IASS POLICY BRIEF 2/2017
Institute for Advanced Sustainability Studies (IASS)
Potsdam, May 2017

Black Carbon in Europe

Targeting an Air Pollutant and Climate Forcer

IASS POTSDAM

Deutsche Umwelthilfe

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Deutsche Umwelthilfe

Environmental Action Germany (DUH) is a non-governmental environmental and consumer protection organisation founded in 1975. The mission of DUH is to ensure that present and future generations enjoy the same opportunities to live fulfilling lives in an intact environment. DUH is a forum for environmental organisations, politicians, and decision-makers from industry. At the same time, DUH informs the general public and makes environmental policy and law more transparent.

This IASS Policy Brief should be cited as: von Schneidemesser, E., Mar, K. A., Saar, D. (2017): Black Carbon in Europe – Targeting an Air Pollutant and Climate Forcer, IASS Policy Brief.

Two challenges: one key substance

Air pollution and climate change are two of the most pressing environmental challenges we face today. Europe is no stranger to both problems. In the period from 2012 to 2014, more than 85% of the population of the European Union was exposed to air pollutant concentrations above the World Health Organization (WHO) guidelines for fine particulate matter ($PM_{2.5}$) and other air pollutants. Europe also stands to suffer from the effects of climate change, including sea-level rise and an increase in extreme weather events.

A key substance with relevance for both air pollution and climate change is black carbon. It is emitted from combustion sources such as vehicles and wood burning, and is a component of particulate matter. By addressing black carbon, we can mitigate climate change and reduce air pollution at the same time. However, policymakers have yet to fully understand its role. A number of policy processes at national and European level now provide a window of opportunity to target black carbon in an effective and coordinated way.

Drawing on our experience as a lead partner in initiatives for the scientific assessment and mitigation of black carbon and other pollutants, and on the latest research on black carbon[1], we recommend the following three measures:

- **Message 1:**

Target diesel transport and residential combustion emissions.
Transport and residential combustion are the main sources of black carbon in Europe. Within the transport sector, reducing diesel emissions from both on-road and non-road transportation is crucial to tackling black carbon.

- **Message 2:**

Produce national emission inventories using a consistent methodology.
Black carbon is co-emitted with other types of particles which together make up the total emitted particulate matter. To ensure that nationally reported black carbon and particulate matter emissions are comparable, a consistent methodology should be agreed upon.

- **Message 3:**

Coordinate policymaking on air quality and climate change.
A joint approach to air quality and climate change policies is essential. Many ongoing policy processes can result in win-wins if the effects of measures on air quality and climate change are considered in a coordinated way.

[1] On the impact of controlling biomass burning emissions for particulate matter in Europe, see Fountoukis et al., 2014; on a coordinated approach to air quality and climate change, see Melamed et al., 2016; and on monitoring and trends in black carbon, see Kutzner et al. (in preparation).

An opportunity to take action on air pollution and climate change

Also known as 'soot' or 'elemental carbon', black carbon is an air pollutant and climate forcer that is formed during the combustion of carbon-based fuels, including biomass and fossil fuels. Black carbon not only has a negative impact on local and regional air quality, but also warms the regional and global climate. It has a far shorter lifetime than carbon dioxide: Once emitted, black carbon normally remains in the atmosphere for several days, and can remain up to four weeks. This means that efforts to reduce emissions can have near-immediate positive effects on both air pollution and climate change.

Double trouble: the undesirable effects of black carbon

Black carbon is putting human health at risk. Several conclusions on the specific health implications of black carbon can be drawn from epidemiological research on total fine particulate matter. Short-term and long-term exposure to black carbon is linked to cardiovascular effects, such as heart arrhythmia and heart rate variability, and respiratory effects, including decreased lung function and the development of asthma, especially in children.

It is not yet possible to state unequivocally that black carbon is more important than other particulate matter components in terms of its health effects, but studies have shown that robust associations for adverse health effects remained even after taking fine particulate matter into account. Of particular importance are the higher mortality and morbidity rates for black carbon compared to those for fine particulate matter, which indicate that this substance is probably one of the most health-relevant components of particulate matter.

