The value of health damage due to sulphur dioxide emissions from coal-fired electricity generation in NSW and implications for pollution licences

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The health impacts of air pollution are increasingly recognised, with the main sources being transport, electricity generation and biomass burning. There is extensive public debate about the transition of the electricity sector away from coal-fired generation, but the health effects are not well heard in this debate.

Estimates of the health externalities of coal-fired power stations (CFPS) for Europe show an air pollution mortality burden from brown coal of 32.6 (credible range 8.2–130) and black coal 24.5 (credible range 6.1–98) deaths per TWh of electricity production based on the ExternE methods.1 The ExternE project uses an impact pathway approach with four steps: the source of emissions; transport and dispersion; a dose response function for health impacts; and a valuation method to express this in monetary terms.2

While it is not too difficult to measure what goes up a chimney, it is much more complex to determine the pathway to the point of human inhalation. Exposure pathways include atmospheric chemical reactions, dispersion, transport and removal, which must be connected to geography and population density.3 The ExternE methods use atmospheric dispersion models because direct measurement is generally not possible. Direct measurement is, however, possible in NSW, where there is only one big population centre, and only five emissions sources of substantial amounts of sulphur dioxide (SO2). This method would not be feasible in Europe or North America, where there are many population centres and many emissions sources within the radius of dispersion.

Analysis by the Australian Academy of Technological Science and Engineering in 2009 adjusted the ExternE methods for Australia using regional population density to arrive at externality cost per MWh of $7.60 for SO2, $4.20 for NOx and $1.40 for PM10, for a total health externality cost of $13.20.3 Merely adjusting European damage costs by Australian population density is an overly simple method that takes no account of actual geography or weather patterns. Sulphur dioxide (SO2) is a by-product of burning coal, and the quantity released is directly proportional to the sulphur content of the coal. NSW coal is regarded as having low sulphur content (typically 0.56%) but, as large quantities are burnt, the combined SO2 emitted is around 250kt/yr. It is possible to remove SO2 from flue gases with post combustion ‘scrubbers’ but no power station in NSW has this equipment. All other sources of SO2 are relatively minor, as shown in Figure 1 from the NSW EPA.4

In the atmosphere, SO2 undergoes chemical reactions to form secondary sulphate particles that will eventually settle out of the air but, as these reactions are slow, it may travel hundreds of kilometres while still in the gaseous phase.4 Sulphate particles are small and respirable, being one constituent of the particulate air pollution in the size fraction smaller than 2.5 microns (PM2.5), which have well-documented health effects. As well as contributing to particle formation, SO2 has direct irritant effects on airways and is known to trigger asthma attacks in children.5

Other important pollutants released by burning coal include nitrogen dioxides (NOx), fine particles PM10 or PM2.5, and mercury.4 The long-range dispersal of these pollutants is, however, not so well understood. There has been worldwide interest in using market mechanisms to drive reductions in pollution. These are attractive, as there is no safe level of exposure for many pollutants. Merely regulating to some pre-set level of emissions will not drive progressive improvements, while a market mechanism that puts a price on pollution can achieve this. Market mechanisms have been very successful in some situations; for example, the Swedish NOx reduction scheme introduced in 1992, which drove a 50% reduction in emissions.6 Since 1999, NSW has a pollution licence system known as load-based licensing, under the Protection of the Environment Operation (General) Regulations 1998, which imposes a price on each kilogram of each pollutant emitted. Typical pollution fees for a MWh of electricity generated in

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Figure 1: Emissions of SO2 in the Sydney Greater Metropolitan Region, which extends from Wollongong to Muswellbrook and Lithgow.

Source: Consultation Paper: Clean Air for NSW 4

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Commentary

NSW are: sulphur dioxide – 4.3 cents; nitrogen dioxide – 23.5 cents; PM10 – 3.4 cents; mercury – 0.7 cents; fluoride – 1.1 cents; for a total fee of 32.95 cents/MWh. The current wholesale price is $88/MWh, so the pollution fees are 0.37% of the sale price, and generally regarded as providing no financial incentive to improve production practices. In this context, it is relevant to examine the value of health costs from coal-fired electricity generation so that licenses can include appropriate pricing of air pollution.

Pieces of the jigsaw puzzle

The four steps of the impact pathway approach have all been described in published research conducted in Sydney, or in routinely collected data. The transport and dispersion step has been studied by Cohen et al. from ANSTO and CSIRO, who showed that between 14% and 18% of PM2.5 in Sydney can be traced back to one of the NSW CFPS. They collected 9,000 teflon filter samples over an 11-year period from a semi-rural location on the outskirts of Sydney and, using ion beam analysis, identified the presence of 22 elements. They then used a statistical method of positive matrix factorisation to identify seven fingerprints of the various particle types. Two of these, secondary sulphate and aged industrial sulphur, are produced in the atmosphere by reactions with sulphur dioxide. Hourly weather data was used to create a meteorological back trajectory to identify where the particles had come from. This was possible, as the eight CFPS then operating were located in just three clusters. This gives a stronger basis for attributing exposure to sources than is available in previous research. In calculations, I used the midpoint estimate of 16% of PM2.5 being derived from CFPS. Although these measurements were from just one location, PM2.5 is widely dispersed and there is high correlation between measurement sites across Sydney. Since the Cohen samples were collected, three of the eight CFPS have closed, but SO2 discharge has not substantially changed as the remaining five have increased their output. The closed plants were in close proximity to remaining plants. There could potentially be other contributions to PM2.5 from coal-fired power stations such as fly ash. This calculation is based only on the sulphur dioxide contribution.

