Supplement to

The legacy of the Nordic contributions to acid rain science and policy

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This document contains four Supplements, one for each of the main chapters of the paper.

Supplement to The building of science and policy platforms, late 1960s - 1979

A socially conscious academic research base

In Swedish academia, there was early research interest in biogeochemistry, beginning around 1950. In 1952, Anders Ångström, director general of the Swedish Weather Bureau, published a paper (Ångström and Högberg, 1952) on the deposition of reactive nitrogen (ammonia and nitrate) in precipitation over Sweden. This work was based on measurements by soil scientist Hans Egnér and hydrologist Erik Eriksson at Ultuna Agricultural College in Uppsala and quantified the nutrient supply to soils from the atmosphere. Carl-Gustaf Rossby (1898-1957) at the Meteorology Department of the University of Stockholm (MISU), recognised the broader implications of this research with respect to biogeochemical cycling of nutrients and estimated that the global deposition of fixed nitrogen in precipitation could be 50 Mt(N) annually, and he wondered about what the sources were (Bolin, 1999).

Rossby recruited Eriksson to the University of Stockholm in 1954. Eriksson, Rossby and Egnér initiated a long-term atmospheric chemistry program, which evolved into the European Atmospheric Chemistry Network (EACN), operational from around 1955. It was a precursor to the acid rain observations starting later and data from the network formed a base for Svante Odén's alarming article in 1967 (Odén, 1967). Bolin (1999) recalled Rossby's advice in 1956 to shift focus from numerical weather forecasting to studying the residence times of atmospheric trace species, including anthropogenic pollutants like SO_2.

Reflecting on Rossby's legacy, Bolin (1999) wrote "I was particularly struck by his deep engagement in fundamental scientific research in meteorology and oceanography, and simultaneously being wholeheartedly devoted to the application of his research results to practical issues in society and willing to set aside a substantial part of his time to achieve this." A part of the legacy was thus a competent academic research environment on biogeochemistry in Sweden, open to societal needs.

Bringing research, policy, and collaboration into action

The research organisation Nordforsk, established in 1947, fitted well as the host for the acid rain project and the organisation offered to keep the secretariat. In 1969, when the ideas of a common Nordic initiative on a European acid rain investigation took form, governmental collaboration on environmental issues on a Nordic level was not yet formalised (Ottar, 1975). The Nordic Council of Ministers was only established in February 1971, four years before the subgroup on environment was formalised.

Senior administrators from research organisations across the Nordic countries were appointed to lead the Nordforsk acid rain project.[1] Alf Nyberg, Director General of Swedish Meteorological and Hydrological Institute (SMHI), chaired the leading group. Alf Nyberg was well aware of the acid rain problem (See for example Brosset and Nyberg, 1971). He was the president of World Meteorological Organisation (WMO) 1965-1971 and chaired the committee that planned to establish ECMWF[2]. His interest was closely linked to the application of science and associated societal issues (Bengtsson, 1994).

Mr Göran Persson at the SNV played a central role in forming the structure for the OECD project and the involvement of the Nordic countries in a central role. He proposed already at the early presentations of the problem in OECD that the Nordic countries should take a central role in the investigation of the acid rain problem. Then, he, as chair of the air pollution committee at Nordforsk, proposed a close cooperation between the Nordic countries and that Nordforsk could both support and host the secretariat for the project. The Nordforsk board acted accordingly and gave support for the project for the entire period until 1976 (Ottar, 1975). Göran Persson was educated under Cyrill Brosset at Chalmers University in Göteborg (see below).

To coordinate the scientific activities, Nordforsk entrusted Brynjulf Ottar, the newly appointed director of NILU. With Ottar in the lead, NILU became a centre for the Nordforsk project as well as for the OECD project.

Working groups involving Nordic experts were established under the expert group to focus on issues, such as ground level measurements, flight measurements and data handling. Collaboration between government stakeholders, research institutions and academia were pivotal in laying the groundwork for the project's success and its extension to European OECD countries.