A climate forcer and health hazard: Black carbon under the microscope

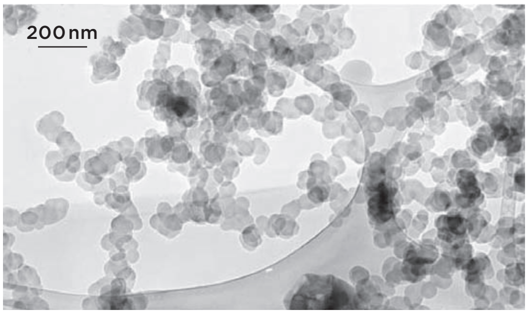


Figure 1: Microscope image of soot particles from biomass burning

Source:
Li et al., 2003; Reproduced with permission from the AGU.

What is black carbon?

Black carbon is an aggregate of small carbon spheres, which are released into the atmosphere during combustion. It is always emitted with a mix of other air pollutants and greenhouse gases. Due to its dark colour, it strongly absorbs sunlight. The relative proportion of black carbon in particulate matter determines its precise climate effect.

In addition to adversely affecting air quality and health, black carbon is a short-lived climate-forcing pollutant (SLCP). As such, it contributes to climate change by interacting with solar radiation. While estimates of the global radiative forcing of black carbon vary, all indicate a net positive or warming effect. Indeed, these estimates suggest that black carbon is one of the largest contributors to global warming after carbon dioxide and methane.[2]

Of particular relevance to the Nordic countries and Russia is black carbon's albedo effect. This is the term used to describe how it darkens highly reflective snow and ice surfaces, thus reducing their capacity to reflect sunlight back and ultimately leading to warming and melting.

Killing two birds with one stone

The dual role played by black carbon means that efforts to reduce it can reap rewards for both air quality and climate protection. Black carbon is currently in the spotlight. In Europe, policy processes aimed at mitigating its effects have been gaining momentum in recent years. For the first time, member states of the European Union are specifically directed to reduce their emissions of black carbon.

The new European National Emission Ceilings (NEC) Directive[3] requires member states to prioritise measures that address black carbon in their National Air Pollution Control Programmes (NAPCPs) when taking action on fine particulate matter. Under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), countries have also begun submitting black carbon emission inventories on a voluntary basis. In parallel, other regional initiatives have been targeting emissions of black carbon. In 2015, Arctic Council ministers adopted a "Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions" and committed to taking "enhanced, ambitious, national and collective action to accelerate the decline in our overall black carbon emissions." And, as partners of the Climate and Clean Air Coalition (CCAC), the European Commission and many individual European countries are currently focusing on reducing black carbon emissions together with other short-lived climate-forcing pollutants.

These are just some of the initiatives that can be built on in future. It is now up to decision-makers at national and European level to capitalise on this momentum and avail of the opportunities to achieve win-wins for air quality and the climate.

[2] This calculation is based on the following considerations: 1) black carbon's direct effect, in which it absorbs solar radiation at all wavelengths and directly warms the atmosphere (in contrast to CO_2, which only absorbs infrared radiation); 2) the snow and ice albedo effect, whereby black carbon darkens bright surfaces, thus reducing reflectivity, increasing surface absorption of radiation, and ultimately leading to warming; and 3) various cloud effects, which lead to both cooling and warming. See Bond et al., 2013 and the IPCC 5th Assessment Report, Chapter 8.

[3] Directive 2016/2284/EU.

Target diesel transport and residential combustion emissions

To reduce black carbon emissions in Europe, the most important sectors to target will be residential combustion and diesel combustion in the transport sector – both on-road and non-road. An analysis of the emission inventory developed through the EU-funded atmospheric and climate monitoring project TNO-MACC[4] shows that, Europe-wide, emissions from these two sectors[5] represent 84% of total black carbon emissions.

However, the relative contributions from these sectors differ from region to region. As illustrated in figure 2, in many Eastern European and Nordic countries, the contribution of residential combustion[6] to black carbon emissions is dominant. Yet in Central and Southern Europe, most black carbon emissions originate in the transport sector, with both on-road diesel and non-road transport representing the most significant sources of black carbon.

