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

1. Introduction

1. Air pollution is one of the most serious environmental challenges at the global level, 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 – most notably black carbon (BC) – are also short-lived climate pollutants that contribute to atmospheric warming. Such impacts are especially detrimental for fragile environments, such as the Arctic.

2. A recent analysis by the OECD (2021, forthcoming[1]) shows that policy action on air pollution in the Arctic Council countries would result in better air quality, and thus in health and economic improvements. Other recent modelling literature highlights the economic benefits of improved air quality and the additional co-benefits of climate policies (Amann et al., 2020[5]; Harmsen et al., 2020[6]; Markandya et al., 2018[7]; Amann et al., 2017[8]; Vandyck et al., 2018[9]). Recent empirical literature also highlights the substantial economic benefits of reducing air pollution (Dechezleprêtre, Rivers and Stadler, 2019[2]).

3. While these studies focus on the aggregate macroeconomic implications of air pollution policies, different sectors contribute to reducing emissions of specific gases and in specific areas. For instance, emission reductions in the transport sector will be mostly beneficial for air quality in urban areas, whereas targeting emissions from the agricultural sector will be beneficial also for rural areas. The emission reduction costs also vary by sector due to the different costs of technologies that are needed for abating emissions.

4. This paper focuses on this issue and aims to highlight the costs and benefits of emission reductions in different sectors. The final aim is to clarify in which sectors emission reductions are most cost effective.

5. The analysis relies on the OECD ENV-Linkages model Linkages (Chateau, Dellink and Lanzi, 2014[11]). This global computable general equilibrium model allows for an economic analysis that also takes into consideration the impacts of environmental policies in a global context. Indeed, emission reductions in different sector have different economic implications also because of the characteristics of each sector in the global economy. The modelling analysis of the economic consequences of air pollution reduction is based on a step-wise approach (OECD, 2016[8]): it links economic activity to projected emissions, pollutant concentrations, biophysical impacts of outdoor air pollution and their feedback effects on the economy. While the main modelling tool used in the analysis is the OECD ENV-Linkages model, the economic analysis is supported by results from the GAINS model (Amann et al., 2011[12]) of the International Institute for Applied Systems Analysis (IIASA) and the TM5-FASST model (Van Dingenen et al., 2018[13]) of the European Commission's Joint Research Centre (EC-JRC).

6. This report focuses on emissions of a set of air pollutants - ammonia (NH_3), black carbon (BC), carbon monoxide (CO), methane (CH4), nitrogen oxides (NO_X), organic carbon (OC), particulate matter ($PM_{2.5}$) sulphur dioxide (SO_2), and non-methane volatile organic components (NMVOCs) – and it considers how their reduction contributes to reducing concentrations of and exposure to fine particulate matter ($PM_{2.5}$), which is the cause of strong negative health impacts. Emission reductions are obtained through the policy-induced implementation of the best available techniques (BAT), following the GAINS model's emission reduction scenarios.

7. Relying on these modelling tools, this report quantifies the *macroeconomic consequences* of the air pollution policies in the different sectors. The macroeconomic consequences are defined as the net effect of the associated costs and benefits, including their indirect effects throughout the economy. In each scenario, firms and households invest in the best available techniques to reduce emissions of air pollutants. These investments result in costs to the economy. These policy costs are compared to the economic benefits from increase air quality. Improvements in air quality result in economic *market benefits* from decreased health expenditures, and higher labour and agricultural

productivity. Specific sectors and counties may also benefit from the changes in competitive position induced by the policy. The advantage of using a large-scale CGE model is that these indirect effects in the economy are brought together to identify the total net market effect.

8. The paper, which so far only includes an analysis of the market benefits, finds that the highest benefits come from emission reductions in agriculture, energy and industry. However, results depend on the country as different countries have different sectoral shares of emission sources.

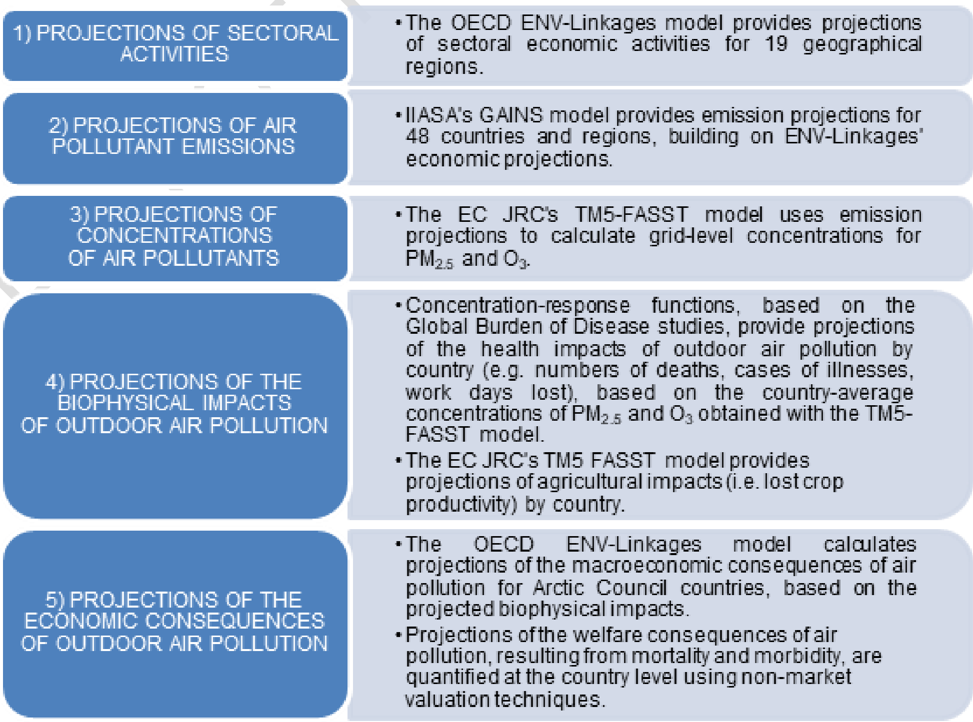
9. The rest of the paper is structured as follows. Section 2 provides a brief overview of the modelling methodology and the scenarios analysed. Section 3 provides an overview of the current air pollution situation in Arctic Council countries. Section 4 presents projections of emissions and air quality. Section 5 presents the main results on the macroeconomic consequences of emission reductions in the different sectors. Finally, Section 6 concludes and provides a discussion of next steps.

