Opportunities for cost-effectiveness in atmospheric policies in the European Union

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Air pollution and climate change share the Earth atmosphere to exert their unwanted impacts on our planet and its inhabitants. In order to understand their mechanisms much scientific knowledge is being shared and it is known that the dominating causal sources for both are the same. While these and other common factors would suppose an integrated approach institutional barriers have, apart from a few exceptions, prevented this at all political levels. In this article we summarise EFCA's activities during the last five years aimed at connecting the two problems at the policy level in the European Union. With respect to climate change this was done against the background of political recognition that decarbonising the energy systems, in combination with resource efficiency will be inevitable towards controlling serious climate effects, but bears a risk to create new air quality problems. With respect to air quality the situation was that regulations for particulate matter were inadequate, because of insufficient health protection and because effective implementation was difficult. EFCA observed that EU legislation in the air quality domain missed any reference to climate objectives and proposed several options to improve this. Based on assessments of scientific developments EFCA subsequently selected the short-lived climate pollutant Black Carbon as example for policymakers to address the problems of air pollution and climate change in an integrated and source-related way. In this article, we also point to the connection between the formation of the toxic PM fraction of Secondary Organic Aerosols and that of the short-lived climate pollutant Ozone as another example with potential for increased cost-effectiveness of legislation in the EU and elsewhere.

Keywords: One atmosphere, Black Carbon, ozone, SOA, SLCPs, particulate matter, atmospheric co-benefits, EU-legislation, EFCA, cost-effectiveness, AAQD, NECD.

1. Introduction

The European Federation of Clean Air and Environmental Protection Associations (EFCA) was founded by European associations in the 90-ies in reaction to the decision to harmonise environmental policies in Europe. EFCA stimulates scientific and professional activity in Europe and, during the last ten years, developed a strategy with priority topics, in line with its mission to connect science and policy (EFCA 2012a). In this paper we report on two interrelated priority topics on which we advised the European Commission:

- "One atmosphere": the need for integrated policies on clean air and climate
- "Particulate matter": the deficiencies in the PM-regulation

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2. EFCA's approach

With 15 Member associations in Europe EFCA is in a position to sponsor a continuous programme of conferences and conference series on atmospheric topics and have specific topics selected. Apart from proceedings also conference reports for policymakers are published. When conferences generate new insights which seem relevant for policy EFCA may take a *Policy Initiative* in which progress is reviewed, deficiencies in European policies are identified and recommendations for improvement are given. Through Forum discussions at its website possible remaining questions may be addressed in order to improve the quality of the advice before it is sent to the European Commission.

3. One atmosphere

The Earth has only one atmosphere which provides an impressive number of eco-services, functions essential for life. However, our atmosphere is facing two causally related problems with high impacts for men and ecosystems: air pollution and climate change.

In 2008 EFCA's French Member APPA, in cooperation with IUAPPA, organised a first conference on addressing the need for integrated policies (APPA 2008). Its conclusions were subsequently tested at a workshop on 'Intermediate policies for climate and clean air', organised at the initiative of the Swedish presidency of the EU in 2009; these formed the basis of a Policy Initiative (EFCA 2010).

An integrated policy approach may generate co-benefits and also help to avoid trade-offs which result from present separate policies and increase overall cost-effectiveness of policies. EFCA's assessment of then existing EU legislation revealed that the Climate and Energy package of 2008 (EU 2008a) generates considerable reductions of the emissions of major air pollutants. Also in vehicle regulations it is attempted to balance limit values for exhaust emissions with fuel-efficiency requirements.

In 2010 the existing legislation which is relevant for air quality, however, did not refer to the climate problem. The *Environmental Impact Assessment Directive* had ample scope to include energy-efficiency as a requirement for consideration in new activities. In the recent revision (EU 2011) energy-efficiency is referred to, though not as a requirement. In the *Industrial Emissions Directive* (EU 2010) energy-efficiency is not either a criterion. Here the Bref's, reference documents on Best Available Technology, provide an easy way to achieve co-benefits by selecting technologies requiring least energy as benchmark. It is uncertain whether this road will be taken. The present *National Emissions Ceilings Directive* (EU 2004) and the *Ambient Air Quality Directive* (EU 2008b) do not refer to the challenge to consider climate objectives; proposals for their revision, announced for this year, are being awaited.

