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

Ozone, the major component of photochemical smog, is arguably the most politically and economically intractable environmental problem facing the nation. (Russell 1989)

1. Introduction

Two of the most important air pollution problems facing industrialized nations are the accumulation of elevated tropospheric (i.e. ground level) ambient ozone concentrations and the deposition of acidifying compounds (i.e. acid rain).[1] Although most discussions (and many policies) focus on one or the other, ozone and acid rain are inextricably linked in the environmental system of the atmosphere and in order to understand the policy problem of ozone we will need to occasionally pay attention to the acid rain policy problem. Ozone and acid rain are particularly problematic because they operate on large scales so that a source of pollution can affect a receptor location hundreds of kilometers away, leading to cases where the source and receptor are in different jurisdictions. By crossing political boundaries ozone and acid rain become classified as *transboundary* problems and present particularly difficult policy problems in that cooperation between different jurisdictions is generally required to solve them. Like all environmental problems, scientific research and insight are essential to understanding and solving the ozone and acid rain policy problems. However, relations between different (semi-) autonomous jurisdictions are not typically thought of as governed by science, but rather by the rules of politics, law, and power. This paper traces the development of the science and policy of ozone over the last 30 years (1967-1997), using the concept of assessment to cover the middle ground of the broad range of activities associated with this process. That is, "assessments" will not refer to basic scientific research or fundamentally political issues; instead it will mean activities like applied science (engineering) and policy analysis.

Some parts of the assessment process are continuous, such as monitoring, while in other cases there are discrete assessment events that punctuate the overall development of science and policy. Discrete assessment events often result in a publication, but it is more useful to consider the entire train of events that led up to the publication as constituting an assessment. Indeed, it is often the preliminary work—research programs, policy planning, evaluation studies, conferences, and internal discussion papers—which have more influence than the final assessment document itself. The case of acidification assessment is already the subject of many analyses, while tropospheric ozone has remained largely unexamined (especially in a comparative way) despite its greater maturity. This paper provides an initial examination of the case of tropospheric ozone in hopes of yielding some insight into the problem itself and, more importantly, into assessment.

While air pollutant emissions leading to ozone formation and acidifying depositions occur world-wide, by far the most extensive experience with assessing and managing them has occurred in Western Europe and the United States, so this paper focuses on these two regions.[2] While there are some differences in the magnitude and specific character of ozone and acid rain on the two continents, their underlying physical natures are essentially identical. The most significant differences between the two continents are in political institutions, legal structures, and power relationships. This paper traces the assessment activities associated with ozone and acidification, focusing on how differences in politics, law, and power relationships affected the character of the science that was developed and the ways in which that science was used. It complements and adds to existing efforts to document and explain the evolution of air pollution

assessment and policy (Krier and Ursin 1977; Pitts 1993; Roth, Ziman et al. 1993; Schultze 1993; Shaw 1993; Cowling and Nilsson 1995; South Coast Air Quality Management District 1997; Hayes 1998; Jordan 1998; Raufer 1998; Victor, Raustiala et al. 1998; Clark, Jaeger et al. forthcoming).

The paper has 5 sections. This introductory section provides the research question, the conceptual framework with which this question will be evaluated, and, a brief description of the context. The second section describes the assessment and policy experience in the Eastern United States, and the third the experience in western Europe. These two contain the empirical material of the paper. The fourth section contains a discussion of the two different experiences, and the fifth is a short concluding section. The paper itself is augmented by a detailed chronology of air quality assessment and policy which can be found in Appendix A. This paper rests to a large extent on a series of interviews conducted in 1997 and 1998 in Europe and the Untied States, and Appendix B contains a list of the interviewees. References, Tables, Figures, and End Notes conclude the paper.

1.1. Research question

This paper will address the general question, "How, and under what conditions, do assessment processes influence social response to multi-jurisdictional air pollution problems?"[3] By assessments we mean those sets of activities which bridge research and action; i.e. activities carried out by technically-trained (e.g. engineers, economists, or physical scientists) designed to solve problems rather than to answer questions. Assessments are conceived of as processes which often produce reports, but they are not solely, or even principally, the documents which result from processes. Assessment is one of several long-term processes that contribute to the coincident development of science and policy. The development of ozone science and policy in the United States and Europe can be thought of as two separate evolutionary streams or paths of science and policy involving all of these components. In this paper, which focuses on policy, and a complementary one focused on science we will look at these two streams and examine how assessments of ozone mattered in each case. We will discuss in detail the Ozone Transport Assessment Group (OTAG) in the US, and the experience of the Convention on Long-Range Transboundary Air Pollution and its Protocols (LRTAP) and the European Union (EU). There is a fairly large literature on the role of assessment in other areas of multi-jurisdictional environmental policy, especially for the cases of acid rain, depletion of the stratospheric ozone layer, and climate change. The ozone and acid rain problems are linked in several ways so it will be necessary to describe them both somewhat, although we will focus mostly on ozone. More complete discussions of acidification (not all of which agree with one another!) can be found in a number of sources (Cowling 1982; Schwartz 1989; Brodin and Kuylenstierna 1992; Levy 1994; Kaiser 1996; Skeffington 1997; Wettestad 1997; Munton 1998; Tunistra, Hordijk et al. forthcoming).

1.2. The basic character of the tropospheric ozone problem

In the troposphere, ozone is essentially formed by the sunlight-driven reactions of oxides of nitrogen (NOx) in the atmosphere. These reactions are regulated (or moderated) by the presence of volatile organic compounds (VOCs), with some compounds being more effective at producing ozone than others. It is common to think of VOCs and NOx, which are referred to as ozone precursors, as both contributing equally to ozone formation and accumulation, but this is a misperception. For a complete discussion of the development of our current understanding of

ozone (including appropriate citations) see Keating and Farrell (1998), however a few salient points need to be made here about ozone formation in order to support the rest of the paper:

- VOC emissions come from a wide array of sources in industrial, commercial, and household settings, plus mobile sources (i.e. cars, trucks, and other vehicles). These source types are very different in number, size, and face very different control costs. Further, natural (biogenic and geogenic) sources of VOCs vary significantly from place to place being almost absent in some locations and overwhelming anthropogenic sources in others.

- The vast majority of anthropogenic NOx emissions are *thermal NOx,* formed in every combustion process (i.e. every power plant, every internal combustion engine, and every place fuel is burned for heat) due to the heating of the molecular nitrogen in the air used for combustion. Thus, NOx can be thought of as ubiquitous in industrialized societies. Natural sources of NOx are not well understood, but they are probably much smaller than anthropogenic sources (although not trivial). Anthropogenic NOx probably overwhelms natural sources in locations where high ozone concentrations exist.

- The reactions which produce ozone from these precursors are highly non-linear, necessitating differentiated and often very large precursor emission decreases in different locations to achieve even modest decreases in ambient ozone concentrations. Further, in some cases NOx emissions *decreases* can cause ozone concentrations to *increase*, just the opposite of what common sense would suggest. (See Figure 1 and the discussion below.)

- A natural background concentration of ozone exists in the atmosphere, some of which "leaks" from the stratospheric ozone layer and some of which is formed in the tropospheric due to naturally-occurring VOC and NOx. However, it is difficult in most cases to clearly differentiate between background and anthopogenically-caused ozone. Indeed, it appears that background levels in "pristine" locations may have increased over the last century, presumably due to anthropogenic activities.

- Ozone formation is very sensitive to local meteorology, topography and emissions profiles, so the character of the problem varies substantially from place to place and from one day to another. Generally, the warmer, calmer, sunnier, and more industrialized an area is, the worse its ozone problem will tend to be.

- Ozone and its precursors can be transported hundreds of kilometers over the course of several days, linking emissions in one or more areas with ambient pollution levels in others.[4] In general, the transport of NO_X between urbanized areas is more important for the formation of ozone downwind than is the transport of VOCs. Anthropogenic VOC emissions tend to be overwhelmed by natural emissions from rural areas between urban and suburban complexes. Additionally, the ozone-forming potential of anthropogenic VOC emissions decreases over time as the most productive chemicals react quickly to form ozone before significant transport occurs. (For simplicity, the term "transport" will refer to the transboundary effects of ozone and its precursors.)

- Ozone is highly textured — the combination of non-linear chemistry, sensitivity to local conditions, and transport mean that over a spatial scale of 100 km or a temporal scale of 24 hours, ozone concentrations can vary by a factor of 2 or 3. Further, the

change in ozone concentration due to changes in precursor emissions (particularly NOx) is also textured — a reduction in NOx emissions in one location can both increase ozone concentrations nearby the same day and decrease ozone concentrations further downwind the next day.[5] And the texture of ozone formation and accumulation can vary from one region to another, although there may be as many similarities as differences.

- Ozone concentrations observed in many parts of the US and Europe are high enough to cause damage to materials and plants, as well as harm human health in some cases, but for the most part these effects do not overwhelm other causative factors. For instance, in the case of human health, contemporary ozone concentrations are sufficiently high on some days (up to about three dozen annually in the eastern part of the country) to be injurious to sensitive sub-populations: asthmatics, the very old, and children. The gross insults to public health and the environment due to ozone so plainly obvious in the 1960s and 1970s are mostly things of the past. Thus, there have been sensible calls for considering the costs and benefits of further ozone regulation. The need for further ozone control programs has a contentious issue, often revolving around different estimates of costs and benefits, or around different views about the acceptability of relatively small environmental risks (i.e. Is access to clean air a right, and if so how clean?), or around larger scale environmental issues related to ozone (as discussed below).
- NOx emissions also cause acidifying deposition and eutrophication, plus other environmental problems, most of which operate on different spatial and temporal scales than ozone. Generally, these problems operate on larger scales than ozone, and possibly have effects which are cumulative in the temporal domain. And it appears that these effects, while somewhat ameliorated compared to decades past, have not been addressed as successfully as the health-related effects of ozone.

It is important to understand just how the multi-jurisdictional air pollution problem emerges out of these characteristics. Figure 1 shows a highly stylized example of the contributions towards total ambient ozone concentrations in one jurisdiction (A) from sources within it's own borders, sources in an upwind jurisdiction (B), and naturally occurring sources (i.e. Background).[6] Five hypothetical cases are shown. The first case is a simple example where the downwind state's concentration is above the standard. In Case 1 it may appear that the upwind state's contribution pushing concentrations over the standard, causing a violation. However, it is important to note that this arrangement of the contributions (and the previous sentence) is only one framing of the issue. The same physical situation could be represented as in Case 2, where the downwind state's contribution is shown crossing the standard. These two images differ only in which jurisdiction's contribution box is presented as crossing the threshold of the standard, so an image like Case 2, for example, could be used to argue that there was no transboundary problem, because the upwind jurisdiction was not causing the violation in the downwind state. This may seem like a trivial point, arguments about how to appropriately represent this sort of information are sometimes heard, as they were in OTAG.

One way to move away from this sort of "blame game" about responsibility for exceeding a standard is to focus on the difference between the background level of ozone and the level of the standard (80 - 40 = 40ppb). This value can be called the "margin for growth" because it represents the allowable ozone concentrations which can be caused by polluting activities (which are often thought of as representing economic growth) before violating an air quality standard.

Thus, transboundary air pollution debates can be thought of as questions about who should be allowed to consume the margin for growth, the upwind or the downwind jurisdiction.[7] In the case where the concentration exceeds the standard and there is no margin for growth, the transboundary question can thus be thought of as questions about how much control is needed where, and who should pay for it.[8]

Figure 1 also illustrates different possible outcomes of NOx control policies. It may be typical to think that moderate decreases in NOx emissions (like a 30% reduction by both jurisdictions) will lead to Case 3, a moderate reduction in ozone concentration. This outcome might be the result, however it would be an error to assume so. It is easy to mistakenly fall into the trap of thinking linearly about this non-linear problem. Because of the texture of ozone described above, NOx emissions decreases might produce results like Case 4—no change in downwind ozone concentrations, but different contributions being made by the downwind source than before. The outcome could even be more unfortunate, decreases in NOx emissions can lead to increases in ozone concentrations in some areas, as illustrated in Case 5.[9] However, the non-linear properties of ozone photochemistry disappear if both VOC and NOx concentrations are decreased at the same time, or if NOx concentrations decrease very sharply (by about an order of magnitude).

Finally, Case 3 can also represent the case of an areas which does not have an ozone problem in that the health standard is not exceeded. However, since economic growth generally brings more ozone precursor emissions, at some point the downwind jurisdiction may find itself in Case 1. Thus, one may ask what are appropriate actions to guard against exceeding the ozone standard in the future and who should pay for such actions?

In addition to these complications it is important to recognize what changes in precursor concentrations are possible outcomes of emissions control strategies. In areas where natural VOC concentrations overwhelm anthropogenic, decreases in human-source VOC emissions can have little or no effect on the chemistry (Atlanta is a good example of such an area). On the other hand, it is always possible to significantly alter NOx concentrations by decreasing NOx emissions, however this is hard to do. While VOC emissions are often the result of incompletely burned fuel (as in automobiles) or potentially valuable chemicals which have evaporated (as in industry), NOx emissions are often inherently associated with highly-efficient combustion.[10] It is possible to design combustion processes which minimize NOx formation, but these often provide only a 30%-60% decrease. Post-combustion processes (such as catalytic converters on cars) can remove NOx once it has been produced, but this tends to be a very expensive proposition, often an order of magnitude more expensive than changes to the combustion process.

Thus, the multi-jurisdictional ozone problem is extraordinarily complex and highly contentious. Upwind areas may have no ozone problem yet their NOx emissions may contribute to downwind ozone concentrations, plus other environmental problems as well. But decreases in NOx emissions may raise local ozone concentrations while lowering downwind concentrations. The ubiquity and scale of NOx emissions suggests the virtual elimination of anthropogenic NOx may be needed to meet current US and European standards for ozone in all areas. This could be incredibly difficult (Russell 1988). However, these characteristics of the multi-jurisdictional ozone problem are not understood equally by all and are relatively recent discoveries. The story of these discoveries and how they affected policy is the central theme of this paper, and begins in the next section .

