# CHAPTER 5 - Emerging Challenges and Opportunities in the Development of Clean Air Policy Strategies


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**KEY MESSAGES:**

- The issue of air quality management is beginning to take on global dimensions, where the linkages between climate change and air pollution, how to control their sources pollutants (greenhouse gases (GHGs) and criteria air contaminants), and how they may interact to pose a cumulative risk to human health are emerging as important challenges.
- Urban areas, especially emissions and health effects associated with particulate matter (PM), are a major concern for air quality management. Other areas of concern include environmental justice and hemispheric air pollution transport.
- Adopting a risk management approach in the form of exposure-response relationships for PM is more suited for developed countries, whereas in developing countries a more traditional approach is more appropriate where recommended guidelines are expressed as a concentration and averaging time.
- For pollutants with no (or very low) effect threshold such as $PM_{2.5}$ it will generally be more beneficial for public health to reduce pollutant concentrations across the whole of an urban area as benefits would accrue from reductions in pollution levels even in relatively "clean" areas.
- The European Commission's adoption of an exposure reduction target in addition to limiting the absolute maximum individual risk for European citizens embodies a form of environmental justice, where policy measures should lead to a uniform improvement in exposure.
- Hemispheric air pollution transport poses significant challenges to the scientific community and policy makers, even at the level of local air quality management.
- The interaction between climate change and air quality poses additional challenges for policy makers. Much of the focus to date has been in the area of atmospheric chemistry, with less emphasis on specific emission reduction technologies and measures that will reduce emissions of all key pollutants (air pollutants, air toxics and GHGs).
- Examples drawn from the EU (especially the UK) and North America (especially Canada) demonstrate the challenges of integrating climate change into the development of air quality policy strategies.
- The health benefits from integrating climate change and air quality management decisions can be non-linear, synergistic and in some cases counteractive. Measures must be taken that result in optimal reductions in emissions of all key pollutants, rather than at the expense of one or the other.
- Opportunities for adopting an integrated approach to air quality management include energy, transport and agriculture. There is no silver bullet among these sectors; hence, a wide suite of effective measures will be required.

## 5.1 Introduction

There are a number of challenges and opportunities facing decision makers in the development of clean air policy strategies, particularly when dealing with specific pollutants, the linkages between air issues, and how best to address them at various spatial scales. To date most of the attention in the literature and among policy makers has been on addressing specific pollutants and air issues (e.g. the precursors to ground level ozone, acid rain), and in some cases even adopting a multi-pollutant approach as in the UNECE Convention on Long Range Transboundary Air Pollution. These issues tend to operate at the local, regional or air shed scale, and in some cases they may cross international borders, thereby requiring a bi-national or multinational response.

In recent years however, the issue of air quality management is beginning to take on global dimensions, as scientific evidence mounts regarding the wide dispersion and deposition of Hazardous Airborne Pollutants (HAPS), air toxics, and Persistent Organic Pollutants (POPs). An emerging issue that is receiving multinational attention is hemispheric air pollution transport, where air pollutants are transported across oceans and contribute to local/regional air quality problems in jurisdictions on another continent, thousands of kilometers away. An even greater concern however is the global threat of climate change, which has the potential to be the most significant environmental issue facing humankind. While climate change has direct implications for air quality, air pollutants can also greatly impact climate change, via the greenhouse gases (GHGs) and some aerosols such as black carbon causing warming effects, and in other cases via sulphate aerosols which have a significant regional cooling effect. Not surprisingly the linkages between climate change and air pollution, how to control their source pollutants (GHGs and criteria air contaminants), and how they may interact to pose a cumulative risk to human health are emerging as important challenges to air quality management.

This chapter outlines many of the challenges for air quality management on local urban scales, and also extends the discussion to wider spatial scales, while considering the important linkages between air quality and climate change policies. The focus is on urban air quality management, with specific reference to particulate matter. The chapter discusses novel approaches to air quality management, including the issue of environmental justice and the policy challenges arising from the management of hemispheric air pollution transport; and the linkages between air quality and climate change, including the opportunities that coupling these air issues provides for air quality management. The chapter concludes with a brief discussion on future research requirements. Although examples are largely drawn from the EU (especially the UK) and North America (especially Canada), the challenges and opportunities apply to both developed and developing countries.

## 5.2 Urban Air Quality Management

In many areas of the developed world air quality management is a fairly mature subject. There have been some recent developments which are of significance to these areas, as well as to developing countries where air quality management systems may be at an earlier stage. A particularly notable development in this context has been the publication of a global update of the World Health Organisation guidelines for air quality (www.euro.who.int/air). The significant feature of this publication in the current context is that it explicitly addresses the problems of air quality management in developing countries. An example of this is the way the WHO has dealt with particulate matter (PM). In its previous publication of air quality guidelines in 2000, the WHO recommended guidance for risk management in the form of exposure-response relationships and suggested that air quality managers quantify the risks relevant to local levels of PM and make the risk management decisions on control policies appropriate to whatever balance of risks and benefits was felt appropriate. While this approach is used in some of the developed countries and regions, in the 2006 update there was a body of opinion presented to the WHO, largely from the developing countries, which felt that this level of detail was not particularly helpful. Accordingly, the 2006 update has now returned to the older approach of recommending a guideline expressed as a concentration and averaging time, together with a series of three successively more stringent 'Interim Targets' which approach the guideline. WHO recognizes this approach as particularly helpful for developing countries whose levels of PM are currently quite some way above the guidelines themselves.

There are several significant implications of this approach for air quality and risk managers. Firstly, the move away from recommending an exposure-response coefficient or function for a non-threshold pollutant such as PM could be viewed in some quarters as not allowing any scope for national or regional air quality managers to undertake their own risk management and to formulate their policy targets considering local prevailing levels of pollution as well as the predominant socio-economic climate. This latter approach is the way policies for the management of PM levels are handled in the UK. For example, expert advisory groups under the umbrella of the UK Department of Health have devoted considerable intellectual resource to assessing the literature and recommending exposure-response coefficients, together with likely uncertainty ranges, so that in formulating policy measures, the Environment Department can undertake the appropriate quantification of the effects on public health and where possible, cost-benefit analysis and proceed with policies which respect the three 'pillars' of sustainable development. This process can still be undertaken of course, but there is now no international body recommending an exposure-response relationship to underpin such risk management analyses. (It is worth noting however that the UNECE/WHO Task Force on Health within the Convention on Long Range Transboundary Air Pollution did assess the then current literature and recommended exposure-response relationships in 2004).

