SEI Stockholm Environment Institute

GREEN TECHNOLOGY CENTER

Developing Regional Cooperation on Air Pollution in Northeast Asia

Transferring lessons from Europe and North America, progress and future development

SEI report
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Green Technology Center Korea (GTC) is a government-affiliated research institute under the Ministry of Science and ICT that fosters national green technology research and development policies and international cooperation on climate change. Since its establishment in 2013, GTC has enlarged its roles to grow as a leading research institute in the area of Green Technology policies, providing dedicated support to the development of national strategies in line with the UNFCCC's technology sector, and operating a number of global cooperation activities connecting developed and developing countries. GTC continues to harness its expertise on the development of future-oriented policies and strengthen international cooperation for the continued advancement and transfer of green technologies, to achieve global goals such as carbon neutrality and the Sustainable Development Goals (SDGs).

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In memory of Martin Williams - a champion of regional cooperation on air pollution who gave his insights and wisdom in the preparation of Chapter 2, but sadly passed away on 21 September 2020. He will be sorely missed.

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Acronyms

AATHP	ASEAN Agreement on Transboundary Haze Pollution
AIT	Asian Institute of Technology
APCAP	Asia Pacific Clean Air Partnership
AQA	Air Quality Agreement
ASAM	Abatement Strategies Assessment Model
ASEAN	Association of Southeast Asian Nations
BAT	Best Available Techniques
BREF	Best Reference
CAPSS	Clean Air Policy Support System
CASM	Coordinated Abatement Strategy Model
CCAC	Climate and Clean Air Coalition
CERL	Central Electricity Research Laboratory
CREATE	Comprehensive Regional Emissions inventory for Atmospheric Transport Experiments
Convention on LRTAP	Convention on Long-Range Transboundary Air Pollution
EANET	Acid Deposition Monitoring Network in East Asia
EEA	European Environment Agency
EGTEI	Expert Group on Techno-Economic Issues
EIPPCB	European Integrated Pollution Prevention and Control Bureau
EMEP	European Monitoring and Evaluation Programme
FGD	Flue Gas Desulphurization
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GTC	Green Technology Center
HLA	High Level Assembly
HTAP	Hemispheric Transport of Air Pollution
IAM	Integrated Assessment Modelling
ICT	Information and Communication Technology
IED	Industrial Emissions Directive
IGES	Institute for Global Environmental Strategies
IIASA	International Institute for Applied Systems Analysis
IMO	International Maritime Organization
IPPC	Integrated Pollution Prevention and Control
IRC	International Regulatory Cooperation
IoT	Internet of Things
JICA	Japan International Cooperation Agency
JEI-DB	Japan Auto-Oil Programme Emission Inventory Database
KAIST	Korea Advance Institute of Science and Technology
KOICA	Korea International Cooperation Agency
LCP	Large Combustion Plants
LTP	Long-range Transboundary Air Pollutants in Northeast Asia
MEIC	Multi-resolution Emission Inventory for China
MOEJ	Ministry of Environment in Japan
MOEK	Ministry of Environment in Korea
MOU	memorandum of understanding
MEIC	Multi-resolution Emission Inventory for China
MEP	Ministry of Environmental Protection
NCCA	National Council of Climate and Air quality
NEACAP	North-East Asia Clean Air Partnership
NEASPEC	North-East Asian Sub-regional Programme for Environmental Cooperation
NEC	National Emission Ceilings
NGO	Non-Governmental Organization
NIER	National Institute of Environmental Research
OAPMP	Online Air Pollution Monitoring Platform
OECD	Organization for Economic Co-operation and Development
PHE	Public Health England
PM	particulate matter
PPP	Public-Private Partnership
RAINS	Regional Air Pollution Information and Simulation
RAPIDC	Regional Air Pollution in Developing Countries
REAS	Regional Emission inventory in Asia
SACEP	South Asia Cooperative Environment Programme
SCR	Selective Catalytic Reduction
SECAs	Sulphur Emission Control Areas
SEI	Stockholm Environment Institute
SIDA	Swedish International Development Cooperation Agency
SLCP	Short-lived Climate Pollutants
SNAP	Supporting National Action and Planning
SOM	Senior Officials Meeting
SPC	Science and Policy Committee
SWAP	Surface Water Acidification Programme
TC	Technical Centres
TFTEI	Task Force on Techno-Economic Issues
TFHTAP	Task Force on Hemispheric Transport of Air Pollution
TEMM	Tripartite Environment Ministers Meeting
TPDAP	Tripartite Policy Dialogue on Air Pollution
UNCED	United Nations Conference on Environment and Development
UNEA	United Nations Environment Assembly
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
VOC	Volatile Organic Compound
WG	Working Group
WHO	World Health Organization
WMO	World Meteorological Organization

Summary

Air pollution is a transboundary issue that requires cooperation at national, regional and global levels. Important examples of implementing solutions to reduce air pollution can be found around the world, and a number of these have achieved significant progress through regional cooperation. In Europe and North America, the consensus and willingness to cooperate on air pollution has been strong. National and regional cooperation has significantly contributed to achieving a remarkable reduction in pollutant emissions and concentrations, although problems still remain.

The situation in Northeast Asia is significantly different from that of Europe and North America. Air pollution is now much higher in Northeast Asia, reminiscent of the highest levels that were seen in Europe and North America in the mid-20th century. While Northeast Asian countries are taking strong action at national scales, there is limited regional cooperation. To solve the severe regional pollution issues, especially related to impacts on human health, it is necessary to use holistic approaches, combining technology, financial and administrative solutions. These can encourage increased national action and promote the regional cooperation that would speed up progress.

This report reviews the cooperation between three Northeast Asian countries: China, Japan and the Republic of Korea (hereafter Korea), and assesses which aspects of the regional collaboration from Europe and North America can be transferred to this part of Asia. The report will serve to advise governments, intergovernmental agencies and others on some key options that can be used to take further action at either national or regional scales. The report also assesses national activities in China, Japan and Korea.

The review of the European and North American pollution policy and regional cooperation focusses mainly on the development of intergovernmental agreements under the UN Economic Commission for Europe (UNECE) Convention on Long-Range Transport of Air Pollution (LRTAP), but also on the development of EU legislation, and agreements between the USA and Canada. There has been a large degree of political will to collaborate, share data and be transparent in Europe, which has allowed negotiations on emission reductions over the last forty years, and the EU has been able to harmonize legislation across Europe.

The review of regional cooperation in Northeast Asia covers the activities of EANET (Acid Deposition Monitoring Network in East Asia), NEASPEC (Northeast Asian Sub-regional Programme for Environmental Cooperation), APCAP (Asia Pacific Clean Air Partnership) and the CCAC (Climate and Clean Air Coalition). Under these cooperation programmes, the focus has been on sharing information and data between countries. This has been on-going, but has not resulted in significant outcomes in terms of emission reductions. Therefore, the potential impact of enhanced regional cooperation in Northeast Asia remains unanswered.

This report compares these cooperative programmes based on the willingness to communicate information; institutional development; amount of funding; and allocation of human resources to support the process. Overall, most cooperative efforts in Northeast Asia do demonstrate the willingness of governments and related organizations to communicate with each other, but they still lack participation by the public. This is a major obstacle, as pressure from the public is a pre-requisite for action by governments.

A comparison of environmental cooperation between China, Japan and Korea shows that each country faces different issues and obstacles. Countries have concentrated on national action and therefore any collaboration between countries has been minimal. However, Northeast Asia is a very dynamic region and opportunities are arising all the time. Recent changes, such as China setting a date of decarbonization by 2060, can improve the likelihood of successful, increased cooperation.

Air pollution is a transboundary issue that requires cooperation at national, regional and global levels

Key strategies for regional cooperation among the three countries are considered in the report. One key aspect is developing a strong consensus among the scientific community and the public about the air pollution issues and the potential to solve it. Identifying best practices by jointly assessing and reviewing activities undertaken in China, Japan and Korea, is a crucial component that can lead to progress. A proposal for technology cooperation among the three countries could provide a promising strategy, if each country were willing to share their experience of using the best available technology. This can enhance connections across the private sector in the different countries and boost business opportunities and the output of industrial goods.

In order to solve transboundary air pollution in Northeast Asia, holistic approaches are important so that technical expertise, economic resources and administrative support work in parallel to solve problems. Sharing data and information is a good start, but it is not enough. Developing appropriate strategies, policies and measures are crucial, if emissions are to be reduced. This report considers cooperation on key technologies for monitoring, raising awareness and supporting solutions to air pollution, through active participation of the private sector, in collaboration with academic institutions. Cooperation can be strengthened by the formation of networks of scientists, engineers and others, to help governments lay out action plans to achieve the common goal of reducing air pollution. The formation of these networks can help increase the participation of the public and private sectors, which in turn can increase the interest of policymakers. Policymaker engagement can also be enhanced when the public become increasingly aware of the air pollution issues.

All of these aspects have been ingredients in the journey that has achieved reduced air pollution in Europe and North America. It is mainly a question of learning from this journey and finding aspects that could be relevant to processes in Northeast Asia, and highlighting those. This report tries to investigate this, whilst understanding that these regions have very different geopolitical contexts and not all elements are applicable.

1. Introduction

Air pollution is the leading environmental risk factor for premature death

Air pollution is the leading environmental risk factor for premature death, and most of this is related to the exposure to particulate matter, especially those particles that are less than 2.5 micrometres in diameter (known as small particulate matter). These small particles reach deep into the lungs, causing damage. They then cross the membranes into the blood stream and are transported around the body, causing further damage. Premature deaths arise from increases in ischemic heart disease, stroke, lung cancer, and acute lower respiratory infections associated with exposure to air pollution. It also affects unborn children, by increasing the risk of preterm births, which has the potential to cause life-long health implications (Malley et al. 2017). Air pollution also increases the prevalence of serious asthma attacks across all ages and is a major cause of childhood pneumonia. Non-fatal health impacts include requiring hospital admission, reduced well-being, increased use of medication, and damage to the economy, for example through reduced productivity.

According to estimates for 2012, the Western Pacific (which includes Northeast Asia) and South East Asian regions already suffer from up to 1.9 million premature deaths per year from ambient (i.e. outdoor) air pollution. This represents more than half of the 3 million total deaths estimated to occur from exposure to air pollution across the two regions annually, from both indoor and outdoor exposure to $PM_{2.5}$ pollution (WHO, 2016).

According to the Organization for Economic Cooperation and Development (OECD), the number of premature deaths globally due to high ambient concentrations of $PM_{2.5}$ and ground-level ozone (O_3)[1], could increase from 3 million per year in 2010 , to between 6 and 9 million per year in 2060 (OECD, 2016), with most of the increase occurring in Asia. To avoid this, strong and immediate policy responses to reduce air pollution are required. The problems caused by $PM_{2.5}$ in Northeast Asia are especially serious due to the region's rapid economic growth and urbanization and because there are insufficient policies to prevent emissions. Today, emissions of air pollutants in Northeast Asia are far in excess of the levels currently found in Europe and North America. But this has not always been the case. For many years, urban areas of Europe and North America had the highest levels of air pollution – comparable to some of the worst air pollution found in Asia today.

The concentrations of $PM_{2.5}$ are made up of a mixture of primary particles (pollution emitted as particles), including black carbon, organic carbon and mineral dust, and secondary particles (particles formed in the atmosphere through chemical reactions involving different emitted gases). Secondary particles (sulphate, nitrate, ammonium and secondary organic particles) are formed from emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_X,), ammonia (NH_3), and non-methane volatile organic compounds (NMVOCs), which can travel over long distances and across national boundaries. The concentrations found today in many parts of Northeast Asia exceed environmental standards by many times, at all times of the year. This poses a major threat to health, well-being and development in the region (Shim, Seo and Noh, 2013). The secondary pollutants made up of sulphate, nitrate and ammonium, form a substantial part of the $PM_{2.5}$ burden in industrial areas and these are also the pollutants that cause acid rain, causing associated ecosystem damage.

Another important pollutant affecting human health is ground-level ozone (O_3). O_3 concentrations in Northeast Asia have been rising due to the increasing emissions of precursor pollutants. O_3 is associated with different respiratory diseases, such as asthma, pneumonia and Chronic Obstructive Pulmonary Disease (COPD) (Malley et al. 2017). It is also the main pollutant affecting crop yields and has been shown to reduce wheat yields by 25–40% in some parts of Asia (Wahid et al. 2006).

1 Ground-level ozone is a secondary pollutant formed in the lower atmosphere from emissions of the precursors nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO) and methane (CH_4) under the action of sunlight. Ground-level ozone refers to the concentrations at the ground which people breathe in and which affects plants (e.g. crops and trees).

Given the large impact of air pollution in Northeast Asia, individual countries in the region are making efforts to respond to this increasingly serious problem. China, which has been seriously affected by $PM_{2.5}$ pollution, due to rapid industrial development and economic growth, has continued its efforts to improve air quality, declaring a "war on air pollution" in 2013. In particular, it announced that the most recent implementation of the "*Winning the Blue Sky War (2018-2020)*" (Feng, 2018) has had the effect of reducing the concentration of particulate matter and improving the air quality in key urban areas of China.

Korea has also continued to develop countermeasures to reduce $PM_{2.5}$ concentrations, as public concerns about small particles increase. Since its first announcement of "Reduction Measures for Particulate Matter" in 2005, the Ministry of Environment has: announced an analysis of the sources of high concentrations of particulate matter; established an environmental concentration standard for $PM_{2.5}$; measured ambient concentrations of $PM_{2.5}$; and identified and implemented countermeasures for $PM_{2.5}$ to improve public health. In 2019, the legal and institutional basis for policy initiatives was strengthened through the enactment of a "Special Act on the Reduction and Management of Particulate Matter: Particulate Matter Law" (MOEK, 2019).

Japan, the first industrialized country in Northeast Asia, has implemented a number of air pollution reduction policies that have reduced major sources of emissions since 1980. The first regulation in Japan was developed in 1932, with a law on particulate matter restriction, which was initially enacted in the Osaka area (MOEJ, 1932). As air pollution became serious due to the rapid economic expansion after the Second World War, the Air Pollution Control Act was enacted in 1968, to enforce strong regulation on air pollutant emissions. Through a process of increasing regulation and implementation, air pollution in Japan has significantly been reduced.

However, air pollution, such as $PM_{2.5}$, is not only a problem within any one country, but it is also a transboundary issue – a common problem in any relatively large area sharing the same airshed. Since particulate matter can be transported over long distances, it is important for any international cooperation to identify and manage mechanisms to control the emission of air pollutants, assess its atmospheric transport and chemical transformation, and understand its impact across national boundaries.

Internationally, efforts have been made to establish bilateral or multilateral cooperation frameworks to solve the problems associated with long-range transboundary air pollution. Members of the UN Economic Commission for Europe (UNECE), including all European countries, central Asian countries, and also the USA and Canada, have addressed the problem through the development of the "Convention on Long-Range Transboundary Air Pollution (Convention on LRTAP)", which was agreed by the Parties to the Convention in 1979. This initiated the process of international negotiations on transboundary air pollution, and has led to significant success in addressing regional air pollution. It was the first international convention to deal with air pollution at a regional scale, and came into force in 1983, establishing an institutional framework. This put in place the general principles of international cooperation to reduce air pollution, and to integrate research and policy. Building on the work of the Convention on LRTAP, the EU has gradually implemented approximately 300 legal and institutional instruments, such as guidelines, orders, decisions and recommendations, over the past 30 years, to help implement effective air quality management policies across the EU (Kuklinska, Wolska and Namiesnik, 2015).

In North America there were separate bilateral negotiations between the USA and Canada on emission reductions. The United States-Canada Air Quality Agreement (AQA) also established air quality goals and adopted practical programmes for individual countries. This imposed obligations to: undertake Environmental Impact Assessments (EIA) on actions, activities and projects likely to cause transboundary air pollution; implement appropriate reduction measures; and notify the neighbouring country of their air pollution status. In addition, in the event of a conflict between countries, consultation and negotiations were conducted, and the two countries launched the Air Quality Committee to facilitate the implementation of the agreement.

Given that it is very difficult to achieve international consensus on international environmental issues between countries, the Convention on LRTAP and the USA-Canada AQA can be regarded as important successful cases, where countries agreed to solve their shared issues together. These can provide important examples of cooperation between countries, to solve the same problems now being experienced in Northeast Asia. In the meantime, various practitioners in the Northeast Asian region have been thinking about the establishment of an international framework that would be most suited to the region, to provide the appropriate solutions to these shared air pollution problems. However, when thinking about the construction of cooperative frameworks for transboundary air pollution in Asia, the differences between Europe and Asia need to be critically analysed.

When thinking about the construction of cooperative frameworks for transboundary air pollution in Asia, the differences between Europe and Asia need to be critically analysed

2. A review of European and USA air pollution policy at urban, national and regional scales

2.1 Development of urban and national air quality management in Europe and the USA

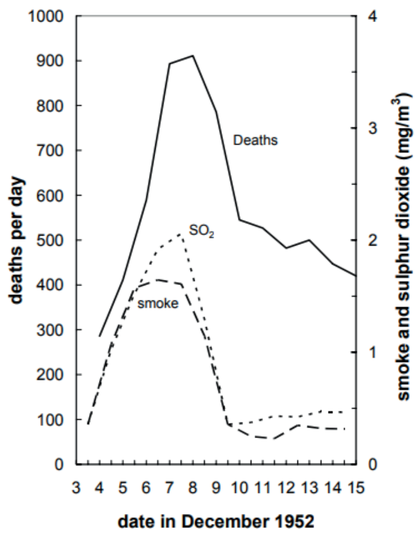
UK and Europe

Air pollution has been an issue for millennia, but it became particularly noticed at urban scales in Europe when the use of coal in London increased in the early middle ages. In 1661, English writer John Evelyn wrote about "clouds of sulphur" and even noted the corrosive nature of pollution on limestone and marble in the city at that time (Brimblecombe, 1987). After the industrial revolution, cities in Europe started to burn significant amounts of coal in houses and for industry, leading to a marked decrease in air quality in the late 19th and early 20th centuries (Brimblecombe, Austin and Sturges, 2002). Many smog episodes occurred during this period across industrialized Europe, leading to a marked increase in deaths (Brimblecombe, 2006). There was a particularly bad episode in the Meuse Valley, Belgium, in the 1930s, leading to respiratory disorders and over 50 deaths (Brunekreef and Holgate, 2002). As pollution increased, governments attempted to take action. The French government, for example, introduced the Morizet Act (1932) on the elimination of industrial smoke emissions. This was the first policy on air pollution in France (Brimblecombe, 1998).

Figure 1. The London smog disaster of 1952

The London smogs

Between 1948 and 1962 eight air pollution episodes occurred in London, but the Great Smog between 5th and 9th December 1952 was the most significant. Smoke concentrations reached 56 times the 'normal' level at the National Gallery and visibility was so bad that people could not see their own feet! Within 12 hours of the beginning of the smog some people showed respiratory problems and hospital admissions increased dramatically. At least 4,000 people above the normal mortality figures are believed to have died during the smog and in the following weeks (see figure below).



Death rate, smoke and SO_2 concentration (daily average) during the Great Smog in December 1952.

Source: Parliamentary Office of Science and Technology (2002)

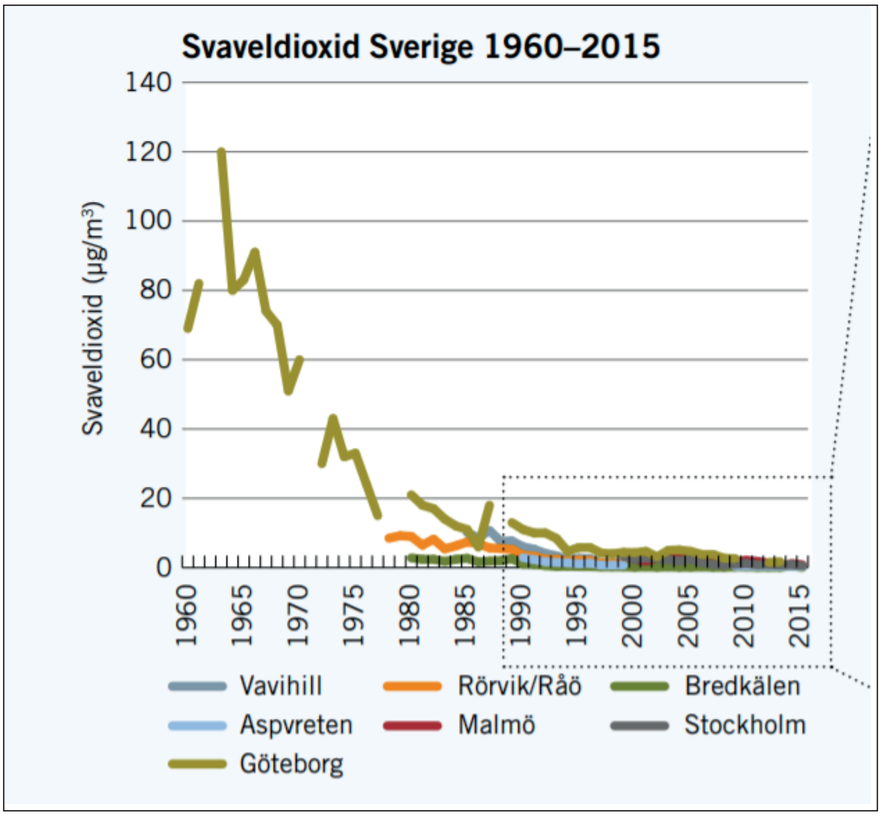
Despite the high frequency of "Pea-souper"[2] smog events in London, few policies were developed to address the sources of pollution (Davis, Bell and Fletcher, 2002). Several coal-fired power stations were located in the city and coal was widely used domestically for heating and cooking (Rafaj et al. 2014). An early attempt to address emissions was made with the development of the Public Health Act of 1936, but its effect was limited (Brimblecombe, 1987). The pollution continued after the Second World War and was an ever-present problem found throughout Europe. Even in Stockholm and other cities of Sweden, air quality was very poor (Hawksworth, 1971). In the UK, the replacement of old electric trams with diesel buses (Brunton, 1992) added to pollution and smog episodes (Cooney, Hawkins and Marriott, 2013). Poorer grade coal was being burnt after the Second World War, since the high-grade coal was increasingly being exported (Elsom, 1992). This continued until an especially serious pollution episode occurred in December 1952, which has been called the "London Smog Disaster" (Davis, Bell and Fletcher, 2002). This occurred when unusual weather conditions locked in the pollution for a number of days. People could not see where they were going, and the death rate soared, with over 4000 excess deaths being recorded between 5–9 December 1952 (Figure 1), which were reported in Parliament and the media soon after (Elsom, 1992). The mortality count is approximately 12,000, rather than the 3,000–4,000 generally reported for the episode, if the excess deaths after the episode are taken into account and if these are assumed to be related to air pollution (Bell, Davis and Fletcher, 2003).

2 "Pea-souper" fogs were a very thick and often yellowish, greenish or blackish fog caused by air pollution that contains soot particulates and the poisonous gas sulphur dioxide that used to be common in London.

Intense media reporting of this event at the time, created widespread interest in these smog events, to a much greater degree than had occurred in previous years (Elsom, 1992). The 1952 event caused a massive public reaction, where people demanded that something be done (Davis, Bell and Fletcher, 2002). The government attempted to calm public concerns by trying, for example, to blame excess deaths on an influenza epidemic, and avoided having to take action, which had previously been a successful tactic (Rose, 1990). However, the extreme pressure on the government to respond, coincided with a Private Member's Bill[3] that was eventually passed by Parliament and which gave rise to the Clean Air Act of 1956. This was a very successful piece of legislation that was copied across Europe (Brimblecombe, 2006). It took some time for air quality to improve and further smog events continued to occur, such as a particularly bad episode in 1962 that killed about 700 people (Elsom, 1992). But gradually, air quality in London improved.

The London Smog of 1952 influenced urban air pollution policy throughout Europe. It had, for example, a considerable influence in Sweden, increasing interest in the potential impacts on human health. Doctor Ragnar Spak in Göteborg undertook a study on soot and sulphur dioxide (Forsberg, 2007). In October 1959, the first measurements of pollution started, and in December 1960, an epidemiological pilot study was initiated, inspired by a British study on patients with bronchitis (Forsberg, 2007). Figure 2 shows how the high values for sulphur dioxide concentrations in Göteborg in the early 1960s, decreased rapidly in the late 1960s and 70s, and that these lower concentrations also became the norm in other Swedish cities.