1.3. Finding and Framing ozone

Ozone and acidification have been issues of interest for many years, but ozone assessment (as we understand it) and policy begins in the late 1940s. In order to understand ozone assessment and policy from 1967 to 1998, it is necessary to look at the scientific understanding of air pollution and policies for controlling it at the beginning of the period. Plus, a basic understanding of the intuitions which had been developed up to that point about air pollution is needed.

We will use the term "frame" to refer to the boundaries that are assumed to exist around a problem and that help shape the interpretation of the problem. Like a camera lens, a problem frame not only defines our field of view, but also defines how we perceive the components of the system within that field of view, and the relationships between them (Litfin 1994). Martin Rein explains "A frame provides us with a whole structure by integrating interests, values, actions, theory, and facts." (Rein and Schon 1996) Thus, a problem frame includes not only the available alternatives and the policy objectives that we seek to achieve (Keeney 1992), but it also includes the structure by which we understand the policy problem and make judgments about it. This broad definition of a problem frame is similar to Baumgartner and Jones' concept of a policy image (Baumgartner and Jones 1993).

Problem frames are reflections of the beliefs of individuals or collections of individuals. These beliefs are shaped by individual experiences and the collective experiences of individuals in the communities to which they belong (Kuhn 1970; Jasanoff 1995; Clark, Jaeger et al. forthcoming). Thus, problem frames are socially constructed. As individuals gather new information from their experiences, they process that information on the basis of their existing beliefs (Morgan, Fischoff et al. 1992; Litfin 1994). Sometimes this new information may cause individuals to change their beliefs. If the new information challenges deeply held beliefs, change may occur, but the change may be gradual (Sabatier and Jenkins-Smith 1993; Connolly 1997).

The discovery and framing of acid rain by the deposition of sulfur dioxide is by now a well-known story of investigation and persistence, initially led by Scandinavian soil scientists, which has been captured by Ellis Cowling and Jan Nillson (Cowling 1982; Cowling and Nilsson 1995). Similarly, the framing of acid rain has also been discussed in the literature (Zehr 1994; Alm 1997). Therefore this section will describe the discovery and assessment of ozone alone, along with some comments on framing.

1.3.1. The early framing of air pollution

The history of air pollution in most of the world up to the late 1960s involved problems that were directly perceptible; a person could generally observe the sources of pollution, patterns of transport, and its effects. There was little need for scientific assessment in early efforts to improve air quality because the environmental problems and their solutions were considered plainly obvious. Both smoke and smog were thought of as localized problems of urban areas, and to a great extent they were. Popular and expert opinions of smoke were derived from every day experiences in the larger industrialized cities and also from extreme, localized pollution episodes. The causes of the problem were thought to be local industrial (and domestic) emissions of smoke, sulfur dioxide, and other gasses. The contemporary understanding of ozone had been mostly developed in California, where ozone was first perceived as a problem by the public and only then investigated by scientists. By the late 1960's only a rough idea of the photochemistry of ozone had emerged, some of the major sources of ozone precursors had been identified (vehicles and industry, with emphasis on the former) and initial efforts at emissions

control were underway. However, the possibility of long-range transport of ozone was not yet considered. But as acid rain and the regionality of ozone emerged from the scientific literature onto the policy scene over the next 20 years, the initial (and popular) framing of air pollution as a local, urban problem has proven very difficult to shake. The remainder of this section provides some details of this initial framing, but can be skipped by the reader who wants to move directly to the discussion of early ozone assessments in the next section.

Atmospheric ozone was first identified and studied in 1840, and in the ensuing half-century it was characterized chemically and measured extensively in Europe, and in at least one place in North America. (Fox 1873; Colebeck and Mackenzie 1994) At the same time, cities such as London, Manchester, Pittsburgh, and Philadelphia were well known for intense smoke pollution; the sun virtually could not shine through the dense clouds of pollution for days on end at times (Clapp 1994; Tarr 1996; Raufer 1998). Both industrial and residential sources contributed to pollution by burning coal for both power and heat in relatively uncontrolled conditions; the industrial sector also contributed substantial amounts of hazardous air pollutants. These pollutants were compounded by the odors of sewage, offal from butchers, and horse manure.[11] Air pollution was found in chiefly urbanized and industrialized areas (which were often indistinguishable), and reports of air quality from the time clearly show that air pollution was perceptibly much better outside of major cities. In addition, both the United States and Europe experienced scattered extreme pollution events in which one could actually identify fatality victims of pollution, recent events include Meuse Valley-1930, Liege-1937, Donora-1948, London-1952, and New York-1966.

After literally hundreds of years of complaints about the quality of urban air, the major cities in the eastern United States and England began to experience sporadic improvements in air quality from the 1880s through the 1930s. While a few of these improvements were due to air quality laws (notably the Alkali Acts in Britian), the majority were due to technological innovation and economic changes. Assessments to define or support the air quality policies that were put into place generally were few and fairly simple. Because the pollution problems addressed at the time were fairly obvious and localized, there was little need for detailed analysis of the problem and potential solutions. Most assessments concerned themselves chiefly with how this could be done with minimal cost and complication, taking the need for emissions decreases as a given (probably correctly, given the extent of the problem at that time)..

One of the most important technical and economic changes in the history of air pollution is a shift in energy consumption patterns away from coal and towards oil and (especially) natural gas, which is accompanied by the incidental effect of improving environmental quality. This shift occurred in the domestic heating sectors in industrialized cities in the United States and England in the late 1940s to the early 1950s, and in other European cities through the 1980s. It occurred in the rail sector (where the switch was to diesel and electric locomotives) from the late 1940s to the 1960s. And it is occurring now in the electricity sector in the United States and Europe, which has come to take a central position (along with the transport sector) in emissions of tropospheric air pollutants. This change in fuels has been accompanied by one of the major technological innovations that cleaned up urban air pollution in the first place — the shift from coal and oil-fired engines to electric motors in virtually every industrial application. However, in the transport sector, the 1950s saw a major transition from the use of electric transit systems in urban areas to the use of automobiles and a shift from freight shipment by rail to shipment by trucks.

Where technological innovation or changes in fuel choice did not improve air quality, the most common solution was to use tall stacks to send emissions many hundreds of feet above the ground, where higher-altitude winds would disperse the pollutants before they descended and could have an effect at ground level. This practice was used even in relatively remote locations where huge smelting operations polluted vast areas. It was in this context that transboundary pollution (in this case acidifying deposition) first became the subject of legal disputes at the national and international levels. The best known examples are the *Georgia vs. Tennessee Copper Co.* (1909) Supreme Court Decision and the *Trail Smelter* (1938) agreement between the US and Canada. These decisions codified the general idea that it was impermissible for one jurisdiction to pollute another in both US and international law. However, in these cases, the effects of pollution were directly sensible—the polluting facilities emitted a visible plume of smoke which was irritating to humans and affected plant growth for several miles. Thus there was little need for assessments to determine that transboundary pollution in fact occurred.

1.3.2. Early ozone assessment and policy in the United States

In all discussions of ozone, Los Angeles (LA) earns special mention because the first ozone problem was discovered in LA, over a decade before it was observed anywhere else (Krier and Ursin 1977). In about 1940, a new sort of problem was observed in LA, a haze which damaged crops and caused eye and respiratory distress. This phenomenon would be termed smog, and although no one knew it at the time, LA's problem was actually photochemical air pollution (largely ozone) and quite different from the original "smogs" of London. The physical conditions in LA (topography, meteorology) are very conducive to the formation of ozone, and the LA area saw truly phenomenal growth in population and economic activity (and related emissions) during the 1920s and 30s. Thus ozone developed as a problem in the Los Angeles area about a decade before it was perceived as a problem anywhere else in the world. Indeed, by the 1940s complaints by the public and by farmers spurred the initial scientific research into the problem we now know as ozone. But it would take nearly half a century before a complete and coherent picture would emerge.

It is important to note that while conditions in LA are extremely conducive to ozone formation, they are not unique—high concentrations of NOx, VOCs and sunlight occur the world over where economic development occurs. However, it is worthwhile noting the distinctions between the physical conditions in LA and those found in the eastern US and Western Europe. Most importantly, there are few natural sources of VOCs in LA (it being largely a desert) and incoming winds originate in a marine environment largely devoid of VOC sources. In the eastern US and parts of Europe, high ozone conditions are usually associated with winds coming from mid-continent that pass over large forested and agricultural areas, carrying with them many biogenic VOCs In addition, the LA basin is ringed by mountains, which tends to limit transport to shorter distances than observed elsewhere. As a result, ozone concentrations in the LA basin tend to be very responsive to decreases in local VOC emissions.

Ozone assessment and policy in the 1940s and 1950s contained all the essential features of subsequent efforts in the US, including OTAG, and some that are not. The salient features of this experience were:

- The original (pre-1940) framing of nuisance law and site-specific prohibitions against perceptible (i.e. visible) smoke proved inadequate to deal with a problem that was a collective action problem and had nothing to do with the traditional pollutants of black smoke and sulfur. The problem of designating the appropriate geographic

scales for control programs continued in the debate about the appropriate size of air pollution management districts in California, which constantly expanded. Site-specific litigation was replaced by local (i.e. municipal) regulation in 1945, which was replaced by county-wide control in 1947 and multi-county regional control and increasing state-wide control after that.

- Very little of the assessment activity appeared in the peer-reviewed literature for the first decade or so. Most of the research into LA's smog problem appeared in the "gray literature", which is made up of things like consultant studies, reports to legislative bodies, and reports by administrative bodies. Generally gray literature material is not peer-reviewed and it is often not readily available to "outsiders".
- There was very little assessment activity in general, and a great deal of antagonism and confusion about what research should be done. LA County and the State of California are the main protagonists at first and there seem to be conflicts over 1) a perception that research was needed to understand the problem and what to do versus a perception that further controls were already clearly needed, 2) the possibility that research might show current control efforts to be ill-founded, and, 3) the appropriate level of government to fund and control the research agenda.
- Initially, leadership (i.e. politicians) responded to public demands for environmental improvement with overly-optimistic promises of quick solutions and an eagerness to find guilty parties (generally industry) on which to place blame. They found it exceedingly difficult to blame the activities of consumers (who are voters as well).
- Within the first year of the formation of the Los Angeles Air Pollution Control District (APCD), it was being investigated by a Grand Jury. This legal pressure was just the beginning for air pollution agencies, which are often pushed both ways, towards greater environmental protection by some groups and towards less regulation by others (different groups tending to use different language to frame the problem).
- There were very strident arguments about the cause of (and therefore about potential solutions to) the ozone problem. While much of the focus in the 1940s was on smoke control, by 1947 some APCD staff as well as the health agencies of the city and county of Los Angeles had determined that smoke was relatively unimportant. Rather, "various invisible gaseous oxides probably entered into smog-forming reactions in the atmosphere" (Krier and Ursin. 1977 p. 75). However the APCD ignored these findings.
- Initial control efforts under the 1947 state law were both broad and uniform (the term "across the board implementation" was used), raising significant debates about their appropriateness. This created concerns for advocates of environmental protection who believed the standard would be a lowest-common-denominator variety based on the needs of firms that have high control costs. Advocates for limited or no action were concerned that uniform standards would be set too high, imposing significant costs on some industries.
- Scientific experts were brought in to study the problem and they often had conflicting views, at least at first. As it became clear that different sectors of industry might be required to control their emissions, these sectors began to sponsor reports, most of

which suggested the sponsors had a relatively minor part to play in solving the problem.[12]

- In 1953 a group of business and political leaders met with government officials and formed the Air Pollution Foundation (APF) as a nonprofit research organization. Originally identified as a Southern California effort, by 1954 it recognized that ozone was becoming a problem elsewhere as well. After several years of study, funded by many different sources (contrasting with the earlier consulting studies), the APF established a significant level of consensus among experts, industry and the public as to the rough contributions of different sectors to the ozone problem by 1957.
- Technologies to reduce motor vehicle emissions of VOCs and (especially) NOx were either primitive or non existent at the beginning of the 1950s, but were developed by the automotive industry over the decade.
- Regulation was consistently tempered by arguments about technological feasibility, and there was a consistent effort to avoid imposing excessive costs on industry (costs which are paid in the end by consumers, of course). Indeed, in a quotation in Krier and Ursin, Haagen-Smit acknowledges that in 1959 there was a widespread understanding that NOx controls would be needed but there was also an equally widespread lack of suggestions about how to control NOx (p. 131) However, other contemporary experts have indicated that the actual magnitude and importance of NOx emissions were poorly known and thus regulators were wary of requiring emission controls. In any case, NOx controls on automobiles were not instituted until 1975, and even later on industrial sources.
- Twice California regulators attempted to require motorists to install new pollution control equipment on their cars when they renewed their registration, and both times a public backlash quickly halted these programs. In both cases, shifting the requirement to new cars and the sale of used cars solved the problem — the technologies were put into place, although more slowly.
- Virtually no progress was made in decreasing ozone concentrations during the 1950s, 60s, and early 1970s, a period during which ozone concentrations in LA were measured as high as 580 parts per billion (compared to the current standard of 120).

Given that the ozone problem was first seen in California and did not seem much like the pollution problems other areas were dealing with at the time (i.e. smoke and industrial pollution), it is not surprising to find that virtually all ozone research and assessment activities were focused on conditions in California, and much of it was performed there. Several important locations of assessment activity already begin to emerge at this time. One pair is at the University of California campuses in Los Angeles (UCLA) and Riverside (UCR). In addition, the automobile companies (particularly Ford and General Motors) developed significant research capacities and performed important parts of the assessment of the problem. In general, the research activities in this period consisted of laboratory experiments investigating atmospheric chemistry typical in California, and plant exposure research (mostly in California). The UCR site grew out of the interest of biologists in the effects of ozone on citrus trees, then a significant part of the Southern Californian economy. Eventually this grew into one of the key sites of assessment activities, the Statewide Air Pollution Research Center (SAPRC). At this stage, there are no field campaigns or monitoring efforts to measure ambient concentrations on a widespread basis (mostly due to

the lack of appropriate analytical instruments), nor is there anything even slightly like integrated assessments as we have come to understand them since.