To carry out risk management analyses of the type described above requires a fairly well developed scientific and economic infrastructure in the air quality management system. The assessment of potential new control policies proceeds according to the following impact pathway chain:

**Possible policy scenario→projected emissions→atmospheric concentrations/ exposures→health and/or environmental effects→monetised damage costs vs control costs**

The first stage requires estimates of the effect on emissions of the proposed policies, the second requires, at the very least, a robust dispersion/chemical model of atmospheric transport, the third requires one or more exposure-response functions and the final stage requires economic analysis of the possible monetary values associated with the effects of the policies. This chain therefore requires a certain maturity of development in the air quality management system. The discussions in the WHO forum which produced the global update felt that this was not appropriate to less well developed systems in many countries and therefore chose to recommend the Guideline and Interim Targets for PM referred to above. The possible criticism that these concentration levels were somewhat arbitrary (in the sense that they were not derived from a balance of costs and benefits as might be thought appropriate for a non-threshold pollutant) was addressed by choosing the guideline for $PM_{2.5}$ as the lowest level at which total, cardiopulmonary and lung cancer mortality were shown to increase with more than 95% confidence in the ACS study of Pope et al. (1995) The highest value (i.e. least stringent) Interim

Target, denoted IT-1, was chosen as the highest observed value in the studies on long-term health effects. The two values in between, IT-2 and IT-3 were essentially arbitrary values chosen between the other two extremes, the change in risk on moving from one level to the next was quoted, using essentially the exposure-response relationships derived by Pope et al. in the ACS study.

While in the short term this approach will no doubt be helpful to developing countries in formulating policies, in the longer term it may well need revision as the policy process matures and both sides of the debate become more knowledgeable and sophisticated. There will be further challenges for developed countries in future too, as they approach the lower end of the IT/guideline scale produced by WHO. The potential difficulty of deriving conclusions of policy relevance from epidemiological studies as levels of PM decrease has been noted in Chapter 2 and this is likely to complicate the policy process. For example, let us suppose a country or region approaches the guideline for $PM_{2.5}$ (10μg/m$^3$ annual mean). Does it stop once the level is reached or will there still be robust epidemiological evidence for the absence of a threshold that suggest further improvements might be warranted? If so, what does one make of the guideline? Questions of this kind will make the management of PM a subject of some difficulty for years to come. As levels continue to decrease, the wider issues of where society should best deploy scarce resources in improving public health and environmental protection will become increasingly important (see for example Krupnick, 2007).

## 5.3 Novel Approaches to Air Quality Management

The final paragraph above serves as a useful introduction to the topic discussed in this section, which was also prefaced in Chapter 2. This concerns the problem of how one manages air quality in areas where standards or guidelines are already met, or where there remain some areas where complete compliance is extremely difficult or expensive. This is particularly important for non-threshold pollutants like PM, and highlights the problems associated with managing air quality via a single air quality standard or guideline. This problem becomes increasingly apparent as ambient levels are successively reduced and the easier control measures have been taken.

Experience in the UK and elsewhere in Europe has shown that for non-threshold pollutants, single limit values or standards may not on their own be the most appropriate way of managing air quality, particularly in areas where existing air quality management systems are mature. This has encouraged the European Commission to propose a new, additional concept, the exposure reduction target (ERT) (which has not entered into force yet, even though the concept is in principle supported by the Council and the European Parliament). The following short description of the basics of the concept is derived from a non-paper issued by the European Commission.

The existing legal framework of the Air Quality Framework Directive and its Daughter Directives (Official Journal of the EC, 1996 and 1999 respectively) require complete compliance, meaning that limit values must be met everywhere. As such, a conventional air quality management strategy would implement measures according to their cost-effectiveness so as to reduce the areas of exceedence of these limits. Such a strategy would deliver increasingly smaller areas above the limit values. In the remaining areas, it may well be that reaching complete compliance is very difficult and costly. In addition, there would be no legal requirement to improve air quality where limit values are already respected.

For pollutants with no effect threshold, such as $PM_{2.5}$, it will generally be more beneficial for public health to reduce pollutant concentrations across the whole of an urban area as benefits would accrue from reductions in pollution levels even in relatively “clean” areas. Therefore, an ERT was proposed by the European Commission for fine particulate matter $PM_{2.5}$. $PM_{2.5}$ is responsible for significant negative impacts on human health. Further, there is as yet no widely agreed threshold below which $PM_{2.5}$ would not pose a risk. Advice from the WHO suggests that it is justified to assume a linear response linking exposure to $PM_{2.5}$ to adverse effects. This advice should apply both in “clean” as well as in “polluted” areas. The exposure reduction concept entails a reduction in the exposure of a larger part of the population compared to the limit value approach which affects (as we approach complete compliance) a smaller number of people. As such, the overall improvement in public health comes at a higher cost with limit values. A Commission Working Group has looked at this issue and concluded that exposure reduction would be a more cost-effective way of reducing air pollution (Amann et al., 2005). [1]

**Environmental Justice**

There is also an issue of environmental justice. The European Commission has stressed that it is necessary to limit the absolute maximum individual risk for European citizens. This is why the Commission proposes to keep a limit value, in addition to the ERT. The new approach combines:

- A relative target for the reduction of ambient concentrations averaged over a wide geographical area. The extent of this reduction could be determined by the balance of costs and benefits. Intuitively higher reductions should be required in more polluted areas, without putting disproportional pressure on these areas and taking into account transboundary aspects. Thus, a percentage reduction would seem appropriate.
- A limit value.

In order that the new system does not return in practice to the old inefficient standards-based system, the limit value or ‘cap’ ought not to the single major driver of air quality management policies. The exposure-reduction approach, including any initiative aimed at improving the accuracy of the exposure-response function, embodies a form of environmental justice, although of a different kind from the ambient air quality standards. As long as there are discrete sources of emission in an urban area, then there will always be differences in exposures due to dilution and dispersion, even if there is uniformity in compliance with ambient standards. If the exposure reduction approach is adopted, and if the reduction amount is required to be the same everywhere, then there will be uniformity in the improvement in exposure, in percentage terms, if not in absolute amounts. In addition, when coupled with a concentration “cap” citizens are guaranteed an absolute minimum standard of air quality to protect them against unduly high risks.