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[1] Danish Meteorological Institute (DMI), Finnish Institute of Occupational Health, Finnish Meteorological Institute (FMI), Meteorological Institute at Stockholm University (MISU), Norwegian Meteorological Institute (DNMI), Norwegian Institute for Air Research (NILU), Swedish Environmental Research Institute (IVL) and Swedish Meteorological and Hydrological Institute, (SMHI) and Veðurstofa, Island.
[2] European Centre for Medium-Range Weather Forecasts

Brynjulf Ottar was an entrepreneur with a research background in physical chemistry. He was a former research assistant to the Nobel laureate Odd Hassel. Ottar was deeply involved in wartime military intelligence and from 1946 he was researcher at the Norwegian Defense Research Institute and was an expert in nuclear matters. He led the research there on dispersion of war gases before becoming the founding director of NILU in 1969 (Arnulf, 2021).

Cyrill Brosset was an important member of the expert group, and he also led the group for development and application of methods for ground level measurements. He had made pioneering work on long range transport of air pollution already in the mid-1960s and discovered the occurrence of "black and white episodes" with soot and ammonium sulphate as the main components. These episodes were associated with air mass transport from the European continent to Scandinavia (Brosset and Nyberg, 1971, Rodhe, 1972, Brosset, 1976). Brosset was the leader of the air pollution unit at IVL in Göteborg from 1967. He had also measured and assessed urban air pollution in many Swedish cities from the end of the 1950s as professor of inorganic chemistry at Chalmers. Ottar and Brosset developed a professional friendship which was important for the scientific agendas both of NILU and IVL and for the Nordic role in long range transport science and policy making.[3] Of the two, Ottar was the action-oriented entrepreneur, Brosset the scientist committed to investigating questions of societal importance.

The Nordforsk project included:

- Develop and apply methods for measurements of the relevant compounds.
- Collect and analyse existing data.
- Implement surface measurement and flight measurement programmes.
- Conduct reaction chamber studies of sulphur dioxide conversion in the atmosphere.
- Execute trace dispersion experiments over 500-1000 km distances.

The activities under Nordforsk thus followed two parallel and integrated tracks: setting up a joint scientific program within the Nordic countries; and taking a leading role in the development of a similar European program (Ottar, 1975).

Political externalities in the cold war context

The diplomat Lars Björkbom of the Swedish Environment Protection Agency and the Ministry for Foreign Affairs was a leading policymaker in the Air Convention. In Björkbom (2004), he provided examples of the importance of externalities in the negotiations under the Air Convention: The Soviet Union and the Western Powers agreed in a Final Act at the Conference for Security and Co-operation in Europe (CSCE)

[3] Cyrill Brosset was Peringe Grennfelt's graduate degree adviser at Chalmers and hired him at IVL in 1969. Brynjulf Ottar hired Øystein Hov at NILU in 1981.

in Helsinki in the summer of 1975 during a rather serious phase of the cold war, to cooperate in armament control, human rights and economic affairs. The implementation of the Final Act slowed. The Soviet Union then in late 1975 proposed cooperation on the environment within the framework of UNECE. The proposal did not arise from strong environmental views, it was rather that "Western and nonaligned governments responded favourably to the proposal, but few of them were guided by urgent environmental objectives. Most likely, it was an area of cooperation that would pose little danger to the overall balance between the two power blocks and at the same time it could serve as the needed bridge or communication link between them. When Norway and Sweden proposed long-range transboundary air pollution as a suitable subject matter for a convention, there was no major, alternative proposal and it was therefore accepted. But a large majority of UNECE member states on both sides of the Iron Curtain saw to it that the negotiation would result in undemanding obligations". Valentin Sokolovsky (2004), the Chairman of the Executive Body of the Air Convention in the first part of the 1980s and Vice-Minister of the Soviet Union's Ministry of the Environment, also emphasised the role of external factors in the Air Convention negotiations, for instance how the position of the Soviet Union could be influenced by an opportunity to uncover and magnify disagreements among EU countries.

Another example: Initially, Soviet bloc countries opposed the proposal for the first sulphur protocol but later reversed their stance. Björkbom (2004) attributed this shift to the NATO/Warsaw Pact dynamics at the time. The Reagan administration in the United States pushed for the deployment of Pershing II missiles and was met with strong public resistance in Germany. The United States and the United Kingdom reacted negatively to the Nordic proposal of a 30 % cut in SO_2 emissions, arguing that there was no scientific justification for it. Leveraging this discontent, Valentin Sokolovsky aligned the Eastern bloc with the Nordic proposal. The move divided NATO on the nuclear issue while gaining favour for stronger anti-air pollution measures across Europe.