The ozone problems which have emerged elsewhere in the world over the last 30 years are somewhat different from those in southern California; biogenic VOC emissions have often dominated anthropogenic sources (making an ozone control strategy based on VOC emissions decreases much less effective), large point sources (such as power plants and factories) contributed a greater proportion of NOx pollution than in southern California, and continental meteorology and topography tended to lead to greater transport of pollutants between urban areas. However, by the late 1960s, these differences were still largely unappreciated by the scientific community, which did not begin to discover them conditions until the mid-1970s.

By the mid-1950s, ozone pollution was beginning to show up outside Southern California. San Francisco has a problem by 1950, New York by 1953, Philadelphia by 1957, and Fresno (a rural area) in 1958. One might hope that these areas would not need to repeat the same process that LA embarked on, but as Krier and Ursin note that while more foresight and initiative and less reaction would have been desirable, "such foresight would have approached prescience" (p. 50).

1.3.3. Early ozone assessment and policy in Europe

The European experience with air pollution up to the late 1960s was similar to the US experience—air pollution was mostly a local, urban problem that was often relieved as an additional benefit of switching fuel sources away from coal, although sometimes process changes or tall smoke stacks were needed. Air pollution could sometimes travel long distances and cross jurisdictional boundaries, but in all cases it was a directly sensible phenomenon. In most cases, scientific research was not needed to understand the basic characteristics of the problem, and the few assessments that were performed tended to be relatively simple processes, which always focused on identifying the source of the emissions and considering ways to curtail the polluting activities.

In contrast to the US however, ozone pollution was not even detected in Europe until the late 1960s, and when it was first detected in Europe, it was observed as a regional pollutant occurring in rural areas (where the research centers were located), not an local, urban pollutant. (Heggestad 1991) And when first detected in Europe, ozone was observed at relatively low concentrations which could affect vegetation, but which were not harmful to people. It was not generally considered a serious problem at first, although scientific study of ozone continued in Europe after 1970.

European national air quality legislation generally starts in the 1960s and 1970s, as in the United States, although the United Kingdom is unique in that industry was controlled by the Alkali Inspectorate as early as 1863 under the leadership of Angus Smith. (Germany had some very weak existing regulations, but they did not appreciably affect emissions, see Boehmer-Christiansen and Skea (1991) pp 156-181.) By the early 1980s, sulfur dioxide emissions are controlled (at least nominally) in virtually every nation in Europe, but ozone and ozone precursors are not regulated, monitored, or controlled at all, as seen in Table 7. This suggests that assessments of tropospheric ozone must either be absent or ineffective in Europe (in contrast to scientific research on ozone), which contrasts sharply with the American experience up to that point.[13]

1.4. Existing Analysis

Multi-jurisdictional air pollution assessment and policy has been long studied. In the United States, at least four very different approaches have been taken: a political approach, a legal/economic approach, a technical approach, and a constructivist approach.

The first approach is called "New Federalism," which has washed over the United States in three waves since the early 1970s. New Federalism has attempted to wear away at New Deal institutions and the regulatory state that had been built up previously during the 20th century (Walker 1996) The principal arguments of Federalism are based in Madisonian notions of democracy and the priority of local control over central authority, and are typically associated with conservatism in the United States (Walker 1996; Pagano 1994).14 Environmental regulation moved in the opposite direction from the late 1960s until at least 1980, with the federal role in environmental regulation growing stronger. So it is not surprising that by the time of the 1994 "Republican Revolution" the conservatives were frustrated with federal environmental regulation they saw as intrusive, expensive, and often ineffective.15 Thus, one of the main areas of action for the new leaders in Congress and state governments across the nation was to "devolve" power from the EPA to the various state environmental agencies (Gingrich 1994; Tobin 1992). As discussed in detail below, the Ozone Transport Assessment Group (OTAG), was an important venue in which some of the potential of devolution were played out.16 However, New Federalism is not a very analytic approach, and generally relies on simplified arguments from the legal/economic approach for justification.

The predominant scholarly approach used in the study of multi-jurisdictional air pollution assessment and policy in the US is a framework in which the work of economists and law professors is thoroughly mixed. This approach is typically thought to originate with Stewart, who made a theoretical case for the need for centralized control in some cases (Stewart 1977). Counter-arguments supporting de-centralized environmental regulation followed (Oates 1988; Revesz 1992). Some of the areas of disagreement in this literature include questions about the representativeness of centralized-decision making given potential differences in preferences for environmental quality, the economies of scale in various parts of the regulatory process, and the relative importance of inter-state trade. Attention is also paid to potential differences in preferences for environmental protection between regions. However, by far the most important question is whether or not jurisdictions compete amongst each other (in a rational actor model) to lower the burden of environmental regulations to attract or keep industry, and, whether such competition is appropriate (Engel 1997). (See Esty (1996) for a good summary.)

In addition, a good deal of attention is given to the failing of US air pollution legislation to deal effectively with interstate transport (Revesz 1996; Novick 1994). However, the legal/economic approach is often quite vague about what kind of air pollution is under consideration. While most scholars writing in this tradition are quick to admit that air pollutants which cross state boundaries are clear examples of situations that need federal regulation, they typically fail to specify which pollutants fall in this category and which do not (Revesz 1996; Oates 1997). Indeed, there is a general lack of attention to empirical issues on the parts of these scholars, although a few notable exceptions exist.[17] This same problem carries over to most legal/economic analysis of international air pollution issues, it is not clear which pollutants exhibit long-range transport and which do not (Revesz 1997). A key observation from the study of international air pollution legislation is the important and very strong linkage between free trade regimes and international environmental issues (Farber 1997). This idea is developed further below.

Ultimately, however, legal and economic scholars do not develop and adequate theoretical basis for evaluating alternative mechanisms to decrease or resolve disputes about air pollution among multiple jurisdictions, spending most of their efforts on issues of state versus federal control (Triantis 1997; Oates, 1997). They all generally recommend a participatory partnership among the states and with the USEPA, as well as the need for trust and flexibility, but none offer any concrete suggestions about how to establish effective partnerships. What is missing is any theory about appropriate means for peer-level jurisdictions to operate among themselves. Importantly, Esty (1996) notes that intermediate levels of government (or merely cooperation) will be needed, often tailored to specific environmental problems, although he does not give the details for any concrete example.

The third approach to multi-jurisdictional air pollution problems is to address the practices of research and assessment themselves. Scholars writing in this tradition of technical analysis generally support ideas on how analytical methods can best be deployed to provide useful knowledge for decision-making. This literature is considerable, much of it focusing on issues of uncertainty and on the US acid rain assessment of the 1980s (Davidson, et al. 1984; Morgan 1992; Oversight Review Board 1991; Rubin 1991; Morgan and Henrion 1990; Levin 1992; Cowling 1992). The authors using this approach argue for increased coordination among researchers, greater clarity in communicating important assumptions and their implications to decision-makers, and improved analysis. There is also some discussion about the value of further information and of knowing when research and analysis is adequate to support decisions without being comprehensive. Important concerns in this literature are to expose any bias which the analyst has, and to separate "politics" from analysis as much as possible. As a result, technical analysis offers virtually no advice for multiple jurisdictions since the sorts of value judgments inherent in inter-jurisdictional disputes are considered outside of the realm of technical analysis.

At great odds with this technocratic view is the third approach, constructivism, which emerges from the field of science and technology studies and is related to the sociology, history, and philosophy of science (Jasanoff 1990; Litfin 1994; Wynne 1996). Central to this approach is the idea that while assessment is "rooted in the positivist credo makes very special claims that science is uniquely reliable among human institutions in identifying fundamental truths about the world," more recent thought holds that "science is not characterized by its findings or discoveries so much as by social institutions and practices which produce and validate them" (Herrick 1995). Scholars working in this new tradition generally believe that it is impossible to separate "politics" from anything since for virtually any interesting question judgment is required and this is the basis of politics. "The theme which emerges most forcefully form theses studies is that scientific uncertainty and the pressures of decision-making lead to a forced marriage between science and politics." (Jasanoff 1990 p. 8)

Nonetheless, constructivism focuses our attention on (among other things) "boundary work," which are efforts to attempt to demarcate different areas of cognitive authority to different types of legitimate agents. The technocratic approach accepts that this boundary can be clearly and lastingly marked in objective ways, the constructivist approach holds that the boundary between "science" and other forms of knowledge is often movable and under dispute. Indeed it is the nature of that dispute that is the subject of boundary work. Interestingly, constructivism can be seen as an extension of the technocratic approach which comes out of a more reflective view of the practice of science. Constructivism is also interested in bias and uncertainty, but views both as much more pervasive and intractable, reaching into the structure

of inquiry and social systems as well as into the technical analysis. Most importantly, perhaps, is the idea that the scientific method is not the unique method for producing truth (i.e. claims about the world generally agreed as correct) but can be part of process which is also partially political that can produce truth. Thus it is useful to investigate examples of such processes and their constituent parts.[18]

A number of constructivist analyses of air pollution have been conducted, including examinations of both the acid rain assessment process that the technocratic analysts mentioned above have looked at and advice those technocratic analysts offer (Alm 1997; Zehr 1994). Probably the most notable constructionist analysis is Jasonoff's (1990) examination of the standard-setting process of ozone. The assessment and policy examined here is different from these examples because the principal issues are photochemical modeling of ozone its constituent parts (including emissions inventories) and possible emissions control strategies, not standard-setting or acid rain research.

We recognize these approaches and hope that the empirical portions of this paper may eventually be used by scholars in all three of these traditions. In this paper, we hope to provide some understanding of how the US states can work together within the framework of US environmental legislation but with special emphasis on the peer-level relationships, not the relationships between the central government and the states. To this end, we look towards the field of International Relations, which examines the interplay of autonomous (and perhaps increasingly semi-autonomous) jurisdictions.

1.5. Conceptual Framework

Over the last thirty years environmental issues have entered the arena of global politics and taken a central role. Save very early examples of nuisance law-like instances of international law being used to resolve disputes between nations (notably in the case of *Trail Smelter*), international air pollution assessment and policy did not exist prior to the late 1960s, when Svente Oden began to publish on acid rain. However, since then substantial and fairly well-documented programs of assessment and policy have been developed for acid rain and (to a lesser extent) ozone in Europe.[19] (Levy 1994; Connolly 1997; Wettestad 1997) These programs have been developed by several different European nations within a cooperative framework, and thus provide a loose parallel to the situation of cooperation between US states.[20]

While US air quality policy may have begun to move towards less centralization recently, many observers note that the European Union is moving in the opposite direction, and some legal theorists are exploring the concept of environmental federalism in the EU, and the European analog, subsidiary (Axelrod 1994; Dahl 1995; Dahl 1997; Revesz 1997). Much of this analysis centers on the ability of federations of sovereign nations to restrain the autonomy of member states. However, Farber (1997) reminds us that "federalism is not just a restraint on unilateral action, it is also a framework for joint action." (p. 1300) He also notes that rather than developing from contrary motivations, international free trade rules and environmental regulation spring from similar interests, and the regimes to support them inside of federations often rely on the same legal bases. Farber makes a persuasive argument that within a federation, environmental law and free trade rules must be closely coordinated or the federation is likely to be unstable. "In short, environmental and trade regimes are mirror images." (p. 1319)

In this light, the concept of bounded notion of national sovereignty has emerged; this is the idea that an increasingly interdependent international world order tends to change the traditional expectations of what a nation can do (Chayes and Chayes 1995). In order to gain the fruits of

proliferating new international regimes (particularly trade regimes), countries must be willing participants in them, even when there are real costs to doing so. Thus, Chayes and Chayes claim that ". . . sovereignty no longer consists in the freedom of states to act independently, in their perceived self-interest, but in membership in reasonably good standing in the regimes that make up the substance of international life. . . The need to be an accepted member in this complex web of international arrangements is itself the critical factor in ensuring acceptable compliance with regulatory agreements" (p. 27).

This line of thinking has a parallel in the domestic US context, where some of the rationale for national-level environmental law is based on a recognition of economies of scale in production (especially in the case of automobiles) and on respect for the Commerce Clause.[21] This suggests there may be only so far New Federalists can go in devolving power to the states, but that there may well be much more of a role for the EU to play in European environmental regulation if economic (and political) union in Europe proceeds forward.

There is at least one other factor which may distinguish between domestic U.S. and international environmental regimes, where the authority to establish standards rests. Again, within the US this is a contested issue, but the current and long-standing policy for air quality is for the federal government to set uniform health standards for the entire country plus more restrictive standards to protect pristine areas. Internationally, this sort of practice is not so common, nations often reserve this sort of power for themselves. However, in Europe there has been a tendency over the last 20 years to establish European-wide air quality standards through the EU.[22] Importantly, these standards are supported by arguments about the rights of "European Citizens" to a clean (or at least healthy) environment, much as the US standards are supported by rights-based arguments.

For our purposes, therefore, European nations in the 20th century are increasingly bound by norms and many entangling agreements into joint action, but generally without an authoritative central government. But in some cases, the EU has increasingly gained centralized power, and it seems likely that this trend will accelerate in the future. In contrast, the US has a strong federal system for air quality management which is coming under pressure to decentralize, and arguably has begun to do so. Further, these debates both involve arguments about the rights of citizens. This suggests that comparisons between US domestic assessment and policy can be reasonably compared to similar European activities.