The ERT would provide a better air quality management system than one relying solely on ambient air quality standards. The following benefits (in addition to those already mentioned above) have been identified:

- Source-related emissions reductions would contribute more effectively and not just in areas where there are exceedences of limit values.
- No need to modify the ambient air quality standard as time elapses as the emphasis is on reducing overall exposure thus saving administrative resources.
- The proposed approach would complement and “fine tune” overall emission ceilings for a Member State or region, which, if implemented, alone would not have the necessary focus on the improvement of public health; i.e. the total emission ceilings might be

[1] See chapter 9 of CAFE Scenario Analysis Report Nr. 4 Target Setting Approaches for Cost-effective Reductions of Population Exposure to Fine Particulate Matter in Europe available at http://europa.eu.int/comm/environment/air/cafe/activities/pdf/cafe_scenario_report_4.pdf.

achieved with a disproportionately small improvement in public health, depending on the spatial relationship between the emission reductions and the populations exposed.

**Hemispheric Air Pollution Transport and Policy Challenges**

In the last few years there has been a growing recognition that transport of air pollutants (as opposed to long-lived greenhouse gases) can occur between continents, particularly in the northern hemisphere. This presents a challenge to the scientific community but also to the policy maker. One step forward in understanding this problem, initially from a scientific point of view was the establishment in December 2004 of the Task Force on Hemispheric Air Pollution within the Convention on Long Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe. The discussion in this section is based largely on a paper produced by the co-chairs of the Task Force, Terry Keating (US EPA) and Andre Zuber (European Commission) (Zuber and Keating, 2005)[2].

There is well-documented evidence for the intercontinental transport of ozone, particles, and their precursors, as well as mercury and some persistent organic pollutants. Emissions from one continent can influence air quality in another through an increase in the overall hemispheric burden of pollution and through discrete episodic flows of enhanced levels of pollution. This latter contribution can clearly vary with location, season and the pollutant concerned.

There have been observations of discrete intercontinental ozone transport events made at mountain top sites and by aircraft, but the more important influence on ground-level ozone concentrations have been an apparent increase in the hemispheric burden in the troposphere. This background level is controlled primarily by global $NO_x$ emissions and to a lesser extent by methane and carbon monoxide. For aerosols and their precursors, episodic flows appear to be the most important influence. The episodes are often natural events such as dust storms, volcanic activity or fires. For mercury, the export of emissions into the free troposphere contributes to a hemispheric or global pool of mercury. Influenced by this global pool, mercury deposition patterns are thought to be more related to patterns of emissions and precipitation than to transport events. Some persistent organic pollutants may be transported long distances as aerosols and remain where they are deposited, while others may revolatilize or become re-entrained and travel further in successive hops to reach environments far from the sources. A classic example is the presence of such pollutants in the Arctic.

Although intercontinental transport can be demonstrated using observations and measurements, it is important, not least for future policy assessment reasons, to understand how changes in emissions in one continent influence air quality in another. This requires a predictive model that can account for the non-linearity and complexities of the atmospheric system. Ideally this simulation should be performed with an integrated system of models capable of linking the local, regional, hemispheric and global scales. Models exist which are capable of simulating these phenomena but more evaluation and development are required before they are applicable with confidence to policy questions.

Although current models are uncertain, the magnitudes of impacts are significant enough to suggest that further investments should be made to better characterize intercontinental transport and the potential impacts of emission changes. For ozone, it has been estimated that such transport contributes between 1 and 10 ppb to average surface ozone concentrations in Europe, North America and Asia. Even at the low end of this range, this contribution may offset the benefits of local air pollution controls, and, depending on whether or not

[2] Available at http://www.unece.org/env/documents/2005/eb/EB/Inf.Doc.05.Hemispheric%20Transport.pdf

ozone is thought to have a threshold for adverse human health effects, it could also have important public health impacts.

For aerosols, current models and observations suggest small but significant contributions (up to 2μg/m$^3$ $PM_{2.5}$ annual mean) of intercontinental transport of anthropogenic pollution. Impacts on an episodic basis can be even larger (10 to 100 μg/m$^3$ $PM_{10}$ maximum daily concentrations). However, such episodic events are primarily associated with wildfires or wind-blown dust. For mercury, it has been estimated that intercontinental transport may contribute between 10 and 75% of the total deposition to the different continents in the northern hemisphere, with individual continents or regions providing between 1 and 40% of observed deposition. It should be stressed that these estimates are uncertain and are based on preliminary work. Further developments are under way to attempt to improve our understanding via improved descriptions of the transport processes, emission inventories and additional observational data.

Intercontinental transport will pose significant problems not just for the scientific community but also for the policy makers. It is reassuring that the first steps in addressing the scientific issues in an institutional framework were made by the CLRTAP which has a very strong track record in the use of science in a policy context. The Task Force on Hemispheric Transport of Air Pollution will look more broadly than the current scope and coverage of the Convention however. It will attempt to build upon a wide variety of existing research efforts in individual countries and internationally, including IGBP/IGAC, UNEP, the World Bank, GEOSS, WMO, and ACCENT within the EU. The EMEP Centres of CLRTAP will also contribute to this effort. Of particular interest is the establishment of contacts and co-operation from scientists and experts outside the UNECE regions including those from Asia, Africa and Central America.

In the longer term, there may well be a need to integrate this scientific endeavour with policy needs. While the Task Force is at present engaged in addressing the scientific questions, thought is being given elsewhere to the policy context via the work of the Global Atmospheric Forum of IUPPA. The Forum recognizes that a number of regional agreements already exist and rather than attempting to set up some form of global instrument (for example along the lines of the Kyoto Protocol) it may be more productive, at least in the early stages of development of thinking on intercontinental transport of air pollution, to attempt instead to foster collaboration and interaction between these regional instruments. The instruments of particular importance here are the UNECE, the EU, the network of the Central Asian Republics, the Male Declaration in South Asia, the Asian Brown Cloud network, the Clean Air Initiative Asia, EANET in East Asia, APINA in Africa, IANABIS the Inter-America network for atmospheric/biospheric studies and the Canada/US Air Quality Agreement. Two of the principal aims of the Forum are to (i) provide a framework for dialogue and co-operation between these networks and related organizations on the practical challenges facing them and for developing joint projects and (ii) to encourage harmonization of systems and approaches in key areas to facilitate co-operation at intercontinental, hemispheric and global scales, to encourage the establishment of new networks in areas where none exist and to encourage capacity-building in areas where resources currently constrain action.

An important area of the Forum's work will also be to provide a forum for debate on common issues and important here of course is the interaction between climate change and air pollution and the policies and institutions needed to tackle pollution at the hemispheric and global scales. This will pose challenges to policy makers and to institutions in the future. Some aspects of the issues surrounding the interaction between climate change and air quality are addressed in the next section.

