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Ground-Level Ozone – A Neglected Problem

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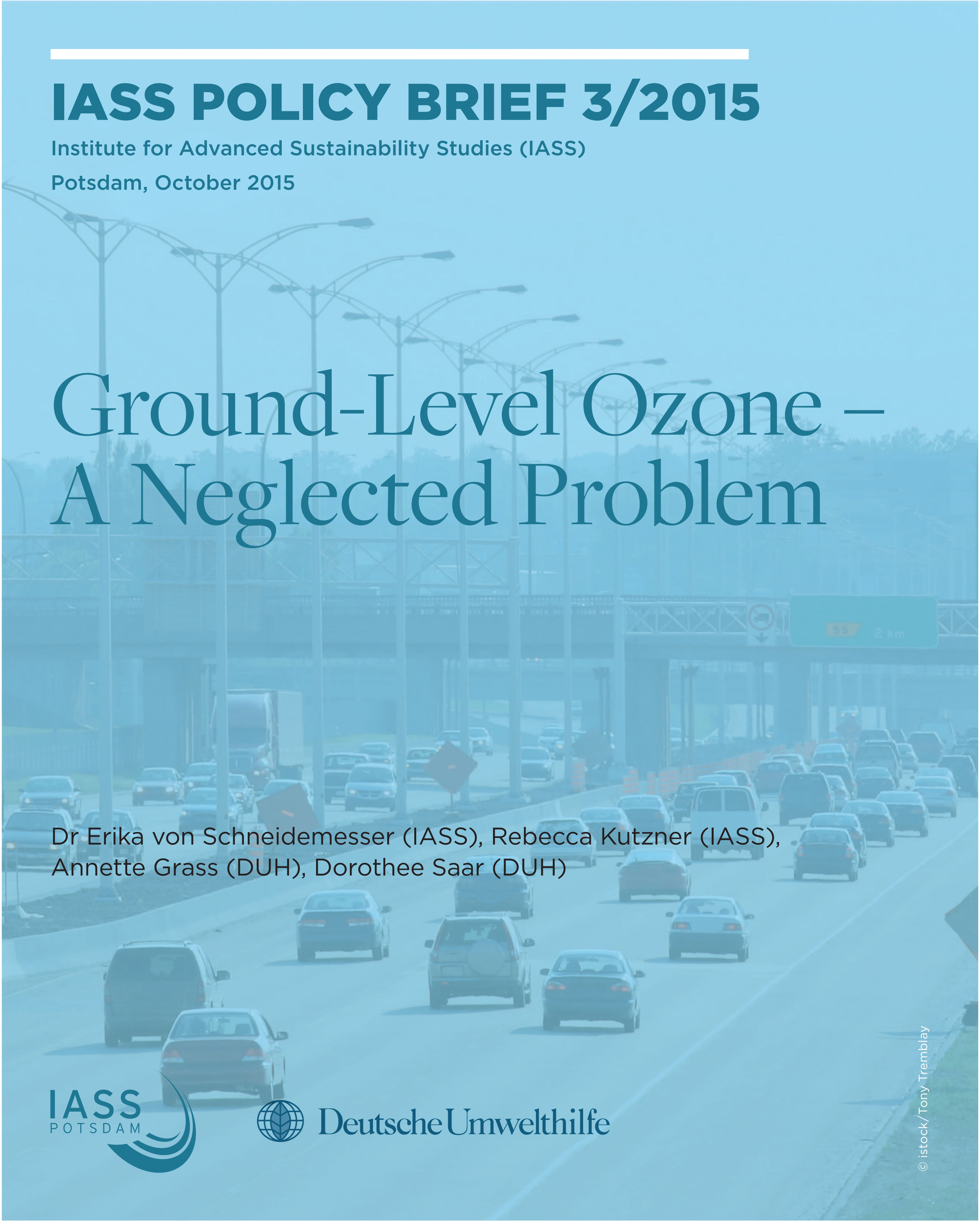

IASS POTSDAM

Deutsche Umwelthilfe

Ozone has all but disappeared as an environmental issue from political and public discussion, even though the problem of ozone concentrations in the air we breathe is far from being resolved. High ozone values have consequences for both our health and the environment. Recommended concentrations are exceeded every year in almost all European countries.[1] According to the European Environment Agency (EEA), two thirds of the monitoring stations in EU countries recorded values in excess of EU limits in 2012. If we consider the recommendations of the World Health Organisation (WHO), then practically all regions in Europe have ozone concentrations that are hazardous to human health. The resulting pressure on the health system is also detrimental to the economy. Furthermore, ozone has an adverse effect on ecosystems, which results in even greater economic losses, for example loss of agricultural earnings. In EU countries as well as Switzerland and Norway, damages of up to three billion euro are incurred annually as a result of wheat crop losses of up to 15 per cent due to high ozone levels.[2]