This paper will compare the assessments and policies developed in Europe under international regime, the 1979 Long-Range Transport of Air Pollution Convention and its Protocols (LRTAP) and by the European Union (EU) and those developed under domestic US effort the Ozone Transport Group (OTAG). To look at these two at the same time places us in a difficult position, since the US government is at once only a single member of one international regime (LRTAP), a non-member of the other (EU) and the superior partner in the federal system which frames domestic assessment processes and policy (OTAG). Thus we cannot avoid the question of how these two dynamics interact, that is how do (near-)simultaneous international negotiations and domestic policy-making on an issue proceed? Further, how do the assessment processes which support these activities interact with each other? To the first of the two questions, the idea of a two-level game, first advanced by Putnam is appealing. (Putnam 1988) In this approach the 'chief of government' bargains simultaneously at the domestic and international levels, and each 'move' taken in any one sphere has effects in both. The focus is on the constrained but still semi-autonomous executive (and his/her deputies), an approach which tends to reify the "nation".[23] That is, it ignores the fact that the "executive" is actually made up

of a group of key decision-makers who do not have uniform views and attempt to influence the chief executive in one direction or another. Thus the problem is essentially about how the executive comes to identify its own interests. Putnam and others who work with the two-level game approach readily admit this deficiency, and in a recent book Hopgood attempts fairly successfully to advance the two-level game theory towards a model which can explain the formation of interests, using a case of US environmental negotiations. (Hopgood 1998) While we cannot avoid this question of the interactions between international and domestic environmental policy processes and have here hinted at theoretical approaches which may illuminate it, we must defer any significant effort to resolve this question for the time being.

Taken as a whole, these ideas suggest that the processes by which multi-jurisdictional environmental policy takes shape may be growing more similar in the international and domestic arenas, and that it is impossible to separate them in any case. Further, it appears that neither a fully centralized (or strong federal) system nor a fully decentralized (or anarchic) system is useful in characterizing emerging orders in which environmental policy will be made in the future, either in the US or internationally. However, we still need an adequate theory to shape our explanations of these emerging systems, and to provide routes for fruitful, rigorous inquiry into them. What we are searching for is a theoretical approach to understanding institutions which are effective in producing hoped-for social responses to multi-jurisdictional air pollution problems in cases in which the jurisdictions are peers. One very appealing way of looking at the problem is the work on international environmental regimes led by Robert Keohane. This approach, most fully laid out in *Institutions for the Earth* provides not only a theory which can be applied here, but is also accompanied by a body of research upon which this paper can build (Haas, Keohane et al. 1994). Specifically, the work on European acid rain under the LRTAP and EU conducted by Mark Levy and Barbara Connolly cover topic areas close enough to those discussed here that we might usefully apply the insights developed in their work to understand our own. (Levy 1994; Connolly 1997)

Very briefly, Haas, Keohane, and Levy (HKL) note that it is very difficult to determine the effectiveness of institutions and processes such as assessments because there are so many confounding issues. However, they identify three conditions which must be met for effective international environmental management: government concern, a hospitable contractual environment, and political and administrative capacity—the three Cs. Thus HKL write that "[i]nstitutional effectiveness . . . can be assessed by judging the extent to which they perform functions that boost the three Cs." (p. 21) Thus, we will look to see if the ozone assessment/policy apparatus (i.e. the total institutional arrangement participating in the assessment process) in the US and in Europe was capable of boosting the 3Cs in the jurisdictions (i.e. US states or European nations) each were trying to serve.

To be more specific, we will be looking for government concern with understanding and solving the ozone problem, and specifically the transboundary characteristics of the problem. We will be looking for an environment where agreements to monitor, model, and manage tropospheric ozone concentrations (in particular to agree to decreases in precursor emissions) have become easier to make and rely on. And we will be looking for capacity to perform those activities in each jurisdiction.[24] These three conditions will be sought in the OTAG participants, and in the participants in European ozone assessment and policy.

The next step is to describe the institutional arrangements of interest (called the assessment apparatus) and the relevant activities in the US and Europe in the following two sections.

2. Air pollution assessment and policy in the Eastern United States

2.1. Assessment Apparatus

This section will discuss the legal, institutional, and political arrangements which provide context for the air pollution assessment and policy in the United States. These arrangements are quite large and complex, involving a multitude of laws, dozens of organizations, and thousands of people, which will collectively be referred to as the "apparatus." As a world leader in scientific efforts, the United States has a significant scientific apparatus, including a large research university system (which essentially operates as a set of competing private entities in this regard), government assessment organizations and sponsors, and an important private capability to fund and conduct assessments. This section will discuss the US assessment ozone apparatus as it existed prior to OTAG, new additions since early 1995 will be discussed below.[25]

2.1.1. Public

2.1.1.1. Federal

The earliest and still one of the most important parts of the US assessment apparatus is the system set up within the US Department of Agriculture dating back to 1860. (Rawson 1993) For pollution-related research, the most important government sources of funding at the Federal level and include the National Science Foundation, the Environmental Protection Agency, environmentally-related units within the various Departments including Energy, Agriculture, Interior, and Commerce, and the Congress itself. Of these, the EPA is by far the largest source of funding, contributing to basic science, model development, implementation guidelines, and integrated assessments. It is not only the size of the investment in research and assessment that matters; as the top environmental regulator in the nation, EPA's opinions are generally regarded as authoritative relative to the opinions of others (this is not to say that the EPA's opinions are not widely criticized or the subject of lawsuits), and the courts frequently defer to the Agency's expertise. Simply put, the Agency's statutory role in the enforcement of environmental statutes in addition to its large share of ozone research and assessment funding give it a preeminent role in the field.

Congress has historically funded some of the most important assessments in terms of shaping national legislation, including *To Breathe Clean Air, Catching Our Breath: Next Steps for Reducing Urban Ozone,* and *Rethinking the Ozone Problem in Urban and Regional Air Pollution* (The National Committee on Air Quality 1981; Office of Technology Assessment 1989; National Research Council 1991). Increasingly, air quality legislation requires specific assessments, often naming the National Academy of Sciences (NAS) to conduct these efforts. The NAS (and to a much lesser degree, the more recently-formed National Academy of Public Administration) is an important part of the assessment apparatus because one of its main functions is to provide consensus reports by committees of senior scientists on issues of relevance to Congress.

Finally, the US Department of Energy operates a number of National Laboratories, which were originally organized to support the development of nuclear weapons during the Second World War. Some of these labs, especially Oak Ridge National Laboratory, Argonne National

Laboratory, and Brookhaven National Laboratory have contributed to our understanding of the ozone problem.

2.1.1.2. State-level

State activities related to ozone are important, especially those conducted by California and to a lesser degree those conducted by several Northeastern and Midwestern states. California has developed a substantial ozone assessment capability, some of which resides within the state university system (especially at UCLA, UC Riverside, and UC Berkeley) and the California Institute of Technology, a private institution, and some of which consists of state or regional bodies. Examples of the latter include the California Air Resources Board (CARB), the South Coast Air Quality Management District (SCAQMD), and the Bay Area Air Quality Management District (BAAQMD). CARB's support of research and assessment (sometimes conducting assessments itself) pre-date the existence of the EPA and any federal work on ozone. It is second only to EPA in both the amount of funding it provides for ozone research and assessment, and the clout it wields in policy-making. Because California began to research ozone and regulate automobile exhausts before the federal government, and partially because California has often been seen (perhaps incorrectly) as a special case, the state has been allowed under the Clean Air Act to develop air pollution policy for itself. In addition to this statutory authority, California has 10% of the US population, more than 10% of the US economy, a leadership position in culture, all of which combine to give CARB and other Californian agencies a position in air pollution assessment and policy-making second only to the EPA.

Outside of California, several important multi-state assessment bodies existed, especially the NorthEast States for Coordinated Air Use Management (NESCAUM) and the Lake Michigan Air Directors Consortium (LADCO).[26] Both of these organizations have quite considerable expertise and assessment capability, especially LADCO, which was the primary focus of the OTAG modeling efforts. A few state agencies have devoted considerable time and effort to ozone research and assessment, particularly Texas and New York. Some of the worst air quality outside of California is in Texas (around Houston) and the state has long claimed that its ozone problems are different from the rest of the nations (partly due to the huge petrochemical complexes there). The Texas Natural Resources Conservation Commission (TNRCC) has developed considerable analytical capability over the last decade or so, and has sponsored considerable research. Similarly, the New York State Department of Environmental Conservation (NY-DEP) has considerable analytic capability and, along with NESCAUM, formed one of the other focus points for OTAG modeling.

Importantly, prior to OTAG virtually the only institutionalized mechanism by which the States could communicate was the professional associations of state- and local-level officials, the State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials (STAPPA/ALAPCO).[27] These organizations mainly help government air pollution managers coordinate efforts and share information, their main products are guides for compliance with air pollution regulations and compendiums of best practices in air pollution planning and control. Importantly, this organization has traditionally had virtually no assessment capability and has not produced any guides or handbooks on atmospheric modeling or any other assessment activity. However, STAPPA/ALAPCO does testify before Congress and the EPA from time to time.

It is important to note that for the purposes of this paper, we consider the planning documents which State environmental agencies must prepare under the requirements of the CAA

to inform the EPA of the steps they will take to achieve clean air standards—State Implementation Plans, SIPS—as assessments. Since almost all states need to devise some sort of SIP, nearly all state environmental agencies can be considered to conduct assessments, however the level of sophistication varies greatly across the country.

Many State universities are important parts of the US assessment apparatus, but because they act more like private institutions than arms of State universities that they will be considered in the next section.

2.1.2. Private

2.1.2.1. Non-Profit

Significant private sources of research funding exist in the United States. Private philanthropies like the MacArthur, Heinz, Mellon, Ford, and Rockefeller Foundations provide some funding, but they generally find air pollution assessment uninteresting and are not very significant. A few private research organizations conduct environmental assessments of one sort or another, including Resources For the Future, Battelle Memorial Institute, and the Tellus Institute. However, they mostly conduct economic or technology-feasibility studies, not photochemical modeling.

Advocacy organizations, which primarily attempt to influence legislation, often sponsor or conduct assessments or assessment-like studies. Advocacy organizations come in a variety of types, from the Natural Resources Defense Council (NRDC, an environmental group) to the American Automobile Association (AAA, which represents drivers) to the American Petroleum Institute (API, a trade group), to the Utilities Air Regulation Group (UARG, a set of electric power companies represented by a powerful Washington law firm). These groups often produce reports and studies which receive significant coverage in the media, but are not subject to peer review and are thus very different from assessments by government science advisory bodies or the NAS. Indeed, assessment products produced by these groups are often accused of being mostly advocacy and sometimes "unscientific".

Universities (and individual faculty members) form an important element of the US assessment apparatus. Most of the peer-reviewed literature is dominated by university faculty, and university research is generally regarded as the most objective and least "tainted" by interests. Universities tend to focus mostly on fundamental research rather than assessments, but assessment leadership is sometimes dominated by university researchers (this is especially true of NAS studies). Several university-affiliated activities are worth mentioning due to their prominence and level of activity. The Center for Air Pollution Trends, Information, and Analysis (CAPITA) at Washington University in St. Louis is a long-standing program that collects and analyzes air quality (i.e. monitoring) data, an activity called Air Quality Analysis (AQA). Several universities in California have very significant assessment capabilities and have some of the longest histories of ozone research and assessment, particularly the California Institute of Technology (CalTech) and the Statewide Air Pollution Research Center (SAPRC) at the University of California, Riverside. The University of North Carolina—Chapel Hill is also important for its work on both basic science (especially smog chamber studies) and policy analysis. [23] The State University of New York in Albany (SUNY) has been very active in

2.1.2.2. Corporate

A significant amount of research relevant to air quality is conducted by and funded by regulated industries, particularly automobile, electricity, and petroleum firms. In some cases, individual companies maintain in-house expertise and capability, notable examples include Ford, General Motors, Exxon, Southern California Edison (SCE), Public Service Electricity and Gas PSE&G), the Tennessee Valley Authority (TVA), and the Southern Company. In other cases, sectoral research groups develop capabilities and fund research, most notably the Electric Power Research Institute (EPRI) and the Coordinating Research Council (CRC). As with government and universities, Californian industry leads the way with SCE, PSE&G, and the Western States Petroleum Association (WSPA). Californian industry has been involved in ozone assessment longer than industry elsewhere and is generally more capable and familiar with ozone assessment.

Lastly, consultant firms often provide technical analysis on environmental issues for a wide variety of clients. Indeed, as discussed in an accompanying paper, some of the most important components of ozone assessments have been conducted by a small number of people acting through several different firms over the years (see Keating and Farrell). In some sub-specialties, much of the expertise in assessment lies with consultants, including detailed industry data and photochemical modeling. Consulting firms often have strong links to the academic community, either hiring them as sub-contractors or having academics as founders and partners of a consulting firm. The names of these consulting companies and their relationships frequently changed over the years as they were formed, grew, were bought up, and closed, but the individuals who conducted the assessments often stayed the same. Of these consultants, Science Applications International (SAI) deserves special mention because it is the firm which developed the principal photochemical model in use in the United States, the Urban Airshed Model (UAM). SAI also conducts air pollution analysis for many different clients, both regulators such as the EPA and the regulated community such as UARG. Interestingly, the issue of conflict of interest at SAI has apparently not become significant.

Industry invests significant resources into ozone assessment, some of which is proprietary and will probably never become widely known. Other studies, particularly consultant efforts funded by regulatory bodies such as the EPA, become widely used by many parties. Interestingly, assessment tools, such as models, developed by industry rarely have an impact. The exception to this is UAM-V, which was the model used in OTAG.

2.1.3. Joint efforts

A striking feature of US ozone assessments is that many of them are joint efforts with participation across a broad range of organizations, both public and private.[29] As an example, the leadership of the three most prominent national assessments mentioned above are shown in the table below:

Leadership of major national US ozone assessments

	Academic	Government	Industry	Private Research	Advocacy
To Breathe Commissioners*	0	7**	1	0	2
Catching Advisory Panel	7	2	4		3
Catching Contributors and Reviewers	15	43	33	4	1
Rethinking Committees	47	9	9	6	1

* Three Commissioners have no affiliation listed and it is not clear who they are.
** These Commissioners are politicians (Senators, a mayor, etc.). In addition, 45 government employees staffed the assessment effort.