## Air Quality and Climate Change

There are a number of emerging challenges and opportunities that are important to consider in the development of clean air policy strategies particularly in the context of the links with climate change. Much of the integrated focus to date has been in the area of atmospheric chemistry, exploring the integration of air quality and climate change, with less emphasis on the specific emission reduction technologies and measures that will reduce emissions of both air pollutants (including air toxics) and greenhouse gases. There are also important linkages to explore between mitigation and adaptation measures, although in the latter context this is probably more for climate change than for air quality. The recently published report by Stern (2007) concluded that measures to combat climate change could lead to significant improvements in air quality and public health, citing a study by the European Environment Agency (2006) which showed that the benefits of an emission scenario aimed at limiting global mean temperature increases to 2C would lead to savings on the implementation of existing air pollution control measures of €10 billion per year in Europe and additional avoided health costs of €16-46 billion per year. Similarly in China, a recent study (Aunan et al., 2006) showed that for carbon dioxide reductions of 10-20%, the air pollution and other benefits more than offset the costs of action.

In North America, the integration of air issues has been somewhat constrained by a nagging ongoing debate around climate change science and whether actions to reduce GHG emissions are actually necessary, despite the findings of the Intergovernmental Panel on Climate Change, the National Academy of Sciences, among other reputable science-based agencies and initiatives. The fact that the United States has yet to ratify the Kyoto Protocol, and Canada's relatively poor record in reducing greenhouse gas emissions (currently 27 percent above 1990 levels, and 35 percent above their Kyoto target) demonstrates the lack of commitment, lack of progress, or simply the challenge of taking meaningful actions. Canada's emissions are projected to be 828 Mt by 2010 and 897 Mt by 2020 (Natural Resources Canada, 2006). Nonetheless, there is growing evidence and concern that climate change is real, is already happening (in some cases/areas occurring at a pace more quickly than previously projected), and that the impacts and effects will be severe. The Intergovernmental Panel on Climate Change (IPCC) Assessment Report Four is scheduled to be released in 2007, and initial results indicate an even greater confidence in the physical science of climate change and the dangers that it poses to humankind (Alley et al., 2007).

Unlike the "co-benefits" research that occurred in the years leading up to the ratification of the Kyoto Protocol, the linkages between climate change and air quality will likely begin to move from the theoretical (discussion) to the practical (and applied) level more quickly than many anticipate. It is already happening in some countries. For example, the UK has analysed the effects on carbon emissions of measures to achieve air quality objectives beyond 'business as usual' in a recent review of the UK Air Quality Strategy (DEFRA, 2006) and the recent publication of the UK Climate Change programme considered the impacts on pollutant emissions of the climate change measures. Some of these measures will be synergistic, leading to cumulative benefits for both air quality and climate change, but some may be contradictory, leading to conflicting outcomes.

In proposing emission standards for vehicles which will probably require aftertreatment with a small fuel economy penalty, the European Commission has tacitly accepted the small disbenefit to GHG emissions for the large improvements in particulate emissions that will result. The Council of the EU, including the UK, recently affirmed its commitment to a reduction of 20% in GHG emission reductions, and endorsed an EU objective of a 30% reduction, 'provided that other developed countries commit themselves to comparable reductions and economically more advanced developing countries to contributing adequately according to their responsibilities and respective capabilities'. (Council of the European Communities, 2007). There is growing acceptance by environmenta-lists, governments and even industry that a global reduction of 60-80 per cent is necessary by 2050 if we are going to keep CO2e (carbon dioxide equivalents) concentrations in the atmosphere below levels that would cause a 2C degrees increase in global temperatures (and avoid dangerous interference with the earth's climate).

With such a huge emission reduction challenge, the need to link air issues together is both necessary and unavoidable. The benefits to air quality of these longer term plans were explored in the recent UK Air Quality Strategy Review referred to above (see also Williams, 2006). In Canada, the current minority Federal Government recently introduced a Clean Air Act that addresses climate change and air quality, promising new national air quality standards and proposing GHG emission reduction targets for 2050. An absolute reduction in GHG emissions of 45 to 65 percent below 2003 levels by 2050 is the target. The notice of intent, however, does not lay out specific dates for new air quality standards, nor does it explain how climate change and air quality will be addressed in an integrated fashion, suggesting instead that they will be addressed as separate air issues. This is not surprising since a comparison of previous clean air strategies and climate change plans in Canada revealed that they were largely disconnected, at best providing lip service to each, but neither providing any real evidence of an integrated and coordinated approach (Bouchard, 2006).

In the fall of 2006, Rona Ambrose, who was then the Federal Minister of Environment, introduced Bill C-30 into Parliament, a new Clean Air Act (CAA) for Canada (Ambrose, 2006). Of particular concern is that the commitment to reduce GHG emissions is framed not in absolute terms, but rather in the context of allowing emissions to rise while lowering emission intensity, an approach also promoted by the Bush administration in the United States. Not surprisingly, many organizations and environmental groups have been critical of the proposed Act, citing the lack of clear short-term and intermediate targets and timelines that address both criteria air contaminants and greenhouse gases. Shortly after it was announced, the Act was sent to The Standing Committee on Environment and Sustainable Development for review, with members of the committee from the opposition parties determined to revise the CAA into a truly "green" piece of legislation by the end of March, 2007. Around the same time the Federal Minister of the Environment was replaced, in part reflecting her weak performance on climate change and air quality, and in anticipation of the environment becoming one of the top three issues in the next Federal election. Within a broader environmental strategy, new initiatives under the CAA have also been announced targeting toxic substances which were supported by some environmental organizations. Unfortunately the negative reaction to the CAA as a whole was so strong that positive steps forward on toxic substances have largely been ignored. This new chemicals management strategy, announced in late 2006 will target new and existing toxic substances in Canada.

Environmentalists are also concerned that the proposed measures outlined in the CAA may obfuscate public attention away from taking meaningful actions on climate change, since air quality had, until recent polls, been regarded as a more significant environmental issue in many parts of Canada. Indeed, the introduction of a tax credit for transit passes and proposed commitments to a 5 percent renewable (ethanol) content in fuels suggests that actions are more symbolic rather than aimed at making meaningful reductions in GHG emissions. Much more aggressive measures are necessary if Canada is to meet its Kyoto commitments. The latter regulation would generate a net reduction of between 2 and 4 Mt of GHGs, representing a very small dent into the 265 Mt reduction needed for Canada (from a Business As Usual projection of 828 Mt in 2010 to 563 Mt, which is 6 percent below the 1990 emission level of 599 Mt) to meet its Kyoto target. Furthermore, given past experience with environmental legislation (e.g. Canadian Environmental Protection Act), there are legitimate concerns that the new CAA may take years before it is passed, an unacceptable period of time in terms of the urgency to deal with climate change today, rather than tomorrow. Reductions can be achieved through the use or strengthening of existing regulatory tools, and reinventing the wheel or developing a new act is viewed largely as unnecessary.