4. Particulate matter

With respect to air pollution, particulate matter is presently regulated by the metrics PM_{10} and $PM_{2.5}$, in Europe and elsewhere. The legitimation for this is their correlation with a number of short term and long term health endpoints as recently confirmed by WHO Europe (WHO 2013). Such 'container metrics' ignore the complexity of the atmospheric mixture of particulate matter which varies with respect to source, size, shape, colour, chemical composition, atmospheric behaviour, interaction with gaseous pollutants and are inadequate, therefore, to reduce impacts on health, environment, climate and weather. This means that the implementation of PM_{10}/$PM_{2.5}$ regulation will not necessarily result in measures with maximal health protection.

5. EFCA Policy Initiative on metrics

In 2007 EFCA's German Member GUS, in cooperation with the Karlsruhe Institute of Technology and EFCA, started a bi-annual series of symposia on ultrafine particles. At UFP-3 in 2011 a group of scientists proposed Black Carbon Particles (BCP) as additional metric to improve health protection, next to PM_{10}/$PM_{2.5}$. It had already been recognised as a valuable instrument for air quality management at local scale (UNECE 2012) and a scientific assessment in support of the proposal was published in 2012 by WHO (WHO 2012). Because questions on other aspects remained EFCA organised a Forum discussion at its website (2011/2012) at which the alternative metric of particle numbers (PN) was well addressed. The outcome was the basis for an EFCA Policy Initiative in 2012 in which the position of present and possible metrics was assessed with respect to their usefulness in air quality policy and in climate policy, and in which EFCA concluded to support the proposal of BCP as additional metric as explained in the next paragraph (EFCA 2012b).

6. Assessment of metrics

In the political discussion cost/benefits analysis of policy options plays an important role. Integrated assessment modelling, primarily a combination of an air quality model with an economic module, is the basis for such analysis; in Europe IIASA's GAINS model is being used to assess present health risks in monetised terms and to compare benefits of reduced excess mortality with the costs of the required policy measures. Reliable modelling, however, requires the availability of input data of sufficient quality.

In table 1 the availability of input data for three metrics, $PM_{2.5}$, BCP and PN is compared; these include:

- Dose-response relations from epidemiological studies, in particular for long term excess mortality
- EU-wide emission inventory
- Validated model: emissions vs. monitoring data

To these we added two additional criteria because of their relevance upon implementation of regulation: source specificity and co-benefits with climate objectives.

Table 1. Comparison of the infrastructure for integrated assessment estimates for three metrics of particulate matter

	PM2.5	BCP	PN
Dose-effect relation (short term effects)	+	+	+/-
Dose-effect relation (long term effects)	+	+/-	-
Emission inventory	+	+/-	(+/-)
Monitoring data (network-based)	+	+/-	-
Source specificity	-	+	-
Co-benefits with climate objectives	?	+[1)]	?

+ available/positive; +/- incomplete; (+/-) scarce data only; - data absent/negative

[1)] BC is one of the Short-Lived Climate Pollutants [SLCPs; other are Ozone and Methane (UNEP/WMO 2012)]; BC is the second largest climate forcer and held responsible for 0.5-1.1°C warming in NH (Bond 2013); contrary to long-lived climate forcers (CO_2, F-gases), emission reductions of BC have an immediate negative effect on global warming

Not surprisingly, the basic modelling database is complete for $PM_{2.5}$, in contrast with those for BCP and PN. When comparing the latter two, however, the situation is much better for BCP than for PN because completing the emission inventory and further roll-out of operational monitoring capacity for BCP in Europe seems feasible within a few years. For PN our estimate is that this could take 5 to 10 years.

For neither of the metrics a dose-effect relation for long-term health effects (excess mortality) is available. For BCP the outcome of studies is inconclusive; for PN such studies have not been reported yet.