Relative contribution of black carbon source sectors

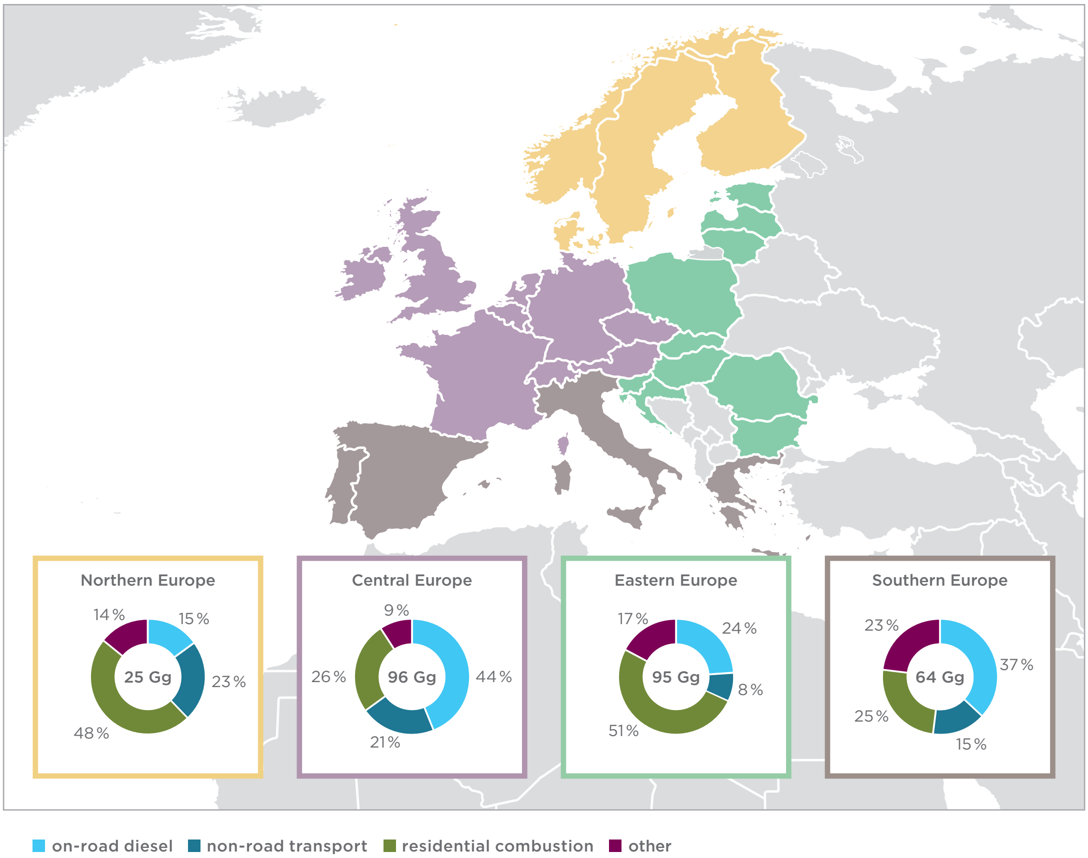


Figure 2: This figure shows the relative contributions of on-road diesel, non-road transport, and residential combustion to total black carbon emissions by region. The total annual black carbon emissions for each region is shown in gigagrams.

Source:
IASS; Data from the TNO-MACCIII emissions inventory; Kuenen et al., 2014.

A critical source of black carbon: diesel transport

In the on-road transport sector, diesel particulate filters have led to reductions in black carbon and particulate matter emissions. However, on-road diesel vehicles continue to be a significant source of black carbon. And while rigorous emission standards have been set for on-road transport, the standards for non-road transport – e.g. construction and agricultural machinery – are very weak in comparison. The operators of most non-road mobile equipment are under no obligation to install a particulate filter.

A looming issue: non-road transport

Since the continued phasing-in of the European standards is likely to further reduce particulate matter emissions from the on-road transport sector, it is expected that black carbon emissions from non-road sources will dominate in the future. Indeed, in a number of countries – Norway, Sweden, Denmark, and Greece, for example – this is already the case. So it follows that more stringent emission regulations for the non-road transport sector are needed if we are to reduce black carbon emissions from the transport sector.

