Climate change and air quality: implications for NSW

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Introduction

The term 'climate change' refers to the possible impacts, including global warming, arising from the increase of greenhouse gases in the atmosphere. This presentation examines one impact—air quality—and how it relates to NSW and to Sydney in particular.

The structure for the presentation is based on an environmental risk framework (Beer 2003) known as the Budapest Manifesto framework (www.iugg.org/budapest.pdf) which contributes to decision-making. The manifesto suggests the following steps to examine technical and social issues related to sustainability:

- anticipating man-made and natural risks through widespread **consultation**
- determining **concerns** by using risk assessment techniques for various scenarios
- identifying the **consequences** by systematically cataloguing hazards
- undertaking **calculations** with appropriate models
- evaluating the **certainties**, uncertainties, and the probabilities involved in the calculations of the vulnerability and of the exposure
- **comparing with criteria** to assess the need for further action
- determining and acting on options to **control**, mitigate and adapt to the risk
- **communicating** the results to those who need to know
- promoting and guiding **monitoring** systems to collect, assimilate and archive data relevant to the determination of sustainability and risk, now and in the future
- integrating the knowledge and understanding from all relevant disciplines to provide society with the tools to **review** the sustainability and the risks of proposed policies and plans.

Context

The context can be found in the various *State of the Environment* reports produced by the NSW (Environment Protection Authority 2003) and the Federal (Manins et al. 2001) governments—as well as in many other publications such as the various studies of alternative fuels that CSIRO has carried out (Beer et al. 2001, 2003, 2004).

Concerns

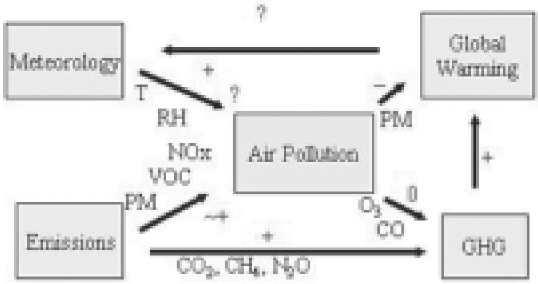
The concerns are that an increase in greenhouse gases leads to a greenhouse effect that manifests itself through global warming which leads to climate change and this climate change, by affecting the meteorology, has air quality impacts. In addition, we need to be aware that air quality can also influence the greenhouse effect directly through the emissions of greenhouse gases, and indirectly through the role of aerosols.

Consequences

The consequences that Hennessy et al. (2003) examined are: smog, bushfires, particulate matter, pollen and asthma. This presentation will concentrate on greenhouse gases and smog issues. The two determinants of air pollution are emissions, and the local meteorology. Figure 1 illustrates this by showing meteorology and emissions as boxes on the left with arrows leading into the box marked 'Air Pollution'.

Calculations

Figure 1: Interaction between air pollution and global warming



The '+', '-', '0' and '?' represent whether the link exacerbates (+), mitigates (-), is neutral (0) or unknown (?). The relevant gases or meteorological variables are also shown adjacent to each link. See the glossary at the end for explanation of abbreviations.

The emissions of the criteria pollutants, particulate matter (PM), volatile organic compounds (VOC) and oxides of nitrogen (NO_x) in general exacerbate air pollution. Because there is a complex chemical reaction that converts VOC and NO_x to ozone, the major constituent of photochemical smog, the arrow in Figure 1 shows '~+' meaning that in general an increase in these emissions leads to more air pollution. Because chemical reactions proceed more quickly in high temperatures (T), higher temperatures also exacerbate air pollution (which is why the '+' sign is linked to the 'T' in the upper left arrow). It is not clear whether changes in relative humidity (RH) affect air pollution (which is why the '?' sign is linked to the RH in the upper left arrow).

When we consider the interaction with greenhouse gases and global warming then there is generally a positive feedback, as shown by the '+' signs next to the bottom arrow and the right hand arrow of Figure 1. However, particulate matter reduces the greenhouse effect (Houghton et al. 2001, Ch.5) so that the upper right diagonal arrow has a minus sign linked to PM. The most complex interaction is that between global warming and meteorology. The question mark on the upper arrow indicates that the link between global warming and meteorology is uncertain because it will depend on the details of how global warming takes place, and the meteorological effects will vary spatially and temporally. GCMs, which can stand for 'General Circulation Models' or 'Global Climate Models', are computer models that work out such interactions.

In the case of Sydney, the results from the CSIRO Climate Change Projections for Australia (http://www.dar.csiro.au/impacts/future.html) indicate that by 2030 there is a likelihood of a 1 degree Celsius rise in mean annual temperature, and by 2070 there is a likelihood of a 3.5 degree Celsius rise in mean annual temperature. The rainfall is expected to decline.

Monitoring

Ozone is the pollutant that is used to measure smog. In examining the number of days that readings from measurement stations in Sydney exceed the ozone standard of 10 ppm (Figure 2), it appears that in Sydney the El Nino cycle plays a strong role, with El Nino years such as 1983, 2001 showing more ozone exceedences than in years such as 1989.