2. Methodology and scenarios

2.1 Modelling framework

10. This report takes a quantitative approach to assess the economic consequences of air pollution to 2050. The modelling framework is based on an impact pathway approach, which includes multiple steps and requires the use of different techniques and models. The methodology relies on the modelling framework used previous OECD reports (OECD, 2016[4]; OECD, 2021, forthcoming[1]). The modelling framework used in this report links 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 1).

Figure 1. Methodological steps



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

11. This methodology relies on a suite of modelling tools. The main tool for analysing the economic consequences of air pollution in the different scenarios is the OECD computable general equilibrium model ENV-Linkages (Chateau, Dellink and Lanzi, 2014[1]). This analysis is supported by results from the GAINS integrated assessment model of the International Institute for Applied Systems Analysis (IIASA), which provides projections of air pollutants, emission reduction potentials, and required investments in emission reduction technologies (Amann et al., 2011[3]; Höglund-Isaksson et al., 2020[4]; Winiwarter et al., 2018[5]; Klimont et al., 2017[6]). The pollutants projected in this report from GAINS model are: black carbon, organic carbon, sulphur dioxide, nitrogen oxides, volatile organic compounds, nitrous oxide (N2O), carbon monoxide, and ammonia. The global air quality source-receptor model TM5-FASST (Van Dingenen et al., 2018[10]) of the Joint Research Centre of the European Commission provides the link between emission projections and exposure to $PM_{2.5}$ and ground-level ozone.

12. Projected emissions are then used to calculate atmospheric concentrations of PM2.5 and ground-level ozone, relying 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[10]). Pollutant concentrations are used to calculate the biophysical impacts of air pollution on human health and agriculture. The biophysical impacts are described by a range of indicators, including mortality, hospital admissions and crop productivity losses. Health impacts at the country level are obtained using concentration-response functions based on the results of the Global Burden of Disease project $PM_{2.5}$ for (Forouzanfar et al., 2015[14]). Finally, the agricultural impacts are calculated using the TM5-FASST model, which estimates the crop yield changes associated with ground-level ozone concentrations (Van Dingenen et al., 2018[15]; Van Dingenen et al., 2009[17])

13. Finally, the economic consequences of air pollution policies are calculated, as the macroeconomic effects quantified reflect the impact of air pollution policies on the economic system as a whole, including impacts on expenditures, factor productivity, production, consumption and trade. The indicator used for the macroeconomic effect is gross domestic product, as in previous OECD work on the costs of environmental inaction (OECD, 2016[4]).

14. The modelling framework takes into account 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

15. This report analyses the economic consequences of policies targeting air pollution, based on a scenario analysis performed with the OECD Computable General Equilibrium (CGE) model ENV-Linkages (Chateau, Dellink and Lanzi, 2014[3]). The report compares several policy scenarios to a reference baseline scenario, all with a 2050 time horizon.

16. The baseline scenario assumes the effective implementation of the **current legislation (CLE)** globally in all the sectors of the economy, including the eight Arctic Council countries. The legislation considered addresses air pollution from combustion plants, industrial processes, road and non-road vehicles, shipping, agriculture, and use of solvents and paint, as well as residential emissions

17. The CLE scenario is compared with the rest of policy action scenarios that reflect the implementation of maximum technically feasible reductions (MTFR) to abate pollutant emissions. The MTFR scenario explores the extent to which emissions could be further reduced through the policy-induced application of all existing best available techniques (BATs), in addition to the implementation of current regulations.

18. The central policy scenario of report considers the achievement of the maximum technically-feasible emission reductions in the eight Arctic Council countries, referred to as the **MTFR-AC scenario**. For this scenario, data on the investments needed to reduce air pollution are provided by the GAINS model and included in ENV-Linkages for all the sectors of the economy. This scenario is central since it is the based for the sectoral implementation of policy action to increase air quality.

19. To show the macroeconomic impact of taking policy action by sector, this report distinguishes emission reductions relative to: agriculture (AGR), agricultural waste burning (AWB), road transport (TRA), energy (ENE), industry (IND), waste treatment (WST), solvent (SLV), residential and commercial (DOM), large-scale open fires (BMB) and international shipping (SHP). For instance, the scenario AC-AGR correspond to an scenario where the agricultural sector is implementing the maximum technically feasible reductions to abate pollutant emissions in the Arctic Council countries while the rest of the sector and countries assumes the current legislation scenario.

20. Finally, an additional scenario ***(MTFR-Global)*** considers a global deployment of the MTFR technologies. This scenario assumes that the policies of the MTFR-Global scenario in all the scenarios of the economy. The global scenario can help understand competitiveness impacts and the role of international trade in adjusting to more stringent policies.