**Science and policy challenges:**

The IPCC, in the summary for policy makers for Working Group II in the Third Assessment Report published in 2002, noted that climate change and air quality were interconnected in two key areas. First, projected climate change will be accompanied by an increase in heat waves, exacerbated by increased humidity and, in many regions, air pollution, which would lead to an increase in heat-related and smog-related deaths and illnesses (Ahmad et al., 2001). The report also notes that common air pollutants such as nitrogen oxides, sulphur oxides, volatile organic compounds and other particulate matter, contribute to the formation of ground level ozone and aerosols which have both positive and negative climate forcing. These findings suggest that as the scientific evidence of climate change and its impact on urban air quality improves, air quality management must consider the possible effects that a changing climate could have on regional air quality. Moreover, policy makers will also need to consider the additional positive or negative climate forcing that common air contaminant emissions could produce with existing or proposed air quality improvement measures.

In a more specific science and policy context, there are at least four additional aspects of the linkages between climate change and air quality that decision makers engaged in air quality management should consider:

1. the chemical/atmospheric interactions between climate change and air quality (how climate change will impact local air quality, and how air quality and emissions of particulates/aerosols affects climate change at a regional level);
2. actions that directly reduce emissions of GHGs and other air pollutants (e.g. fuel switching, best available technologies (BATs), renewables – however some BATs that reduce air pollutants may actually increase GHG emissions);
3. actions that indirectly reduce energy use and emissions (e.g. efficiency, conservation, pollution prevention, land use and transportation planning); and
4. actions that are both mitigation and adaptation; that is measures that reduce emissions and reduce vulnerability by enhancing adaptive capacity (this issue has received very little attention in the climate change literature). One example is the adoption of community-based energy systems such as combined heat and power, and wind power projects that both reduce emissions and reduce vulnerability to a catastrophic system-wide failure of the energy grid.

There are also other air issues to consider, e.g. HAPS, acid rain, particularly in terms of the cumulative impacts and effects, but the primary focus for this discussion are the links between air quality and climate change. It should be noted that some sectors or regions may also be subject to emission reduction controls or targets due to non-human health effects, such as emissions causing acid rain which continue to have significant impacts on aquatic and terrestrial ecosystems (Morrison and Caron, 2004).

The Air & Waste Management Association (AWMA) recently dedicated an entire issue to the linkages between air and climate change, but it was almost exclusively tied to the science and chemistry, rather than focusing on specific locations where it needs to be adopted, which sectors are more suitable for such measures, or what technologies are likely to generate the greatest benefits (Air & Waste Management Association, 2005). A quick scan of the issue illustrates what we know so far about the science and the challenges that remain. Of note, Pennell et al. (2005) identify the following significant interactions from a scientific perspective: emissions – which are highly dependent upon future economic growth, technological change, and energy use, recognizing that we need to be moving towards a zero net carbon emissions future; atmospheric processes and effects; modeling and simulation; monitoring; and policy making. The latter is obviously most germane to this discussion, but the authors do not go beyond concluding that the issues need to be addressed together, and that some policy analyses are beginning to focus on "co-benefits."

"Co-benefits" are gains to the environment that accrue due to reductions in emissions of GHGs and other air pollutants, such as reduced acid rain and improved air quality, leading to improved ecosystem and human health. Such benefits from taking actions to reduce GHGs especially by reducing fossil fuel combustion can be significant, especially for human health, at both the global and national level. This is particularly the case for measures that reduce GHGs while at the same time reducing emissions of coarse and fine particles. A study by Davis et al. (1997) estimated that by the end of 2020, just over 700,000 premature deaths would be avoided on an annual basis, if reductions in GHG emissions of 15% and 10% for developed and developing countries were to be achieved by 2010. This included 138,000 avoided premature deaths in developed countries, of which 33,000 would be avoided in the United States alone. While Canada was not specifically considered in this study, it is expected that hundreds if not thousands of premature deaths would be avoided in this country (Chiotti and Urquizo, 2002).

Pennell et al. (2005) also note that research activities in both areas are beginning to converge, but are relatively absent in day-to-day environmental policy and technology management decisions. To complicate matters, Prinn and Dorling (2005) argue that managing air quality in a way that supports a climate-stabilization policy could be more difficult than one would think. Based on Article 2 of the United Nations Framework Convention on Climate Change, climate-stabilization would occur at a level below where CO2e concentrations would cause "dangerous" interference with the earth's climate (between 450 – 550 ppmv). While this is a valid concern (and indeed a challenge), the authors provide few insights towards resolving the basic conundrum of addressing these issues together: does addressing air quality issues through actions that reduce greenhouse gas emissions produce a broader suite of benefits and outcomes, than addressing climate change by reducing emissions of other air pollutants?

Ten years ago the challenge of addressing air quality and climate change issues together was noted by Pearce et al. (1996) in the IPCC Second Assessment Report from Working Group II. They noted that the question of secondary benefits from carbon abatement should be distinguished from the more comprehensive issue of the optimal abatement mix with respect to all pollutants. In the case of the Kyoto Protocol, the argument has largely been driven by the implicit primacy of the greenhouse problem, with improvements in air quality viewed as welcomed side effects, rather than considered in their own right. International stakeholders attending the NERAM Colloquium Series generally agree that a joint approach to the management of air quality and climate change is the best way to proceed (Craig et. al., 2007a; 2007b). Nonetheless, there are some who may adopt the view that perhaps each pollutant (and air issue) should be assessed (and measures adopted to reduce emissions) in proportion to the environmental damage that it causes. As Pearce et. al. (1996) pointed out, interdependencies matter, as does location, and greenhouse gas emission reduction measures should be concentrated in places where the joint benefits of reducing all emissions is highest.

Similar observations are found in the UK (Air Quality Expert Group, 2007) where 6 key questions are raised that address 4 different areas related to air quality and climate change. Not surprisingly, most of the focus is on atmospheric science, and similar to the AWMA issue only gives cursory treatment to the implications for emissions and control options and concludes with the ominous observation that synergies and trade-offs exist in technical control measures, and that there is a need for integrated assessments across sectors and across effects. These last observations are precisely the issues which policy makers have to grapple with in the real world. They need to be recognized, explored, analysed and managed. There can be no hiding from them, nor denying their existence simply because they are inconvenient. As noted above, we are already facing some of them. With respect to the main points, the first three questions are worth closer consideration, dealing with the impact of climate change on air quality (question 1) and the impact of air quality on climate change (questions 2 and 3).