Every year in Europe, more than 400,000 premature deaths are attributed to air pollution. In Germany alone, 34,000 people died prematurely from the effects of air pollution in 2010. Alongside particulate matter, ozone is one of the main causes of adverse health effects due to severe air pollution.[3]

It is clear that existing laws and regulations are not sufficient to bring about a lasting reduction in ozone concentrations that would sufficiently protect the population from its harmful effects. To direct political and public attention to the problem of ozone and develop proposals for how to deal with it, the DUH and the IASS organised an expert discussion on 30 July 2015 on "Ozone and its Precursors" with policy experts, national and local authorities, local governments, scientific institutes and environmental associations. Three messages emerged from this discussion:

- **Message 1:** To lower ozone concentrations as quickly and effectively as possible, precursors (NO_x, NMVOCs and methane) must be reduced. This will require the imposition of stricter limits, including the verification of real-world vehicle emissions, and concrete obligations to reduce methane emissions in agriculture in the EU's 2030 Framework for climate and energy and the National Emission Ceilings (NEC) Directive.

- **Message 2:** Greater awareness of the considerable danger ground-level ozone poses to the environment and human health is required among policymakers and the public if this issue is to return to the political agenda. A public discussion of the causes, effects, sources and damages can encourage politicians to introduce more comprehensive ozone reduction measures and ensure that they are implemented. Only in this way will we be able to avoid damages to the environment and human health from ozone in the future.

- **Message 3:** Continued basic research on the formation and interactions of ozone as well as its effects on the climate, human health and the environment should be funded. Such scientific research is fundamental to efforts to reduce ozone concentrations.

[1] EU target value: the maximum 8-hour value of any one day may exceed 120 µg/m³ on no more than 25 days of the calendar year, averaged over three years. In the long term, the 8-hour value should not exceed 120 µg/m³ at all. WHO target value: an 8-hour value of 100 µg/m³.

[2] ICP Vegetation, Report 2014–2015, http://icpvegetation.ceh.ac.uk/publications/documents/FinalICPVegetation-annualreport2014-15.pdf

[3] http://www.eea.europa.eu/soer-2015/europe/air

1. The formation of ground-level ozone

Ground-level ozone is not emitted directly, but formed from precursors (mainly nitrogen oxides and volatile organic compounds (VOCs)) in complex photochemical processes that occur under conditions of intense sunlight and hot temperatures. Because of this, ozone is described as a secondary pollutant. The concentration of ozone in the air varies over the course of a single day, depending on the intensity of sunlight and the concentration of the precursors. Usually, maximum ozone concentrations occur at midday or in the afternoon. Typical ozone episodes with higher-than-average levels (>180 $\mu g/m^3$) are to be expected in summer and often coincide with heatwaves.

To effectively counteract the formation of ozone in the long term, a reduction of all precursors from anthropogenic sources is required. Within the group of VOCs, methane is particularly relevant for background ozone: future scenarios in which global methane levels increase all predict higher background concentrations of ozone.[4] Ozone and methane are both greenhouse gases that contribute to global warming.

1.1 Sources of precursors

Ozone precursors originate to a large extent in anthropogenic, or human-made, sources, specifically, transport, agriculture and industry. These sources should be the focus of reduction measures. There are also natural sources of ozone precursors, but their contribution to emissions in cities is negligible compared to anthropogenic sources.

Nitrogen oxides are an important precursor. According to the German Environmental Protection Agency (UBA), 40 per cent of these emissions originate in the transport sector, primarily road transport. The rest of the NOx emissions are attributed mainly to power plants (electricity and heat generation by combustion) and 9 per cent originate in agriculture.

Non-methane VOCs (NMVOCs) from anthropogenic sources are released mainly through the use of solvents and in road transport. Solvents can be found in a range of products, including paint, varnish, glue and cleaning agents. In the transport sector, VOCs are released primarily through fuel combustion. Other sources include agriculture and small-scale combustion, for example residential heating.

Methane is formed in anoxic (i.e. oxygen-free) fermentation processes. Over half of all methane emissions originate in agriculture. The rest originate in roughly equal measure in landfill sites and the energy sector, in particular in the production, distribution and use of fossil fuels.