Figure 2. Sulphur dioxide in the air in Sweden from 1960 to 2015, with the longest measuring series for Gothenburg



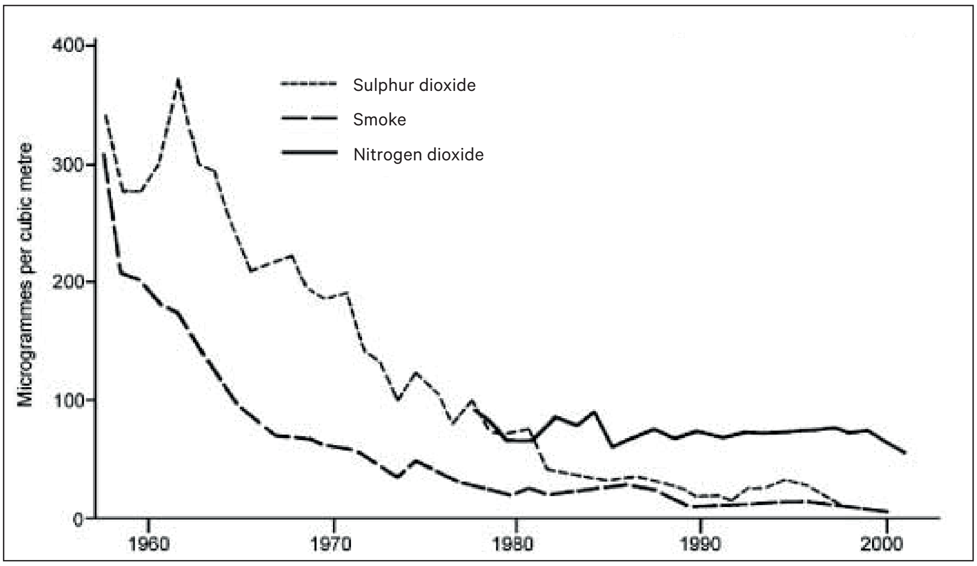
Source: Forsberg (2007)

The UK's Clean Air Act of 1956, was the first legislation which attempted to control domestic as well as industrial sources of pollution (Elsom, 1992). This was important because previous to this, policymakers in the UK had been reluctant to place restrictions on what people could do in their own homes (Brimblecombe and Schuepbach, 2006). However, due to the serious smog events, citizens were aware that these sacrifices were small compared to the advantages of achieving clean air, thus there was little resistance to the new Act (Brimblecombe, 1987).

Following the introduction of the Clean Air Act, there were a number of early policy initiatives in the UK that were particularly effective. The first was the establishment of "Smoke Control Areas" in cities, which forbade the burning of coal in unauthorized appliances, and stipulated that only smokeless solid fuels could be burnt. Over time, there was a move among householders to replace coal-fired heating and cooking with natural gas (Brimblecombe and Schuepbach, 2006). This was not strictly required by policy but a combination of the Clean Air Act, the economics of gas as a fuel, and the overall ease of using gas, was probably responsible for this trend. This switch of fuels was copied by most cities in Europe, although the

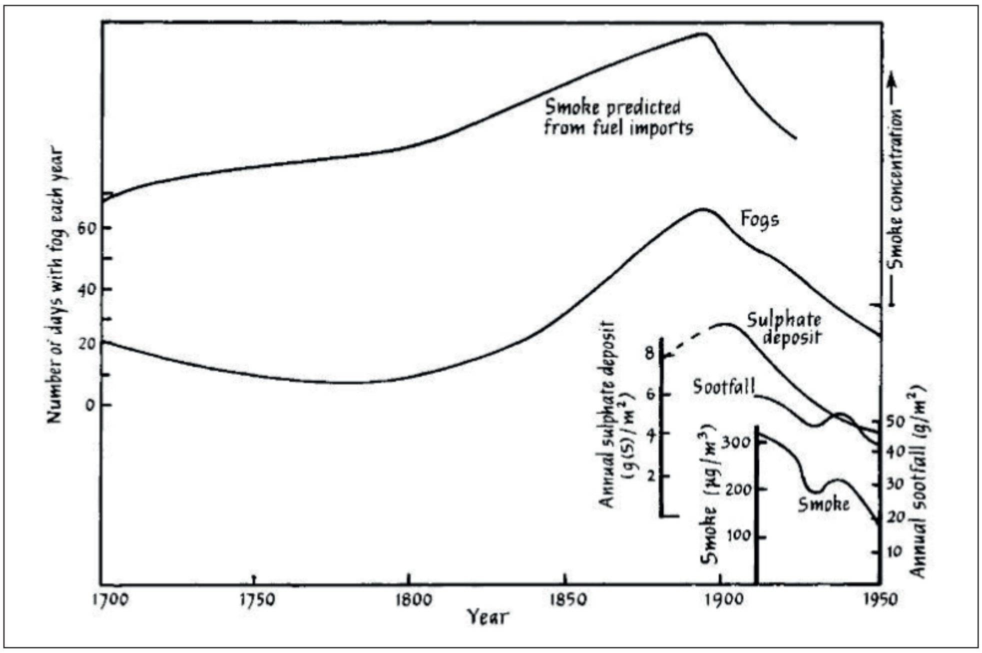
3 In the UK system, Private Member's Bills are Public Bills introduced by MPs and Lords who are not government ministers. As with other Public Bills, their purpose is to change the law as it applies to the general population. A minority of Private Member's Bills become law, but by creating publicity around an issue, they may affect legislation indirectly.

Figure 3. Changes in smoke, SO_2 and NO_2 in London from 1956 to 2000



Source: Adapted from Brimblecombe (2006)

Figure 4. Air pollution values measured in London since the 17th century



Source: Brimblecombe (1987)

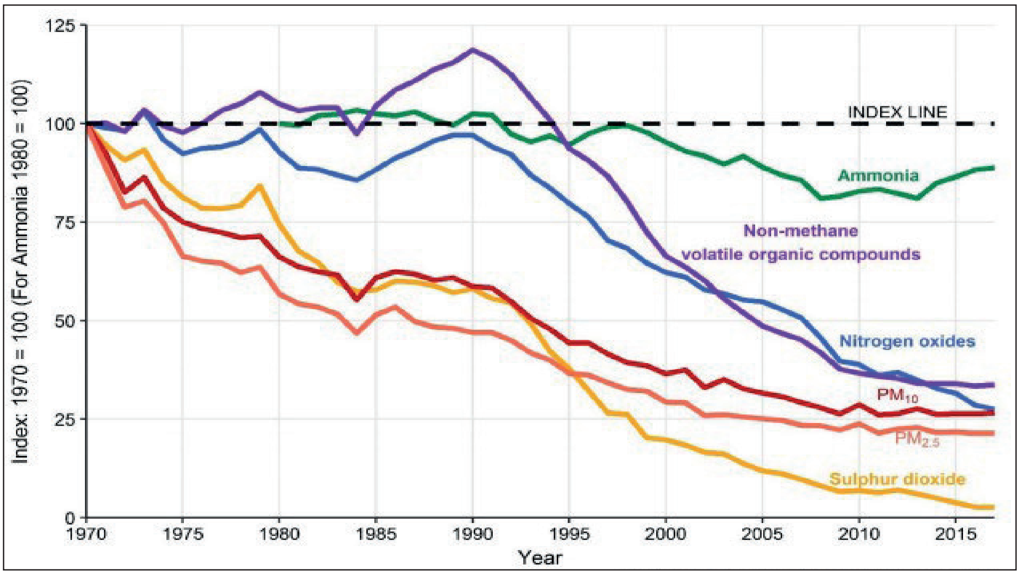
response differed. For example, district heating[4] was favoured in Sweden, and restrictions on the sulphur content of fuels was also implemented (Nyberg et al. 2000). In addition, the habit of putting polluting industry in cities was discouraged and all large industrial sources, including power stations, were moved out of the city centres (Brimblecombe, 1987). They were built with tall chimneys, as per a "tall stacks" policy, intended to disperse the pollutants from large point sources of pollution (such as coal-fired power stations) and to avoid high pollutant concentrations locally (Elsom, 1992).

The consequence of the changes in cities was that from 1956 onwards, the levels of pollution in London improved considerably (see Figure 3), as it did in cities across Europe. Admittedly, in the UK, levels of pollution had started to come down before the Clean Air Act, from about 1900 (see Figure 4). The Act was also operating alongside some significant changes in fuel use, technology and a shift in industrial sources of pollution (Elsom, 1992). The shift from coal to gas was a radical shift in fuel use, not originally envisaged in the 1950s, and it avoided the problem of providing enough smokeless solid fuel (Brimblecombe, 2006). It was this shift that caused much of the reduction of sulphur emissions (Elsom, 1992). It should be noted that while pollution was successfully reduced in cities, this was partly due to the fact that industry had relocated away from the population, and so the emissions produced in this sector did not cease, but continued to be produced elsewhere. The effect of this was that the incentive to cut emissions was removed (Elsom, 1992). Furthermore, it was not understood at the time that, although tall chimneys reduced local air pollution, they allowed continued high levels of emissions, and their pollutants travelled long distances. Thus, the pollution still contributed to the acid rain crisis that arose, after the urban air pollution problem was considered to be solved, or at least to be work in progress (Rose, 1990).

4 District heating is a system for distributing heat, generated in a centralized location, through a system of insulated pipes for residential and commercial heating requirements, such as space heating and water heating.

The Clean Air Act was modified in 1968 and 1993, and the use of gas also spread to power stations from the 1990s which led to further reductions in air pollution overall in the UK, as well as in cities (Brimblecombe, Austin and Sturges, 2002). One pollutant that was not being reduced was nitrogen dioxide. This has since been the subject of intense pressure, requiring emission reductions. By 2017, the UK had achieved a 70% reduction in nitrogen oxide emissions since 1990 (Figure 5) (DEFRA, 2019). Ammonia emissions however, mainly from agriculture, has remained stubbornly high in the UK (Grennfelt et al. 2019), and the emissions of primary $PM_{2.5}$ particles have only reduced by a small amount since 2002 (see Figure 5). This demonstrates that more needs to be done and is a common picture across Europe, but with differences, depending on national circumstance. However, the development of regional air pollution policy in Europe, since 1979, has had a large impact on addressing this (Grennfelt et al. 2019).

Figure 5. Trends in annual emissions of sulphur dioxide, $PM_{2.5}$, PM_{10}[5], nitrogen oxides, non-methane volatile organic compounds and ammonia in the UK between 1970-2017



Source: DEFRA (2019)
The index line is a comparator that shows the level of emissions if they had remained constant from the beginning of the time series.

USA

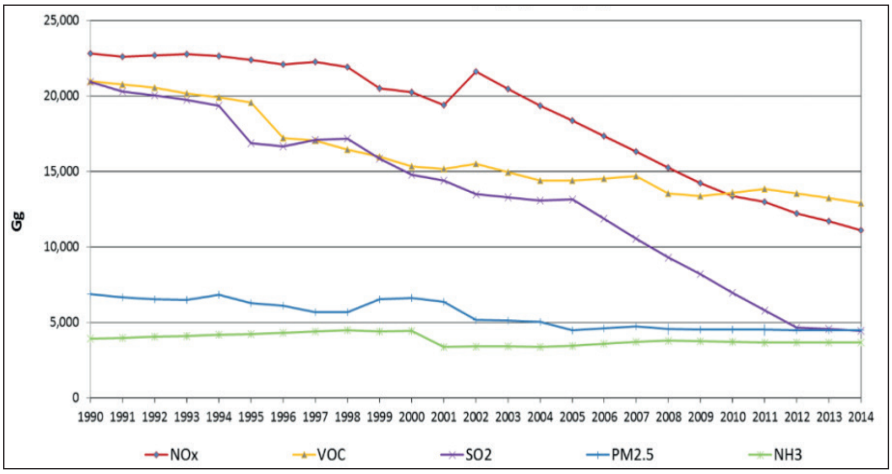
The USA has a similar air pollution story to Europe. In the early 1940s, Los Angeles, California, was subjected to a series of photochemical smog episodes, causing nose and eye irritation (Goodwin, 1979). Some of these smog episodes were different to those experienced in London, with ground-level ozone pollution being a more prominent problem in California (Brimblecombe, Austin and Sturges, 2002). Then, smog episodes more typical of the smoke, sulphur and nitrogen oxide pollution experienced in London and other parts of Europe, began occuring in other parts of the United States. In 1948, there was “The Donora Episode” in which six days of smog resulted in 6000 cases of illness and 20 deaths, in a district just south of Pittsburgh in Pennsylvania (Brimblecombe, Austin and Sturges, 2002). Then, in 1953, there was another smog episode in New York City, which resulted in 200 deaths (Elsom, 1992). These events put pressure on the government to develop federal legislation, motivating the Air Pollution Act of 1955, and the Motor Vehicle Exhaust Study Act in 1965 (Goodwin, 1979). Both of these events led to the provision of funding for research, but did not bring about immediate reductions of air pollutant concentrations (Elsom, 1992). The Motor Vehicle Pollution Control Act was produced in California in 1965, five years before the Federal Act by the same name was introduced. This highlights California’s tendency to lead pollution control legislation in the USA (Elsom, 1992).

The major piece of legislation to bring about emission reductions in the USA, was the Clean Air Act of 1970 (Francis and Crandall, 1984). It is described as being “swept into enactment by the political strength of the environmental movement” (Elsom, 1992, p. 207), demonstrating the powerful public attitude to air pollution during this era. The Act established the Environmental Protection Agency (EPA) and set national air quality standards for sulphur dioxide (SO_2), nitrogen

5 Particles that are less than 10 micrometres in diameter.

oxides (NO_X), particulate matter (PM), carbon monoxide (CO), ground-level ozone (O_3) and lead (Pb) (Brimblecombe, Austin and Sturges, 2002). There were minimal air quality improvements at first and in 1977 the Act was amended to set a deadline of 1987 to achieve emission reductions. After this, the EPA gained authority to provide sanctions for not meeting targets (Elsom, 1992). In 1990, the Clean Air Act was revised and the majority of emission reductions came after this time (see Figure 6). Overall, the implementation of the Clean Air Act between 1970 and 2014, achieved a 69% reduction in pollutant emissions, despite a marked increase in GDP, vehicle miles travelled, energy consumption and population (Grennfelt, 2016).

Figure 6. Trends in USA emissions of $PM_{2.5}$ and its precursors from 1990 to 2014



Source: United Nations Economic Commission for Europe (2016)

It was significant that the serious smog episodes occurred in California, given that this State took the lead in developing solutions to air quality issues (Elsom, 1992). In the USA, California is the only state permitted to issue emissions and air quality standards itself, under the Federal Clean Air Act (Gerard and Lave, 2005). It is also exempt from the Federal ruling that no state could adopt emission standards for new vehicles that are more stringent than the Federal ones (Elsom, 1992). Other states could then choose to follow the standards set by the California Air Resources Board (CARB) or Federal standards (Gerard and Lave, 2005). The reason for this exception relates to the time when Federal air quality laws were being produced, and California was already developing innovative laws and standards to address its unique air pollution problems (Gerard and Lave, 2005). For example, in 1978, California required all new cars to be equipped with three-way catalytic converters, which reduce emissions of nitrogen oxides, one of the major precursors of ground-level ozone. This then became a requirement for all states under Federal law in 1981 (Rose, 1990). This illustrates alternative legislative approaches – one of which was to set emission standards (which was a technology neutral approach), and the other to require the use of specific technologies.

The technological advance of catalytic converters in the USA enabled similar emission reductions to be copied in European legislation (Elsom, 1992). One significant factor leading to the EU legislation was that some countries like Sweden and Germany promoted catalytic converters on vehicles by, for example, providing subsidies for their purchase. They were first introduced in Germany in 1985, however, the UK opposed the idea until 1989 (Rose, 1990). It was important that some countries took early action to promote good practices in Europe, as it was only in 1993 that EU passenger car emission standards became stringent enough to require the general application of three-way catalytic converters, and this was only for petrol-driven cars (Rafaj et al. 2014). It is interesting that despite the existence of proven technology in the USA, and a Federal law from 1981, it took over a decade for the EU to adopt this in the framework of the Euro Standards[6]. There was also a difference in the application of the legislation – EU car emission standards have traditionally been stricter for petrol-driven cars than for diesel ones. This has led to higher emissions of nitrogen oxides and primary $PM_{2.5}$ in Europe for many years, compared to the USA, where diesel vehicles had been set the same standards as petrol-driven ones.

6 Euro Standards are European emission standards that define the acceptable limits for exhaust emissions of new vehicles sold in the European Union and European Economic Area (EEA) Member States. The emission standards are defined in a series of European Union Directives, staging the progressive introduction of increasingly stringent standards.

2.2 Development of cooperation on transboundary air pollution under the Convention on Long-Range Transport of Air Pollution (LRTAP)

The development of intergovernmental agreements under the UN Economic Commission for Europe (UNECE)

The existence of long-range transport of air pollution has been documented for a long time. Soot falling on and darkening snow in Norway when the wind blew from Britain was described in the late 19th century (Brimblecombe, Davies and Tranter, 1967). The science and policy debates on the long-range transport of air pollution in Europe and North America focused on the issue of "acid rain" (Pleijel, 2007). This is related to the deposition of sulphur and nitrogen compounds (Brimblecombe, Austin and Sturges, 2002), which has often been transported over hundreds or thousands of kilometres from the point of emission (Elsom, 1992). Although these pollutants could acidify the rain, the ecosystem damage was caused by deposition of sulphur (in particular) and nitrogen compounds, whether this be in rainfall, dry deposition[7] or fog.

Transboundary air pollution started to have serious impacts on the lakes, streams and rivers of Norway and Sweden, which were increasingly becoming devoid of fish (Grennfelt et al. 2019). Several scientists highlighted the issue of acid rain and the damage it was doing in the 1960s, including Professor Svante Odén, a Swedish agricultural scientist, who compiled 15 years of monitoring data to conclude that the sulphur content in the air created acid rain. The sulphur could travel long distances across national boundaries, causing environmental issues, such as damaging rivers and aquatic life, as well as potentially damaging (acidifying) the soil, leading to forest die-back (Odén, 1968). These findings were published in the media and scientific literature and his work gained international recognition (Pleijel, 2007). In turn, this meant that during the Stockholm Conference on Environment and Development in 1972, a lot of space was devoted to the issue of acid rain (Grennfelt and Larsson, 2018).

At the same time, as the lakes were suffering in the Nordic countries, people in Germany were becoming very concerned about "*Waldsterben*" or forest decline (Wettestad, 1997), which was also linked to the increase in gaseous pollution and acidic deposition (Ulrich, 1983). There was an increasing understanding of the effects of acid rain on the corrosion of buildings and historical artefacts across Europe (Pleijel, 2009). Similarly, the lakes in Canada were becoming more acidic and equivalent scientific and political arguments started between Canada and the USA (Thompson and Carroll, 1984).

In the 1970s, OECD's Environment Policy Committee launched technical projects on transboundary air pollution, bringing together data from monitoring stations in 11 different countries, to examine the degree of transboundary transport of pollution (Grennfelt et al. 2019). In the face of a degree of scepticism over the issue, not least in the UK, these data demonstrated conclusively that a large part of the air pollution emitted in one country, could be deposited in another, after having been blown hundreds of kilometres, causing various harmful impacts (Grennfelt et al. 2019). In 1974, the OECD Council published "*Guidelines to Reduce Emissions of Sulphur Oxides and Particulate Matters from Fuel Combustion in Stationary Sources*". This work provided the building blocks for two major international achievements: (1) a Cooperative Technical Programme to Measure the Long-range Transport of Air Pollutants in Europe[8], launched in 1978 by UNECE; and (2) the UNECE Convention on Long-Range Transboundary Air Pollution (the Convention on LRTAP) signed in 1979 by the EU and 31 industrialized countries, including the USA and Canada (Sliggers and Kakebeeke, 2004). These countries committed to limit and gradually reduce the emission of air pollutants that contributed to long-range transboundary air pollution (Grennfelt and Larsson, 2018). This was the first regional framework developed to address air pollution as a transboundary issue and

7 Dry deposition is the deposition of pollutants, including gases and particulate matter, as they settle out of the atmosphere or are absorbed by plant tissues in processes not involving rainfall or other forms of precipitation.
8 Referred to unofficially as the European Monitoring and Evaluation Programme or "EMEP".

Table 1. The Protocols of the Convention on LRTAP

Place/ date	Date entered into force	Protocol
Geneva, 1984	1988	Long term financing of cooperative programme of EMEP (Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe)
Helsinki, 1985	1987	Reduction of sulphur emissions or their transboundary fluxes (movement across national boundaries) by at least 30%
Sofia, 1988	1991	Control of emissions on nitrogen oxides (NO_X) or their transboundary fluxes
Geneva, 1991	1997	Control of emissions on Volatile Organic Compounds (VOCs) or their transboundary fluxes
Oslo, 1994	1998	Further reduction of sulphur emissions
Arhus, 1998	1998	1) Heavy metals (amended in 2012) 2) Persistent organic pollutants (amended 2009) - neither amendments are in force.
Gothenburg, 1999	2005	Abate acidification, eutrophication and ground-level ozone (amended in 2012 to include primary $PM_{2.5}$ and provisions on black carbon, and entered into force 2019)

Source: Adapted from Sliggers and Kakebeeke (2004)

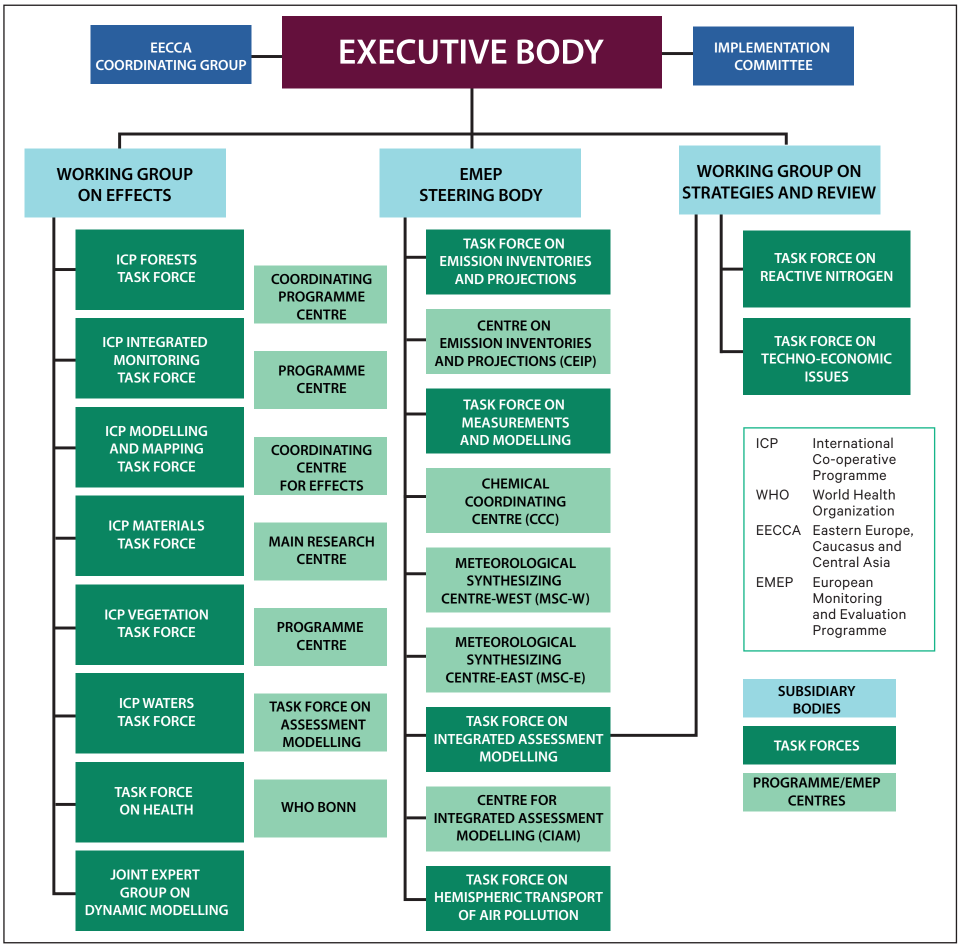
subsequently developed into international legally-binding Protocols (see Table 1) (Lidskog and Sundqvist, 2011).

The Convention on LRTAP has been an interesting and effective process for negotiation between countries to limit emissions in Europe. It included both Canada and the USA, as well as Russia and other non-EU countries (Sliggers and Kakebeeke, 2004). Some countries championed the development of the Convention. Sweden and other Scandinavian countries were clearly enthusiastic because they wanted to solve the acid rain problem affecting them. Likewise, Germany was keen to solve their forest decline (Rose, 1990) and there were changes in Germany at the time that led to their active engagement. This included the Green Party winning seats in the Parliament for the first time in the early 1980s. This changed policy considerably, with Germany developing many “green” policies and becoming enthusiastic for the development of Protocols under the Convention (Underdal and Hanf, 2019). Similarly, in the UK, green parties did very well in local authority elections in the early 1980s, which also contributed to a change in policy.

One of the main successes of the Convention on LRTAP is the organizational structure, which accomplished the effective development of a science-policy interface. The structure of the LRTAP Convention (see Figure 7) has closely linked the science needed to understand the flows and impacts of transboundary air pollution, and the modelling strategies that help understand the impact of air pollution reductions in Europe. This has informed the policy process (Sliggers and Kakebeeke, 2004). Different task forces and international cooperative programmes maintained a close network of country experts, developed from the Convention on LRTAP and from the international scientific community (Sliggers and Kakebeeke, 2004). This created an all-round international consensus on the effects of air pollution and the transboundary issues, encouraging action to be taken (Lidskog and Sundqvist, 2011).

The Executive Body and Working Groups of the Convention on LRTAP would often decide on the scientific information required to support the decision-making and negotiations within the Convention. Sometimes this would push the Task Forces to produce results at a faster pace than the scientists within them were used to working (Sliggers and Kakebeeke, 2004). The science produced in these collaborative efforts would not only support the negotiations, but also contribute to the overall knowledge that was driving policy (Lidskog and Sundqvist, 2002).

