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The economic consequences of air pollution policies in Arctic Council countries: A sectoral analysis

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The economic consequences of air pollution policies in Arctic Council countries

A Sectoral Analysis

Environment Working Paper No. 212

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Abstract

Arctic Council countries have a critical role in reducing air pollution as, due to their proximity to the Arctic region, improving air quality serves the double purpose to preserve the Arctic climate and improve health and welfare in the region. To substantially reduce air pollution and its negative health and environmental impacts, emission reductions are necessary for all emitting sectors. However, each sector has its own characteristics so that policy action is not uniformly effective across sectors.

This report takes a modelling approach and compares a baseline scenario that reflects current legislation, with sectoral policy scenarios in which the best available techniques (BATs) to reduce emissions, are deployed by sector. In each sectoral scenario, firms and households invest in the BATs to reduce the emissions of air pollutants. The macroeconomic effects of policy action can be considered as GDP neutral (-0.02% with respect to the baseline scenario), with costs (-0.26%) and benefits (+0.24%) roughly offsetting each other. The results suggest that substantial benefits from air quality improvements can be obtained when considering emission reductions throughout the economy, and not just in the sectors that are targeted more often, such as industry and transport. Furthermore, the results highlight the need for a country-specific policy package as the current levels of policy stringency, the sectoral contributions, and the needs for sectoral investment in new technologies vary by country.

Keywords : air pollution, computable general equilibrium models, best available techniques

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Résumé

Les pays du Conseil de l'Arctique ont un rôle essentiel à jouer dans la réduction de la pollution atmosphérique car, en raison de leur proximité avec la région arctique, l'amélioration de la qualité de l'air sert le double objectif de préserver le climat arctique et d'améliorer la santé et le bien-être dans la région. Pour réduire sensiblement la pollution de l'air et ses effets négatifs sur la santé et l'environnement, des réductions d'émissions sont nécessaires pour tous les secteurs émetteurs. Or, chaque secteur a ses propres caractéristiques. Par conséquent, une action politique n'est pas uniformément efficace dans tous les secteurs.

Ce rapport adopte une approche de modélisation et compare un scénario de référence qui reflète la législation actuelle, avec des scénarios de politique sectorielle dans lesquels les meilleures techniques disponibles pour réduire les émissions, sont déployées par secteur. Dans chaque scénario sectoriel, les entreprises et les ménages investissent dans les meilleures techniques pour réduire les émissions de polluants atmosphériques. Les effets macroéconomiques de l'action politique peuvent être considérés comme neutres pour le PIB (-0,02 % par rapport au scénario de référence). Les coûts (-0,26 %) et les avantages (+0,24 %) se compensant à peu près. Les résultats suggèrent que des avantages substantiels de l'amélioration de la qualité de l'air peuvent être obtenus en tenant compte des réductions d'émissions dans l'ensemble de l'économie, et pas seulement dans les secteurs qui sont le plus souvent ciblés, tels que l'industrie et les transports. En outre, les résultats soulignent la nécessité d'un ensemble de politiques spécifiques à chaque pays, car les niveaux actuels de rigueur politique, les contributions sectorielles et les besoins d'investissement sectoriel dans les nouvelles technologies varient d'un pays à l'autre.

Mots clés : pollution de l'air, modèles d'équilibre général calculable, meilleures techniques disponibles

Classification JEL: C68, Q53, Q52

Acknowledgments

This report presents a sectoral analysis of the projected economic consequences of air pollution policies in Arctic Council countries to 2050. The report builds on the 2021 OECD report on "The economic benefits of air quality improvements in Arctic Council countries" and on the 2016 report "The economic consequences of outdoor air pollution", which was prepared as part of the OECD's CIRCLE project on the costs of environmental inaction.

This report was prepared by Daniel Ostalé Valriberas and Elisa Lanzi of the OECD Environment Directorate, Zbigniew Klimont of the International Institute for Applied Systems Analysis (IIASA), and Rita Van Dingenen of the European Commission's Joint Research Centre, under the guidance of Shardul Agrawala, Head of the Economy Environment Integration Division at OECD Environment Directorate.

The report benefitted from feedback of the Delegates of the Working Party on Integrating Environmental and Economic Policies (WPIEEP) during and after its meetings in November 2021 and November 2022 and from the valuable comments and suggestions of OECD colleagues, including Hugo Valin (OECD Trade and Agriculture Directorate), Jean Chateau (OECD Economics Department), Ruben Bibas and Rob Dellink (OECD Environment Directorate). The report was discussed by the WPIEEP and subsequently declassified by the Environment Policy Committee (EPOC) in January 2023. Illias Mousse Iye provided editorial support.

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Table of contents

FIGURES

TABLES

Executive summary

Air pollution is one of the most serious global environmental challenges, with adverse effects on human health, well-being, the environment and consequently also on the economy. In the Arctic, emissions of some air pollutants that are also short-lived climate forcers also contribute to atmospheric warming. Due to their proximity to the Arctic region, Arctic Council countries - Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States - can play a key role in reducing air pollutants, as polluting particles can reach the Arctic even when emitted in distant areas. Some of these particles – Black Carbon in particular – also have high global warming potential. Therefore, improving air quality in Arctic Council countries has the double purpose to preserve the Arctic climate and to improve air quality, health and welfare.

To substantially reduce air pollution and its negative health and environmental impacts, emission reductions are necessary for all emitting sectors: agriculture, transport, energy, industry, waste treatment, residential and commercial. With each sector contributing towards emissions of different air pollutants, having different technological options and emission reduction costs, the macroeconomic consequences of policy action can be expected to vary substantially across sectors.

This report quantifies the environmental, health and economic consequences of policy action on air pollution in Arctic Council countries with a focus on sectoral differences. The case of Arctic Council countries is particularly interesting due to the large differences in emission sources, emission levels and policy stringency across Members.

The report takes a modelling approach[1] and compares a baseline scenario that reflects current legislation, with a policy scenario in which the best available techniques (BATs) to reduce emissions, are deployed in all emitting sectors. In each sectoral scenario, firms and households invest in the BATs to reduce emissions of air pollutants. The sector-specific investment result in costs to the economy, which are compared to the economic benefits from the reduced air pollution impacts. Indeed, air quality improvements result in economic benefits from decreased health expenditures, as well as higher labour and agricultural productivity.

The sectoral emission composition is different by country. While in Russia, energy and industry represent a high share of emissions, in the United States the transport sector has the largest contribution and in the rest of Arctic Council countries, most emissions are caused by the residential sector. In the coming decades, current legislation will lead to emission reductions, except for methane and ammonia, which are projected to increase in the coming decades. However, the wide deployment of BATs could reduce emissions in all sectors, with a decrease by around 60% for most pollutants in Arctic Council countries altogether by the middle of the century. Aggregate emission reductions result from different sectoral contributions to overall abatement, which vary by pollutant.

Emission reductions by sector and by pollutant contribute unevenly to the overall decrease in concentrations of fine particulate matter ($PM_{2.5}$) and ground-level ozone. The reduction for each sector and pollutant sector depends on two factors. First, the potential for technological improvements in each specific sector. For instance, in Russia, the largest share of reductions in fine particulate matter concentration

[1] The analysis relies on the OECD's computable general equilibrium (CGE) model ENV-Linkages. The economic analysis with the ENV-Linkages model is supported by projections on emissions and technology costs from the GAINS model of the International Institute for Applied Systems Analysis (IIASA) and on the biophysical impacts of air pollution from the TM5-FASST model of the European Commission's Joint Research Centre (EC-JRC).

comes from technical improvements in industrial sectors. Second, the relative contribution of each sector to concentrations in the current legislation scenario, which depends on the different structures of the economy of the countries. For instance, in the United States, the agricultural sector is one of the sectors that contribute the most to concentrations of fine particles overall, primarily due to NH_3 emissions.

These air quality improvements result in better health, ensuing 136 thousand less air pollution-related deaths compared to the baseline scenario. The strongest reductions in air pollution-related mortality come from emission reductions in the agricultural sector, followed by the industrial sector, which constitutes a large share of air pollution-related deaths in Russia. In Nordic countries, the transport sector has a significant impact mainly due to shipping transport.

Besides improvements in human health, lower concentrations of ground-level ozone are estimated to increase crop yields. The strongest improvements in crop yields result from policy action in the energy sector, which correspond specifically to the reductions in nitrogen dioxide and methane. These are gases that drive concentrations of ground-level ozone as well as affect global warming in the case of methane.

The macroeconomic effect of policy action in Arctic Council countries can be considered as GDP neutral (-0.02% with respect to the baseline scenario), with costs (-0.26%) and benefits (+0.24%) offsetting each other. This result only considers market benefits and costs however, there are other welfare benefits from reducing premature mortality and air pollution-related illnesses that would increase the benefit of increasing air quality.