A critical source of black carbon: residential combustion

Residential combustion, primarily for heating purposes, is another key source to target in Europe in order to reduce black carbon emissions. Emissions from the residential sector typically come from burning wood or other biomass, but in some countries in Eastern Europe residential coal combustion remains a significant source of black carbon. As reductions in other sectors are implemented, the relative amount of emissions from residential combustion is increasing. By 2030, domestic heating is expected to account for nearly 70% of black carbon emissions in the European Union.[7]

Residential heating need not compromise air quality

Given the EU's commitment to obtaining greater amounts of energy from renewable sources, efforts should be made to ensure that the promotion of biomass as a renewable fuel does not end up compromising air quality. In the residential heating sector, standard wood combustion units can be replaced with automated pellet stoves with sufficient exhaust-control technology, boilers based on wood-gasification technology, or woodchip/firewood appliances with effective particle separators. All three of these technologies are compatible with both climate and air quality goals.

[4] The TNO-MACC emission inventories are based on country-reported emissions under the Convention on Long-Range Transboundary Air Pollution, but they include additional gap-filling and correction of errors that can be identified based on inconsistencies in submitted data (Kuenen et al. 2014).

[5] Transport, including diesel on-road emissions and all non-road emissions – the vast majority of which are from diesel combustion – and residential combustion.

[6] While residential combustion is not limited to wood burning, wood dominates over other fuels such as coal in this sector.

[7] Clearing the Air: A critical guide to the new National Emission Ceilings Directive (2017, Brussels, EEB), p. 29.

Produce national emission inventories using a consistent methodology

Emission inventories are used in air quality and climate models to simulate past, present, and future atmospheres. They allow us to assess how air quality has changed over time and what role various factors, such as human activities, weather, and climate, play in determining atmospheric composition. They are thus fundamental to being able to evaluate potential mitigation measures before they are set in motion.

Emission inventories are politically significant

At present, many European countries are producing emission inventories for black carbon under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The development of national black carbon inventories is a politically important step that supports the development of country-specific mitigation strategies, and allows countries to develop priorities in an informed and politically acceptable manner.

Distinguishing between warming and cooling emissions

In the context of developing national emission inventories, it is crucial to consider not only black carbon, but also the substances that are co-emitted with it. Black carbon cannot be reduced in isolation from those other components of particulate matter. Knowledge of the relative fraction of black carbon in total particulate matter emissions is particularly important for understanding the overall climate impact of a given source. This is because some co-emitted particulate species, in particular organic carbon, contribute to cooling (see figure 3). Thus, mitigation of sources that are black carbon-rich, as opposed to those with a higher fraction of cooling pollutants, is generally seen as the best way to improve air quality and mitigate climate change in one fell swoop.

The pitfalls of using inconsistent methodologies to develop inventories

Studies have shown that when compiling emission inventories, differences in measurement methodologies can lead to vastly different evaluations of the relative proportions of black carbon in total particulate matter emissions from a given source.[8] Inconsistencies in measuring and reporting particulate matter emissions across countries can lead to distorted representations of emissions data, which are not a sound basis for decision-making on appropriate measures.

[8] Differences in total particulate matter arise when different measurement methods are used to determine emission factors. Particulate matter is sometimes measured 'in-stack' and at other times in dilution tunnels (directly after the stack), and the choice of method determines how much condensable particulate matter is included in the final calculation (Denier van der Gon et al., 2015).

The case for the application of a common methodology

A European study assessed the potential of replacing standard wood combustion units with the more efficient pellet stoves in all households. The initial version of the emission inventory used in the study pointed to significant country-to-country differences and predicted that the proposed measure would result in only minimal reductions in black carbon and particulate matter.[9] However, an updated version of the emission inventory[10], which applied a consistent methodology for all of Europe, predicted decreases of up to 50% in ambient concentrations of black carbon in urban hotspots and an overall decrease of between 15% and 40% in fine particulate matter over continental Europe.