Figure 7. The organisational structure of the LRTAP Convention



Source: Sliggers and Kakebeeke (2004)

The work of the Convention on LRTAP built upon the progress made by the OECD, by developing the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) (Sliggers and Kakebeeke, 2004) through the Geneva Protocol in 1984 (see Table 1). Known unofficially as the "European Monitoring and Evaluation Programme", EMEP provides a channel for exchanging standardized scientific information and empirical data at a large scale. Prior to the Geneva Protocol, data exchange had not happened at such a large scale before and it was deemed necessary for smooth negotiations and to understand the exchange of pollutants between countries (Pleijel, 2007).

EMEP provides sound scientific support to the Convention, in particular in the areas of: atmospheric monitoring and modelling; emission inventories and emission projections; and integrated assessments (Grennfelt and Larsson, 2018). As the source of information on the emission, transport and deposition of air pollution, EMEP, since its creation, has played a major role in informing policy development under the Convention (Lidskog and Sundqvist, 2011). The "Working Group on Effects", which works in parallel with EMEP, has been instrumental in quantifying the scope of damage to ecosystems and health, and has shown the improvement in the impacts on ecosystems since the establishment of the Convention.

In order to make rapid progress, the countries agreed that they would make an across-the-board reduction in sulphur emissions (Sliggers and Kakebeeke, 2004), – one of the main transboundary air pollutants – and a good starting point for action on acid rain (Murdoch, Sandler and Sargent, 1997). The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes, aimed to reduce emissions of all signatories by at least 30% from 1980 levels by 1993 (Pleijel, 2007). This was known as the "30 per cent club" and famously, the UK did not sign, which led to a scientific and political struggle in the 1980s, with the UK's Central Electricity Generation Board –who mainly burnt coal in their power stations without equipment to scrub out the sulphur – lobbying the UK government (Rose, 1990).

The UK government position maintained that the scientific case for the transboundary transport of air pollution and the subsequent acidification of lakes, was not based on sufficiently sound science (Mason, 1990). Given that the scientific arguments lay behind the impasse between the UK and Nordic[9] countries, they co-funded the "Surface Water Acidification Programme" (SWAP), which was undertaken by academics in the UK, Norway and Sweden (Mason, 1990). Projects within the SWAP helped develop the strong evidence that encouraged the UK government to change its policy (Rose, 1990). Key research looked at diatom remains in sediments (small unicellular plants which have different pH preferences), which showed how the pH in lakes had declined, as sulphur emissions and deposition increased, and how the pH decrease also mirrored soot deposition in the sediments (Battarbee et al. 1984). This evidence showed that what was happening in Scotland and the Lake District in the UK, was also occurring in Scandinavia (Mason, 1990).

The UK Central Electricity Research Laboratory (CERL) produced a document called *"Acid Lakes in Scandinavia – an evolution of understanding"* (by P.F. Chester) in 1986, which signalled this change in UK policy. As it happens, the emissions of sulphur declined in the UK by more than 30% over the period of the Helsinki Protocol (1985 – 1994) (known as the first Sulphur Protocol), due to the shift from coal to natural gas with a very low sulphur content (as described in Section 2.1) (Rafaj et al. 2014), especially in electricity generation and industry (Elsom, 1992). So, the UK could have avoided a number of years where they were described as the "Dirty Man of Europe", especially by Scandinavians, during the period of inaction (Rose, 1990).

The UK became an active participant in the development and implementation of subsequent Protocols in the LRTAP Convention (Sliggers and Kakebeeke, 2004), including: the 1988 NO_X Protocol (Protocol concerning the Control of Emissions of Nitrogen Oxides); the 1991 VOC Protocol (Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes), the Oslo Protocol (1994) (known as the Second Sulphur Protocol); and the 1999 Gothenburg Protocol (the so-called "Multi-Pollutant- Multi Effect Protocol") (Table 1). One feature of the development of the so-called "second-generation" Protocols (from 1994), has been the targeted approach to emission reductions, based on the impacts that these emissions are having (Grennfelt, 2016). This meant that there was less pressure on countries to mitigate emissions where their pollution did not have significant harmful effects on sensitive ecosystems (Lidskog and Sundqvist, 2002).

"Critical loads" were also developed as a way to express nature's tolerance to withstand pollution inputs, by setting scientifically-based safe deposition levels of sulphur and nitrogen compounds (Ringquist and Kostadinova, 2005). Integrating critical loads into policy allows cost-effective abatement strategies to be used and overcomes the assumption that all ecosystems have the same sensitivity to acidification, as would be implied with a flat rate reduction i.e. all countries reducing their emissions by the same percentage (Pleijel, 2007). The first map of critical loads for acidification to be used in Integrated Assessment Models (IAMs) that supported the Convention, was developed by the Stockholm Environment Institute (SEI) (Chadwick and Kuylenstierna, 1990, 1991). This was then replaced by critical load maps that were developed based on inputs from different countries, and were compiled into European maps by one of the LRTAP Convention bodies – the Coordination Centre for Effects (Grennfelt et al. 2019).

9 Specifically Denmark, Norway, Sweden, Finland.

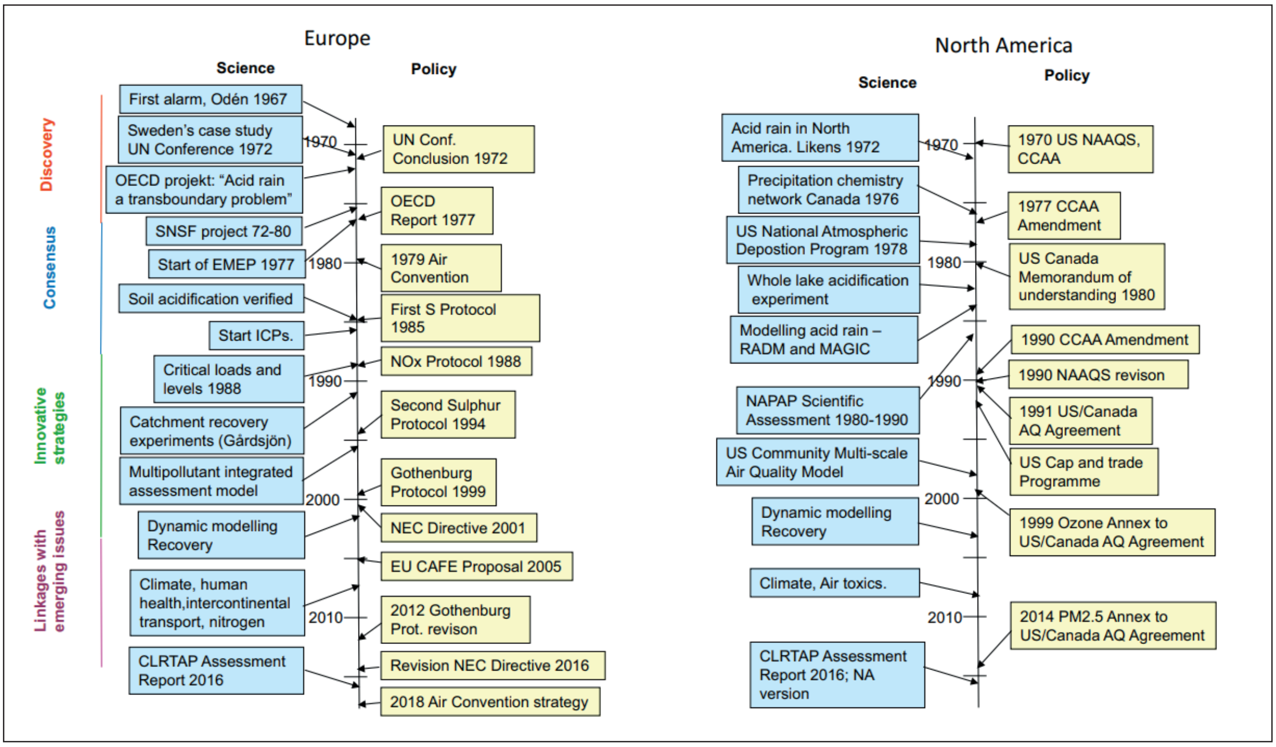
The different bodies of the LRTAP Convention developed methods and compiled data from countries on all of the information required to supply the negotiations with the data they needed (Sliggers and Kakebeeke, 2004). This included: emission inventories and projections; atmospheric transport modelling; pollution monitoring; impacts on waters, forests and other vegetation; health and corrosion; and the Integrated Assessment Models (IAM) that linked all of these aspects together (Grennfelt et al. 2019). Integrated assessment modelling has been a bridging concept, by bringing together scientific knowledge and a comprehensive systems analysis tool, leading to the formation of a new way of framing environmental policies (Grennfelt et al. 2019). Initially three IAMs were developed: (1) the Regional Air Pollution Information and Simulation (RAINS) model, by the International Institute for Applied Systems Analysis (IIASA); (2) the Coordinated Abatement Strategy Model (CASM) by SEI; and (3) the Abatement Strategies Assessment Model (ASAM) by Imperial College, London. However, it was decided that the formal negotiations should be informed primarily by the results from the RAINS model, to set national emission reduction targets (Gough, Castells and Funtowicz, 1998). The IIASA Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model is also now used to inform the negotiations, and to further develop the LRTAP Convention (Pleijel, 2007). The development and use of the RAINS model is the first time all parties to a major international convention accepted a computer simulation model and made it an integral part of their negotiations (Gough, Castells and Funtowicz, 1998). The use of the IAM as a basis for negotiations has been a major part of the success of the LRTAP Convention (Lidskog and Sundqvist, 2002).

The critical loads concept and IAMs were used to determine the targets for emission reductions allocated to each country (Sliggers and Kakebeeke, 2004). Interestingly, countries agreed to accept different percentage reduction targets that were developed using the results of the RAINS model. The RAINS model used optimization methods to arrive at emission reductions by country, that would minimize critical load exceedance at the least cost, for a given overall budget for Europe (Grennfelt et al. 2019). This fed into the negotiations of the different protocols, and countries committed to reduce emissions to target levels by a certain date (Gough, Castells and Funtowicz, 1998). These country negotiations took place at meetings of the “Working Group on Strategies” and the Executive Body (see Figure 7). After political agreements had been reached, usually after at least 2-3 years of preparatory work and negotiations, they were signed and then ratified by countries (Sliggers and Kakebeeke, 2004).

It is interesting to consider the LRTAP Convention from a Russian perspective. For the first 10 years of the existence of the Convention, the Cold War was in full flow (Raustiala, 1997). The signing of the Convention by representatives from countries separated by the Cold War was seen as extraordinary (Sliggers and Kakebeeke, 2004), and is thought to be largely because scientists, specialists and the general public in Europe and North America were fully aware of the need for joint cooperation to solve the urgent ecological problems (Sliggers and Kakebeeke, 2004). The Russian view was that the Convention allowed collaboration to occur, which crossed the divide between east and west. This was an opportunity to have two very different political systems, discussing something relatively uncontroversial, such as the science behind air pollution and policies to address them (Sliggers and Kakebeeke, 2004). Scientific collaboration was enhanced by the establishment of two centres for atmospheric modelling, one in Oslo, and one in Moscow, known respectively as the Meteorological Synthesizing Centre (MSC)-West and MSC-East (EMEP, WMO and UNEP, 1999).

The policy making in North America followed a different path to Europe. What happened in Europe and what happened in North America is summarized in Figure 8. A key difference was the USA’s focus on setting emission standards for various source sectors, instead of developing a strategy based on agreed environmental targets (Elsom, 1992). In addition, the USA decided to establish emissions trading programmes. The first of these was the Environmental Protection Agency (EPA) Emission Trading Programme, established in 1979, for various emissions resulting from stationary sources. However, the main programme was the 1995 Acid Rain Cap and Trade scheme (Ellerman, Joskow and Harrison, 2003). Emission trading aimed to give

Figure 8. A timeline of science and policy interactions in Europe and North America from 1967–2018



Source: Grennfelt et al., (2019)

OECD - Organization for Economic Cooperation and Development, **ICPs** - International Cooperative Programmes of Convention on LRTAP, **EMEP** - Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe, **SNSF project** - Acid precipitation – effects on forest and fish 1972-1980, **MAGIC** – Model for Acidification of Groundwater in Catchments, **RADM** - Regional Acid Deposition Model, **NAPAP** – National Acid Precipitation Assessment Programme (USA), **NAAQS** – National Ambient Air Quality Standards (USA), **CCAA** – California Clean Air Act. It should be mentioned that Canada and the USA are both parties to the Air Convention.

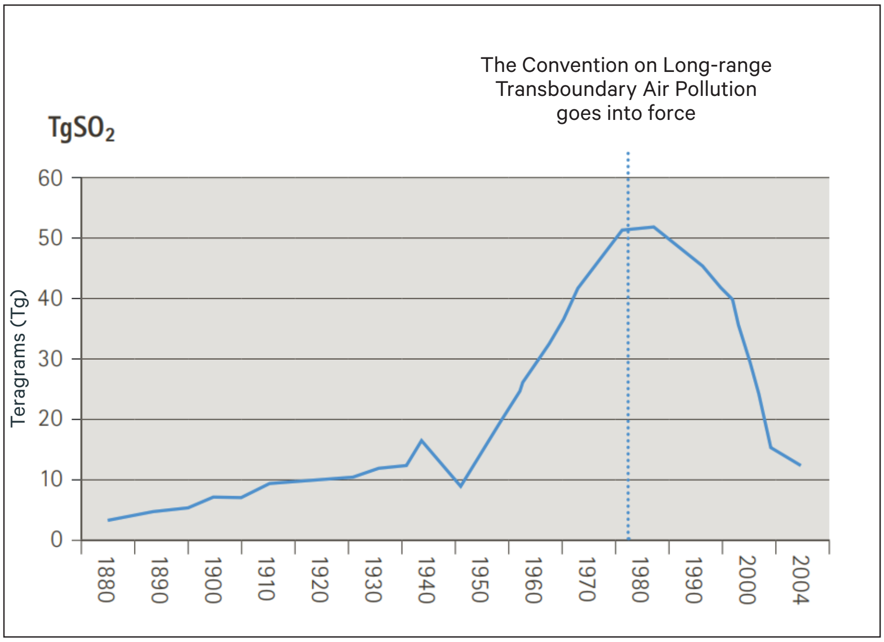
flexibility to plant managers to find the cheapest, most efficient way of meeting pollution control standards (Howarth, 2007).

Regarding cooperation between countries, the USA and Canada were signatories to the LRTAP Convention, contributing to the different subsidiary bodies and to the work of the Executive Body (Grennfelt et al. 2019). Interestingly, at the beginning of the acid rain crisis, when Canada was trying to persuade the USA to act on emissions acidifying the south-eastern part of Canada, the USA actually had more stringent emission regulations than Canada. The negotiations were successful , but Canada had to adopt tighter regulations themselves in order to get the USA to agree (Government of Canada, 2012). The Canada-United States Air Quality Agreement was signed by Canada and the United States in 1991, to address transboundary air pollution leading to acid rain. They therefore had their own bilateral agreements on acid rain, and limiting emissions, which were separate from the Convention on LRTAP Protocols.

Reduction of transboundary air pollution emissions related to the work of Convention on LRTAP

Implementation and enforcement of the Protocols is up to the Convention on LRTAP. The role of UNECE is to provide the Secretariat for the Convention. The LRTAP Convention has limited powers to enforce action or take sanctions if a country fails to live up to its pledges (Lidskog and Sundqvist, 2011). It can put pressure on countries by "naming and shaming", or providing support to build capacity to move processes forward, but that is about all it can do (Sliggers and Kakebeeke, 2004). However, over the period of the existence of the LRTAP Convention, emissions of many of the key pollutants that fall under the Protocols have reduced remarkably in Europe – particularly sulphur (see Figure 9).

Figure 9. Emissions of sulphur dioxide over the period 1880 – 2004 for all European countries (including the European part of Russia, Ukraine, Belarus, Serbia)



Source: UNECE (2009)

That said, even in 2017, sulphur dioxide emissions are approximately at the same levels as they were around 1900, when damaging smog events in some of the large cities of Europe were occurring. However, now emissions are dispersed over a much larger area, and local impacts are greatly reduced (UNECE, 2009). As well as sulphur emission reductions, nitrogen oxide (NO_X), primary $PM_{2.5}$ and Non-Methane Volatile Organic Compound (NMVOC) emissions have also decreased (see Figure 10). This has improved air quality and reduced ground-level ozone concentrations which affect human health, forest health and crop yields (Grennfelt et al. 2019). Ammonia emissions have proved harder to address, as this requires significant changes to the agriculture sector (Grennfelt, 2016).

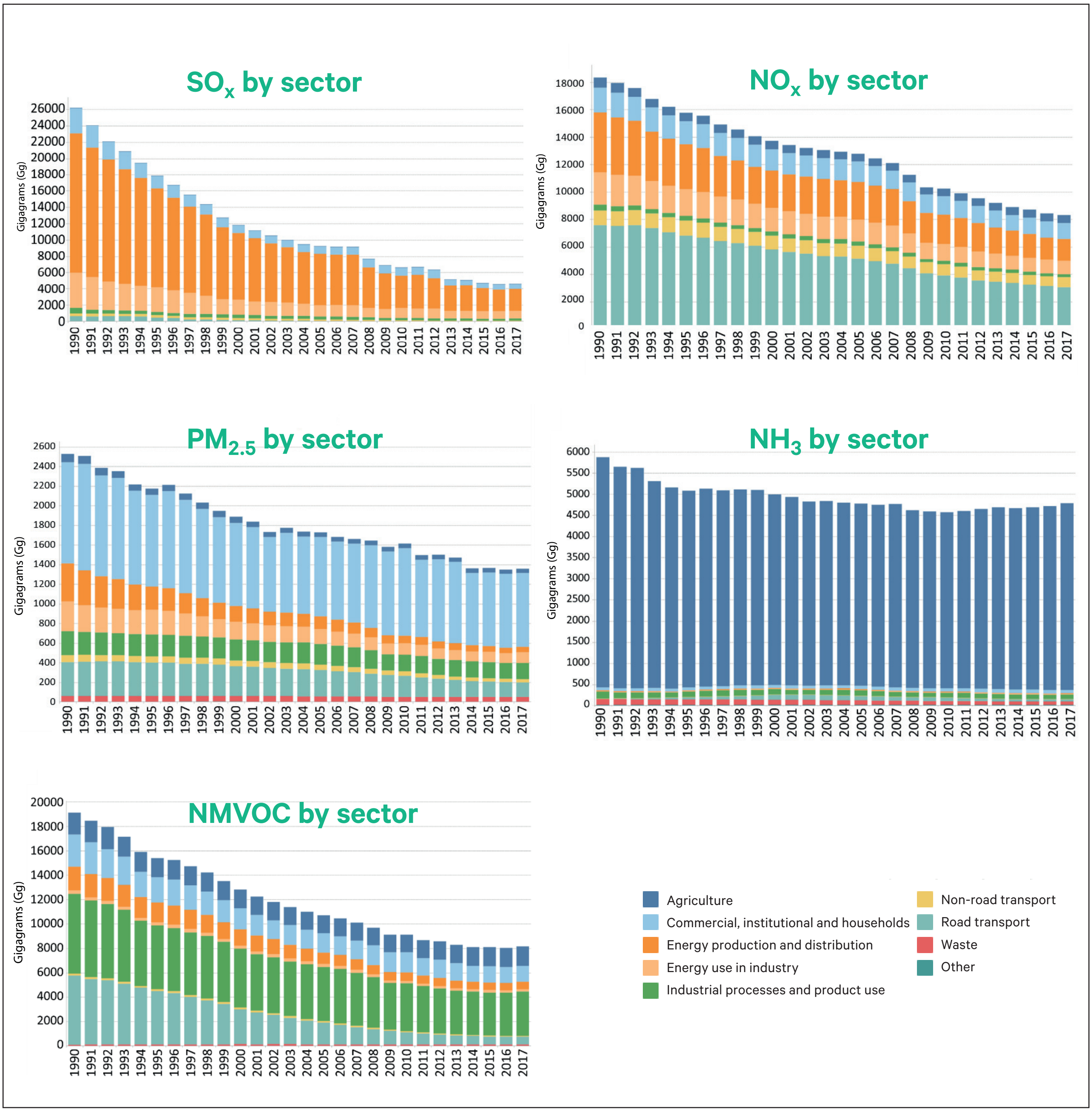
Multiple factors have led to the emission reductions seen in Europe. Successful environmental negotiations are one reason, the elements for which include: that the issue warrants international cooperation; there is a scientific consensus; and that cooperation adds value to the efforts to reduce the problem (Sliggers and Kakebeeke, 2004) (see Table 2). In addition to the elements outlined in Table 2, the political will of participating countries to negotiate is a key

Table 2. Prerequisites for successful completion of negotiations on international environmental agreements

• **Is the relevant environmental issue addressed at an appropriate geographical level?**
• **Does the international community recognise the environmental issue as warranting international action?**
• **Is there a high level of international scientific consensus?**
• **Is sufficient and accepted leadership available?**
• **Compared to national measures, does international action add value?**
• **Are measures to address the problem available and affordable?**

Source: Sliggers and Kakebeeke (2004)

Figure 10. The emission of sulphur oxides (SO_X), nitrogen dioxide (NO_X), non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and primary $PM_{2.5}$ by sector in the EU-28 plus Norway, Switzerland and Turkey from 1990 to 2017



Source: European Environment Agency (2019) prerequisite. There was a remarkable willingness in the governments of most European countries (Pleijel, 2007), which cannot be taken for granted in other parts of the world (see section 5 where this is further discussed in relation to South Asia and southern Africa). There also needs to be a "first mover" country, driving the change. This country must be adopting the most stringent regulations in order to be taken seriously by neighbouring countries. Sweden has often been a first mover – adopting policies before others – and uses this as basis for taking a moral stance and influencing other countries to be more ambitious.

It is important to be aware that while the LRTAP Convention can clearly claim it was responsible for reducing air pollution, air pollution policy is not the only reason that these reductions have occurred. For example, sulphur emissions in Europe began to decline in 1980, before the first Sulphur Protocol (i.e. the Helsinki Protocol) had been ratified in 1985. That said, emissions did then steeply decline after 1985, once the Protocol came into force (see Figure 8) (Rafaj et al. 2014). Analysis by Rafaj et al. (2014), shows that changes to the energy structure in Western Europe, with a switch to different fuels – especially natural gas – combined with reduced energy intensity, have offset continued growth in energy consumption (see Figure 11). For example, the UK didn't ratify the Protocol, but still met the 30% target, due to the changing fuel mix with the "dash for gas". Some of the structural changes in energy, including fuel shifts and improved energy efficiency, were most likely triggered by the oil crises in the 1970s (Rafaj et al. 2014), so the extent to which these changes were a response to air quality concerns is debatable. That said, SO_2 emissions, as shown in Figure 11, have been reduced by end-of-pipe control measures – a direct air pollution policy – and is responsible for a small part of the overall reduction.

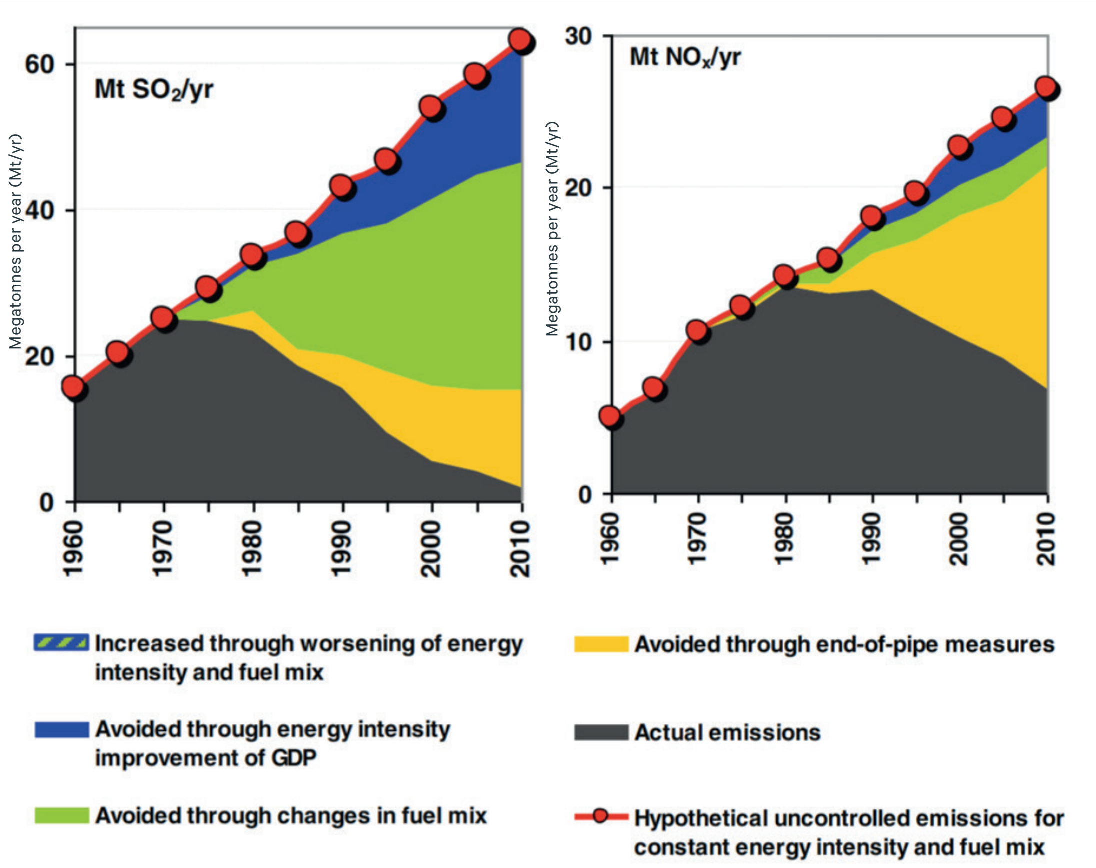
Because the changes in energy structure and fuels used are not factored into the modelling, this can lead to an overestimation of abatement costs in the RAINS/GAINS model. This was the case for the Gothenburg Protocol negotiations, where the model only accounted for technical emission abatement measures (often end-of-pipe measures) and not structural changes, for example in the energy or transport systems (Sliggers and Kakebeeke, 2004). One thing that happened between 1980 and 2010 was "industrial restructuring", whereby a lot of heavy polluting industry closed down in Europe and shifted to other parts of the world, such as in Asia, due to lower labour costs. It is important to try to understand how such factors are contributing to emission changes, so that future policy initiatives can be as targeted as possible.