Comparison with criteria

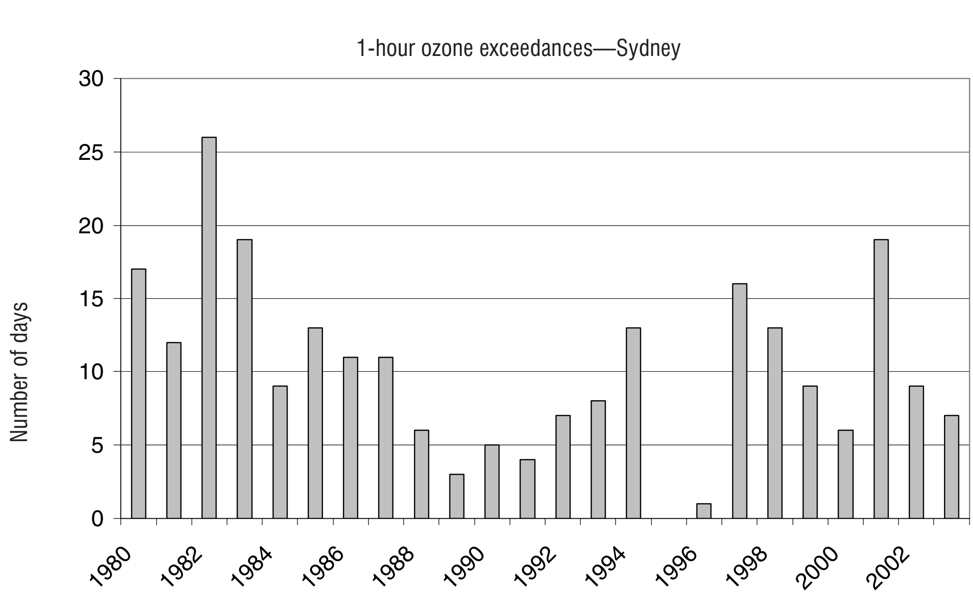
Recent work examined the expected ozone in US cities as a result of global warming (Lashof et al. 2004). In every case the number of days with low ozone concentrations go down, and unhealthy days, namely those with high ozone concentrations, go up.

An indicative guide to the likely effects that meteorology may have on air pollution consists of the number of days that the temperature exceeds 31 degrees Celsius. The monthly distribution of such days in Sydney is the same as the monthly distribution of smog days—namely from October to March. This indicates that if the temperature were to rise by three degrees then the number of days of ozone exceedence (smog days) would go up from 12 days per year (on average) now to 15 days per year in 2030, and 30 days per year in 2070. This is based on the meteorology alone, and assumes that nothing further is done to control emissions.

Control, communication and review

In terms of reducing greenhouse gases, policy options are directed towards abatement of emissions in the energy

Figure 2: The number of days in NSW that exceed the one-hour ozone standard appears to be strongly influenced by the cycle of El-Nino events



sector, which produces 68% of Australian greenhouse gas emissions. Such energy policy options can be divided into four groups: supply-side changes, demand-side changes, fuel switching and pollutant capture.

In general, measures to reduce greenhouse gases will reduce air pollution (and vice versa) but this is not always the case and one needs to examine possible policy options to ensure whether they are positive (they reduce both greenhouse gases and air pollution) or perverse (they increase one or both of greenhouse gases or air pollutants).

Diagrammatically, we can show this using a four-division quadrant with air quality and greenhouse gas options divided into good and bad options. Most greenhouse gas abatement options and air quality improvement options are good in terms of both greenhouse gases and air quality. But some policy options are not as clear cut.

For example, is the option of 10% ethanol in petrol in Sydney a positive or a perverse policy option? There are some important imponderables that make it difficult to provide a clear answer.

The first imponderable is whether the greenhouse gas emissions are better, worse, or the same. Greenhouse gas accounting rules say that a 100% renewable fuel may be treated as emitting zero greenhouse gases from the tailpipe. The fuel when burnt emits carbon dioxide but the carbon dioxide is not counted as a greenhouse gas because it is not fossil carbon dioxide. One way to think of this is to envisage red carbon dioxide and green carbon dioxide coming out of the tailpipe of a car, with the green carbon dioxide not being counted as a greenhouse gas.

On the basis of the NSW ethanol trials that were run in 1997, 10% ethanol in petrol leads to a 7% decrease in tailpipe greenhouse gases. When the whole life cycle is taken into account (Beer et al. 2003) then the greenhouse gas savings from renewable fuels range from 1.7% (from wheat) to 5.1% (from molasses, using co-generated power).

A second imponderable is that adding 10% ethanol to petrol increases the octane number—which is desirable, but also increases the vapour pressure, which is generally undesirable. NSW wishes to control the vapour pressure of petrol, even though the NSW long-term goal of 57 kPa for the Reid vapour pressure is higher than the present Californian standard of 48.3 kPa.