EMEP initially had three centres: the Meteorological Synthesizing Centre West at the Norwegian Meteorological Institute (MSC-W), MSC-East (MSC-E) in Moscow and the Chemical Coordinating Centre (CCC) at NILU. The location of the centre in Moscow was originally a consequence of finding a balance between East and West with respect to science centres. Later the Centre for Integrated Assessment Modelling (CIAM) was established at IIASA in Austria and the Centre for Emission Inventories and Projections (CEIP) at Umweltbundesamt in Vienna. The western economic boycott of Russia after 2022 led to the relocation of MSC-E to Ljubljana in Slovenia. The EMEP framework has been important for the European capability to support international environmental research and policy development, not only for the Air Convention, but also in the European Union and the European Environment Agency (EEA) in Copenhagen, for the

Baltic Marine Environment Protection Commission HELCOM [4], the Convention for the Protection of the Marine Environment of the North-East Atlantic OSPAR [5], the Stockholm Convention on persistent organic compounds [6], Arctic Monitoring and Assessment Programme (AMAP) [7], Minamata Convention on Mercury [8], Intergovernmental Panel on Climate Change (IPCC) and many others.

Early in the 1970s, the European Commission initiated activities on the physico chemical behaviour of atmospheric pollutants through the concerted action programme COST 61a (1972–1976) and COST 61a bis (1979–1983). The atmospheric oxidation mechanisms of SO_2 to sulphate were explored. There was mutual benefit between the Nordforsk project and later EMEP and the COST action. Cyrill Brosset chaired the COST61a/61a bis steering committee around 1980. Later[9] Øystein Hov had that role, which i.a. led to EEC-assessments on acid rain and photooxidants over Europe (Hov et al., 1986 and 1987), preceded by e.g. the paper on acid deposition in Europe by Beilke (1983) in COST 61a. The communication between Nordforsk's Air Management Group (AMG), EMEP, the Air Convention and the European Commission helped pave the way for EEC to adopt many of the elements in the Air Convention in the air pollution control directives in the EEC early in the 1980s and later followed by the EU Acid Rain Strategy and the Clean Air for Europe (CAFE) programme (Hey, 2005; European Commission, 2005).

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[4] Signed 1974 by the Baltic Sea countries to address the increasing environmental challenges from industrialization and other human activities.
[5] Paris 1992, combines and up-dates the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution.
[6] Global treaty to protect human health and the environment from the effects of persistent organic pollutants (POPs), 2004.
[7] AMAP, Arctic Council working group established 1991 to monitor Arctic pollutants and climate change effects on ecosystems and human health.
[8] Agreed 2013, entered into force 2017.
[9] Professor Arnaldo Liberti, Institute of Atmospheric Pollution in Rome (CNR-IIA), followed Brosset as the chair of COST61a-bis.

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Acronyms, Supplement to The building of science and policy platforms, late 1960s - 1979

AMAP Arctic Monitoring and Assessment Programme (Arctic Council)

AMG Air Management Group (Nordforsk)
CCC Chemical Coordinating Centre (EMEP, NILU)
CCE Coordination Centre for Effects (Air Convention, RIVM, the Netherlands)
CEIP Centre for Emission Inventories and Projections (EMEP, Umweltbundesamt Austria)
CSCE Conference for Security and Co-operation in Europe
DMI Danish Meteorological Institute
DNMI Norwegian Meteorological Institute (Now MET Norway)
EACN European Atmospheric Chemistry Network
ECMWF European Centre for Medium-Range Weather Forecasts
EEA European Environment Agency in Copenhagen (EU)
EEC European Economic Community
FMI Finnish Meteorological Institute
HELCOM Baltic Marine Environment Protection Commission
IIASA International Institute for Applied Systems Analysis at Laxenburg in Austria
IPCC Intergovernmental Panel on Climate Change (UNFCCC)
IVL Swedish Environmental Research Institute
MISU Department of meteorology (University of Stockholm)
MSC-E Meteorological Synthesizing Centre East in Moscow, recently moved to Ljubljana (EMEP)
MSC-W Meteorological Synthesizing Centre West at Norwegian Meteorological Institute (EMEP)
NILU Norwegian Institute for Air Research
OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic
POPs Persistent Organic Pollutants
SMHI Swedish Meteorological and Hydrological Institute
SNV Swedish Environmental Protection Agency
WMO World Meteorological Organisation