The influence of air pollution policy is clearer for NO_X emissions, where most of the reduction in emissions has been due to end-of-pipe measures (Figure 11). The biggest end-of-pipe NO_X emission reductions have come from road traffic, with more than 75% of effective measures up until 2010 involving the transport sector (Rafaj et al. 2014). Emissions from traffic have also been reduced through changes in traffic infrastructure and management, and engine modification and exhaust treatments using catalytic converters , which require low sulphur unleaded fuels (Grennfelt and Larsson, 2018). Up until 2010, only a few countries, such as Germany, Sweden, the Netherlands and Austria, had widely applied secondary measures such as Selective Non-Catalytic Reduction[10] (SNCR) on large combustion plants. These measures have produced significant reductions of NO_X emissions and provide quick results while system changes are taking place (Sliggers and Kakebeeke, 2004).

It is important to try to understand how such factors are contributing to emission changes, so that future policy initiatives can be as accurate as possible. Decision-making on major shifts in the economy is complex by nature and involves many different stakeholders. Identifying only one factor in this decision-making process that has overriding influence is naïve and simplistic (Lidskog and Sundqvist, 2011). In the end, what is clear is that the negotiations as part of the

10 Selective Non-Catalytic Reduction (SNCR) is a method to lessen nitrogen oxide emissions in conventional power plants that burn biomass, waste and coal. The process involves injecting either ammonia or urea into the firebox of the boiler to react with the nitrogen oxides formed in the combustion process. The resulting product of the chemical redox reaction is molecular nitrogen (N_2), carbon dioxide (CO_2), and water (H_2O).

Figure 11. Determinants of the reduction in sulphur dioxide (SO_2) emissions (left-hand side) and nitrogen oxide (NO_X) emissions (right-hand side) in Western Europe between 1960 and 2010



Source: Rafaj et al. (2014)

LRTAP Convention acted as a focus for combined action in Europe and the emissions of most pollutants have reduced to a significant degree (DEFRA, 2019).

Importance of NGOs in the national and regional processes

Public acceptance is key to progress in adopting and implementing policy and this acceptance is highly dependent on awareness and understanding of the issues. This is often provided by NGOs, who play a crucial role in supporting environmental negotiations (Selin and VanDeveer, 2003).

Initially, the Convention on LRTAP attracted little attention from environmental NGOs until internationally coordinated air pollution activities began in 1982. This was other than in a brief period in 1979, where youth environmental groups sent thousands of postcards with demands to cut pollution of acidifying sulphur emissions to governments in the UK and Germany (Sliggers and Kakebeeke, 2004). In 1982, several European NGOs joined forces to act simultaneously as watchdogs, lobbyists, media contacts and information resources, which could communicate negotiation developments from closed meetings via the media to the public (Pleijel, 2007). At international meetings, NGOs' role as watchdogs was highly important, to ensure that national delegates provided a fair and correct representation of a countries official policy (Selin and VanDeveer, 2003).

In many cases, they have acted as a translator of scientific knowledge, putting the facts forward in a language that people could understand, and acted as an interface between science and the media (Raustiala, 1997), for example, reporting on data from long-term experiments into acid rain and its impacts on ecosystems and human health (Grennfelt et al. 2019). Often, governments would have dialogues with NGOs, and NGOs had freedom to say things that governments could not, which provided overall transparency to the public (Grennfelt, 2016).

NGOs in Europe also collaborated and developed common narratives in the different countries – and so provided a community that crossed between countries (Selin and VanDeveer, 2003). This helps to establish a trust-building process, which is an essential part of developing cooperation between countries who are trying to collaborate on transboundary issues such as air pollution (Raustiala, 1997). NGOs played an important role in driving awareness beyond local or national actions and were important for a more global movement towards cleaner air (Grennfelt et al. 2019). However, in the late 1990s, the majority of NGOs gradually lowered their priorities to regional air pollution, as climate change became the environmental priority (Raustiala, 1997).

2.3 Technology advice by the Convention on LRTAP

The Convention has tried to help countries evaluate their options to reduce emissions through exchanging technical knowledge and advice. In the early 1980s to 1990s, there was a "Working Group on Technology", as well as a special "Task Force on Exchange of Technology" (Sliggers and Kakebeeke, 2004). These allowed developing Western European technologies to be filtered through to Eastern European countries, in order to modernize their emission abatement systems. The exchange of information included international seminars on Flue Gas Desulphurization (FGD) and Large Combustion Plants (LCPs), for example. These Working Groups helped underpin the Technical Annexes to the Protocols (Sliggers and Kakebeeke, 2004).

In the early 2000s, "The Task Force on Techno-Economic Issues" (TFTEI) was formed and worked under the "Working Group on Strategies and Review". TFTEI[11] works to update and assess information on emission abatement technologies and their costs . It is tasked with establishing and maintaining a regional clearing house of control technology information, with the aim of being a reference place for the dissemination of information to the experts of the Parties (UNECE, 2017b). TFTEI also cooperates with other technical bodies of the Convention — in particular, the "Task Force on Emission Inventories and Projections" and the "Task Force on Integrated Assessment Modelling" (TFIAM) — to create synergies, maximize results and optimize resources when performing its tasks (UNECE, 2017b).

Recent products of the TFTEI include the *"Guidance document on control techniques for emissions of sulphur,* NO_X*, VOC, and PM from stationary sources" and the "Guidance document for emission control techniques for mobile sources under the Gothenburg Protocol"* (Sliggers and Kakebeeke, 2004). Currently, this Task Force is preparing a *"Code of good practice for wood-burning and small combustion installations"*. The priority interest of TFTEI is the active involvement of European industry, with the aim of establishing a positive and constructive dialogue between industry and administrations of the EU Countries, on economic and technical issues (Sliggers and Kakebeeke, 2004). The information this Task Force provides may also be used both in the formulation of draft revisions of Technical Annexes to existing Protocols, as well as for input data to Integrated Assessment Models (IAMs).

The work undertaken by TFTEI is complementary to the work carried out by the European Integrated Pollution Prevention and Control Bureau of the European Commission's Joint Research Centre. That is, to draft the Best Available Technique Reference documents (BREFs) for different industries, within the framework of the implementation of the EU's Industrial Emissions Directive (IED) (UNECE, 2019). The BREFs contain details about the Best Available Techniques (BATs) relevant to the different environmental issues covered by the IED (UNECE, 2019). BATs are

11 For more information on TFTEI visit https://tftei.citepa.org/en/.

described in detail and are assessed in technical terms by the European Integrated Pollution Prevention and Control Bureau for accuracy, in association with Member States, industry and environmental NGOs (Grennfelt and Larsson, 2018). Having guidance on BATs is highly important, as without techniques/technologies to abate pollution, meaningful international agreements cannot be made (Sliggers and Kakebeeke, 2004).

Currently, some of the most influential BATs are Flue Gas Desulphurization (FGD), Selective Catalytic Reduction (SCR), electrostatic precipitators and three-way catalytic converters (Pleijel, 2007). FGD was a major step forward in technical development and was reflected in the 1985 and 1994 Sulphur Protocols and the EU Large Combustion Plants Directive (1988, 2001). Emission standards that usually required the use of FGD on large combustion plants, were introduced in German national legislation in the early 1980s, and were gradually introduced in other European countries (Sliggers and Kakebeeke, 2004).

As well as the promotion of actions towards implementation of the LRTAP Convention in Europe, the TFTEI Task Force also promotes cooperation with a group of countries outside of the UNECE region. This includes countries in Eastern Europe, Caucasus and Central Asia, with the purpose of providing technical and scientific assistance to those countries (UNECE, 2017a). For example, in 2007, the “Working Group on Strategies and Review” revised an action plan for capacity building in Eastern Europe, the Caucasus and Central Asia, to involve these countries in the work of the Convention (UNECE, 2007). The action plan includes strategies such as using the EMEP Protocol, as a first step for all countries to achieve major benefits from cooperation with the Convention’s programme centres and other Parties. Other steps included organizing workshops on technical issues such as emission inventories, particulate matter measurements, ecosystem monitoring, and emission monitoring. Both decision-makers and specialists participate in these. This assures political commitment at the ministerial level, and agreement on priority air pollution problems; the need for international cooperation; the steps to be taken; and who to involve (UNECE, 2007).

Another example of the engagement of the LRTAP Convention outside the UNECE region is the “Task Force on Hemispheric Transport of Air Pollution” (TFHTAP), which was set up under the Convention in 2004. It is an international scientific cooperative effort, to improve the understanding of the intercontinental transport of air pollution across the Northern Hemisphere (UNECE, 2017b). The TFHTAP represents a “bridge” between a regional agreement like the Convention on LRTAP and the increasing recognition that some pollutant problems are hemispheric and even global in nature. Ground-level ozone is a good example, where for a long time it has been known that damage to plants and crops can occur at levels close to the typical tropospheric background. This background level is determined by global emissions of precursor pollutants, especially of methane, which is well mixed in the atmosphere, and also by the transport of ozone, once formed, across the northern hemisphere. Local ozone levels are more controlled by the concentration of the ozone precursors NO_X and Non-Methane Volatile Organic Compound (NMVOCs) (Dentener, Keating and Akimoto, 2010).

One of the ways TFHTAP aims to understand the hemispheric nature of air pollution is by quantifying the intercontinental transport of pollutants and then from this, comparing models and their outcomes over different continents (Grennfelt, 2016). The Task Force reports to the Convention’s EMEP Steering Body, but participation is open to all interested experts, both inside and outside the UNECE region (UNECE, 2017b). In 2010, the Executive Body renewed and expanded the TFHTAP. It’s three main objectives are to (1) Deliver Policy Relevant Information to the LRTAP Convention, Other Multi-Lateral Forums, and National Governments, (2) Improve Our Scientific Understanding of Air Pollution at the Global to Hemispheric Scale, and (3) Build a Common Understanding by Engaging Experts Inside and Outside the LRTAP Convention (UNECE, 2017b). Through the work of the TFHTAP, several regional emission inventory tools are now available for Asia, including GAINS, the National Aeronautics and Space Administration’s (NASA) Total Risk Assessing Cost Estimate for Production (TRACE-P) inventory, and the Japanese Regional Emissions Inventory in Asia (REAS) (UNECE, 2017b). For some Asian countries, the available inventories are of similar quality to those in Europe and North America – particularly for Japan, Korea and the Taiwan Province of China (UNECE, 2017b).

2.4 European Union legislation on air quality

The LRTAP Convention may have had limited legislative powers to enforce emission reductions, but this is not the case with the European Commission, which can enforce policy in EU Member States (Lidskog and Sundqvist, 2011). The first EU Air Quality Directive was agreed in 1980, with an initial focus on urban air quality and the impact on human health (Council of the European Union, 1980). The EU came later to the regional air pollution debate but the Technical Annexes to the LRTAP Protocols have strong connections to EU Directives, which has aided the acceptance and implementation of them (Sliggers and Kakebeeke, 2004). The EU has developed several different policies affecting atmospheric emissions, the first of these came into place in the late 1980s, with the 1988 Large Combustion Plant (LCP) Directive, followed by the National Emission Ceilings (NEC) Directive, Air Quality Directives, Euro Standards for vehicles and numerous pieces of source-sector legislation and climate policies (see Table 3).

The technology to reduce emissions from LCPs had been around for a while before the LPC Directive was introduced, but it was thought that countries held off from implementing it due to the influence of industry. The original 1988 LCP Directive imposed emission limits on new large plant emissions, as well as some modest emission reductions for existing plants. But despite this, LCPs continued to be a significant source of SO_2 and NO_X emissions (Amann and Cofala, 2001). LCPs were estimated to contribute about 44% of total EU15 emissions of SO_2, and 12% of emissions of NO_X, even under the 1988 LCP Directive (Amann and Cofala, 2001). This Directive was revised in 2001, with stricter emission limits, although it was still criticized for having standards which were too lax (Goldenman and Levina, 2004).

During the second half of the 1990s, the European Commission presented strategies for combating acidification and ground-level ozone within the EU. This laid the foundation for the 2001 National Emission Ceiling (NEC) Directive (see Table 3). The preparatory work and the analysis by the Commission relied heavily on the science base of the Convention on LRTAP, principally using the same methodology as the one applied by the LRTAP Convention for the negotiations of the Gothenburg Protocol (the critical loads approach and the RAINS/GAINS integrated assessment model). In the development of the NEC Directive, it was the first time this methodology was used for EU policy (Grennfelt et al. 2019). The NEC Directive specifies national emission ceilings for the same pollutants as the Gothenburg Protocol (European Environment Agency, 2019). However, being part of the binding EU

Table 3. Air pollution policies for the EU

1980: Smoke and SO_2 Directive	**1999: EU Ozone Strategy**	**2008: EU rev. AQ Directive**
1985: NO_2 Directive	**1999: EU rev. S-in-fuels Directive**	**2010: EU IED (rev. IPPCD+LCPD)**
1988: EU LCP Directive	**1999: EU AQ|DD (SO_2/NO_2/PM_{10}/Pb)**	**2012: EU rev. S-in-fuels Directive**
1992: EU S-in-fuels Directive	**2001: EU NECD + rev. LCPD**	**2013: EU Clean Air Package**
1996: EU AQ Framework Directive	**2005: EU CAFE Thematic Strategy**	**2015: EU MCP Directive**
1996: EU IPPC Directive	**2005: EU rev. S-in-fuels Directive**	**2016: EU rev. NECD**
1997: EU Acidification Strategy		

Source: Pleijel (2007); DEFRA, (2018); Grennfelt et al. (2019); Council of the European Union (1980; 1985)

LCP – Large Combustion Plant, **AQ** – Air Quality, **IPPC** – Integrated Pollution Prevention and Control, **AQ DD** Air Quality Daughter Directive, **NECD** – National Emission Ceilings Directive, **LCPD** Large Combustion Plant Directive, **CAFE** – Clean Air For Europe, **S-in-fuels** – Sulphur in fuels, **IED** – Industrial Emission Directive, **MCP** – Medium Combustion Plant, **rev.** - revised.

legislation, it represents a stronger legal instrument (Lidskog and Sundqvist, 2011). The first NEC Directive was adopted in 2001 (see Table 3) and had targets which were to be attained by 2010 (European Environment Agency, 2019). A revised Directive in 2016 kept the 2010 emission caps in place, to be attained in 2020, and established more far-reaching legally binding Emission Reduction Commitments (ERCs), with a first set of ERCs to be achieved by 2020, and a second set of stricter ERCs to be achieved by 2030, as well as intermediate reduction targets for 2025 (AirClim, 2019). The 2016 revision required Member States to develop national air pollution control programmes, to comply with their ERCs (European Environment Agency, 2019).

It was generally accepted that air pollution control targets and measures adopted by the EU and its Member States by 2001, were not sufficient to achieve the EU's long-term objectives for the protection of human health and the environment, and so in 2001 the Commission launched the Clean Air for Europe (CAFE) programme (see Table 3). CAFE was designed to take a broader view of air pollution, and in 2005, resulted in a Thematic Strategy on Air Pollution, with the aim of cutting the annual number of premature deaths from air pollution-related diseases by almost 40% by 2020 (compared with the 2000 level) (Pleijel, 2007). This brought together different Directives to create one overarching air pollution abatement strategy (Lidskog and Sundqvist, 2011).

The EU Air Quality Directive of 1999, set legally binding particulate matter limits for PM_{10} ($PM_{2.5}$ was added in 2008) and SO_2 limits to be met by 2005, and NO_2 limits to be met by 2010. This Directive was updated and became the 2008 Ambient Air Quality Directive, setting legally binding limits and targets for concentrations of major air pollutants (DEFRA, 2018). It merges and replaces nearly all the previous EU ambient air quality legislation (European Environment Agency, 2019). The Ambient Air Quality Directive also requires Member States to assess air quality, then adopt and implement plans to improve air quality where standards are not met, and then to maintain this higher standard of air quality where it has been achieved (European Environment Agency, 2019). It was transposed into law across the UK through the Air Quality Standards Regulations 2010 (DEFRA, 2018).

In the EU, a different approach was taken to the USA, with regard to transport emission standards. In the USA, the same emission standards had been set for all vehicles independent of which fuel they used (Elsom, 1992). Catalytic converters, first developed in California in the late 1970s, were promoted in the mid-1980s by a number of European countries (an initiative of the Swedish Government including Sweden, Denmark, Finland, Canada, Lichtenstein, The Netherlands, Norway, Switzerland, Germany and Austria) (Dagens Nyheter, 1985), by providing subsidies and other policies to promote their adoption. This began to happen before they were adopted by the EU in the Euro Standards (see Table 4). However, when developing the EU legislation in the late 1980s and early 1990s, the EU held talks with the car and oil industries. The result of this was that the car emission standards for diesel vehicles were more relaxed than for petrol vehicles (Table 4), because the technology at the time for diesel vehicles could not reach the same standards that were set for petrol vehicles. This relaxation for diesel vehicles has contributed to the difficulty countries have had in reaching the EU concentration air quality limits for PM_{10} and NO_2 (Čavoški, 2017). A big contribution to motor manufacturers pushing diesel, were their obligations under EU legislation, which put a cap on the fuel consumption of new car sales, to meet CO_2 reduction targets. The car industry in the EU chose to meet this by prioritizing diesels (European Commission, n.d.).

The Euro Standards got stricter over time (see Table 4). However, it emerged that some parts of the vehicle industry, such as Volkswagen, had been using "cheating software" to trick regulators into believing that their diesel vehicles were adhering to the emission standards, but in reality, emissions were much higher. This became known as the "Dieselgate" scandal (Brand, 2016). This highlighted the gap between the level of pollutants produced during testing, and actual emissions produced when driving on roads in real conditions. Now, some of the major diesel car manufacturers have agreed to cooperate on real-world emission testing and

Table 4: Details of the EU Euro Standards introduced by the EU, along with the emission limits

Standard		Emission Limits
Euro 1	1992	Required switch to unleaded petrol and the universal fitting of catalytic converters to petrol cars. Emission limits: CO = 2.72 g/km, HC + NO_X = 0.97 g/km (petrol and diesel), PM = 0.14 g/km (diesel)
Euro 2	1996	Emission limits - petrol: CO = 2.2 g/km, HC + NO_X = 0.5 g/km, PM = no limit Emission limits - diesel: CO = 1.0 g/km, HC + NO_X = 0.7 g/km, PM = 0.08 g/km
Euro 3	2000	Emission limits - petrol: CO = 2.3 g/km, HC = 0.2 g/km, NO_X = 0.15, PM = no limit Emission limits - diesel: CO = 0.64 g/km, HC = 0.56 g/km, NO_X = 0.5 g/km PM = 0.05 g/km
Euro 4	2005	Emission limits - petrol: CO = 1.0 g/km, HC = 0.21g/km, NO_X = 0.08, PM = no limit Emission limits - diesel: CO = 0.5 g/km, HC = 0.3 g/km, NO_X = 0.25 g/km PM = 0.025 g/km
Euro 5	2009	Emission limits - petrol: CO = 1.0 g/km, HC = 0.1g/km, NO_X = 0.06, PM = 0.005 g/km (direct injection only) Emission limits - diesel: CO = 0.5 g/km, HC = 0.23 g/km, NO_X = 0.18 g/km PM = 6.0x10^11/km
Euro 6	2014	Emission limits - petrol: CO = 1.0 g/km, HC = 0.1g/km, NO_X = 0.06, PM = 0.005 g/km, PM – 6.0x10^11/km (direct injection only) Emission limits - diesel: CO = 0.5 g/km, HC = 0.17 g/km, NO_X = 0.08 g/km, PM = 0.005 g/km, PM = 6.0x10^11/km

Source: Adapted from Williams and Minjares (2016); The AA (2019)

reductions (Brand, 2016) and stricter versions of the Euro 6 legislation have been agreed, to incorporate on-road testing of emissions as well as laboratory-based tests.

2.5 A focus on international shipping

Although all territorial emissions in Europe could be considered under the LRTAP Convention and EU air quality legislation, international shipping adheres to rules set globally by the International Maritime Organization (IMO), adding another policy dimension to the effort to reduce air pollution. In Europe, emissions from international shipping are responsible for some 50,000 premature deaths per year, due to $PM_{2.5}$ (Brandt et al. 2013) and ship emissions also contribute significantly to the exceedance of critical loads for acidification and eutrophication. While land-based pollution sources have been reduced, shipping emissions kept on increasing throughout the 1980s and 1990s (European Environment Agency, 2019).

In the late 1980s, Swedish/Norwegian initiatives encouraging regulation in the IMO, resulted in the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI Agreement. This introduced a global cap on the sulphur content of ship bunker fuels (at 4.5%), and set the first nitrogen oxide (NO_X) standards for ships. The Agreement was first adopted in 1997, but only entered into force in 2005. Annex VI then went onto establish special Sulphur Emission Control Areas (SECAs), which limits the sulphur content of fuel used on board ships to 1.5%. As an alternative, exhaust gas cleaning systems could be fitted (e.g. a scrubber) to limit their sulphur dioxide (SO_2) emissions. The first SECA to enter into force in 2006 was the Baltic Sea, closely followed by the North Sea in 2007 (AirClim, 2011).

However, the standards in the Agreement were considered weak. In 2008, after three years of negotiating a revision of Annex VI, IMO Member States agreed to strengthen the emission standards. It was decided that all marine fuel sulphur contents would be capped at 0.5% worldwide from 1 January 2020 (IMO, 2016a). This is expected to cut global ship SO_2 emissions by 8.5–9 million tonnes/year and prevent more than 100,000 annual premature deaths from $PM_{2.5}$ (IMO, 2016b). From 2012, the global cap was lowered from 4.5% to 3.5%. Stricter limits of 1.0%

sulphur were applied to SECAs from July 2011 and 0.1% sulphur from January 2015. In addition, NO_X emission standards for new ship engines were strengthened. In a first step, there was a cut in NO_X emissions by 16-22% by 2011, relative to the 2000 standards, and in a second step by 80% by 2016. However, the latter limit applies only in specially designated NO_X Emission Control Areas (ECAs) (AirClim, 2011).

Introducing NO_X-ECAs around Europe could in the long term (by 2040) cut ship NO_X emissions by 63%, compared to 2015, but only 37% by 2030 (Winnes et al. 2016). Significant short-term reductions are possible through economic instruments such as Levy and Fund initiatives[12] which could provide a 72% reduction by 2030 (Winnes et al. 2016). The benefits of implementing NO_X-ECA and Levy and Fund significantly outweighs the financial costs. The monetized benefits are typically six times higher than costs in 2030, and 12 times higher in 2050 (Cofala et al. 2018).

The USA and Canada followed suit in 2009 and applied to the IMO to have their coastline designated as a combined sulphur and NO_X Emission Control Area, which then entered into force in 2011.

2.6 Social acceptance and the role of the media in developing air quality management approaches in Europe

The media has had an important role to play in the development of air pollution policy in Europe over the years. During the London smog events, media sources were instrumental in spreading the word about the damage caused. This created awareness of the issues and prepared the way for the acceptance of the regulation that followed. The Clean Air Act (1956) is thought to have arisen partly due to the extreme pressure from the media, and hence the public, forcing the government to act (Elsom, 1992). Newspaper reports of the Great Smog of London in 1952, drove this public interest and stated that there were 4000 excess deaths caused by the smog (Figure 12). Headlines compared air pollution deaths to the death toll from cholera, another major public health crisis that affected London almost 100 years earlier (Figure 12).

The interest of the media in air pollution moved away from urban air pollution during the 1980s, and concentrated more on the impacts of long-range transported air pollution on acid rain and forest decline (Grennfelt and Larsson, 2018). During the early days of the acid rain debate, Professor Svante Odén, published the results of his research in the peer-reviewed literature and wrote an article in the Swedish newspaper “Dagens Nyheter” (the News of the Day), which immediately became a top public story (Grennfelt and Larsson, 2018). This provided some of the impetus needed for increased policy interest in the issue (Sliggers and Kakebeeke, 2004). As the Scandinavian media focused on lake acidification, the German press focused on the issue of forest decline (see Figure 13), which helped align Germany behind the need for coordinated action in Europe (Grennfelt et al. 2019). Media engagement was used by NGOs to communicate the complicated science to the public, to increase public awareness and understanding of the issues faced (Raustiala, 1997). This created the public opinion that legislation and cooperation between countries was required to develop solutions, and in turn put pressure on the governments of different countries to act (Pleijel, 2007).