[4] IPCC AR5

2. Ozone as a health hazard

Ozone is harmful to human health. For that reason, ozone concentrations in the air we breathe should be kept as low as possible. Possible adverse human health effects include a reduction in lung function and a higher susceptibility to asthma and infections. Ozone also irritates the mucous membranes and the membranes of the eyes. The DFG MAK[5] Commission has categorised ozone as "a substance that is suspected of being carcinogenic". Further research is necessary to confirm or disprove this.

There is no known threshold level for ozone under which no danger to human health can be assumed.

Specific groups of the population are particularly vulnerable to high ozone concentrations, including children (especially infants), pregnant women, the elderly and people with underlying health conditions such as asthma. In general, physical exertion under conditions of high ozone levels is a health hazard. There is still little knowledge about the significance of background concentrations, the chronic ozone exposure associated with them, and the long-term damages to health that may result.

In Germany, the relevant state authorities issue a warning to particularly vulnerable population groups when ozone concentrations exceed 180 µg/m³ (1-hour value) and inform the entire population when they exceed 240 µg/m³ (1-hour value). In these cases, extended physical exertion outdoors should be avoided around midday and in the afternoon. UBA recommends reconsidering participation in outdoor sporting events when levels reach 120 µg/m³ (1-hour value).

[5] German Research Foundation Commission on Maximum Workplace Concentrations.

3. Adverse effects of ozone on ecosystems

Ozone is harmful to plants, including many important and widely planted species (e.g. wheat, potatoes, rice, tomatoes, soya beans, onions and cotton). Ozone enters the plant and produces toxic oxygen radicals in the process of decay. These oxygen radicals alter biochemical processes (e.g. metabolism), cause tissue damage, accelerate the aging process, and lead to reduced growth and lower yields in the case of extended exposure. Even short ozone episodes can cause visible damage to leafy vegetables, thereby lowering their market value.

Critical loads, for example AOT40 (cumulative ozone levels above the threshold of 80 $\mu g/m^3$), are based on experiments on the relationship between exposure and effect. An alternative approach to ozone limits, the phytotoxic ozone dose (POD) has recently been developed. It takes the actual amount of ozone that a plant absorbs into account, as well as additional factors like light, temperature, soil moisture and humidity. POD is recommended by the scientific community as an improvement on the previously used AOT40. According to the latest research findings (using POD), up to 15% of wheat crop losses in EU countries, Switzerland and Norway can be attributed to ozone. This amounts to annual financial losses of up to three billion euro.[6]

Current research suggests that today's ozone levels hinder the growth of forest trees and can thus have a negative impact on the carbon storage capacity of forests. The carbon storage plays a vital role in moderating climate change. There is a general lack of research on the effects of ozone on wild plants and plant communities (plant species that occur together in similar environmental conditions). Furthermore, our understanding of how ecosystems react to ozone pollution is inadequate. Thus there is an urgent need for more research in these areas.

[6] ICP Vegetation, Report 2014-2015,
http://icpvegetation.ceh.ac.uk/publications/documents/FinalICPVegetationannualreport2014–15.pdf

4. Statutory regulations and limits for ozone and its precursors

There is no legally binding ozone limit value in Europe. Yet the European Ambient Air Quality Directive does set target values: for human health the average ozone concentration over a period of eight hours should not exceed 120 µg/m³.[7] The information threshold is 180 µg/m³ and the alert threshold is 240 µg/m³ for 1-hour values.[8] These values are, however, all higher than that recommended by the WHO (100 µg/m³ as an 8-hour value).

For the protection of vegetation, an AOT40 target value of 18,000 (µg/m³) · h averaged over five years applies.[9] AOT40 refers to the sum of the differences between the average 1-hour values over 80 µg/m³ (=40 ppb) and the value of 80 µg/m³ between 8 am and 8 pm from May to July. The long-term goal is to have a maximum annual value of 6,000 (µg/ m³) · h.

In order to actively reduce ozone concentrations, there are laws that regulate the emission of the precursors nitrogen oxides (NO_x) and VOCs in ambient air. They are meant to ensure that less ozone is formed and ozone concentrations are thereby reduced.