An analysis of sectoral effects, beyond the aggregate macroeconomic results, highlights the importance to consider all sectors in aiming to reduce emissions of air pollutants to the maximum feasible levels. Sectors that already have policies in place can reduce emissions relying on higher cost technological options, while sectors that have less policies on air pollution can exploit both low- and high-cost technological options available. For instance, deploying BATs in the agricultural sector results in higher macroeconomic benefits (+0.07%), compared to other sectors. This effect corresponds to the large contribution of this sector to air quality improvements and to the relatively lower cost of the BATs in this sector. On the other hand, investment in BATs in the residential and transport sectors appear to be more costly (-0.1% for transport and -0.09% for residential) while they lead to lower benefits (+0.02% for residential and almost zero for transport). This result does not however imply that emission reductions in the transport sector do not pay off. It is rather a result of the specific characteristics of the countries considered. Indeed, in most Arctic Council countries there is already a high level of emission reductions in the transport sector in the current legislation scenario.

Overall, the results presented in this report suggest that substantial benefits from air quality improvements can be obtained when considering emission reductions throughout the economy, and not just in the sectors that are targeted more often, such as industry and transport. This is especially the case for OECD countries that already have a high level of stringency in air pollution policies but could achieve substantial benefits by further reducing their emissions. Furthermore, the results highlight the need for a country-specific policy package as the current levels of policy stringency, the sectoral contributions, and the need for sectoral investment in new technologies vary by country. Additional research is needed to provide information on optimal country-specific policy packages.

1 Introduction

Air pollution is one of the most serious global environmental challenges, with adverse effects on human health, well-being and the environment. It has significant impacts on ecosystems and contributes to climate change, as some air pollutants, generally referred to as Short-Lived Climate Forcers (SLCF), such as black carbon (BC) and methane (CH_4), also have an impact on climate change. In particular, BC contributes to atmospheric warming and negatively affects the fragile Arctic environment due to its dark colour and high warming potential.

A recent report by the OECD (2021[1]) shows that policy action on air pollution in Arctic Council countries[2] would result in better air quality, and thus in health and economic improvements. This analysis shows that 80 000 air pollution-related deaths could be avoided in these countries yearly by 2050. Curbing air pollution would also reduce other illnesses such as asthma, bronchitis as well as cardiovascular illnesses. Finally, improved air quality leads to economic benefits through higher labour productivity, higher crop yields and lower health expenditures.

To achieve air quality levels that are in line with those recommended by the World Health Organisation, emissions of air pollutants need to be substantially reduced in all economic sectors. Various economic sectors contribute unevenly to the issue of air pollution, as each economic activity leads to emissions of a specific set of air pollutants and the emission intensity of production varies across sectors. Furthermore, the emission reduction potentials and the technologies available to reduce air pollution also vary by sector. Finally, the difference in technological options implies that the investment in Best Available Techniques (BATs) needed to reduce air pollution are also sector-specific.

While the existing literature focuses on the differences in emission reductions by sector (Caiazzo et al., 2013[2]; Lanzi, Dellink and Chateau, 2018[3]) and on the uneven economic implications of sectoral policies (Gu et al., 2018[4]) in the context of climate change, less efforts have been made to understand the macroeconomic consequences of sectoral air pollution policies. Only recently, Vandyck et al. (2020[5]) analysed the sectoral and regional differences in the abatement costs of both greenhouse gases (GHG) and fine particulate matter ($PM_{2.5}$).

This report aims at improving the understanding of the potential contribution of each sector to air quality improvement in Arctic Council countries, quantifying the socio-economic consequences of sectoral policy action on air pollution. The case of Arctic Council countries is of particular interest given the differences in economic structure, air pollution levels, and current technology options across the different countries. The report focuses on the technological improvements targeted at reducing emission sources in agriculture, road transport, energy, industry, waste treatment, residential and commercial and international shipping.

To analyse sectoral contributions to reducing air pollution, the report relies on the OECD's computable general equilibrium (CGE) model ENV-Linkages (Chateau, Dellink and Lanzi, 2014[6]), exploiting its detailed sectoral and regional structure. While ENV-Linkages is the main modelling tool used in the report, additional models are needed to quantify the health and economic consequences of air pollution. In particular, the report links economic projections obtained with the ENV-Linkages model, with emission and air pollution control cost projections from the GAINS model (Amann et al., 2011[7]) of the International

[2] The Arctic Council is comprised of the following countries: Canada, Denmark, Finland, Iceland, Norway, the Russian Federation (hereafter Russia), Sweden and the United States.

Institute for Applied Systems Analysis (IIASA) as well as calculations of the biophysical impacts of air pollution with the TM5-FASST model (Van Dingenen et al., 2018[8]) of the European Commission's Joint Research Centre (EC-JRC). The analysis uses concentrations of $PM_{2.5}$ and ground-level ozone (O_3) as the two main indicators of air quality, due to the negative health impacts associated with the pollutants.

Building on the framework of (OECD, 2021[1]), the report compares the costs and benefits of achieving the maximum feasible reduction in emissions in each sector in Arctic Council countries. It further considers how each sector contributes toward overall emission reductions. In each scenario, firms and households invest in sectoral BATs to reduce emissions of air pollutants. The sector-specific investment result in costs to the economy, which are compared to the economic benefits from the reduced air pollution impacts. Indeed, air quality improvements result in economic benefits from decreased health expenditures, as well as higher labour and agricultural productivity. Specific sectors and countries may also benefit from the changes in competitive positions induced by the policy.

The remainder of the report is structured as follows. Section 2 summarises the methodology and describes the policy scenarios. Section 3 provides an overview of the sectoral contributors to air pollution in Arctic Council countries and presents emission projections in the different scenarios. Section 4 presents the consequences of sectoral policy action, including changes in concentrations of $PM_{2.5}$ and O_3, the associated consequences for human health and crop yields, and the sectoral macroeconomic economic consequences of air pollution policies. Section 5 provides a discussion of the results.

2 Methodology and scenarios

2.1. Modelling framework

This report relies on a quantitative approach to assess the economic consequences of air pollution up until 2050, as used in previous OECD work (OECD, 2021[1]; OECD, 2016[9]). The modelling framework is based on a stepwise approach, which uses different modelling tools to link projections of (1) sectoral economic activities to (2) emissions of air pollutants, (3) concentrations of fine particulate matter and ground-level ozone, and finally to (4) the biophysical and (5) economic impacts of outdoor air pollution (Figure 2.1). These steps are repeated for each sectoral policy scenario. The economic benefit of policy action in each sector is calculated by comparing each sectoral scenario with the results from a baseline scenario, which assumes the implementation of current legislation (CLE).

Figure 2.1. Methodological steps

1) PROJECTIONS OF SECTORAL ACTIVITIES	• The OECD ENV-Linkages model provides projections of sectoral economic activities for 19 geographical regions and 32 sectors.
2) PROJECTIONS OF AIR POLLUTANT EMISSIONS	• IIASA's GAINS model provides emission projections for 95 countries and regions, building on ENV-Linkages' economic projections.
3) PROJECTIONS OF CONCENTRATIONS OF AIR POLLUTANTS	• The EC-JRC's TM5-FASST model uses emission projections to calculate grid-level concentrations for $PM_{2.5}$ and O_3.
4) PROJECTIONS OF THE BIOPHYSICAL IMPACTS OF OUTDOOR AIR POLLUTION	• Concentration-response functions, based on the Global Burden of Disease studies, provide projections of the health impacts of outdoor air pollution by country (e.g. numbers of deaths, cases of illnesses, work days lost), based on the country-average concentrations of $PM_{2.5}$ and O_3 obtained with the TM5-FASST model. • The EC-JRC's TM5 FASST model provides projections of agricultural impacts (i.e. lost crop yileds) by country.
5) PROJECTIONS OF THE ECONOMIC CONSEQUENCES OF OUTDOOR AIR POLLUTION	• The OECD ENV-Linkages model calculates projections of the macroeconomic consequences of air pollution for Arctic Council countries, based on the projected biophysical impacts and including the air pollution control costs provided by IIASA's GAINS model.

Source: Methodology based on OECD (2016[9]).

This methodology relies on a suite of modelling tools. The main model – used for the economic quantifications in steps (1) and (5) – is the OECD computable general equilibrium model ENV-Linkages, described in Chateau, Dellink and Lanzi (2014[6]). As described in step (2), ENV-Linkages provides projections of the economic activities to the GAINS model (Amann et al., 2011[7]; Höglund-Isaksson et al., 2020[10]; Klimont et al., 2017[11]; Gómez-Sanabria et al., 2018[12]), which in turn provides projections of air pollutants by country, including black carbon (BC), organic carbon (OC), sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), methane (CH_4), and ammonia (NH_3).[3] The emissions of these pollutants are also included in ENV-Linkages but with a higher regional aggregation.