Once the issues of urban air pollution and acid rain had been largely perceived as “solved”, the interest in air pollution in Europe faded, as the media and society concentrated more on the global issues like climate change (Čavoški, 2017). However, since about 2010, there has been a resurgence in interest in air pollution in Europe, partly driven by increasing knowledge of the health impacts. This is based largely on epidemiological data from large-scale studies and the increased quantification of these impacts. This research initially came from studies in the USA, which showed

12 Levy and Fund initiatives are those that tax emissions (the levy) and use part of the revenue to fund further emission reductions.

Figure 12: Newspaper articles from 1953-4 describing the London smog disaster

DEATH-RATE IN FOG WEEK EXCEEDED CHOLERA TOLL

THE rise in deaths in the week following London's great fog early last month was greater than that in the worst week of the cholera epidemic in 1866. This is disclosed in a report of the Health Committee of London County Council, to come before the Council next Tuesday.

The Committee reports that the figures recorded by the Council's observation station at the County Hall for smoke and sulphur dioxide pollution of the atmosphere on December 7-8 are the highest which can be traced in records, which date back from 1932.

Deaths registered in London rose from 945 for the week ended December 6, to 2,484 for the following week. The general death-rate experienced in this latter week was slightly greater than that associated with the severe fog of 1873 and was comparable with rates experienced at the peak mortality of major epidemics.

FIGURES

The excess of deaths over normal per million inhabitants

Sir Herbert gives Commons his views about smog

SIR HERBERT WILLIAMS, M.P. for Croydon East, spoke in the House of Commons on Wednesday—on "smog."

Smoke and fog, he told an intrigued House, did not create the evil known by this name. Power stations, with their high chimneys, could take a slight responsibility for smog conditions, but the domestic coal fire was most to blame.

On the other hand, he said, the open fire had been largely displaced by gas and electric fires with the result that there was less fog than at the beginning of this century.

Sir Herbert, speaking on the second reading of the City of London (Various Powers) Bill, moved the deletion of a clause which empowered the City corporation to prohibit the emission of smoke in the City. He said his purpose was to obtain a debate on air pollution. After his speech and some discussion, the motion was withdrawn.

In the clause, smoke was defined as including soot, ash, grit or gritty particles.

A sub-section makes blameless the smoke from railway trains—done solely, according to Sir Herbert, to avoid opposition from the British Transport Commission.

He thought a number of locomotives had been designed on the principle of consuming their own smoke, but realised this was not easy.

SMOKELESS ZONES

So far, 17 local authorities had obtained powers to create "smokeless zones" but, he said, only Manchester and Coventry had made use of the opportunity.

The "magnitude" of the smog problem arose in December, 1952, when about five days of serious smog led to about 4,000 deaths.

"This compares with 40,000 deaths as a result of six years bombing by Hitler or about 5,000 deaths a year from road accidents, said Sir Herbert.

He was not sure if, from the health point of view, it was of much importance to tackle the problem of smoke alone, although a smokeless area was much more pleasant than one full of smuts.

Tackling the chemical aspect, Sir Herbert said most coal contained about 1½ per cent. sulphur When it was burnt, the result was carbon dioxide (which suffocated but did not poison) and carbon monoxide (tasteless, smell-less and invisible, but deadly poison).

In addition, it gave off sulphur dioxide which might combine with moisture to form sulphurous acid. This, combining with oxygen, became sulphuric acid and was responsible for the destruction of stonework and metal.

A Harley-street doctor had told Sir Herbert that the two products which caused harm to health were sulphur dioxide and the particles of tarry matter. He doubted if particles of soot, ash or grit did much harm.

SULPHUR DIOXIDE DANGER

Sulphur dioxide was particularly damaging to people with asthma or chest conditions. It could produce violent attacks of coughing, putting a tremendous strain on the heart.

The doctor had said, "Sulphur dioxide is not filtered by any kind of mask and it seems the only way to reduce the morbidity and mortality is by preventing the pollution of the atmosphere with sulphur dioxide."

Modern boilers, Sir Herbert went on, gave off less soot, carbon monoxide and carbon dioxide, but he did not think they had much effect on the amount of sulphur dioxide going into the air.

The amount of sulphur in the coal burnt every year was over two million tons. This resulted in nearly five million totns of sulphur dioxide.

"If all this combines to form sulphuric acid — which I hope it does not—nearly nine million tons of sulphuric acid would be produced each year; more than five times as great as the total industrial production in this country.

The trouble did not end with coal-burning. The exhausts from internal combustion engines must be considered.

"The combustion of petroleum products is far from complete and the result is the emission of very considerable quantities of carbon dioxide and carbon monoxide."

Mentioning a recommendation that rubbish should not be burned nor bonfires lit while fog was about, Sir Herbert commented, "The Ministry of Works was busy having bonfires of leaves in Hyde Park during the fog some months ago."

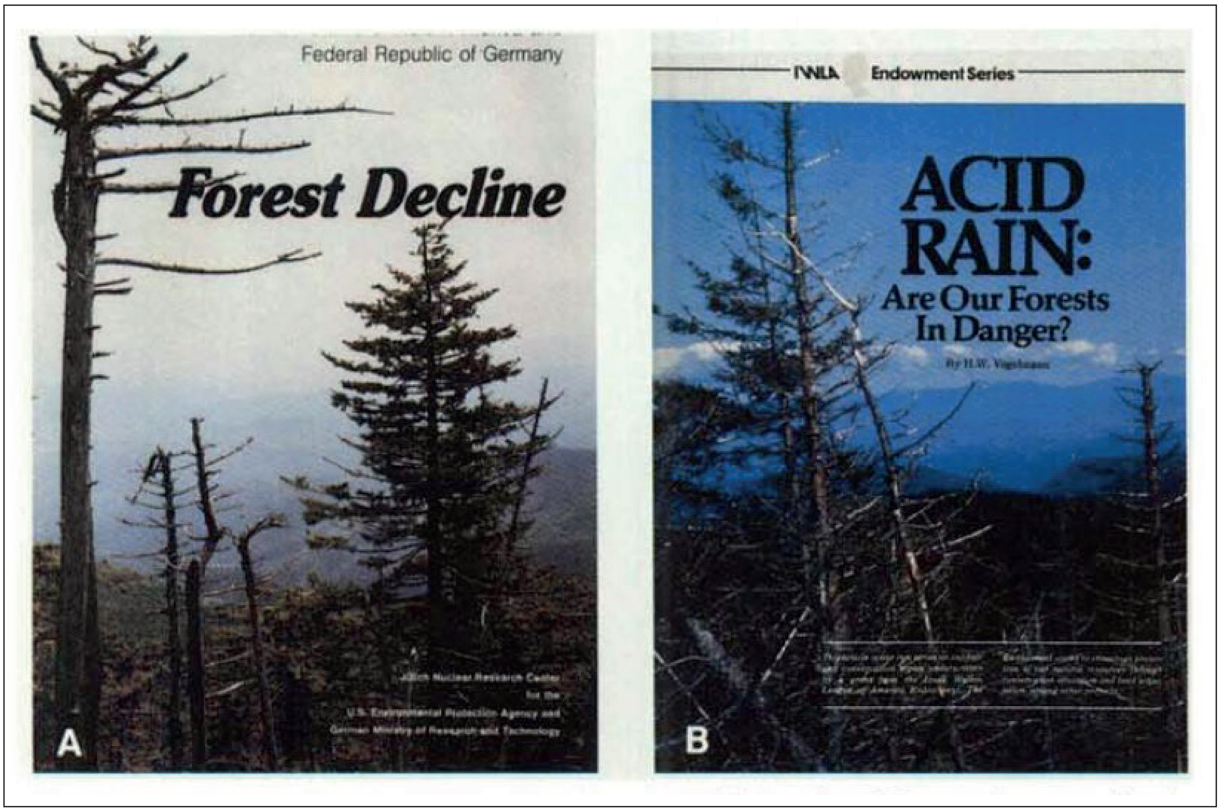
THE BANKRUPTCY ACTS, 1914 & 1926

Source: British Newspaper Archive, The Sunderland Echo 1953 and Norwood News (1954)

associations between premature mortality and particulate matter at concentrations almost ten times lower than those observed in the notorious smog events. Because of the relatively low levels of particulate matter involved, the studies were met with a high degree of scepticism. But that initial research has been repeated and a large number of studies all over the world have now established the links between particulate matter and premature mortality.

An influential use of this research was the 2014 report released by the World Health Organization (WHO), estimating that in 2012, there were 7 million premature deaths from particulate air pollution (from outdoor and indoor exposure). This was more than twice the figure previously released for the year 2004, where the number of premature deaths due to exposure to both indoor and outdoor pollution was recorded as 3.1 million (WHO 2009). This figure of 7 million deaths has been

Figure 13. German media showing the '*Waldsterben*' - the damages of acid rain.



Source: Skelly and Innes (1994)

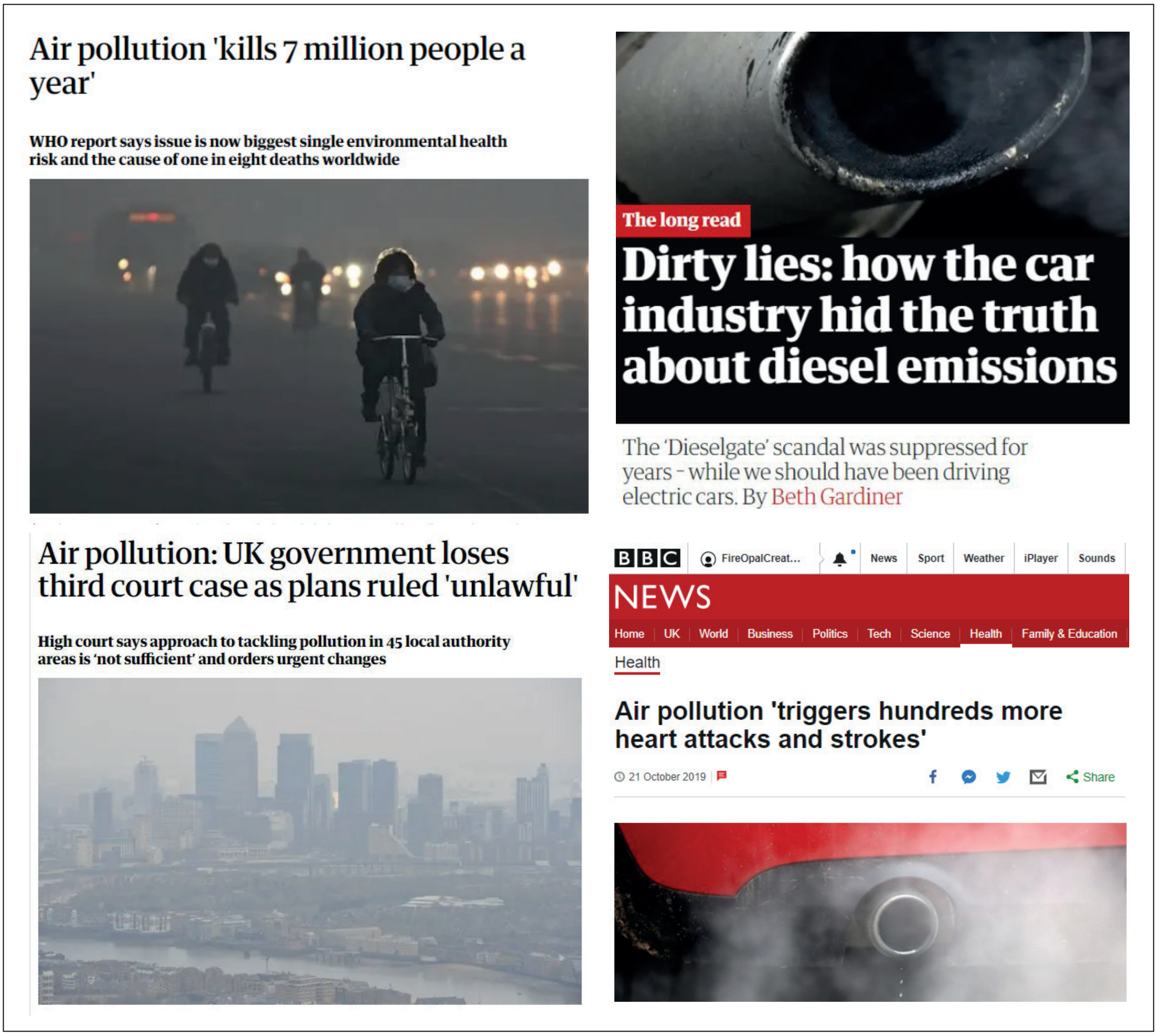
repeated in the media many times since (see Figure 14). Another example of the quantification of health impacts is the "*Understanding Health Impacts of Air Pollution in London*" report by Kings College London and Public Health England (PHE), which estimated numbers of hospital admissions and deaths due to air pollution. In 2010, it found $PM_{2.5}$ to be associated with approximately 1990 respiratory and 740 cardiovascular hospital admissions, and 52,630 life-years lost, equivalent to 3,537 deaths (Walton et al. 2015). An additional study from Kings College London (Williams et al. 2019), indicated that there is a correlation between above average air pollution days and an increase in hospital admissions for heart attacks and strokes. This information hit the media headlines in 2019 (Figure 14), demonstrating the current interest of air pollution.

The European Environment Agency (EEA) annually publishes a report showing the health impacts of air pollution in different countries. According to their latest report, more than three quarters of the EU's urban population is exposed to levels of $PM_{2.5}$ in excess of the WHO guideline for health protection[13], and more than 95% are exposed to ground-level ozone (O_3) levels higher than the WHO guideline (European Environment Agency, 2019). It also reports that in the EU-28, the numbers of premature deaths attributed to $PM_{2.5}$, NO_2 and O_3 exposure were 374,000, 68,000 and 14,000, respectively (European Environment Agency, 2019). This type of information brought home to people that despite the air getting a lot cleaner, it is still having a major impact on human health.

The Volkswagen emissions test cheating scandal has also kept emissions, especially those from diesel vehicles, in the media focus (Brand, 2016). The high proportion of diesel vehicles with emissions worse than expected is one reason why countries have failed to meet NO_2 concentration standards.

13 The WHO $PM_{2.5}$ concentration guideline is 10 micrograms per cubic metre (/m^3)

Figure 14. Newspaper headlines relating to air pollution in the UK



Source: The Guardian (2014; 2018; 2019); BBC (2019).

The legally binding concentration standards of the EU for PM_{10} and NO_2 should have been achieved by 2010, and countries are finding them difficult to attain (Čavoški, 2017). This, as well as the annual publishing of the EEA report, has led to legal challenges for countries, often initiated by NGO actions (Deutsche Umwelthilfe, 2019). For example, the breaches of pollution standards were exposed in *Client Earth v Secretary of State for the Environment, Food and Rural Affairs*, which unveiled the illegality of NO_2 concentrations in the United Kingdom (Čavoški, 2017). Currently, legal action is on-going in 13 European countries, and just within Germany, the Deutsche Umwelthilfe (Environmental Action Germany) is suing 35 cities (Čavoški, 2017). The threat of fines at the EU level (i.e. after a ruling in the European Court of Justice) is important, since the potential fines could be very high, however, this has not happened as of yet. The failure to attain goals has also had the impact of propelling the air pollution issue to the front of newspapers (Figure 14), but more importantly, has in some cases, forced specific measures to be taken in cities (Deutsche Umwelthilfe, 2019).

Research has been focusing not only on the rather abstract term of premature mortality, but also bringing alive the impact on people's lives. This has included the impact of air pollution on preterm births (Malley et al. 2017), asthma prevalence (Anenberg et al. 2018) and childhood pneumonia (Adaji et al. 2019). One particular campaign by a mother who lost her daughter to asthma has also made the human suffering from air pollution more tangible. The story in the Guardian newspaper *"Air pollution: Invisible killer: how one girl's tragic death could change the air pollution story"* (Guardian, 22 September, 2018), described the campaign by Rosamund Kissi-Debrah, for an inquest to make it explicit that air pollution was the cause of her daughter's death.

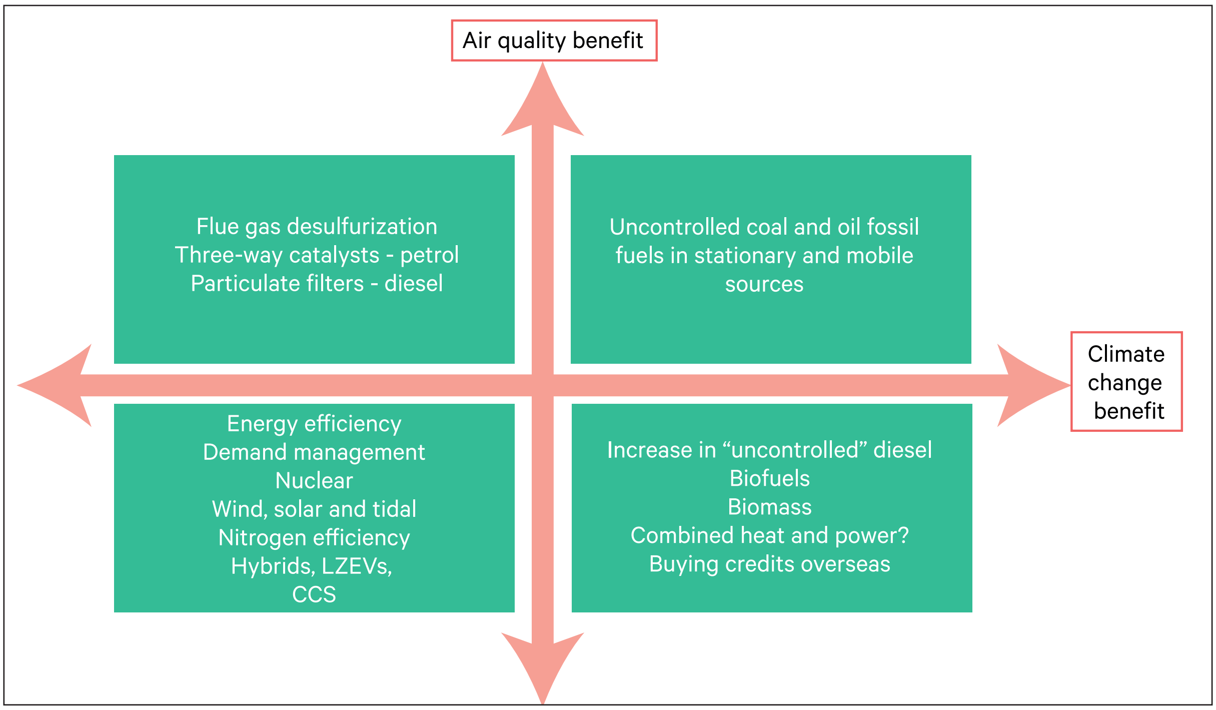
Overall, the media has been a strong tool, which educates and influences people and their perception of air pollution and has been key in influencing the policy surrounding air pollution (Pleijel, 2007).

2.7 The linkages between air pollution and climate change and implications for policy development

There are close linkages between air pollution and climate change. The main sources of air pollutants and greenhouse gases are the same, especially related to combustion processes, transport and agriculture (IIASA, 2007). Many mitigation measures (such as increasing energy efficiency) affect both air pollutants and greenhouse gases (Pleijel, 2009). Other measures reduce one emission while increasing another. This is known as "pollution swapping" (Pleijel, 2009), for example, using renewable biomass for domestic heating. This would reduce net CO_2 emissions, but increase the emissions of NO_X and particulate matter, since these are emitted from burning biomass (IIASA, 2007). The synergies and trade-offs between air pollution and climate change were assessed and highlighted by Williams (2012) in Figure 15.

Some pollutants are also climate warming in themselves. For example, black carbon is a component of $PM_{2.5}$ and also warms the atmosphere (Schmale et al. 2014). Ground-level ozone (O_3) is a pollutant affecting human health, and crop and forest yields, and is also a greenhouse

Figure 15. The synergies and trade-offs from policies and technologies to address climate change and air pollution



Source: Williams (2012) **LZEVs** - Low/Zero Emission Vehicles, **CCS** - Carbon Capture and Storage gas (Monks et al. 2015). Methane is an important precursor of (O_3) formation, especially related to the continued increase in background ozone levels and is also the second most potent greenhouse gas (Shoemaker et al. 2013). However, there are also important aerosols that are air pollutants, but also cool the atmosphere (Adams, Seinfeld and Koch, 1999). Sulphate particles and organic carbon are two of the most important ones, but nitrate and ammonium also cool the atmosphere and it is important to understand how air pollution policies will affect the climate (Adams, Seinfeld and Koch, 1999).

The pollutants that warm the climate – black carbon and O_3 – were the focus of a global assessment published by the United Nations Environment Programme and the World Meteorological Organization in 2011 (UNEP and WMO, 2011), which considered both the health and agricultural impacts of pollution, and also the net warming of changes in emissions of different substances, when different measures were implemented.

The UNEP/WMO assessment looked into different measures (like shifting to low emission vehicles; reducing methane from rice paddy fields; capping landfill sites to recover methane) that reduce both warming and air pollution impacts. It concluded that if carefully chosen measures, focused on providing the double benefit of reducing warming and air pollution, were fully implemented, then the rate of warming until 2040 could be halved, providing about 0.5°C reduced warming in 2050 (UNEP and WMO, 2011). The interesting aspect to this impact on warming is that given these substances are relatively short lived in the atmosphere, the resulting change in global temperatures occurs over a shorter time frame compared with CO_2 mitigation (UNEP and WMO, 2011). Models showed that these strategies would also reduce premature mortality and other health impacts considerably, with millions of premature deaths avoided every year, once all the measures had been implemented, compared with a baseline where they were not (UNEP and WMO, 2011). This focus on the so-called "Short-Lived Climate Pollutants" (SLCPs) was taken up by a number of countries and in 2012, they formed the Climate and Clean Air Coalition (CCAC) with UNEP to realise the benefits outlined in the UNEP/WMO assessment. The CCAC is now working to implement measures.

The CCAC has developed Regional Assessments to look in more detail at the opportunities to address climate change and air pollution together, focusing on the issues of importance in different regions. A recent assessment in Asia showed that air pollution policy and climate policy can be compatible, even when the main focus is on reducing emissions to prevent health impacts (UNEP, 2019a) . Models showed that most of the climate benefit would result from the implementation of "development-oriented" policies and measures that addressed both climate change and air pollution. This included structural changes, such as increased efficiency and roll-out of renewable energy. There were 25 measures and policies identified that would massively improve air quality in Asia and also result in 0.3°C lower warming by 2050, compared with a baseline scenario (UNEP, 2019a). This was in line with the 0.5°C outlined in the global assessment, even though the analysis and entry points were different.

Clearly, there is a real opportunity to promote the mitigation of both air pollution and climate change, if they are considered together to develop integrated strategies that can provide the maximum benefit for both issues at lower cost (Pleijel, 2009). However, policies to tackle air pollution and climate change have largely been designed independent of one another, despite the fact that integrating them is also cost-effective (Sliggers and Kakebeeke, 2004). It is estimated that the multi-pollutant approach of the Gothenburg Protocol reduced costs by around 75%, compared to a single pollutants approach. This highlights the huge potential economic co-benefits from integrating air and climate pollutant policy (Pleijel, 2009).

It is interesting to note that even in the last year, the integration of climate and clean air has become a more popular topic. The CCAC has been championing this approach since 2012. Now, in China, there is great interest in this. There is a serious effort to reduce air pollution in China, which is proving successful. At the same time, in countries around the world, national governments are focusing on climate change and have a desire to make the Paris Agreement successful. The CCAC initiative on Supporting National Action and Planning (SNAP) has developed support for countries and promoted the development of integrated strategies for air quality and climate change (SEI, CCAC and Ghana EPA, 2019). It has provided guidance on integrating air pollution into Nationally Determined Contributions (NDCs) with the guidance of the document "*Opportunities for Increasing Ambition of Nationally Determine Contributions through Integrated Air Pollution and Climate Change Planning: A Practical Guidance Document*" (SEI, CCAC and Ghana EPA, 2019). A recent report has been made by Tsinghua University and the CCAC on the co-control of climate and air quality, which looks at the opportunities to further develop integrated strategies in China and other countries, to reduce air pollution and climate change (UNEP, 2019b).

2.8 Transferring the European approaches to South Asia and Southern Africa

Given the success of international cooperation on air pollution in Europe, the Stockholm Environment Institute (SEI) coordinated a programme on Regional Air Pollution in Developing Countries (RAPIDC), funded by the Swedish International Development Cooperation Agency (SIDA). This tried to create regional collaboration on air pollution in two regions: South Asia and Southern Africa (Hicks et al. 2001). In South Asia, working with the UNEP Regional Resource Centre for Asia and Pacific, based at the Asian Institute of Technology (AIT) in Bangkok, a policy dialogue was held in 1997, to discuss the potential for a regional agreement on air pollution. The countries of South Asia all agreed that they would like to collaborate, and the President of the Maldives insisted that the agreement be named after their capital city of Malé. The agreement between the 7 South Asian countries partly echoed text from the Convention on LRTAP, which showed that the ambition was to address the regional problems in a coordinated way. The Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia, was eventually adopted by 7 countries of South Asia (Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and the Maldives) and also by Iran in 1998. This was followed up by a series of intergovernmental meetings of designated "National Focal Points", and the development of coordinated scientific studies and training was carried out in each country on: the impacts on crops; emission inventories; atmospheric modelling and monitoring of pollutants; and corrosion and mitigation.