3. Overview of air pollution in Arctic Council countries

3.1 Main anthropogenic sources of air pollution in Arctic Council countries

21. In the Arctic Council region, the largest contributors to the emission of black carbon and organic carbon (OC) – both components of primary $PM_{2.5}$ – are the energy and industrial sectors, together with residential wood burning, and transport. While Arctic Council countries have set an aspirational emission reduction target for black carbon, substantial health benefits can only be achieved if other pollutants are also reduced. Specifically, reducing emissions of total primary $PM_{2.5}$ and of other air pollutants that contribute to the formation of secondary $PM_{2.5}$ is necessary to reduce $PM_{2.5}$ pollution, which is the main driver of the health impacts of air pollution. Abating emissions of gases which form secondary $PM_{2.5}$ (precursor gases), such as sulphur dioxide, nitrogen oxides (NO_X), ammonia (NH_3), and non-methane volatile organic compounds (NMVOCs), could further contribute to reducing the concentration of fine particles in the atmosphere

22. Transport is an important source of air pollution in Arctic Council countries. 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 2).

23. According to estimates of IIASA's GAINS model, the industry and energy 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 and one-third of NMVOCs and NO_X emissions in the region. These sectors are also responsible for a significant share of BC (18%) and OC (6%) emissions (Figure 2). Flaring alone represents 7% of total anthropogenic NMVOCs and 14% of black carbon emissions.

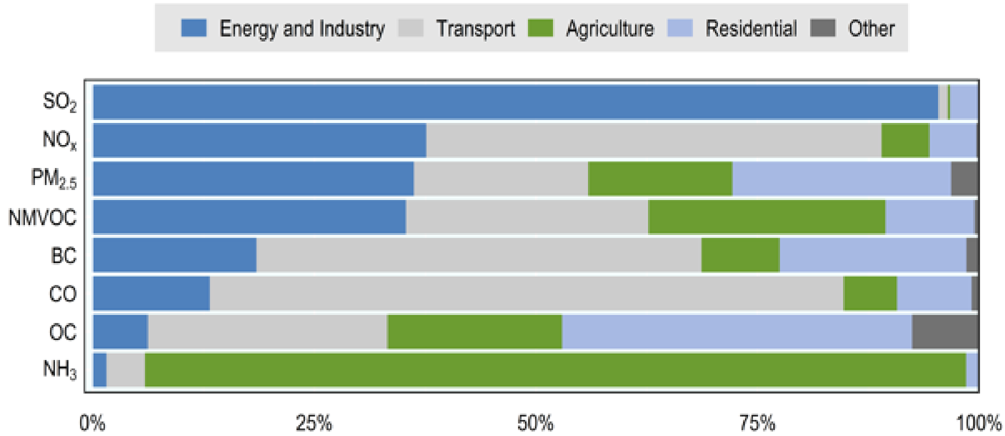
24. The residential sector is a key contributor to the formation of primary and secondary $PM_{2.5}$ and ground-level ozone. In particular, the combustion of solid and liquid fuels for domestic heating is a major source of organic carbon (40%) and black carbon (over 20%), while also contributing to NMVOCs (10%), NO_X (5%) and SO_2 (3%) emissions in the region (Figure 2).

25. Finally, the agricultural sector is a major contributor of NH_3 (92%) and N_2O (60%) emissions, and it also has an important role in the emission of NMVOCs (25%) and OC (20%) (Figure 2). Agricultural fires, which are often used to dispose of crop residues, are

responsible for nearly all the OC, NMVOCs and BC emissions from the sector and for 70% of primary $PM_{2.5}$ emissions in the region.

Figure 2. Emissions of the air pollutants in the Arctic Council countries

Sectoral shares in 2015



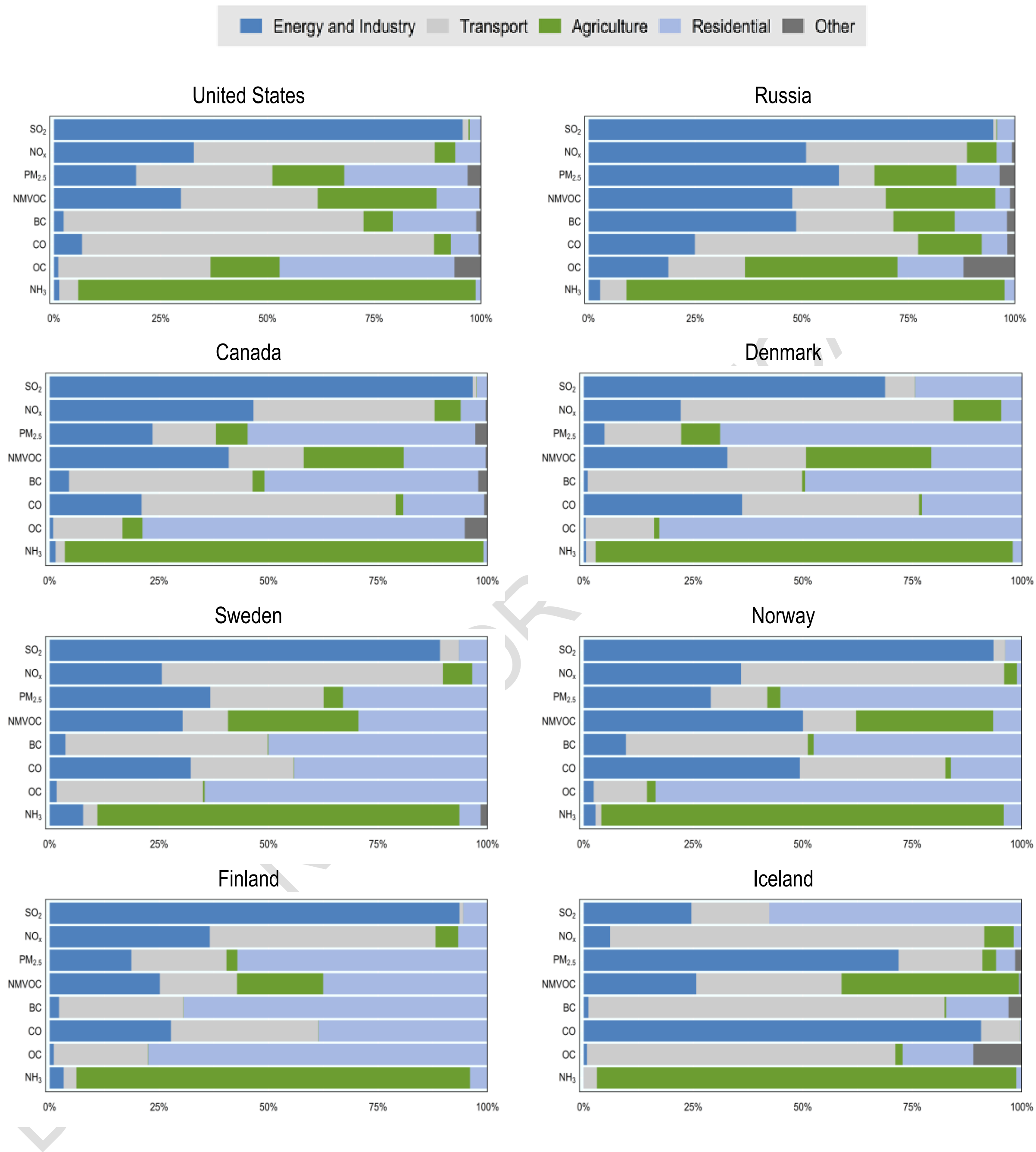
Note: "Residential" emissions are due to wood and fuel burning. "Other" includes emissions form the waste sector (except agricultural waste, which is included in "Agriculture"). $PM_{2.5}$ refers to primary emissions only
Source: IIASA's GAINS model.

