# MULTI-JURISDICTIONAL AIR POLLUTION ASSESSMENT: A COMPARISON OF THE EASTERN UNITED STATES AND WESTERN EUROPE

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The Global Environmental Assessment (GEA) project is a collaborative team study of global environmental assessment as a link between science and policy. The Team is based at Harvard University. The project has two principal objectives. The first is to develop a more realistic and synoptic model of the actual relationships among science, assessment, and management in social responses to global change, and to use that model to understand, critique, and improve current practice of assessment as a bridge between science and policy making. The second is to elucidate a strategy of adaptive assessment and policy for global environmental problems, along with the methods and institutions to implement such a strategy in the real world.

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Publication abstracts of the GEA Project can be found on the GEA Web Page at http://environment.harvard.edu/gea. Further information on the Global Environmental Assessment project can be obtained from the Project Associate Director, Nancy Dickson, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138, telephone (617) 496-9469, telefax (617) 495-8963, Email nancy_dickson@harvard.edu.

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# FOREWORD

This paper was written as part of the Global Environmental Assessment Project, a collaborative, interdisciplinary effort to explore how assessment activities can better link scientific understanding with effective action on issues arising in the context of global environmental change. The Project seeks to understand the special problems, challenges and opportunities that arise in efforts to develop common scientific assessments that are relevant and credible across multiple national circumstances and political cultures. It takes a long-term perspective focused on the interactions of science, assessment and management over periods of a decade or more, rather than concentrating on specific studies or negotiating sessions. Global environmental change is viewed broadly to include not only climate and other atmospheric issues, but also transboundary movements of organisms and chemical toxins.

The Project seeks to achieve progress towards three goals: deepening the critical understanding of the relationships among research, assessment and management in the global environmental arena; enhancing the communication among scholars and practitioners of global environmental assessments; and illuminating the contemporary choices facing the designers of global environmental assessments. It pursues these goals through a three-pronged strategy of competitively awarded fellowships that bring advanced doctoral and post-doctoral students to Harvard; an interdisciplinary training and research program involving faculty and fellows; and annual meetings bringing together scholars and practitioners of assessment.

The core of the Project is its Research Fellows. Fellows spend the year working with one another and project faculty as a Research Group exploring histories, processes and effects of global environmental assessment. Academic year 1997-8 focused specifically on the past three decades of climate change, long-range transport and tropospheric air pollution assessment experience with special attention to Europe and North America. These papers look across a range of particular assessments to examine variation and changes in what has been assessed, explore assessment as a part of a broader pattern of communication, and focus on the dynamics of assessment. The contributions these papers provide has been fundamental to the development of the GEA venture. I look forward to seeing revised versions published in appropriate journals.

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Of course, all opinions expressed herein are the authors' as is the responsibility for remaining errors.

# ABSTRACT

The assessment of tropospheric air pollution has emerged out of a long history of scientific and public concern about air pollution and action to remediate it in both the United States and Europe. While the pollutants of greatest interest have changed over time, much of the current focus is on emissions which lead to tropospheric ozone (i.e. smog) or cause acidification of soil and groundwaters. This paper focuses on the co-evolution of science and policy of ozone over the last 30 years, looking especially at the emergence of the transboundary characteristics of the problem (i.e. the regionality of ozone). The paper highlights differences in the way the regionality of ozone has been understood by experts and reflected in policies in the U.S. and in Europe. In the U.S. ozone was initially framed as an essentially a local problem, whereas in Europe the regionality of ozone has been part of the scientific and policy debate from the start.

In addition to differences in the science, we also see important differences in the politics of ozone between the U.S. and Europe, most importantly the character of and the relationships between the jurisdictions over whose border ozone is transported. In the U.S. these are boundaries between sub-national jurisdictions in a strong federal system which has recently begun to move towards decentralization in relevant areas; while in Europe they are between sovereign nations in an international system which has taken some initial steps towards centralization. Thus a comparative analysis of ozone assessment these two systems is developed, using a theoretical approach suitable for understanding joint actions by semi-autonomous agents taken from the field of International Relations.

The paper focuses on several detailed examples. For the U.S. the focus is on the Ozone Transport Assessment Group (OTAG), a brief but intensive assessment process that operated from 1995 to 1997. OTAG was the product of a crisis in air management in late 1994 and broke new ground in U.S. environmental policy in several ways, most notably by moving the initiative for regional assessment to the states and by it's unprecedented use of Internet technologies in an assessment process. For Europe, the focus is on the Convention on the Long-Range Transport of Air Pollution and its Protocols (LRTAP) plus the relevant activities of the European Union (EU).

A companion paper deals with the technical component of these issues in more detail. Appendix A is a chronology of the co-evolution of science and policy on tropospheric pollution over the last 150 years.

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## ACRONYM LIST

| | |
|---|---|
| ALAPCO | Association of Local Air Pollution Control Officers |
| AMRG | Air Management Research Group |
| AQIRP | Air Quality Improvement Research Program |
| AQA | Air Quality Analysis (Workgroup within OTAG) |
| BAT | Best Available Technology |
| CAA | Clean Air Act |
| CAPTIA | Center for Air Pollution Trends, Information, and Analysis |
| CARB | California Air Resources Board |
| CIEMAT | Research Center for Energy, Environment, and Technology (Spain) |
| CO | Carbon Monoxide |
| CO2 | Carbon Dioxide |
| DNMI | Norwegian Meteorological Institute |
| DOE | US Department of Energy |
| DG | Directorate General (European Union) |
| EC | European Community |
| ECAS | Euro-Citizen Action Service |
| ECOS | Environmental Council of the States |
| EEA | European Environmental Agency |
| EEB | European Environmental Bureau |
| EEC | European Economic Community |
| EIS | Environmental Impact Statement |
| EKMA | Empirical Kinetic Modeling Approach |
| EMEP | European Monitoring and Evaluation Program |
| EPA | US Environmental Protection Agency |
| EU | European Union |
| EUMAC | European Modeling of Atmospheric Constituents |
| EUROTRAC | EURopean experiment on the TRAnsport and transformation of environmentally relevant trace Constituents in the troposphere over Europe |
| FERC | Federal Energy Regulatory Commission (US) |
| GLOREAM | Global Modeling Of Atmospheric Constituents |

| | |
|---|---|
| IIASA | International Institute for Applied Systems Analysis |
| I/M | Inspection and Maintenance |
| IPPC | Integrated Pollution Prevention and Control Directive |
| LADCO | Lake Michigan Air Directors Consortium |
| LAER | lowest achievable emissions rate |
| LMOS | Lake Michigan Ozone Study |
| LRTAP | Convention on Long-Range Transport of Air Pollution |
| MARAMA | Mid-Atlantic Regional Air Management Association |
| MMBtu | Millions of British Thermal Units |
| MSC - E | Meteorological Synthesizing Cener - East |
| MSC - W | Meteorological Synthesizing Cener - West |
| NAAQS | National Ambient Air Quality Standards |
| NAPAP | National Acid Precipitation Assessment Program |
| NARSTO | North American Regional Strategy for Tropospheric Ozone |
| NCAR | National Center for Atmospheric Research |
| NESCAUM | Northeast States for Coordinated Air Use Management |
| NGO | Non-Governmental Organization |
| NILU | Norwegian Institute for Air Pollution Research |
| NMHC | Non-Methane Hydrocarbon |
| NLEV | National Low-Emission Vehicle Program |
| NOAA | National Oceanic and Atmospheric Administration |
| NOx | nitrogen oxides |
| NOx MOU | Ozone Transport Commission Memorandum of Understanding on the Control of NOx Emissions |
| NRC | National Research Council |
| NSPS | New Source Performance Standards |
| O3 | Ozone |
| OAQPS | Office of Air Quality Planning and Standards |
| OECD | Organization for Economic Cooperation and Development |
| OJ | Official Journal of the European Union |
| OMS | Office of Mobile Sources |
| OTAG | Ozone Transport Assessment Group |

| | |
|---|---|
| OTC | Ozone Transport Commission |
| OTR | Ozone Transport Region |
| PAMS | Photochemical Analysis Monitoring System |
| PHOXA | Dutch/German Photochemical Oxidants and Acid Deposition Study |
| QVM | Qualified Majority Voting |
| RADM | Regional Acid Deposition Model |
| RACT | Reasonably Available Control Technology |
| RAINS | Regional Acidification INformation and Simulation model |
| RFG | ReFormulated Gasoline |
| RFP | Reasonable Further Progress |
| RIVM | Dutch National Institute of Public Health and Environmental Protection |
| ROG | Reactive Organic Gases |
| ROM | Regional Oxidant Modeling (or model) |
| SAI | Systems Applications International, Inc. |
| SAPRC | Statewide Air Pollution Research Center (CA) |
| SCR | selective catalytic reduction |
| SEA | Single European Act |
| SIP | State Implementation Plan |
| SNCR | selective non-catalytic reduction |
| SO2 | sulfur dioxide |
| SOS | Southern Oxidants Study |
| STAPPA | State and Territorial Air Pollution Program Administrators |
| SUNY | State University of New York |
| TAP | Transboundary Air Pollution project (IIASA) |
| TOG | total organic gas |
| TVA | Tennessee Valley Authority |
| UAM- # | Urban Airshed Model, Version (#) |
| UARG | Utility Air Regulatory Group |
| UK | United Kingdom |
| UN/ECE | United Nations Economic Commission for Europe |

| | |
|---|---|
| US | United States |
| VMT | vehicle miles traveled |
| VOCs | volatile organic compounds |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |

# 4. Discussion

## *4.1. The US experience*

As an assessment process, OTAG served mainly as a means of improving analytical capacity in the states, increasing the number and type of people who understand the regionality of the ozone problem, and delaying action until the uncertainties of the 1994 Republican Revolution had been largely resolved. Importantly, OTAG did not serve to develop any scientific insights (with possible the exception of some work by CAPITA, which may have occurred anyway), nor did it serve (or could it have done so) to resolve disputes about appropriate ozone control strategies. OTAG improved the capacity in states by providing an opportunity for technicians from state agencies to work with their peers in Workgroups and thereby learn about the ozone problem from a larger perspective than that available in their own states. It also provided resources to some state agencies so that they could upgrade their computers and run UAM-V, as well as providing funds for EPA to create its own modeling center at its facility in Research Triangle Park, North Carolina. This was an investment of approximately $700,000 which was necessary to give the EPA the capability to perform the analyses demanded during and after the OTAG process.[62] Further, the development of emissions inventory protocols for VOCs and NOx and the state-by-state emissions inventories represents a significant analytical advance.

It is important to note that there has been (and probably will be) very little in terms of a report produced by the OTAG process. The principal document is a 59-page executive summary which has received limited distribution. The final report is available on the Internet (http://www.epa.gov/ttn/otag/) but will probably never be published in a paper version. A CD-ROM version was originally planned, but this may not come to fruition. Further, most of the analysis conducted during the OTAG process will probably not be published in the literature. OTAG mattered, yet it barely exists in the published record, giving added force to the arguments that the process of assessment can be more important than their products.

In terms of the increase in understanding of the regionality of ozone it is largely the political leaders of the state-level environmental agencies (i.e. the Commissioners) whose understanding increased. At the beginning of OTAG, the research community (which did not participate, for the most part) understood that tropospheric ozone had both local and regional components which would need to be addressed in order to: 1) attain the NAAQS across the country, 2) make progress towards the NAAQS, or 3) to complete appropriate analysis and assessment of alternative strategies. They also understood that NOx control would be needed in at least some large parts of the OTAG region. Most of the staff of OAQPS largely understood this problem as well, having learned it from the Regional Oxidant Model (ROM) runs of the mid- and late-1980s. While many of the technically-trained staff in the state environmental agencies who were charged with air quality understood the general idea of regionality, it appears that few of them were at that time familiar with the magnitude of the issue from a national perspective.

Indeed, prior to OTAG it can be said that there were at least three perspectives on the regionality of ozone: 1) national (held by EPA staff at OAQPS and many atmospheric scientists), 2) regional (held by participants in LADCO, OTC, SESARM, CARB, and so forth), and state-level. And there was significant variability in understanding from state to state and those states which had greater incoming ozone and precursors probably had a greater appreciation of the problem since their own situation would tend to emphasize the importance of transport. Overall,

the technicians learned more about the scope of the problem, while the Commissioners learned a great deal about the character of the problem, including its scope.

Before OTAG, non-experts, such as Commissioners (and Governors even more so) generally had no real understanding of the regionality of ozone, the outmoded concept of ozone as a "local pollutant" continuing to dominate the popular view of the environmental system despite at least 20 years of scientific assessment pointing to the contrary. The modeling exercises and the dramatic graphical animations which were used during the OTAG meetings to communicate the results were able to challenge and alter these outdated mental models of the problem in a way that reports and testimony probably could not have. In this sense, OTAG could be thought of as a highly successful educational process for both technically-trained experts and political leaders in that it ended up changing the mental models of both experts and decision-makers in many state agencies, some firms, and some federal agencies. It also influenced how they viewed their own interests.

A related issue is the dramatic improvement in the protocol for creating NOx and VOC emissions inventories and the completion of detailed inventories for all of the OTAG states for 1990. These inventories are important because they represent an extension of best practices, they are an important update of the prior data, which dated from 1985 and was part of the NAPAP study. They also provide a relatively consistent data set across all the OTAG states, coordinated by one technical team (from Alpine Geophysics), something which was sorely needed for region-wide analysis and which had not existed before. Major deficiencies in emissions inventories still exist, and OTAG did not contribute significantly to the improvement of state inventories for those states which have historically been interested in ozone, but OTAG increase the quality of practice in states which had previously lagged behind.

As luck would have it, the states began to realize the problems associated with the November 1994 SIPs while the 1994 Republican Revolution was brewing. By the beginning of 1995, the Republican team that had written the *Contract with America* had gained control of both houses of Congress, and many Governor's mansions and statehouses across the country had been similarly radicalized.[63] Strong action by the EPA to remedy the failure of virtually any state to submit a satisfactory SIP would have risked reopening the Clean Air Act in a hostile Congress, to, as some saw it, potentially disastrous consequences. In the name (if not the spirit) of returning power to the states, therefore, the EPA and environmentalists (particularly NRDC) decided to hold off on action (or on lawsuits, in the case of NRDC) and let the states attempt to resolve the problem of interstate transport for themselves. Perhaps unsurprisingly, OTAG fell well short of this goal, the actual outcome (especially the content of the Executive Summary) is a broad political compromise that contains language which any stakeholder can point to as supporting its position. However, a voluntary assessment process such as OTAG cannot be expected to resolve difficult policy issues; the traditional mechanisms of addressing this sort of problem in the political sphere (i.e. the legislative and judicial processes) remain in place. However, OTAG has clearly changed the context in which those traditional means now operate on the ozone issue, highlighting the crucial role which assessments have in affecting the context of decision-making. (In this sense it is much like the LRTAP process.)

### *4.2. The European experience*

As an assessment process, the LRTAP effort to manage ozone is tightly bound up in its efforts to control acidification, and thus has been driven largely by Northern Western European interests, particularly the interests of Germany, Sweden, Norway, the United Kingdom and the

Netherlands. As in other studies of LRTAP's role in the control of acidification, this research shows that the Protocols tend to only affirm at the international level, policies which are essentially determined at the domestic level within each nation. The LRTAP agreements to control ozone have, to date, never required any nation to pursue any costly environmental control strategies which were not either already in place or planned, or which were expected to be achieved due to endogenous changes in the energy sector (i.e. the dash for gas).