Supplement to The second phase of the Air Convention 1985-2000

The Nordic Expert Groups and System thinking and linking to policy in the Air Convention

AMG's agenda included many additional activities in support of the further development of the Convention. For photooxidants, the European distribution of ground-level ozone and its transboundary nature were addressed in Nordic workshops (e.g. Grennfelt, 1976) followed by an investigation of the regional distribution of ozone in Europe (Schjoldager et al., 1981; Grennfelt and Schjoldager, 1984; Grennfelt et al. 1989).

Some of the ICPs were run by Nordic institutions, sometimes with Nordic support: ICP Water with its centre in Norway, ICP Material with its centre in Sweden and Czechoslovakia, ICP Integrated Monitoring which had a shared centre between Sweden and Finland. ICP Forests was established in Germany in 1985, while ICP Vegetation was set up in the United Kingdom in 1987. With the establishment of the ICPs, the Air Convention covered the pollution system from emissions to effects. Blame matrices were calculated on a routine basis to quantify how a given emission source could impact a receptor. The monetary damage was quantified by integrated assessment modelling at IIASA as well as the minimum cost of reducing the emissions to limit the exceedance of critical loads or levels. In this way the policy was knowledge based. Nordic researchers took part as experts in the negotiations to take note of critical issues and make sure that the strengths and weaknesses in the science base were known to all. AMG also supported Nordic expert involvement in the IAM work at IIASA.

As described also by Grennfelt et al. (2020) a precursor to and model for the ICP Integrated monitoring under the Air Convention was the interdisciplinary ecosystem-oriented, decade long Norwegian research programme "Acid precipitation — effects on forest and fish" which started in 1977. It became a model for a series of research projects set up in many countries affected by acid precipitation, including Germany, the Netherlands, Czechoslovakia, Finland, Sweden (Lake Gårdsjön project) and the UK (Overrein et al., 1981, Andersson and Olsson, 1985). The projects became sites for science communication where politicians, negotiators, media and the public went to gain problem insight and understanding. The basis of these projects was long term ecosystem monitoring and field experiments, not only for compounds related to acid rain but also for other pollutants such as mercury and persistent organic compounds. The outcomes have given important input to the development of dynamic ecosystem models for the analysis of the consequences of different emission scenarios.

The operationalisation of the CL-concept took place through workshops supported by AMG, and a first manual was prepared for the mapping of ecosystem sensitivities over Europe (Sverdrup et al., 1990). The Netherlands took responsibility for the further work with CL-mapping and data handling, and the Coordination Centre for Effects was established at RIVM[10]. AMG supported the further developments of the CL concept: CL for nitrogen 1992 (Grennfelt and Thörnelöf, 1992), general methodology in 1999 in Copenhagen (Løkke et al., 2000). Following the 1999 workshop the Joint Expert Group on Dynamic Modelling was established under the Air Convention and included as part of the WGE agenda in 2001. Methodologies for mapping critical levels of effects of exposure of gases to ecosystems were also developed with support from AMG (e.g. Kärenlampi and Skärby, 1996).

The Nordic countries promoted sometimes more basic research activities to strengthen the basis for the Air Convention policy. An example is the initiative to increase the scientific understanding of the behaviour of nitrogen in ecosystems. Ecosystems on the European continent were leaching nitrogen with detrimental effects in groundwater and streams. In Scandinavia the opposite mostly occurred: nitrogen was retained, and leaching was in general very small. AMG initiated therefore field experiments of the risk for increased nitrogen leaching in Scandinavian forests. The pilot work of AMG was followed by a large project (NITREX) funded by the EU (Wright and van Breemen, 1995: Emmett et al., 1998).