With this in mind, European countries should strive for comparability and consistency or, at a minimum, transparency, in national emissions reporting for black carbon in the broader context of total particulate matter emissions. This could be achieved in the context of the European Monitoring and Evaluation Programme (EMEP), the implementing body of the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

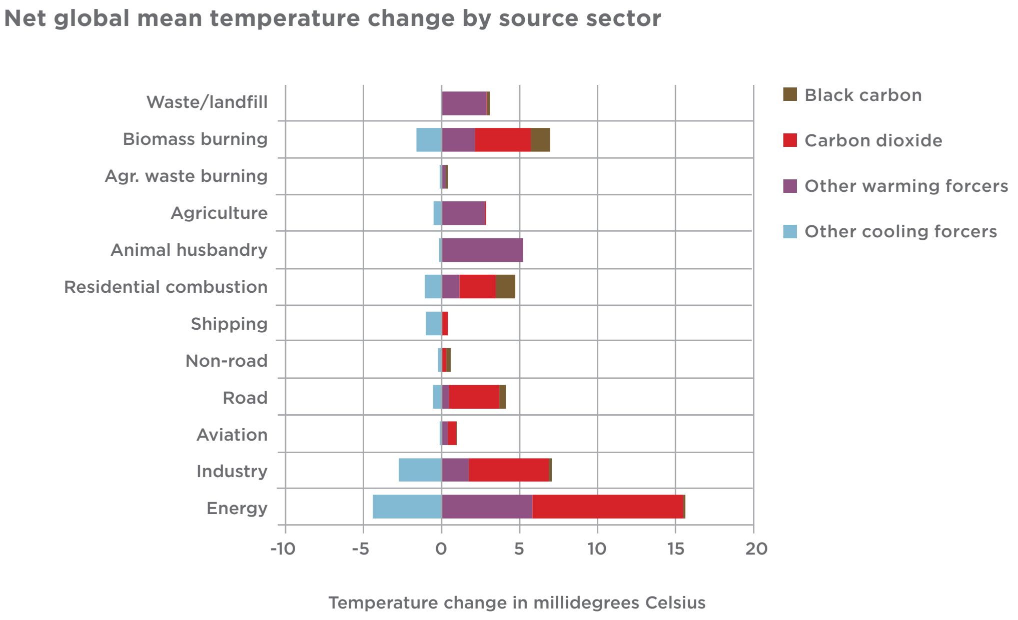


Figure 3: Black carbon warms the atmosphere by absorbing solar radiation and diminishing snow and ice albedo: this figure shows the impact of black carbon emissions and co-emitted species on temperatures after twenty years.[11]

Source:
IASS; adapted from Myhre et al., 2013.

[9] Fountoukis et al., 2014.

[10] The updated emissions included condensable particulate matter.

[11] The colour bars show the temperature impact of black carbon, CO_2 and other warming and cooling climate forcers, by global source sector, 20 years after the emissions occurred. The bars are additive and the horizontal width of each bar represents the degree of warming or cooling. The temperature impact of a pulse of black carbon peaks almost immediately, but despite its short atmospheric residence time, it can still have a measurable effect after twenty years due to the long memory of the climate system.

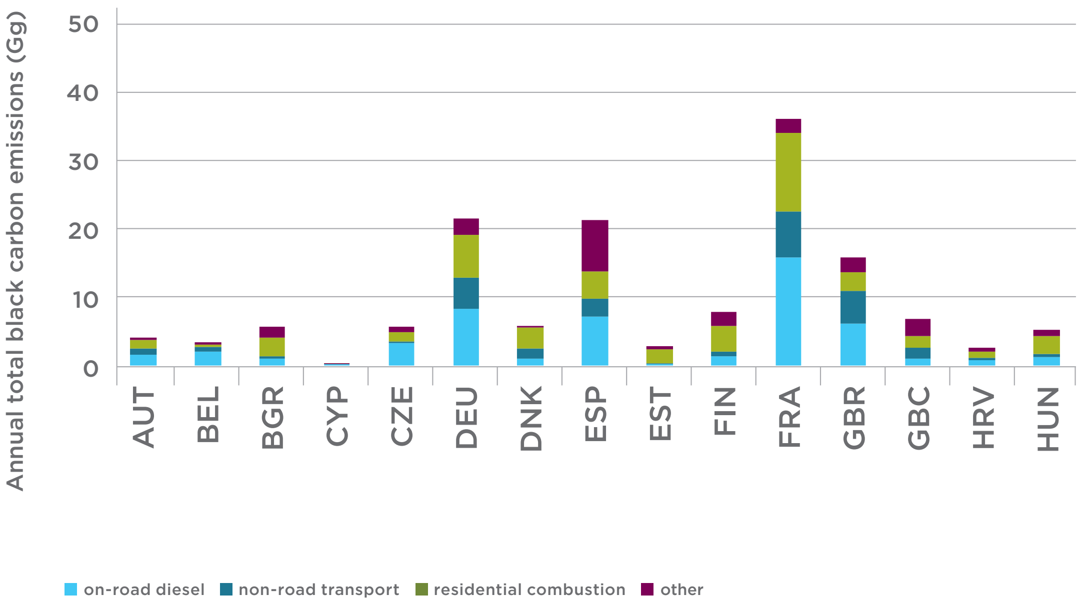
Coordinate policymaking on air quality and climate change