Despite this general conclusion, LRTAP has had important impacts on European environmental policy for a number of reasons. First, the WorkGroups and Task Forces of LRTAP have been important venues for international scientific coordination and capacity development (see Figure 3). This is clearly true in EMEP, the Working Group on Effects, and the several International Coordination Centers which together have changed the understanding of the environmental system and perceptions of the acid rain and ozone policy problems. However, the US and European assessment processes have been quite separate, despite several attempts by different researchers (especially Cowling, Chang, Derwent) to bridge the gaps, especially through the EPA/Germany exchange program and the NAPAP review. LRTAP is meant to address all forms of air pollution "starting with sulfur dioxide and with possible extension to other pollutants", and thus has served as an institution by which new transboundary pollutants have been assessed and policy on them developed, including tropospheric ozone, heavy metals, and persistent organic pollutants.

The entry of ozone into LRTAP's area of concern is an illustrating case. Tropospheric ozone followed acidification as an effect of concern, and the tools used for the assessment of ozone and the individuals performing the assessments are virtually identical to the tools and the individuals working on acidification. Thus, the EMEP/RAINS modeling system operated by DNMI, the IIASA TAP project, NILU, and RIVM has been the assessment tool for tropospheric ozone as well, operated by the same team. This approach has been questioned from a scientific point of view because the low-resolution, annualized, linear analysis of the EMEP/RAINS modeling system is not well suited to representing the fine-grained, episodic, and highly non-linear character of ozone formation and accumulation. However, this discrepancy may not be terribly important to the leading nations such as Sweden and Finland, which have little, if any, ozone problem. For them the focus on ozone simply provides an additional argument for the decrease of NOx emissions, which are now a major source of acidification and thus a high priority for nations like Sweden and Germany. Indeed, the initial cuts in NOx emissions in Europe were spurred by an interest in reducing acidification effects, not ozone concentrations. Further, the initial motivation for ozone control was Waldsterben in Germany. By the mid-1980s it was clear that acidification alone could not account for the damage to German forests and it was discovered that photoxidants were also damaging forests. This contrasts sharply with the US perspective, where human health has always been the primary issue and damage to vegetation has never become an important issue in policy, despite being recognized first.

At the same time, it was recognized that acidification-based NOx control would tend exacerbate ozone formation in much of Europe because most of the continent is VOC-sensitive. The freeze in NOx emissions called for in the First NOx protocol could have actually made the ozone problem *worse* over time if VOC emissions continued to increase (cuts in NOx could cause a widespread but probably small increase in ozone concentrations). Thus, many nations, especially Germany, are interested in the assessment of ozone control options, and particularly in the impacts of decreases in NOx emissions. This recognition of the two aspects of the problem (i.e. that NOx leads to both acidification and ozone) is indicative of the more comprehensive

view of the LRTAP assessment process in understanding the multiple-pollutant, multiple-effects (sometimes multiple-receptor) concept. For NOx control, this had meant an emphasis on the role of NOx in the eutrophication of waterways.

In contrast to the UN-ECE LRTAP apparatus, the portions of DGXI associated with ozone control and the related Workgroups and institutions have existed for only a short period of time. To date, the EU Commission has busied itself more with writing regulations than performing assessments, and the nations pushing environmental regulations in the EU are identical to the ones pushing for tougher LRTAP agreements: Germany, Denmark, the Netherlands, and Sweden, plus Austria and Finland. Further, the people performing the assessments which are conducted for the EU, and the government officials on the EU Workgroups are generally identical to the people performing similar roles in the LRTAP process. Indeed, the assessments of ozone control performed for the EU are often exactly identical to those conducted under the LRTAP Convention, albeit with a different name on the cover. In some cases differences exist because the EU sometimes specifies different scenarios and the nations in LRTAP are different from those in the EU, but the vast majority of assumptions and analytic techniques remain constant. Thus, the EU Directives being developed contain differentiated emissions targets for each country, just as the second-generation LRTAP Protocols do.

Assessments have clearly not been conducted for all EU legislation. In particular, little or no assessment of environmental impacts were conducted to support the mobile source (vehicle and fuels) legislation of the 1970s and 1980s. There is some indication that the emphasis on and character of European mobile source regulation for the control is a result of policies adopted in the United States. These, in turn rested significantly on the scientific advances and control strategies for the ozone problem in Southern California from the period 1950-75. This suggests that the scientific assessments and technological options were simply transplanted to the Eastern United States and Western Europe without sufficient analysis of whether they were appropriate. Indeed there are some cases where the adoption of these standards appreciably worsened the ozone problem.[64] In this case the concept of assessment hardly mattered at all, but what seems to have mattered are economic issues (essentially economies of scale arguments for large, uniform markets) in the vehicle and fuel markets in Europe. Until very recently (1997) the RAINS model holds mobile source sector emissions constant so even assessments of the economic impacts of mobile source regulation are not feasible (thus limiting the extent of claims of "optimal" cost-effectiveness). Other assessment activities (such as the Auto/Oil studies) have all been conducted in the 1990s. This is all the more amazing for the fact that the costs of this sort of regulation have been very significant and are thought by some to have contributed significantly to the difficulties of some European automakers. Thus it is not surprising to see that one of the principal mechanisms by which the EU adopted the standards that it is currently phasing in as a strong push by Germany to create a European market that was similar in emissions requirements to the profitable US export market . Of course, the US auto emissions regime (and in particular the focus on VOC emission cuts) had been largely transplanted from California along with an understanding of the problem based on Californian assessments. Thus, the Californian solution was imported into Europe in the 1970s and 1980s where it may not have been appropriate.

Although the EU is widely decried for its "democratic deficit", it still tends to be more open than the LRTAP process. Environmental NGOs rarely ever participate in the LRTAP negotiations with the exception of a few crucial organizations such as the Swedish Acid Rain NGO Secretariat (which is mostly funded by the Swedish government but not part of it). To be more precise, the Working Groups other advisory bodies to the European Commission tend to be fairly open, but the Commission itself has considerable discretion in crafting proposed

legislation and this process is less open. Further, the actual decision-making process takes place in large part in the (more or less) secret meetings of the Council of Ministers, making it hard to observe what this process is like, and even less to hold any particular government accountable.

Nonetheless, there are still means by which influence can be had, principally by nations supplying National Experts to supplement the Commission staff, and through a new "revolving door" program aimed at hiring NGO members into temporary (3-year) positions. The Commission staff in DGXI tend to be fairly supportive of increased environmental protection (as are most environmental regulators) and these two programs tend to increase this trend. And since the Council generally reflects the interests of the government (although it is impossible to verify this) it may also be possible for interested parties to influence EU environmental policy by influencing their domestic positions. Finally, the European Parliament has been granted growing power over the years, and typical lobbying activities can be used.

Of course, there are significant differences between EU and LRTAP policies in that the former can have the force of law (or something approaching the force of law) and are attached to evolving notions of European governance and citizenship, whereas the latter are not. This changes the character of the assessment processes that for each in that EU assessments are taken much more seriously than LRTAP since there is the possibility that EU legislation could push actual requirements at the national level past the point where purely domestic concerns would place them. This has evolved over the last 30 years; EU legislation initially followed LRTAP Protocols (which themselves were least-common-denominator agreements) in terms of stringency, but recently European Commission proposals have begun to be more stringent than concurrent LRTAP proposals.[65]

The EU Directives on air quality have displayed a move towards a tighter link between assessment and policy in the recent past as the Framework Directive on Air Quality has been put into place and development of the Daughter Directives has begun. The Framework Directive sets up the need for further analysis.

An important distinction between the Ozone Directive (92/72/EEC of Sept. 21 1992, OJ 13.10.92) and the other directives on specific air pollutants (eg. 80/779/EEC on Sulfur Dioxide, 82/884/EEC on lead, and 85/203/EEC on Nitrogen Dioxide) is that the Ozone Directive does *not* specify limit values (i.e. thresholds) for ozone which nations are required to prevent. Rather, warning levels are specified, and nations are required to monitor ozone concentrations, report exceedances of these ambient thresholds to the EU, and inform the public as well. However, the Ozone Daughter directive and the Ozone Strategy (both under consideration currently) vary sharply from this warning approach by specifying target values. This is turning out to be a problematic issue in the negotiations because the technicians conducting the assessments and negotiations appear to realize how difficult achieving these standards might be. Further, since EU Directives are laws binding on national governments, negotiators are very concerned that passage of an EU directive on ozone limit values could make national governments potential targets for lawsuits in domestic court systems. Essentially, since EU Directives count in ways that LRTAP Protocols don't, EU negotiations are much more important and delicate.

This point is driven home by the observation that the amount and intensity of critical analysis of EU-associated (and by definition LRTAP-associated) assessments conducted by industry has risen sharply recently, mostly in response to the EU Acidification Strategy. Similarly, NGO participation in EU activities partially reflects a recognition that EU Directives open up new avenues for pressuring national governments.

# 5. Conclusions

## 5.1. *Understanding assessments*

### 5.1.1. Assessments change who knows what, but not what is known

Recall that by assessments we mean activities which bridge research and action; i.e. activities carried out by technically-trained people and are designed to solve policy problems rather than to answer scientific questions. They are practically-oriented things, often in short, but frequent, bursts, and often done to gain social assent about knowledge.

Thus, assessments can increase the number of people who understand the scientific characterization of the problem and the policy implications thereof. They can build capacity and trust - to some degree. They can legitimate largely pre-made decisions. Most importantly, they can change the context in which hard choices with political content are made.

As defined here, individual assessments like OTAG can but rarely advance the science, but longer programs of ongoing assessment can indeed contribute to research. They also are incapable of resolving serious disputes generated by differing interests, although they can significantly reduce disputes due to differences in technical understanding between different parties. Authoritative decision-making power still resides in traditional arenas - the legislatures, the Executive, and the courts. Finally, assessments tend to be conducted at all times within the bounds of scientific understanding, and most of the time within political bounds as well. But assessments can move political constraints, while they cannot move scientific ones.

## 5.2. *Applying the 3Cs to domestic assessment processes*

Finally, we are left with the question of how to understand multi-jurisdictional assessments within a strong federal system, such as the Ozone Transport Assessment Group which we have seen recently in the United States. There seem to be some rough correspondences between these processes and international environmental regimes, which can be evaluated in terms of building capacity, improving contractual negotiations, and raising official concern. Thus, there may be something useful to be gained in a comparison such as we offer here, perhaps in both directions.

# Appendices

## Appendix A: Chronology of the Evolution of the Science and Policy of Tropospheric Ozone and Acid Rain in North America and Europe Assembled by Alex Farrell and Terry J. Keating