Short-term effects have been reported for both metrics and provide conclusive evidence for BCP with higher RR values than those for $PM_{2.5}$ (WHO, 2012); for PN there are strong indications for a correlation (Peters 2009).

The differences with respect to infrastructure for assessment modelling plead for BCP as additional metric when compared with PN. Its source-specificity and its potential for creating co-benefits with climate objectives would enable Member States and local authorities to select more cost-effective measures to reach compliance with air quality requirements while contributing to climate targets and makes it the preferred additional metric.

7. EU Vehicles Regulations

The preference for BCP may seem at odds with the existing regulation for emissions limit values for PN in the type approval phase of new vehicles (EU 2007; EU 2009). The risk for inconsistencies is small, however, because combustion-generated nanoparticles are likely to be black for a major part. Nevertheless, it is presently impossible to make an estimate of the impact of the regulation on excess mortality, other health end-points or its co-benefits for climate objectives. Establishing robust relations between BC- and PN-emissions for specific sources could diminish this knowledge gap.

8. Black Carbon and Organic Carbon

Black carbon is a major fraction of $PM_{2.5}$ which has a robust correlation with short and long term health effects. It seems logical, therefore, that reducing emissions of black carbon will also reduce health effects, including excess mortality. However, reducing all black carbon emissions to zero is no guarantee for elimination of all PM health effects, because also other fractions of PM may be responsible for these.

One of these is the fraction of organic carbon (OC) which is co-emitted from combustion processes in engines, heating and cooking devices, incinerators and open fires due to incomplete combustion of the fuels. The OC-fraction contains the semi-volatile polycyclic aromatics (PCA). Part of these may be emitted adsorbed on particles; elevated temperatures at combustion conditions cause that a substantial amount is emitted in gaseous state. At the recent EFCA-symposium on Ultrafine particles in May this year in Brussels and the ETH Conference on

Combustion Generated Nanoparticles in June in Zurich new findings on the fraction of organic carbon (OC) were presented.

In recent years advanced monitoring techniques have become available which provide information on the two sub-fractions of OC, Primary and Secondary Organic Aerosol (POA and SOA, Prévot 2013). Observations in California made clear that the SOA fraction develops during the day in summer conditions; from a dual approach of cellular and chemical assay of ambient air it could be concluded that this 'aged smog' is more active in genotoxic tests than the POA-fraction and has the higher oxidative capacity (Sioutas 2013). The SOA fraction primarily consists of ultrafine particles (<170 nm) which enhances the risk of causing oxidative stress in humans.

SOA production is part of the process of photochemical smog formation which produces ozone via reactions of NO_x and organics under influence of sunlight. It was confirmed that SOA were formed when irradiating diluted exhaust gas under simulated atmospheric conditions in a smog chamber (Platt 2013). Exhaust gases from petrol fuelled cars appeared to be much more productive in SOA production than those from diesel fuelled cars. Diesel particle filters effectively suppress POA emissions; this is important because diesel exhaust contains more PCAs than petrol exhaust. The filters do not reduce SOA formation, however, because gaseous PCA emissions may pass the filters.

Tropospheric ozone and SOA are the most relevant pollutants which result from photochemical smog formation; addressing them together provides another option to protect public health and simultaneously having the co-benefit of reducing atmospheric level of the SLCP ozone.

9. Conclusions

- Integrated policy approaches on air quality and climate in the EU and elsewhere may further cost-effectiveness and require urgent attention
- Black Carbon is preferred as additional metric for particulate matter above Particle Numbers: its contribution to global warming and its source specificity furthers the implementation of air quality legislation
- Specific regulation for Black Carbon and Particle Numbers are no-regret options
- Protection of public health requires that also Organic Carbon emissions are being addressed; this may be best achieved in combination with policies aiming at reducing tropospheric ozone levels
- Knowledge gaps for sound AQ policies on particulate matter include:
    - Dose-response relations for long-term health effects of BCP and for short-term and long-term health effects of PN
    - Databases of emissions and monitoring data of BCP and PN
    - Robust relations between BC-emissions and PN-emissions from vehicles
    - Technology for simultaneous removal of solid particles and semi-volatile organics from combustion sources

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