26. Although ground-level ozone is not directly emitted to the atmosphere, human activities contribute to the emission of its precursor gases, which include methane, NMVOCs, NOX, and carbon monoxide (CO). In Arctic Council countries, the transport, industry and power generation sectors emit large shares of these pollutants (Figure 2). Most notably, emissions of methane and CO, which are particularly relevant to ground-level ozone formation, are largely driven by industry and energy-related emissions (58% of methane emissions), and by transport emissions (72% of CO emissions).

27. The sectoral shares of emissions vary across countries (Figure 3). For instance, residential emissions represent a higher share in Canada and most Nordic countries, while energy and industry emissions represent a higher share in Russia. However, if there are some specific pollutants such as NH_3 and SO_2 which composition are similar across countries.

Figure 3. Emissions of air pollutant by countries.

Sectoral shares in 2015



Note: "Residential" emissions are due to wood and fuel burning. "Other" includes emissions form the waste sector (except agricultural waste, which is included in "Agriculture"). $PM_{2.5}$ refers to primary emissions only
Source: IIASA's GAINS model.

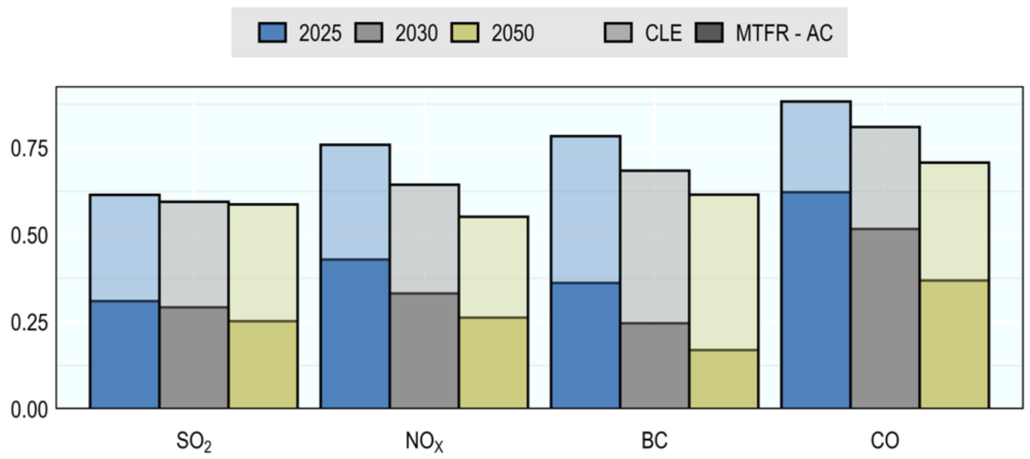
4. Projection of air quality improvements

4.1 Emission projections

28. Based on existing policies, emissions in Arctic Council countries are projected to decrease in the coming decades, even in the absence of additional policy action (baseline CLE scenario). Altogether, under the baseline scenario, by the middle of the century Arctic Council countries are projected to see emissions fall by 25% to 40%, depending on the pollutant (Figure 4). Emissions of SO_2 are projected to decrease by 40% by 2025 and to then decrease only marginally by 2050. Strong abatement of SO2 emissions has already taken place prior to 2013, so by 2025 most of the abatement potential is exhausted. Emissions of other pollutants are projected to decrease more substantially over time. However, according to the GAINS model projections, Arctic Council countries are projected to achieve an aggregate BC emission reduction of 21% by 2025 compared to 2013 in the baseline scenario, coming close to their aspirational collective target of reducing these emissions by 25-33%.

Figure 4. Projected emissions of key air pollutants in Arctic Council countries

Index with respect to 2013 (Index =1 in 2013)



Note: For each bar in this figure, the sum of dark and light colours represents emission levels under CLE, while dark colours alone represent emission levels under MTFR-AC. CLE: Current Legislation baseline scenario; MTFR-AC: Maximum Technically Feasible Reduction in Arctic Council countries scenario.
Source: IIASA's GAINS model.