Marine issues integrated with AMG

AMG was seen as even-handed and independent of specific national interests, even though joint political priorities in the Nordic countries were the driving force. It succeeded in fostering a collaborative and result-oriented culture. But AMG failed to integrate the experiences from the atmospheric part into the marine domain. Even with a well-intentioned ambition to foster a closer collaboration between atmospheric and marine pollution research and applications, AMG concluded that this would require commitment and working together in research and practical policy applications over quite some time. The national marine research institutions and the affiliated governance structures have old historical roots and a strong culture in carrying out knowledge development and societal applications within a national governmental framework. AMG was recruited from the environmental branch of the Nordic governments, while marine pollution belonged more to the fisheries, shipping and coastal management and development sectors with other parts of government in the lead, and where environmental issues were but one of several concerns when political priorities and decisions were made.

Systems for science-policy interaction emerged during the second phase

EEC was a Party to the Air Convention from the outset. Its role was in the beginning limited due to lack of legislation related to transboundary air pollution, but this changed with the Single European Act in 1986, by which the European political cooperation was

[10] National Institute for Public Health and the Environment

established, including the field of environment. In the Maastricht Treaty from 1992 the European Union (EU) was formed, and environmental policy was elevated to a core EU competency. The development of air quality directives in the EU was aligned with the methodology in the Air Convention.[11]

WMO has been an important organisation for the Air Convention and particularly EMEP already since EMEP's start in 1977. WMO provided the UN platform by which East and West required to collaborate. As a global organisation, WMO could demonstrate how to address transboundary air pollution in other parts of the world. Nordforsk and later AMG followed up the global agenda setting that started with the UN Stockholm conference in 1972 by developing Nordic collaboration which also benefited the European and global problem solving.

Towards the end of the 1980s climate change took over the global awareness agenda from air pollution as such.[12] The severity and scope of climate change has since then had a profound impact on environmental and earth system research and policy making, including air pollution regionally and globally. In Table 1, a summary is given of how we think the factors discussed above for the Air Convention function in IPCC/UNFCCC.

From the mid-1980s other countries and organisations in addition to the Nordic ones realised that a pan-European approach and responsibility would be helpful and EMEP and the ICPs facilitated such involvement. The RAINS model developed at IIASA supported the pan-European perspective. New numerical models for atmospheric pollutants were developed and applied particularly by German, British and Dutch research groups, and challenged and complemented the work at MSC-W in EMEP. An important initiative at this time that partly challenged the EMEP structure but also made important scientific contributions to EMEP was the Eurotrac programme, which run between 1988 and 2003. Eurotrac was initiated by scientists mainly from academia and was led by Germany.[13] Eurotrac was organised under Eureka[14]. The project formed a

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[11] In the 1980s EU directive for limiting emissions from industries and power plants was put in place. In 1996 the Air Quality Framework Directive (96/62/EC) established how to assess and manage air quality in the EU.

[12] The World Climate Research Programme (WCRP), established 1980, is the main force in international climate research and assessment, sponsored by WMO and International Council of Scientific Unions (ICSU, now International Science Council ISC), from 1993 also by Intergovernmental Oceanographic Commission (IOC) of UNESCO. IPCC was created jointly 1988 by WMO and United Nations Environment Programme (UNEP) to provide scientific assessments on climate change, the first by Houghton et al., 1990.

[13] Fraunhofer Institute for Environmental Research in Garmisch Partenkirchen was secretariat.

[14] Eureka: Agreed 1985 between 18 countries and the European Commission to foster competitiveness and market integration and to encourage cooperation in research and development.

significant framework for European atmospheric chemistry research in support of policy. It arose partly from the assumption that the science developed and applied by EMEP was not state-of-the-art. During its time it was one of the largest coordinated programmes in environmental research and involved hundreds of scientists. The project was successful in developing atmospheric and air pollution-related research and fostered a cadre of highly skilled international scientists. It was also important for the understanding of air pollution mechanisms and processes. At the end of both the first and the second phase of Eurotrac, key scientific findings of importance for policy were communicated (Borrell et al., 1997, Midgley et al., 2003). The programme was only to a limited extent recognised by policymakers, who found that the already existing set-up under the Air Convention (EMEP, WGE with their scientific bodies) functioned well for the integration of scientific knowledge into policy development. Many of the scientists that contributed to EMEP were also involved in Eurotrac, and the results became important input to EMEP, including improved atmospheric chemistry models and parameterisations of gas and particle exchange between the atmosphere and ecosystems.