Projected emissions are then used to calculate atmospheric concentrations of $PM_{2.5}$ and ground-level ozone. This constitutes step (3) and relies on the Fast Scenario Screening Tool TM5-FASST, a global air quality source-receptor model developed by the European Commission's Joint Research Centre (EC-JRC) (Van Dingenen et al., 2018[8]). The concentrations of pollutants are used to calculate the biophysical impacts of air pollution on human health and agriculture, which constitutes step (4). These biophysical impacts are described by a range of indicators, including mortality, hospital admissions and crop yields losses. Health impacts at the country level are obtained using concentration-response functions based on the results of the Global Burden of Disease project $PM_{2.5}$ (Forouzanfar et al., 2015[13]) and as described in OECD (2021[1]). Finally, the agricultural impacts are calculated using the TM5-FASST model, which estimates the crop yields changes associated with ground-level ozone concentrations (Van Dingenen et al., 2009[14]; Van Dingenen et al., 2018[8]).

Finally, the macroeconomic consequences of air pollution policies are calculated in step (5), based on (i) the macroeconomic benefits from increased air quality; and (ii) the macroeconomic costs from implementing such policies. The macroeconomic benefits from increased air quality come from decreased health expenditures, and higher labour and agricultural productivity. The macroeconomic costs from implementing more stringent air quality policies instead are related to the investment needed to deploy BATs. Both benefits and costs are included in ENV-Linkages model to calculate the net macroeconomic effects.

The net macroeconomic effects quantified reflect the impact of air pollution policies on the economic system, including impacts on expenditures, factor productivity, production, consumption, and trade. The indicator used for the macroeconomic effect is the gross domestic product (GDP), as in previous OECD work on the costs of environmental inaction (OECD, 2015[15]; OECD, 2016[9]). The modelling framework considers both direct and indirect effects. For instance, changes in households' health expenditures (direct costs) lead to changes in their consumption choices (indirect costs). Furthermore, in ENV-Linkages, higher government spending encourages firms to increase investment, therefore leading to a positive effect on economic growth that partly offsets the initial costs.

2.2. Policy scenarios

This report analyses the economic consequences of policies targeting air pollution, based on the OECD Computable General Equilibrium (CGE) model ENV-Linkages (Chateau, Dellink and Lanzi, 2014[6]). The report compares several policy scenarios that reflect the implementation of air pollution policies in various sectors to a reference baseline scenario, all with a 2050-time horizon.

The baseline scenario assumes the effective implementation of current legislation (CLE) globally in all sectors of the economy, including the eight Arctic Council countries. This scenario considers policies in place as well as legislated policies but it also assumes no changes to current legislation in place, i.e., no

[3] Due to lack of data, the report does not cover other pollutants that affect the Arctic region, such as mercury (AMAP/UN Environment, 2019[18]) and persistent organic pollutants (POPs) (AMAP, 2016[19]).

increase in ambition of air quality standards and therefore no further measures are introduced. It considers national and regional laws and regulations on emission limit values, energy efficiency and relating to climate change in place in 2017. The legislation covers emissions from a number of activities, including combustion plants, industrial processes, transport, agriculture, use of solvents and the residential sector.[4] In this current legislation scenario, growth is projected to be steady for OECD countries while non-OECD countries are projected to enjoy a high level of growth (OECD, 2019[16]).[5] Current legislation does not imply that emission levels are constant over time, as growth varies by country and sector. Furthermore, efficiency improvements (e.g., energy use and total factor productivity growth) imply a weak relative decoupling of emissions from output growth (i.e., emissions grow more slowly than production volumes and GDP).

All policy scenarios reflect the achievement of the maximum technically feasible reductions (MTFR) of emissions in the eight Arctic Council countries, referred to as the MTFR-AC scenario. For this scenario, the GAINS model provides data on the investment needed to reduce air pollution, corresponding to the technologies deployed in each sector to reduce emissions. Investment is included in ENV-Linkages for the various sectors to study the economic consequences of the sectoral policies. This scenario is central since it serves as a basis for the sectoral analysis.

The MTFR-AC scenario explores the extent to which emissions could be further reduced through the policy-induced application of all existing best available techniques (BATs) to reduce emissions, in addition to the implementation of current regulations. The reduction of air pollutants comes from the introduction of more stringent limits for large scale stationary processes and combustion, road and non-road vehicles, medium and small-scale residential boilers. Additional incentives and regulations are assumed to assure steady improvement of energy and nutrient efficiency as well as more efficient application of organic and mineral nitrogen fertilizers resulting in a reduction of ammonia and soil NO_x emissions. Evaporative NMVOC losses from the storage and distribution of liquid fuels can be reduced by installing capture and recovery systems, while policies to reduce emissions from solvents use could include incentives to increase the application of low solvent and water-based paints and products. For methane, additional policies include for instance instruments aiming at reducing venting emissions from fossil fuel (coal, oil, gas) production and distribution, incentivising the development of efficient waste management systems for industrial and municipal water and solid waste, limiting emissions from rice production, and increasing farm-based biogas production capacity. The introduction of these policies assures that the maximum technical mitigation potential is achieved in all sectors.

To illustrate the macroeconomic impact of sectoral technological improvements, this report focuses on five sectoral emission sources: agriculture (which includes solvent use and agricultural waste burning), transport (which includes international shipping transport), energy, industry and residential and commercial. Sectoral scenarios are implemented individually. For instance, the agriculture scenario corresponds to a scenario where the agricultural sector implements the maximum technically feasible reductions to abate pollutant emissions in Arctic Council countries while the rest of the sector and countries maintain current legislation.

[4] A detailed description of the emissions control policies considered is provided Amann et al. (2018[21]) . For a detailed description of the climate, energy use and energy efficiency policies, please refer to the New Policies Scenario of the World Energy Outlook 2018 (IEA, 2018[20]).

[5] OECD (2019[16]) details the key assumptions and exogenous trends underpin this scenario.

3 Sectoral emissions and potential for emission reductions

3.1. Sectoral sources of air pollution in Arctic Council countries

To improve air quality in Arctic Council countries, emissions need to be reduced in all the main emitting sectors and targeting the range of pollutants that drive the concentrations of fine particulate matter, which is the main driver of the health impacts of air pollution. Specifically, it is necessary to reduce emissions of primary $PM_{2.5}$ – including black carbon (BC) and organic carbon (OC) - and of other pollutants that contribute to the formation of secondary $PM_{2.5}$, which include sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and non-methane volatile organic compounds (NMVOCs).

According to estimates from IIASA's GAINS model, transport, including shipping, is an important source of air pollution in Arctic Council countries.[6] It contributes significantly to the formation of $PM_{2.5}$ and ground-level ozone. Transport accounts for half of NO_x and BC emissions and for one-quarter of organic carbon and NMVOCs emissions in the region (Figure 3.1).

Energy and industry sectors are other key sources of pollution in Arctic Council countries. Together, energy production and consumption, and the industrial sector are responsible for nearly all SO_2 emissions (54% energy and 39% industry) and one-third of NMVOCs and NO_x emissions in the region. The energy sector is also responsible for a significant share of BC (17%) emissions, which accounts for 90% of all the BC emissions in this sector.

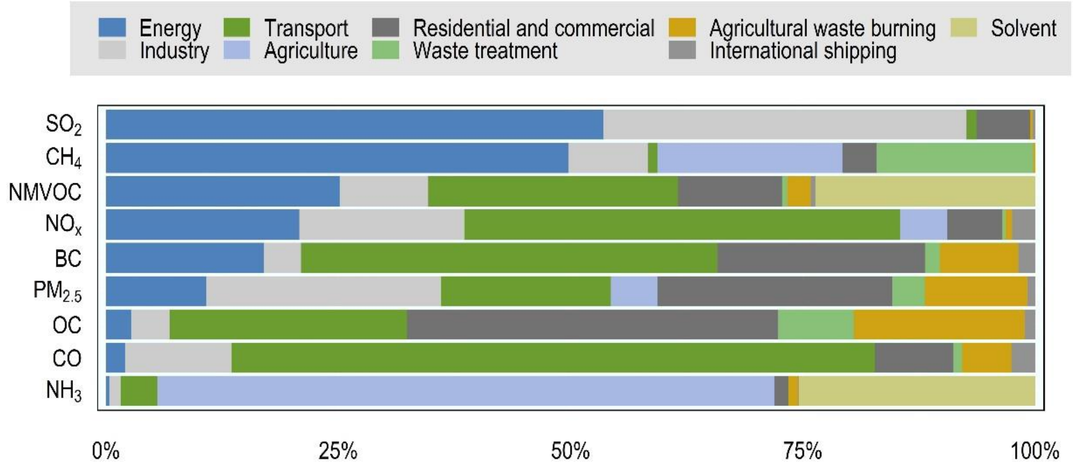
The residential sector is a key contributor to the emissions of primary and formation of secondary $PM_{2.5.}$ In particular, the combustion of solid and liquid fuels for domestic heating is a major source of organic carbon (40%) and black carbon (over 20%), while also contributing to NMVOCs (11%), NO_x (6%) and SO_2 (6%) emissions in the region.