Estimates of the health burden attributable to fine particle pollution at current levels of exposure in Sydney have been recently published. Broome et al. used a damage function approach, linking PM2.5 exposure at four monitoring stations to 2007 values for deaths and hospital admissions across 39 local government areas using the BenMap-CE software. This showed that, despite PM2.5 levels in Sydney being generally low by international standards and less than the 8ug/m3 national standard for annual average exposure, there were 430 premature deaths annually (95%CI 310–540) and 5,800 years of life lost (95%CI 3,900–7,600) due to current exposures. They further estimated that a 10% reduction in PM2.5 would result in a reduction in deaths over a 10-year period of 650 (430–850) and 3,500 (2,300–4,600) years of life lost. In addition, there would be 700 (95%CI 450–930) fewer hospital admissions with heart or lung disease. The estimates are calculated over 10 years, as these effects are from cardiovascular disease that has a long lead time. For the purposes of estimating long-term health effects, I used one-tenth of this value as an annual effect.

Our valuation method uses the statistical value of a life, and of a statistical life year, as recommended for use in Australia by the Department of Prime Minister and Cabinet. The statistical value of a life, current at 2014, is $4.2 million, and for a year of life is $182,000. The value of statistical life is an estimate of the financial value society places on reducing the average number of deaths by one. A related concept is the value of a statistical life year, which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year. These estimates are widely used for cost-benefit analyses of regulatory impact assessments where regulations might save lives, such as in road and vehicle design or health and safety laws.

A hospital admission in Australia for cardiovascular disease costs on average $9,982 for men and $8,634 for women in 2008–09. The average of these values, $9,308, is used, as the Broome et al. study does not give breakdown by sex or between CVD and respiratory admissions. Electricity generation amounts were retrieved from the Australian Energy Market Operator. In 2014, total NSW generation was 59,370 GWh and total coal-fired generation was 53,002 GWh.

The health costs

If the proportion of PM2.5 that is secondary sulphate particles attributable to CFPS were removed from the atmosphere, PM2.5 would be 16% lower, which would lead to 104 fewer deaths and 560 fewer years of life lost, as shown in Table 1.

This would have a value of $437 million based on deaths or $102 million based on years of life lost. The large difference between these two estimates is because air pollution deaths are due to heart disease and stroke, which mostly occur in older people with less remaining life expectancy than the population average. In addition to these values, there would also be a direct financial saving from avoided hospital admissions for CVD of $1.04 million.

As NSW CFPS produce 53,002 GWh of electricity annually, there are 1.96 deaths per TWh of production.

Discussion

The value of $1.94 (95%CI $1.28, $2.55) based on years of life lost plus hospital admissions is the best estimate. This value is considerably lower than the previously available estimate, but it is based on high quality local research rather than adaption of European values. It is a strong basis for formulating pollution control policy. This figure should be compared to the 4.3 cents per MWh currently paid as SO2 pollution fees by existing generators. The amount of $1.94 is only the SO2 contribution to health damage from sulphate particles, and does not reflect the health damage from NOx, other particles, mercury and gaseous SO2, which are in addition to the sulphate particle effect. Increasing the pollution fee to match the value of the health damage would have several substantial policy advantages. It would provide financial incentive for cleaner

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<th>Table 1: Annual health burden due to fine particle air pollution from coal-fired electricity in NSW.</th>
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<td>Annual burden avoided with 10% reduction in PM2.5 (95% CI)</td>
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production where the marginal cost of abatement is lower than the pollution fee. It would make the dirtiest power stations less profitable and potentially hasten their closure. Applying a fee per tonne emitted creates an incentive that matches what we know about air pollution science: for many pollutants there is no safe level and there will be benefits from reduced emissions at any level. It would provide a revenue stream that could be used for any purpose, but one option would be to offset the effect on power prices, in which case the pollution fee is in effect a transfer from high pollution electricity generators to low pollution electricity generators.

Our estimate of 1.96 deaths per TWh based only on SO2 emissions is considerably lower than the estimate for black coal in Europe of 24.5 per TWh. However, this is not surprising, as the European estimate includes all pollutants, and the NSW generators are located much further away from population centres than is possible in Europe. While this result is directly applicable to NSW it cannot be applied to Victoria, where the Latrobe Valley generators are located east of the capital city in what is nearly always the downwind direction.

While this estimate is valid for the health effects of SO2 emission on the population of Sydney, there is urgent need for research to establish the health damage due to NOx, mercury, and direct particle emissions, as well as to apply similar methods in the other Australian states.

Public health implications

Climate imperatives and the ageing of the CFPS plants will see them all close over coming decades, but there has been little public discussion of the closure order after the planned closure in 2022 of Liddell Power Station at Muswellbrook. Incorporating the health costs into the cost of operation of CFPS will ensure that health considerations are part of the decisions about closure order and, in the meantime, will provide a financial incentive for cleaner operation.

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References


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