Lessons from the second phase

There was a level playing field among the scientists who supported the Air Convention. EMEP with its centres and WGE with the ICPs provided a suitable framework characterised by mutual trust, respect and interest centred around the scientific issues and mission of the Air Convention. Of particular importance was the collaboration between MSCW, CCC and MSCE, where annual meetings in Oslo or Moscow brought the researchers together in an informal scientific setting with exchange of ideas, results, problems and opportunities in an atmosphere of free thinking and curiosity. CCC scientists travelled widely to national laboratories that measured and analysed the EMEP pollutants. Professional and personal contacts were established in most EMEP countries, not least in East Europe. This experience was part of the foundation of the more formal sessions in the Air Convention bodies in Geneva. Unofficial meetings could be held outside of the official venue with "open and friendly" discussions that could overcome the political difficulties raised in the official circuit. Science diplomacy was also played out in series of workshops and other scientific meetings, e.g. when the critical load concept was introduced, from the end of 1980s and onwards involving scientists from most of the UNECE countries.

In the early phases of Nordic collaboration, a strong ("thick") relationship was established between research and practise. Pollution sources, dispersion, deposition, exposure, effects and economic impacts were linked together in integrated assessment modelling in a transparent way. The trust and integration achieved secured major international agreements, including the GP, a cornerstone of the Air Convention. In contrast, environmental ministries and agencies are today strong organisations, governed by comprehensive rules and regulations and in-house expertise. The open interaction between governmental structures and the science community is today replaced and governed by *New Public Management*. This has changed the science sector into being more of a provider in a seller-customer relationship. The opportunity, legitimacy and encouragement for the science community to engage with the domain of practise i.e. in societal applications are weakened and have made the domain of research more distant and a "self-marketing" attitude has emerged in its societal involvement. Air pollution regulations in the EU are being developed within a similar detached relationship between the domain of research and the domain of practise. Fewer scientists are intimately engaged as providers of knowledge in the development of new ideas and policies. The distance between basic science and policy formulation has increased (Figure 3 in the paper). One question, worth asking is therefore if the sharing of ideas and results, which in our experience traditionally has been quite generous in the Air Convention, is shrinking?

In the literature about making sense of science in policy and politics, Roger A Pielke Jr. (2007) introduced the concept of the "Honest Broker" in researcher-policy maker interactions. "The Honest Broker (or sometimes named as Science Broker) actively engages with policy makers and societal sectors to solve particular problems by developing policy alternatives." This role differs from others Pielke identifies: The issue advocate, "who uses research results to influence a political agenda, thus narrowing the scope of choices", the science arbiter, who "answers questions of policy-makers, but without providing further assistance (e.g. on whether the question is the right one)", and the pure scientist who "communicates facts without paying any attention to the political context". We argue that a clue to the success of Nordforsk, OECD and later the Air Convention-policy work is that key persons acted as "Honest brokers". Professional ethics also play a critical role in the science-policy interface. Ethics can be "thin" or "thick".[15] "Thick" ethics is both world-guided and action-guiding, whereas "thin" ethics is action-guiding but "do not display world-guidedness". Bolin's (1999) description[16] of Carl-Gustaf Rossby is an example of "thick" ethics. The modern scientist with the eyes on metrics like the H-index[17] to meet the score demands defined in a New Public Management regime, is pushed towards "thin" professional ethics. The science-policy interface thrives when the professional ethics is "thick". It is an open question to discuss

[15] Williams,1985 p. 152 in Internet Encyclopedia of Philosophy https://iep.utm.edu/thick-co/ (accessed 2nd March 2025).

[16] See the section *A socially conscious academic research base* in the supplement to The building of science and policy platforms, late 1960s - 1979.

[17] H-index: a measure of the productivity and citation impact of publications, initially used for an individual scientist.

if "the thinning" of researcher ethics during the last decades has reduced the societal benefit of research?