The reason for controlling vapour pressure is to try to control smog formation. Addition of 10% ethanol to petrol will increase the volatile organic compounds being evaporated and those being emitted from the tailpipe, by 45% and 7% respectively.

But these increases in VOCs turn out to produce only slight increases in ozone. Modelling work by Cope et al. (2003) indicates that the overall trend is towards ozone reduction—though this is very dependent on the meteorology.

Overall, the results from studies on ethanol are variable. There are positive greenhouse gas (GHG) and air quality (AQ) benefits, but in each case there is a 25% probability that the benefits may not materialise. This may be shown diagrammatically (Figure 3) by drawing quadrants of possible policy options and placing the 10% ethanol in petrol option (denoted by E10) in a circle, displaced from the centre such that the displacement is towards the improved GHG and improved AQ quadrant.

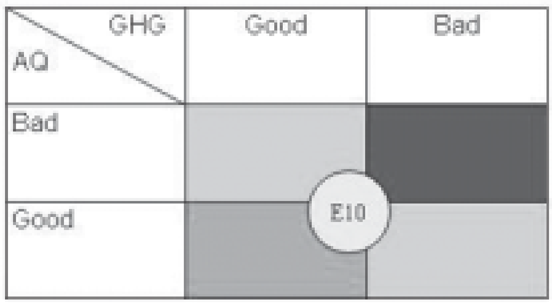


Figure 3: Diagrammatic representation of the uncertainties associated with the policy option of introducing petrol containing 10% ethanol

Overall the option may be expected to be positive, but there is a finite probability of a perverse outcome.

Some policy options that are good for greenhouse gases may be bad for air quality. Producing electricity in the Hunter valley and sending it to Sydney through transmission lines is wasteful because of the transmission losses. Putting small scale distributed power stations where they are needed will save greenhouse gases, but the emissions from those generators may worsen air quality.

Cars being driven around a city also constitutes an example of many, small-scale, distributed power generators. We know that they are bad for air quality. However, hybrid electric vehicles use only half the petrol of an ordinary petrol car when used in the city. This means that their use will reduce both air pollution and greenhouse gas emissions, provided that one does not try to charge the electric car using the grid-generated electricity, in which case the greenhouse gas advantages are lost. Thus, in the policy options diagram (Figure 4), distributed power is a perverse policy option being good for greenhouse gases but bad for air quality. Nevertheless, the policy option does have a chance of being positive if the noxious emissions can be properly controlled.

A policy option that is good for air quality but may be bad for greenhouse gases is the use of selective catalyst reduction on trucks so that they can meet Euro4 diesel standards (Coffey, 2004). This particular technology requires urea—a nitrogen-based fertiliser—to be added to the catalyst. This is going to produce nitrous oxide, N_2O, which is a greenhouse gas. Thus, in the policy options diagram (Figure 4), on the basis of our present knowledge, selective catalyst reduction (SCR) is a perverse policy option.

Similarly, the idea of using hydrogen-powered buses and cars is very good for air quality but the greenhouse gas situation is more complicated. If the hydrogen supply is from natural gas reformulation then, on a life-cycle basis, there is no greenhouse gas advantage to using hydrogen fuel (Beer et al. 2001). However, there is a substantial advantage in terms of low emissions of urban pollutants. This is because the combustion of hydrogen produces only water vapour as its emission.

However, if hydrogen is produced from renewable sources such as wind, solar or tidal power then there could be both reduced urban pollution and greenhouse benefits. The same would be true of the carbon dioxide emissions where it can be sequestered. Thus in the policy options diagram of Figure 4, hydrogen vehicles can also be viewed as a perverse policy option—though it has the possibility of being positive if properly implemented.

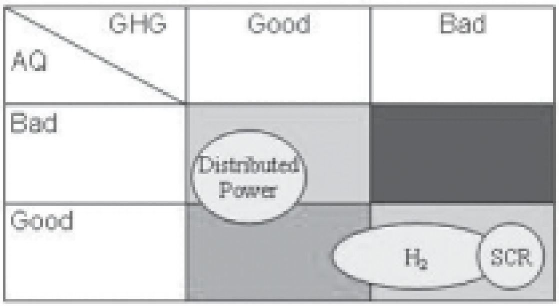


Figure 4: Policy options diagram for distributed power generation and for the use of hydrogen as a transport fuel

Issues such as these are being examined by the Energy Transformed Flagship, which is one of the CSIRO major flagship programs. The Energy Flagship has four major themes:

- energy futures
- low-emissions electricity
- low-emissions transport, and
- low-emissions distributed energy.

Further information is available at: www.energytransformed.csiro.au

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Glossary

Symbol	Name	Meteorological variable	Greenhouse gas	Air pollutant
CH_4	Methane		X	
CO	Carbon monoxide			X
CO_2	Carbon dioxide		X	
N_2O	Nitrous oxide		X	
$NO_x(NO + NO_2)$	Oxides of nitrogen			X
O_3	Ozone			X
PM	Particulate matter			X
RH	Relative humidity	X		
T	Temperature	X		
VOC	Volatile organic compounds			X