**Question 1: How could the likely impact of climate change on the general weather patterns and emissions of air pollutants and their precursors affect atmospheric dispersion and chemistry processes in general, and air quality in particular?** For example, might an increase in heatwaves affect air pollution episodes? Might the frequency and intensity of winter inversions decrease? If so, how will this affect air quality?

Several issues arise here. Unless there are any new non-linearities introduced by enhanced climate change, the effects on policy measures are probably minor. It should simply mean that we might need to do more than we thought (more of the same) if say, climate change leads to more frequent and more intense summer smog episodes. We might actually get more improvement than we thought, for the same emission reductions, in 'winter' episodes due to less frequent and less intense winter stagnation periods. It is probable that biogenic VOC emissions will play an increasingly important role in future summer smog episodes if present warming trends continue. Emissions from these sources vary non-linearly with temperature.

There are some estimates of climate change impacts on air quality that apply to Canada. On a broad scale, the Intergovernmental Panel on Climate Change (2001) has projected that, based on some scenarios, background levels of ground-level ozone will increase by more than 40 parts per billion over most mid-latitudes of the Northern Hemisphere. This would result in a doubling of average levels of ozone, and reach levels that would be in exceedance of current Canada Wide Standards. On a finer scale, Cheng et al. (2005) provides projections for air quality affecting Windsor, Toronto, Ottawa and Montreal, and estimated that for 3 different emissions scenarios the number of low ground-level ozone days would generally decrease and the number of high ground-level ozone days would generally increase. In the worst case scenario of air pollutant emissions increasing by 20 per cent by 2050 and 32 per cent by 2080, the study estimated that the annual total number of poor ozone days (one-hour maximum $O_3 \geq 81$ ppb) could increase by 4-11 days by the 2050s, and by 10-20 days by the 2080s. The number of good days (one-hour maximum $O_3 \leq 50$ ppb) could decrease by 24-40 days by the 2050s, and by 42-52 days by the 2080s.

Health Canada and Environment Canada are developing some new scenarios of climate change impacts on air quality for a national assessment on climate change and health due out later in 2007, but it remains uncertain if these efforts will improve our understanding substantially. It is probably prudent to agree with the Air Quality Expert Group (2007) and the point that different models show quite a wide range of responses, and that there are large uncertainties in the modelling output. In Canada, and southern Ontario and Quebec specifically, there is little doubt that air quality will get worse with climate change; however, by exactly how much is less certain, but the conclusion is nonetheless clear – that we need to do even more on reducing emissions causing air pollution, and ideally do so without adding more greenhouse gas emissions.

A logical extension of this work would be to project health effects, building on current health impact assessments. For example, an analysis of the recent summer ozone episode in the UK and Europe in August 2003 estimated that between 225 and 593 deaths were brought forward associated with ozone concentrations and some 207 associated with $PM_{10}$ (Stedman, 2004). Research in Canada has looked at the synergistic impacts of temperature change and air quality under three climate change emission scenarios (Cheng et al., 2005) and projected under the worst case conditions that mortality due to poorer air quality would increase 15-25 per cent by 2050 and from 20-40 per cent by 2080. Add to these numbers projections that heat-related deaths are estimated to double and triple by 2050 and 2080 respectively. These are not trivial numbers in terms of human health, since an estimated 6,000 premature deaths already occur across Ontario due to air pollution, and hundreds of deaths due to heat stress annually (Ontario Medical Association, 2005). The synergistic and cumulative impacts on managed and unmanaged ecosystems could also be substantial, whether in concert with air quality, acid deposition or air toxics.

Undoubtedly, a key to the assessment of future ozone effects is the issue of whether or not there is a threshold for effect. If there is, then the projected effects could be large; if there isn't, then they will be small and potentially significantly less than those due to PM.

Ozone is also difficult because the behaviour of future trends depends on the metric one is examining. Peak hourly ozone will behave differently from the annual mean (in general in urban areas the former will decrease with decreasing NOx and VOCs but the latter will increase, being dominated by the titration in urban areas), and metrics between these two extremes will differ in their behaviour too. In fact the behaviour is controlled by three factors: (i) the local NOx environment and the titration effects; (ii) the behaviour of the NOx/VOC smog reactions in future scenarios; and (iii) the influence of the global tropospheric background. Because of these (especially (i) and (ii)) future ozone trends will be strongly location specific and this means that one has to do urban scale modelling – not something the ozone modelling community has addressed very much as yet (Gower et al., 2005). This conclusion is consistent with conditions experienced in Ontario and Quebec, a region that is subject to considerable transboundary pollution from the U.S. Ohio Valley. In Toronto, for example, during smog episodes driven by ozone, more than 90 percent of the pollution comes from the U.S.; whereas during PM driven episodes, the percentage is closer to 50 percent (one assumes that on days when air quality levels do not warrant the issuance of a smog advisory, most of the air pollutants are from domestic sources, whether they are ozone precursors or PM) (Yap et al., 2005). This implies that local actions to reduce emissions, especially during ozone events, will have little impact on ambient conditions, and that for measures to be effective, they either have to be international or airshed in scope, or at a much finer spatial resolution. In the latter case, emission reductions targeting ozone precursors that are known to cause serious health effects (e.g. $NO_X$ and ultrafine particles) may need to be neighbourhood (or even site) specific, in addition to micro-modelling of individual risk exposure. The effectiveness of site specific actions would be determined by the mix of the pollutants during the smog episode (in Ontario during the traditional smog season from May to September, although smog episodes are largely driven by ozone, they often include significant amounts of ozone precursors and PM). The other important issue in terms of climate change and ozone is the influence of biogenic emissions which needs fuller assessments in considering control scenarios for future years.

**Question 2: What are the links between the sources of emissions responsible for climate change and air quality?** What are the main scientific issues associated with the interactions of GHGs and air pollutants in the atmosphere and their impacts on climate change and air quality?

**Question 3: What do future trends in UK air pollutant emissions tell us about the potential impact on climate for the UK and Europe?** Given that some air pollutants cause air quality concerns on a regional scale, over what scale will their impact on climate be felt?

The answers to these questions are even more complex than the previous question and relationship. The role of aerosols in off-setting climate change on a local scale is still very much an emerging science, and policy makers risk venturing into the debate of having decision makers ponder polluting more SO2, NOX and PM in order to off-set climate change. In the Summary for Policy Makers from the IPCC Assessment Report Four, it is estimated that without the cooling effect from human-made emissions of aerosol pollutants, it is likely that greenhouse gases alone would have caused more global mean temperature rise than what was recorded in the past 50 years (Alley et al., 2007). The report also estimates that if all sulphate aerosol particles were somehow removed from the atmosphere, there would be a rapid increase of about 0.8°C within a decade or two in the globally averaged temperature.