Even if the development of the interplay between science and policy occurred without any knowledge and refection on the theoretical aspects put forward by Schön, Pielke and others, considering the process from a knowledge theory perspective offers important insights when looking at new environmental and societal problems. Solutions of complex problems seldom occur only by science without policy interaction and policy development needs to rely on independent scientists.

Table 1

Categories that contributed to the development of the Air Convention during the three periods discussed in this paper. For comparison the situation in IPCC/UNFCCC after 2000 for the same categories is suggested in the right-hand column.

Category	**Air Convention 1970-1985**	**Air Convention 1985-2000**	**Air Convention after 2000**	**IPCC/UNFCCC Climate after 2000**
Public awareness (low/high)	High	High	Low	High
Political externalities (weak/strong)	Strong	Strong	Weak	Strong
Academic research group(s) (distant/involved)	Involved	Involved	Less involved	Very involved
Research institute sector/applied research sector (distant/involved)	Involved	Involved	Involved	Very involved
Policy makers in ministries (distant/involved)	Involved	Involved	Less involved	Very involved
Government ministries (uncommitted/committed)	Committed	Committed	Less committed	Committed
Research ethics (thick/thin)	Thick	Thick	Thinner	Both thin and thick
Organisational openness (high/low)	High	High	Medium	Medium
Pilot countries with large credibility (few/many)	Few (Nordic)	Several (Nordic, NW Europe)	Few	Many

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Acronyms, Supplement to The second phase of the Air Convention 1985-2000

AMG Air Management Group (Nordforsk)
CCC Chemical Coordinating Centre (EMEP, NILU)
CCE Coordination Centre for Effects (Air Convention, RIVM, the Netherlands)
CL Critical Load (Air Convention)
EMEP European Monitoring and Evaluation Programme (Protocol to the Air Convention)
ICP International Co-operative Programme (Air Convention)
ICSU International Council of Scientific Unions (now International Science Council ISC)
IAM Integrated Assessment Modelling
IIASA International Institute for Applied Systems Analysis at Laxenburg in Austria
IOC Intergovernmental Oceanographic Commission (UNESCO)
IPCC Intergovernmental Panel on Climate Change (UNFCCC)
MSC-E Meteorological Synthesizing Centre East in Moscow, recently moved to Ljubljana (EMEP)
MSC-W Meteorological Synthesizing Centre West at Norwegian Meteorological Institute (EMEP)
NITREX Nitrogen Saturation Experiments (EU)
NPM New Public Management

RAINS The Regional Air Pollution Information and Simulation Model developed (IIASA)
RIVM National Institute for Public Health and the Environment
UNEP United Nations Environment Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
UNFCCC United Nations Framework Convention for Climate Change
WCRP World Climate Research Programme (WMO, IOC-UNESCO, ICSU now ISC)
WGE Working Group on Effects (Air Convention)
WCRP World Climate Research Programme (WMO, ICSU/ISC, UNESCO)
WMO World Meteorological Organisation

Supplement to The third phase – broadening the scope of international air pollution science and policy

Saltsjöbaden workshops

The broadening of the scope to issues outside the main topics in the Gothenburg protocol included i.a. nitrogen and SLCFs. For nitrogen the issues are integrated in a broader perspective through the Air Convention's subsidiary body Task Force on Reactive Nitrogen (TFRN) established in 2007. TFRN is also a part of European and global reactive nitrogen research and policy making (International Nitrogen Initiative INI, EU, UNFCCC, Convention on Biodiversity (CBD)), a field of large significance for global food production, biodiversity, and water quality (Galloway et al., 2008).

SLCFs were brought up as a topic of concern for AMG and the Air Convention at the third Saltsjöbaden meeting in 2007. The recommendation from this workshop formed a basis for several workshops and other initiatives by AMG. A workshop was held in Stockholm in 2008 organised by Stockholm Environment Institute, and SLFCs became a key topic at the 4th Saltsjöbaden in 2009. These workshops informed policy e.g. at a side event at the 15th Conference of the Parties to UNFCCC (COP-15) in Copenhagen in collaboration with the United States. SLCFs were also discussed among Nordic scientists and policy experts at a workshop in Denmark in 2012 (Møller, 2012), and at Saltsjöbaden V (Grennfelt et al., 2013). Later AMG supported projects to improve emission data on black carbon.