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1840 | Germany | *Boebachtungen über den bei der Elektrolysation des Wassers and dem Ausstromen der gewohnlichen Electrizitat aus spitzen eich entwichelnden geruch.* | Schonbein. First identification of ozone as a chemical compound. |
| 1852 | UK | | Smith publishes the first paper on acid rain: Mem. Lit Phil. Soc. Manchester, Series 2. 1852. 10, 207-217. |
| 1854 | Germany | *Über verschiedene Zustande des Sauerstoffs, liebigs.* | Schonbein. First observations of ozone in the atmosphere. |
| 1856 | UK | *On the constitution and properties of ozone.* | Andrews. First English-language paper on ozone |
| 1869 | US | Pittsburgh ban on beehive coke ovens | Example of early attempt to control smoke - generally ineffective. |
| 1872 | UK | *Air and Rain: The Beginnings of a Chemical Climatology* | Smith. First book on acid rain. |
| 1872 | UK | *Ozone and Antozone* | Fox. First book on ozone. |
| 1876-1910 | France | Ozone measurements at Montsouris, France | |
| 1881 | US | Chicago and Cincinnati pass first municipal smoke and soot control laws | Noted in Portney, *Public Policies for Environmental Protection*. pg 29. In next 30 years some counties did likewise. |
| 1907 | US/Canada | *Georgia vs. Tennessee Copper Co.* | Supreme Court case: States have standing in nuisance cases against neighboring states. |
| 1909 | US/Canada | International Joint Commission formed | |
| 1912 | US | *City Smoke Ordinances and Smoke Abatement* | Samuel B. Flagg. Municipal regulation of smoke in the US is surveyed. 23 of 28 cities with populations > 200,000 have regulations. They all essentially failed. (Bulletin 49. Bureau of Mines. 1912) |
| 1918 | | *Ultraviolet transparency of the lower atmosphere and its relative poverty in ozone.* | Strutt. First to accurately measure ozone in the lower atmosphere, which he did by measuring ozone's absorption of UV light at ground level over a long path. |
| 1927 | US/Canada | IJC called upon to deal with US complaints of SO2 fumigations from a Canadian smelter. | Recommendation for monitoring and emission controls at smelter. Arbitration Commission is set up. Leads to *Trail Smelter* |
| 1930 | UK | *Notes on London and suburban air* | Reynolds (J. Soc. Chem. Ind. 49, 168-172.) |
| 1930 | Belgium | Meuse Valley, air pollution episode leaves 60 dead and thousands ill. | |
| 1938 | US/Canada | Trail Smelter: Arbitrated settlement between US and Canada. | "No state has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another." |
| 1938 | US | SO2 and Dust Sampling stations are set up under the Federal Works Progress Administration | |
| 1940 | US | St. Louis anti-smoke law | First law regulating individual households for smoke control. Low-smoke fuel or equipment was required. |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1941 | US | Pittsburgh smoke-control ordinance | Not enforced against domestic sector until Winter 1947-48. Fight before passage had all the characteristics we have seen since: coal industry jobs, manufacturing interests, mobile vs. stationary sources, regressivity, CBA, popular support, political will |
| 1943 | California | First recognized episodes of smog occur in Los Angeles. | |
| 1945 | California | City of Los Angeles establishes Bureau of Smoke Control. | Part of the Health Department |
| 1945-50 | US | Midwest "dash to gas" | Widespread availability of natural gas in urban areas piped in from mid-continent. Coal price rises & gas convenience induce demand for gas in residential sector. Accelerated in Pittsburgh due to smoke control laws - over half of households switch. |
| 1946 | California | Raymond Tucker, of Washington University and former Smoke Commissioner of the City of St. Louis, recommends that Los Angeles establish a county-wide air pollution control program. | |
| 1947 | California | Los Angeles Air Pollution Control District formed. | |
| 1948 | US | Donora, Pennsylvania, air pollution episode kills 20 people and numerous animals, 6,000 people become ill. | |
| 1950 | US | *Injury to herbaceous plants by smog or air pollution* | Middleton, J. T. Kendrick, J. B. Schwalm, H. W. publish the first paper on ozone damage to plants |
| 1950 | US | More than 100 electric transit systems are replaced with buses in 45 U.S. cities including Los Angeles. | |
| 1951 | US | *Investigation on injury to plants from air pollution in the Los Angeles area* | Haagen-Smit, Darley, et al. Haagen -Smit and coworkers demonstrated the causal relationship between vegetable crop damage and the formation of photochemical pollution in the Los Angeles Basin. |
| 1952 | UK | "Killer Smog" in London blamed for 4,000 deaths. | |
| 1952 | US | *Chemistry and physiology of Los Angeles smog* | Haagen-Smit. Haagen-Smit elucidated the role of NOx and VOCs in the photochemical formation of O3. |
| 1952 | US | Oregon passes first meaningful ordinances combating foul air | Noted in Portney, *Public Policies for Environmental Protection*. pg 29. |
| 1952 | Europe | Treaty of Paris: European Coal and Steel Community | Trade Union designed to reduce tariffs between member nations and thus increase internal trade. Meant to prevent another European war by binding German and French economies. |
| 1954 | US | *Photochemical ozone formation with hydrocarbons and automobile exhaust* | Haagen-Smit and Fox elucidated the role of NOx and VOCs, and hence automobile exhaust, in the photochemical formation of O3. This article reportedly contains some of the first ozone isopleth diagrams. |
| 1955 | US | Air Pollution Control Act | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1955 | California | California establishes the Bureau of Air Sanitation within the state Department of Public Health. The multi-county Bay Area Air Pollution Control District is formed. LAAPCD starts Los Angeles County Motor Vehicle Pollution Control Laboratory. | |
| 1956 | UK | "Killer Smog" in London blamed for 1,000 deaths. | |
| 1956 | US | Interstate Highway Act | Increases highway construction. |
| 1957 | Europe | Treaty of Rome: European Economic Community | 6 nations, came into force 1958, OJ 13.7.67 152 Created European Economic Community (EEC). Strengthened economic ties, reduced internal tariffs. |
| 1959 | California | State legislation calls for the establishment of air quality standards and motor vehicle emission controls. | |
| 1959 | US | Air Pollution Control Act | Extended. |
| 1960 | US | *Organic matter in the atmosphere and its possible relation to petroleum formation* | Went. Went was the first to suggest that biogenic VOC emissions could have a significant effect on atmospheric chemistry. |
| 1960 | California | State establishes Motor Vehicle Pollution Control Board | |
| 1960 | US | Federal Motor Vehicle Act | Requires federal research to address pollution from motor vehicles. |
| 1961 | US | *Photochemistry of Air Pollution* | Leighton. This is a classic text that describes the role of NOx and VOCs in the photochemical formation of O3. |
| 1961 | California | First automotive emission control technology (positive crankcase ventilation) mandated by California, first in the nation. | |
| 1962 | US | Air Pollution Control Act | Act extended. More ambitious federal powers contemplated, but scrapped for research, training, and technical assistance to the states. |
| 1963 | US | Clean Air Act (original) | Permanent federal assistance for air pollution research, continued and increased aid to states, and mechanism for the federal government to assist states where cross-boundary pollution problems arose among them. |
| 1965 | US | *Air Conservation* | AAAS: "There is a time and a place for everything. The time and place to pollute is downwind." Mentions formation of acid mist from bituminous coal burning but unknown global effects. |
| 1965 | US | Clean Air Act Amendments | Directed HEW to set federal emissions standards. |
| 1965 | US | Motor Vehicle Air Pollution Control Act | Permitted Sec'y of Health, Education and Welfare (HEW) to set emissions standards for new vehicles. |
| 1966 | California | California adopts first tailpipe emission standards for hydrocarbons and nitrogen oxides. California Highway Patrol begins random roadside inspections of vehicle emission controls. | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1967 | US | Air Quality Act | More money to states - for planning. Required states to form Air Quality Control Regions. HEW to investigate and publish information about adverse health effects of air pollutants, and identify control methods. (Nat'l Center for Air Pollution Control) |
| 1967 | California | Mulford-Carrell Air Resources Act combines the Motor Vehicle Pollution Control Board and the Bureau of Air Sanitation to form the California Air Resources Board. | |
| 1967-8 | Sweden | Svente Oden publishes on transboundary acidifying pollution | |
| 1968 | Europe | Air Management Research Group: Decisions and conclusions of the 1st Session, Paris, 2-4 October 1968 | OECD. First session of AMRG- 15 member nations and observers from 4 IGOs. Identification of priority problem areas and research needs. GER, ITL, JPN, USA #1 issue: "application of mathematical models for prediction of pollution". |
| 1968 | California | Haagen-Smit is appointed Chairman of CARB by Governor Reagan. Monterey Bay Unified Air Pollution Control District is formed. | |
| 1969 | California | First state Ambient Air Quality Standards are promulgated for TSP, photochemical oxidants, SO2, NO2, and CO. | |
| 1970 | EEC | 70/220/EEC: Motor vehicles | |
| 1970 | US | Clean Air Act (actually Amendments, but the '70 legislation is a big break from previous regs and forms the basis for most of the rest of the | Automobile emissions targeted for 90% reduction by 1975/6: HC(4.1 - 0.41), CO (34.0-3.4), NOx(4.0-0.4). All units g/mi. shown actual 1970 levels and standard. |
| 1971 | US | Svente Oden gives 14 lectures in US on acid rain | |
| 1971 | US | EPA establishes NAAQS for 6 pollutants | |
| 1971 | California | CARB adopts first automobile NOX standards in nation. | |
| 1972 | EEC | 72/306/EEC: Diesel engines | |
| 1972 | Europe | Rodhe and Munne develop first quantitative analysis of long-distance transport of sulfur in Europe. | |
| 1972 | | UN Conference on the Human Environment | Stockholm. Principle 21 is to prevent transboundary air pollution, text taken from *Trail Smelter*. |
| 1972 | US | | Likens publishes on regional distribution of acid precipitation and ecosystem impacts. Indicates that NOx leads to nitric acid, which adds to acidity in Eastern US |
| 1972-80 | Europe | *Acid Precipitation Effects on Forest and Fish* | Norwegian government project (SNSF). Overrein (??) et al. 1980 |
| 1973 | US | OPEC Oil Embargo | |
| 1973 | EEC | Denmark, Ireland, UK accede to the EEC | |
| 1973 | EEC | First European Commission environmental program | |
| 1973 | Germany | *The role of NO and NO2 in the chemistry of the troposphere and stratosphere* | Crutzen. According to Stockwell et. al., this paper was an important milestone in establishing that photochemical production of O3 is a major source of O3 throughout the troposphere, not just in urban areas. |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1973-1974 | Europe | Ottar leads OECD study of acid rain | |
| 1974 | Germany | FRG: Parliament passes Federal Clean Air Act (Bundes Immissionsschutzgesetz, BImSchG) | |
| 1974 | US | *Mathematical modeling of photochemical air pollution - I. Formulation of the model* | Reynolds, Roth, and Seinfeld. This is the first paper on the development of UAM. |
| 1974 | US | *Rural and urban ozone relationships in New York State* | Stasiuk and Coffey. Stasiuk and Coffey found ozone concentrations in the rural community of Glen Falls, NY, to be similar to those measured in New York City. |
| 1975 | EEC | 76/161/EEC Council Decision on a common procedure for setting up and constant updating of an inventory of sources on the environment in the Community | OJ L 031 05.02.76 p.8 |
| 1975 | US | EPA launches a 5-year review of the scientific bases of the NAAQS for all six criteria pollutants | Incorporated into 1977 CAAA |
| 1975 | Europe | Helsinki Agreement at the Conference on Security and Cooperation in Europe | Forms IIASA and indicates that reducing air pollution is a supra-national effort. |
| 1975 | US | US Congressional hearings on acid rain (first) | |
| 1975 | California | 2-way catalysts come into use under CARB's motor vehicle emissions control program. | |
| 1975-6 | | First International Symposium on Acid Precipitation and the Forest Ecosystem | By US Forest Service, at Ohio State |
| 1976 | US | *Formation and transport of secondary air pollutants: Ozone and aerosols in the St. Louis plume* | White, et al. document transport. |
| 1976 | US | | Schofield article in *Ambio* - first on US acid rain. Media coverage |
| 1976 | California | South Coast Air Quality Management District is formed, includes portions of Los Angeles, Orange, Riverside, and San Bernardino Counties. | |
| 1976 | Europe | Volvo introduces 1977 model car billed as "Smog Free" uses first 3-way catalyst. | |
| 1977 | US | Clean Air Act Amendments | CSAC review of NAAQS required |
| 1977 | US | *Combined use of modeling techniques and smog chamber data to derive ozone-precursor relationships* | Dodge. Describes the Empirical Kinetic Modeling Approach (EKMA) -- only EPA-accepted alt. to photochemical grid modeling. Reinforces urban focus of control strategies, describing ozone as formed from downwind transport of emissions from urban core. |
| 1977 | | International Symposium on Sulfur in the Atmosphere | By UNEP and others, at Dubrovnik, YUGOSLAVIA |
| 1977 | Europe | *OECD Programme to Measure Long-Range Transport of Air Pollutants* | Confirms Scandinavian claims against UK |
| 1977 | Europe | UN ECE negotiations begin | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1978 | UK | Elevated ozone levels from natural sources | Derwent, Eggleton, et al. |
| 1978 | Europe | *Long-range transport of tropospheric ozone*, and *Ozone generation over rural areas* | Hov, Hesstvedt, et al., and Isaksen, Hov, et al. "Pioneering studies" that demonstrated that ozone concentrations can build up to > 100 ppb over several days, persisting for several days, allowing for long range transport. (based on NRC, 1991) |
| 1979 | Europe | LRTAP Convention adopted | Entry into force March 1983 |
| 1979 | US | Photochemical Oxidant NAAQS reviewed | Adjusted to refer specifically to ozone |
| 1979 | Europe | *The OECD Programme on Long Range Transport of Air Pollutants, Measurement and Findings, Second Edition* | 11 nations, NILU acted as the Central Coordinating Unit to compile the measurement data, perform modeling and analysis, and prepare the final report. First transfer (i.e. "blame") matrix for pollution in Europe |
| 1980 | California | SCAQMD adopts Rule 1135.1 requiring NOX controls for utilities. | |
| 1980 | Europe | 80/779/EEC: SO2 and Particles | |
| 1980 | US | *Development of an ozone river associated with synoptic scale episodes in the eastern United States.* | Wolff, Lioy. This article coined the phrase "river of ozone" to describe the transport of ozone in the Northeast Corridor. The river concept dominated the understanding of transport in the East until around 1990 and SOS. |
| 1980 | | Third International Conference on Acidification | |
| 1981 | EEC | Greece accedes to the EEC | |
| 1981 | US | NAPAP starts | |
| 1981 | US | *To Breathe Clean Air* | Assessment by the National Commission on Air Quality |
| 1982 | EEC | *82/459/EEC: Council Decision establishing a reciprocal exchange of information and data from networks* | OJ L 210 19.07.82 p.1 |
| 1982 | US | *Development of a second-generation mathematical model for urban air pollution--I. Model formulation* | McRae, Goodwin, Seinfeld present first workable Eulerian model. |
| 1982 | Norway | Stockholm Conference on acidification | |
| 1982 | Germany | Waldsterben | German concerns about "Forest Death" first emerge. Air Pollution |
| 1983 | Europe | LRTAP Convention enters into force | (see 1979 entry) |
| 1983 | US | Hydrocarbon NAAQS revoked | Designed to address ozone. Emissions are still controlled on that basis although no NAAQS exists. |
| 1983 | Europe | RAINS project starts at IIASA | Regional Acidification Information and Simulation model. *The RAINS model of Acidificatio.* Alcamo, Shaw and Hordijk, eds. 1990. Laxenburg: Austria. |
| 1983 | US | *Regional scale (1000km) model of photochemical air pollution, Part 1. Theoretical Foundation.* | Lamb, The development of ROM, the first regional photochemical grid model to provide insights about regional transport. |
| 1984 | US | NAPAP review of competing proposals | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1984 | US | CMU Proposal for NAPAP | "Conceptual Framework for Integrated Assessments of the Acid Deposition Problem." |
| 1984 | US | National Laboratory Proposal for NAPAP | Schindler, Streets, et al. |
| 1984 | Europe | 30% Club Expanded | Ministerial meeting of the Council for Security and Cooperation in Europe on the environment and water pollution. Munich. |
| 1984 | EEC | 84/360/EEC: Council Directive on combating air pollution from industrial plants | OJ L 188 16.07.84 p.20, modified last by OJ L 377 31.12.91 p.48 |
| 1984 | Europe | 30% Club Founded | Sweden calls for 30% cuts in European sulfur emissions at a LRTAP meeting in Ottowa. |
| 1984 | Europe | EMEP Protocol to LRTAP | Entered into force January 1988. |
| 1984 | US | *Acid Rain and Transported Air Pollutants: Implications for Public Policy* | Office of Technology Assessment |
| 1984 | California | California "Smog Check" Vehicle Inspection and Maintenance Program goes into effect. | |
| 1985 | Europe | First Sulfur Protocol (FSP) in LRTAP | Entered into force September 1987 |
| 1985 | EEC | 85/337/EEC - Council Directive on the assessment of the effects of certain public and private projects on the environment | OJ L 175 05.07.85 p. 40 |
| 1985 | EEC | 85/203/EEC: Council Directive on air quality standards for nitrogen dioxide | OJ L 087 27.03.85 p.1, modified last by OJ L 377 31.12.91 p.48. |
| 1985 | US | CO NAAQS review and NO2 NAAQS review | no change in either |
| 1985 | | First World Conference on Acidification | Canada. Held every five years hereafter. |
| 1985 | | IBM PC introduced | Desktop computing begins mature phase. RAINS modelers eventually develop portable version. Moreover, this is the "Big Bang" in computing power growth -- signals beginning of exponential growth at all scales up to and including supercomputers. |
| 1985 | US | *Tropospheric ozone: Seasonal behavior, trends, and anthropogenic influence.* | Logan. Tropospheric ozone concentrations are affected by 1) in situ photochemical formation and destruction and 2) incursions of air from the stratosphere. |
| 1986 | EEC | Single European Act | Focus on single market. Subsidiarity applied specifically to environmental regulations, added articles 130r/s/t, OJ 29.6.87 L169/1 at 11 and 12 |
| 1986 | Europe | 86/277/EEC: Council Decision on EMEP | OJ L 181 04.07.86 p.1 |
| 1986 | US | ADAM completed | Development of an operational level II Acid Deposition Assessment Model by Carnegie Mellon University. |
| 1986 | US | Air Quality Criteria for Ozone and Other Photochemical Oxidants | No official action. (23) EPA-600/8-84-020(a-c)F |
| 1986 | US | *Development of the CBM-X mechanisms for urban and regional AQSMs.* | EPA document on chemical modeling mechanisms. |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1986 | US | *Guideline on Air Quality Models (Revised)* | Made UAM the "recommended model" for urban ozone. |
| 1986 | US | Ozone NAAQS reviewed | No official action |
| 1986 | Europe | Scientific Conference on Acidification | Amsterdam. Organized under LRTAP. |
| 1986 | EEC | Spain and Portugal accede to the EEC | |
| 1987 | EEC | 88/77/EEC: Council Directive on approximation of laws of Member States on emissions of gaseous pollutants from diesel engines used in vehicles. | OJ L 036 28.03.87 p.40, last modified by OJ L 295 25.10.91 p.1 |
| 1987 | Europe | FSP enters into force | |
| 1987 | US | *A three-dimensional Eulerian acid deposition model: Physical concepts and formulation* | Chang, Brost, et al. |
| 1987 | US | *Models and observations of the impact of natural hydrocarbons on rural ozone.* | Trainer, Williams, et al. This study shows that ozone production in some rural areas in the eastern United States is limited by the availability of NOx, as opposed to VOCs, and that biogenics play a key role in the production of ozone in rural areas. |
| 1987 | California | Southern California Air Quality Study | |
| 1987 | US | PM NAAQS reviewed changed | New standard based on 10 microns |
| 1988 | Europe | EMEP Protocol enters into force | |
| 1988 | Europe | EUROTRAC is begun | |
| 1988 | US/ Germany | US/FRG Workshop on Photochemical Ozone Problem and it's control -- Proceedings on the US Experiences and the Situation in Europe. | |
| 1988 | EEC | 88/609/EEC: Council Directive on the limitations of emissions of certain pollutants into the air from large combustion plants. | OJ L 336 07.12.88 p. 1, last modified by OJ L 337 24.12.94 p.83 |
| 1988 | Europe | First NOx Protocol in LRTAP | Entered into force February 1991 |
| 1988 | US | *Ozone Pollution: The Hard Choices* | Russell. Science. September 9. 241: (4871) 1275-1276 |
| 1988 | Europe | Evaluation of the Montsouris series of ozone measurements in the nineteenth century. | Volz and Kley. Reanalysis of ozone measurements made at Montsouris, near Paris, from 1878 to 1910 shows that surface ozone concentrations about 100 years ago were around 10 ppb, current concentrations in rural areas in Europe averages 20-45 ppb. |
| 1988 | US | The Role of Biogenic Hydrocarbons in urban photochemical smog: Atlanta as a case study | Chameides, Linday, Richardson, and Kiang. Article is accompanied by editorial that criticizes EPA for taking a VOC-focused approach and ignoring the need for NOx control. Subsequent issue, separate responses from OAQPS and ORD reveal a split between 2. |
| 1988 | California | California Clean Air Act requires periodic planning and rate of progress demonstrations for attaining state ambient air quality standards. | |
| 1989 | US | *Catching Our Breath: Next Steps for Reducing Urban Ozone.* Office of Technology Assessment | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1989 | EEC | 89/429/EEC: Council Directive on the reduction of air pollution from existing municipal waste-incineration plants. | OJ L 203 15.07.89 p.50 |
| 1989 | US | Review of the National Ambient Air Quality Standards for Ozone, Assessment of Scientific and Technical Information, OAQPS Staff Paper | (23) EPA 450/2-92-001 |
| 1989 | US | Health effects of ozone: A critical review. | Lippmnan, et al. This is an important review of health effects of ozone coming during the reconsideration of the CAA and between NAAQS reviews. |
| 1989 | US | NAPAP ends | NAPAP Report published in December 1990 |
| 1989 | US | US Air Quality Improvement Research Program (AQIRP, or Auto/Oil), Phase I begins | |
| 1989 | US | Work on NRC report *Rethinking* begins | Published 1992 |
| 1989 | US | Southern Oxidants Study begins, later performs intensive field studies in Atlanta and Nashville | |
| 1990 | US | Clean Air Act Amendments | Second Phase of NAPAP. SO2 Emissions Trading. Prescriptive SIPs for ozone control. Ozone Transport Commission created. |
| 1990 | EEC | EEC Council Regulation No. 1210/90 - establishing the European Environmental Agency and the European Environment and Observation Network | OJ L 120 11.05.90 p.1 |
| 1990 | | 4th World (International) Conference on Acidification | Scotland |
| 1990 | California | San Joauquin Valley Air Quality Study/Atmospheric Utility Signatures, Predictions, and Experiments | |
| 1990 | California | CARB adopts Cleaner Burning Fuels and Low and Zero Emission Vehicle Programs. | |
| 1991 | Europe | First NOx Protocol enters into force | |
| 1991 | Europe | Transboundary Environmental Impact Assessment Convention | Not yet in force |
| 1991 | EEC | 91/441/EEC: Council Directive on the approximation of the laws of the Member States relating to measures taken against air pollution by emissions from motor vehicles | OJ L 242 30.08.91 p.1 |
| 1991 | US | *Controlling Urban Air Pollution: A Benefit-Cost Assessment* | Krupnick and Portney demonstrate that the costs of air pollution controls particularly for ozone may not be justified by the benefits produced. Claim more should be spent on PM10 control than on ozone, due to higher benefits of avoiding excess mortality. |
| 1991 | Europe | VOC Protocol enters into force | |
| 1991 | US | Lake Michigan Ozone Study | |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1992 | EEC | Maastricht Treaty | Entered into force 1 Nov 1993, 12 nations, monetary and political union, subsidiarity, co-decision power for Parliament |
| 1992 | US | Rethinking the Ozone Problem in Urban and Regional Air Pollution. | National Research Council |
| 1992 | Europe | Transboundary Effects of Industrial Accidents Convention | Not yet in force |
| 1992 | EU | 92/72/EEC: Council Directive on air pollution by ozone | OJ L 297 13.10.92 p.1 |
| 1992 | US | AQIRP Phase 1 ends | |
| 1992 | Europe | European Auto/Oil study starts | |
| 1992 | Europe | Long-Period Modeling of Photochemical Oxidants in Europe - Model Calculations for July 1985 | Simpson presents the EMEP Ozone model and evaluates control strategies for Europe. |
| 1993 | California | SCAQMD adopts Regional Clean Air Incentives Market (RECLAIM) program for SOX and NOX. | |
| 1993 | Europe | EUROTRAC Application Project begun | |
| 1993 | EU | 93/12/EEC: Council Directive relating to the sulfur content of certain liquid fuels | OJ L 074 27.03.93 p.81 |
| 1993 | US | AQIRP, Phase 2 begins | |
| 1993 | US | Ozone NAAQS challenged in court by American Lung Association | EPA reaffirmed standard but began more comprehensive review (ALA v. Administrator of the EPA, 884 F. Supp. 345 (D. Ariz. 1994); and 58 FR 13008.) |
| 1993 | US | SO2 NAAQS review | no change |
| 1994 | EU | Commission Regulation No. 3528/86: Detailed rules for the implementation of Council Regulation (EEC) No. 3528/86 on the protection of the Communities forests against atmospheric pollution. | OJ L 125 18.05.94 p. 25, modified by OJ L 071 31.03.95 p.25 |
| 1994 | EU | 94/63/EC: European Parliament and Council Directive on the control of VOCs resulting from the storage of petrol and its distribution from terminals to service stations. | OJ L 365 31.12.94 p.24 |
| 1994 | Europe | LRTAP Second Sulfur Protocol signed | |
| 1994 | EU | 94/12/EC: Directive of the European Parliament and the Council relating to measures to be taken against air pollution by emissions from motor vehicles and amending Directive 70/220/EEC | OJ L 100 19.04.94 |
| 1994 | US | Republican Revolution | Republican Party takes over the US House of Representatives and many governorships. |
| 1994 | US | SIPs due to EPA | Many states fail to submit SIPs which show attainment |
| 1994 | Europe | Second Generation Abatement Strategies for NOx, NH3, SO2, and VOCs | Grennfelt, Hov, and Derwent present the multiple-pollutant, multiple-effects concept. |
| 1995 | US | OTAG starts | (see separate OTAG timeline) |