The specific composition of these assessment efforts varies quite a bit, partly because they are from different periods, and partly because they were constituted differently. Nonetheless, it is clear that they all had fairly broad participation. In fact the NAS study which resulted in the *Rethinking* publication was partly funded by the EPA, API, the Department of Energy, and the Motor Vehicle Manufacturers Association of the United States. This pattern of joint sponsorship of ozone research and assessment stretches from nearly the beginning of the history of the problem. While the very earliest efforts at assessing what later became know as the ozone problem were single-sponsor (and sometimes highly contentious, see Krier and Ursin, pp. 80-84), the founding of the Air Pollution Foundation in 1953 marked the earliest joint industry-government ozone research effort.

Since the founding of the APF some of the most important ozone research and assessment efforts have been jointly-funded and operated. Three industries have tended to be most involved, the automobile (generally either Ford or GM), the petroleum (often operating through API or WSPA), and the electric power (often operating through EPRI). Some semi-permanent cooperative organizations involved in ozone assessment have been formed, such as the Coordinating Research Council (CRC) which brings together representatives from the automobile and petroleum industries the Society of Automotive Engineers (SAE), and government to coordinate existing research programs and fund new efforts. The CRC organized one of the largest ozone-related technology assessment efforts the Air Quality Improvement Research Program (AQIRP, or the Auto/Oil study). Other important joint ozone assessment efforts include the Southern Oxidants Study (SOS) which began in 1989 is aimed a coordinating research to understand the ozone problem in the southern part of the US, and Modeling Ozone Cooperative Application (MOCA) which was designed to apply a sophisticated photochemical model to the ozone problem in the Northeastern United States. MOCA was helped in a large part to develop the modeling protocols which were later used in OTAG.

Currently, much of the ozone research community in the United States is involved in the North American Research Strategy for Tropospheric Ozone (NARSTO), which functions as a forum for researchers and scientific program managers across a broad range of institutions to meet and discuss their individual efforts. NARSTO is nominally a tri-national program, but in practice it is overwhelmingly a US program.[30] NARSTO has no facilities or research capabilities itself, and does not issue it's own reports. A significant exception to this policy is the ongoing development of NARSTO State of the Science report which is made up of a series of critical review papers and a synthesis report.[31]

This assessment apparatus conducts a wide variety of activities. There are at least five different research areas in ozone and at least one type of assessment. Chemistry research

involves the identification and characterization of relevant chemical reactions including the use of "smog chambers" (Atkinson 1998; Dodge 1998). Field campaigns involve the measurement of chemical and meteorological parameters in the ambient environment (Solomon, Cowling et al. 1998). Effects research includes human health risk assessment activities, plus investigations into the impacts of ozone on crops, vegetation, and materials (U.S. Environmental Protection Agency 1986). Engineering research involves the development of emissions inventories and efforts to characterize (and improve) emissions control technologies, including pollution prevention (STAPPA/ALAPCO 1993; STAPPA/ALAPCO 1994; STAPPA/ALAPCO 1996; OTAG Emissions Inventory Workgroup 1998) Model development research is aimed at producing useable computer simulations of the atmosphere which can be used to better understand the ozone problem and possible solutions to it (Russell 1997; Keating and Farrell 1998)

Of course, the assessment apparatus also conducts modeling studies and other forms of integrated assessment, which can now be discussed with this basic description of the apparatus in as background.

2.2. 1967 - 1990: Mixed success and seeds for failure

By the late 1960s the environment had become a key issue in national affairs, compared to its virtual non-existence as a national issue in 1960.[32] Cause and effect is difficult to determine at this point, but at the same time national political figures such as Senator Edmund Muskie and President Richard Nixon seized upon environmental issues and seemed to position for competition for the environmental voter. Local and state-level efforts to reduce air pollution were decades old, but most had been ineffective in producing a clean environment. and for a variety of reasons the nation turned towards national-level solutions to environmental problems. In 1967 the US saw the first use of regulatory mechanisms in national air pollution regulation when the Secretary of the Department of Health, Education, and Welfare was directed to set emissions standards for new motor vehicles. However it was the amendments to the Clean Air Act in 1970 that was the real watershed in air pollution policy, it set the basic frame for virtually all ozone and acid rain control in place today.

By this time, only the basics of the physical problem of photochemical smog formation were understood; ozone had been identified as a chief pollutant, NOx and VOC emissions were understood to somehow cause ozone under certain stagnant weather conditions, and many important sources of NOx and VOCs were known. However, the actual chemistry of ozone was not understood, nor was the possibility of long-range transport of ozone and its precursors considered, and the potential importance of stationary NOx sources was ignored. For example, the Department of Health, Education and Welfare felt that "instances of troublesome intestate air pollution are few in number. . . unlike water pollution, air pollution is essentially a local problem."[33]

In addition, the policy-oriented literature of the time shows a clear tendency to emphasize the importance of automobile emissions over stationary-source emissions. For instance, Davies and Davies emphasize the need for reductions in transportation-related emissions over controls on stationary sources even though the latter had over three times as many emissions when weighted for effects (1975 pp. 21-22). Interestingly, the reason given is that mobile-source pollution is probably most concentrated in urban areas. Similarly, Kneese and Schultze emphasize the importance of sulfur emissions from stationary sources and ozone precursor emissions from mobile sources, citing Haagen-Smit's original work in the late 1940s and 1950s

(1975 p. 46) Finally, they note the very low standing of the automobile industry in the late 1960s as an important factor in the focus on mobile source controls (pp. 48-50.)

These tendencies may seem to be shortcomings in some sense, but it is hardly reasonable to judge efforts of a quarter-century ago against contemporary knowledge. Moreover, these tendencies have good reasons for being. The motivating examples for air pollution came in two sorts, extreme urban pollution events such as Donora, and the photochemical smog of Los Angeles. Urban episodes tended to be very localized events which occurred during periods of stagnant air trapped under local temperature inversions, while the problem in Los Angeles had been identified by the APF as largely due to automobiles. In addition, urban areas had just emerged from under a long-standing cloud of smoke pollution. Thus, the characteristics of the air pollution problems which were best understood at the time seemed to appropriately focus the control of photochemical smog on autos while stationary sources were seen to be mostly sources of smoke. Still, the APF reports indicate the stationary sources are important, and it is not clear why this was generally ignored in policy.

Due to the variety of source types and changes in scientific knowledge and emissions control technology from different source types (including changes in the cost of doing so over time), ozone controls have evolved significantly over the last 30 years. Table 1 illustrates some of the major trends in this evolution as seen in the US federal legislation; a steadily increasing federal role, an early focus on mobile sources, an early focus on VOC controls (lasting until the 1990 Clean Air Act Amendments), increasing prescriptive control programs, and increasingly detailed levels of planning.[34] It is important to distinguish between regulations on mobile sources and regulations on stationary sources. For mobile sources, the CAA splits the regulation of tailpipe emissions between the federal government (the EPA), which controls new vehicle standards, and local governments (state and some county or municipal bodies), which control maintenance requirements of in-use vehicles. Stationary sources are controlled mostly by the federal government through an approach called conjoint federalism in which the Federal government sets air quality standards and the states implement the policies needed to achieve that standard.

A crucial part of this approach is the use of the State Implementation Plan (SIP), which states are occasionally required to prepare and submit to the EPA for approval. A SIP defines what steps a state will take to achieve the National Ambient Air Quality Standard (NAAQS) by a date required by law. Most programs in a SIP will affect the operation and inspection of motor vehicles (but not the tailpipe standards for new cars), transportation planning activities, and regulations for existing sources. (The EPA regulates new sources directly with New Source Performance Standards and New Source Review requirements.) A state "demonstrates attainment" with a SIP by modeling the effects of the control programs in its SIP on emissions and ambient pollution concentrations to show that these concentrations will eventually meet the NAAQS.

Importantly, the SIP planning process is an assessment process. Over the last 20 years, the level of detail and analysis required for such an attainment demonstration has increased significantly, and currently photochemical grid modeling is usually required (see Keating and Farrell, section 4.2). But a SIP involves more than just an air quality model, it also includes emissions estimates, engineering estimates of available control strategies, economic models of future growth, transportation demand models, and other such efforts. Effects modeling is generally not included in SIP planning and neither is economic modeling, rather the goal is to

demonstrate that the standard for ambient concentrations of ozone is attained and maintained. Except for effects modeling, however, SIPs can be considered an integrated assessment process.[35]

However there is an essential problem with the CAA in that states are treated as entirely individual in the SIP planning process; a framing held over from late-1970s thinking about the ozone problem, informed entirely by the experience in LA and codified in the original 1970 CAA. However, in the rest of the country ozone is a regional problem; northeastern states are actually part of a "river of ozone", and southeastern states are part of a "rising tide of ozone". The realization that the physical nature of the problem was different in the eastern part of the country emerged in the scientific literature slowly over the last two decades (as described in Keating and Farrell section 4.1) but the legal and political framework for ozone control is still struggling to adapt. Further, with every set of amendments to the CAA, the Congress has written increasingly prescriptive requirements into law, reducing the choices left to the states and causing significant conflict. (Novick and Westerfield 1994)

However, the CAA has other significant flaws as well, most importantly that it relies on 19th century ideas of dispersion and dilution through the use of tall smoke stacks as adequate means to deal with pollution. As Revesz (1996, pp. 2352-2358) discusses in great detail, the 1970 CAA 1977 amendments actually reward the use of tall stacks by permitting more pollution the taller the stack. This is despite the fact that evidence of long-range transport of ozone (in Europe as well as the United States) were already appearing in the scientific literature, and numerous conferences on long-range air pollution were being held. (Stasiuk and Coffey 1974; Cox, Eggelton et al. 1975; White, Anderson et al. 1976) Thus it is not surprising to see the number of stacks over 500 feet tall go from 2 in 1970 to 203 in 1985 (of these, 23 were over 1000 feet tall).

Despite its problems, the CAA was responsible for significant progress in reducing air pollution in the 1970s and 1980s, but most of these improvements were in lead, sulfur, and carbon monoxide levels. Ozone levels declined somewhat but in most urban areas they remained above national standards. In terms of ozone precursors, the old frame of ozone as a strictly urban problem which could be adequately addressed by local VOC controls, most of the cuts in emissions came from the mobile source sector. New cars were required to become much cleaner, largely due to the introduction of catalytic converters and unleaded gasoline in the late 1970s and reformulated gasoline (RFG) in the 1990s. However, existing stationary sources, major sources of NOx were not controlled. Many of those same sources did come under sulfur dioxide controls due to local problems with ambient SO2 concentrations (not acid rain) and thus these facilities responded with very tall smoke stacks.

Since the late 1970s, research on tropospheric ozone has grown steadily, and our understanding of the problem has become much greater. Over the last ten years, a number of important US summary assessments on ozone have been conducted, especially the Office of Technology Assessment's *Catching Our Breath: Next Steps for Reducing Urban Ozone* and the National Research Council's *Rethinking the Ozone Problem in Urban and Regional Air Pollution* (Office of Technology Assessment 1989; National Research Council 1991). Both of these documents were developed as the most recent round of Clean Air Act Amendments were being drafted and had substantial impacts on the text of the amendments. More recently a number of physical science assessment efforts have been carried out (and continue now), most notably the North American Research Strategy for Tropospheric Ozone (NARSTO) and the Southern Oxidants Study (SOS) (Cowling and Chameides 1995). These two efforts have engaged many of the scientists and research institutions which in the 1970s and 1980s produced the information

reviewed in *Catching* and *Rethinking*, and represent part of a long-standing stream of scientific assessment efforts which have helped shape our understanding of the problem.

2.3. 1990 - 1997: Adaptation and crisis

While the CAA was due to be reauthorized and revised in 1981 it was not, and by 1988 progress on reducing ozone levels in the US had slowed to a crawl. Environmental advocates and Congress were frustrated and the provisions in 1990 CAA Amendments contained important adaptations which broke new, but somewhat troubling ground.

In terms of the regionality of ozone, the creation of the Ozone Transport Commission (OTC) was an important step (101st Congress 1990) §184).[36] Made up of 12 states in the Northeast — from Virginia and West Virginia north — and the District of Columbia, this body mostly functions partially as a coordinating and negotiating group for regional ozone policy. In creating the OTC the Congress acknowledged and responded to the regionality of ozone, a great advance over the previous legislation.[37] The responsibilities and authorities created under the conjoint federalism of the Clean Air Act do not change due to the creation of the OTC, ambient standards are still set by the federal government and most implementation steps (save new vehicle emissions enforcement) are conducted by the states. However, the Commission allows the member States to coordinate assessment and planning activities. Ultimate responsibility for attaining the air quality standards still lie with each state, however, and plans made at the OTC level are implemented within each state individually. These decisions are generally made by majority vote. So far, these decisions have been implemented through Memoranda of Understanding (MOU), which a state can choose to sign or not to sign.

One potentially troubling part of the OTC language in the 1990 Clean Air Act Amendments is that mandatory controls (VOC RACT requirements and enhanced Inspection & Maintenance programs) are required within the region (US Congress, 1990 § 184, 176A).

In addition, the OTC states have the statutory power to petition the EPA to hold them individually accountable for decisions made at the OTC level. Under this procedure, a state which did not want to adopt a particular control program would vote against the OTC adopting it and against a petition to the EPA. If both votes went the other way, the state could find itself mandated by the EPA to implement the control program it had voted against twice. It is not clear at this point if this power will survive judicial review. Currently Virginia has chosen not to adopt the OTC MOU on NOx controls from stationary sources and has successfully defended in court its decision not to implement a low-emissions vehicle (LEV) program which was put into place via the petition process.

In some ways the OTC has been quite successful—plans for deep cuts in both mobile stationary source emissions (far beyond anything contemplated elsewhere in the nation, save California) and other responses to the ozone problem are now going forward. Several of the most obvious accomplishments of the OTC are shown in Table 2. As an initial estimate, it appears that most of these accomplishments would not be possible for the OTC states to accomplish independently (as indicated on the table), and their achievement points towards substantial effectiveness.