Finally, the agricultural sector is a major contributor to NH_3 (66%) emissions, and NMVOCs (25%) Other emissions are associated with agricultural activity, such as the use of solvents, responsible for 25% of NH_3 and 24% NMVOC, as well as agricultural waste burning, that emits 20% of the OC emissions, 11% of $PM_{2.5}$ and 8% of BC emissions in Arctic Council countries.

[6] Transport emissions include road, rail, maritime and air transport, for merchandise as well as personal transportation and including both domestic and international transportation.

Figure 3.1. Emissions of air pollutants in Arctic Council countries

Sectoral shares in 2019



Note: "Residential" emissions are due to wood and other fuels combustion. $PM_{2.5}$ refers to primary emissions only.
Source: IIASA's GAINS model.

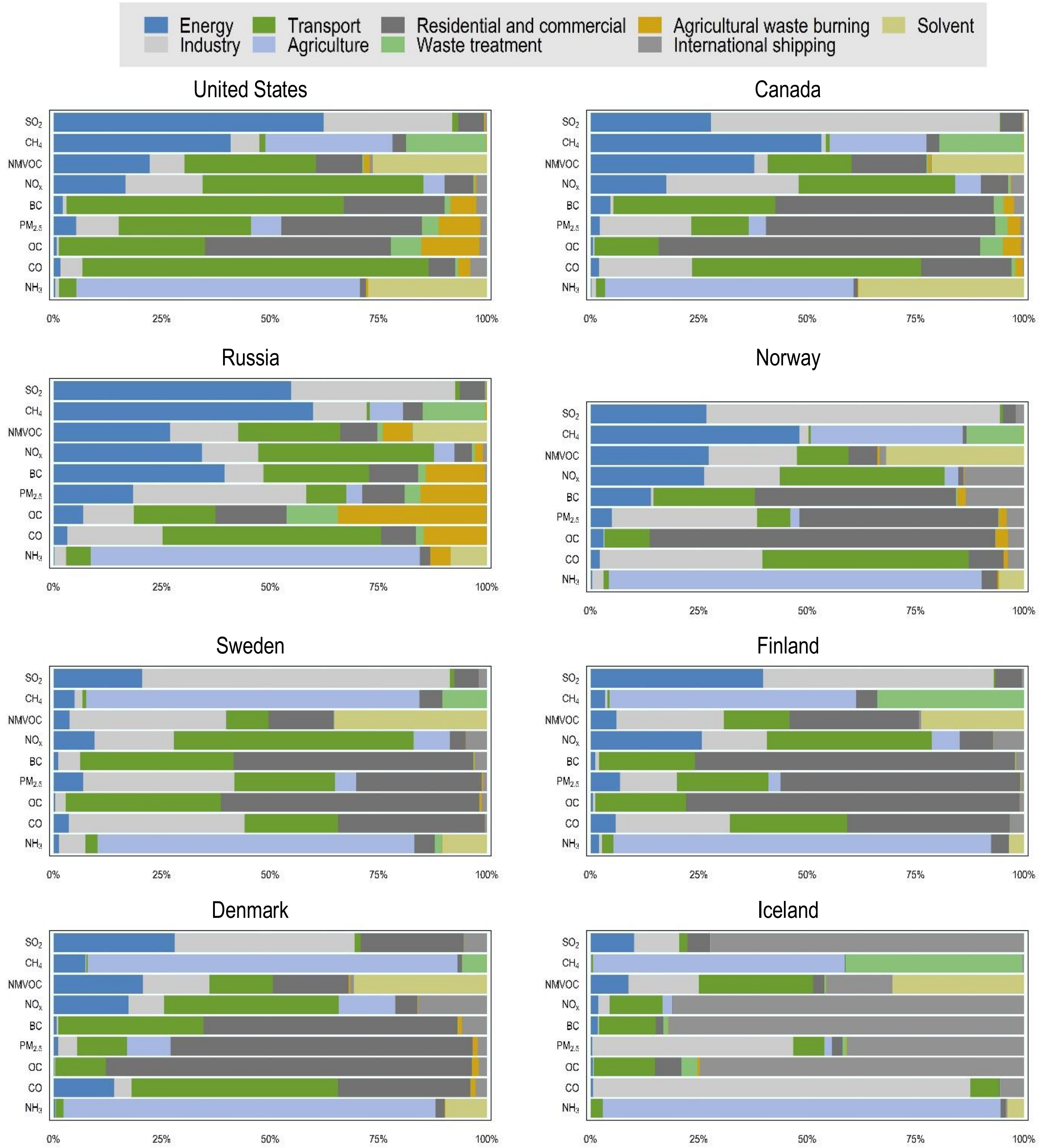
Although ground-level ozone is not directly emitted to the atmosphere, human activities contribute to the emission of its precursor gases, which include methane (CH_4), NMVOCs, NOx, and carbon monoxide (CO). In Arctic Council countries, the transport and power generation sectors emit large shares of these pollutants (Figure 3.1). Most notably, emissions of methane and CO, which are particularly relevant to ground-level ozone formation, are largely driven by energy-related emissions (50% of methane emissions), and by transport emissions (69% of CO emissions from land transport and 3% from shipping).

Despite some similarities in the sectoral composition of certain pollutants (e.g. NH_3), sectoral emissions vary across countries (Figure 3.2). For instance, a high share of emissions is caused by the residential sector in Canada and in most Nordic countries,[7] while energy and industry represent a high share of emissions in Russia. In the United States, the transport sector represents a significant share of overall emissions, especially for CO and BC.

[7] Nordic countries include Denmark, Finland, Iceland, Norway, and Sweden.

Figure 3.2. Emissions of air pollutants by country

Sectoral shares in 2019



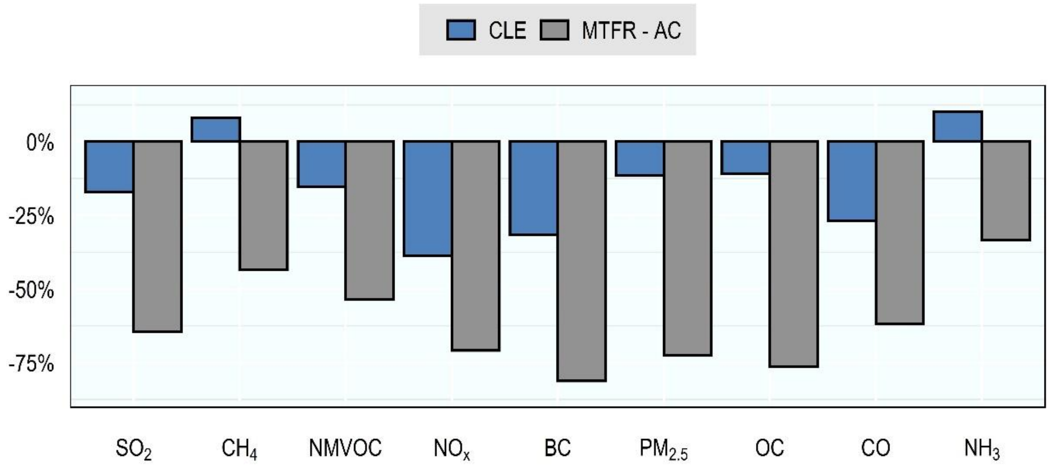
Note: “Residential” emissions are due to combustion of wood and other fuels. $PM_{2.5}$ refers to primary emissions only.
Source: IIASA’s GAINS model.

3.2. Emission projections

Based on current legislation, emissions in Arctic Council countries are projected to decrease in the coming decades. Altogether, in the current legislation scenario, by the middle of the century, Arctic Council countries are projected to see emissions of most pollutants fall by 20% to 40%, depending on the pollutant (Figure 3.3). Only emissions of ammonia (NH_3) and methane (CH_4) increase in the current legislation scenario. The increase in NH_3 emissions is mostly due to the agricultural sector, while CH_4 emissions are largely from the residential and commercial sectors.