| Year | Country /Region | Title | Notes |
|---|---|---|---|
| 1995 | US | *The State of the Southern Oxidants Study: Policy-Relevant Findings in Ozone Pollution Research, 1988-1994.* | W. Chameides and E. Cowling. A long-term university based research program aimed at understanding of ozone in the southeastern US, SOS grew out of a workshop in summer 1988 at the request of the Southern Governor's Assoc. |
| 1995 | EU | Austria, Finland, Sweden join EU | |
| 1995 | Europe | Strategies and Policies for Air Pollution Abatement: 1994 Major Review under the Convention on Long-Range Transboundary Air Pollution. | United Nations Economic Commission for Europe. |
| 1995 | | 5th World (International) Conference on Acidification | Goteborg |
| 1995 | EU | COM(95) 350: Proposed Mobile Machinery Engines Directive | |
| 1996 | US | TAF developed | Tracking and Analysis Framework Model Documentation and User's Guide. Argonne National Laboratory. |
| 1996 | EU | 96/61/EC: Integrated Pollution Prevention and Control (IPPC) Directive | |
| 1996 | EU | 96/62EC: Air Quality Framework | |
| 1996 | EU | COM(96)0164: Proposed quality of petrol and diesel fuels Directive | |
| 1996 | EU | COM(96)538: Proposed VOC-Solvents Directive | |
| 1996 | Europe | European Auto/Oil study ends | |
| 1997 | Canada | *Canadian 1996 NOx/VOC Science Assessment: Summary for Policy-Makers* | |
| 1997 | EU | EU Acidification Strategy | "No exceedance of Critical Loads" becomes EU policy. Industry caught off guard. |
| 1997 | Europe | *Photo-Oxidants, Acidification and Tools: Policy Applications of EUROTRAC Results.* | Peter Borrell, Peter Builtjes, Peringe Grennfelt, Oystein Hov (eds.) |
| 1997 | US | 8-hour, 80 ppb NAAQS established by the EPA | White House involvement. Presidential Directive. |
| 1997 | US | *OTAG Executive Summary* | |
| 1997 | US | AQIRP Phase 2 starts | |
| 1998 | Europe | Second Sulfur Protocol in force. | |

# Appendix B: List of interviewees

## Interviewees from the US ozone assessment apparatus

| | | |
|---|---|---|
| Praveen | Amar | North East States for Coordinated Air Use Management |
| John | Bachmann | Environmental Protection Agency |
| William | Baker | Environmental Protection Agency |
| Kathleen | Bassi | Illinois Environmental Protection Agency |
| Andrea | Bear-Field | Hunton and Williams (Utilities Air Regulatory Group) |
| Bruce | Carhart | Ozone Transport Commission |
| Robert | Collum | Southeastern States Air Resource Managers |
| Cyril | Durrenberger | Texas Natural Resource Conservation Commission |
| John | Elston | New Jersey Department of Environmental Protection |
| Stefan | Falk | CAPITA, Washington University |
| Harold | Feldman | Health and Environmental Sciences Department |
| David | Festa | Center for Clean Air Policy |
| David | Flannery | Midwest Ozone Group |
| Richard | Forbes | Illinois Environmental Protection Agency |
| Mary | Gade | Illinois Environmental Protection Agency |
| Larry | Gautney | Tennessee Valley Authority |
| Joseph | Goffman | Environmental Defense Fund |
| D. Alan | Hansen | Electric Power Research Institute |
| David | Hawkins | Natural Resources Defense Council |
| J. Wick | Havins | Pennsylvania Department of Environmental Protection |
| G. Tom | Helms | Environmental Protection Agency |
| Danny | Herrin | Southern Company |
| George | Hidy | University of Alabama |
| Sheila | Holman | North Carolina Department of Environment, Health, and Natural Resources |
| John | Jansen | Southern Company |
| Harvey | Jeffries | University of North Carolina, Chapel Hill |
| Robert | Kaleel | Illinois Environmental Protection Agency |
| Alan | Krupnick | Resources For the Future |
| Dennis | Lawler | Illinois Environmental Protection Agency |
| Peter | Lidiak | EPA – Office of Mobile Sources |
| Bharat | Mathur | Illinois Environmental Protection Agency |
| Brian | McLean | Environmental Protection Agency |
| Jim | Meagher | Tennessee Valley Authority |
| Paul | Miller | North East States for Coordinated Air Use Management |
| J. David | Mobley | Environmental Protection Agency |
| Mary | Nichols | Environment Now (former EPA Assistant Administrator for Air & Radiation) |
| Brock | Nicholson | North Carolina Department of Environment, Health, and Natural Resources |
| Carmelita | Olivetto | Environment Canada |
| S.T. | Rao | New York Department of Environmental Conservation |
| Jim | Rue | (former Pennsylvania Department of Environmental Protection |
| Chris | Salmi | New Jersey Department of Environmental Protection and Energy |
| Ken | Schere | EPA, ORD |
| Nelson | Seaman | Pennsylvania State University |
| John | Seitz | EPA, OAQPS |
| Ellen | Shapiro | American Automobile Manufacturers Association |
| Sally | Shaver | Environmental Protection Agency |
| Robert | Shinn | New Jersey Department of Environmental Protection |
| Don | Schregardus | Ohio Department of Environmental Protection |
| Sanford | Sillman | University of Michigan |
| Paul | Solomon | Pacific Gas and Electric |
| Tom | Tesche | Alpine Geophysics |
| Joseph | Tikvart | EPA - OAQPS |
| Sarah | Wade | Environmental Defense Fund |
| Susan | Wierman | Mid-Atlantic Regional Air Management Association |
| Merrylin | Zaw-Mon | Maryland Department of the Environment |

## References

101st Congress (1990). Clean Air Act Amendments - Public Law 101-549. Washington, DC, U.S. Government Printing Office.

ACEA/EUROPIA (1996). European Programme on Emissions, Fuels and Engine Technologies. Brussels.

Aeppel, T. (1995). Not In My Garage: Clean Air Act Triggers Backlash as Its Focus Shifts to Driving Habits. Wall Street Journal. New York, NY: A1, A10.

Alcamo, Joseph, Roderick Shaw, Leen Hordijk., Eds. The RAINS Model of Acidification: Science and Strategies in Europe. Laxenberg, International Institute for Applied Systems Analysis.

Alm, L. R. (1997). "Scientists and the acid rain policy in Canada and the United States." Science, Technology & Human Values 22(3): 349-368.

Anonymous (1996). Ozone Attainment, Proceeding in the Right Direction: Will Sound Science and Objectivity Prevail? Charleston, WV, Midwest Ozone Group.

Atkinson, R. (1998). Atmospheric Chemistry of VOCs and NOX: 1998 NARSTO Assessment - Critical Review. http://odysseus.owt.com/Narsto/assess_activities.html, NARSTO.

Axelrod, R. S. (1994). "Subsidiarity and Environmental Policy in the European Community." International Environmental Affairs 6(2): 115-132.

Baumgartner, F. R. and B. D. Jones (1993). Agendas and instability in American politics. Chicago, University of Chicago Press.

Bennett, G., Ed. (1991). Air Pollution Control in the Eurpoean Community: Implementation of the EC Directives in the Twelve Member States. International Environmental Law and Policy Series. Boston, Wolter Kluwer Academic Publishers.

Boehmer-Christiansen, S. and J. Skea (1991). Acid Politcs: Environmental and Energy Policies in Britain and Germany. New York, Belhaven Press.

Boehmer-Christiansen, S. A. (1989). "Vehicle Emission Regulation in Europe - The Demise of Lean-Burn Engines, the Polluter Pays Principle . . . . and the Small Car?" Energy and Environment 1(1): 1-25.

Boehmer-Christiansen, S. A. (1990). "Curbing Auto Emissions in Europe." ENVIRONMENT 32(6): 17-20, 34-39.

Borrell, P., P. J. Builtjes, P. Grennfelt and O. Hov, Eds. (1997). Photo-oxidants, Acidification and Tools: Policy Applications of EUROTRAC Results. Transport and Chemical Transformation of Pollutants in the Troposphere. New York, Springer.

Botcheva, L. (1998). Doing is Beleiving: Use and Participation in Economic Assessments in the Approximation of EU Environmental Legislation in Eastern Europe. Cambridge, MA, Global Environmental Assessment Project, Kennedy School of Government.

Brodin, Y.-W. and J. C. Kuylenstierna (1992). "Acidification and Critical Loads in Nordic Countries: A Background." AMBIO 21(5): 332-338.

Chayes, A. and A. H. Chayes (1995). The New Soverereignty: Compliance with International Regulatory Agreements. Cambridge, MA, Harvard University Press.

Clapp, B. W. (1994). An Environmental History of England. London, Harlow, ENGLAND.

Clark, W. C., J. Jaeger, J. vanEijndhoven and N. M. Dickson, Eds. (forthcoming). Learning to Manage Global Environmental Risks: A Comparative History of Social Responses to Climate Change, Ozone Depeletion, and Acid Rain. Cambridge, MA, MIT Press.

Colebeck, I. and A. Mackenzie (1994). Air Pollution by Photochemical Oxidants. New York, Elsevier.

Commission of the European Communities (1992). European Symposium: Auto Emissions 2000, Brussels, BELGIUM, Office for Official Publications of the European Communities.

Connolly, B. (1997). Organizational Choices for International Cooperation: East-West European Cooperation for Regional Environmental Problems. Cambridge, MA, Global Environmental Assessment Project.

Cowling, E. and W. Chameides (1995). The Southern Oxidants Study: Policy-Relevant Findings in Ozone Pollution Research 1988-1994. Raleigh, NC, North Carolina State University.

Cowling, E. and J. Nilsson (1995). "Acidification research: Lessons from history and visions of environmental futures." WATER AIR AND SOIL POLLUTION 85(1): 279-292.

Cowling, E. B. (1982). "Acid precipitation in historical perspective." Environmental Science & Technology 16(February): 110-123.

Cowling, E. B. (1992). "The Performance and Legacy of NAPAP." Ecological Applications 2(2): 111-116.

Cox, R. A., A. Eggelton, R. G. Derwent, J. E. Lovelock and D. Pack (1975). "Long-range transport of photochemical ozone in north-western Europe." Nature 225: 118-121.

Dahl, A. (1995). "Environmental Actors and European Integration." International Environmental Affairs 7(4): 299-320.

Dahl, A. (1997). "National Freedom of Action in EU Environmental Policy: The Cases of Denmark and the Netherlands." Environmental Politics 6(3): 68-98.

