their in-house IAM. What follows are some first results which indicate the importance of taking the full implications of SLCF into account in developing future policy. Importantly, the work clearly indicates that the inclusion of the considerations into the optimisation strategy significantly shifts the policy emphasis away from further controls for SO_2 and NOx on stationary sources, even at relatively low carbon prices and long-time horizons.

Figure 10 shows the additional cost of stationary source measures (beyond 2020 baseline) for a number of PM impact reduction targets. The costs are shown for each pollutant. Here the optimisation strategy did not include the CO_2 compensation cost for SO_2 and the Organic Carbon (OC) content of $PM_{2.5}$ emissions. Nor did it include the savings in CO_2 mitigation cost in the baseline derived from any reductions in Black Carbon (BC) emissions. Figure 11 shows a repeat of the same analysis, but in this case the SLCF compensation costs were included in the optimisation strategy[28]. In both figures the net costs (abatement costs plus CO_2 compensation costs) are shown as the grey area. As in earlier sections, this analysis has been based on the PRIMES 2009 GAINS data set used for the central policy analysis for the recent revision of the Gothenburg Protocol.

[27] First presented by Markus Amann at the 38th session of the UN-ECE TFIAM meeting in Dublin, May 17-19, 2010

[28] With a 2050 target date for Climate Stabilisation in view and a 2020 policy horizon for delivering the PM impact reduction target, an integration period of 30 years was used for the relative GWPs of SLCFs compared to CO2. These were determined by linear interpolation of the data in Table 1.

Figure 10
Annual Abatement Costs for EU-27 by Pollutant For Stationary Sources (Including Agriculture) Above the 2020 Baseline versus PM Impact Reduction Including Carbon Compensation Cost for SLCFs Case 1: 30 €/tCO_2 and SLCFs Compensation Costs not in Optimisation Source: Concawe IAM

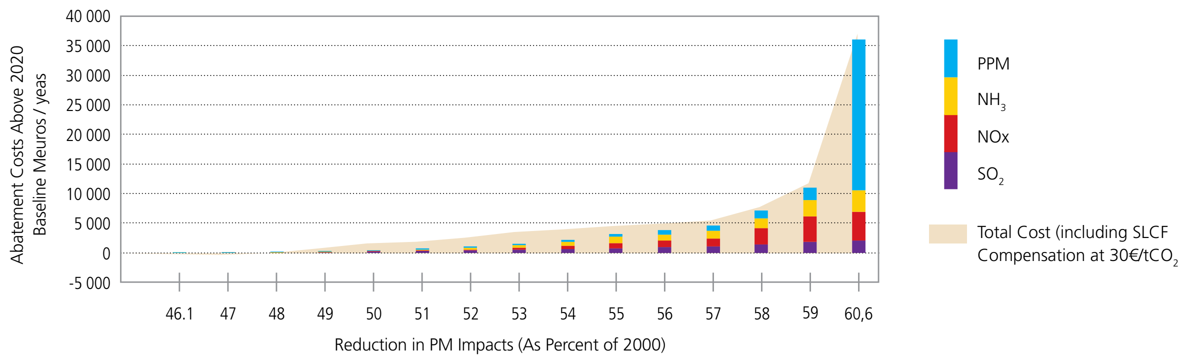
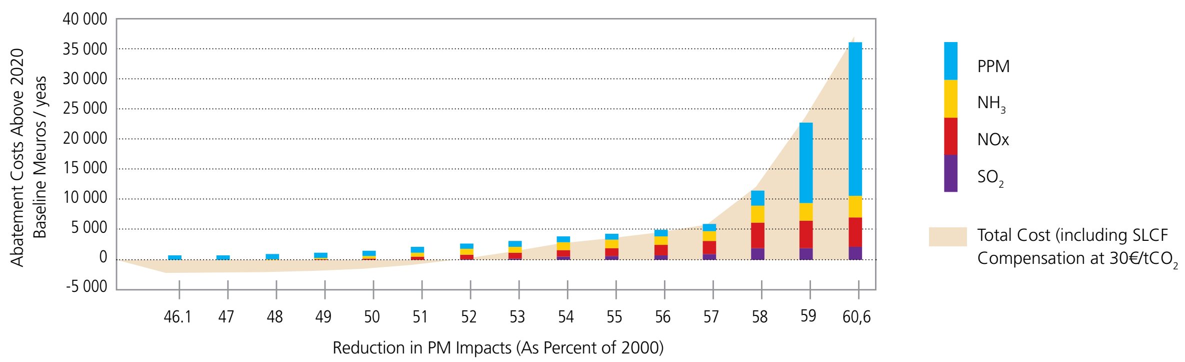


Figure 10 shows how the optimiser, at least up to the 54% improvement target, picks abatement measures on SO_2, NH_3 and NOx rather than primary $PM_{2.5}$ reducing measures. As may be seen, this results in a significant additional cost of measures to compensate for reductions in SLCF (here mainly SO_2).

At the 54% point, the cost of further abatement measures would be some 1.5b€/y. To this needs to be added the implied CO_2 compensation cost, which, assuming a carbon price 30€/t CO_2, would be some 2.1b€/y. Thus the net cost, as shown on Figure 10, would be 3.6b€/y. At and beyond the more ambitious improvement target of 58%, most SO_2 measures have been exhausted and the optimiser picks Primary $PM_{2.5}$ measures. Since these emissions include a black carbon component, their reduction results in savings in the cost of climate mitigation measures included in the baseline, and the difference between abatement cost and net overall costs reduces.

An important policy perspective emerges when SLCF compensation costs are included in the optimisation. The results are shown in Figure 11. What is immediately clear in Figure 11 (compared to Figure 10) is that optimiser first targets primary $PM_{2.5}$ abatement measures with a high fraction of BC component. This is not surprising based on the relative GWP for BC given in Table 1. Using the 20 year integration period value of 2200, a carbon price of 30€/tCO_2 and a BC content of $PM_{2.5}$ of 50% yields a compensation cost of -33,000/t$PM_{2.5}$. If the cost of $PM_{2.5}$ abatement in such a case was 15,000€/t$PM_{2.5}$ the net cost for the measure would be a cost saving of 18,000 €/t$PM_{2.5}$ and that measure would be picked by the optimiser as a 'first pick'. This is why, at the lower end of the improvement target range in Figure 11, net costs are negative.

Figure 11
Annual Abatement Costs for EU-27 by Pollutant For Stationary Sources (Including Agriculture) Above the 2020 Baseline versus PM Impact Reduction Including Carbon Compensation Cost for SLCFs Case 2: 30 €/tCO_2 and SLCFs With Compensation Costs in Optimisation Strategy. Source: Concawe IAM



Importantly, while net costs remain negative up to the 53% improvement target, abatement costs themselves are clearly higher than those shown in Figure 10. In other words, as well as moving away from measures controlling secondary sources of $PM_{2.5}$, the overall abatement burden on some sectors would increase.

Finally, the shift to focussing on black carbon rich PM abatement measures is consistent with the emerging evidence, at least from toxicological studies, that the black carbon fraction of PM is likely to be a more potent actor than the secondary component in impacting human health.

In CONCAWE's view, these first results serve to demonstrate the importance of accounting for SLCF in the context of the current Air Policy review process.