Figure 3.3. Projected emissions of key air pollutants in Arctic Council countries

Percentage change in 2050 compared to 2019 levels



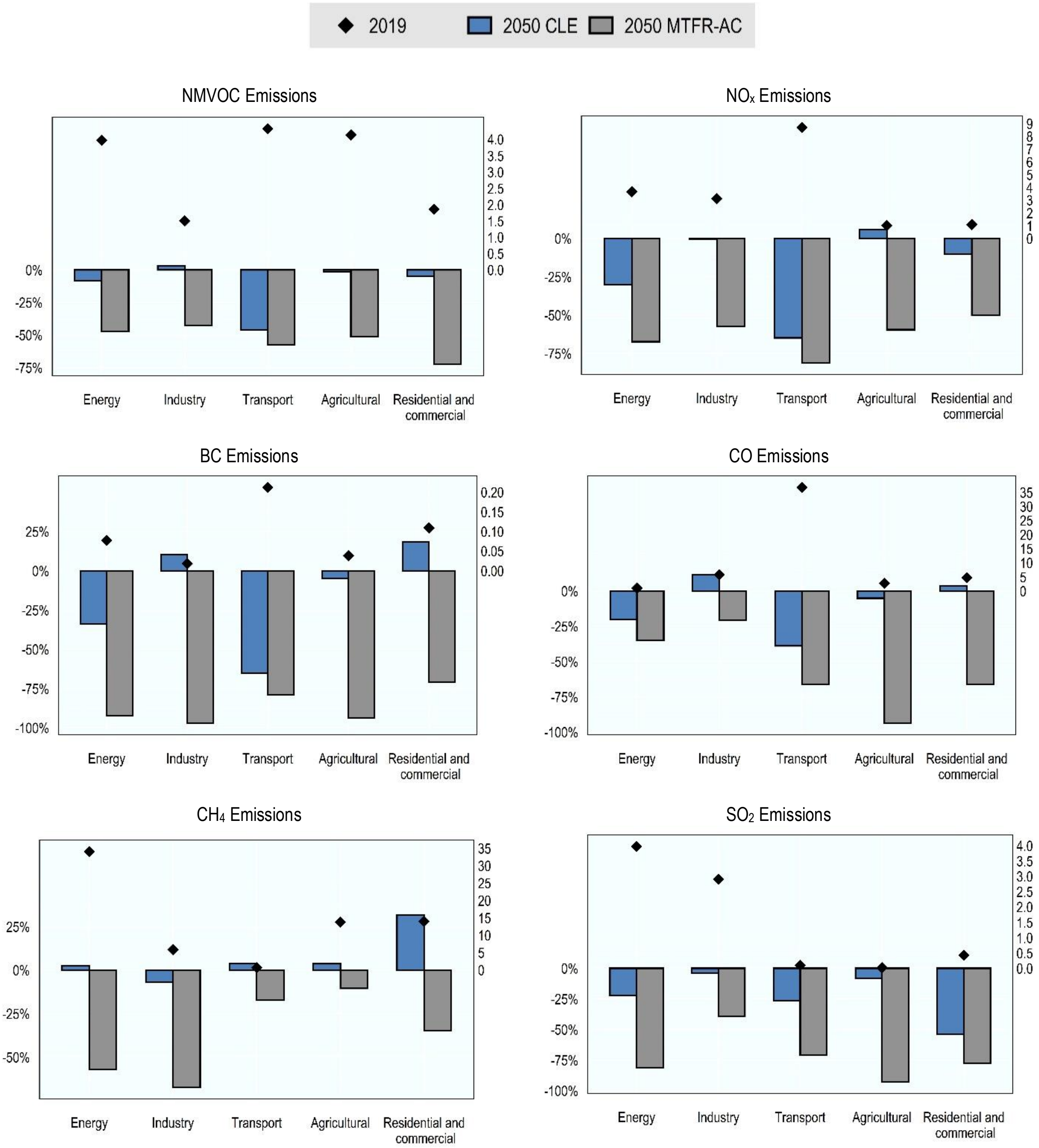
Source: IIASA's GAINS model.

The implementation of policies to deploy the best available techniques could achieve much greater emission reductions. Indeed, in the scenario reflecting the Maximum Technically Feasible Reduction in emissions in Arctic Council countries (MTFR-AC), NO_x, SO_2, and CO emissions are projected to decrease by 60% by the middle of the century. Methane and Ammonia emissions reverse their projected trends and decrease by 43% (CH_4) and 33% (NH_3).

Aggregate emission reductions result from different sectoral contributions to overall abatement, which vary by pollutant (Figure 3.4). In the current legislation scenario, the largest emission reductions are projected to take place in the transport sector, especially for CO, BC, and NO_x while energy and industry are responsible for emission reductions of SO_2 in the current legislation scenario. However, not all sectors reduce their emissions. For instance, BC, CO and CH_4 emissions are projected to increase in the residential sector while CO emissions also increase in the energy and industry sectors.

Figure 3.4. Projected sectoral emissions by pollutant in Arctic Council countries

Mt emitted in 2019 (right axis); percentage change in 2050 compared to 2019 (left axis)



Note: Right axis Mt/year: (Million tonnes per year), in the left axis percentage emission reduction with respect to 2019 levels. The graphs use different scales.
Source: IIASA's GAINS model.

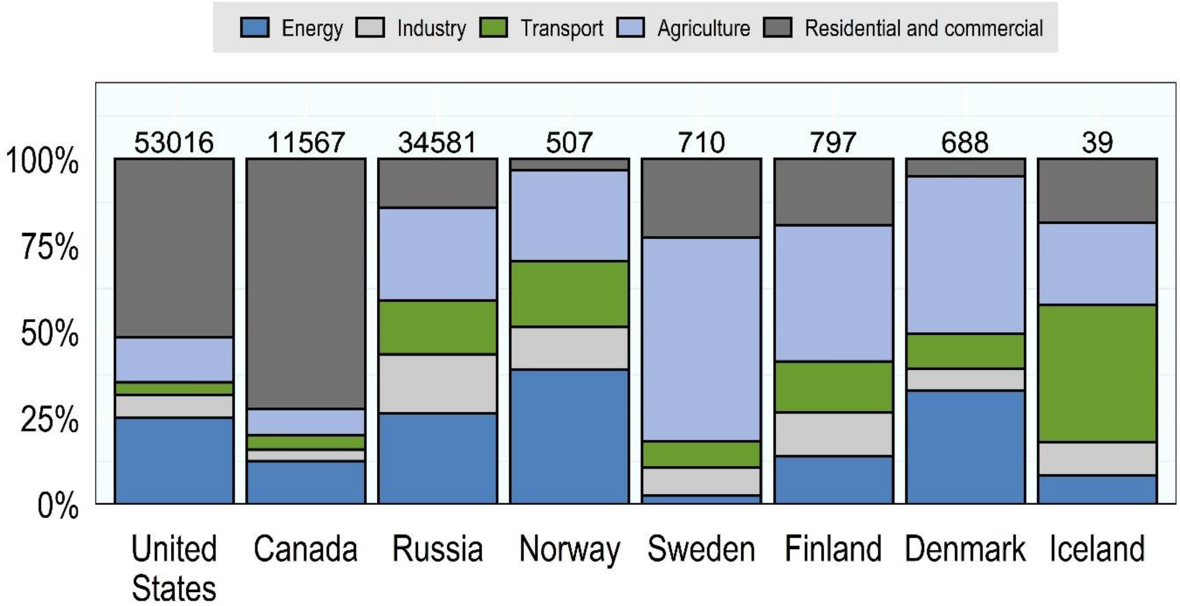
In the MTFR-AC scenario, there will be further sectoral emission reduction in sectors and regions in which emissions are already projected to decline with current legislation and reversing the trend for other emission sources. For instance, in the residential and commercial as well as in the energy sector, emissions of methane (CH_4) will decrease by more than 60% compared with current legislation in 2050. Reduction in the residential sector derives from the development of more efficient waste management systems for industrial and municipal water and solid waste while in the energy sector it is due to improvements in venting emissions from fossil fuel production and distribution. Therefore, the implementation of improved waste management systems can benefit different environmental issues, including not only air pollution and climate change but the transition to a circular economy.

3.3. Sectoral investment in Best Available Techniques

These emission reductions are the consequence of investment in BATs in each sector in Arctic Council countries (Figure 3.5). Investment are higher in sectors where fewer air pollution-related measures have been taken in place, such as the agricultural sector, where both low- and high-cost technologies are needed to reach the maximum feasible reduction in emissions. Sectors such as transport already have several regulations in place. Thus, most low-cost technologies are in place, leaving fewer and more expensive options. Similarly, country differences depend on already existing policies and technology. The United States and Canada require relatively more investment in the residential and commercial sector while in Nordic countries, more investment is needed in the agricultural sector.

Figure 3.5. Arctic Council country investment in BATs

Value in million USD, 2017 PPP exchange rates, MTFR-AC scenario, 2050



Note: In the graph, the left axis represents the share of investment in each sector. The figure at the top of each bar represents the total investment in BATs in million USD, 2017 PPP exchange rates.
Source: IIASA's GAINS model.