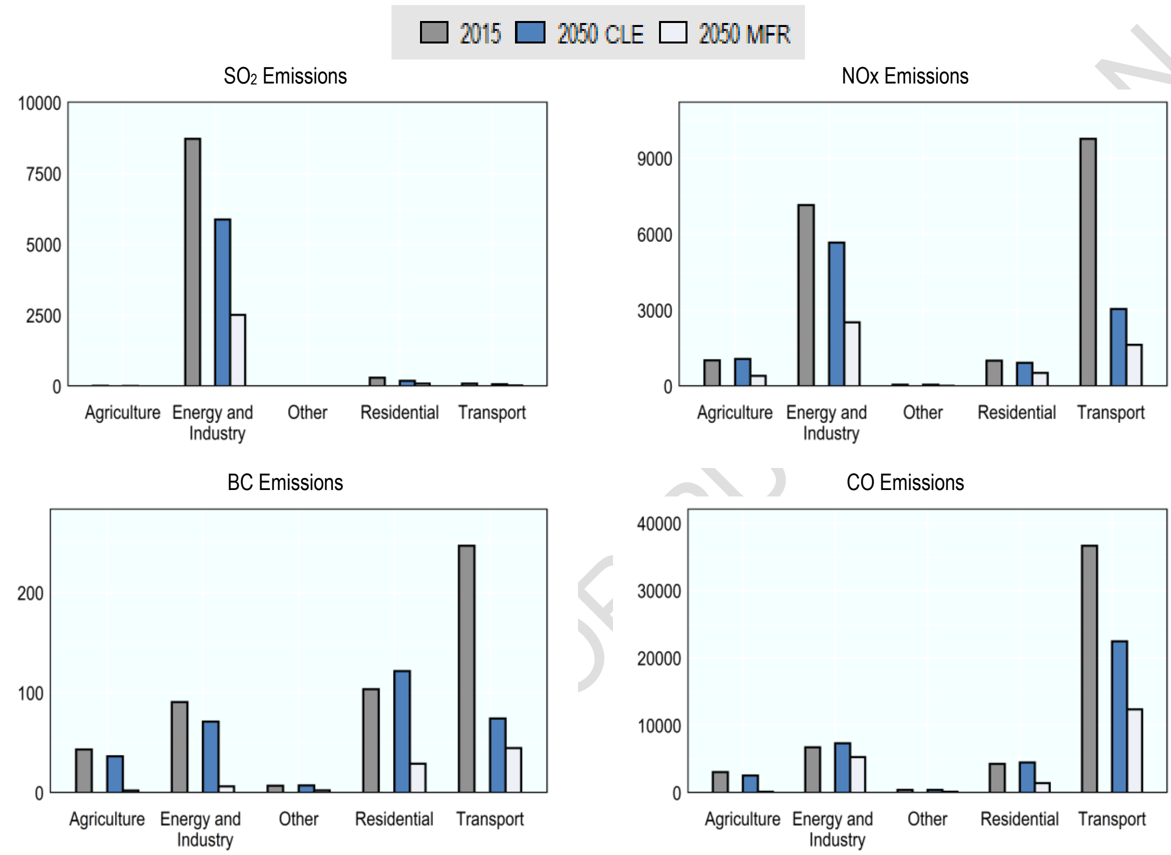
29. Although emissions are set to decline in Arctic Council countries even in the absence of additional policies, the implementation of policies to deploy the best available techniques could achieve much greater air quality improvements. Indeed, under the scenario of Maximum Technically Feasible Reduction 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. In addition, the MTFR-AC scenario would also allow a collective reduction of BC emissions by 65% by 2025, thus significantly exceeding the countries' reduction target.

30. The aggregate emission reductions result from different sectoral contributions to overall abatement, which vary by pollutant (Figure 5). In the baseline scenario, most projected reduction will take place in the transport sector, especially for CO,BC and NO_X. while energy and industry are responsible for the emission reduction of SO2 in the baseline. In the MTFR-AC scenario, there will be further reductions in sectors where reductions were already planned, but also, it would change the tendency of emissions that were projected

to grow in the CLE scenario. For instance, for the residential sector emissions of BC and CO which were projected increase under the CLE scenario will decrease in the MTFR-AC scenario.