Davidson, C. I., R. W. Hahn, M. Henrion, L. B. Lave, G. J. McRae, E. S. Rubin, M. J. Small and S. N. Talukdar (1984). A Conceptual Framework for Integrated Assessments fo the Acid Depositiion Problem. Pittsburgh, PA, Carnegie-Mellon University.

Davies, J. C. and B. S. Davies (1975). The Politics of Pollution. Indianapolis, IN, Bobbs-Merrill.

Derwent, R. G. (1993). "Evaluation of the Chemical Mechanism Employed in the EMEP Photochemical Oxidant Model." Atmospheric Environment 27A: 277-279.

Derwent, R. G. and T. J. Davies (1994). "Modelling the impact of NOx and Hydrocarbon control on photochemical ozone in Europe." Atmospheric Environment 28(12): 2039-2052.

Dietrich, W. F. (1996). "Harmonization of Automobile Emission Standards." William and Mary Environmental Law and Policy Review 20: 175-221.

Dodge, M. (1998). Chemical Oxidant Mechanisms for Air Quality Modeling. http://odysseus.owt.com/Narsto/assess_activities.html, NARSTO Critical Review paper.

Edgar, J., D. Sundquist, D. Beasly, J. Gilmore, F. O'Bannon and J. Engler (1998). .

EMEP Workshop (1991). EMEP Workshop on Photooxidant Modelling for Long-Range Transport in Relation to Abatement Strategies. Berlin, Umweltbundtesamt.

Engel, K. H. (1997). "State Environmental Standard-Setting: Is There a "Race" and is it to the "Bottom" ?" Hastings Law Journal 48(January): 271-398.

Esty, D. C. (1996). "Revitalizing Environmental Federalism." Michigan Law Review 95(December): 570-653.

Farber, D. A. (1997). "Environmental Federalism in a Global Economy." Virginia Law Review 83: 1283-1319.

Farrell, A. (1998). Environmental Assessment and Policy in Follower Nations: Air Pollution in Spain. GEA Discussion Paper. Cambridge, MA, Harvard University.

Fox, C. B. (1873). Ozone and antozone : their history and nature. When, where, why, how, is ozone observed in the atmosphere? London, J. and A. Churchill.

Geiger, J. (1995). "Canary In A Coal Mine? Federalism And The Failure Of The Clean Air Act Amendments of 1990." William and Mary Environmental Law and Policy Review 20: 81-119.

Gingrich, N. and D. Armey (1994). Contract With America. New York, Times Books.

Haas, P. M., R. O. Keohane and M. A. Levy, Eds. (1994). Institutions for the Earth. Cambridge, MA, MIT Press.

Harrison, R. M., P. Brimblecombe, R. Derwent, G. Dollard, S. Eggleston, R. Hamilton, A. Hickman, C. Holman, P. Laxen and S. Moorcroft (1996). Airborne Particulate Matter in the United Kingdom. London, Department of the Environment (UK).

Hayes, S. P. (1998). Explorations in Environmental History. Pittsburgh, University of Pittsburgh Prress.

Heggestad, H. E. (1991). "ORIGIN OF BEL-W3, BEL-C AND BEL-B TOBACCO VARIETIES AND THEIR USE AS INDICATORS OF OZONE." Environmental Pollution 74(4): 264-291.

Herrick, C. and D. Jamieson (1995). "The Social Construction of Acid Rain." Global Environmental Change 5(2): 105-112.

Hopgood, S. (1998). American Foreign Environmental Policy and the Power of the State. Oxford, Oxford University Press.

Jacobs, F. G. (1002). "Europe after 1992: The Legal Challenge." The University of Chicago Legal Forum 1992: 1-16.

Jasanoff, S. (1990). The Fifth Branch: Science Advisors as Policymakers. Cambridge, MA, Harvard University Press.

Jasanoff, S. (1995). Product, process, or programme: Three cultures and the regulation of biotechnology. Resistance to new technology. M. Bauer. Cambridge, Cambridge University Press: 311-331.

Jordan, A. (1998). "EU environmental policy at 25: the politics of multinational governance." Environment 40(1): 14-20, 39-45.

Kaiser, J. (1996). "Acid Rain's Dirty Business: Stealing Minerals From Soil." Science 272(April 12): 198.

Katz, M. and C. Shapiro (1994). "Systems Competition and Network Effects." Journal of Economic Perspectives 8(2): 93-115.

Keating, T. J. and A. Farrell (1998). Problem Framing and Model Formulation: The Regionality of Tropospheric Ozone in the US and Europe. ENRP Discussion Paper E-98-11. Kennedy School of Government, Harvard University.

Keeney, R. (1992). Value-Focused Thinking. Cambridge, MA, Harvard University Press.

Kramer, L. (1997). Focus on European Environmental Law. London, Sweet & Maxwell Limited.

Krier, J. and E. Ursin (1977). Pollution and Policy: A Case Essay on California and Federal Experience with Motor Vehicle Air Pollution 1940-1975. Berkeley, CA, University of California Press.

Kuhn, T. S. (1970). The structure of scientific revolutions. Chicago, University of Chicago Press.

Levin, S. (1992). "Orchestrating Enviornmental Research and Assessment." Ecological Applications 2(2): 103-106.

Levy, M. A. (1994). European Acid Rain: The Power of Tote-Board Diplomacy. Institutions for the Earth: Sources of Effective International Environmental Protection. P. M. Haas, R. O. Keohane and M. A. Levy. Cambridge, MA, MIT Press.

Litfin, K. (1994). Ozone Discourses. New York, Columbia University Press.

Miller, P., P. Amar and M. Tatsutani (1997). The Long-Range Transport of Ozone and It's Precursors in the Eastern United States. Boston, MA, Northeast States for Coordinated Air Use Management.

Morgan, G., B. Fischoff, A. Bostrom, L. Lave and C. J. Atman (1992). "Communicating Risk to the Public." Environmental Science & Technology 26(11): 2048-2056.

Morgan, M. G. and M. Henrion (1990). Uncertainty : a guide to dealing with uncertainty in quantitative risk and policy analysis. New York, Cambridge University Press.

Munton, D. (1998). "Dispelling the Myths of the Acid Rain Story." ENVIRONMENT 40(6): 4-7,27-34.

National Research Council (1991). Rethinking the ozone problem in urban and regional air pollution. Washington, DC, National Academy Press.

Nichols, M. (1995). MEMORADUM: Ozone Attainment Demonstrations. O. o. A. a. Radiation. Washington, DC, U.S. Environmental Protection Agency: 4.

Novick, S. and B. Westerfield (1994). "Whose SIP Is It Anyway? State-Federal Conflict In Clean Air Act Enforcement." William and Mary Journal of Environmental Law 18: 245-284.

Oates, W.E. and R. M. Schwab (1988). "Economic Competition Among Jurisdictions: Efficiency Enhancing or Distortion Inducing?" Journal of Public Economics. 35:333.

Oates, W. E. (1997). "On Environmental Federalism." Virginia Law Review 83: 1321-1329.

OECD (1990). Control Strategies for Photochemical Oxidants across Europe. Paris, Organization for Economic Co-operation and Development.

OECD, (1968). Air Management Research Group: Decisions and conclusions of the 1st Session, Paris, 2-4 October 1968. N. D. Delegates of the Air Management Research Group, Members of the Committee for Research Cooperation. Paris, Directorate for Scientific Affairs.

OECD, (1979). The OECD Programme on Long Range Transport of Air Pollutants, Measurement and Findings, Second Edition. Paris, Organisation for Economic Cooperation and Development.

Office of Technology Assessment (1989). Catching Our Breath: Next Steps for Reducing Urban Ozone. Washington, D.C., U.S. Government Printing Office.

Office of Technology Assessment (1989). Catching Our Breath: Next Steps for Reducing Urban Ozone. Washington, DC, Congress of the United States.

OTAG Emissions Inventory Workgroup (1998). OTAG Technical Supporting Document - Chapter 3. Raleigh, North Carolina, US Environmental Protection Agency.

Oversight Review Board (1991). The Experience and Legacy of NAPAP. Washington, DC, National Acid Precipitation Assessment Program.

Pagano, M. A. and A. Bowman (1994). "The State of American Federalism 1994-1995." Publius: The Journal of Federalism 25(3): 1-21.

Pitts, J. N. (1993). "ANTHROPOGENIC OZONE, ACIDS AND MUTAGENS - HALF A CENTURY OF PANDORAS NOX." Research on Chemical Intermediates 19(3): 251-298.

Putnam, R. D. (1988). "Diplomacy and Domestic Politics: The Logic of Two-Level Games." International Organization 43(2): 430.

Raufer, R. (1998). Pollution Markets in a Green Country Town: Urban Environmental Management in Transition. Westport, CT, Praeger Publishers.

Rawson, J. M. (1993). Agricultural Research and Extension: Current Issues. Washington, DC, Congressional Research Service.

Rein, M. and D. Schon (1996). "Frame-critical policy analysis and frame-reflective policy practice." Knowledge and Policy 9(1): 85-104.

Revesz, R. L. (1992). "Rehabilitating Interstate Competition: Rethinking the "Race to the Bottom" Rationale for Federal Environmental Regulation." New York University Law Review 67: 1210.

Revesz, R.L. (1996). "Federalism and Interstate Environmental Externalities." University of Pennsylvania Law Review 144: 2341.

Revesz, R. L. (1997). "Federalism and Environmental Regulation: Lessons for the European Union and the International Community." Virginia Law Review 83: 1331-1346.

Roth, P. M., S. D. Ziman and J. D. Fine (1993). Tropospheric Ozone. Keeping Pace With Science and Engineering: Case Studies in Environmental Regulation. M. F. Uman. Washington, DC, National Academy Press: 39-90.

Rubin, E. S. (1991). "Benefit-Cost Implications of Acid Rain Controls - An Evaluation of the NAPAP Integrated Assessment." Journal of the Air & Waste Management Association 41(7): 914-921.

Rubin, E. S., L. B. Lave and M. G. Morgan. (1991). "Keeping climate research relevant." Issues in Science and Technology 8(2): 47-49.

Russell, A. (1997). Regional photochemical air quality modeling: model formulations, history, and state of the science. Annual Reveiw of Energy and Environment. 22: 537-588.

Russell, M. (1988). "Ozone Pollution - The Hard Choices." Science 241(4871): 1275-1276.

Sabatier, P. A. and H. C. Jenkins-Smith, Eds. (1993). Policy change and learning: An advocacy coalition approach. Boulder, Westview Press.

Schultze, R. H. (1993). "The 20-year history of the evolution of air pollution control legislation in the USA." Atmospheric Environment 27B(1): 15-22.

Schwartz, S. E. (1989). "Acid Deposition: Unraveling a Regional Phenomenon." Science 243(February 10, 1989): 753-763.

Shaw, R. W. (1993). Acid-rain negotiations in North America and Europe: a study in contrast. International Environmental Negotiation. G. Sjostedt. Newbury Park, CA, Sage Pubilcations: 84-109.

Simpson, D. (1992). "Long period modeling of photochemical oxidants in Europe - Model calculations for July 1985." Atmospheric Environment 26A(9): 1609-1634.

Skeffington, R. A. (1997). What is a Critical Load?: A Critical Appraisal. Wiltshire, UK, National Power PLC.

Solomon, P., E. Cowling, G. Hidy and C. Furiness (1998). Comparison of Scientific Findings from Major Ozone Field Studies in North America and Europe, NARSTO: 118.

South Coast Air Quality Management District (1997). Fifty Years of Progress Towards Cleaner Air: The Southland's War on Smog:. Diamond Bar, CA.

STAPPA/ALAPCO (1993). Meeting the 15-Percent Rate-Of-Progress Requirement Under the Clean Air Act: A Menu of Options. Washington, DC, State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officials.

STAPPA/ALAPCO (1994). Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options. Washington, DC, State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officials. July.

STAPPA/ALAPCO (1996). Controlling Particulate Matter Under the Clean Air Act. Washington, DC, State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officials.

Stasiuk, W. N. and P. E. Coffey (1974). "Rural and urban ozone relationships in New York state." Journal of the Air Pollution Control Association 24: 564-568.

Stewart, R. B. (1977). "Pyramids of Sacrifice?: Problems of Federalism in Mandating State Implementation of National Environmental Policy" Yale Law Journal 86: 1196-1220.

Tarr, J. (1996). The Search for the Ultimate Sink: Urban Pollution in Historical Perspective. Akron, OH, The University of Akron Press.

The National Committee on Air Quality (1981). To Breathe Clean Air. Washington, DC, The National Committee on Air Quality.

Tobin, R. J. (1992). "Environmental protection and the new federalism: a longitudinal analysis of state perceptions." Publius 22(1): 93.

Triantis, G. G. (1997). "The Allocation of Government Authority." Virginia Law Review 83(7): 1275-1282.

Tunistra, W., L. Hordijk and M. Amman (forthcoming). "Using Computer Models in International Negotiations: Acidification in Europe." ENVIRONMENT.

U.S. Environmental Protection Agency (1986). Air Quality Criteria for Ozone and Other Photochemical Oxidants. Research Triangle Park, NC, Environmental Criteria and Assessment Office.

U.S. Environmental Protection Agency (1997). Proposed Rule for Reducing Regional Transport of Ground-Level Ozone (Smog): Federal Register Notice. Washington D.C., Government Printing Office.

United Nations (1996). 1979 Convention on Long-Range Transboundary Air Pollution and its Protocols, UN Economic Commission for Europe.

VanDeveer, S. D. (1998). European Politics with a Scientific Face: Transition Countries, International Environmental Assessment, and Long Range Transboundary Air Pollution. ENRP Discussion Paper E-98-09. Kennedy School of Government, Harvard University.

Various (1997). OTAG Stakeholder Presentations. Atlanta, GA and Chicago, IL.

Victor, D. G., K. Raustiala and E. B. Skolnikoff, Eds. (1998). The Implementation and Effectiveness of International Environmental Commitments. Global Environmental Accord. Cambridge, MA, MIT Press.

Wagenbaur, R. (1992). "Regulating the European Environment: The EC Experience." The University of Chicago Legal Forum 1992: 17-39.

Walker, D. B. (1996). "The advent of ambiguous federalism and the emergence of New Federalism III." Publius: The Journal of Federalism 56(3): 271-280.

Wettestad, J. (1997). "Acid Lessons? LRTAP implementation and effectiveness." Global Environmental Change 7(3): 235-249.

White, W. H., J. A. Anderson, D. L. Blumenthal, R. B. Husar, N. V. Gillani, J. D. Husar and W. E. Wilson (1976). "Formation and transport of secondary air pollutants: Ozone and aerosols in the St. Louis air basin." Science 194: 187-189.

Wilcox, G. L. (1996). "New England and the challenge of interstate ozone pollution under the Clean Air Act of 1990." Environmental Affairs 24(1): 1-101.

Winebrake, J. J. and A. Farrell (1996). "The AFV Credit Program and Its Role in Future AFV Market Development." Transporation Research D forthcoming.

Working Party on Methods of Measuring Air Pollution and Survey Techniques (1964). Methods of Measuring Air Pollution. Paris, Organization for Economic Co-operation and Development.

Wynne, B. (1996). Misunderstood misunderstandings: Social identities and public uptake of science. Misunderstanding Science? The public reconstruction of science and technology. A. Irwin and B. Wynne. Cambridge, Cambridge University Press: 19-46.

Zehr, S. C. (1994). "The centrality of scientists and the translation of interests in the United-States acid-rain contoversy." Canadian Review of Sociology and Anthropology 31(3): 325-353.