The following relevant regulations exist at European level:

- National Emissions Ceilings (NEC) Directive[10]; relevant for NO_x, NMVOCs
- EURO emission standards for cars, vans, lorries and buses[11]; relevant for NO_x, NMVOCs
- Industrial Emissions Directive (IED)[12]; relevant for NO_x, CO
- Non-Road Mobile Machinery (NRMM)[13]; relevant for NO_x, NMVOCs, CO
- EU Paints and Solvents Directives[14]; relevant for VOCs

Despite the successive introduction of increasingly stringent emission standards (EURO-NORMs) for road vehicles since 1990, road transport is the largest emitter of NO_x in Germany and Europe.[15] One reason for this is that many vehicles do not adhere to emissions limits under real driving conditions and thus emit far more NO_x than permitted by law. Further efforts are urgently required to solve this problem.

[7] EU target value: the maximum 8-hour value of any one day may exceed 120 µg/m³ on no more than 25 days of the calendar year, averaged over three years. In the long term, the 8-hour value should not exceed 120 µg/m³ at all.

[8] EU Directive 2008/50/EG

[9] See previous footnote.

[10] EU Directive 2001/81/EC

[11] Regulation (EG) No. 715/2007

[12] EU Directive 2010/75/EU

[13] Proposal for a Regulation on requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery, COM/2014/0581 final – 2014/0268 (COD)

[14] EU Directive 2004/42/EC, Council Directive 1999/13/EC.

[15] http://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1/assessment.2010-08-19.0140149032-3

A clear reduction in VOC emissions in Germany was observed in the period from 1990 to 2013. Many practical measures to reduce emissions have already been taken, especially in the area of road transport (e.g. the evolution of regulated catalytic converters and improvements to the devices used in petrol stations to reduce evaporative emissions). Similarly, in the industrial and commercial sectors (e.g. printing, paint shop), a reduction of the solvent content has led to fewer NMVOC emissions. However, there is significant potential for greater reductions in a revision of the EU Paints and Solvents Directives.

Agriculture is the third sector that contributes significantly to the emission of VOCs, in particular methane. In Germany, 53 per cent of all methane emissions originate in livestock farming (animal husbandry and manure management). The relative contribution of agriculture to emissions is expected to increase in future, as other sources of methane emissions (the waste disposal and energy sectors) in Germany have already instituted a range of reduction measures. Moreover, 95 per cent of NMVOC emissions are due to the use of fertilisers. Here too, there is not only a great urgency to take action, but also considerable potential for emission reductions that should be exploited in future.

Current Situation in Germany

UBA's preliminary findings (10/2015) show that in 2015 the information threshold of 180 µg/m³ was exceeded at 205 out of 263 measuring stations in Germany (78%) and the long-term goal of 120 µg/m³ was exceeded at 261 out of 263 stations (99%).