Figure 5. Sectoral emissions in the Artic Council countries by pollutant

Kt/year

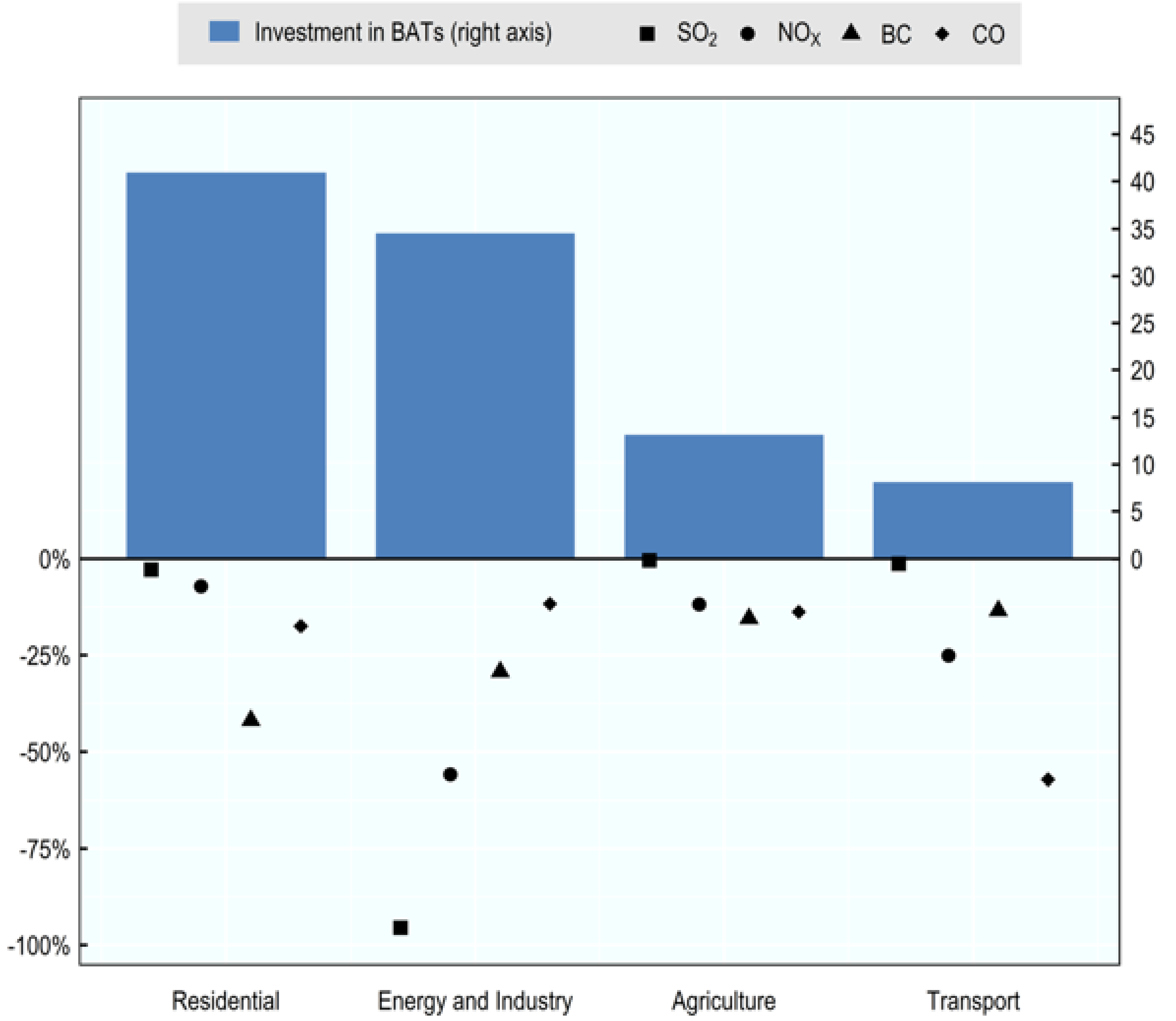


Note: Kt/year: thousand tonnes per year. The graphs use different scales.
Source: IIASA's GAINS model.

31. These sectoral emission reductions are not necessarily proportional to the sector-specific investments and they lead to reduced emissions for different pollutants (Figure 6). The benefits of the sectoral investments in terms of emission reductions depend on the cost of the BATs and their efficiency. For example, emission reductions in the residential sectors are more costly than in other sectors, but they are also most efficient in reducing black carbon emissions. Something similar occurs in the energy and industry sector, which is the major polluter of SO_2 and investing there would effectively reduce that pollutant. Furthermore, these costs may fall on different stakeholders depending on the sector, while the benefits may be seen elsewhere. For example, reducing residential wood-burning emissions can be costly, and households might only benefit marginally from improved air quality.