More specifically, the challenges, complexities and trade-offs between air quality and climate change can be illustrated by considering three key sectors: energy, transportation and agriculture. Although it ultimately comes down to how society generates, produces and uses energy, policy-makers also need to consider the need to move towards a net zero carbon future, where we need to decouple the global economy from fossil fuels and rely upon non-carbon sources of energy.

Both climate change and air quality policies deal essentially with the same emission sources, so it is clearly sensible to ensure they are considered together by policy makers. Some key observations regarding challenges and opportunities are as follows:

*Energy*

- Any policy measure which reduces the use of fossil fuels in existing applications will be co-beneficial for air quality and climate change. Such measures include energy efficiency in buildings and households, which could also have co-benefits in the form of improved indoor air quality.
- Measures to increase the proportion of carbon-free energy generation in the portfolio will be co-beneficial. Sources would include, wind, solar, hydro, tidal, wave, and nuclear, although some of these have their own associated problems and challenges (i.e. nuclear waste issues and public acceptance of wind farms). Community-based systems enhance local adaptive capacity, create and retain jobs in the local community, and potentially reduce a wide range of pollutants contributing to air pollution and climate change, in addition to CFCs, although these outcomes are necessarily clear (see below).

- Potential trade-offs could arise where energy generating sources fit aftertreatment of the flue gases, a practice which usually leads to a small fuel consumption penalty. Historically this penalty has been considered worth paying due to the significant air quality benefits for public health and the wider environment which can accrue. Reductions of air pollutants like sulphur dioxide has resulted in a decrease in aerosol sulphate concentrations which, on the basis of current knowledge, has lead to an increase in radiative forcing. Despite this, it is unlikely that policy measures would be considered to increase sulphur emissions as a means of alleviating radiative forcing.
- Measures to increase the efficiency of fossil fuel use by replacing remote, central energy generation from fossil fuels by local small scale combined heat and power sources in urban areas, running on fossil fuels or biomass could lead to climate change/air quality trade offs which should be quantified and assessed. Moreover, even if biomass is burned such that air quality does not worsen, but stays broadly constant, then the potentially larger air quality, public health and environmental benefits resulting from truly zero-carbon sources of energy are foregone

*Transport*

- The classic problem here is the diesel vehicle. This has more efficient use of fossil fuel energy than petrol/gasoline and hence smaller carbon emissions per kilometre travelled, all other things being equal. However, there are potentially significant public health disbenefits arising from the higher emissions of particulate matter which have arisen to date from diesel vehicles compared with petrol/gasoline equivalents. Technology is available to reduce significantly these emissions of particulate matter and proposals for emission standards for light duty vehicles which it is thought will require such technologies have been proposed by the European Commission (see Chapter 4). Concern has been expressed that these devices lead to increased fuel consumption, on the order of a few percent, and this has been cited as a reason not to proceed with these controls. It seems likely, at the time of writing, that the EU will go ahead with agreeing to such standards so that by implication the EU has tacitly accepted that the small fuel penalty is outweighed by the relatively large (potentially of the order of about 90%) reductions in particulate matter. One factor which has not been included in analysing these trade-offs is the benefit to radiative forcing which may arise from the reduction in black carbon emissions from diesel vehicles. The reason this has not been done is the uncertainty in the science in this area, and that of the wider issue of aerosols and climate change as a whole where more research is clearly needed. However, measures such as particulate filters/traps which reduce particulate matter emissions by significant amounts will clearly be effective in reducing these trade-offs. As with energy use in fixed sources, any policies which lead to reduced travel and/or fuel use will be a win-win for climate change and air quality. Such measures are usually fiscal and could involve such policies as road user charging, fuel duty measures, tax/duty measures on high-emitting vehicles (although until the primary particulate emissions from diesel vehicles are reduced significantly-as discussed above-there are potential perversities in applying such measures to the current fleet). Measures on aviation are probably of wider interest in the climate change context but reductions in $NO_x$ emissions from aircraft engines in the cruise and take-off engine modes will benefit both climate change and local air quality which can be a problem around larger airports.

- In the medium to longer term, low carbon vehicles (hybrids, fuel cell vehicles etc) will also be win-wins, providing the primary energy generation is also low or zero carbon.

*Agriculture*

- The common issues linking climate change and agriculture are mainly related to methane emissions and its impact on tropospheric ozone levels, and ammonia emissions which can affect ecosystems directly in the vicinity of sources, and at longer range through the formation of secondary particles which can affect health and can be deposited on ecosystems where they contribute to acidification and eutrophication problems, and which also have potentially important climate effects.
- The commonality of air quality and climate change issues and tropospheric ozone is clear and there will clearly be co-benefits arising from any measures to reduce methane emissions from agricultural sources world wide.
- Solutions to the problems of ammonia, air quality and climate change are less obvious. The problem arises through the so-called 'pollution swapping' concept and the management of nutrient nitrogen in the agricultural context. Nitrogen releases in this sector arise from fertiliser use and the excretion of nitrogen by animals. Depending on the specific local practices, residence times of manure and slurry in containers and soils etc, this nitrogen can potentially enter the environment as nitrate in streams and rivers where it can cause water quality problems, or it can be released to the atmosphere as ammonia and contribute to the problems outlined above, or it can be released as nitrous oxide, a powerful greenhouse gas. Abatement methods and policies to reduce the effects of nitrogen on the environment need to recognise these potential problems and seek to find optimal solutions. This is an area of developing science.

### 5.4 Future Research Requirements

What are the current gaps in our knowledge? Where should future research focus to provide appropriate scientific information to inform decisions about the comparative benefits of air quality and climate change mitigation measures? Are the currently available scientific tools sufficient to answer these gaps in our knowledge, and if not, what further developments are required? Based on the UK and Canadian experience, it may be prudent for developed and developing countries to consider the synergies between air quality and climate change policies for future time intervals, at both intermediate and long-term periods, say 2020 and 2050. This has been done in the UK context, with specific reference to London, and the linkage between GHG emission reductions and future concentrations of NOX and PM (Williams, 2006).