Mitigation measures designed to address air pollution can have unintended consequences on the climate – both positive and negative – and vice versa. For example, in the USA, the reduction of air pollutants under the Clean Air Act (CAA) also resulted in a decrease in carbon dioxide emissions. On the other hand, climate friendly policies that promoted diesel and biomass burning had an unintended negative impact on air quality. This is why we recommend an integrated approach to addressing air quality and climate change, where the implications of any mitigation measures for human health, climate, and ecosystems are considered. A holistic approach of this kind should account for the mix of emissions, the respective atmospheric lifetimes of air pollutants and greenhouse gases, and the benefits and trade-offs inherent to measures.

Adopting a coordinated approach

Black carbon-rich sources are prime examples of why this coordinated approach is crucial. As explained above, the mix of emissions from a given source determines its effect on air quality and climate change. For example, improving the energy efficiency of residential combustion technologies will reduce emissions of particulate matter, of which black carbon is a substantial component, as well as carbon dioxide – a win-win for air quality and the climate. Yet if wood combustion for residential heating continues to be incentivised as a measure to reduce carbon dioxide emissions without considering the technology used, increases in particulate matter and black carbon emissions will result, a definite trade-off.

Country contributions to black carbon emissions



Viewing emissions through a climate and air quality lens

Member states of the European Union are in the process of developing their national air quality plans with a view to implementing the new National Emission Ceilings (NEC) Directive. At the same time, Europe is fleshing out its plan for implementing its Nationally Determined Contributions (NDCs) under the Paris Climate Agreement. A key piece of legislation in this respect is the proposed Renewable Energy Directive (REDII)[12], where it is stated that "Member States shall endeavour to increase the share of renewable energy supplied for heating and cooling by at least 1% every year." All of these ongoing policy processes would benefit enormously from viewing emissions through both a climate and an air quality lens. In so doing, they will be able to maximise the gains and minimise any potential trade-offs of measures to deal with black carbon.

Making the energy transition compatible with air quality goals

To ensure that renewable energy policies do not inadvertently compromise air quality in Europe, the proposed Renewable Energy Directive should be strengthened to include safeguards for air quality, and it should also address the climate impact of heating-related emissions of black carbon, especially in the Nordic countries. The accompanying proposed directive on the Governance of the Energy Union[13], which governs the implementation of the proposed Renewable Energy Directive, will also be directly relevant in this regard. There is now a clear opportunity to bolster this governance directive by requiring member states to consider European air quality goals when planning how to achieve their renewable energy targets.

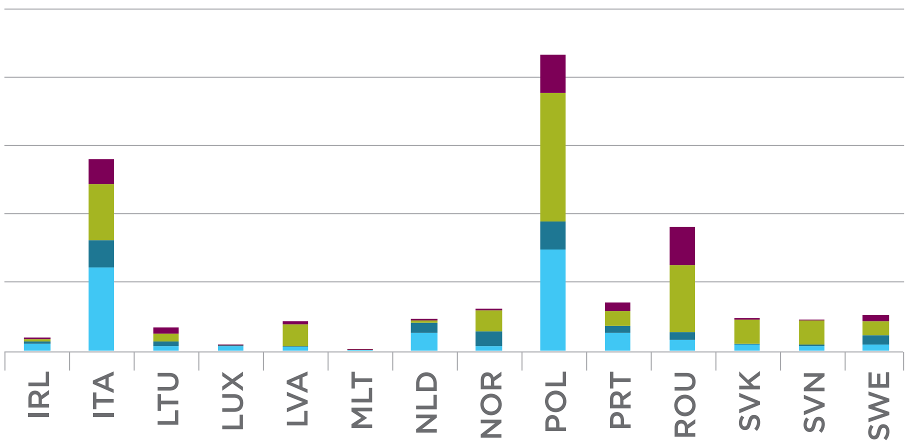


Figure 4: Annual total black carbon emissions by sector and country. European countries should strive for comparability in national emissions reporting for black carbon.