Figure 6. Emission reductions and investment

2050

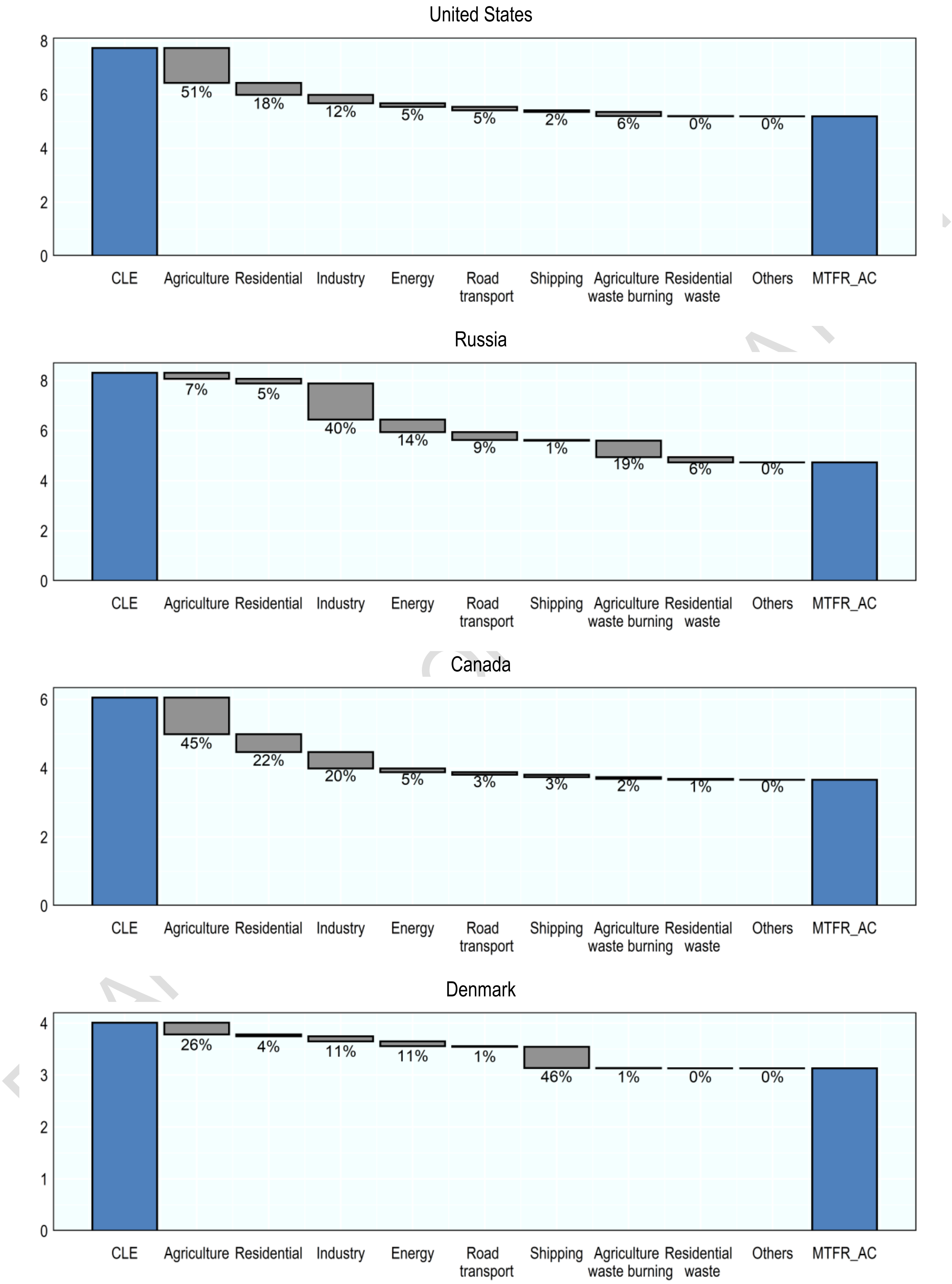


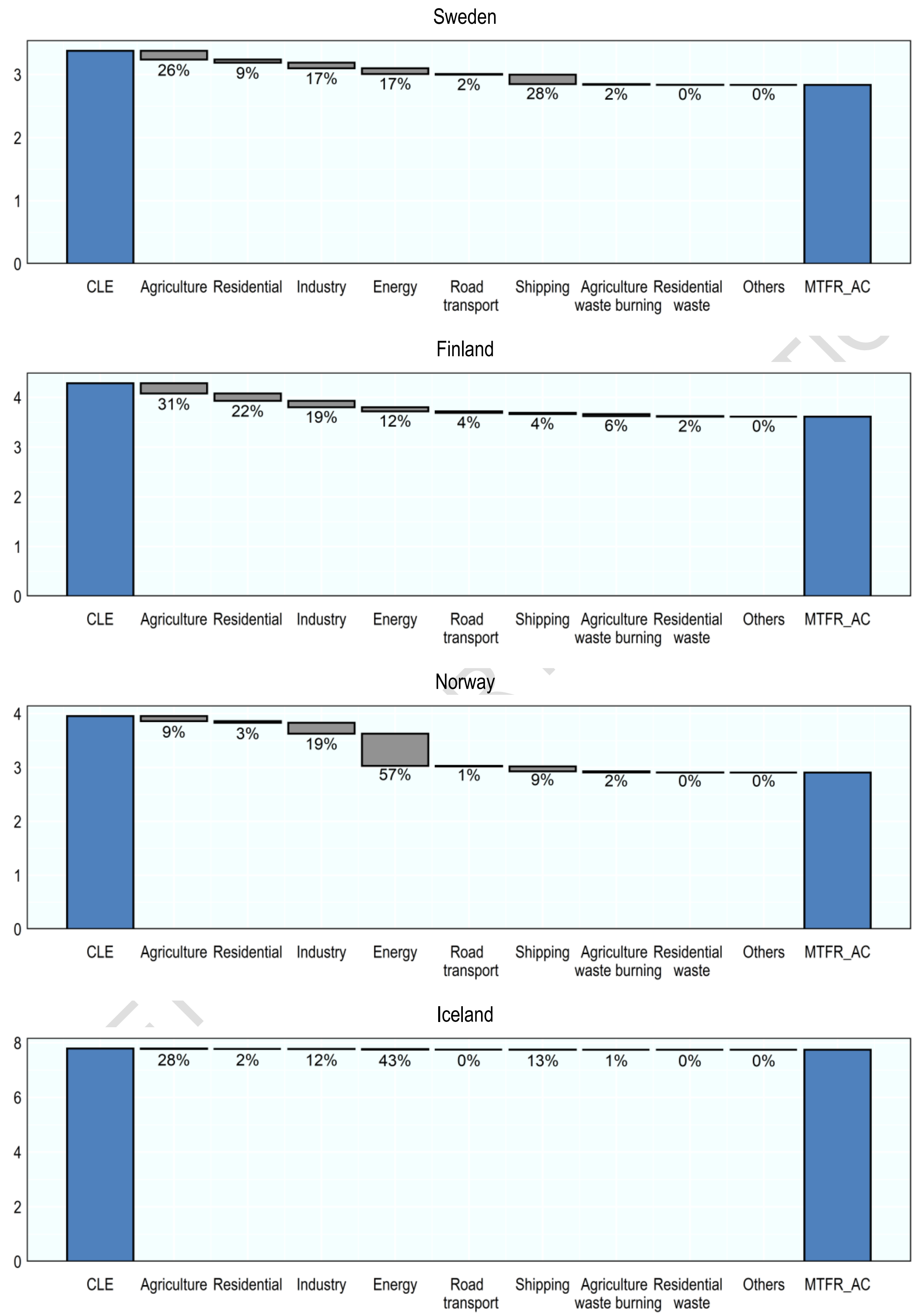
Note: IIASA's GAINS model

4.2 Average concentrations with results by sector

32. Emission reductions in the different sectors contribute unevenly to the overall reductions of concentrations in the MTFR-AC scenario (Figure 7). This distribution varies by country, for instance, in the United States the agricultural sector account for half the total $PM_{2.5}$ concentration level that are reduced under the MTFR-AC scenario. In Russia, the industry sector are the one with the greatest capacity to increase air quality if policy action is only taking place in that sector. In Canada and rest of the Arctic Council countries, the distributions are more evenly distributed.