At this point we can begin to at least map out the challenge. Certainly technology will play a big role in determining how successful we are in reducing emissions of GHGs and other air pollutants. In Canada, there are large dollars being invested by government and industry in sustainable technologies, and a review of the Canadian situation illustrates which sectors are attracting the most attention from an investment perspective. According to Sustainable Development Technology Canada (2005) the two sectors receiving the most funding are energy exploration and production (24%), and energy utilization (25%), followed by power generation (16%), transportation (12%), forestry and wood products (9%), waste management (9%), and agriculture (5%).

The three examples discussed above illustrate the challenges of making connections between air quality and climate change. These include energy – specifically the feasibility of less polluting alternatives such as "Clean Coal," green renewables (e.g. river run hydro, wind, solar, biomass), and other less polluting fossil fuels (distributed energy systems, co-generation natural gas for example). The National Roundtable on the Environment and Economy recently released their own climate change and energy strategy for 2050, and this included the adoption of clean coal technologies in western Canada (in Alberta and Saskatchewan where it may be geologically feasible to sequester CO2 underground, and at the same time make it easier to extract oil and natural gas from the tar sands), but this would not be suitable to Ontario where the geological conditions do not support underground storage (NRTEE, 2006). There may be some potential in the U.S. where coal plants are more likely to be located closer to coal mines, but under the Clean Air Interstate Rule there seems to be almost exclusive commitment to improving air quality rather than dealing with climate change (undoubtedly a reflection of the current Bush administration's attitude towards climate change), where significant reductions in NOx, SO2, and even mercury are possible through end of pipe technology. Of course these technologies do nothing about CO2 and in some cases can even add GHG to the atmosphere.

This point is well known in the non-ferrous smelting sector, and INCO[3] and Falconbridge[4] in particular. In the case of INCO's superstack in Copper Cliff (Sudbury) Ontario, their sulphur extraction process results in a lowering of temperature in the plume that otherwise contributes to acid rain hundreds and thousands of kilometers away. The lower temperature, unless addressed, would result in the plume falling almost immediately, thereby placing INCO in a non-compliance position with respect to local air quality standards. As a result, they have to burn propane in order to heat up the superstack sufficiently for the SO2/NOx laden plume to rise sufficiently high enough to be dispersed more broadly. Ironically, the superstack represents outmoded 1970s technological solution to reduce pollution by dilution, and address years of non-compliance with local air standards. However, the addition of burning propane clearly puts the companies operating the smelters in conflict with any regulatory requirements or expectations to reduce GHG emissions. Furthermore, there are other smelters operating in some provinces (e.g. Manitoba) where local air quality standards and enforcement are not as strong as in Ontario, raising Federal concerns about gaps in Provincial regulations to protect human health. Consequently, in the recent Pollution Prevention plan posted on the Canada Gazette for the regulation of SO2 emissions from non-ferrous smelters, community-scale air standards and monitoring were also included (Department of the Environment, 2006).

Non-carbon alternatives pose challenges in terms of pricing and intermittency, and also open the door to include the nuclear option (which has resurfaced in Ontario, and in parts of Europe, despite wishes to retire and decommission nuclear plants). In many countries the best places to develop renewables, including large scale hydro, tend to be located far away from where the demand is, which poses additional challenges in terms of transmission and distribution. Nonetheless, there is great untapped potential for renewables in many countries, including Canada. In northern Ontario, for example, untapped river-run hydro and wind power in the James Bay and Hudson's Bay lowlands could easily supplant the electricity currently generated by nuclear plants, although an extensive and costly transmission grid would need to be constructed.

It is also important to recognize that energy efficiency and energy conservation may in fact be two of our most important measures to lower emissions (by reducing

[3] In October 2006 Companhia Vale do Rio Doce (CVRD) acquired control over INCO, and the company is now officially called CVRD Inco Ltd.

[4] In November 2006 Xtrata Plc acquired control over Falconbridge.

the problem at the source, simply reducing our use of energy). Canada's use of coal-fired electricity and emissions causing air pollution and climate change would be much higher today, if we hadn't been so successful at improving energy intensity and efficiency. That being said, Ontario is about 50 per cent less efficient than neighbouring New York State suggesting that there is much room for improvement (ICF, 2006). At the residential scale, energy efficiency/conservation options such as improved insulation, heat and air exchange systems, green roofs, etc. can lead to reduced energy and electricity use, and also provide co-benefits for urban biodiversity, and improved indoor air quality.

In terms of transportation, improved fuel efficiency standards are essential to reduce GHG emissions, and represent an important opportunity to lower emissions causing climate change (Oliver, 2005). However, as noted in the UK experience, improved fuel efficiency does not necessarily equate to reduced air pollutant emissions (generally it does, but sometimes it does not) and an analysis of the impact on public health of the increased dieselization of the UK car fleet has recently been published (Mazzi and Dowlatabadi, 2007). Alternative fuels are also an option, as many governments are now moving towards the expansion and promotion of ethanol and biofuels. Life-cycle assessments suggest however that the overall benefits to the environment and health in terms of GHGs and air pollutants are not that large, if at all, depending upon the pollutant that you are considering.

Using less fuel or moving to less emitting vehicles on a km-passenger basis is another option, such as modal shifts from single occupant vehicles to public transit, car pooling, telecommuting, or active commuting. The latter has huge implications for children and youth, in terms of combating obesity and diabetes, but runs into the problem of promoting physical activity during smog episodes. Land use and transportation planning is also essential – specifically the problem of sprawl, as North American cities know only too well (to a lesser degree in Europe and South East Asia). In Toronto, BAU projections are for an additional 3 million people by 2030, an equal number of passenger vehicles, and a 30-40 per cent increase in GHG emissions from transportation sources (Ontario Smart Growth, 2003). Building more efficient vehicles, installing better emission control technologies, and using alternative fuels are all good measures, but we also need to go beyond and consider not using cars period. Similar challenges exist for the movement of commercial goods and freight, involving air, rail, shipping, and intercity and local trucking. Incorporating intermodal use into a sustainable transportation strategy remains the unsolvable problem, as does addressing "just-in-time" delivery systems (the equivalent to sprawl as a huge structural problem).

In the end, it is important to recognize the need to look at these problems and challenges more closely, accept that these challenges are significant, and that there is no silver bullet that is going to solve the problem of both air quality and climate change. A wide suite of measures will be required, and we need to move quickly and effectively. The challenge may be great, but the need to move forward in this direction is certain. As Williams (2007) states:

*…we have not yet reached the limit of improvements to air quality. There will inevitably be debate over the feasibility of such improvements, and the costs which society will be prepared to devote to them, seem clear that significant reductions are still possible and that such air pollution levels could represent substantial reductions in adverse effects on public health and ecosystems… there are potentially significant advantages to be gained from a harmonized and concerted analysis of policies on climate change and air quality.*

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