# Tables

## TABLE 1: Major Federal US Air Pollution Laws*

| Year | Name | Major Provisions |
|---|---|---|
| 1955 | Air Pollution Control Act | • Initial authorization for federal research, training, and demonstration projects related to air pollution. (Extended in 1959 and 1963.) |
| 1963 | Clean Air Act | • Established permanent federal research and state aid funding<br>• Gave enforcement powers to the federal government through "enforcement conferences" aimed at interstate issues. |
| 1965 | Motor Vehicle Pollution Control Act | • Gave HEW authority to set auto emissions standards as soon as practicable |
| 1965 | Clean Air Act Amendments | • Directed HEW to set auto emissions standards |
| 1967 | Air Quality Act | • Authorized HEW to oversee state air quality practices and established State Implementation Plans (SIPs)<br>• Provided more money to states for planning<br>• Required state to create Air Quality Control Regions<br>• Directed HEW's National Center for Air Pollution Control (NCAPC) to investigate adverse health effects of air pollutants.<br>• Set national standards for auto emissions (90% reduction by 1976) |
| 1970 | Clean Air Act Amendments | • Sharply expanded federal role in setting and enforcing standards<br>• Set national standards for auto emissions (90% reduction)<br>• New Source Performance Standards (NSPS) for major sources |
| 1977 | Clean Air Act Amendments | • SIP requirements for non-attainment areas<br>• Clean Air Act Scientific Advisory Committee (CASAC)<br>• Mandated 5-year reviews of NAAQS<br>• Delay in auto emissions standards<br>• New Source Review (NSR) to enforce Lowest Achievable Emissions Rate (LAER) on new stationary sources for VOCs only<br>• Existing stationary sources subject to Reasonably Available Control Technology (RACT) requirements for VOCs only<br>• Vehicle inspection programs for non-attainment areas<br>• Prevention of Significant Deterioration (PSD) requirements for areas with good air quality. |
| 1990 | Clean Air Act Amendments | • Designation of non-attainment areas as "Serious," "Moderate," etc. and corresponding hierarchy of NSR requirements for VOCs<br>• Ozone Transport Commission<br>• Prescriptive SIPs (employer commute option, Inspection & Maintenance, Tier 2 auto emissions standards<br>• Indirect Source Control Plans<br>• Rate-Of-Progress requirements for emissions control<br>• Establishes NOx NSR requirements for the first time<br>• Expansion of types of sources covered by VOC RACT and establishes NOx RACT requirements for the first time<br>• Regional transportation plans |

* Omitted: 1962 extension of the Air Pollution Control Act
*Sources:* Kneese and Schultze (1975), Roth, et al. (1973)

## TABLE 2: Accomplishments of the Ozone Transport Commission

| Accomplishment | Description |
|---|---|
| OTC NOx Memorandum of Understanding | Emissions trading program designed to control NOx from 417 major stationary sources in the Northeastern United States. Estimated reductions are over 85% on average. Minimization of competitive disadvantage by gained by multi-state trading significantly reduced opposition by affected sources. |
| National Low-Emission Vehicle (NLEV) | Voluntary low-emission vehicle program based on the California program. Major difference is the NLEV program requires no zero-emission vehicles. Resulted from negotiations with 12 Northeastern states, but auto industry offered to adopt the program nationwide. State-by-state efforts through CAA mechanism failed for various reasons. |
| Coordinated actions with other groups | Together the 12-state OTC has a larger population and economy than any other state, plus almost one quarter of all Senate votes and more than 25% of House seats (although citizens in the District of Columbia have no Congressional representation). This may enable them to be more effective in negotiations with upwind states, the EPA, and various industry groups. |
| Coordinated research | The OTC's several sub-committees have gained economies of scale and scope in the investigation of numerous policy questions including EPA's Tier 2 Auto Emission Regulations, the role of sulfur in gasoline, control technologies and costs, and so forth. |
| Coordinated air quality assessments | Expanded, improved, and more efficient emissions inventories and air quality modeling through coordinated action. |
| Ozone Map | Development, and marketing of a graphical, multi-state ozone forecasting product. Sales to TV weather services increased in 1996 and 1997. Note: due to the dominance of major news centers serving multiple states (e.g. Philadelphia media sources serve DE, NJ, and PA; New York media outlets serve CT, NJ, NY) a state-by-state effort would not have worked. |

## TABLE 3: Major Conclusions Reached by OTAG*

| |
|---|
| Regional NOx reductions are effective in producing ozone benefits; the more NOx reduced, the greater the benefit. |
| Ozone benefits are greatest closest to where emissions reductions are made; the benefits decrease with distance. |
| Both elevated (from tall stacks) and low-level (from mobile and area sources) NOx reductions are effective. |
| VOC controls are effective in reducing ozone locally and are most advantageous to highly polluted urban areas. |
| Air quality data (as differentiated from modeling results) indicate that ozone is pervasive, that ozone is transported, and that ozone aloft is carried over and transported from one day to the next. |
| The range of transport is generally longer in the North than in the South. |

## TABLE 4: Major OTAG Recommendations*

| |
|---|
| Additional modeling and analysis is need at the regional level as the states develop their specific control strategies. |
| The recommended range of utility NOx control levels in the rectangular region stretching from approximately the northeast corner of Louisiana to approximately Portland, Maine is between the existing requirements in the Clean Air Act and an 85% reduction. |
| NOx controls on non-utility sources should be similar to those made at comparably-sized utility sources. |
| That EPA should continue to develop, adopt, and implement stringent national controls for architectural and industrial maintenance coatings, consumer/commercial products, autobody refinishing, reformulated gasoline, small engines, heavy-duty highway and non-road engines, and locomotives. |
| That EPA should reach closure on the TIER 2 motor vehicle emissions study. |
| Continued use of reformulated gasoline is supported. The EPA needs to assess an sulfur standards for liquid fuels. |
| The EPA should determine the need for appropriate standards for diesel fuel. |
| Vehicle emissions inspections and maintenance programs are supported. |
| Ozone Action Days programs to increase public awareness of ozone are supported. |
| The establishment of NOx emissions market systems to reduce the cost of compliance is supported. |

*Paraphrased slightly to reduce the jargon content. See the original for authoritative text.
*Source:* Ozone Transport Assessment Group (1997)

**Table 5: National LRTAP and EU Members and Applicants**

| LRTAP Parties | | EU Members | EU Applicants — Negotiating 1998 | EU Applicants — Not Yet Negotiating |
|---|---|---|---|---|
| Armenia | Luxembourg | Austria | Cyprus | Bulgaria |
| Austria | Malta | Belgium | Czech Republic | Croatia |
| Belarus | Netherlands | Denmark | Estonia | Latvia |
| Belgium | Norway | Finland | Hungary | Lithuania |
| Bosnia- | Poland | France | Poland | Malta |
| Herzogovnia | Portugal | Germany | Slovenia | Romania |
| Bulgaria | Moldova | Greece | | Slovakia |
| Canada | Romania | Ireland | | Turkey |
| Croatia | Russia | Italy | | |
| Cyprus | Slovakia | Luxembourg | | |
| Czech | Slovenia | Netherlands | | |
| Denmark | Spain | Portugal | | |
| Finland | Sweden | Spain | | |
| France | Switzerland | Sweden | | |
| Germany | Macedonia | United | | |
| Greece | Turkey | Kingdom | | |
| Hungary | Ukraine | | | |
| Iceland | UK | | | |
| Ireland | US | | | |
| Italy | Yugoslavia | | | |
| Latvia | EU | | | |
| Liechten. | | | | |
| Lithuania | | | | |

## Table 6: The LRTAP Convention and Its Protocols

| | |
|---|---|
| 1979 | **LRTAP Convention:** Framework convention, states agree to "endeavor to limit" and/or reduce air pollution using best available technologies and to share scientific, technical and environmental policy information. (Adopted in Geneva, 13.11.1979; Entry into force, 16.03.1983; 33 Signatories and 43 Parties, as of 01.04.98) |
| 1984 | **EMEP Protocol:** Creates a multilateral trust fund for the long-term financial support of EMEP activities. (Adopted in Geneva, 28.09.1984; Entry into force, 28.01.1988; 22 Signatures and 37 Parties, as of 01.04.98) |
| 1985 | **Sulphur Protocol:** States agree to reduce sulfur emissions or their transboundary fluxes by 30 percent, from 1980 levels, by 1993. All Parties in compliance by 1998. (Adopted in Helsinki, 08.07.85; Entry into Force, 02.09.87; 19 Signatories and 21 Parties) |
| 1988 | **NOx Protocol:** States commit to freezing NOx emissions (at 1987 or earlier levels) by the end of 1994, and to future cooperation to further reduce NOx emissions and establish critical loads. Eighteen of the Protocol's 25 parties complied with the terms of the freeze. The twelve EC states went farther, aiming to reduce NOx emissions by 30 percent by 1998. By 1994, only 2 EC states appeared on track to achieve a 30 percent reduction. (Adopted in Sophia, 31.10.88; Entry into Force, 14.02.91; 25 Signatories and 25 Parties, as of 01.04.98) |
| 1991 | **VOCs Protocol:** States agree to reduce VOCs emissions by 30 percent from a chosen baseline year between 1984 and 1990. Most countries chose 1988. Reliably assessing progress toward implementation remains complicated, if not impossible, by the lack of accepted emissions data. (Adopted in Geneva, 18.11.91; Entry into Force, 29.09.97; 23 Signatories and 17 Parties, as of 01.04.98) |
| 1994 | **Second Sulphur Protocol:** Replaces expired 1985 Sulphur Protocol. Retaining 1980 levels as a baseline and using an "effects based" approach setting "target loads" based on calculated critical loads, states agreed to different emissions reductions by 2000 (toward their target loads) which represent a 60 percent reduction in the difference between existing deposition levels and critical loads (the so called "60 percent gap closure" approach). (Adopted in Oslo, 14.06.94; Will Enter into Force 05.08.98; 28 Signatories and 16 Parties, as of 07.05.98) |
| 1998 | **Heavy Metals Protocol:** (Scheduled for Signature, Arhus, Denmark, June 1998) |
| 1998 | **POPs Protocol:** (Scheduled for Signature, Arhus, Denmark, June 1998) |
| | **Multi-Pollutant/Multi-Effects Protocol:** (Previously the Second NOx Protocol, under negotiation) |

*Source*: Adapted and expanded by Stacy VanDeveer from McCormack, 1997: 59; and UNECE 1995.

Full names of the finalized agreements are, respectively: Convention on Long-range Transboundary Air Pollution; Protocol to the 1979 Convention on Long-range Transboundary Air Pollution Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollution in Europe (EMEP); Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at Least 30 per cent; Protocol to the 1979 Convention on Long-range Transboundary Air Pollution concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes; Protocol to the 1979 Convention on Long-range Transboundary Air Pollution concerning the Control of Emissions of Volatile Organic Compounds or Their Transboundary Fluxes; Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Further Reduction of Sulphur Emissions.

**TABLE 7: Early EU Member State air pollution policies (selected nations)**

| Nation | Year | Notes |
|---|---|---|
| BELGIUM | 1964 | Act of 28 December 1964 empowers the Crown to regulate and prohibit different forms of air pollution. |
| | 1971 | Royal Decree of 26 July 1971 establishes "special protection zones" against sulfur pollution |
| | 1975 | Royal Decree of 8 August 1975 against sulfur and smoke |
| | 1978 | Royal Decree of 31 May 1978 against lead |
| | 1986 | Royal Decree of 1 July against NO2 and conforms to Directive 85/203 |
| GERMANY | 1845 | General Trade Regulations give limited authority to local officials |
| | 1959 | Federal Air Purity Act slightly strengthens policy. Introduces BAT requirements. |
| | 1971 | Environmentally-motivated product standards for sulfur in fuel and lead in gasoline |
| | 1974 | Federal Air Pollution Control Act set ambient air quality standards (long term and short term) for both health and environmental protection. Regulated pollutants include TSP, Pb, Cd, Cl, HCl, CO, SO2, NOx, Fl compounds, Thallium compounds |
| | 1974 | Road Traffic Act specifies vehicle emissions |
| GREECE | 1975 | Article 24 of the Constitution protects the environment |
| | 1980, 81 | Multiple air quality laws for lead in gasoline, motor vehicle and industrial standards. Quickly superseded when Greece acceded to the EU, which occurred starting in 1987. |
| SPAIN | 1961 | Decree of 30 November 1961 requires the control of unhealthy activities. Some anti-sulfur provisions in the Third Plan for Development at the end of the 1960s. |
| | 1972 | Air Protection Act (38/72). First comprehensive air quality law and the basis for current regulations. Most regulation by Ministries of Industry, of Public Works, of Finance, and of the Interior. Mandatory monitoring requirements, but no apparent enforcement mechanisms. Air quality standards for SO2, TSP, Pb, and NOx. |
| | 1974 | Decree 3025/74 set standards for fuels and vehicles, added CO emissions standard, and created new monitoring requirements. |
| | 1975 | Regulation D.833/75 defined and gave authority to control industrial sources |
| | 1978 | Beginning of devolution of competences to the Autonomous Communities |
| NETHERLANDS | 1970 | Air Pollution Act dealt with "major" sources of pollution |
| | 1974 | Beginning of regulation of sulfur in fuel oil and lead in gasoline. |
| UNITED KINGDOM | 1821 | Smoke Prohibition Act – ineffective. |
| | 1853 | London air pollution act introduces "best practicable means" to air quality regulation |
| | 1863 | Alkali Act is the first effective control of industrial sources. Expanded in 1875, 1881, 1892, 1906, 1935, and 1958 to include more and more industries and pollutants. |
| | 1935 | Manchester begins to implement "smokeless zone" rules against household coal use. Widely copied by the mid 1950s. |
| | 1956 | Clean Air Act broadly expands regulatory and enforcement power. Expanded in 1986 to control fuel standards |
| | 1974 | Control of Pollution Act gives Secretary of State the power to set sulfur and lead standards for liquid fuels. |

*Note:* Case law on nuisance grounds often precedes specific legislation
*Sources*: (Bennett 1991; Boehmer-Christiansen and Skea 1991; Clapp 1994)

## Table 8: EU air quality legislation*

| Year | Name | Major Provisions |
|---|---|---|
| 1970 | 70/220 | • Established standards for emissions of CO and HC from spark-ignition vehicles.<br>• Principle of "optional harmonization" established (see text) |
| 1972 | 72/306 | • Established standards for emissions of smoke from diesel engines. |
| 1974 | 74/290 | • Tightened spark-ignition vehicle CO and HC standards |
| 1975 | 75/716 | • Established limit for sulfur content in gas oil (i.e. heating oil) |
| 1977 | 77/102 | • NOx controls added to spark-ignition vehicle standards |
| 1977 | 77/537 | • Tightened smoke standards for diesel engines. |
| 1978 | 78/665 | • Tightened spark-ignition vehicle CO, HC, NOx standards |
| 1978 | 78/611 | • Established limit on lead content in petrol (i.e. gasoline). |
| 1980 | 80/779 | • First air quality limit values - sulfur dioxide and suspended particles. Proposed in 1976, but it raised "important matters of principle". Compliance due April 1993. |
| 1982 | 82/884 | • Established air quality limit value for lead. Compliance due December 1989. |
| 1983 | 83/351 | • Tightened spark-ignition vehicle CO, HC, NOx standards |
| 1984 | 84/360 | • Regulation on air pollution from industrial plants |
| 1985 | Luxembourg Agreement | • > 2.0 l CO - 25, HC - 6.5, NOx - 3.5 spark-ignition vehicles<br>• 1.4 - 2.0 l CO - 30, HC and NOx - 8 (units: gm/test)<br>• < 1.4 l CO - 45, HC - 15.0, NOx - 6.0 |
| 1985 | 85/203 | • Established air quality standard for nitrogen dioxide (augmented by stricter guide values). Compliance due January 1994. Can be made more strict or relaxed. |
| 1985 | 85/210 | • Changed limits on lead in petrol |
| 1987 | 87/219 | • Tightened sulfur content in gas oil |
| 1987 | 87/416 | • Changed limits on lead in petrol |
| 1988 | 88/76 | • Tightened spark-ignition vehicle CO, HC, NOx standards<br>• Principal of optional harmonization revoked |
| 1988 | 88/77 | • Established heavy-duty diesel emission standards for CO, HC, and NOx |
| 1988 | 88/436 | • Introduced diesel PM regulations |
| 1989 | 89/427 | • Corrected deficiencies in SO2 measurement techniques in 80/779 |
| 1988 | 88/609 | • Large Combustion Plant directive. |
| 1989 | 89/458 | • Established more stringent emissions standards for smaller vehicles (<1.4 l) |
| 1989 | Small Car Agreement | • CO - 19, HC and NOx 5.<br>• 1989 Council Promise added high speed component to the test |
| 1990 | 90/313 | • Establishes requirement for the public's freedom of access to environmental information. |
| 1991 | 91/441 | • Extends small-car standards of 89/458 to all size classes. |
| 1991 | 91/542 | • Tightened heavy duty diesel vehicle CO, HC, NOx standards<br>• Established heavy duty diesel PM standards |
| 1992 | 92/72 | • Requires ozone monitoring.<br>• Established health and vegetation-based ozone concentration standards. |
| 1994 | 94/12 | • Introduces more stringent limit values for all ambient pollutant concentrations.<br>• Reflects Auto/Oil study recommendations to evaluate all transporation-related policies according to cost/effectiveness guidelines. |
| 1996 | 96/61 | • Integrated Pollution Prevention and Control Directive creates multi-media permitting system. |
| 1996 | 96/62 | • Air Quality Framework Directive. Defines and sets objectives for ambient air quality. Requires assessment of ambient air quality and the availability of this data to the public, including alert notices when threshold values are exceeded. Requires maintenance of good air quality. |
| 1996 | 96/63 | • Controls VOC emissions from petrol storage and distribution. |

*Sources*: Boehmer-Christiansen 1990, Bennett 1991, and http://europa.eu.int/en/comm/dg11/dg11home.html
*Some entries are not categorized by the EU as "air quality legislation," specifically 88/609, 90/313 and 96/61.