4 The socio-economic benefits of sectoral air pollution policies

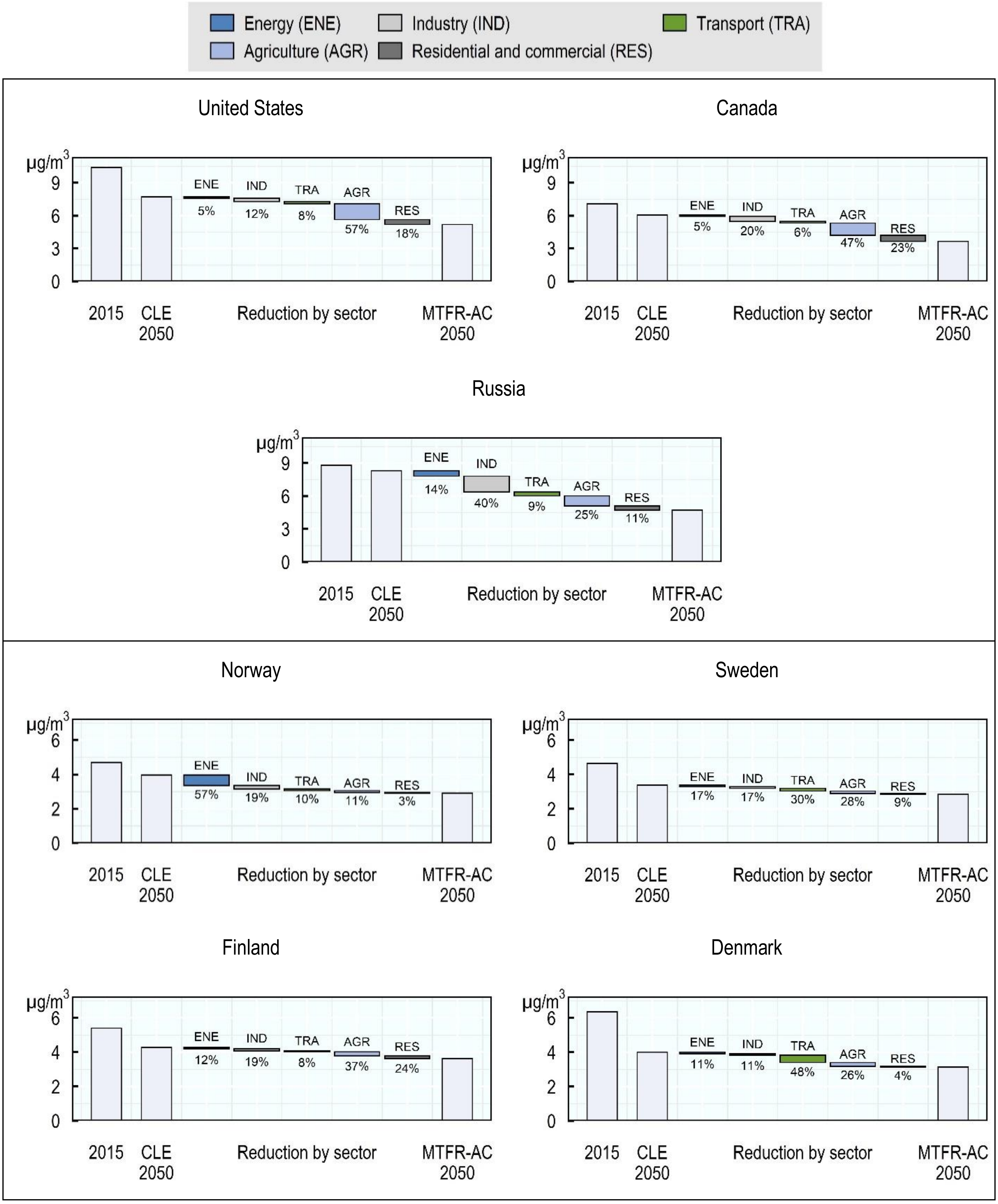
4.1. Air quality benefits

Following the decline in emissions in Arctic Council countries, $PM_{2.5}$ concentrations are projected to decrease even in the absence of further policy action (Figure 4.1), especially in the United State, Finland, and Denmark. However, by 2050 the additional policies in the MTFR-AC scenario would lead to an even greater improvement in air quality.

Emission reductions in the different sectors contribute unevenly to the overall decrease in concentrations in the MTFR-AC scenario (Figure 4.1). In the United States, the agricultural sector accounts for half of the total reduction in $PM_{2.5}$ concentrations, while in Russia, the largest contribution comes from emission reductions in the industrial sector, and in Norway, a large share comes from energy-related emissions. These differences depend on two main factors. First, the changes in sectoral emissions in each country, which in turn depend on the potential for technological improvements in each specific sector. For instance, in Russia, the largest share of reductions in $PM_{2.5}$ emissions comes from improvements in the industrial sector. Second, the differences depend on the relative contribution of each sector to concentrations in the current legislation scenario. For instance, in the United States, the agricultural sector is one of the sectors that contributes the most to concentrations of fine particles.

Figure 4.1. Country specific changes in population weighted $PM_{2.5}$ concentrations

Sectoral policy action in Arctic Council countries only, 2050



Note: In light grey absolute concentration level in microgram per cubic meter in the CLE and MTFR-AC scenarios. The graphs use different scales.
Source: TM5-FASST model.

4.2. Health benefits

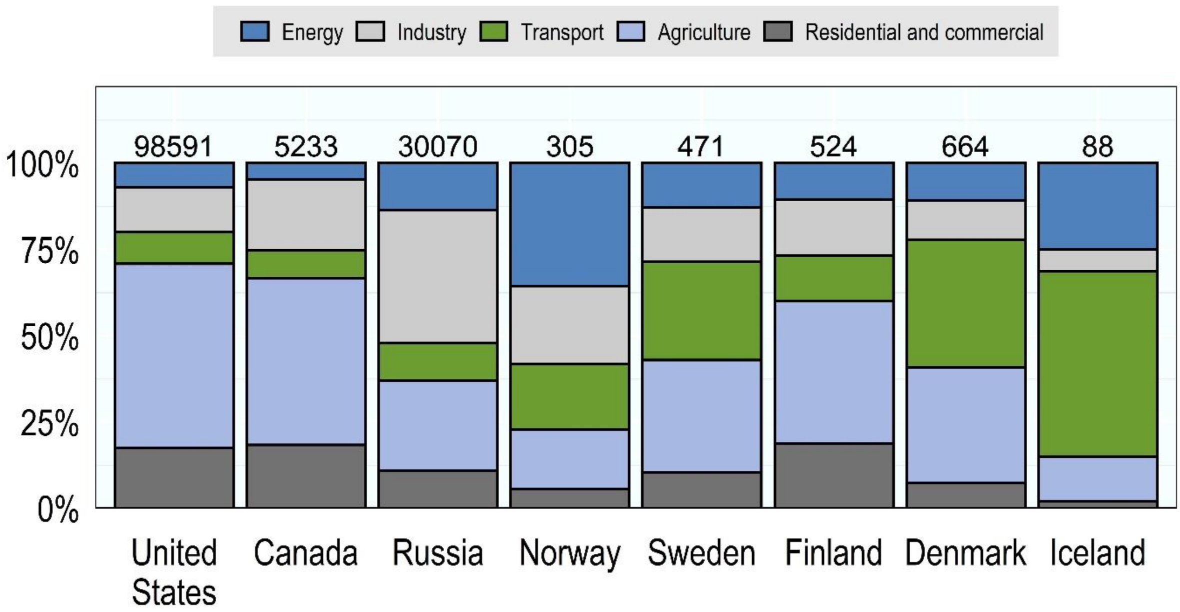
In Arctic Council countries, fine particulate matter and ground-level ozone are responsible for more than 200 000 deaths every year (OECD, 2021[1]). One third of this air pollution-related mortality could be avoided thanks to the wide deployment of BATs, with around 80 thousand less air pollution-related deaths yearly by 2050.

While policies in the various sectors act together to reduce air pollution and its health impacts, considering emission reductions by sector can help decompose the contribution of each sector to health benefits from policy action. Based on the reductions in concentrations of fine particles and ground-level ozone (presented in Section 4.1), it is possible to quantify changes in air pollution-related mortality from policy action in each sector therefore showing the relative contributions of each sector to health benefits from air quality improvements.

In most countries, policy action to reduce air pollution in the agricultural sector leads to a large share of the avoided air pollution-related mortality: 20 thousand, mostly taking place in the United States and Canada. Policy action in the industrial sector also contributes to avoiding a large share of reduced deaths: 15 thousand, mostly taking place in Russia (Figure 4.2). In Nordic countries, policies that lead to emission reductions from transport (mainly shipping) have a significant impact, especially compared with other Arctic Council countries.