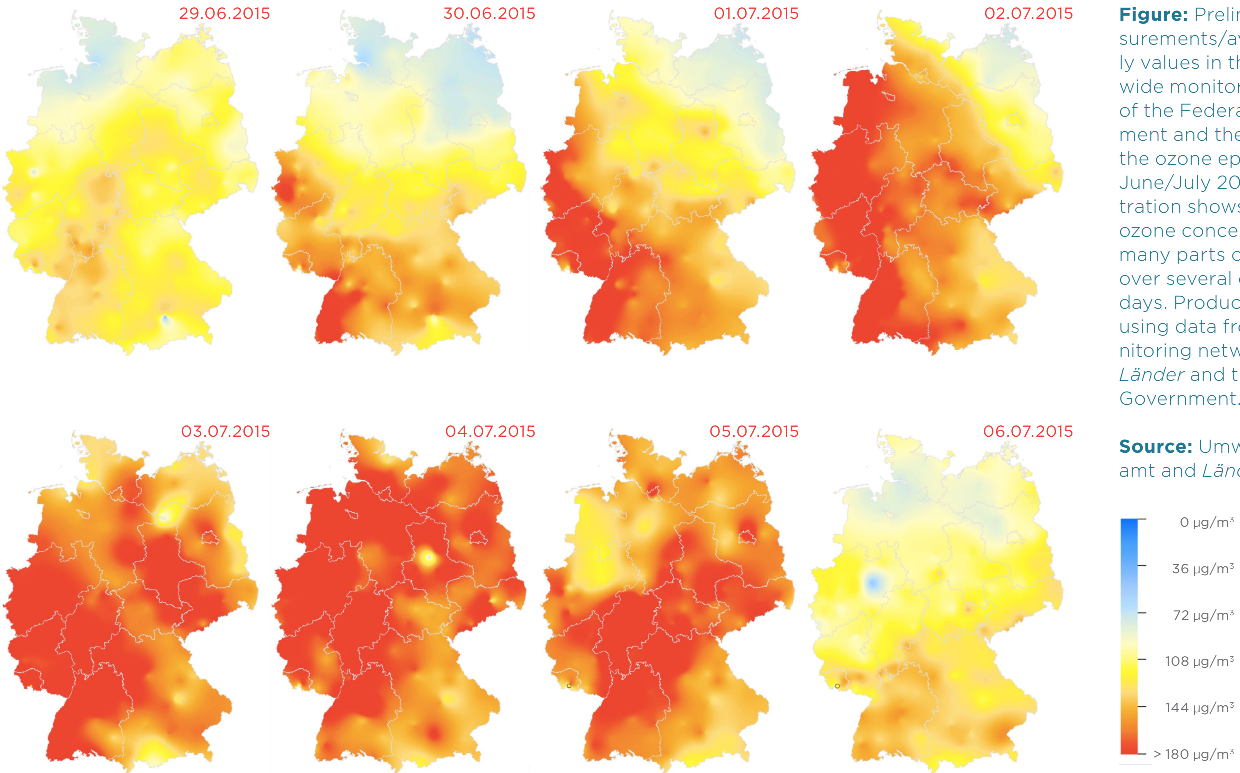

Figure: Preliminary measurements/average hourly values in the countrywide monitoring network of the Federal Government and the *Länder* for the ozone episode of June/July 2015. The illustration shows very high ozone concentrations in many parts of Germany over several consecutive days. Produced by UBA using data from the monitoring network of the *Länder* and the Federal Government.

Source: Umweltbundesamt and *Länder*

5. Key messages

Message 1: To lower ozone concentrations as quickly and effectively as possible, precursors (NO_x, NMVOCs and methane) must be reduced.

Previous efforts to reduce precursors have not led to a sufficient reduction in ozone concentrations. This goal could be realised by implementing the following measures:

- Updating the EU Paints and Solvents Directives to reduce VOC emissions;
- Introducing regulations to test NO_x emissions under real driving conditions – not just in laboratory conditions – and banning vehicles that produce high emissions (emission standards);
- Establishing a limit for methane emissions in the EU National Emission Ceilings (NEC) Directive;
- Instituting concrete obligations to reduce agricultural methane emissions in the EU's 2030 Framework for climate and energy.

Message 2: Greater awareness of the considerable danger ground-level ozone poses to the environment and health is required among policymakers and the public if this issue is to return to the political agenda.

If we assume the target value for ozone recommended by the World Health Organisation (WHO) as a basis, then practically all regions in Europe have ozone concentrations that are hazardous to health. The resulting pressure on the health system is also detrimental to the economy. Furthermore, ozone has an adverse effect on ecosystems, which results in even greater economic losses, for example loss of agricultural earnings. In spite of these negative effects, there is no substantial public discussion of causes, sources, effects and damages. A public discussion and the public pressure it creates would increase political awareness of this issue and foster action, leading politicians to introduce and implement more wide-ranging measures to reduce emissions. Only in this way will we be able to avoid damages to the environment and human health in the future.

Message 3: Continued basic research on the formation and interactions of ozone as well as its effects on the climate, human health and the environment should be funded. Such scientific research is fundamental to efforts to reduce ozone concentrations.

According to the latest research, ozone is, together with particulate matter, one of the most important and harmful air pollutants in Europe. Additionally, initial findings indicate the existence of further adverse effects, which only serve to highlight the importance of reducing ozone to protect the environment, climate and human health. Further research is required on the interactions of precursor species and ozone, as well as on possible feedback effects. This will ensure that future reductions in nitrogen oxides and VOCs will result in significantly lower ozone concentrations for the adequate protection of human health, the environment and the climate.

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 guided by the belief that beyond the benefits it provides to people, nature has its own irreplaceable intrinsic value. For that reason, it champions sustainable lifestyles and modern forms of doing business that respect ecological limits.

DUH is a forum for environmental organisations, politicians and decision-makers from industry. At the same time we inform the general public and make environmental policy and law more transparent. Other important partners include critical citizens, environmentally- and health-conscious consumers as well as the media. Environmental Action Germany addresses the following topics: energy & climate protection, transport & air quality, urban environmental protection, circular economy, nature conservation & biodiversity, environmental education, and consumer protection.

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

Founded in 2009, the IASS is an international, interdisciplinary hybrid between a research institute and a think tank, located in Potsdam, Germany. The publicly funded institute promotes research and dialogue between science, politics and society on developing pathways to global sustainability. The IASS focuses on topics such as sustainability governance and economics, new technologies for energy production and resource utilisation, and Earth System challenges like climate change, air pollution, and soil management.

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