Despite enthusiasm from the participants from Ministries of Environment and academic institutions in the region, once the funding from SIDA ceased, the activity around the Malé Declaration decreased. This may partly be due to the fact that no negotiation process was created, which would have encouraged development of the scientific underpinning by countries. Since there was no discussion of regional policy development, the focus for further development of the Declaration was therefore lacking, and countries concentrated on their national arrangements. The agreement still exists under the auspices of the South Asia Cooperative Environment Programme[14] and could still play an important role in addressing regional air pollution problems, if it could be sufficiently resourced and if there was sufficient high-level political buy-in that would make the Declaration a more relevant regional agreement.

In Southern Africa, the focus was on the Southern African Development Community (SADC) region. SADC develops regional cooperation between 15 countries in Southern Africa and has developed regional policy, leading to a free trade area and several protocols that countries have to adhere to. The RAPIDC programme helped to fund activities of the Air Pollution Information Network for Africa (APINA), which was formed on the suggestion of African academics, following a meeting on air pollution in 1996 in Harare, Zimbabwe (Hicks et al. 2001; Simukanga et al. 2015). This was a network of universities and research institutes in the region, with strong linkages to decision-making, and discussions with SADC. It led to a lot of activity, including emission

14 SACEP – see http://www.sacep.org/programmes/male-declaration

inventories, impact assessments, policy dialogues and led to the development of the Harare Resolution on the Prevention and Control of Regional Air Pollution in Southern Africa and its likely Transboundary Effects in 1998. However, when the funding from SIDA stopped, the activities of the network reduced. Still, the capacity built in the region has remained and APINA members have still worked together on related projects, such as transport in Southern Africa. APINA is still relevant in meetings and agreements in SADC, such as a recent meeting on fuel quality[15] and still has a place on the SADC website[16]. So, it has been a worthwhile attempt to develop regional cooperation, but has not led to the same level of negotiation on air quality as in Europe.

These two examples demonstrate in different ways that despite having regional processes, which managed to start transferring some of the experience from the LRTAP Convention to these regions, this has not led to a sustainable process of regional policy development or to the same level of negotiation and emission reduction as was achieved in Europe. There are a number of reasons for this – resources are in short supply for regional cooperation in these regions; the political situation of each region is different; strong well-resources champions did not emerge to help drive the process forward; and there were fewer well-resourced institutions in these regions at that time that could help lead cooperation.

2.9 Conclusions on regional cooperation on air pollution

There are a number of elements for successful collaboration between countries in Northeast Asia that can be developed from the experience in Europe, and also from the examples of developing collaboration in other regions. These are:

- Each region is different and what happened in Europe or North America will not necessarily be directly transferable to another region with a different political and financial context.
- Successful initiatives tend to have champion countries that feel the need to drive change in neighbouring countries, but it is important to realise that this was successful in Europe due to the habit of collaboration that had been developed through the European Union.
- The European example can still be useful, mainly through understanding those elements that helped to cement cooperation between countries.
- Strong regional institutions help progress, as do strong national institutions in the different countries.
- A strong science base in the region and a desire to create regional scientific collaborations can help to develop linkages between countries, especially if a linkage between science and policy is built into the process.
- Trust between countries needs to be enhanced – avoiding blame. Scientific projects can help cement ties. The process needs to belong equally to all countries. Countries wanting to promote collaboration and policy progress also need to ensure that they are at the forefront of policy development to reduce air pollution, implementing clean technology, and be seen as a leader in the area. Doing so can have greater influence on other countries.
- Proper resourcing of the processes is necessary – both of the scientific and political engagement. It is helpful if the funding is not from one country, but that all countries contribute and that the commitment to fund is long term.

15 See: https://www.unenvironment.org/events/workshop/sadc-regional-framework-harmonisation-low-sulphur-fuels-and-vehicle-emission
16 See: https://www.sadc.int/issues/environment-sustainable-development/air-quality/

3. Regional cooperation on air pollution in Northeast Asia

The development of the Northeast Asian region is a story of strongly emerging economies. China, Japan, and Korea have undergone rapid industrialization (OECD, 2019) and this rapid economic growth has caused intense environmental degradation. This has had implications for air pollution and climate change, as greenhouse gases and particulate matter pollution have increased significantly since the 1990s. The particulate matter problem in the region has emerged as a particularly serious issue, and “air pollution” is under discussion as a major agenda item.

Internally, countries have made efforts to mitigate pollution and improve air quality for their citizens, but it has been clear for a long time that countries cannot fully protect the health of their citizens through national efforts alone. This is because the transboundary movement of pollutants can affect human health across national borders (Zhang et al. 2017; Jung, 2016; WHO, 2003). As air pollution has evolved as an international problem, international cooperation has been initiated and neighbouring countries have attempted to find solutions to the air pollution problem through intergovernmental cooperation. However, the transboundary transport of air pollutants has caused diplomatic tensions, and the countries involved will need to find ways to build a consensus to help solve these problems.

This section initially reviews the national programmes in place in China, Japan and Korea, which is followed by a review and assessment of the transboundary programmes within the region.

3.1 National programmes to address air pollution

Every country in Northeast Asia is applying policies and measures to promote emission reductions. There is an opportunity to share experiences about introducing policies and measures to a greater extent than is done at the moment. Aspects of progress in China, Japan and Korea are highlighted in the following sections.

China

China has achieved a considerable reduction in air pollution through successful implementation of policies and measures. A process that set specific targets and goals for different regions has been implemented by the Government of China and has achieved a reduction in $PM_{2.5}$ and improved air quality. The Chinese Air Law was first adopted in 1987 and has been revised several times. Particularly firm action was taken from the time when the Chinese Premier declared the “war against pollution” between 2013 and 2017. Initiated by the National Air Quality Action Plan, the Government of China set out to improve the air quality of China's major industrialized cities in the regions of Beijing-Tianjin-Hebei, Pearl River Delta and the Yangtze River Delta. The Air Pollution Prevention and Control Action Plan sets out 10 actions to meet the goals of the National Air Quality Action Plan 2013 – 2017, which are outlined in Table 5 below.

More specifically, the actions taken during 2013 to 2017 include: prohibiting the building of new coal-fired power plants in the three regions; introducing policies to restrict the number of cars on the road in large cities including Beijing, Shanghai and Guangzhou; reducing the iron and steel making capacity in the industrial sector, (partly by shifting the location of steel production away from these regions to other parts of China); and replacing household coal boilers with gas or electric heaters in the Beijing-Tianjin-Hebei region. As a result of implementing the measures of the Air Pollution Prevention and Control Action Plan on air quality, China’s most populated areas have experienced remarkable improvements in air quality, ranging from a 21 to 42 percent reduction in $PM_{2.5}$ (the actual target for reducing $PM_{2.5}$ in the Beijing-Tianjin-Hebei, Pearl River Delta, and Yangtze River Delta was 25 percent, 20 percent, and 15 percent, respectively) (Greenstone and Schwarz, 2018).

Table 5. Ten actions in China's Air Pollution Prevention and Control Action Plan[17]

Actions	Contents
1	Increase efforts of comprehensive control and reduce emissions of multi- pollutants
2	Optimise structure of industrial sector and promote industrial restructure
3	Accelerate the technology transformation and improve the innovation capability
4	Adjust the energy structure and increase the clean energy supply
5	Strengthen environmental thresholds and optimise industrial layout
6	Emphasise the role of market mechanisms and improve environmental economic policies
7	Improve law and regulation system and enhance the supervision
8	Establish regional coordination mechanism and integrated region environmental management
9	Establish monitoring and warning system. Cope with heavy pollution weather
10	Clarify the responsibilities of the government, enterprise and society. Mobilise public to participate.

Source: Clean Air Alliance of China, (2013)

The Government of China has continued to increase the level of action on sources of air pollution and announced new measures to tackle air pollution between 2018 and 2020. The "*Three-year Action Plan for Winning the Blue Sky War*", which applies to all the 338 cities in China, mandates at least an 18% reduction in average $PM_{2.5}$ levels, and a reduction in high-pollution days by 25%, compared with a 2015 baseline. The actions are mainly being implemented in industrial, energy, transport and land-use sectors. The main areas targeted by these policies were the Beijing-Tianjin-Hebei region (where the $PM_{2.5}$ concentrations are heavily influenced by emissions from heating in the winter period), and the surrounding areas including Shandong Province, Henan Province and Fenwei Plains. The Pearl River Delta was excluded due to its greater than expected progress in reducing air pollution in the previous term.

The Ministry of Ecology and Environment in China, formerly the Ministry of Environmental Protection of China, announced in 2019 that the Action Plan for Winning the Blue Sky War has shown progress in reducing air pollution. The reduction rate of emissions of $PM_{2.5}$, SO_2 and NO_2 in 2018 was 9.3%, 22.2% and 6.5%, respectively, for the 338 cities, compared to 2017. China's success in policy development and practice will provide useful examples for other countries in Northeast Asia to follow.

Japan

After the initiation of the 1968 Air Pollution Control Act (Kuroki, 1996), a series of air pollution policies have been introduced in Japan. Among them, in 1992, the Ministry of Environment in Japan (MOEJ) adopted the "Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides Emitted from Motor Vehicles in Specified Areas". This was to cope with NO_X pollution problems from existing vehicle fleets in highly populated metropolitan areas (MOEJ, 1992). Through a process of increasing regulation and implementation, air pollution in Japan has significantly been reduced.

The Japanese government is implementing short-term and long-term plans to reach air quality standards. In the early stages, air pollution was improved by replacing fossil fuels with clean fuels in large-scale power plants and factories. Meanwhile, pollution coming from vehicles, construction machinery and ships have been managed with ever stricter environmental

17 For more information, refer to the document of Air Pollution Prevention and Control Action Plan issued by the Clean Air Alliance of China

regulations (Hashimoto, 1989). Recently, air pollution has increased due to the transboundary transport of air pollution from other countries. The monitoring of air pollution has been strengthened to look into this. Following this step-by-step approach to pollutant management, Japan's current atmosphere meets their air quality standards, but clearly there is an appetite to do more.

In 2013, Japan introduced its first comprehensive measures on particulate matter (PM). These measures include: (1) enhancing safety through appropriate alerting to the public; (2) achieving environmental standards through the identification of fine dust and related reduction measures; and (3) China-Japan-Korea policy cooperation and dialogue to achieve clean air in Asia. In addition, information on the source and predicted amount of fine dust generated, is being collected. This feeds into the improvement of atmospheric environment monitoring and scientific simulation modelling, showing the movement of fine dust across the region. In relation to this, the MOEJ plans to set up a "Fine Dust Inventory" and "Source Profile Development Review Committee" to accurately grasp the emission status from both stationery and mobile sources of fine dust, from small and medium-sized sources (Lee, 2017).

Korea

The Korean government has been implementing domestic measures to deal with transboundary air pollutants, specifically related to yellow dust[18] and PM. Korea's Ministry of Environment has been continuously promoting mitigation policies for yellow dust and the short and long-term plans for dealing with PM, to improve people's health and the socio-economic consequences of severe air pollution. Current policies include seasonal PM management systems, forecasting and development of an early-warning system.

In the long-term, the Ministry of Environment of Korea has developed a comprehensive plan to mitigate domestic PM emissions. This includes developing an international cooperative response on transboundary air pollutants and reinforcing air pollutant policies (Ministry of Environment of Korea (MOEK), 2018). The plan is currently only implemented in Seoul, but can be applied in other regions as well. Moreover, considering the significant socio-economic impacts of PM, relevant Korean ministries (i.e. the Ministry of Environment; Ministry of Education; Ministry of Interior and Safety; Ministry of Industry and Ministry of Oceans and Fisheries) have legislated and enacted the Special Law on Fine Dust Reduction Management, which was enforced in 2019 (OECD, 2020). The law includes the preparation of the Fine Dust Special Act as a legal basis for: emergency reduction measures; adjustment of operation of emission facilities in order to efficiently reduce and manage fine dust due to seasonal and emergency factors; designation of intensive management areas; performance certification of simple fine dust measuring instruments; the establishment of the Fine Dust Special Countermeasure Committee and Fine Dust Improvement Planning Group; installation of the National Fine Dust Information Center; and the establishment of a comprehensive fine dust management plan and implementation plan (MOEK, 2018). The special law for PM mitigation and management was amended so that the National Air Emission Inventory and Research Center in Korea was officially for the monitoring and maintenance of emission data. Furthermore, since energy use and production are closely related to PM emissions from the industrial sector, future energy planning aims to transit from fossil fuel to alternative energy sources. The national target of renewable energy will increase from 7.6% in 2017, to 20% by 2030, to 30–35% by 2040 (MOEK, 2018). Additionally, the Korean government has specific policies for targeting each sector, such as power generation, transport, and households, so that transboundary air pollutant mitigation can be achieved successfully.

To sum up, Korea is attempting to reduce its national emissions and help solve both its domestic air pollution problem and its contribution to the transboundary air pollutant problem.

18 Yellow dust is defined as a meteorological phenomenon that affects much of East Asia specifically around the spring months. The dust originates from China, the desert of Mongolia and Kazakhastan and coinciding with the economic development of China, yellow dust has become a serious health problem.

3.2 A review of cooperation frameworks and programmes related to transboundary air pollution in Northeast Asia

In Northeast Asia, there are various types of environmental cooperation frameworks, including cooperation led by international organizations, and multilateral and bilateral cooperation (also referred to as International Regulatory Cooperation by OECD. Table 6 summarizes these frameworks and programmes, which includes four cooperation programmes led by international organizations; two multilateral cooperation initiatives; and bilateral cooperation between Korea and China, and China and Japan. Each cooperation framework has different parties and covers different pollutants. Figure 16 shows the scope and participants of the cooperation frameworks .

Table 6. Comparison of cooperation and organizations of transboundary air pollution in Northeast Asia

Type	Name	Year of establishment	Participating Countries	Operating Entity	Purpose	Instruments for Cooperation	Main Issues	Remarks
International Organization-led cooperation frameworks	EANET[a]	2001	13 countries (including China, Japan and Korea)	UNEP Asia Pacific Office	Acid rain monitoring and data building in East Asia	Monitoring, data collection system, capacity building, raising public awareness, periodic assessments, and joint research	Acid rain	
	NEASPEC[b]	1993	6 countries (including China, Japan and Korea)	UNESCAP	Intergovernmental consultation body for comprehensive environmental conservation in Northeast Asia including air pollution	Capacity building of each country, information sharing and awareness raising	Transboundary air pollution, nature conservation, marine reserves, low carbon cities, desertification, and land degradation	* Establishment of NEACAP[c] (2018) Comprehensive consultation body related to air pollution
	APCAP[d]	2015	41 countries (including China, Japan and Korea)	UNEP Asia Pacific Office	Prevention of duplication programs, air pollution control, and promotion of p9reventive activities in Asia Pacific	Joint Forum and Science Panel	Coordinating and harmonizing various programs related to air pollution, sharing scientific knowledge and information, supporting reduction policy implementation, preparing science-based policy evaluation reports, and supporting national capacity building.	
	CCAC[e]	2012	71 state partners, 78 non-state partners, 19 international organizations, 59 NGOs, 181 actors (including Japan and Korea)	Operation in partnership with UNEP	Quick action and provision of benefits for addressing the climate, public health, energy efficiency, and food security problems	Strengthening training and system Support for development of laws, regulations, policy, and plan Technology demonstration, raising awareness, funding Development of knowledge resources and tools	Reduction of air polluting emissions	
Multilateral cooperation frameworks	TEMM[f]	1999	3 countries (China, Japan and Korea)	Environment Ministries of South Korea, China, and Japan	Joint response to environmental problems in Northeast Asia, focusing on cooperation in the environmental industry such as yellow dust, acid rain, and transboundary problem.	Joint response to environmental issues	Yellow dust and acid rain Air pollution Marine pollution	* Establishment of TPDAP[g] (2014) Policy dialog of a special meeting type of TEMM
	LTP[h]	1996	3 countries (China, Japan and Korea)	National Institute of Environmental Research	Collection and analysis of scientific data to address long-range air pollution problem	Monitoring Modeling GHG inventory building	Long-range transboundary air pollutants	

(Table 6. continued)

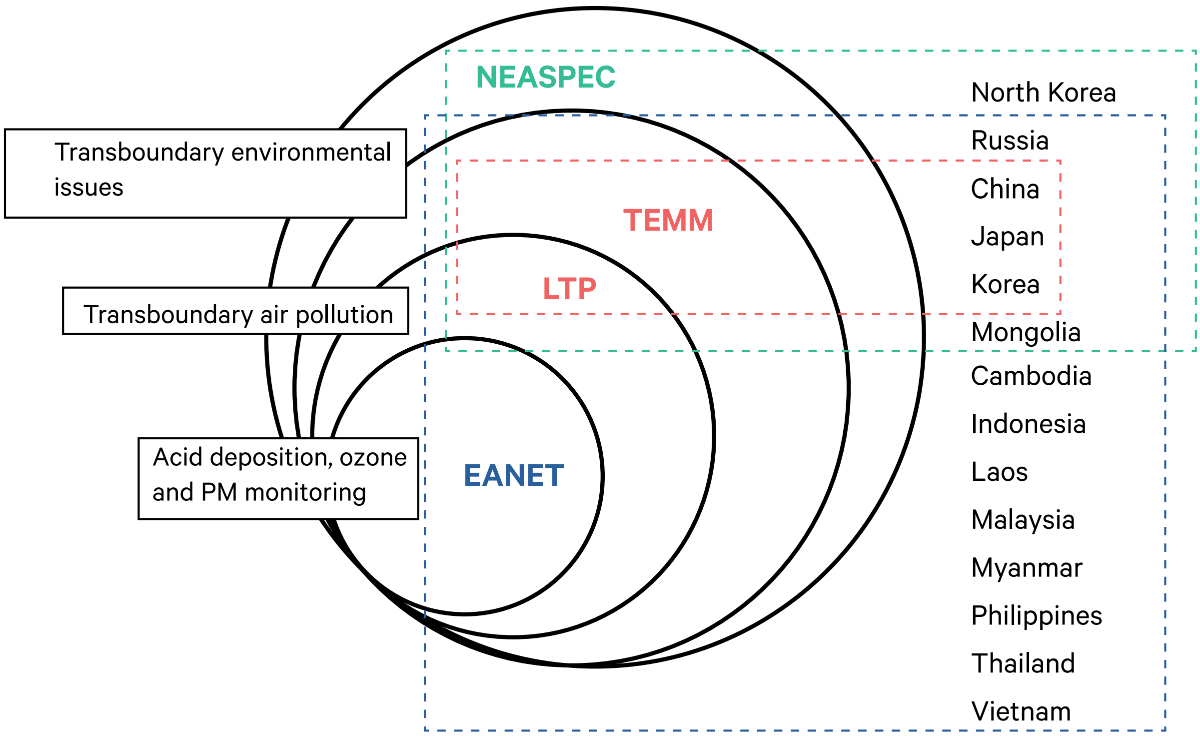
Type	Name	Year of establishment	Participating Countries	Operating Entity	Purpose	Instruments for Cooperation	Main Issues	Remarks
Bilateral cooperation frameworks	Korea-China Environmental Cooperation[i]	1993 2003	2 countries (Korea and China)	Governments of two countries	Bilateral environmental cooperation	Cooperation in detailed areas including air pollution, yellow dust, and environmental industry	Strengthening air quality improvement cooperation, air pollutant measurement, air pollution forecast model, and cause study of high concentration	
	China-Japan Environmental Cooperation	1994	2 countries (China and Japan)	Governments of two countries	Bilateral environmental cooperation	Cooperation in detailed areas including air pollution, yellow dust, and environmental industry	Strengthening air quality improvement cooperation, air pollutant measurement, air pollution forecast model, and cause study of high concentration	
	Korea-Japan Environmental Cooperation	1993	2 countries (Korea and Japan)	Governments of two countries	Bilateral environmental cooperation	Cooperation in detailed areas including air pollution, yellow dust, and environmental industry	Strengthening air quality improvement cooperation, air pollutant measurement, air pollution forecast model, and cause study of high concentration	

a Acid Deposition Monitoring Network in East Asia
b North-East Asian Sub-regional Programme for Environmental Cooperation
c North-East Asia Clean Air Partnership
d Asia Pacific Clean Air Partnership
e Climate and Clean Air Coalition
f The Tripartite Environment Ministers Meeting among China, Japan and Korea
g Tripartite Policy Dialogue on Air Pollution
h Joint Research Project on Long-range Transboundary Air Pollutants in North East Asia
i Air pollution prevention demonstration cooperation project, Korea-China air quality joint research project, Korea-China air quality measurement information sharing system, air quality forecast information and forecast technology exchange, etc.

Cooperation led by international organizations

The Acid Deposition Monitoring Network in East Asia (EANET) and the Northeast Asian Sub-regional Programme for Environmental Cooperation (NEASPEC) fall into the category of cooperation led by international organizations. While EANET focuses on acid deposition, ground-level ozone and PM, NEASPEC has a broader scope covering many different environmental issues including nature conservation, low carbon cities, desertification and land degradation. The other two cooperation frameworks led by international organizations are the Asia Pacific Clean Air Partnership (APCAP) and the Climate and Clean Air Coalition (CCAC). The Japan Ministry of Environment (MOEJ) helped set up and fund APCAP and meetings are regularly attended by scientists from China, Japan and Korea. The CCAC has a global remit, but has focused on issues in Asia in more detail, with Japan and Korea as state partners.

Figure 16. Overlaps in constituencies and topics of International Regulatory Cooperation (IRC) arrangements for air quality in Northeast Asia - note that while acid deposition is a transboundary issue, the other regional frameworks more explicitly deal with transboundary air pollution and NEASPEC an even broader suite of transboundary issues



Source: OECD (2019)

Acid Deposition Monitoring Network in East Asia (EANET)

EANET was established in 2001, to increase awareness about the acid rain problem in East Asia. The UNEP Regional Office for Asia and the Pacific provides the secretariat for EANET. EANET (2019) aims to support decision-making and policy formulation based on scientific evidence, focusing especially on: (1) effective solutions to improve air quality based on scientific assessments, for the benefit of human health, crop yields, climate, environment and socio-economic development, and (2) identifying sources of finance and mechanisms for access, to ensure the appropriate budget is allocated for implementing the prioritized air quality actions (Takahashi and Asuka, 2001). In order to support efforts to prevent or reduce pollutants, EANET is promoting mutual cooperation for certain scientific issues among 13 countries including Cambodia, China, Indonesia, Japan, Korea, Laos, Malaysia, Mongolia, Myanmar, Philippines, Russia, Thailand, and Vietnam (Nitta, 2008). EANET continues to receive support from the Asia Centre for Air Pollution Research in Japan, which plays the role of a technology network centre. EANET operates using voluntary funding from the participating countries.

EANET is currently dedicated to activities such as: acidic deposition monitoring; data accumulation, evaluation, storage and supply; facilitation of quality assurance and quality control (QA/QC) activities; support and capacity building activities; facilitation of research on acidic precipitation issues; promotion of awareness among the general public; and information exchange and cooperation between internal and external networks. The achievements of EANET so far include: (1) the establishment of 51 regional monitoring stations in 13 participating countries; (2) establishment of a data collection system for acidic precipitation; (3) strengthening researchers' capabilities in monitoring and evaluating acidic precipitation; (4) increased public awareness of acidic precipitation issues; (5) periodic assessment of the condition of acidic precipitation in the region; and (6) joint research activities among participating countries to reach a common understanding of acidic precipitation issues. EANET also publishes periodic reports, covering the state of acid deposition.

Northeast Asian Sub-regional Programme for Environmental Cooperation (NEASPEC)

Following an examination of activities that could improve the air pollution situation in the Asia Pacific region, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) helped form the North-East Asian Sub-regional Programme for Environmental Cooperation (NEASPEC). NEASPEC was established by six countries (China, Democratic People's Republic of Korea, Japan, Korea, Mongolia, Russian Federation) to promote environmental cooperation between Northeast Asian countries, as a follow-up to the United Nations Conference on Environment and Development (UNCED), which was held in 1992 (Chung, 2008).

Initiated at an expert meeting in May 2014, NEASPEC serves as the international comprehensive networking platform for environmental consultation between the participating countries (Kim, 2016). With regard to air pollution, their goal is to dramatically reduce deaths and diseases from air pollution for health and well-being. In the initial meeting, the participants agreed to the participation of Russia, to enhance the cooperation on air pollution mitigation between countries. The activities of NEASPEC include transboundary air pollution, biodiversity and nature conservation, marine protected areas, low carbon cities, desertification and land degradation. Kim (2016) have suggested that NEASPEC could usefully cooperate with the Joint Research Project on Long-range Transboundary Air Pollutants in North East Asia (LTP) and also with EANET, as shown in Figure 17. This would link emissions, pollutant transport modelling, monitoring, mitigation modelling and policy assessment. In short, by combining the strengths of LTP and EANET, NEASPEC could play a key role in providing science-based environmental information to support regional policy cooperation.

In addition, the NEASPEC aims to liaise between multilateral, regional, and global mechanisms for transboundary air pollution and develop partnership activities. Funding required for these activities is stable and receives predictable contributions from participating countries, in addition to the funding from UNESCAP. They also receive human resources support from related organizations and are requesting the financial participation of interested groups.