Source:
IASS; Data from the TNO-MACCIII emissions inventory; Kuenen et al., 2014.

[12] Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources, COM(2016) 767.

[13] Directive of the European Parliament and of the Council on the Governance of the Energy Union, COM(2016) 759.

Targeting black carbon in Europe: next steps

Emissions of black carbon are damaging because of their adverse effects on human health, as well as their warming effect on the climate. In Europe, the main sources of black carbon are diesel combustion in the transport sector (on-road and non-road) and residential combustion. Since the relative importance of these sources varies from country to country, the country-specific approach to developing mitigation strategies under the national air quality plans is appropriate.

Adopting comparable methods for reporting emissions

That said, EU-wide technology-specific emission standards would also be helpful in sectors where they are either lacking or weak, such as non-road transport and residential wood burning. To best assess mitigation measures and understand the implications of different policy options, emissions inventories are crucial input data. Comparable methods for reporting national emissions – not only in the black carbon emission inventories that are currently being developed under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), but also for particulate matter and emission inventories across Europe more generally – would go a long way to ensuring that effective mitigation measures are implemented. An understanding of the most relevant sources to target, reflected in comparable and accurate emission inventories, can guide decision-making. To foster effective policy decisions, the implications for air quality and climate change should be considered jointly.

Opportunities to advance an integrated policy response

The recommendations of this policy brief are directly relevant for a number of ongoing policy processes. For one, the new National Emission Ceilings (NEC) Directive calls for a reduction in fine particulate matter with a specific focus on black carbon. Here, a coordinated approach that takes climate goals into account when developing national air quality plans will result in mitigation measures that reap rewards for both air quality and climate change. Similarly, the proposed Renewable Energy Directive (REDII) and its implementation through the governance directive also present an opportunity to add air quality stipulations and ensure that increased use of biomass in the residential heating sector does not lead to a rise in black carbon and total particulate matter emissions and their associated negative health impacts.

Find out more ...

To learn more about targeting air pollution and climate change, see the following publications and articles:

- Lode, B., Toussaint, P. (2016): **Clean Air for All by 2030?** IASS Policy Brief, December 2016.
- Melamed, M. L., Schmale J., von Schneidemesser, E. (2016): **Sustainable policy – key considerations for air quality and climate change.** In: Current Opinion in Environmental Sustainability, 23, 85–91.
- von Schneidemesser, E., Kutzner, R., Grass, A., Saar, D. (2015): **Ground-Level Ozone – A Neglected Problem**, IASS Policy Brief, October 2015.
- Schmale, J., Shindell, D., von Schneidemesser, E., Chabay, I., Lawrence, M. G. (2014): **Air pollution: Clean up our skies.** In: Nature, 515, 335–337.
- Deutsche Umwelthilfe, The Danish Ecological Council (2016): **Residential wood burning, environmental impact and sustainable solutions.** Clean Heat Campaign Background Paper, March 2016.

About the authors

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Dorothee Saar heads the transport and air quality team at Deutsche Umwelthilfe. Her work focuses on reducing CO_2 and other emissions from on-road and non-road vehicles. She also coordinates a European NGO network to address pollutants like black carbon that are harmful for both human health and the climate.

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Institute for Advanced Sustainability Studies (IASS) e. V.

Funded by the ministries of research of the Federal Republic of Germany and the State of Brandenburg, the Institute for Advanced Sustainability Studies (IASS) aims to identify and promote development pathways for a global transformation towards a sustainable society. The IASS employs a transdisciplinary approach that encourages dialogue to understand sustainability issues and generate potential solutions in cooperation with partners from academia, civil society, policymaking, and the business sector. A strong network of national and international partners supports the work of the institute. Its central research topics include the energy transition, emerging technologies, climate change, air quality, systemic risks, governance and participation, and cultures of transformation.

IASS Policy Brief 2/2017
May 2017

Institute for Advanced Sustainability Studies Potsdam (IASS) e. V.

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DOI: 10.2312/iass.2017.010
ISSN: 2196-9221

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