Figure 7. Country specific changes in $PM_{2.5}$ concentrations





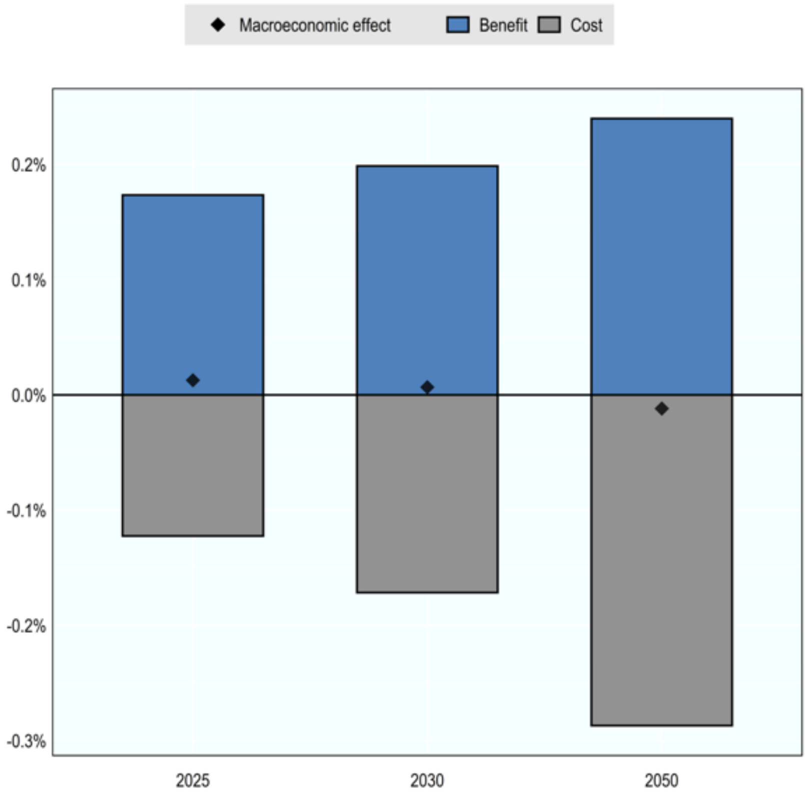
Source: TM5-FASST model.

5. Economic consequences of sectoral air pollution policies

33. Overall, the costs and benefits of emission reductions offset each other (Figure 8). On the one hand, the benefits spur from improved labour and agricultural productivity, and lower health expenditures. On the other hand, it is costly to invest in BATs to reduce emissions. The economic benefits from the reduced market impacts of air pollution in Arctic Council countries in 2025 amount to 0.18% of their aggregate GDP growing up to 0.22% by the middle of the decade.

Figure 8. Overall GDP impact of adopting BATs to reduce air pollution in Arctic Council countries

% GDP in the MTFR-AC scenario

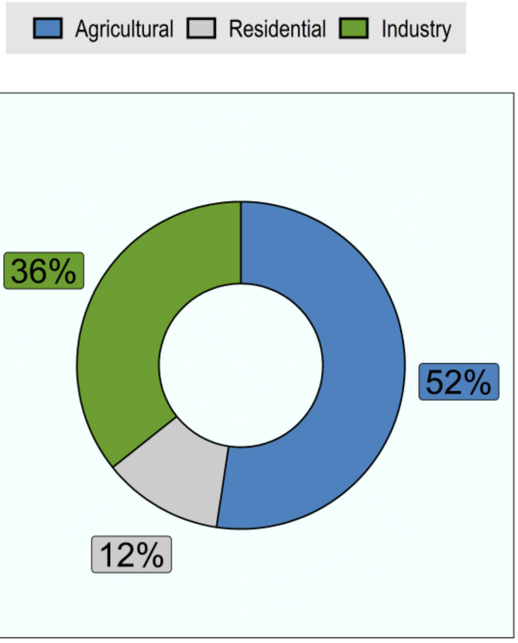


Source: OECD ENV-Linkages model (OECD, 2021, forthcoming[1]).

34. Emission reductions in the different sector contribute unevenly to the overall macroeconomic benefits from increase air quality. From the overall expected benefit in 2050, more than half of it is associated with the agricultural sector, followed by industry (36%) and residential (12%) (Figure 9).The composition of the benefit are not equally distributed by region. In the United States, most of the benefit are associated with the implementation of policy action in the agricultural sector, accounting for 75% of the benefit in the Agricultural benefit in the arctic region. For the case of Russia, the country benefits more when policy action takes place in the industry sector is taking place accounting for more than half of the benefits associated with this sector.

Figure 9. Contribution of sectoral emission reductions to economic benefits

2050



Source: ENV-Linkages model.

6. Discussion and next steps

35. This paper is focused in the sectoral implementation of air pollution policies increase air quality in the Arctic Council countries. However, similarly to (OECD, 2021, forthcoming[1]), this paper also aims show a sectoral implementation of such policies globally in order to study the gains or loss of competitiveness of taking policy action.

36. (OECD, 2021, forthcoming[1]) shows that implementation of policies to increase air quality in the Arctic Council countries have economic benefit and costs but, overall ,the modelling analysis shows that such policies can be considered GDP-neutral. This version of the paper goes beyond this result, showing which sectors has a greater impact in such economic benefit. However, a future version of the paper will include also sectoral specific economic cost to recognize which sector lead to the greatest net macroeconomic cost.

37. Finally, a future version of the paper will go deeper in which are the macroeconomic drivers of economic benefit associated to improve air quality. (OECD, 2021, forthcoming[1]) and this version of the paper do not show how much of the total macroeconomic benefit is associated to increase in labour and agricultural productivity or reduce in health expenditure. (OECD, 2021, forthcoming[18]) shows that most of the benefit from reduce air pollution in Japan, Korea and China comes from increases in labour productivity. In the following version of this paper, a similar analysis will be done to clarify which economic impact has a greater weight in the Arctic Council countries.

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