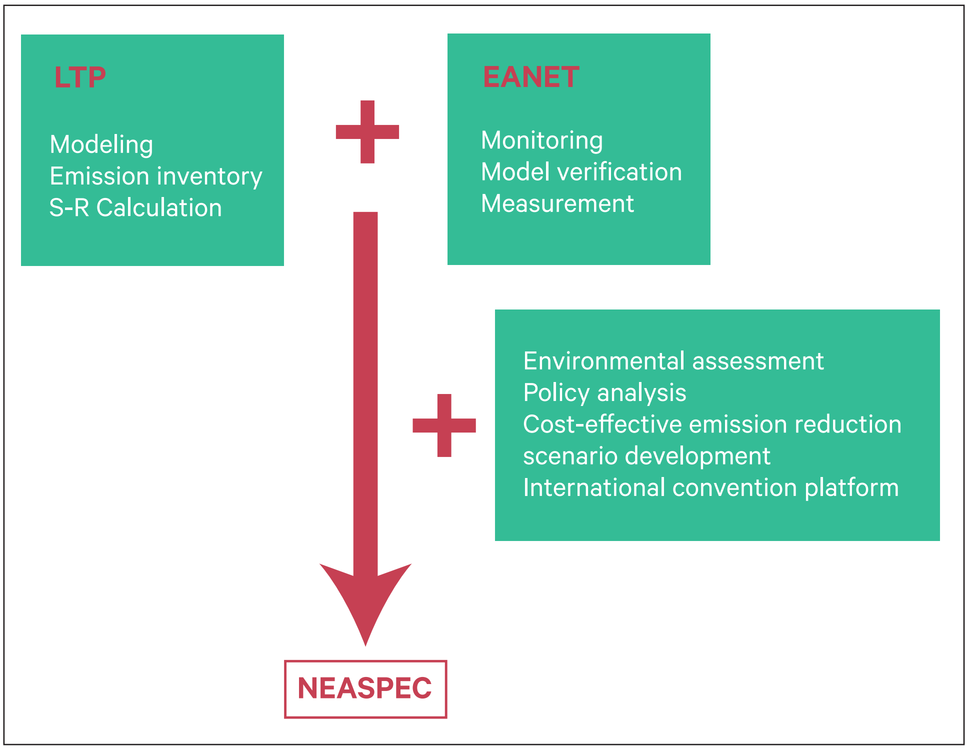
According to NEASPEC's 2016-2020 Strategic Plan adopted by the 20th Senior Officials Meeting (SOM)[19], members of the SOM have pursued a joint project related to transboundary air pollution until 2020, to share information and conduct joint research and cooperation among the related countries and organizations. To that end, they will strengthen the connection between science and policy, by supporting cooperation among international organizations that are modelling the sources and recipients of transboundary air pollution under different policy scenarios, and evaluating their impact. Members of the NEASCAP will also support the cooperation of scientific and academic experts, by promoting the wide-ranging participation of stakeholders in the region, and encouraging the exchange of emissions data (Ben, 2018).

One aspect of progress made as a result of this plan is the establishment of multiple regional emission inventories in Northeast Asia. This includes: the Comprehensive Regional Emissions inventory for Atmospheric Transport Experiments (CREATE); the Regional Emission inventory in Asia (REAS) 2.1; and MIX[20] (Li et al. 2015). MIX combines REAS with the best available national inventories of the Multi-resolution Emission Inventory for China (MEIC), the Japan Emission Inventory Database (JEI-DB) in Japan, and the Clean Air Policy Support System (CAPSS) in Korea, which also includes other countries in Asia. CREATE serves as the emission

19 The first SOM held in 1993 was the first gathering on environmental issues in an official level in the sub-regions in Northeast Asia, with membership of six countries: China, Democratic People's Republic of Korea, Japan, Korea, Mongolia, and the Russian Federation. Since then, the annual meeting has developed into policy dialogue forum.

20 A mosaic Asian anthropogenic emission inventory under the international collaboration framework of the Model Inter-Comparison Study (MICS)-Asia and Hemispheric Transport of Air Pollution (HTAP).

Figure 17. Cooperation suggestion for NEASPEC with Long-range Transboundary Air Pollutants in Northeast Asia programme (LTP)* and EANET



Source: Kim (2016)

* See section on "Multilateral Cooperation" for further information on LTP **S-R** - Source-Receptor

inventory for the source-receptor relationship modelling (to identity the origin location of the dust) under Long-Range Transboundary Air Pollutants (LTP) in Northeast Asia.

The 21st SOM in March 2017, discussed the establishment of the North East Asia Clean Air Partnership (NEACAP). This was to specifically address the transboundary air pollution problem in Northeast Asia and it was launched in October 2018. NEACAP supports the comprehensive intergovernmental cooperation framework by creating the basis for common information on air pollution emissions, scientific assessments, policy dialogues, and technology cooperation. The 23rd SOM meeting held in October 2019, discussed options to deepen practical cooperation among Member States, and recommended the promotion of policy and science linkages, to serve as a key platform for information and experience sharing among stakeholders and Member States. NEACAP aims to address multiple pollutants including particulate matter ($PM_{2.5}$ and PM_{10}), ground-level ozone (O_3) and other relevant pollutants. It shares scientific research results related to air pollution in the region through the NEASPEC network. In a sense, it serves as a platform for policymakers and science/technology experts to derive practical policies through a process of collaboration. The main duties of NEACAP, within the frame of the NEASPEC, include:

- promoting science-based and policy-oriented collaboration;
- conducting joint research activities to develop information exchange experience;
- addressing transboundary air pollution issues in Northeast Asia;
- identifying and promoting the knowledge related to air pollution;
- contributing to the development of relevant national and sub-regional policies (Lee and Paik, 2020).

NEACAP's operation is composed of the Science and Policy Committee, Working Groups, and Technical Centres, through the SOM. In July 2019, the "1st NEACAP Science Policy Committee and Technology Center Meeting" was held. Through the meeting, the Northeast Asian countries expect to lay the foundation for the institutionalization of discussions on joint responses to reduce PM in the region.

Asia Pacific Clean Air Partnership (APCAP)[21]

In 2014, the "immediate and concrete measures to solve air pollution and its effects (1/7)" was included in the resolutions of the United Nations Environment Assembly (UNEA). Subsequently, the third UNEA resolution in 2017, included the "prevention and reduction of air pollution to improve global air quality (3/8)." This resolution demanded that the Executive Director of UNEP strengthened regional cooperation to solve air pollution, and the Asia Pacific Clean Air Partnership (APCAP) was formed to organize regional working communities through the UNEP regional offices[22].

APCAP was established to pursue "a mechanism and platform to facilitate coordination and collaboration between various clean air initiatives in the Asia-Pacific region" (UNEP, 2015). A total of 16 countries in the Asia-Pacific[23] are participating in this partnership, which is based on the participation of government, Non-Government Organizations (NGOs), and experts. The APCAP has the following objectives:

- to play the role of a mechanism for better adjustment and cooperation on a regional clean air programme;
- to provide a platform for creating and sharing knowledge about the regional air pollution initiatives, policies, and technologies;
- to provide technical support for strengthening institutional competency and air quality management, and to support air quality assessments to identify solutions for clean air.

APCAP is striving to achieve the above objectives through holding Joint Forums; organizing an international science panel; publishing policy briefs; undertaking capacity building programmes; and providing technical assistance (Shim, 2017). In particular, the Joint Forum is being used as a platform for sharing the latest policies and related scientific knowledge and information related to solving air pollution problems. The Joint Forum adopts a regional approach to define priorities related to air quality and solve problems that must be dealt with prior to solving the air quality issue. The Forum's goal is to identify the appropriate forum or existing mechanism for solving the air pollution problem of the region. The first Joint Forum was held in 2016, and the second in 2018.

The international science panel was established by APCAP to provide policy options based on scientific knowledge, combined with various existing initiatives. Recently, APCAP published a report in partnership with the Climate and Clean Air Coalition (CCAC), titled *"Air Pollution in Asia and the Pacific: Science-based solutions" (UNEP, 2019a),* that assessed scientific issues and responses to air pollution in Asia-Pacific countries. This report identified a package of 25 air pollution prevention measures that could bring $PM_{2.5}$ levels for 1 billion people, below the World Health Organization (WHO) air quality guideline of 10 μg m^{-3} by 2030. This would have numerous development benefits for public health, such as fewer premature deaths and reduced incidence of chronic disease, and economic development and the climate (UNEP, 2018).

21 See https://www.unenvironment.org/asia-and-pacific/asia-pacific-clean-air-partnership/what-we-do

22 The UNEP regional office supports the enhancement of regional cooperation to address air pollution…in close cooperation with the Asia Pacific Clean Air Partnership, and to organize regional communities of practice for air quality management through the regional offices of the United Nations Environment Programme." (Paragraph 7(c))

23 Afghanistan, Cambodia, Iran, Japan, Korea, Malaysia, Maldives, Mongol, Nepal, New Zealand, Pakistan, Philippines, Sri Lank, and Thailand (Gyeonggi-do participated as partnership in 2019)

Capacity building is another activity heavily promoted by the APCAP. APCAP is providing capacity building programmes to assist air quality managers of the member countries in identifying pollution sources and achieving clean air goals, including national planning/strategy development and raising awareness for air pollution reduction.

Technical assistance is also being provided. In this regard, APCAP has performed air quality and health assessments in Mongolia, Sri Lanka, and Thailand to support evidence-based policymaking. They have also supported the clean air planning of Agra, India and Phnom Penh, Cambodia (UNEP, 2015).

Climate and Clean Air Coalition (CCAC)[24]

The Climate and Clean Air Coalition (CCAC) is an international voluntary cooperation framework established by UNEP and six countries (Bangladesh, Canada, Ghana, Mexico, Sweden and the USA) in 2012, to reduce Short-Lived Climate Pollutants (SLCP), including black carbon, methane, ground-level ozone and hydrofluorocarbons (HFCs). UNEP hosts the Secretariat and is in charge of general operation, management and supervision. The CCAC is being operated based on a wide variety of partnerships with countries, NGOs, private companies, and environmental organizations. Currently, in 2020, 71 state partners (including Korea and Japan), 78 non-state partners, 19 international organizations, 59 NGOs and 181 actors, are partners of the CCAC. The operation deadline of CCAC was recently extended from 2023 to 2030.

The main purposes and strategies of the CCAC consist of:

- raising awareness and establishing strategies for addressing SLCPs;
- overcoming obstacles in developing measures, building capacity and expanding support;
- identifying optimal management techniques and sharing success stories;
- improving scientific understanding of the impact of SLCP's, in order to develop mitigation strategies.

To achieve these goals, the CCAC have established 12 initiatives under which member countries and partner organizations promote SLCP reduction activities. The official meetings of the CCAC, such as the Working Group and High-Level Assembly, provide opportunities to share information and achievements of each initiative and establish mid- to long-term activity plans. For example, the CCAC has made an effort to mitigate methane emissions from the oil and gas sector using public-private partnerships (UNEP, 2014). As mentioned, in partnership with APCAP, the CCAC has also undertaken an assessment of air pollution and related climate mitigation in Asia, which resulted in the report "*Air Pollution in Asia and the Pacific: Science-based solutions*", published in 2019 (UNEP, 2019a). This shows the large impact that 25 measures can have on reducing air pollution across Asia. The CCAC initiative "Supporting National Action and Planning (SNAP) to reduce SLCPs" has also helped countries such as Bangladesh, develop national plans for emission reductions.

The rising cooperative atmosphere amid the East Asian countries, and thus CCAC's role in reducing SLCPs using a science-based approach, is likely to be more significant in the future. As a member of CCAC, Japan has been actively involved in the following specific and crosscutting initiatives: (1) Mitigating SLCPs from the Municipal Solid Waste Sector; (2) Supporting National Action and Planning on SLCPs (SNAP); (3) Regional Assessments on SLCPs; and (4) Addressing SLCPs from Agriculture.

24 CCAC - https://www.unenvironment.org/asia-and-pacific/asia-pacific-clean-air-partnership/what-we-do

Korea joined the CCAC as a member in 2012, and since 2014 the Ministry of Environment in Korea (MOEK) has been participating in the Working Group meetings and performing other duties as a major partner (MOEK and KEITI, 2017). The major usefulness of CCAC in Korea is highly related to monitoring international environment regulation trends and relating them to the domestic market, which will allow local industries to respond more strategically. From 2016, the government of Korea has been actively participating in CCAC projects, to enhance the development of cooperation through Korea's SLCP reduction systems, in policy and technology.

Multilateral cooperation

Two multilateral cooperation frameworks have been developed by China, Japan and Korea: the Tripartite Environment Ministers Meeting (TEMM), and the Long-range Transboundary Air Pollutants in Northeast Asia (LTP). TEMM has a specific focus on air pollution and as shown in Figure 16, covers all transboundary environmental issues across these three countries.

Tripartite Environment Ministers Meeting (TEMM) among China, Japan, and Korea

The Tripartite Environment Ministers Meeting (TEMM) among China, Japan, and Korea was organized by a proposal of South Korea, in the 6th meeting of the UN Commission on Sustainable Development, held in New York in May 1998. The purpose of this was to prepare mutual cooperation measures on the environmental problems of Northeast Asia, such as hazardous waste control, control of yellow dust, reducing air pollution and to raise awareness on the environmental community within China, Japan and Korea. Since 1999, the TEMM has been held once every year, alternating between the three countries. The TEMM is the only Minister-level meeting in the environmental field in Northeast Asia and this means it provides a chance for the highest-level regulators from the three countries to meet and promote environmental cooperation between China, Japan and Korea. The co-achievements of the TEMM were submitted to the World Summit on Sustainable Development, which has raised the profile of the group in international circles and is recognized as important.

In the 10th TEMM, Japan wanted to prioritize marine litter or floating waste that was travelling from Korea to the coasts of Japan (TEMM, 2008). The 11th meeting held in Beijing in June 2009, evaluated achievements for the past decade and agreed on ten high-priority areas for cooperation for the following five years (2010-2014) (TEMM, 2009). In the 15th meeting in June 2013, in Kitakyushu, Japan agreed to strengthen mutual cooperation among the three countries, in relation to the Green Climate Fund, climate change, biodiversity, yellow dust, and air pollution (TEMM, 2013). In particular, the Tripartite Policy Dialogue on Air Pollution (TPDAP) was established to respond to the air pollution problem in Northeast Asia, such as particulate matter and yellow dust, and established a practical consultation body to address the air pollution problem.

In the 16th meeting, which was held in Daegu, South Korea, in April 2014, the three countries reflected new matters of interest, adjusted some priority cooperation areas, and selected nine new priority cooperation areas including: air quality improvement; biodiversity; cross-border movement of electrical and electronic waste; climate change response; rural environment management; and transition to a green economy. These were to be promoted for five years, from 2015 to 2019 (TEMM, 2014). In the 19th meeting, held in South Korea in August 2017, the three countries shared the common recognition that air pollution is a serious problem for each country by adopting the "Joint Communique on Environment" (TEMM, 2017). They emphasized the need for prevention and sustainable solutions to regional and global environmental problems, such as air pollution and climate change, for example, through the reduction of pollutant emissions.

Long-range Transboundary air Pollutants (LTP) Research Project between China, Japan and Korea

The LTP was initiated in 1995 in a response to a proposal of Korea, as part of an international joint research project between China, Japan and Korea. The LTP is similar to the EANET in that the LTP has attempted to enhance scientific cooperation within the region (Kim, 2007). The goal of the LTP is to prepare effective measures to address air pollution. This includes: conducting research on emissions; atmospheric transport and deposition in the three countries; establishing a monitoring system for long-distance air pollutants in Northeast Asia; and establishing a substantial cooperation framework between participating countries. The 1st Expert Meeting for LTP in July 1996, agreed on monitoring for long-distance transport of contaminants, modelling joint research, and the organization of the Secretariat and Working Groups. Since then, the expert meeting has been held every year, with five aims (Kim, 2007): (1) to discuss the results of each country's research; (2) to discuss the uncertainties and gaps among country data; (3) to give more clear understanding on the long-range transboundary air pollutants; (4) to make a formal research base about long-range transports; and (5) for providing this information to policymakers in each country (Park, 2005).

The 19th Expert Meeting held in Seoul in 2016, agreed to expand joint research and cooperation on long-range transboundary air pollutants, such as particulate matter (PM_{10} and $PM_{2.5}$) and ozone (O_3). In particular, the three countries agreed to perform scenario modelling to estimate the effects of each country's policies on air quality, through joint research from 2018. This included monitoring studies on changes in the chemical composition of $PM_{2.5}$ in the atmosphere (NIER, 2016). The 20th Expert Meeting in October 2017, discussed the publication of a report about the results of past projects. A summary report of the past projects was published at the end of 2019.

In November 2019, the National Institute of Environmental Research of Korea published the first LTP summary report (NIER, 2019). This report contained the result of joint research of scientists from the three countries, on the causes of air pollution, such as sulphur oxides (SOx), nitrogen oxides (NO_X), and fine particulate matter, from 2000–2017. Scientists in China, Japan and Korea who have participated in the LTP report, emphasize that this report could be the starting point for the continuous reporting on the accurate measuring and monitoring of air pollution emissions.

Bilateral cooperation

Korea-China Environmental Cooperation

The environmental cooperation with China started in earnest with the Korea-China Environmental Cooperation Agreement in October 1993. In 2003, the ministries of environment of the two countries signed a memorandum of environmental cooperation and revised the memorandum in July 2004. Since then, the two countries have been closely cooperating in areas such as air pollution, yellow dust, and other environmental projects. To enable joint research between the two countries, the office of the Korea-China Joint Air Quality Research Group opened in Beijing in June 2015 (MOEK, 2019), which is conducting research on the chemical characteristics of fine particulate matter. To reduce particulate matter concentrations in both countries, the governments and companies within both countries have carried out air pollution reduction demonstration projects, worth 65 million Korean Won by 2016. Briefings have been held continuously to identify additional projects.

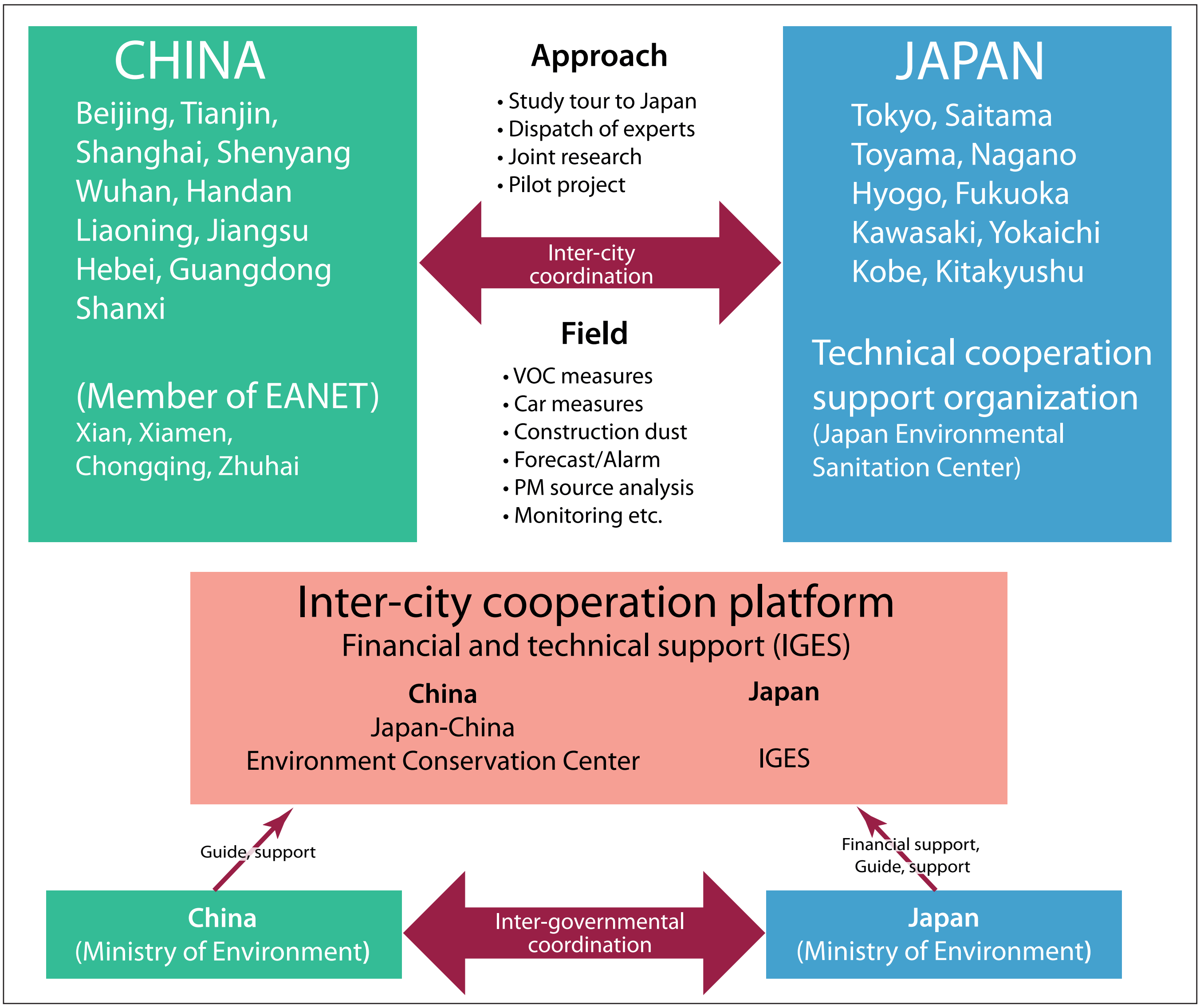
In April 2016, the environment ministries of the two countries agreed to establish a regular Director-level consultation body – the Korea-China Environmental Cooperation Center – in order to develop mid- to long-term cooperation plans. With these agreements, the environment ministries signed the Letter of Intent to Strengthen Environmental Cooperation and held the first

Korea-China Environment Ministry Director meeting in Seoul, in November 2016. In this, they shared information about the environmental policies of air, water, and soil in both countries, and discussed the development of measures for environmental cooperation between Korea and China. In the above-mentioned 19th TEMM in August 2017, the two countries agreed on the Korea-China Environmental Cooperation Plan (2018–2022) through a separate discussion.

China-Japan Environmental Cooperation

Environmental cooperation between China and Japan is in the form of technology transfer and joint research. Japan has shared its experience on air pollution mitigation and its professional knowledge on environmental technology, with China (JFS, 2013). To improve air quality and strengthen the network between cities in China and Japan, a workshop was held whereby industry, academia and governmental organizations identified the technical demands and needs of each city. From this, specific cooperation measures were identified and task forces were formed. The implementation of these cooperation measures are supported by

Figure 19. China-Japan Environmental Cooperation



Source: MOEJ (2015); Lee (2017)

governmental institutions and research centres (Lee, 2017). The city-to-city strategy between China and Japan has been quite successful so far and it is hoped the approach will continue to improve relationships and cooperation between the two countries.

From 2015, the Japanese government has been actively implementing bilateral cooperation projects to improve the air quality between local cities in China and Japan. Through pilot projects, the Japanese government is providing funding, manpower, and technical support for corporate-linked cooperation projects between 10 cities, including Tokyo, Kawasaki, and Fukuoka in Japan, and 15 cities including Beijing and Shanghai in China, as shown in Figure 19. Japan provides a training programme for Chinese local government and business officials, and conducts joint research and modelling projects. The areas of cooperation include on volatile organic compound (VOC) measures, automobile measures, dust control measures for construction works, forecast/alarm systems, and pollution source analysis and monitoring.

Japan – Korea Environmental Cooperation

In 1993, Japan and Korea agreed to have regular dialogue on environmental issues, so the Japan-Korea Environmental Conservation Cooperation Agreement was concluded. Since then the two countries have been leading discussions on a periodic basis to promote working-level policy dialogues on their respective environmental policies, and bilateral and multilateral environmental cooperation. Starting from 1999, Japan and Korea have been having serious talks on transboundary air pollution matters and have conducted joint research activities. Since then, various projects on monitoring of long-distance transport of air pollutants and acid deposition in Northeast Asia have been agreed and implemented. The long-term projects have been continuous and most of them are still ongoing.

3.3 A comparison of cooperation frameworks related to air pollution in Northeast Asia

Assessing the effectiveness of cooperation frameworks

To understand the relative effectiveness of these cooperation frameworks, Shim and Jang (2015) conducted a comparative evaluation of four of the major cooperation frameworks. This included the international frameworks of EANET and NEASPEC, and the multilateral frameworks of TEMM and LTP. The study focused on five evaluation indicators including the frameworks, (1) coordination capability, (2) institutional development, (3) financial balance and mobilization capability, (4) information sharing, and (5) participation of parties.

The results of the study have been summarized against the five indicators in Table 7. Where there is both a formal intention and successful implementation for the indicator, there is a filled circle next to the framework. If there is an intention to act, but no implementation, there is a hollow circle. If both are absent, it is left blank (-).

In summary, the results for each of the indicators were as follows:

1. Coordination capability
All four frameworks advocate data sharing and expanding the exchange of expertise with other organizations and non-member countries, but the actual coordination performance was assessed to be relatively insufficient (NIER, 2012; Kang, Elder and Shang, 2013; EANET, 2014).