As an initial application of the 3Cs theory developed by HKL to evaluate sub-national multi-jurisdictional environmental efforts, we could examine whether the OTC improved the three conditions for the OTC states. It appears that this is the case, but a complete analysis of the question would probably be a sufficient task for another paper and will leave it for further

research. However, a few comments should be made nonetheless. The first comment is that it is difficult to evaluate the OTC under the Concern criteria since the existence of the Clean Air Act and the potential sanctions for failure to meet (or move towards meeting) the NAAQS forces concern at the state level. Further, OTC is actually the *result* of concern about ozone transport on the part of Congress, or at least the representatives of the states in the OTC (save the District of Columbia, which is not represented in Congress). The idea of transport was fairly well-understood in the northeastern states before the OTC came into being, so it is difficult to say anything about concern. Nonetheless, a review of the OTC meeting materials and minutes shows that confidence in the reality of transport, understanding of the specific dimensions of transport, and the importance of NOx transport to ozone formation and other environmental problems (notably fine particles and eutrophication) increased substantially from early 1995 to mid-1998.

Evaluating the contractual environment of The OTC is easier. Prior to the OTC no inter-state cooperation on emission control programs existed, with only minor exceptions.[38] The success in launching both stationary and significant mobile source NOx control programs is clear evidence of an improved contractual environment. Further, the regular contact at OTC meetings by both technical staff and political leadership (especially state environmental commissioners) improves their ability to rely on each other in creating lasting agreements. The regular and standardized sharing of data and technical capabilities similarly supports this view. Finally, the participation of the member states as a group in negotiations with other organizations (such as the auto manufacturers) improves the ability of the states to bargain by creating a collective position which all can be assured will be supported by the entire group.

Similarly, it is easy to observe an increase in political and administrative capability within each of the state governments. This is most notable in terms of technical capabilities.

Nonetheless, it is important to note that the achievements of the OTC have not been unqualified. Two significant problems stand out. First, most of the states in the OTC have fairly similar ozone problems; most experience ozone concentrations significantly in excess of air quality standards and are both upwind and downwind relative to other states. Thus, their interests in collaborating for a joint solution are fairly uniform. Interestingly, the states which do not fit this pattern, and especially the states at the upwind and downwind extremes of the OTC (ME and VA) appear to be participating less fully in the OTCs efforts, especially those which involve costly or unpopular emission control efforts. The second qualification relates to the expectations of Congress and the National Research Council that the EPA (or possibly the states themselves) would join the OTC or similar bodies formed elsewhere in the country. This has not happened, and the reason is fairly clear, the Amendments place substantial mandatory NOx control requirements on the OTC states. Any state which joined the OTC or similar organizations would have similar burdens placed on it and this had made the prospect of joining such a group unattractive.[39]

While the OTC was an important positive step, the 1990 CAA Amendments also had a number of notable failures which helped precipitate a crisis in US air quality management in late 1994. The new SIP provisions contained a large number of mandatory programs which the Congress required various non-attainment areas to put in place, depending on the severity of their ozone problem. Several of these turned out to be (often with the help of daytime talk radio programs) wildly unpopular, and were largely revoked by public outcry in 1994, including the Employee Commute Option, Enhanced Inspection and Maintenance, and Reformulated Gasoline. (Aeppel 1995) Indeed, the backlash to various federal air quality programs (those aimed

principally at the driving public) was so significant that this became an issue in several elections in the 1994 national elections at the state legislature, Governor, and Congressional levels.

"Intrusive federal environmental rules" were a general theme of the 1994 elections, and a major part of the highly successful election strategy of the Republican Party. Many different environmental issues were under fire at the time, but about half of the nation lived in areas where these mobile source emissions control programs could have been applied, so they may have been some of the most politicized of environmental issues in the 1994 campaign season.

To compound that problem, the new SIPs, prepared in response to the new 1990 Amendments were due in November of 1994. States had not prepared SIPs since 1988, when minor modifications to their previous efforts in 1980 had been submitted. Thus, the states had not needed to demonstrate attainment for 14 years, that is, they had not needed to perform an assessment of emission control strategies needed to decrease ozone concentrations for over a decade.

During that 14-year interlude many things had changed; the scientific understanding of the ozone problem had dramatically changed and the quantitative models used in the ozone assessment process had significantly increased in size and complexity. Rapid increases in motor vehicle use, increased economic activity (i.e. increased ozone precursor emissions), the spread of commuting and production into from urban areas to formerly rural (and now suburban) areas, the imposition of significant VOC control programs and a gradual shift in the profile of NOx sources (i.e. from the mobile source sector which was now being controlled, to the stationary source sector which was largely uncontrolled) from 1980 to 1994 may have changed the character of the ozone problem itself. The capacity of state staff to forecast ozone concentrations with models declined, although other capacities (such as transportation planning, monitoring, permit writing) improved. California, the EPA, and the research community had continued to push scientific exploration and assessment tool (eg. ozone model) development forward dramatically.[40] Some states and joint state ventures had kept up, notably New York, the Lake Michigan Air Directors Coalition (LADCO) and the Northeast States for Coordinated Air Use Management (NESCAUM), but during the 1980s most state air quality management offices had focused on the implementation of emissions control programs. Further, this focus on in-state emission control programs and the absence of a need to perform air quality emissions modeling caused state air quality staff lose much of the overall perspective on the ozone problem they once had. Given these changes in the science, possible changes in the character of the physical problem, and the increasingly outdated technical capacity in state air programs, the mental models of the ozone problem held by state professionals trained in the 1970s and early 1980s may not have matched the actual problem in 1994 very well.

Thus, the task of preparing a SIP for 1994 turned out to be very difficult and by early 1994 many states had come to believe that due to upwind emissions in other states demonstrating attainment would be nearly impossible short of curtailing nearly all ozone precursor emissions in their own state. For some, this is tantamount to halting all economic activity in the state.[41] And submitting a SIP which failed to show attainment presents only a slightly less disturbing option - a Federal Implementation Plan (or FIP), which the EPA is empowered in the CAA to devise for states when conditions warrant.

November came and went. The nation received a new and radicalized House of Representatives under the leadership of Newt Gingrich, and the EPA received exactly one State

Implementation Plan showing attainment. From Louisiana. Across the eastern part of the United States a crisis in air quality management had begun.

In January of 1995 the EPA hosted a two-day "All States" meeting, a recently introduced mechanism to bring the heads of all the state, tribal, and territorial environmental departments together in Washington DC to meet with senior EPA staff. Interviews with numerous participants in that meeting have used the words, "heated", "fireworks", and "angry" to describe the mood of the states during the session on air quality with Mary Nichols, the Assistant Administrator for Air and Radiation. They complained about an impossible task, inadequate resources, inflexible rules, and, in many cases, about unfair emissions from upwind states making attainment demonstration impossible. This session served not only to inform the EPA about what was going on in the states; what their assessments were turning up and why they had not submitted SIPs, it also served to inform the states themselves about what was going on across the country in other air management offices. There was most likely some prior communication between the technical staff of different states, possibly through their professional association. However, it is clear from the interviews we conducted that the Commissioners (who are political appointees, not civil servants) became aware for the first time about the scope of the problem and many state-level technical people learned a great deal in that session as well. Also at that meeting, the Commissioner of the Illinois Environmental Protection Agency (ILEPA), Mary Gade, approached senior EPA staff and offered to head up any sort of committee they would set up to discuss the matter further.

On March 2nd of 1997 Mary Nichols issued a memorandum inviting the states to join in an "alternative approach" and "participate in a consultative process to address regional transport," to allow "EPA and the affected states to reach consensus on the additional regional, local, and national emission reductions that are needed for the remaining rate-of-progress requirements and attainment" (Nichols 1995).[42] Previous to this memo, Mary Gade had already agreed to chair such a consultative process, and so OTAG was born.

2.4. The Ozone Transport Assessment Group

It became obvious in early 1995 that there is a considerable transport of ozone and ozone precursors in the eastern United States, and that this transport would make it virtually impossible for states to comply with the CAA and submit SIPs explaining how they would meet the air quality standard. The problem can be most easily explained by thinking of ozone concentrations at any location as being comprised of a combination of contributions from various sources. Thus, elevated precursor concentrations at state boundaries cause situations such as those illustrated in Figure 1, Case 1 or 2. To address this problem, the Ozone Transport Assessment Group (OTAG) was formed by the recently-created Environmental Council of States (ECOS), a national organization based in Washington, DC.

OTAG was organized (largely by Mary Gade and her staff in the ILEPA, and Bob Shinn of New Jersey) in the spring of 1995 and had it's first meeting that May. Following that beginning, participants met regularly for the next 25 months in an enormous variety of meetings, conference calls and Internet interactions. The volume of email traffic and material transmitted via the World Wide Web (including many lengthy debates, hundreds of color images, white papers, logistical information, and animated model results) during and after the OTAG process is truly staggering.[43] The final report of OTAG is currently available on the Web: it may never be published, but if it is, it will be published as a CD-ROM. In its use of contemporary computer communications technology it can truly be called a 21st century assessment.

OTAG ultimately included more than 700 individuals representing state and federal government, industry, and environmental groups, including 37 states and the District of Columbia. The states led the assessment with strong technical and financial support from EPA. This state-led process, with significant input and support from industry and environmental groups. A complete and detailed calculation of the total cost of OTAG to all participants does not yet exist, but it is likely to be between $10 Million and $20 Million.

Organizationally was divided into three levels: the Policy Group, Subgroups, and Workgroups, see Figure 2. Each group was responsible for a very specific set of tasks.

Technical data and policy positions were first developed in the Workgroups, co-chaired by state or regional organization representatives and a representative from EPA. In many cases, the Workgroups created subcommittees, often chaired by non-government stakeholders, to address specific issues. When the issues were resolved, the subcommittees were dissolved. Virtually all participants agree that the technical analysis and interaction at the Workgroup level was central to the OTAG process. It was here that stakeholders were able to use their technical expertise in a development process rather than in the responsive process they normally experience when dealing with environmental agencies.

The Workgroups reported their data and policy positions to their respective Subgroups, where debate was robust because of the inclusion of participants who had not worked within a particular Workgroup. The Subgroups provided the forum for all participants to express their positions, discuss the pros and cons from all points of view, and develop the compromises that became an inherent gelling factor for OTAG. The Subgroups reported directly to the Policy Group. Minority views were also reported when expressed. Debate in the Policy Group occurred, for the most part, among participants of that group, although others were recognized and their views included in the Policy Group's deliberations.

In terms of process, the Policy Group proceeded on a consensus (i.e. unanimity) basis except for the final recommendations, which are discussed below. Where issues were particularly vital and not all participants at a Policy Group meeting agreed, objections were noted. For the final recommendations, the Policy Group developed a process by which each state cast a vote.

Several technical achievements of OTAG stand out: the development of a consistent and improved emissions inventory across all the eastern states, a very significant photochemical modeling effort which also increased the capacity of several groups to conduct such analysis, and a much more widely shared understanding of the transboundary character of the ozone problem in the Eastern United States (see Keating and Farrell, section 4).

We conducted extensive interviews and a one-day workshop with OTAG participants and observers, see Appendix B. These revealed significant variation in participant impressions and insights into the OTAG process. This data is still being organized and evaluated, and will be used to develop further research products in the future. A more complete analysis of the OTAG process must wait until then, but some initial observations can be made now.

Many believe that OTAG has come to represent a new way of developing environmental policy for other reasons, and we agree with this characterization. While maintaining the ultimate authority in the EPA, the OTAG process was essentially a participatory effort directed by state environmental commissioners. In addition to the commissioners, OTAG also included the active participation of technical and policy staffs from the states and EPA, representatives of potentially affected industrial sectors, and representatives of the environmental NGOs.[44] These latter two

groups collectively were called "stakeholders", although for almost all of the OTAG process NGO participation was very small and industry participation substantial.

In many ways the process developed by OTAG was much more open than most assessment processes used air quality management. Stakeholders were invited to participate in every phase of the development of technical data and the policies growing from them—i.e. everywhere but in the Policy Group meetings, although they could be heard there too upon occasion. Most decisions made in the various OTAG groups were made by consensus, loosely-defined.[45] However, the final results OTAG forwarded to EPA were passed by majority vote by the Policy Group (32 to 5) with one vote per state. Votes were cast first on each recommendation and then on the final package of recommendations. Regarding the total package of recommendations, in some instances the states provided caveats to their votes; written comments explaining the caveats were also included with the final package of recommendations. Subsequent to approval of a recommendation, any stakeholder could submit written comments within 10 days; such comments were included in the package of recommendations forwarded to EPA. See Tables 3 and 4 for conclusions and recommendations.

While these factors do indeed suggest that OTAG marks a significant departure from traditional assessment and decision-making in US environmental policy, others suggest caution in drawing a conclusion too quickly. First, the EPA's response to the OTAG process, embodied in the call for new SIPs in response to the OTAG process has been criticized by many as denying the "spirit of OTAG" and inadequately respecting the OTAG results. (U.S. Environmental Protection Agency 1997; Edgar, Sundquist et al. 1998) In the view of many OTAG participants an appropriate course of action for the EPA would have been to follow the OTAG recommendations as closely as possible and provide justification in cases where it did not. As it was, the EPA's response varies from the recommendations of OTAG in several ways.

However, OTAG's recommendations are problematic as well from this standpoint since they are quite broad, with the key finding (on utility emissions) suggesting a range from the status quo to decreases of 85% on average. This result looks strikingly similar to the type of least-common-denominator result found in international environmental negotiations such as LRTAP. (Boehmer-Christiansen and Skea 1991; Levy 1994) This is evidence that voluntary assessment processes among multiple jurisdictions within a strong federal system may have some similarities to international environmental regimes as described in *Institutions for the Earth*. (Haas, Keohane et al. 1994)

Now to the HKL's framework for understanding effectiveness in multi-jurisdictional environmental institutions, did OTAG raise the 3Cs: concern, capacity, and contracting ease? The initial answer appears to be yes for each. In terms of concern, there are now more state governments that understand and are concerned about the transport of ozone and ozone precursors (this increase is especially noticeable at the levels of the Environmental Commissioner and, presumably, the Governor). Indeed, it appears that a significant part of the success that OTAG achieved is to narrow the range of debate about the existence and extent of transport. While not fully documented here due to space limitations, the results of our interviews and literature review clearly shows a decrease in argumentation about the existence of transport, even by states in whose interest it would be to deny transport exists.