## Figures

**FIGURE 1: Incremental Contributions to Ozone Concentrations**

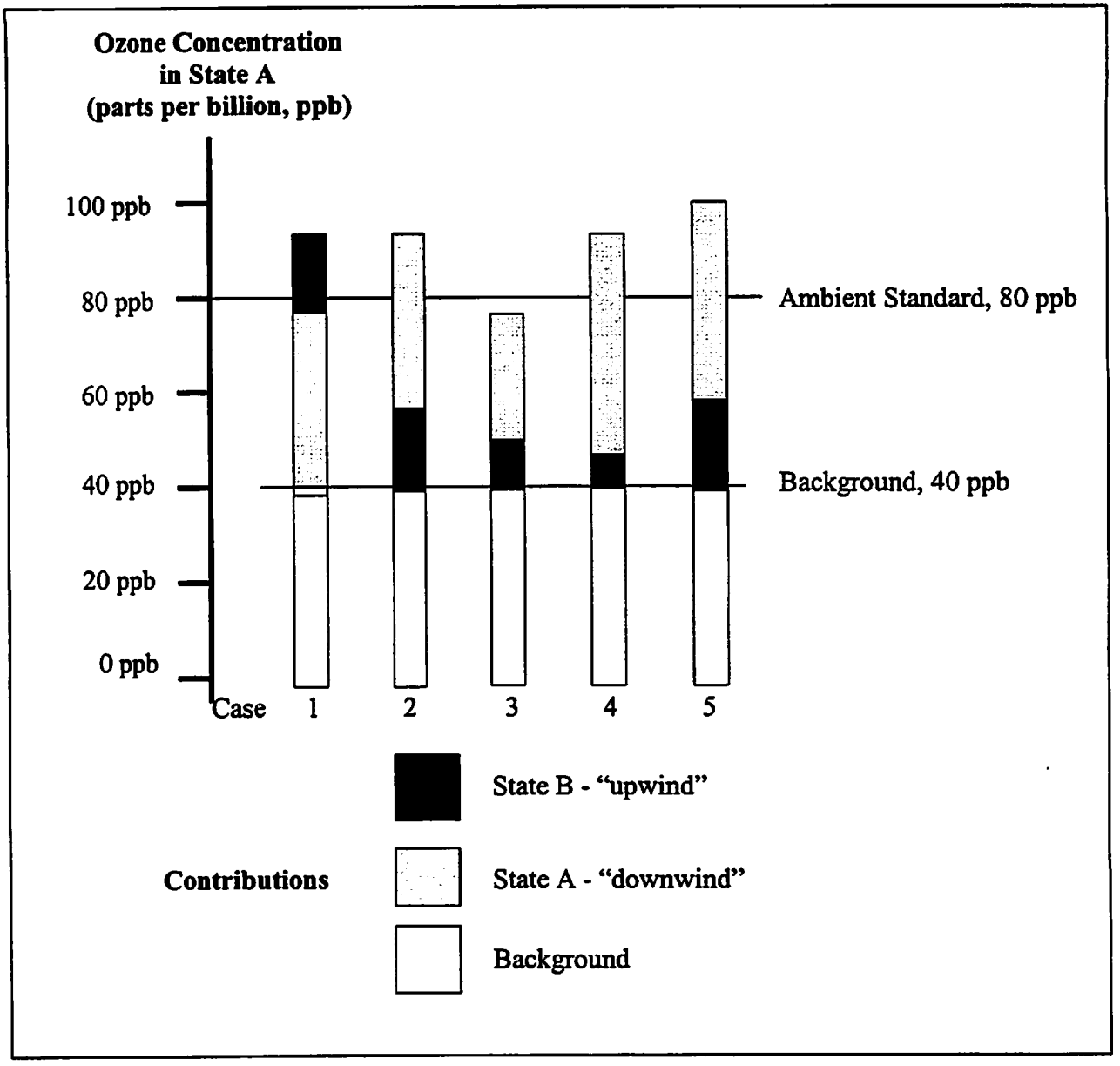


**FIGURE 2 : OTAG Organization Chart**

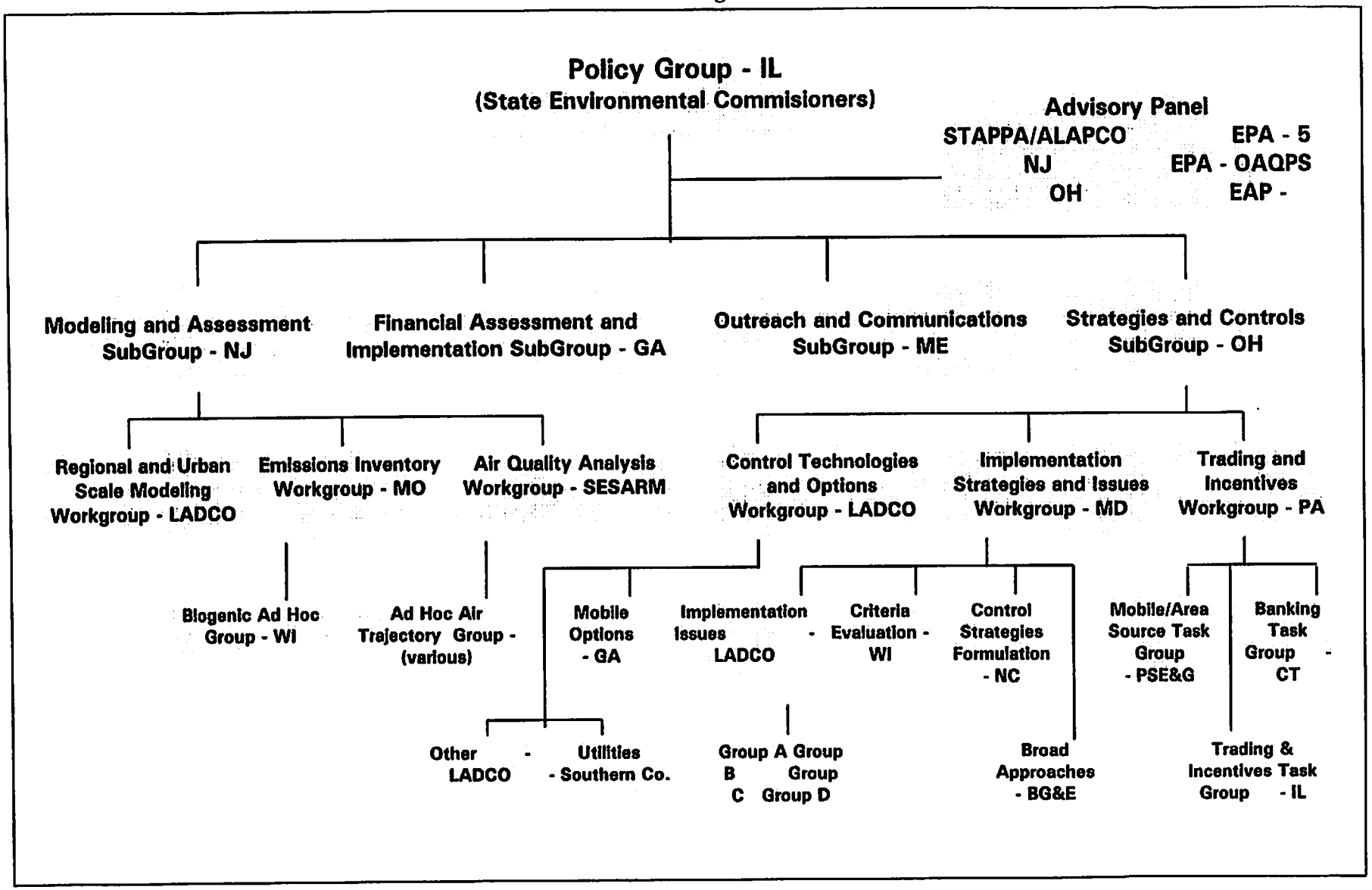
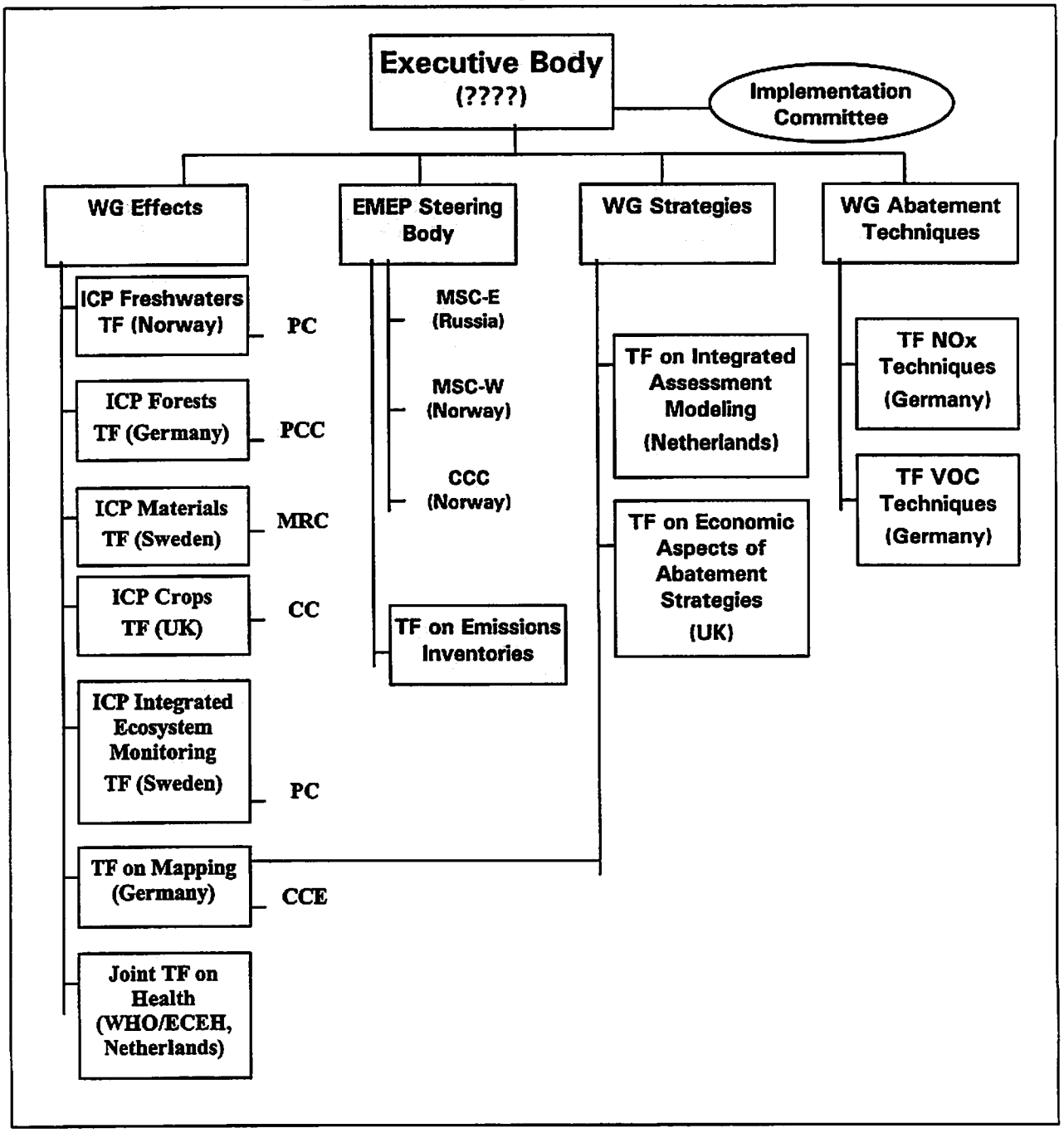


**Figure 3: LRTAP Organizational Structure**




*Notes*: **WG** = Working Group; **ICP** = International Cooperative Program; **TF** = Task Force; **PC** = Programme Centre; **PCC** = Programme Coordination Centre; **MRC** = Main Research Centre; **CC** = Coordination Centre; **CCE** = Coordination Centre for Effects (in the Netherlands); **MSC-E** = Meteorological Sythesizing Centre-East; **MSC-W** = Meteorological Synthesizing Centre-West; **CCC** = Chemical Coordinating Centre; **WHO** = World Health Organization; **ECEH** = ; **EMEP** = European Monitoring and Evaluation Program; **NOx** = oxides of nitrogen; **VOCs** = volatile organic compounds.
*Source*: UNECE website, 1998.

# Endnotes

[1] For the purposes of this paper "ozone" will mean only tropospheric ozone, not ozone in the stratospheric ozone layer, and generally we mean the accumulation of ozone in the atmosphere (not formation). In addition the phrase "acid rain" will refer to all types of acidifying deposition, including $SO_2$, NOx, and $NH_3$. Additionally, since this paper compares domestic policy in the U.S. with international policy the term "state" could be confusing; here "state" will always refer to one of the 50 U.S. states such as Massachusetts and Pennsylvania, and the word "nation" will always be used to refer to sovereign countries such as Austria and the United States. Also, where the paper refers to "states" it generally means those states east of Rocky Mountains, and in particular excludes California, which, as we will see, is the crucial exception in ozone assessment and policy. No discussion of ozone can avoid California, which has been a leader in assessment and policy development, and this one does not, but the focus will be on the states east of the Rockies.

[2] The authors acknowledge that the Canadian experience with these pollutants (particularly acidification) is an important to understanding the European and US experiences, but due to resource constraints must defer research on Canada (plus the rest of the world) for another effort.

[3] Although ozone and acid rain are only two of many different air pollutants, from this point the term will be used narrowly to refer to only those two substances. However, we do not mean to imply that the observations and insights developed here are necessarily applicable to other air pollution problems.