The SLCFs are of joint interest to the Nordic countries as they contribute to Arctic temperature amplification (AMAP, 2021). Aerosol pollution and the Arctic climate response was studied based on the Norwegian climate model (NorESM) in a collaboration between Norwegian and Swedish scientists (Navarro et al., 2016), showing that the response in temperature, precipitation and sea ice to the European aerosol load could have been significant in the European Arctic, particularly during the decades of very high precursor emissions in Europe. For example, the increase in temperature in the Arctic (70-90° N) 1980-2005 was calculated to be 63 % larger and the global temperature increase 17 % larger when the European SO_2 emissions followed their actual decreasing pathway 1980-2005, compared to a calculation where the European SO_2 emissions were kept constant at their 1980-level. Results of these activities have been presented and incorporated in discussions and reports from the 6th and 7th Saltsjöbaden workshops (Engleryd and Grennfelt, 2018, Engleryd et al., 2023).

AMG has had as a priority to support further development of policies under the Convention, including the GP amendment in 2012 and the second amendment expected to be finalised in 2026. As a start of the second amendment AMG contributed to an assessment report (Maas and Grennfelt, 2016). The protocol amendments have covered the pollutants already in the original GP, as well as specific reductions of black carbon and recently also methane.[18] An example of AMG support is the assessment and analysis of all EMEP observations from its start in 1977 to 2000 prepared as a collaboration between Sweden and Norway (Lövblad et al., 2004).

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Acronyms, Supplement to The third phase – broadening the scope of international air pollution science and policy

AMG Air Management Group (Nordforsk)
CBD Convention on Biodiversity (UN)
CCC Chemical Coordinating Centre (EMEP, NILU)
COP Conference of the Parties (UNFCCC)
EMEP European Monitoring and Evaluation Programme (Protocol to the Air Convention)
GP Göteborg Protocol (Air Convention)
HELCOM Baltic Marine Environment Protection Commission
HTAP the Task Force on Hemispheric Transport of Air Pollution (Air Convention)
ICP International Co-operative Programme (Air Convention)
INI International Nitrogen Initiative
MSC-E Meteorological Synthesizing Centre East in Moscow, recently moved to Ljubljana (EMEP)
MSC-W Meteorological Synthesizing Centre West at Norwegian Meteorological Institute (EMEP)
NorESM Norwegian Earth System Model
SLCF Short Lived Climate Forcers
TFRN Task Force on Reactive Nitrogen (Air Convention)
UNFCCC United Nations Framework Convention for Climate Change
WGE Working Group on Effects (Air Convention)

Supplement to Nordic collaboration as a force in future environmental risk reduction

Nordic collaboration as a force in future environmental risk reduction

The question is how can regional leadership such as shown by the Nordic countries in the Air Convention, develop to lower the societal risks of regional and global air pollution?

A line of action where the Nordic countries are particularly well positioned is to strengthen the interaction between operational services ("domain of practice") and research and innovation in environmental risk reduction ("domain of research"). In operational services high spatial resolution and high frequency sampling take place systematically and continuously in the probability space for the forecast or reanalysis evolution of weather, ocean and pollution parameters, done by combining the information from the observations and the representation of earth system processes in numerical models. A wealth of advanced information is thus created of high relevance for environmental research and policy development.

The Copernicus Climate Change Service (C3S) and Copernicus Atmospheric Monitoring Service (CAMS) for atmospheric composition depend on reanalyses (https://climate.copernicus.eu/, https://www.ecmwf.int/en/newsletter/163/news/ai-and-machine-learning-ecmwf). The recent breakthrough using artificial intelligence and machine learning (AI/ML) for operational weather forecasting is based on model training using the ECMWF data, see e.g. Price et al., 2025. There are other services for marine waters, the land surface, and security and emergency events.[19]

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Acronyms, Supplement to Nordic collaboration as a force in future environmental risk reduction

AI Artificial Intelligence
C3S Copernicus Climate Change Service (EU)
CAMS Copernicus Atmospheric Monitoring Service (EU)
ML Machine Learning

[19] Copernicus.eu/en