Similarly, capacity to model ozone accurately and engage in substantive debates about transport has also increased in many states. However, political capacity to deal with transport may not have increased much, and it may not be possible for upwind states to develop such a capacity as long as they remain within a strong federalist system where the federal system is

given the responsibility to deal with interstate issues. This view may be part of the reason that one of the main consensus statements from the OTAG Workshop was that while there are a variety of legitimate roles for different levels of government to play, the federal government must have the ultimate responsibility for resolving disputes about transport and it must retain sufficient power to enforce solutions. Interestingly, concern about transport may have gone up most in those states in which capacity to understand it went up most.

The contractual environment has also improved through the extensive networking which occurred during the OTAG process. This may be the strongest outcome for many participants — many spoke strongly of a genuine sense of respect and commonality even amid differences in opinion and interest. As time passes and the direct memories of OTAG fade, this effect will fade as well, but many of the network-building activities (data sharing, cooperation in modeling, and opportunities for informal interaction at conferences and such) continue, and a few have been institutionalized.

This completes a brief examination of ozone assessment and policy in the Eastern United States, next we turn to Western Europe.

3. Air pollution assessment and policy in Western Europe

This section will discuss the legal, institutional, and political arrangements which provide context for the air pollution assessment and policy in Europe. These arrangements are quite large and complex, involving dozens of a multitude of laws, dozens of organizations, and hundreds (perhaps thousands) of people and each will be given the title "apparatus." In order to evaluate the effectiveness of each apparatus, it will be necessary, therefore to identify how each operated to improve the "3Cs" in the target jurisdictions for each one (i.e. the nations of Europe). This section briefly describes the apparatus in Europe.

European air quality assessment policy is fairly complicated because there are several dozen individual nations (the actual number of nations depends on how one defines "Europe") with their own domestic assessment and policy apparatus and two separate international organizations exist, the United Nations LRTAP Convention and the European Union. Since the focus of this paper is on multi-jurisdictional assessments, LRTAP and the EU will be described in this section. But first the European ozone assessment apparatus will be described. It is important to note that many of the organizations in this apparatus have significant roles within the LRTAP framework, which is shown in Figure 3. In addition, some parts of the apparatus are associated with the European Union (EU), a supra-national trade and political organization. Table 5 lists the countries involved, Table 6 lists the LRTAP agreements along with their basic requirements, and Table 7 lists the most important EU legislation.[46]

3.1. Assessment Apparatus

This section will discuss the legal, institutional, and political arrangements which provide context for the air pollution assessment and policy in Europe. These arrangements are quite large and complex, involving a multitude of laws, dozens of organizations, and thousands of people, which will collectively be referred to as the "apparatus." As the source of Western scientific thought with several world-class national scientific infrastructures, Europe has a significant scientific apparatus including many research universities (which generally tend to be more closely associated with government than in the US), several national and EU assessment organizations and sponsoring bodies, and an important private capability to fund and conduct

assessments.[47] It is important to note that the distinctions between components of the assessment apparatus and the roles they play in parts of the international regimes can be confusing. For example, the monitoring network set up for the European acid rain assessment under LRTAP (which is an international effort) is coordinated by a Norwegian institution with participation from national institutions from the other nations which are part of LRTAP. Similarly, the EU contracts some of its assessment activities out to national institutions within member countries.

3.1.1. Public

3.1.1.1. International

Two parts of the European assessment apparatus stand out as the core elements. The first is the European Monitoring and Evaluation Program (EMEP), which coordinates the collection of ambient monitoring data across Europe under LRTAP. In this system each country monitors meteorological and environmental conditions at several sites according to standardized procedures and submits this information to a Meteorological Synthesizing Center (either Eas or West) which then forwards the data to EMEP.[48] In addition, EMEP uses atmospheric chemistry models to develop source/receptor relationships for all of Europe. These source/receptor relationships can be arranged into a transfer matrix (sometimes called a "blame matrix") The EMEP program and model were originally developed to deal with sulfur dioxide emissions and acidifying deposition of sulfur compounds. It has since been expanded to cover other sorts of emissions and pollutants.

The second core component of the European assessment apparatus is the Transboundary Air Pollution (TAP) project at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. IIASA was created in 1975 as a part of the process of détente during the Cold War and was one of the only venues in the world where Eastern and Western European nations cooperated on anything. Among the issue areas which IIASA conducts research is the environment and in 1983 the TAP project was started as part of LRTAP. The principle role of the TAP project has been the development and application of the RAINS (Regional Acidification INformation and Simulation) model, which is an constrained optimization model that solves for emissions and costs for various scenarios and uses the EMEP source/receptor relationships to determine acidifying deposition (or ozone concentration) values corresponding to those emissions patterns (Alcamo et al. 1990). The RAINS model was one of several developed in the late 1980s and early 1990s which were used as centerpieces for the LRTAP negotiations.

The original international air pollution (acid rain) assessment conducted in Europe was performed by the Organization for Economic Cooperation and Development (OECD) in the 1960s and 1970s at the urging of several Scandinavian countries. (Working Party on Methods of Measuring Air Pollution and Survey Techniques 1964; OECD 1968; OECD 1979) While the OECD does continue to conduct environmentally-related research, it does not participate significantly in air pollution assessment, except where they have economic implications (OECD 1990).

Currently, the EUROTRAC effort coordinates a large number of nationally- and EU-funded atmospheric science efforts across Europe, and so is similar to NARSTO. EUROTRAC does not provide funding, and has a very small staff funded by the German Government.

The EU is an excellent example of an international institution that started as a trade union and that has expanded over time into other areas of policy, particularly environmental policy. IT

is a good example of the interdependence of nations who engage in free trade, much as Farber and Chayes and Chayes describe. Several components of the European assessment apparatus are associated with the EU. The structure of the EU is discussed below, so suffice it for now to say there are both decision-making and administrative bodies that participate in air pollution assessments (mostly as sponsors and consumers), the Council of Ministers and Directorates General for the Environment and for Research and Development (XI and XII, respectively). Important operational components include the relatively new European Environmental Agency (EEA) in Copenhagen and the European Topic Center for Air Quality (ETC-AQ) located at a Dutch research institute in Bilthoven. These two bodies mostly collect, synthesize, and redistribute environmental information. Finally, the EU has several Joint Research Centres (JRC), including one at Ispra, Italy, which focuses on environmental issues.

3.1.1.2. National

Several of the most important parts of the assessment apparatus are located at national scientific facilities in Norway, specifically the Norwegian Meteorological Institute (DNMI) and the Norwegian Institute for Air Pollution Research (NILU). These two groups process the data that is collected by the EMEP system, perform atmospheric modeling (DNMI), work on model development (NILU), and sponsor monitoring efforts outside of Europe. A similar operation is the UK Meteorological Office, which focuses on monitoring and model development (Derwent 1993; Derwent and Davies 1994; Harrison, Brimblecombe et al. 1996). Still another major center of activity is at the Dutch National Institute of Public Health and Environmental Protection (RIVM), which works on many issues, including model development, effects research, and the ETC-AQ. RIVM is more active in air pollution than most national environmental research facilities, but all European nations have some domestic capability. For instance, in Spain the Research Center for Energy, Environment, and Technology (CIEMAT) in involved in many phases of air pollution research (as well as other efforts), and is complimented by university-based research, particularly at the Center for the Study of the Mediterranean Environment at the University of Valencia.

Finally, an important part of the policy apparatus (and less involved in assessment) is the Swedish Acid Rain NGO Secretariat, which publishes *Acid News*. This organization mainly serves typical NGO functions, such as disseminating information to the public and lobbying governments, but it is largely funded by the Swedish government and is thus somewhat different from the typical US-style environmental NGO.

3.1.2. Private

3.1.2.1. Non-Profit

There are relatively few private, non-profit organizations which participate in air quality assessment and policy in Europe, and their effect is certainly much less than the effect of similar groups in the United States. Virtually no such group conducts research in Europe, although some do publish reports of various kinds. The Swedish Acid Rain NGO Secretariat functions much like and NGO, but is actually funded by the government of Sweden. The large, well-known environmental advocacy groups such as Greenpeace and Friends Of the Earth seem to participate in air pollution issues from time to time, especially in the case of but they have never had a significant influence in assessment efforts of any kind, or in ozone policy. In general,

there appears to be more environmental NGO activity in EU assessment and policy activities than in LRTAP (with the exception of the Swedish Acid Rain NGO Secretariat).

From the limited research conducted at the national and sub-national level so far, it appears that where ozone is taken up by environmental NGO groups, it is taken up by locally-focused organizations. These groups seem to focus on policy, not on assessment, and they focus on national (or sometimes sub-national) governments. As discussed in some detail towards the end of the paper, the increased "Europeanization" of domestic decisions in the members of the EU creates something of a problem for locally-focused groups. One result of the emergence of international interdependence is that policies which are of interest to domestic groups (such as local environmental groups) are increasingly framed and determined in international settings which domestic groups may have difficulty gaining information about or influencing. This tendency has not gone unnoticed, there are now several organizations in Brussels which serve as linkages between domestic environmental NGOs and the EU, the Euro-Citizen Action Service (ECAS) and European Environmental Bureau (EEB). They mostly collect and disseminate information to help local- and national-level groups understand and influence EU policies and perhaps more importantly, influence domestic policies where they fall short of established EU policies. ECAS and EEB perform some lobbying and provide some facilities for local domestic organizations to use while in Brussels.

3.1.2.2. Corporate

There is substantial participation in air pollution assessment and policy-making by industrial firms and groupings, generally those most affected by actual or potential regulation. These include chiefly the energy sector and automobile manufacturers, although the chemical industry participates as well to some degree. There has been an increase in these activities over the last decade as the EU has come to take a more significant role than LRTAP (the reasons for this are discussed below). Some of the more prominent companies include Exxon, Powergen, National Power (the last two are UK electricity companies), and Petrofina. However, trade groups are much more active in both assessment and policy-making, particularly CONCAWE ("the oil companies' european organization for environment, health and safety") and the Union of Industrial and Employers' Confederations of Europe (UNICE). A number of consultant companies are employed to provide research and assessment activities, including especially AEA Consultancies in the UK, which is one of the few groups conducting Benefit/Cost analyses in Europe.

3.1.3. Joint efforts

Europe does not have the same kind of tradition of public/private partnerships for conducting air quality research and assessments as does the United States. None were identified in this research, although there is a European Auto/Oil study which studied issues which were causing tensions between the two industries (as in the US) — the relative importance of vehicle design and fuel quality/consistency in auto emissions.

3.2. The Convention on Long-Range Transboundary Air Pollution (LRTAP)

Traditionally the leading institution for European cooperation on environmental policy, the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP) and its Protocols is a

classic example of an international regime.[49] LRTAP's roots are in Swedish concerns about increases in freshwater acidity over the 1950s and 1960s, which drove extensive European research on the issue. LRTAP was actually created as part of the Cold War maneuvering in Europe, because the Soviet Union desired a means of continuing the process of détente and chose environmental issues (among others). The appropriate body for this task was thought to be the United Nations Economic Commission for Europe (UN-ECE). The UN-ECE is one of five regional UN bodies which collect and distribute information, and facilitate cooperation between nations and is based in Geneva. It is a fairly large body, containing 34 nations, including the United States and Canada.

The initial convention, signed in 1979 and entered into force in March of 1983 was simply a framework identifying transboundary air pollutants as an important issues and highlighting sulfur dioxide as the first pollutant to deal with, "with possible extension to other pollutants"(United Nations 1996). There is a very small administrative body, called the LRTAP Secretariat, housed within the Air Pollution Unit of the ECE's Environment and Human Settlement's Division. The Secretariat's primary job is to organize meetings of various LRTAP bodies (more on in a moment), and with some two to three score per year, the five staff persons have little opportunity to do anything except ensure the meetings themselves run smoothly and drafting meeting reports. As a result, virtually all of the substantive work of LRTAP is done by scientists and government officials of signatory nations through a system of Workgroups and TaskForces. This structure can be seen in Figure 3.

The policy-making group is the Executive Body (EB) which is made up of government officials and meets once per year. The Working Groups are open to all representatives from all signatories and primarily draft the regulatory protocols and manage collective research projects (most notably EMEP[50]). Below the working groups are various Task Forces which carry out specific activities for the EB. These Task Forces are open to any willing participant, but in practice all of the workgroups and task forces are headed and predominantly staffed by representatives from the northern, western countries.[51]

Very complete discussions of the structure of LRTAP are contained in Boehmer-Christansen and Skea (1991), and in Levy (1994) and will not be repeated here. Two important issues should be mentioned, however. First, the original efforts to monitor and model ozone in Europe was an outgrowth of the EMEP efforts related to Acid Rain, although substantially more information is now collected at a national level and synthesized by the ETC-AQ and there are currently several different atmospheric models under development and in use in Europe. Second, participation by NGOs and industry has been somewhat limited in the LRTAP process for several reasons. To a significant degree LRTAP is a creature of the Cold War and an forum for (relatively minor manifestations of) high East-West politics. The ability for interested parties other than governments to participate was thus somewhat limited. In addition, there is no real enforcement mechanism in LRTAP and it appears that many people associated with industry hold a "realist" view of politics that suggests enforcement mechanisms are needed in international agreements for them to be effective.[52] This also helped limit industry participation in LRTAP.