[4] The exact details of the transboundary nature of ozone remains a contentious issue, at least in the United States. There is little disagreement among the scientific community that ozone is a regional problem crossing state boundaries (National Research Council 1991). Similarly, the United States Environmental Protection Agency (EPA) has repeatedly demonstrated its belief that ozone is a transboundary problem. (U.S. Environmental Protection Agency 1997). Nonetheless, very significant differences remain on this issue among the state environmental agencies and affected parties (Anonymous 1996; Miller, Amar et al. 1997; Various 1997). Indeed, this disagreement lies at the heart of the controversy about ozone control in the United States.

[5] Increases in ozone concentrations following decreases in NOx emissions is variously called NOx titration, NOx scavenging, and NOx disbenefit. This phenomenon can occur in areas with high NOx emissions because NOx acts to both form and destroy ozone, depending on its concentration relative to VOCs in the atmosphere. It does occur in many urban areas in the United States and Europe, and there is some evidence that there is the potential for this phenomenon to occur across wide areas of Northern Europe in the future if currently planned NOx controls go forward.

[6] The images shown in Figure 1 cannot be derived from measured empirical values—it is impossible to distinguish ozone molecules from one another based on where the emissions which created them came from. However, images like Figure 1 are produced by interpreting observed and calculated values (including model results).

[7] For a more complete discussion of this concept from a legal perspective, see Revesz (1996 pp2360-2374).

[8] The authors would like to thank Gail Tonnesen for pointing this out.

[9] Even this representation only captures a small part of the texture of ozone because Figure 1 only illustrates ozone concentration at one location. Decreases in emissions will likely cause changes in other locations as well such as the upwind area. A decrease in NOx emissions will result in lower ozone concentrations somewhere, although concentrations could go up in other places. It is impossible to predict the pattern of changes with a simple heuristic, emphasizing the point that it is impossible to rely on linear thinking when trying to understand the impacts of ozone control strategies—one must always go back to a photochemical model.

[10] In some cases VOC emissions are the *intended* result of industrial processes such as painting or the use of solvents.

[11] Hazardous and noxious air pollutants remain a significant, and in some cases growing, problem, but for reasons of space and clarity they will be ignored for the remainder of this paper. It should be noted in passing, however, that these pollutants may have a bearing on ozone policy in that they tend to be emitted in far greater quantities by coal-fired facilities than by natural gas-fired plants. Thus the regulation of hazardous pollutants may provide an extra incentive to switch to natural gas.

[12] The phenomenon of producing analytic efforts which evaluate very narrow questions about specific emissions control efforts has been called "the race to insignificance." Tropospheric ozone pollution is the result of many

small contributions, so it is always possible to show that the marginal contribution of any single source approaches zero. Thus, a successful strategy in avoiding controls is to rely on narrowly-defined assessments. Note that the legal remedies of nuisance suits and CAA Section 126 petitions are not well suited to addressing such problems.

[13] It is important to emphasize that there *is* scientific research (mostly initial monitoring efforts) in Europe by the mid 1980s, as well as the beginning of atmospheric modeling. See Farrell and Keating (1998) section 5.1.

[14] See, for example, The Federalist No. 45.

[15] In the 1994 elections the Republican Party gained majorities in both the Senate and the House of Representatives for the first time since the 1950s. At the state level, there were 18 Republican Governors before the 1994 elections, and 30 afterwards, and 31 state legislative bodies controlled by Republicans before the 1994 elections and 49 (out of 99) afterwards. Moreover, many of the newly-elected leaders (especially new Representatives) were self-proclaimed "Revolutionaries" devoted to smaller government and devolution of power to the states.

[16] It should be noted that there is a significant range of disagreement about the degree to which OTAG actually represented devolution and what it implies about the future of state and federal relations in the environmental arena. As discussed in detail in a subsequent section, OTAG did not have any authoritative decision-making capability, it merely advised the federal government.

[17] In particular, there seems to be a split in the legal literature between theorists such as Revesz and Stewart and more practically-oriented scholars. Few of the theorists seem to pay much attention to empirical analysis, as Engel (1997) notes. In contrast, she examines the literature on firm location and conducts original empirical work on to investigate the question of a "race-to-the-bottom." Her research firmly supports the idea that interstate competition does indeed reduce social welfare, not improve it, for the cases she looks at (Engel 1997). Practically-oriented legal scholars often acknowledge the transboundary nature of many air pollutants in passing or implicitly, often focusing on the problems in current air pollution legislation in dealing with this problem (Novick and Westerfield 1994; Tobin 1996). But they do not generally go much further in identifying the important physical characteristics of the problems environmental law are meant to solve. In fact Wilcox appears to be the only legal scholar over the last decade or so who has chosen to review current assessments of ozone (Office of Technology Assessment 1989; National Research Council 1991) and consider the implications for current and future policy (Wilcox 1996). Not surprisingly, this attention to important details of the physical nature of the problem and his willingness to examine the specifics of US ozone control legislation provide Wilcox a more useful platform with which to analyze the legal/economic issues of ozone regulation than others in this tradition.

[18] Thanks to Clark Miller for his comments on earlier versions of this section.

[19] It would be misleading to suggest that the European example is typical. In fact just the opposite is true, international air pollution agreements with any degree of effectiveness exist only in Europe (save the Montreal Protocol). And to take the constructivist analysis seriously, it is necessary to acknowledge that more significant peculiarities exist in Europe, notably a fairly long-standing and well-developed tradition of democracy in the northwestern European nations which are principals in European air pollution efforts, the effective rule of law which produces the ability to enforce national-level commitments at the local level, high levels of wealth and scientific capacity, and very strong exogenous factors supporting joint action (e.g. the Cold War). Obviously, the same factors also exist in the United States. However, these factors do not exist in part (and sometimes at all) in many countries elsewhere in the world, suggesting that the analysis presented in this paper may have limited generalizability.

[20] Two things are worth emphasizing here, the fact that European air pollution efforts have been very uneven between different nations and that there are substantial distinctions between sovereign nations and U.S. states.

[21] Proposals for state-by-state environmental regulation are sometimes defeated in the courts based on arguments that they restrain free trade between states. Examples include cases involving municipal waste and low-sulfur coal.

[22] The setting of Europe-wide standards is discussed below in the Section 3.

[23] It would be more typical to say "reify the state" at this point, but due to the convention adopted at the outset of the paper on the use of the word "state" forces the somewhat awkward construction in the text. Similarly, the theory that Putnam is associated with is often called a "state-centric" approach, but attempting to use this term here would be too confusing, so it is avoided.

[24] It is not clear in the HKL framework how to think about pre-existing capacity, but it is clear that some capacity predates both LRTAP and OTAG. In fact, it may be the case that some minimal level of capacity is needed for the initiation of coordinated assessment/policy efforts. Otherwise, it there may be too little (commonly shared)

understanding of the issue for different jurisdictions (and other stakeholders) to agree on any plan of action for conducting assessments or developing policies.

[25] In this paper we ignore the portions of the assessment apparatus which deal with standard-setting, which are the focus of most other analyses of air quality policy (e.g. Jasanoff 1990 and Skeffington 1997). See Keating and Farrell (1998) Figure 4 and accompanying discussion.

[26] NESCAUM was formed in 1967 to deal with SO2 emissions from large power plants near state borders and has since expanded to include ozone. It currently includes the states of CT, ME, MA, NH, NJ, NY, RI, and VT. LADCO was formed in 1989 as the result of a court order against the Chicago area, a series of ensuing interstate lawsuits, and a finally a Memorandum of Understanding between for the states of WI, IL, IN, and MI to work together on ozone.

[27] STAPPA and ALAPCO are separate legal entities with different memberships and boards of directors, but they share a single Executive Director and staff. In general these organizations act together.

[28] Of course proximity helps, UNC—Chapel Hill is located very close to the offices of the EPA group most directly associated with air pollution assessment and policy, the Office of Air Quality Standards and Planning (OAQPS).

[29] The term Public-Private Partnership (PPP) is often used to label such efforts.

[30] NARSTO's overwhelmingly US character can be seen in the makeup of the Executive Steering Committee (8 US, 1 Canadian, 1 Mexican) and the Sponsoring Partners (53 US, 1 Canadian, 2 Mexican). For more information, see http://odysseus.owt.com/Narsto/index.html

[31] It is the opinion of the authors that the NARSTO State of the Science report is likely to be the last comprehensive assessment document on tropospheric ozone that will be completed before the next revision of the US Clean Air Act (which will probably begin in the 1999-2000 Congress).

[32] Kneese and Schultze (1975 p. 2) note that in a November 1960 report to President Eisenhower, *Goals for Americans*, only five short paragraphs out of 372 pages are devoted to the environment. However, there was some national-level action in the 1950s to support research, such as Eisenhower's 1955 health message and the 1955 Air Pollution Control Act. This reflected the view that research on pollution is a broad issue of concern, not something that states should deal with.

[33] HEW sources cited in (Davies and Davies 1975).

[34] For a more complete discussion of this evolution, with particular attention to the 1990 Amendments, see Roth et al (1993), Revesz (1996) and Wilcox (1996).

[35] In Keating and Farrell, sections 4 and 5, a distinction is drawn between bounded, sequential assessments and fully integrated assessments, but for simplicity this difference is ignored.

[36] The OTC's progress is best documented in the series of briefing binders it has produced for it's thrice-a-year meetings.

[37] Congress also created the Grand Canyon Visibility Commission, acknowledging and responding to the regionality of haze, a closely pollutant closely related to ozone.

[38] Interstate cooperation does occur on a routine basis for transportation planning in areas where metropolitan areas (and particularly where the boundaries of statutorily-defined Metropolitan Planning Organizations) cross state boundaries, such as in the case of Philadelphia. In some cases this could include the decision to use RFG, but in most cases no significant control programs were implemented this way, especially since the legislated employer-commute option and enhanced inspection and maintenance programs were canceled. In any case, no stationary-source control programs have ever been implemented due to interstate cooperation before the OTC NOx MOU.

[39] As will be seen in a later section, the OTAG process was not created under the CAA and thus the states which joined it were not subject to any extra emission control requirements like those in § 184 and 176A. This problem is implied in the 1991 NRC report, *Rethinking the Ozone Problem* (p. 74).

[40] It should be noted that most states retained the capability to conduct (or review) relatively simple models like Gaussian dispersion and EKMA models, but these became increasingly outdated through the 1980s and 90s as ozone modeling methods.

[41] This notion is echoed in the terminology used for modeling zero emissions from a given state—"turning off New Jersey," for instance.

[42] The use of the term "emissions reductions" is standard in the environmental field but has been avoided for the most part in this paper due to the possible imprecision of the term "reduced". Specifically does this phrase mean the quantity of emissions is decreased, or have the emissions been chemically reduced (i.e. the opposite of oxidation)?

[43] Some of the principal OTAG-related web sites include http://www.epa.gov/ttn/otag/; http://capita.wustl.edu/OTAG/; and http://www.cleanair-mog.org.

[44] The study of non-governmental organizations is still in a very early stage, and even the definition of NGO is not very well established. For the purpose of this discussion, NGO refers to non-profit, public service organizations which do not attempt to promote the economic interests of specific groups of people or industrial sectors.

[45] Our interviews and workshop results revealed a wide range of opinion about the actual openness of the OTAG process and the fairness of decision-making, with a majority being more satisfied than not.

[46] Tables 5 and 6 and Figure 3 were produced by Stacy VanDeveer, whom the authors thank for his generosity.

[47] In this paper we ignore the portions of the assessment apparatus which deal with standard-setting, which are the focus of most other analyses of air quality policy (e.g. Jasanoff 1990 and Skeffington 1997). See Keating and Farrell (1998) Figure 4 and accompanying discussion.

[48] The reason for the extra step of an MSC is that during the Cold War the Soviet Union did not want to reveal the detailed pattern of industrial pollution in Eastern Europe for fear that it would provide militarily-useful location data of industrial sites. Therefore the MSC-E only provided pollutant flux data, not gridded emissions data to EMEP.

[49] Much of the description of LRTAP comes from Levy (1994).

[50] EMEP is the ambient air quality monitoring network of LRTAP, and stands (more or less) for The Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.

[51] For a discussion of the differences in "peripheral" European nations see (Botcheva 1998; Farrell 1998; VanDeveer 1998).

[52] For a brief review and critique of realist theory, see chapter 1 of Chayes and Chayes (1995) and for a more complete discussion of the implications of this critique in environmental policy see Victor, Raustiala, and Skolnikoff (1998).

[53] This discussion is based on several sources, (Kramer 1997) (Jacobs 1002) (Wagenbaur 1992)

[54] There are other forms of EU legislation, Recommendations and Regulations, but these are used only infrequently and will be ignored here.

[55] The use of the singular term "Council" is a bit confusing. There is actually a number of separate Councils based on different substantive areas of policy made up of government representatives from the relevant Ministries. Thus, for example, EU Directives on financial matters are approved the Council of Ministers made up of Ministers of Finance (or other title as appropriate).

56 In essence, QMV is a means of solving the problems tyranny of the majority and tyranny of the strong in a single legislative body. A more typical approach, of course, is to have two legislative houses, as in the United States.

57 The strong role for national governments in the EU is particularly problematic for countries with a strongly regional or federal political structure, such as Spain.

58 The June 1997 Amsterdam Summit introduces further changes to this process, but the agreements made in that meeting have not yet been ratified by the Parliaments of Member States and gone into effect. See Jordan (1998 pp. 42-44).

[59] A crucial issue for motor vehicle standards is that the format of the test is as important as the numerical standard. In an emissions test the vehicle is put on a test platform (i.e. a dynamometer) and a variety of driving conditions are simulated, often including a cycle of start-up, acceleration, idling, hill-climbing, and so forth as specified in the testing protocol. Because engine conditions change so much through such a cycle, its specification can determine what sorts of technology are needed to meet the numerical standard. An important area of debate whether emissions standards and test cycles for new cars provide a good method for regulating actual emissions, since on-road conditions are so different from test conditions.

[60] There are three key economic issues. First, the automotive and fuel industries are very competitive international, especially in comparison to the power sector (which has significant natural monopolies and has frequently been government-owned in the past). Second the automotive industry has very significant economies of scale, and manufacturers have great incentives to design and produce the same vehicle for all markets. Third, the automotive and fuel industries display what economists call "network effects", which occur when there are two different products which must be consumed together to form a system. These products then engage in "systems competition", such as occurs between diesel vehicles, regular gasoline vehicles, and gasoline vehicles which have catalytic converters and must use unleaded fuel. For a general description of these concepts see (Katz and Shapiro

1994), for a more detailed discussion of how they apply to the automotive sector, see (Winebrake and Farrell 1996).

[61] Of course many other rights have been discussed in the European context such as the right of free passage, standing in the European Court of Justice, and so forth. These issues are currently evolving and are among the most contentious of political debates in Europe.

[62] Interestingly, these funds came from "state assistance funds".

[63] In the 1994 elections the Republican Party gained majorities in both the Senate and the House of Representatives for the first time since the 1950s. At the state level, there were 18 Republican Governors before the 1994 elections, and 30 afterwards, and 31 state legislative bodies controlled by Republicans before the 1994 elections and 49 (out of 99) afterwards.

[64] In this case, the control of NOx emissions diminished the NOx titration (i.e. scavenging) effect in urban air, causing ozone concentrations to soar. For example, the introduction of catalytic converters in Athens, Greece lowered vehicular NOx emissions and therefore ambient concentrations, but it caused ozone concentrations to soar from a level near background (~50ppb) to very unhealthful levels (~200ppb).

[65] EU legislation is also more likely to be translated into national legislation if passed at the EU level than LRTAP agreements (which can be ratified or not, as the case may be), and enforcement mechanisms exist in the EU structure but not LRTAP. Over the last several years, there has been increasing number of enforcement actions in the European Court of Justice, and this may eventually become a powerful force in European environmental policy, although there are currently still many complaints that the process is slow and ineffective. In any case, these enforcement mechanisms tend to make the same requirement more effective in EU legislation than in LRTAP, so the same requirement can be thought of as more stringent as a Directive.

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