2. Institutional development
It was found that all programmes have relatively clear main principles and objectives, and currently have regular meetings (NIER, 2012; Kang, Elder and Shang, 2013; MOEK, 2015). However,

Table 7. Evaluation of major transboundary air pollution cooperation frameworks in Northeast Asia.

	TEMM	NEASPEC	EANET	LTP
Coordination capability				
Communication with other institutions and organizations	○	○	-	-
Cooperation with international organizations	○	●	●	○
Communication with non-member countries	-	-	○	○
Institutional development				
Clarifying and sharing basic principles and goals	●	●	●	●
Continuous regular meetings	●	●	●	●
Establishment of a permanent secretariat	○	●	●	●
Financial balance and mobilization capability				
Participation in financial support by member countries	○	○	○	-
Efforts to secure external finance	-	○	○	-
Information sharing				
Securing and sharing scientific data	○	●	●	●
Continuous public education activities	●	○	●	-
Publishing periodicals	●	-	●	●
Participation of parties				
Operation of open symposium for participation of the parties	●	●	●	○
Participation of ngos	○	●	-	-

Source: (Shim and Jang, 2015, p.43)

Key: Possess both intention and implementation (●), possess intention (○), and none (-).

in the case of TEMM and LTP, it was assessed that because the framework secretariats are operated by each country in turn, this limits operational effectiveness (NIER, 2012).

3. Financial balance and mobilization capability

Consistent funding, with a balanced contribution between member countries, is regarded as a very important element of an international cooperation framework, however most frameworks have weaknesses in this area. Programmes are mainly funded by one or two countries, meaning those voices are stronger than other countries. This can result in the programme becoming associated with the country that provides funding, rather than considered as a joint initiative.

4. Information sharing

It can be considered that information sharing has been carried out relatively steadily in all programmes. EANET and TEMM have been making efforts to share technology and scientific methods, and are publishing reports annually through continuous international exchanges. However, some countries are not yet actively applying this approach.

5. Participation of parties

Regarding the participation of the parties, dialogue channels are being steadily created through open symposiums. However, efforts such as communication and public relations with NGOs are still insignificant in all programmes. Ideally, each country would have the same level of expertise, so that data sharing can be continuous and over the long-term. In order to achieve this goal, capacity building and links to policy development and implementation – beyond ministerial-level – needs to be increased.

Benefits and shortcomings of current cooperation frameworks in Northeast Asia

The study of Kauffmann and Saffirio (2020) concludes that the cooperation on air pollution in the Northeast Asia region has not yet established an inter-connected strategy for mitigating transboundary air pollutants and is yet to proceed to agreeing common regulatory frameworks. They suggest the following to address this: (1) capitalize on the existing international cooperation initiatives and integrate the fragmentary cooperation; (2) promote international scientific research along with the regulatory frameworks, to develop a common sense of transboundary air pollution for each country and establish co-used data and reliable methodologies; (3) recognize the main and other drivers of air pollutant emissions; (4) understand and deploy international cooperation mechanisms for air pollution regulatory frameworks; and, (5) build on the current situation to make progress on International Regulatory Cooperation (IRC), with mutually agreed targets and stronger binding force.

International cooperation frameworks

EANET and APCAP have high levels of expertise, political neutrality, and the ability to coordinate joint work. Mutual cooperation has been enhanced by launching capacity-building activities and through continuous joint monitoring frameworks. These mainly focus on sharing scientific information on air quality monitoring, and building databases on air pollution levels in Asia. However, the cooperation led by international organizations is based on voluntary and uncertain funding from different sources. This means they have great difficulty in finding stable funding, compared to a case where these are linked to bilateral and multilateral cooperation frameworks. Developing effective projects through cooperation, using the advantages that international organizations have in the region due to great interdependencies, will be very important in terms of project expansion and sustainability in the future – as long as stable funding can be assured.

NEASPEC has recently attempted to promote more focused frameworks, for example through the launch of NEACAP, to address transboundary air pollution. However, the degree of cooperation concerning the development of regional policy is considered to be very low, because the cooperation frameworks are not designed for, and are not in a position to, assign legal obligations to countries. Rather, they are based on voluntary participation by countries. However, the international organizations can create a positive environment for technology cooperation, by sharing relevant data and scientific knowledge. However, so far this has not led to significant practical technology cooperation, but it presents a potential to develop cooperation and further partnership in the near future.

Multilateral cooperation frameworks

The LTP is highly important because it is the only research project on long-range transboundary air pollutants in which the government agencies of three major countries in Northeast Asia officially participate. Furthermore, the LTP is achieving concrete results, such as investigating the causes of long-range movement of air pollutants and the contribution ratios of air pollutants from China. However, the research results have not led to actual air pollution improvement policy at a transboundary level. Nevertheless, the fact that three countries accept the research results of the LTP, with no significant disputes, and adopt them as the basis of joint discussion, shows the possibility of non-political cooperation measures on the air pollution problem in Northeast Asia.

For both TEMM and LTP, the annual meetings are the highest decision-making body. They do not have independent secretariats, but a dedicated department within each country acts as the secretariat. For this reason, the administration and support to these initiatives are to some extent weak. As with the international cooperation frameworks described in this report, multilateral cooperation frameworks do not bind countries to obligatory agreements. Furthermore, these initiatives are not designed as a forum for negotiation. However, although there is no independent body to supervise, the multilateral cooperation frameworks have facilitated somewhat active forms of cooperation, such as knowledge exchange, cooperation agreements, letters of intent, specific arrangements, and action plans. In relation to technology, Northeast Asian countries are taking an active approach through research activities associated with LTP. However, the countries are in the relatively early stages of cooperation, currently focusing on activities such as sharing scientific knowledge, rather than more advanced levels of collaboration, such as dedicated technology cooperation as part of multilateral cooperation frameworks. However, the fact that the countries participate in continuous processes, including holding annual meetings and striving to achieve common goals, will provide advantages for the practical development of projects in the future.

3.4 Summary

In summary, these cooperation programmes have limitations such as lack of funding, overlapping responsibilities, and an inability for countries to agree on targets (Jung, 2016). The main characteristic of the Northeast Asian air quality cooperation frameworks is that cooperation on the development and negotiation of agreements, outlining specific obligations and commitments, is lacking. The individual environmental cooperation bodies or cooperation projects of Northeast Asia, have almost no binding force that obligates the participating countries (entities) to fulfil any agreements. It is difficult in the case of the transboundary air pollution problem in Northeast Asia, to develop binding agreements with agreed obligations by participating countries, such as in Europe. This is because the economic, historical and cultural context of Northeast Asia is different, and it may not be easy to transfer the experience and approach from one region to another, especially when there is no political will to enter into such arrangements.

Therefore, it is necessary to break away from trying to develop an approach which, for the moment at least, is not desired by one or more countries. Rather, it is better to start cooperating from the point where everyone agrees. In that sense, technology-based collaboration can be an alternative. Hoel (2005) stressed that technology-based cooperation could be a solution to overcome historical and cultural obstacles to address global warming and other cross-border environmental problems. In fact, as noted earlier, there is a movement to exchange technology to reduce fine dust among China, Japan and Korea, and the willingness of each country to expand it is very high. In other words, expanding the technical cooperation framework by taking full advantage of the existing cooperative frameworks, may be a way to overcome the limitations of the existing frameworks noted earlier.

Furthermore, each country participating in a cooperation initiative often has a different perspective on the same air pollution problem. The interest of a country around an environmental problem can be complicated, and this results in different actions undertaken by different countries. In the view of technology and scientific procedures, transboundary air pollution is difficult to evaluate quantitatively, and requires cooperative monitoring and modelling activity at an international scale. Various scientific techniques exist and are being used for the analysis to control air quality in Northeast Asia. However, results vary due to differences in the models used by each country.

According to the OECD (2019), most of the regional cooperation in Northeast Asian countries on air pollution issues is limited. It is often limited to data collection or just exchange of information with each other. In particular, there have been limited practical efforts to mitigate air pollution, such as the development of pilot studies and actual initiatives that have mitigation potential. The efforts to develop international cooperation have yet to produce an approach to adequately address air pollution. Although numerous initiatives covering the challenges for air pollution mitigation exist, Northeast Asian countries do not seem ready to develop consensus on a process that sets targets for emission reduction such as those agreed by countries in Europe in the Convention on LRTAP and the USA-Canada Air Quality Agreement (Kauffmann and Saffirio, 2020).

In a study on environmental cooperation mechanisms in Northeast Asia, Choo et al. 2005 described the obstacles (see Table 9). The Table is a summary of interviews with experts on environmental cooperation. Considering that policies, regulations and activities on air pollution are very different in each country and that in some countries these are based on a voluntary basis, the exact comparison of a particular cooperation over a certain time frame was not possible. Therefore, the interviews are qualitative and based on expertise experience. However, the results of the analysis can be used to assess the prospects for further environmental cooperation. The main obstacles to cooperation in the Northeast Asian region include: a lack

Table 9. Obstacles to Environmental Cooperation in Northeast Asia

	China	Japan	Korea	Mongolia
No. 1	Political, economic, history, and security conflicts	Political, economic, history, and security conflicts	Lack of available resources for cooperation	Low understanding and lack of common awareness
No. 2	Lack of effective cooperation projects	Low understanding and lack of common awareness	Lack of effective cooperation projects	Lack of available resources for cooperation
No. 3	Lack of available resources for cooperation	Conflict of interest and power relations among stakeholders	Low understanding and lack of common awareness	No response

Source: Choo et al., (2005, p.191)

of resources for cooperation, a lack of effective cooperation projects, and a number of political, economic, historical factors and security conflicts.

The above results can be used to assess how progress can be made to address air pollution through regional cooperation in Northeast Asia. The reality that no substantial agreement has been produced thus far, despite the existence of multiple cooperation frameworks, is not very different to the obstacles to environmental cooperation recognized by Choo et al. 2005. It is difficult to organize or create a negotiated treaty in the region, due to the complex historic and cultural contexts of Northeast Asia.

4. Strategies for international cooperation to solve air pollution in Northeast Asia

The successful reduction of air pollution levels in Europe and North America that started in the 1950s, has provided a good example for different parts of the world. The development of the Convention of Long-Range Transboundary Air Pollution (Convention on LRTAP), and building on and working with national air pollution reduction programmes in European countries, has resulted in a remarkable degree of reduced air pollution. The journey in these regions has been a long one, but has led to agreements and action to reduce emissions. The type of negotiation on emission reductions which occurred between European countries, is not necessarily the only, or the most appropriate, solution for every region. However, aspects of that journey can help highlight how Northeast Asia could increase regional cooperation and help solve the very high concentrations of air pollution being experienced – to the benefit of all in the region.

The many attempts to create regional cooperation between the governments of China, Japan and Korea and other Northeast Asian countries over the last decades, have brought a certain degree of progress, resulting in the development of institutions for international cooperation and sharing of relevant information. However, creating an international scheme to reduce air pollution that would be comparable to the regulatory regime implemented in Europe, remains challenging. Aiming for this in the near term, may not be the best way for experience in Europe to inform progress in Northeast Asia, given the different political context (Yarime and Li, 2018). From the progress in bilateral and multilateral cooperation, it would seem that there is a desire and willingness to reduce air pollution in the region, even if this does not extend yet to readiness or commitment to negotiate on emission reductions between countries. Therefore, it seems more fruitful to concentrate on learning from the progress that the Convention on LRTAP has made on sharing information, developing joint scientific programmes, developing regional centres of excellence on air pollution, and sharing information on best available techniques to reduce emissions.

The first International Forum co-hosted by the National Council of Climate and Air quality (NCCA) of Korea and UNESCAP, held in Seoul in 2019, emphasized that blaming countries about transboundary air pollution is not helpful. At this stage, more progress could be achieved by building trust and promoting joint actions, based on scientific cooperation, sharing best practices for policy development, and technological cooperation. Together these can be an efficient and capable way to increase regional action, to deal with this urgent shared regional air pollution matter.

In this chapter the three pillars of: (1) building scientific consensus; (2) sharing best practices and policies; and (3) spreading practical approaches and technology among the Northeast Asian countries, are suggested as a useful starting point for Northeast Asia. This could further build trust and foster a cooperative atmosphere to tackle air pollution. This needs to build on current progress in existing efforts and also needs to emphasize the multiple health and economic benefits for the region.

4.1 Developing consensus among scientific communities

One aspect of the work under the LRTAP Convention that may be transferable to Asia, is the cooperation on science that has been developed between countries and the scientific institutions within those countries. Having cooperation and increasing transparency over the science, is an essential part of international cooperation on air pollution. This is because the air pollution issue depends on scientific research, to build a thorough understanding of the complexities that are inherent with this issue. Cooperative frameworks to build a consensus about scientific knowledge are considered to be crucial for successful environmental cooperation among countries.

The LRTAP Convention has developed a structure that promotes cooperation on all aspects of scientific research that is required to understand, agree upon and mitigate air pollution. This includes cooperation on emission inventories – where there is an accepted method that all countries follow; capacity building to implement these; and reporting of data and emissions to specialized centres under the Convention, where quality control is carried out. There is then cooperation on modelling the transboundary transport of air pollution, and coordination of the monitoring efforts in each country to measure pollution levels. EMEP, which is a body under the Convention on LRTAP (see Section 2), organized the guidance on methods, reporting and quality control for monitoring air pollution, as well as undertaking modelling. The development of EMEP was crucial to cooperation in Europe and can be a good example to follow. There are further bodies under the LRTAP Convention that look into impacts on ecosystems, agriculture, health and materials (metals and stone), and under each, there is cooperation between researchers from many countries. This leads to communities across Europe, which have helped the policy process.

Northeast Asia is striving to create a consensus on the issues and develop joint responses to the problem, rather than pointing fingers. EANET is a good example – it now covers many different countries and there is reporting of monitoring data. Further cooperation is required to increase transparency and quality assurance of the data, in order for this type of cooperation to spread to other issues, such as emissions, atmospheric transport and impact assessments. In Europe, all countries agreed that the Norwegian Institute for Air Research (NILU) in Norway would develop an atmospheric transport model for pollutants that formed the basis for negotiations on emission reductions. If countries of Northeast Asia could agree to develop one model, which they all trusted, that would be a step forward.

In November 2019, the co-hosted International Forum by the National Council of Climate and Air quality (NCCA) of Korea and UNESCAP, was created for the region to prepare for agreements, including "best-practice-sharing-partnerships" among the Northeast Asian countries. The development of the Forum is an important step, as it has encouraged the participation of relevant stakeholders, including representatives from international and national scientific communities, as well as government officials from different countries, and it has provided opportunities for the countries of the region to seek solutions on air pollution. One notable achievement from the 2019 NCCA International Forum is related to Provisions that were negotiated. This included: advanced policy cooperation; science and technology cooperation; the use of a global international cooperation platform; measures to strengthen capabilities and engage the younger generation; strengthening networks with neighboring countries; and promotion of cooperation among stakeholders. At the Forum, Mongolia's Environment Minister shared experience in a panel at the meeting, by saying he has achieved common goals to address climate change and air pollution, by developing measures such as strengthening international cooperation, promoting capacity building and through continuous science-policy dialogues with neighbouring countries.

Those continuing efforts of the Northeast Asia countries are expected to strengthen the solidarity to solve air pollution in the region, by promoting an objective and goal-oriented dialogue based on scientific evidence. These need to be supported by shared assessments and scientific projects, reporting of data, and encouraging transparency. This in turn can lead to increased trust in the region.

4.2 Sharing best practice and assessment of activities and measures in China, Japan and Korea

Every country in Northeast Asia is applying policies and measures to reduce air pollution emissions, as a national priority. Exchanging experience of current policies and measures can be a plausible way to learn from each other that will in turn, lead to cooperation. Thus, the policies and measures of China, Japan and Korea – countries that are willing to be involved in "best-practice-sharing-partnerships" – can be followed, and best practices shared. Establishing linkages between the cities and businesses of China, Japan and Korea will help to tackle fine dust, for example, by sharing experiences within the private sector.

From 1993 to mid-2010, dynamic cooperative action was initiated to promote environmental cooperation between China and Korea. However, scientific and engineering collaboration is still limited, with science research projects mainly being undertaken and further activity such as comparing the practical policies from the two countries, lacking (Choi, 2019). Environmental cooperation between China and Japan, is in the form of technology transfer and joint research.

4.3 Promoting technology cooperation in Northeast Asia

Technology exchanges can invigorate connections between private companies in the different countries and boost the business opportunities and industrial output, which in turn will lead to mutual economic benefits and reduce political friction. The acquisition and development of technology is the fundamental part for innovative solutions, leading to revenue generation and improvement of business opportunities. However, appropriate infrastructure and building relevant capacities are necessary pre-conditions for the diffusion of new technologies. To encourage the sharing of data and further interaction, cooperation mechanisms should be emphasized to enable “effective interaction to take place among science, technology, production and market” (Arranz and de Arroyabe, 2009, p.2).

Technology cooperation is referred to as the liaison between institutions, whether it is technical, research and development, or administrative issues. This is seen as a complex array of organizational arrangements, rather than a simple transfer (Geisler, 2003) where various perspectives and views interact, leading to increases in technology adoption and innovation (Mallett, 2007). It is expected that technology cooperation can be a platform to support and enforce the interactions among the participants and thus create business opportunities. Korea and China are already in the stage of exchanging technologies. China and Japan, are also cooperating in the form of joint research and science and technology exchange.

One example from 2010 relates to the Korean NGO “Good Neighbors”, who collaborated together with the Korean Advanced Institute of Science and Technology (KAIST) and Korea International Cooperation Agency (KOICA), and implemented a technology called “G-saver” to fight against the cold winter in Mongolia, where the coal combustion for heating and cooking are responsible for 60% of pollutants in the Mongolian capital. The domestic energy-efficient technology reduces heating air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, while carbon monoxide can be reduced up to 40% (Global Innovation Exchange, 2018). The G-saver has been playing a role in increasing the temperature indoors and also reducing the cost of fuel. In 2014, nearly 20,000 G-savers were distributed across the nation, with a further 72,000 more distributed by 2016 (KoreaNet, 2015).

Korea’s Ministry of Environment has also promoted mitigation policies to address “yellow dust” and developed short- and long-term planning to reduce PM, to improve health and reduce the socio-economic consequences of the severe air pollution. In Northeast Asia, Korea is one of the countries that actively participates in technology exchange with nearby countries. From the follow-up action of the Korea-China Summit in July 2014, Korea started a technology exchange with China based on a Public-Private Partnership (PPP) from 2015, to mitigate PM with co-development from both countries’ environmental industry (MOEK, 2019).

Through this cooperative action between Korea and China, transboundary air pollutant emitting facilities, such as coal-fired thermal power generation in Shaanxi and Hebei Provinces, adopted Korea’s air pollutant mitigation technology. The main purpose of this cooperation was to establish the atmosphere mitigation system in China, especially for 16 areas, including Beijing, Shanghai, and Hebei Province. To tackle the air pollution issue, Korea suggested installing the mitigation systems into steel mills, power plants, and heat pumps. Moreover, the Korean Ministry of

Environment and Korea Environmental Industry and Technology Institute held the Korea-China PPP-based atmospheric technology exchange meeting in March 2019, with 21 companies, which have potential to participate in demonstrative cooperation projects for Korea-China PM mitigation at Shanghai, Tenjin, Hebei and Shaanxi Provinces.

5. Conclusions

Levels of air pollution in Northeast Asian countries are very high and are having a major impact on human health and the economies of the countries

In Europe and North America, a whole process of research assessment, modelling, technical cooperation, and policy development was initiated. This supported agreements on air pollution, which were signed by countries; Protocols were agreed; and policies were developed and implemented, to address transboundary air pollution problems. Levels of air pollution in Northeast Asian countries are very high and are having a major impact on human health and the economies of the countries, to an extent that brings back memories of pollution in Europe and North America at the peak of their emissions. Public pressure to do something about this problem is also very high and governments of the most polluted countries are taking urgent national action, which is leading to successful reductions in air pollution in some parts. These countries have also been exploring frameworks of regional environmental cooperation for a few decades now, as the advantages of regional cooperation as an important driver to reduce regional air pollution, has been clear to them.

Some progress has been made, especially in relation to scientific cooperation, but even in this, many gaps remain to be filled. However, despite multiple discussions at different policy levels, including meetings of ministers from the different countries, negotiating emission reductions between countries – as has happened under the LRTAP Convention in Europe – has not progressed. There are many social, economic, political and geopolitical reasons for that, and not all aspects of the European experience may be relevant to Northeast Asia. Having said that, there does seem to be a willingness to expand cooperation. This implies that experience from the European example that is most relevant to the situation in Northeast Asia, is not related to the negotiations on emissions itself, but rather the process of technical and scientific cooperation and discussion between policymakers.

In 2020, China, Japan and Korea have all pledged to become carbon neutral by 2050 or 2060. As these climate commitments have an impact on fossil fuel use, this will also affect air pollutant emissions. Therefore, it is possible that in the future, the appetite to negotiate between countries may increase. However, this does not look likely in the very near future and in the meantime, other efforts are needed to increase the level of activity at a regional scale, to increase cooperation, trust and promote action on emissions. This includes taking forward activities to promote the three pillars outlined in Section 4 (building scientific consensus, sharing best practices, and spreading practical approaches and technology) by drawing parallels to what happened in Europe and North America. These activities can be pushed forward using existing frameworks, but the ambition needs to be increased, with commitments to share data, increase transparency, monitor emissions and share details of national strategies. This will require additional agreements between the countries and additional financial and institutional resources to be invested into this.

5.1 Next steps

Scientific cooperation between the countries can be used to examine progress towards common goals

Based on the review and assessment in this report, several key findings can be derived. These learning points can be taken forward and implemented in the Northeast Asian context, building on existing efforts and establishing new frameworks where necessary.

A common framework for scientific cooperation, similar to EMEP in Europe, which develops common methods, approaches and models – which all countries agree on – would promote progress. This could enable national action plans to be constructed and evaluated, in line with regional goals. The cooperation through EANET, which is led by UNEP, has developed monitoring by combining common protocols, with training and quality control, and sharing of data between countries in Northeast Asia. This increased data sharing needs to happen in other areas as well, for example, countries could agree on common methods for emission inventories and then share results with other countries to increase transparency and trust. All countries develop atmospheric models, and the next step would be to develop joint atmospheric transport modelling, validated using monitoring results from EANET, which all countries can agree upon. Countries in the region could also share the results of impact and economic studies, to highlight the importance of addressing air pollution.

Increased public awareness and active participation of the public can motivate policy development by governments

Creating a platform for technology cooperation would be important to promote joint action. Businesses, institutions and research centers from different countries could be encouraged to come together and share their technical and scientific expertise. Technology cooperation could be promoted by Public-Private Partnerships. Examples of technology cooperation between Korea-China, China-Japan, and Korea-Mongolia previously discussed, provide good examples of cooperation to solve problems, free from any historical, political or cultural obstacles. This can create opportunities for private companies, meanwhile countries can achieve air pollution reduction goals. Therefore, developing and promoting practical technology cooperation programmes could play a pivotal role in solving the air pollution problem in Northeast Asia.

Active participation of the public is critical. Increased public awareness and active participation of the public can motivate policy development by governments, resulting in regulations and firm commitments. In 2019, the National Council of Climate and Air quality launched the "National Policy Participation Group", an official channel for citizens to engage with policymaking and promote linkages (Global Asia, 2019). This allows the public to present opinions through deliberation, debate and public opinion polls, and propose policies that the people can support. The group recently selected several of the best ideas to combat air pollution that came from a group of citizens and experts. These awareness raising activities and projects are encouraged by the Korean government every year. In Europe and North America, public pressure built on media interest in these issues was a key driver of progress. Increasing public awareness and engaging additional stakeholders in Northeast Asia, to increase public pressure on policymakers, will be a key driver of interest and action to reduce emissions. Campaigns using social media can keep the public and private sector engaged and informed about the issues.

The International Day of Clean Air for blue skies was launched in year 2020 by the United Nations. This annual event on the 7 September, aims to increase public awareness, demonstrate the close link of air quality to other environmental challenges such as climate change, promote and facilitate solutions that improve air quality, and bring together diverse approaches for effective air quality management (WHO, 2020). This annual event can be a focus for campaigns at national levels. In Europe, NGOs have been important catalysts for change on air pollution and they have played a constructive role, which could be very relevant for Northeast Asia. Engagement by NGOs is still at an early stage in Korea and other Northeast Asian countries, but could be encouraged.

In conclusion, in the case of Europe and North America, countries realized that they were unable to address transboundary air pollution without regional action. They developed regional policy processes supported by science and by sharing experience, adequately financed and organized. This was a joint effort that highlighted transparency and annual reporting. In order to solve air pollution problems in Northeast Asia, national action is needed and, in addition, as was the case in Europe, the reduction of long-range transboundary air pollution is also necessary, through implementing appropriate policies. At this stage, it may be most appropriate to actively promote scientific cooperative activities, cooperation to share experience on mitigation policies, sharing best practice and assessment of policies and measures, and promoting technology cooperation. All of this needs to utilize the existing cooperation frameworks in the region and emphasize the development benefits of taking action. At the same time, it is important to follow the rapidly changing circumstances in the region and grasp opportunities to jointly reduce air pollution when they present themselves.

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