3.3. The European Union (EU)

Although it is heavily involved in environmental regulation, the European Union (EU) developed out of an earlier customs union designed to achieve economic growth through the development of a common internal market and to harmonize national regulations affecting

commerce, and the EU remains largely dedicated to these economic goals today.[53] The EU originated as the European Coal and Steel Community in 1962 and throughout its development the primary goal of the organization has been to increase economic development of the Member States (i.e. the nations which have joined). Understanding this fact takes us a long way towards understanding the patterns of air quality assessment and policy in Europe. In 1957 six western European nations took a further step and signed the Treaty of Rome, creating the European Economic Community (EEC) and agreed to reduce tariffs between member states. Subsequently Denmark, Ireland, and the United Kingdom acceded to the EEC in 1973, and Greece, Spain and Portugal in the 1980s. The Treaty of Rome remains the basic charter of the EU, but it considered to have been "completed" with the Single European Act (SEA) of July, 1987. The final component which shapes the current EU is the Treaty of European Union, signed in Maastricht and ratified in 1994.

Currently, the EU can be best thought of as a supra-national system which has some aspects of a federal system and some aspects of an international regime. It has four institutions, the European Commission, the Council of Ministers, the European Parliament, and the European Court of Justice. In addition, the Presidency of the EU is held by Chief Executives of the Member states for six month periods on a rotating basis.

There is no specific mention of environmental issues in the Treaty of Rome, but as environmental issues became more salient in the 1970s, Article 100 was used to justify the development of EC environmental regulations. The text of Article 100 reads:

> "The Council shall, acting unanimously on a proposal from the Commission, issue directives for the approximation of such provision laid down by law, regulation, or administrative action in Member States as directly affect the establishment or functioning of the common market. The Assembly and the Economic and Social Committee shall be consulted in the case of directives whose implementation would, in one or more Member States, involve the amendment of legislation."

This approach proved inadequate since it did not provide any firm commitment to environmental policy or any substantive guidance to the appropriate institutions for forming this policy. Thus, the major treaties amending the Treaty of Paris (i.e. SEA and Maastricht) have each considerably strengthened and broadened the basis for EU environmental legislation. These modifications are contained in Articles 100a, 100b, 130r, 130s, and 130t. The EU legislative process starts with a "Proposal" from the European Commission, which are informed by assessments and reports of various kinds and are usually developed with some degree of communication between the Commission and the Council and Parliament. Proposals do not have any force, actual legislation comes in the form of EU "Directives" which are approved by the Council and sometimes the Parliament as well. EU Member nations are required to pass and implement legislation which achieves the goals of (i.e. "approximates") the EU legislation.[54]

The prime mover of environmental regulation in the EU is the Commission, which is staffed by civil servants and headed by political appointees according to a rough proportionality from each Member State. The Commission can be thought of as the Executive Branch of the EU and is divided up into Directorates-General (or "DGs") headed by a Commissioner. Each DG is assisted by "National Experts" who are loaned to the EU for periods of time and expert committees which can have participants from industry and NGOs as well. These expert groups can have considerable influence because they advise the Commission directly, and it is only the Commission that can draft EU legislation. As we will show later, the work performed by

National Experts and the meetings of the expert committees are key means by which the results of assessment processes are conducted and influence EU legislation. However, mechanisms to make the consultation and legislation-writing processes transparent do not exist - there is no open formal means of making public comments on draft legislation and it is often hard to obtain copies of assessment and policy documents.

The European Parliament and the Council of Ministers currently operate under "consultation", "co-operation" and "co-decision" arrangements and can be thought of as legislative bodies, each with the power to veto proposed legislation originating in the Commission. In some cases (co-operation), a unanimous vote in the Council will override a veto in the European Parliament.

The European Parliament (EP) is popularly elected using proportional elections in most cases (but not in the United Kingdom, where it is a winner-take-all system) and votes on legislation are based on a simple majority. The EP can be seen as the primary democratic forum through which the citizens of Europe (i.e. the citizens of Member States acting on the European level) influence decision-making. The EP has traditionally been less powerful than it is now (due to provisions in the Maastricht treaty) and remains much less important than the Commission and Council. Indeed, some Members of the European Parliament (MEPs) feel that they are more like lobbyists (affecting the Commission and Council) than legislators. (Dahl 1995) Finally, the EP has traditionally been more open and accountable to the public than the Council.

The Council is made up of the Ministers of the Environment from the governments of each Member State and operates under several systems of voting on proposed legislation.[55] The Council is best seen as a traditional international negotiating group where national interests are represented by individuals appointed by the Chief Executive of each nation. The Council generally meets every six months, and the interests of the EU President determine the agenda and short-term priorities of the Council. Much of the Council's staff work is also performed by the nation holding the presidency, so the interests and capability of the presiding nation are often very important in determining the shape of EU environmental policy. The Council can also instruct the Commission to perform research or other services. Depending on which provision of the amended Treaty of Rome is used as the legal basis for a proposal, the Council will use either unanimous voting or a rule of Qualified Majority Voting (QMV) which prevents single large countries and small groups of smaller countries from effectively blocking action which the remainder of the Member Nations wish to see pass.[56]

The EU is sometimes criticized for having a "democratic deficit," because it tends to reduce the power of popularly-elected national Parliaments. Part of this problem comes from the difficulty domestic interest groups have in affecting EU politics, as noted above. Another part of the problem is that the un-elected European Commission is largely responsible for developing the language of EU legislation. The leadership of the European Commission is appointed by individual Governments of Member Nations, handing them significant power. This is augmented by the structure and operation of the Council of Ministers, who are generally appointed by Prime Ministers. Council meetings are held behind closed doors without records of votes except whether a measure passes for fails. And since the Council often has the final word on EU legislation, this hands significant power to the national Governments.[57] However, the EU Member Nations have taken steps to improve the representitiveness of the EU, including changes to voting procedures and access to information. (Jordan 1998)

The current status of the EU legislative process is described in the following table:

Current (1/1/1998) status of EU environmental legislative process[55]

Article	100A	130S
Rationale	Approximation of laws to establish and protect the single market	Environmental legislation not related to the internal market.
Council voting rule	QMV*	QMV* (some exceptions - fiscal, land use, and energy policy require unanimity)
Role of European Parliament	Cooperation	Consultation

*Qualified Majority Voting

The European Court of Justice (ECJ) has jurisdiction between the different institutions of the EU and between the EU and Member States. It can also review and put aside EU legislation, if it deems necessary to do so. In several cases, it should be noted, the ECJ has held that EU legislation is supreme over national law. The ECJ also provides binding interpretations of EU law for national courts, a role that has grown increasingly important over the recent past.

The principal mechanism by which the EU directs Member States is the Directive, which obligates the Member States to change their national legislation so that the outcomes defined in the Directive are achieved. Importantly, issues of implementation and enforcement of EU legislation into national law are left largely to national authorities, and has proved problematic. The Commission has frequently brought Member States before the ECJ, charging them with failing to implement or enforce EU legislation. However, individuals and NGOs do not have standing in the ECJ and the types of suits seen in the US (where an NGO can sue the EPA or a state body for failing to protect the environment) are not pursued against EU Member States or the Commission.

In late 1994, a new EU institution was established in order to provide an information gathering and dissemination role, the European Environmental Agency (EEA), located in Copenhagen. The EEA does not currently have a strong regulatory role, that function being left to the national level. The EEA will operate the European Information and Observation Network (EION) to serve this goal, and will establish EU Topic Centers to handle information on specific issues, such as the EU-Topic Center on Air Quality (ETC-AQ) located at RIVM in the Netherlands. These mechanisms are just beginning to operate in a substantial way and will likely become important parts of the overall assessment processes.

While the SEA focused primarily on creating a single internal market in Europe, it also had important implications for environmental regulation. The SEA introduced the idea of subsidiary formally and declared that it applied in all areas where the EU did not have sole authority (i.e. competence), and raised the importance of the European Parliament in environmental decision-making. Despite it's beginnings as a trade union, and the continuing emphasis on economic issues, the EU is slowly taking on more and more attributes of a government exercising genuine power over European citizens. This is particularly noticeable after the Maastrict treaty, which aims at political and monetary union in Europe, although whether or not this can be achieved is yet to be seen. In addition, the Maastrict treaty introduced new areas of co-decision power for the European Parliament.

To provide a sense of the development of air quality regulation in Europe Table 7 presents the early national air pollution policies for some EU Member States and Table 8 presents all of

the current EU legislation on air quality. The EU information is different from most presentations of similar material in that it is arranged chronologically rather than by issue area. Thus it is easier to see patterns and trends over time. These include an early emphasis on mobile-source regulation, other than heating oil, the first stationary source regulation is the Large Combustion Plant Directive (88/609). A second observation is an emphasis on the same pollutants as in the United States, first carbon monoxide and hydrocarbons, followed by NOx later on.[59] In addition to following US trends, it is also true that the pattern of European regulation of vehicle emissions generally followed a concern for urban pollutants, and the interest of Germany in pollution control. Third, from 1970 to 1985 the principle of "optional harmonization" was in place, whereby national approximation of EU standards was not required, but nations were not permitted to refuse entry of imported vehicles which met the standard. Thus, the EU (then the EEC) established *maximum* standards for vehicle emissions until 1985, rather than the more usual *minimum* standards. Fourth, in contrast to the US, emissions standards were legislated earlier than ambient standards (which did not come until 1980 for sulfur and 1985 for NOx). As in the United States, it appears that in Europe ozone-forming VOCs and NOx were thought to be primarily mobile-source problems and acidifying sulfur dioxide emissions were thought to be primarily stationary-source problems. Note that the ambient standard for sulfur and the heating oil (i.e. gas oil) content standard for sulfur both predate LRTAP, indicating they are meant to address local air quality. Also note that LRTAP contains no specific standards of any sort, commitments are for decreases in total emissions (or transboundary fluxes) of pollutants.

Overall, these trends tend to support the arguments made by a wide variety of analysts that EU regulation for "air quality" was essentially about harmonization of standards to promote more free trade, not about achieving environmental objectives (Boehmer-Christiansen 1989; Boehmer-Christiansen 1990; Bennett 1991; Dietrich 1996) Harmonization of standards is particularly important to the automotive and vehicle fuel sectors due to their economic structure, and less for the electricity (and electricity generating equipment) markets.[60] Indeed, both Boehmer-Chritiansen and Dietrich strongly argue that the environmental regulations were very important factors (although not dominating) in the evolution of the structure of the European automobile industry. A key part of this argument (particularly Dietrich's version) is the importance of the US market, in which very stringent emissions standards were introduced. Firms which exported to the US (such as Mercedes, Saab, and Renault) had to meet these standards and thus had incentives to promote their adoption everywhere in their sales territory. Indeed, Sweden had adopted US standards in 1976, as did several other nations by 1985 (Boehmer-Christiansen 1989).

A number of recent EU Directives indicate an important change in environmental regulation that are closely related to changes in the political character of the EU itself. Generally, the EU has evolved from a trade union involved mostly with reducing tariffs towards greater economic and political union. With this change has come an increasingly strong notion of European Citizenship, and the development of a Europe-wide polity. Naturally enough, the idea that citizens of Europe have rights has also developed, including some right to a clean, or at least healthful, environment.[61] Manifestations of these idea are included in EU Directives on air quality standards, freedom of environmental information, and the obligation of national Governments to inform its citizens when air quality standards are violated (See Table 8, Directives 80/779, 82/884, 85/203, 90/313, 92/72, 96/61, 96/62). An important feature of these changes seems to be a potential increase the avenues for influencing national legislation and executive decisions. By increasing the obligations of Member States to approximate more and

more EU environmental legislation while at the same time providing the citizens of Member States more justification (environmental rights) and more ability (environmental information) to apply pressure for further environmental protection (assuming they want more environmental protection), national governments are increasingly caught in the middle. The ability of national governments to deviate from EU standards *in practice* (few deviate from EU standards on paper) will probably decline if the EU continues to become more politically unified and democratic.

This background of politics and air pollution policies can be compared with the historical information development of ozone assessment in Europe. The earliest European research occurred in the late 1960s, when biological indicators (i.e. sensitive plant species planted for the purpose of ozone "monitoring") began to indicate widespread accumulations high ozone concentrations across the continent. These early signs were confirmed in the 1970s through a series of mostly independent scientific efforts to measure the long-range transport of ozone and its precursors. Thus, in the 1970s ozone research was being conducted, but the only two European air pollution assessments of the period, an OECD study an a Swedish-led effort examined only acidity. These focused on sulfur compounds, but did consider NOx somewhat.

In 1982, the widely publicized discovery of "Waldsterben" focused new attention on ozone as it quickly became clear to German researchers that acidifying deposition may not be solely responsible for the observed forest damage, tropospheric ozone was implicated. At the same time, a variety of field studies and modeling projects were conducted that helped to characterize the processes of ozone formation and accumulation in northern and southern Europe (EMEP Workshop 1991). A European-wide effort was begun in the late 1980s to coordinate atmospheric research. (Borrell, Builtjes et al. 1997)

It is not clear at this time how much these research efforts contributed or not to the development of post-1985 EU air quality regulation, or the LRTAP Protocols for NOx or VOCs. There were relatively few, if any, ozone assessment activities until the mid-1990s in Europe. It appears that some informal assessment-like activities took place in terms of meetings among scientists and that some modeling of NOx transport and fate (which is not the type of photochemical modeling required to investigate ozone accumulation and control) did take place in support of the 1988 NOx protocol, but that protocol was meant primarily to control acidification. The RAINS model used at that time may not have contributed much since as late as 1990 it was reported that "Currently, it is assumed that only sulfur deposition contributes to acid load in lakes and their watersheds." (Alcamo et al. 1990 p. 249, see also model equation 6.1 on p. 258)

By the early 1990s, however, several ozone assessment efforts have gotten underway, including the policy applications portion of EUROTRAC, the European Auto/Oil study, the Auto Emissions 2000 study, and extensions of the EMEP/RAINS modeling system (Commission of the European Communities 1992; Simpson 1992; ACEA/EUROPIA 1996; Borrell, Builtjes et al. 1997). However, these have all been completed relatively recently (and some remain ongoing), suggesting that they may have influenced the 1991 VOC Protocol and EU legislation in the 1990s.