Figure 4.2. Avoided air pollution-related deaths

2050



Note: In the top legend, the absolute value of avoided air pollution-related mortality, in the left axis the share by sector. The agricultural sector includes agricultural waste burning and solvent use.
Source: ENV-Linkages' model projections, based on Global Burden of Disease (GBD, 2018[17]).

4.3. Benefits for agricultural productivity

Besides improvements in human health, ground-level ozone pollution also reduces plants' physiological functions, resulting in lower crop yields. Increasing air quality in Arctic Council countries is therefore projected to increase crop yields (Table 4.1). The strongest improvements come from policy action in the energy sector, which corresponds specifically to the reductions in NO_x, one of the gases that contribute to the formation of ground-level ozone.

The increase in crop yields is spread to all the Arctic Council countries. For each country, the overall effect on agricultural production will depend on the increase in crop yields but also on crop production levels, as well as crop production. For instance, the production of maize is 10 times larger in the United State than in the rest of the Arctic council together, therefore, a change in crop yields in this country would have a larger effect.

Table 4.1. Projected increase in crop yields in the policy action scenarios

Percentage increase in crop yields in MTFR-AC compared to current legislation scenario in Arctic council countries, 2050

	Maize	Soybean	Wheat	Rice
Agriculture	2%	2.5%	2.6%	5%
Residential and commercial	2.3%	2.4%	2.3%	2.8%
Industry	4.2%	4.3%	4%	5%
Energy	6.1%	6.3%	5.9%	7.5%
Transport	2.2%	4.7%	2.5%	3.5%

Note: Rows contains the sectoral policy scenario while columns differentiate effects for the different cereals considered in the report.
Source: EC-JRC's TM5 FASST Model

4.4. Economic consequences of sectoral air pollution policies

Health and environmental benefits, in the form of higher agricultural productivity, also have positive consequences on economic output and growth. Following the methodology of OECD (2021[1]), macroeconomic benefits are associated with increased labour productivity, reduced of health expenditure, and increased agricultural productivity.[8] However, these benefits come with the costs associated with the investment in BATs.

The macroeconomic effect of policy action in Arctic Council countries can be considered GDP neutral when BATs are deployed in all sectors (Figure 4.3). In the sectoral scenarios considered, both macroeconomic benefit and cost are small since the sectoral changes in emissions and concentrations only bring about one part of the overall health and environmental benefits and correspond to only part of the BAT investment.

While overall costs and benefits offset each other, this aggregate effect hides large disparities across sectors. Deploying BATs in the agricultural sector results in higher macroeconomic benefits, compared to other sectors. This effect corresponds to the large contribution of this sector to air quality improvements, as outlined in Section 3. On the other hand, investment in BATs in the residential and transport sectors

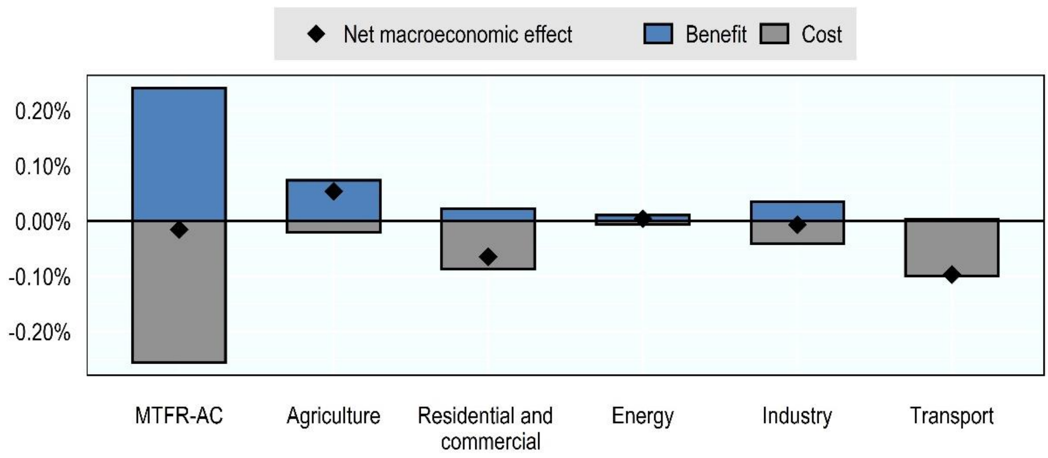
[8] This report only considers market impacts from better air quality while there are other welfare benefits associated to it. OECD (2021[1]) quantifies the welfare improvements in from lower risk of mortality and lower incidence of illnesses in the MTFR-AC scenario for all Arctic Council countries. These non-market effects result in large economic benefits from air quality improvements.

appear to be more costly and lead to lower benefits. This result does not however imply that emission reductions in the transport sector do not pay off. It is rather a result of the specific characteristics of the countries considered as well as the existing investment already accounted in the CLE scenario. In most Arctic Council countries, there is already a high level of emission reductions in the transport sector in the current legislation scenario. Therefore, the transport scenario mostly reflects the deployment of more expensive technological options.

This result supports the idea that air pollution reduction policies such as those carried out in the transport sector have been and continue to have positive effects on air quality. However, additional benefits can be obtained considering emission reductions in sectors that are not frequently targeted, such as the those from the agricultural sector.

Figure 4.3. Macroeconomic consequence of BAT investment in Arctic Council countries

Percentage change in GDP compared to CLE, 2050



Note: The MTFR-AC simulation considers policy action in all sectors.
Source: OECD ENV-Linkages model.

Most macroeconomic benefits are due to the health improvements that follow the emission reductions.[9] Therefore, the sectoral results reflect the relative changes in emissions and concentrations, with GDP benefits being higher when BATs are deployed in the agricultural sector (+0.07% GDP in 2050, compared to the current legislation scenario), followed by the industrial sectors (+0.04%) and residential (+0.03%).

Concerning the macroeconomic costs, reducing residential and transport emissions results in higher costs, compared to other sectors. Investment in BATs in these sectors would reduce the aggregate GDP of Arctic Council countries by 0.09% in the transport sector scenario and 0.08% in the residential scenario, compared to the current legislation scenario. Macroeconomic costs from reducing emissions in the agricultural sector are the lowest since some emission reductions could also be obtained from better practices with low costs.

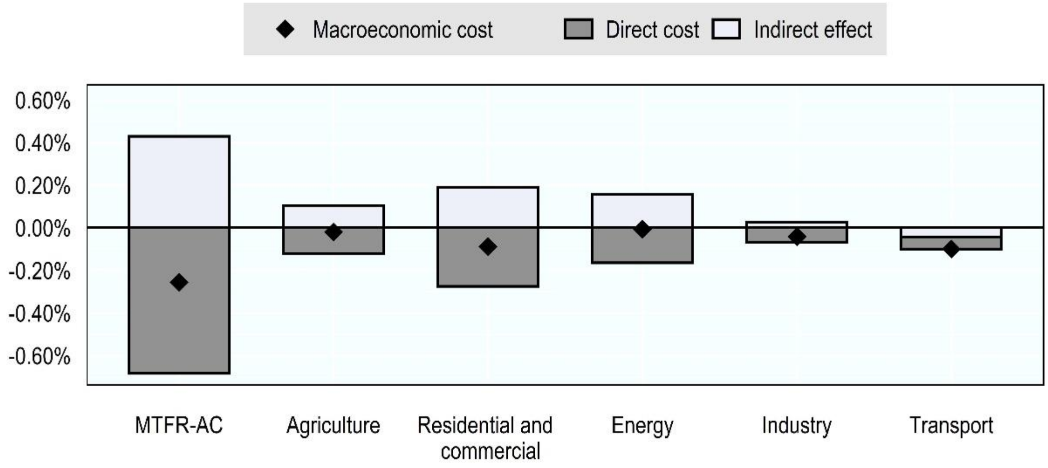
The macroeconomic costs can be decomposed into direct and indirect effects (Figure 4.4). Direct costs represent the investment in BATs, which are higher in the residential, energy and agricultural sector. Sectoral investment in more efficient technologies results in a boost in economic growth, which represent

[9] By using a similar methodology, OECD (2022[30]) shows that most of the macroeconomic benefits come from increase in labour productivity followed by reduction in health expenditure and increase in agricultural productivity.

an indirect effect of investing in such technologies. Indirect effects are positive to most sectors, offsetting at least partially the direct costs. The only exception is the transport sector, where the indirect effects are negative. This is due to a loss in competitiveness and therefore in the trade balance, which means that the countries rely less on transport.

Figure 4.4. Decomposition of effects leading to the macroeconomic cost

Percentage change in GDP compared to current legislation, 2050



Note: The results in this figure reflect simulations implemented with investment costs only, i.e., disregarding the benefits from reduced air pollution impacts. The macroeconomic costs (diamonds) correspond to the macroeconomic costs (grey bars) in Figure 4.3.
Source: OECD ENV-Linkages model.

5 Discussion

While the analysis presented in this report focuses specifically on benefits from health[10] and crop yields improvements, there are additional benefits from air pollution that could not be quantified, such as those on biodiversity and ecosystems and the interactions with climate change, which are particularly relevant for preserving the Arctic environment. An overview of additional benefits is presented in OECD (2021[1]). Furthermore, as mentioned in Section 4, this report focuses on market impact while there are additional benefits from improving air quality, such as the decrease in air pollution-related deaths and the welfare improvements that result from the reduction in air pollution-related illnesses (OECD, 2021[1]).

The framework used in this report provides information on the contribution of sectoral policies in improving air quality, without focusing on the optimization of the investment to increase air quality. An optimisation exercise over costs in the various sectors would need to consider the relative contribution to costs and benefits of each pollutant in each sector and would not be possible with the current available tools. Nevertheless, the report provides information on the heterogeneity of the macroeconomic effects of sectoral investment.

The results of the modelling analysis presented in this report are subject to uncertainties concerning the emission projections, including the link between concentrations and exposure to air pollution, the quantification of the biophysical impact, and the economic projections. In addition, there are some limitations in combining different modelling tools.[11]

Despite uncertainties about the exact figures presented in this report, there are clear environmental, health and welfare benefits to scaling up commitments to reduce air pollution in Arctic Council countries. The sectoral analysis highlights the need for each country to focus on the largest emission sources and exploit technological options, especially in sectors that can lead to higher benefits.

[10] Besides the ones considered in the report, air pollution can also have other impacts on health, affecting fertility (Nieuwenhuijsen et al., 2014[22]), cognitive abilities in children (Allen et al., 2017[23]; Basner et al., 2014[24]) and low weight at birth (Wang et al., 1997[25]). There are other pollutants like SO_2 and NO_x that have a direct impact on human health (WHO, 2013[28]; Walton et al., 2015[29]), as well as increased mortality (RCP, 2016[27]). Finally, exposure to air pollution can also exacerbate the consequences of diseases that affect the respiratory system, such as COVID-19 (Wu et al., 2020[26]).

[11] See Figure 2.1.

References

Allen, J. et al. (2017), "Cognitive Effects of Air Pollution Exposures and Potential Mechanistic Underpinnings", *Current Environmental Health Reports*, Vol. 4/2, pp. 180-191, https://doi.org/10.1007/s40572-017-0134-3. [23]

Amann, M. et al. (2018), *Progress towards the achievement of the EU's air quality and emissions objectives*, International Institute for Applied Systems Analysis (IIASA). [21]

Amann, M. et al. (2011), "Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications", *Environmental Modelling & Software*, Vol. 26/12, pp. 1489-1501, https://doi.org/10.1016/j.envsoft.2011.07.012. [7]

AMAP (2016), *AMAP Assessment 2015: Temporal Trends in Persistent Organic Pollutants in the Arctic. Arctic Monitoring and Assessment Programme (AMAP)*, AMAP, Tromsø. [19]

AMAP/UN Environment (2019), *Technical Background Report for the Global Mercury Assessment 2018*, AMAP/UN Environment, Tromsø. [18]

Basner, M. et al. (2014), "Auditory and non-auditory effects of noise on health", *The Lancet*, Vol. 383/9925, pp. 1325-1332, https://doi.org/10.1016/s0140-6736(13)61613-x. [24]

Caiazzo, F. et al. (2013), "Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005", *Atmospheric Environment*, Vol. 79, pp. 198-208, https://doi.org/10.1016/j.atmosenv.2013.05.081. [2]

Chateau, J., R. Dellink and E. Lanzi (2014), "An Overview of the OECD ENV-Linkages Model: Version 3", *OECD Environment Working Papers*, No. 65, OECD Publishing, Paris, https://dx.doi.org/10.1787/5jz2qck2b2vd-en. [6]

Forouzanfar, M. et al. (2015), "Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013", *The Lancet*, Vol. 386/10010, pp. 2287-2323, https://doi.org/10.1016/S0140-6736(15)00128-2. [13]

GBD (2018), *Global Burden of Disease Study 2017: All cause Mortality and Life Expectancy 1950-2017, Global Burden of Disease Collaborative Network.*, Seattle, United States: Institute for Health Metrics and Evaluation (IHME). [17]

Gómez-Sanabria, A. et al. (2018), "Carbon in global waste and wastewater flows – its potential as energy source under alternative future waste management regimes", *Advances in Geosciences*, Vol. 45, pp. 105-113, https://doi.org/10.5194/adgeo-45-105-2018. [12]

Gu, Y. et al. (2018), “Impacts of sectoral emissions in China and the implications: air quality, public health, crop production, and economic costs”, *Environmental Research Letters*, Vol. 13/8, p. 084008, https://doi.org/10.1088/1748-9326/aad138. [4]

Höglund-Isaksson, L. et al. (2020), “Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model”, *Environmental Research Communications*, Vol. 2/2, p. 025004, https://doi.org/10.1088/2515-7620/ab7457. [10]

IEA (2018), *World Energy Outlook 2018*, International Energy Agency, Paris, https://dx.doi.org/10.1787/weo-2018-en. [20]

Klimont, Z. et al. (2017), “Global anthropogenic emissions of particulate matter including black carbon”, *Atmospheric Chemistry and Physics*, Vol. 17/14, pp. 8681-8723, https://doi.org/10.5194/acp-17-8681-2017. [11]

Lanzi, E. et al. (2022), “The economic benefits of international co-operation to improve air quality in Northeast Asia: A focus on Japan, Korea and China”*, OECD Environment Working Papers*, No. 197, OECD Publishing, Paris, https://doi.org/10.1787/5c5ee1a3-en. [30]

Lanzi, E., R. Dellink and J. Chateau (2018), “The sectoral and regional economic consequences of outdoor air pollution to 2060”, *Energy Economics*, Vol. 71, pp. 89-113, https://doi.org/10.1016/j.eneco.2018.01.014. [3]

Nieuwenhuijsen, M. et al. (2014), “Air pollution and human fertility rates”, *Environment International*, Vol. 70, pp. 9-14, https://doi.org/10.1016/j.envint.2014.05.005. [22]

OECD (2021), *The Economic Benefits of Air Quality Improvements in Arctic Council Countries*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9c46037d-en. [1]

OECD (2019), *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264307452-en. [16]

OECD (2016), *The Economic Consequences of Outdoor Air Pollution*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264257474-en. [9]

OECD (2015), *The Economic Consequences of Climate Change*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264235410-en. [15]

RCP (2016), *Every breath we take: the lifelong impact of air pollution | RCP London*, Report of a working party of the Royal College of Physicians. London., https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution (accessed on 30 November 2020). [27]

Van Dingenen, R. et al. (2018), “TM5-FASST: A Global Atmospheric Source–receptor Model for Rapid Impact Analysis of Emission Changes on Air Quality and Short-lived Climate Pollutants”, *Atmospheric Chemistry and Physics*, Vol. 18, pp. 16173-16211, https://doi.org/10.5194/acp-18-16173-2018. [8]

Van Dingenen, R. et al. (2009), “The global impact of ozone on agricultural crop yields under current and future air quality legislation”, *Atmospheric Environment*, Vol. 43/3, pp. 604-618, https://doi.org/10.1016/j.atmosenv.2008.10.033. [14]

Vandyck, T. et al. (2020), "Quantifying air quality co-benefits of climate policy across sectors and regions", *Climatic Change*, Vol. 163/3, pp. 1501-1517, https://doi.org/10.1007/s10584-020-02685-7. [5]

Walton, H. et al. (2015), *Understanding the Health Impacts of Air Pollution in London For: Transport for London and the Greater London Authority*, Title: TFL 90419 Task 5: Understanding the Health Impacts of Air Pollution in London, https://www.london.gov.uk/sites/default/files/HIAinLondon_KingsReport_14072015_final_0.pdf (accessed on 30 November 2020). [29]

Wang, X. et al. (1997), "Association between air pollution and low birth weight: a community-based study.", *Environmental Health Perspectives*, Vol. 105/5, pp. 514-520, https://doi.org/10.1289/ehp.97105514. [25]

WHO (2013), *Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide*, World Health Organization, Regional Office for Europe, Bonn, Germany, https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/health-risks-of-air-pollution-in-europe-hrapie-project.-recommendations-for-concentrationresponse-functions-for-costbenefit-analysis-of-particulate-matter,-ozone-and-nitrogen-dioxide (accessed on 30 November 2020). [28]

Wu, X. et al. (2020), *Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study*, Cold Spring Harbor Laboratory, https://doi.org/10.1101/2020.04.05.20054502. [26]